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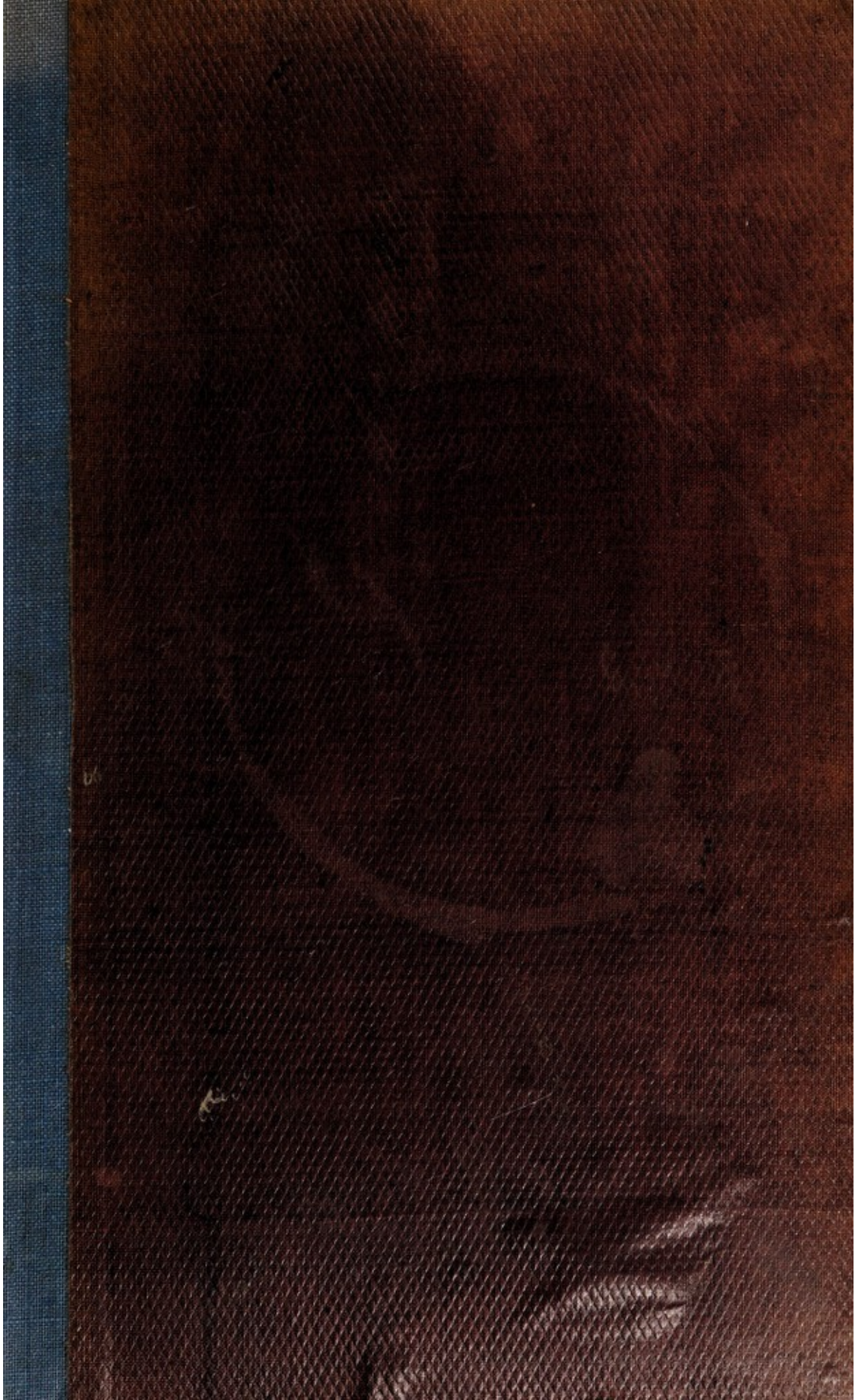

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Henry Hele Tuby

1871

Sir Henry de la Beche, died
suddenly on Friday the 22nd of April
1855, in the 59th year of his age,
a most useful public officer & a
very great loss — buried at
Kensal green Cemetery —

Sir Henry De la Beche. the great geologist, who died a short time since, passed his youth in this county, having received his first education at Ottery St. Mary. In 1810 Mr. De la Beche entered the Royal Military College then at Great Marlow, and subsequently entered the army, but he shortly after resigned the military profession for the pursuit of science. In 1817 he became a member of the Geological Society, and for some years after he published many interesting papers, and in 1830 his first book, "Geological Notes," appeared. This was followed by several other works, the chief of which was a voluminous report on the Geological Survey of Cornwall, Devonshire, and West Somerset. In 1848 the honour of Knighthood was bestowed on him, and in addition to this in 1853 Sir Henry was elected corresponding member of the Academy of Sciences of Paris. He also received the order of the Dannebrogg from the King of Denmark, and the order of Leopold from the King of the Belgians.

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for N. James
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D. F. Price
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REPORT

ON THE

GEOLOGY

OF

CORNWALL, DEVON,

AND

WEST SOMERSET.

By HENRY T. DE LA BECHE, F.R.S., &c.
Director of the Ordnance Geological Survey.

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NOTICE.

THE Ordnance Geological Survey forms a branch from the Trigonometrical Survey of Great Britain, of which Colonel Colby, Royal Engineers, LL.D., F.R.S., &c., is Superintendent.

During the progress of the Ordnance Geological Survey in Cornwall, it received able assistance from Mr. Henry M'Lauchlan, F.G.S., and Mr. Henry Still, F.G.S., Ordnance Surveyors. Mr. M'Lauchlan laid down the mineral veins, ranges of elvan, and southern granite line near St. Austell, the mineral veins of St. Agnes, and many of those in Gwennap, Redruth, and Camborne. Mr. Still laid down the mineral veins in the vicinity of Breague, Binner Downs, Clowance, Gwinnear, Marazion, St. Ives, and St. Just. Independently of these labours, both gentlemen, as their more immediate duties would permit, from time to time communicated a mass of important geological facts which were of the greatest value to the Survey.

The Maps, to which frequent reference is made in the following Report, are those executed by the Ordnance Geological Survey, and of which Plate I. is an Index.

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ERRATA.

Page 6, *line* 35, *for* Davidston *read* Davidstow
13 —— 37 — British Channel *read* Bristol Channel
125 —— 20 — compressions *read* impressions
247 —— 42 — 90 *read* 70
285 —— 39 — North Tawton *read* North Molton
289 —— 4 — North Tawton *read* North Molton
322 —— 36 — Relistran *read* Relistian
333 —— 8 — Relistran *read* Relistian
351 —— 37 — could be *read* could not be
363 —— 9 — whether, from any *read* whether, any
419 —— 18 — British Channel *read* Bristol Channel

LIST OF WORKS AND MEMOIRS

RELATING TO

THE GEOLOGY AND MINING OF THE DISTRICT.

1602. Survey of Cornwall. By Richard Carew.
(Reprinted, with a Life of the Author, in 1769.)

1666. Some promiscuous Observations made in Somersetshire. By Dr. Beale.—Philosophical Transactions for 1666, No. 18, p. 323. Phil. Trans. abridged, vol. i. p. 121.
(The submarine forest near Bridgewater is noticed in this paper.)

1671. Some Observations on the Mines of Cornwall and Devon, describing the art of training a load; the art and manner of digging the ore: and the way of dressing and blowing tin. Communicated by a person acquainted with those mines.—Philosophical Transactions, No. 69, p. 2096; and Phil. Trans. abridged, vol. i. (from 1665 to 1672), p. 565.
(An interesting document, from the view it affords of the mining in Devon and Cornwall in those days.)

1678. Account of the Tin Mines in Cornwall, By Dr. Christopher Merret.—Philosophical Transactions, No. 138, p. 949; and Phil. Trans. abridged, vol. ii. p. 424.

1750. Natural History of Scilly and Cornwall. By Heath.

1753. Of the great alterations which the Islands of Scilly have undergone since the time of the ancients, who mention them, as to their number, extent, and position. By the Rev. W. Borlase.—Philosophical Transactions for 1753, p. 55.

1757. Of some trees discovered under ground on the shore at Mount's Bay, in Cornwall. By the Rev. W. Borlase. — Philosophical Transactions for 1757.

1758. The Natural History of Cornwall. By the Rev. William Borlase.

1778. Mineralogia Cornubiensis. By William Pryce, of Redruth.

1781. Voyages Métallurgiques. Par M. G. Jars.
(There is a chapter on the tin and copper mines of Cornwall, from personal observations made in 1765. Tom. iii. p. 186.)

1787. Klaproth, on the Mineral and Chemical History of the Fossils of Cornwall. Translated by Dr. I. G. Grosche.

1790. Reise von London in die Graffchaft Kornwall (1783).—Köhler's Bergmännisches Journal, Dritter Jahrgang, Zweiter Band, p. 1—143.

1794. General View of the County of Cornwall. By Robert Fraser.—Agricultural Reports, vol. i.

1794. General View of the County of Devon. By Robert Fraser. — Agricultural Reports, vol. ii.
(In this report there is a map of the soils of Devonshire.)

1794. General View of the County of Somerset. By John Billingsley.—Agricultural Reports, vol. iv.
(In this report there is a coloured map of the soils of Somersetshire.)

1795. Sketch of Cornwall, taken from Pryce's Mineralogia Cornubiensis, and principally relating to Mines: with additional notes from the German Journals.—Journal des Mines, tom. i. 3. p. 91. (An. III.)

1797. Tour in the Western Counties. By Dr. Maton.
(Contains a geological map, and numerous geological observations.)

1799. Sketch of the History of Mining in Devon and Cornwall. By John Taylor.—(Philosophical Magazine, vol. v. pp. 357.)

1801. Account of the Discovery of Silver in Herland Copper-mine. By the Rev. Malachy Hitchins.—(Philosophical Transactions for 1801, part i. p. 159, with a plan of the lodes, pl. xi.

1802. Illustrations of the Huttonian Theory of the Earth. By Professor John Playfair.
(Notices Bovey coal, p. 152; the fossiliferous character of the Plymouth limestones, p. 164; cross-courses in Cornwall, p. 254; Cornish elvans, p. 310; granite-veins of St. Michael's Mount, p. 317; the mouths of the rivers on the south coast of Devon and Cornwall, p. 368; the Logan stone, p. 395.)

1803. Sur le Gisement. l'Exploitation, et le Traitement de l'Etain, dans le Duché de Cornouailles. Par A. H. Bonnard.—Journal des Mines, tom. xiv. p. 443. (An. XI.)
(The author more particularly describes Polgooth Mine, Carclaze Mine, and Pentowan Stream-work, near St. Austell, from personal observations.)

1808. An Account of the Relistian Tin-mine. By Joseph Carne.—Nicholson's Journal, vol. xx. p. 24.

1808. General View of the Agriculture of the County of Devon. By Charles Vancouver.

1811. Geological Tour in Devon and Cornwall. By Dr. Berger.—Geological Transactions, vol. i. 1st series.

1811. Geological Travels. By J. A. de Luc.
(Vols. ii. and iii. contain his travels in Cornwall, Devon, and Somerset.)

1813. Mineralogical Observations on Cornwall. By Dr. Thomson.—Annals of Philosophy, vol. ii. pp. 247, 346.

1814. Magna Britannia, Cornwall. By the Rev. Daniel Lysons, and Samuel Lysons, Keeper of the Records in the Tower of London.

1814. On the Porcelain Earth of Cornwall. By Dr. Fitton.—Annals of Philosophy, vol. iii. p. 180.

1814. On the Granite Tors of Cornwall. By J. MacCulloch, M.D.—Geological Transactions, vol. ii. 1st series, p. 66.

1814. On the Veins of Cornwall. By William Phillips.—Geological Transactions, vol. ii. 1st series, p. 110.

1814. On the Economy of the Mines in Cornwall and Devon. By John Taylor.—Geological Transactions, vol. ii. 1st series, p. 309.

1814. Memoranda relatively to Clovelly, North Devon. By the Rev. J. J. Conybeare.—Geological Transactions, vol. ii. 1st series, p. 498.

1816. Sketch of the Geology of the South-Western Part of Somersetshire. By Leonard Horner. (Read 17 Feb. 1815.)—Geological Transactions, vol. iii. p. 338.

1817. Account of some remarkable Disturbances in the Veins of the Mine called Huel Peever, in Cornwall. By John Williams, jun. (read 2nd June, 1815).—Geological Transactions, vol. iv. 1st series.

1817. Description of the Tunnel of the Tavistock Canal, through Morwell Down, in the County of Devon. By John Taylor.—Geological Transactions, vol. iv. 1st series.

1817. Memoranda relative to the Porphyritic Veins, &c., of St. Agnes, in Cornwall. By the Rev. J. J. Conybeare (read 3rd December, 1813).—Geological Transactions, vol. iv. 1st series.

1817. On the Stream-works at Pentowan. By Edward Smith (read 3rd June, 1814).—Geological Transactions, vol. iv. first series.

1817. Observations respecting the Limestone of Plymouth. By the Rev. R. Hennah (letters dated 26th Sept. 1814, and 19th Jan., 1815).—Geological Transactions, vol. iv. 1st series.
(The author notices the raised beach at Plymouth in this paper, p. 412.)

1817. Notice of Fossil Shells in the Slate of Tintagel. By the Rev. J. J. Conybeare.—Geological Transactions, vol. iv. 1st series, p. 425, plate 25.

1817. An Account of some Fossil Remains of the Rhinoceros, discovered by Mr. Whitby, in a cavern enclosed in the limestone-rock from which he is forming the Breakwater at Plymouth. By Sir Everard Home, Bart.—Philosophical Transactions for 1817, part i. p. 176.

1818. Transactions of the Royal Geological Society of Cornwall, vol. i. Contains, relating to the Geology and mining of Cornwall—

a. On a recent Formation of Sandstone, occurring in various parts of the Northern Coast of Cornwall. By Dr. John Ayrton Paris. p. 1.

b. An Account of some Granite Veins at

Porth Just, near Cape Cornwall. By Dr. John Davy. p. 20.

c. Notes on the Coast west of Penzance, and on the Structure of the Scilly Islands. By Ashurst Majendie. p. 27.

d. A Sketch of the Geology of the Lizard District. By Ashurst Majendie. p. 32.

e. Hints on the Geology of Cornwall. By Sir H. Davy. p. 38.

f. On Elvan Courses. By Joseph Carne. p. 97.

g. Notes on the Limestone Rocks in the parish of Veryan. By S. J. Trist, p. 107.

Appendix to the above, by the Rev. J. Rogers. p. 114.

h. On the Discovery of Silver in the Mines of Cornwall. By Joseph Carne. p. 118.

i. On Submarine Mines. By John Hawkins.

Account of the Wherry Mine, Penzance. p. 136.

k. On some remarkable Phenomena attending the Lodes of Polgooth Tin Mine. By John Hawkins, p. 143.

l. Observations on the Geological Structure of Cornwall, with a view to trace its connexion with, and influence upon, its Agricultural Economy, and to establish a rational system of Mineral Manure. By Dr. John Ayrton Paris. p. 168.

m. On a Cavern in Dolcoath Mine. By John Rule. p. 225.

n. On Stones and Clays annually exported from Cornwall, for the purposes of Architecture, Manufactures, and the Arts. By Dr. Paris, p. 231.

o. Observations on Gold found in the Tin Stream Works of Cornwall. By Sir Christopher Hawkins. p. 235.

p. Vegetable remains in the Basin at Portleven. By the Rev. John Rogers. p. 236.

q. Contributions towards a Knowledge of the Geological History of Wood Tin. By Ashurst Majendie. p. 237.

1819. Report on a Survey of the Mining District of Cornwall, from Chasewater to Camborne. By Richard Thomas. (Accompanied by a Mining Map and Sections of that district.)

1821. On the Physical Structure of those Formations which are immediately associated with the Primitive Ridge of Devonshire and Cornwall. By the Rev. Adam Sedgwick. (Read 20 March, 1820.)—Transactions of the Cambridge Philosophical Society, vol. i. p. 89.

1821. On the Physical Structure of the Lizard District, in the County of Cornwall. By the Rev. Adam Sedgwick. (Read 2 April, and 7 May, 1821.)—Transactions of the Cambridge Philosophical Society, vol. i. p. 291

1821. On the Red Rock Marle, or Newer Red Sandstone, by the Rev. J. J. Conybeare. Annals of Philosophy, new series, vol. i. p. 254.

Principally descriptive of the red conglomerates near Dawlish and Teignmouth.

1821. On the Geology of the Neighbourhood of Okehampton, Devon. Rev. J. J. Conybeare. Annals of Philosophy, new series, vol. ii. p. 161.

Contains also additional memoranda on the Red Marle of Devonshire, chiefly relating to the connexion of the Trappean Rocks of Thorverton and Silverton with it.

1821. A farther Account of Fossil Bones discovered in Caverns in the Limestone Rocks of Plymouth, by Joseph Whidbey.—Philosophical Transactions, 1821, part i. p. 133.

1821. On the Smelting of Tin Ores in Cornwall and Devon. By John Taylor. (Read June 4. 1819.)—Geological Transactions. vol. v. 1st series, p. 358.

1821. Account of the Plymouth Limestones. By the Rev. R. Hennah. (Read April 2, 1819.)—Geological Transactions, 1st series, vol. v. p. 619.

1822. Magna Britannia, Devonshire. By the Rev. Daniel Lysons, and Samuel Lysons, Keeper of the Records in the Tower of London.

1822. Observations on the Temperature of Mines in Cornwall, by M. P. Moyle. —Annals of Philosophy, new series, vol. iii. p. 308.

1822, Remarks on Mr. Moyle's "Observations on the Temperature of Mines in Cornwall," by R. W. Fox.—Annals of Philosophy, vol. iii. p. 381.

1822. On the Temperature of the Mines in Cornwall, by M. P. Moyle.—Annals of Philosophy, vol. iii. p. 415.

1822. On the Temperature of Mines, by R. W. Fox.—Annals of Philosophy, new series, vol. iv. p. 440.

1822. Transactions of the Royal Geological Society of Cornwall, vol. ii. Contains relating to the Geology and Mining of Cornwall—

a. On some advantages which Cornwall possesses for the Study of Geology,

and on the use which may be made of them. p. 1.

b. On the Temperature of Mines. By R. W. Fox. Part i. read September, 1819, p. 14. Part ii. read October, 1820. p. 19.

c. On the Stratified Deposits of Tin-stone, called Tin Floors, and on the diffusion of Tin-stone through the mass of some Primitive Rocks. By John Hawkins. p. 29.

d. On the relative Age of the Veins of Cornwall. By Joseph Carne. p. 49.

e. Observations on the Submersion of part of the Mount's Bay; and on the Inundation of the Marine Sand on the North Coast of Cornwall. By Dr. Boase. p. 129.

f. On the Nomenclature of the Cornish Rocks. By John Hawkins. (Read October, 1818.) p. 145.

g. On the Temperature of Mines. By Dr. John Forbes. (Read September, 1819, and October, 1820.) p. 159.

h. Observations on the Hornblende Formation in the Parish of St. Cleer. By the Rev. John Rogers. (Read October, 1818.) p. 218.

i. On the Phenomena of Intersected Lodes, and the legitimate Inferences which may be drawn from them. By John Hawkins. (Read October, 1820.) p. 225.

k. On the Intersection of Lodes in the direction of their Dip or Underlie. By John Hawkins. (Read October, 1820.) p. 232.

l. On the Geology of the Land's End District. By Dr. John Forbes. (Read September, 1819.) p. 242.

m. An Account of the Alluvial Depositions of Sandrycock. By Philip Rashleigh. Drawn up in 1792. p. 281.

n. Observations on the Alluvial Strata at Poth, Sandrycock, and Pentuan. By John Hawkins. (Read September, 1819.) p. 285.

o. On the Mineral Productions and the Geology of the Parish of St. Just. By Joseph Carne. (Read 1821.) p. 290.

p. On the Geology of St. Michael's Mount. By Dr. John Forbes. (Read September, 1819.) p. 366.

q. On some instances of the alternate Disposition of the Primitive Strata which have been observed in Cornwall. By John Hawkins. (Read October, 1820.) p. 376.

r. On the Tin Ore of Botallack and Levant. By Dr. Henry Boase. (Read October, 1822.) p. 383.

s. On the Temperature of the Cornish Mines. By M. P. Moyle. (Read October, 1822.) p. 404.

t. Observations on the Serpentine District of Cornwall. By the Rev. John Rogers. (Read October, 1822.) p. 416.

1823. On some Fossil Bones discovered in Caverns in the limestone quarries of Oreston. By Joseph Whidbey.—Philosophical Transactions for 1823, part. i. p. 78.

1823. On the Temperature of Mines, by M. P. Moyle.—Annals of Philosophy, new series, vol. v. p. 34.

1823. On the Geology of Devon and Cornwall. By Rev. J. J. Conybeare. —Annals of Philosophy, new series, vol. v. p. 184; vol. vi. p. 35.

1823. On the Temperature of Mines. By M. P. Moyle.—Annals of Philosophy, new series, vol. vi. p. 15.

1823. On Granite Veins, by M. P. Moyle. —Annals of Philosophy, new series, vol. vi. p. 90, pl. xxi.
(Describes those east of Trewarvas Head.)

1823. An Account of the Observations and Experiments on the Temperature of Mines, which have recently been made in Cornwall and the North of England.—Philosophical Magazine, vol. lxi. p. 347, 436; vol. lxii. p. 38, 94.

1824. Remarks on the Geology of the South Coast of England, from Bridport Harbour, Dorset, to Babbacombe Bay, Devon, by H. T. De la Beche. Read 5th March, 1819.—Geological Transactions, 2nd series, vol. i. p. 40.

1824. On the Excavation of Valleys by Diluvial Action, as illustrated by a succession of valleys which intersect the south coast of Dorset and Devon. By the Rev. W. Buckland. Read 19th April, 1822.—Geological Transactions, 2nd series, vol. i. p. 95.

1824. Observations on the South-Western Coal District of England. By the Rev. W. Buckland and the Rev. W. D. Conybeare.—Geological Transactions, 2nd series, vol. i. p. 210.

1824. On the Temperature of Mines. By M. P. Moyle.—Annals of Philosophy, new series, vol. viii. p. 446.

1825. Observations on the Temperature of Springs, Wells, and Mines in Cornwall. By Dr. John Davy.—Brewster's Edinburgh Journal of Science, vol. iii. p. 75.

1826. On the Temperature of Mines. By M. P. Moyle.—Annals of Philosophy, new series, vol. xi. p. 259.

1827. Voyage Métallurgique en Angleterre. Par MM. Dufrénoy et Elie de Beaumont.—Notice sur le Gisement, l'Exploitation, et le Traitement des Minerais d'Etain et de Cuivre de Cornouailles, p. 1—254.

1828. Account of the Iron Mine at Haytor, Devonshire. By I. T. Kingston.—Phil. Mag. and Annals of Philosophy, new series, vol. iii. p. 359.

1828. Transactions of the Royal Geological Society of Cornwall, vol. iii. Contains, relating to the Geology and Mining of Cornwall—

a. On the Changes which appear to have taken place in the Primitive Form of the Cornish Peninsula. By John Hawkins. p. 1.

b. Some Observations on the Alluvial Formations of the Western Part of Cornwall. By Dr. Boase. Read October, 1824. p. 17.

c. On the Period of the Commencement of Copper Mining in Cornwall, and on the improvements which have been made in Mining. By Joseph Carne. Read October, 1824. p. 35.

d. Some Arguments in support of the opinion that the Iktis of Diodorus Siculus is St. Michael's Mount. By Dr. Barham. Read October, 1825, p. 86.

e. On the Intercourse which subsisted between Cornwall and the Commercial States of Antiquity, and on the State of the Tin Trade during the middle ages. By John Hawkins. Read October, 1824, p. 113.

f. On the singular state of some Ancient Coins lately found in the sands at Hayle, and on the evidence deducible from them relative to the period of the earliest deposition of sand on the northern coast of Cornwall. By Joseph Carne. Read October, 1825, p. 136.

g. Some further Observations on the Temperature of Mines. By T. F. Barham. Read 1824, p. 150.

h. On the Sand Banks of the northern shores of Mount's Bay. By Dr. Henry Boase. Read October, 1826, p. 166.

i. On a singular Exudation of Gas in the Union Mines. By W. J. Henwood. Read October, 1826. p. 203.

k. On the Granite of the Western Part of Cornwall. By Joseph Carne. Read July, 1827, p. 208.

l. Some further Observations on the Temperature of Mines. By Robert Were Fox. Read Oct., 1827, p. 313.

m. Notice of some Circumstances connected with the Heave of a Copper Lode by a Flucan Vein, in the Consolidated Mines, Gwennap. By W. J. Henwood, p. 329.

n. Notice of a Granite Vein discovered in Herland Mine. By Richard Edmonds, p. 332.

o. Notice of the Native Copper of Condorrow Mine. By E. W. W. Pendarves, M.P.

1829. On the Lias of the coast in the vicinity of Lyme Regis, Dorset. By H. T. De la Beche. Read 21 Nov. 1823.—Geological Transactions, 2d series, vol. ii., p. 21.

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a. Some General Observations on the Structure and Composition of the Cornish Peninsula. By John Hawkins. Read October, 1828. p. 1.

b. Some Observations on Metalliferous Veins, and their Electro-magnetic Properties. By Robert Were Fox. Read October, 1830. p. 21.

c. A Description of Happy-Union Tin Stream Work, at Pentuan. By John W. Colenso. Read October, 1829. p. 29.

d. Some Observations made in Cornwall, in the Summer of 1829. By John Hawkins. Read October, 1829. p. 40.

e. A Description of the Stream-Work at Drift Moor, near Penzance. By Joseph Carne. Read October, 1830. p. 47.

f. On some of the Deposits of Stream Tin-Ore in Cornwall, with Remarks on the Theory of that Formation. By W. J. Henwood. Read in 1828 and 1829. p. 57.

g. On the State of our Tin Mines, at different periods, until the commencement of the Eighteenth Century. By John Hawkins, Read October, 1830. p. 70.

h. An Account of the Discovery of some varieties of Tin-Ore in a Vein, which have been considered peculiar to Streams; with Remarks on Diluvial Tin in general. By Joseph Carne. Read October, 1830. p. 95.

i. On a very singular Deposit of Alluvial Matter on St. Agnes Beacon, and on the Granitical Rock which occurs in the same situation. By John Hawkins. Read October, 18 3. p. 135.

k. On the Manipulations to which the Ores of Tin and Copper are subjected in the Central Mining District of Cornwall. By W. J. Henwood. Read October, 1828. p. 145.

l. Contributions towards a Knowledge of the Geology of Cornwall. By Dr. Henry Boase. Read October, 1830 and 1831. p. 166.

m. Some Account of the Soft Growan at Beam Mine, in the parish of Roche, and at Carclaze Mine, in the parish of St. Austell. By John Hawkins. Read October, 1830. p. 475.

n. Notice of Wood and Peat found below high-water mark, on the beach at Main Porth, in Cornwall. By the Rev. John Rogers. p. 481.

o. Notices of Pseudomorphous Crystals of Oxide of Tin, found in Huel Coates, in St. Agnes, in the year 1828. By Stephen Davy. p. 484.

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REPORT

ON THE

GEOLOGY OF CORNWALL, DEVON, AND WEST SOMERSET.

CHAPTER I.

SKETCH OF THE PHYSICAL FEATURES OF CORNWALL, DEVON, AND WEST SOMERSET.

THE physical features of a country, comprising its varied form as regards the different heights of its component parts above any given level, such as that of the sea, the connexion of such component parts with each other, the character and direction of its valleys, and the other general conditions of its surface, usually so termed, being the present state to which a given portion of the earth's surface has been brought by the varied and successive geological changes that have occurred upon it, a notice of such physical features would, probably, be more strictly in place if it followed rather than preceded any account of the geological events which have produced them. It has, however, been found so convenient to make the physical features of a district generally understood, before any detail of its geological structure is attempted, that we have considered it better to conform to, than deviate from, a plan which possesses many advantages, more particularly that of impressing upon the memory the positions of the more important elevated lands relatively to each other, and the general relief of the whole surface.

The district under consideration comprises Cornwall, Devon, a large portion of Western Somerset, and a small part of Dorsetshire adjoining Devon. It is represented, with the exception of the Scilly Islands, in the sheets from Nos. 20 to 33, both inclusive, of the Ordnance Survey of Great Britain, as will be seen by

reference to the accompanying index map (plate 1). It embraces an area of about 4,712 square miles; the whole (with the exception of about 100 square miles) being occupied by uneven or hilly ground.

A glance at these Ordnance Maps will show that the principal high lands do not form any continuous system or range of hills, but are distributed in patches in different places.

The Quantock Hills have somewhat of an elliptical form, the major axis being in a direction about south-east and north-west, the principal heights ranging from 1,000 to 1,100 feet above the level of the sea, and attaining an elevation of 1,270 feet at Wills Neck Hill.

Exmoor, with that part of the adjoining country which forms a portion of the same mass of elevated land, extends from the valley of Stogumber and Crowcombe, separating it from the Quantock Hills on the east, to the Hangman Hills, on the Bristol Channel, near Combe Martin on the west. Near the latter place, this high land forms a point, whence it sweeps to the south-east by a curved line passing by Paracombe, Chapman Barrows, Span Head, and North Molton Ridge. Its southern boundary ranges from thence, by Mollond Down, Dulverton Common, and Haddon Down, to Heydon Down, and Main Down, near Wiveliscombe, whence the high land trends away to the Stogumber and Crowcombe valley above noticed, part of which so rises between the Exmoor mass of high land and the Quantock Hills as to throw the drainage waters in opposite directions. The highest portion of this elevated land is Dunkery Beacon, on the south of Porlock, which rises to the height of 1,668 feet above the level of the sea. On the west, Chapman Barrows attain an approximative height of 1,540 feet,* and Span Head, east-north-east from High Bray, a height of 1,610 feet (*a*) above the same level. Along the southern boundary, the southern end of North Molton Ridge rises to an elevation of 1,413 feet (*a*) above the sea, and Haddon Hill, on the east of Dulverton, to 1,140 feet (*a*). The hills and cliffs bordering the Bristol

* By approximative heights, those are to be understood which have not been taken with large instruments, but with ordinary sized theodolites, or having been taken with large instruments there was something uncertain in the observations, arising either from the state of the atmosphere, or other disturbing cause, which prevented great accuracy. The approximative heights will be marked (*a*) in the text, and may generally be considered as approaching to the truth within a few feet, more particularly for the smaller heights.

Channel, and constituting a portion of the general Exmoor highland from Minehead to Combe Martin, attain somewhat corresponding heights, forming a coast remarkable for its general elevation and the sub-alpine character of some of its valleys, as, for example, those near Linton. North Hill, on the coast near Minehead, attains a height of 1,059 feet, according to the Admiralty Charts, by Captain Denham, R.N., and, following the same authority, Culborne Hill, near Porlock, is 1,211 feet; Hall Hill, Countesbury, near Linton, 1,145 feet; the hill on the west of Trentishoe Barrow, 1,187 feet; and the Great Hangman Hill, near Combe Martin, 1,083 feet above the level of the sea.

On the south-east of Exmoor, the Blackdown Hills rise above the fertile vale of Taunton on their north, and the rich lands of the vale of Collumpton on the west. They cannot be said to form a range of hills, but rather an elevated table-land cut into, more particularly on the west and south, by deep valleys, which thus divide it into several long lines chiefly running to the west, south-west, and south. The longest continuous line of this kind is that which extends from Staple Hill on the north, and runs about seventeen miles by Brown Down, Birch Hill, the hill forming the left side of the valley of the Otter to Honiton, Faraway Hill, on the west of Northleigh, Gittisham Hill, and the hill on the east of Ottery St. Mary, to Beacon Hill above Harpford on the Otter. A depression here takes place for about three quarters of a mile, after which Peake Hill and High Peak, near Sidmouth, continue the line to the sea for about two miles and a quarter, so that, including the depression, which is itself upon high ground, this line of high land extends about twenty miles, varying in elevation from about 600 to 750 feet. The whole of the high land between Sidmouth and Lyme Regis, and thence for some distance in the direction of Golden Cap Hill, beyond the limits of the district under consideration, forms both geographically and geologically, a portion of the Black Down system of hills, though not usually included in it.

The principal rivers occupying the valleys scooped out of this elevated land are the Culm, the Otter, and the Axe, with their tributaries. The cliffs on the coast from the vicinity of Sidmouth to Charmouth vary from 400 to 600 feet in height, Charlton Common, between Lyme Regis and Axmouth, being 582 feet above the level of the sea. The aspect of the higher portion of these hills

is somewhat uniform, consisting of a sharp slope of 25° or 30°, for about a third of the height from the summit downwards, after which the slope becomes more gentle. Bold promontories and isolated portions at the termination of the lines of elevated land have, from their commanding positions, been seized upon at different periods for military purposes, and the remains of ancient earth-works or camps are seen in various directions, among which may be noticed Castle Neroche, rising above Curland, Membury Castle, Musbury Castle, Hawksdown near Axmouth, Sidbury Hill near Sidmouth, Dumpdon (879 feet above the sea) on the north of Honiton, and Hembury Castle near Broadhembury.

On the south-west of Exmoor, and distant from it about twenty-six miles, rises the high land of Dartmoor. This elevated mass of land is of an irregular form, broken into numerous minor hills, many crowned by groups of picturesque rocks, provincially termed *Tors*, and for the most part presenting a wild mixture of heath, bog, rock, and rapid streams. The highest part of Dartmoor is on the north, where Yes Tor, apparently its most elevated point, rises 2,050 feet (*a*) above the sea. The summit of Amicombe Hill, on the north-west part of the moor, attains an elevation of 2,000 feet (*a*), and Fur Tor, south-south-east from it, rises to about the same height. The height of Cawsand Beacon, on the north of Dartmoor, one of the stations of the great triangulation, on which the Ordnance Maps are based, is 1,792 feet above the sea; and Newlake Hill, four miles to the south of it, has an elevation of about 1,925 feet (*a*). On the west, Cock's Tor, near Tavistock, rises to the height of 1,472 feet (*a*), and Great Mis Tor, a short distance to the east of it, to 1760 feet (*a*).* On the south, Pen Beacon, above Cornwood, attains an elevation of 1,470 feet (*a*), and Shell Top, one mile behind it, one of 1,600 feet (*a*).

From Butterton Hill, 1,203 feet above the sea, to Cawsand Beacon, on the north, a distance of about twenty-two miles, the higher lands gradually attain an elevation of 1,510 feet (*a*) at Three Barrow Tor, and of 1,785 feet (*a*) at Peter's Stone, on Holne Ridge, after which the higher points seem to keep an ele-

* The western frontier of Dartmoor has its otherwise abrupt character in a great measure relieved by Black Down (1,160 feet) and Heathfield, on the north of Tavistock, and by Roborough Down, on the south of the same town; Brent Tor (about 1,100 feet *a*), on Heathfield, a conspicuous object in the surrounding country, carrying the attention from the main mass of tors which range along the skirts of the moor.

vation varying from 1,700 to 1,900 feet. Rippon Tor, one of the frontier tors on the east side of the moor, is 1,549 feet above the sea.

Although both geographically and geologically, the elevated land which extends eastward from Cawsand Beacon to Cranbrook Castle, Buttern Down, and Mardon Down, near Moreton Hamstead, ranging thence round by Bridford and Hennock, to High, or Hey Tor, forms part of Dartmoor, the main high land of the moor is bounded on the east by a line passing from Cawsand Beacon, by Castor Rock, Thornworthy Tor, Shapeley Common, King Tor, Hamilton Tor (1,738 feet *a*), and Hamilton Beacon (on the north of Withycombe on the Moor), Honey Bag Tor (near the same place), and Leign Tor, to High, or Hey Tor, and Rippon Tor.

Dartmoor is the parent of numerous streams which water a large portion of Devon, giving birth to several which constitute some of its principal rivers, such as the east and west Okements, the Taw with several of its tributary streams, the Dart with many of its tributaries, the Avon or Aune, the Erme, the Yealm, the Plym, the Wallcombe, and Tavy.*

On the east of Dartmoor, and separated from it by the valley of the Teign, are the Haldon Hills, high land of the same class as the Black Down Hills, ranging in a direction about eight miles in a north-north-west and south-south-east direction, and having a nearly uniform elevation, with the exception of the depression between the portions named Great and Little Haldon. The trigonometrical survey station on the latter is 818 feet above the sea.

On the south-south-east and south-east of Dartmoor, the country, though hilly, is of moderate elevation, the most marked high land being Black Down, on the west of Modbury, and Morleigh Downs, above Morleigh, until we arrive at that portion of the South Hams, as this part of Devonshire is named, of which the coast of the Bolt Tail, Bolt Head, the Prawle, and the Start Point, forms a part, and also the most southern land in Devonshire. The Bolt Head rises only 430 feet above the sea, though its bold outline generally impresses the spectator with the belief that it attains a much greater elevation.

On the south-west of Dartmoor, Plymouth Sound and its con-

* The valleys of many of these rivers, particularly where they enter the moor, present a happy mixture of rock, wood, and water, well deserving the attention of the artist and lover of the picturesque.

tinuation up the Tamar, constitute marked portions of the physical features of the country. Maker Heights, on the west of the Sound, attain an elevation of 402 feet, but generally the shores of the Sound and the banks of the Tamar, and of its tributaries, for several miles to the northward, are of much less height. At Morwell Rocks and New Bridge, about three miles from Tavistock, the Tamar cuts through high land, the most elevated part of which is Kit Hill, the western portion of Hingston Down, rising 1,067 feet above the sea, which flows up to Morwell Rocks. This hill, being much higher than the surrounding country, forms a conspicuous object in it, and from its insular character, is visible for considerable distances.

About sixteen miles to the west of Dartmoor, we find another tract of country of a similar general character to it, though the constituent features are not often so strongly marked. Like Dartmoor, this land rises conspicuously above the surrounding country, more particularly on the east, the two most prominent and elevated heights being those of Brown Willy and Rough Tor, near Camelford, the former being 1,368 feet, and the latter 1,296 feet (*a*) above the sea. Trewartha Tor, Sharp Point Tor, and Caradon Hill, skirting this tract of country on the east, are respectively 1,050, 1,200, and 1,208 feet above the sea, the two former being approximative heights, and the last that of the trigonometrical survey station, obtained with great care. On its western side we find St. Breward Hill, 727 feet (*a*); Carbilley Tor, 860 feet (*a*); Durford Hill, 690 feet (*a*); Bellarmine Tor, 884 feet (*a*); and Cardinham Bury, 840 feet (*a*), above the sea. Between Cardinham Bury and Caradon Hill, on the south, are Carbarrow, Goldmill Barrows, Bury Down, and Mennaclew Down, respectively 915, 883, 925, and 1,124 feet (*a*), above the sea. In the interior, Temple Tor, near Temple, and Tober Tor, near the Jamaica Inn, attain respective elevations of 900 and 1,127 feet (*a*). This tract of elevated land does not terminate abruptly with Brown Willy and Rough Tor on the north, but falls gradually off by Davidston Moor, 1,005 feet (*a*), whence a line of high land extends to Titch Beacon, 1,010 feet (*a*); Otterham Hill, 758 feet (*a*); and Tresparrett Down, 843 feet (*a*); another line running to Cadon Barrow, 1,011 feet, and overlooking the lower coast of Tintagel and Bossiney.

In the south-west of the last-mentioned boss of high land, and about eleven miles from it, is another of somewhat less elevation,

of which Hensbarrow Hill (1,034 feet) forms the most lofty part. The two bosses are, to a certain extent, connected by the Bodmin high land, and the elevated downs extending to the Tregoss Moors and Roche. Bodmin Down, on the south of the town, attains an elevation of 645 feet above the sea. Killivreth Down, on the west of Hensbarrow, nearly attains the height of the latter, being 1,000 feet (*a*) above the sea. This boss of high land falls somewhat gradually to the north, in the direction of the Tregoss Moors, above which, still on the north, rise the two marked and twin-like hills of Castle an Dinas (729 feet *a*) and Belovely Beacon (765 feet *a*). On the south, the land after throwing out broad-backed branches to St. Stephen's Beacon (700 feet *a*), Watch Hill (850 feet *a*), and the long celebrated Carclaze Tin Mine (665 feet *a*), falls somewhat suddenly upon the lower lands of St. Stephen's (296 feet *a*) and St. Austell. The valley of the Fal cuts through part of this elevated land, the western extremity of which is formed by a ridge extending from Fatwork Hill, which rises gradually above the Tregoss Moor, near the Indian Queen, to Burthy Hill (607 feet *a*), Carliquoita Rock, a remarkable tor upon it, attaining an elevation of 690 feet (*a*).

On the north of the Hensbarrow boss of high land there is a range of hill running from the Camel river on the east, to the sea on the west; also forming a marked feature in the relief of this part of the country. This range is highest on the east, where at the Great Stone (a Druidical remain) on St. Breock's Down, it attains an elevation of 739 feet (*a*) above the sea. Further westward on the same down, it falls to 670 feet (*a*) at the barrow near Scotland Corner. At the line of ancient barrows on Bogee Downs, the range has fallen to 567 feet (*a*), and at St. Eval it only attains a height of 326 feet (*a*).

About fifteen miles from the Hensbarrow high land, there is another boss of elevated country, in which Carn Menelez attains a height of 822 feet: between them the hills vary from 200 to 350 feet in height. Probus, which stands conspicuously upon one of these hills, is 305 feet (*a*) above the sea, and a barrow on the north of New Mill, near Ladock, is 376 feet (*a*), upon a hill which seems to rise above the usual average. The Carn Menelez boss of high land, including under this name the elevated country of the surrounding district, falls somewhat gradually towards the Falmouth estuary, and its branches on the eastward. The hill above Burnthouse, west from Penryn, is 680 feet (*a*) above the sea, and

the plantations near Carnhingey, are 500 feet (*a*). Carn Brea and Carn Marth, rising amid the mines, though somewhat separated from the main mass of the Carn Menelez boss, may still be considered to form a portion of it, both geographically and geologically. According to Mr. Thomas, the former rises 740 feet, and the latter 757 feet above high-water mark of spring tides in the Falmouth estuary. The land also declines somewhat gradually on the south-east and south, towards the sea and Gweek river. At Pelastine rocks near Mabe, it has a height of 700 feet (*a*), and at Budock, near Falmouth, of 280 feet (*a*). At Constantine it falls on the south to 390 feet (*a*).

On the north of the Carn Menelez district, and about four miles distant, is St. Agnes Beacon, a hill of no great elevation, being only 621 feet above the sea, but which nevertheless constitutes a conspicuous object in the country, from its position on the coast, and from its isolated situation, rising above the surrounding land, which may have a general elevation of 300 and 400 feet. On the west-south-west of the same district, and separated from it by land of about 200 and 250 feet high, are Godolphin and Tregonning Hills, properly perhaps forming two of the more elevated parts of the same hill, and conspicuous objects, more particularly when viewed from the westward, the first being 495 feet (*a*), and the latter 596 feet (*a*) above the sea.

On the south of the Gweek river there is an extensive tract of country, generally known as the Lizard district, from the Lizard Point, which forms its southern extremity, and, at the same time, the most southern land of Great Britain. When seen from the east or the west, the general appearance of this land has a tabular character with a slight fall to the south, one which is in a great measure borne out by closer examination, for though cut occasionally into valleys, the higher lands do not vary much in elevation, and are generally more raised above the sea on the north, as at Dry Tree, on Goonhilly Downs (367 feet *a*), and Roscreage Beacon (380 feet *a*) near St. Keverne, than at Grade (250 feet *a*), and the Lizard Town (236 feet *a*) on the south.

The Land's End high land is separated from that of the Carn Menelez district by country which, on the east of the Hayle river, varies generally from 200 to 300 feet in elevation. The Hayle river, and its tributary stream from Germoe, nearly cut this part of Cornwall across from the Bristol to the English Channels. Between the sea in Mount's Bay and the tidal water in the Hayle

river, the land is of very moderate height, probably not above 100 feet. At Wheal Fortune it is only 90 feet (*a*). Even at St. Hilary on the higher ground separating the Hayle river, near Tregember, from the sea in Mount's Bay, the elevation is only 190 feet (*a*).

The country of the Land's End district is less elevated than that of Carn Menelez; its highest part is the hill on the north-west of Towednack, which rises 805 feet above the sea. The other principal and elevated features of this district are Chapel Carn Brea (640 feet *a*) on the north-east of the Land's End, Carnidjack (640 feet *a*), Trannock Downs, near Sancreed (660 feet *a*), Castle an Dinas (735 feet *a*), and Trerobben Hill (652 feet *a*) near Lelant.

From this sketch of the relative positions of the tracts of country which stand out most prominently amid the general irregularities of Cornwall, Devon, and West Somerset, it will be observed that Dartmoor is the highest mass, and Exmoor somewhat inferior in elevation, while the Black Downs do not attain more than about half their height. It will also be seen that the different bosses of elevated land which occur between Dartmoor and the Land's End, somewhat gradually decrease in elevation, so that the higher parts of the Land's End district are not above half the elevation of those in Dartmoor, and consequently are about equal to those in the Black Down Hills.

The Scilly Islands, formed of a multitude of rocks and small islands, may be compared to Dartmoor, sunk to such a level that the sea should run among its tors and more elevated masses of land, thus keeping a large portion of the tors above the sea-level, forming the smaller masses usually termed rocks, while the larger and more extended masses would constitute islands of various sizes. St. Mary's is the largest of these islands and is of moderate elevation.

While on the subject of the heights in this district above the level of the sea, it may be useful to observe that those whose attention has been directed to the subject of heights of land above tidal seas are by no means agreed as to the time of tide which would best afford a level whence to obtain them. In this district, the north and south coasts are under very different conditions as to tidal levels at the time of high tide. On the north, from the form of the Bristol Channel, the tidal wave on the flood is so driven into a gradually diminishing channel, both as regards depth and

breadth, that high-water mark at Cape Cornwall is beneath the level of high-water mark at Chepstow and Bristol, and consequently intermediate heights on land, if calculated from high water at the two ends of the Channel, would not agree. On the south coast, from its oceanic character, levels are probably more even at high water; but a glance at Mr. Whewell's valuable chart of the variable range of tides round the British islands will show that this coast only forms a portion of the general variations in the height of the tide observed among these islands; * and it will be obvious, from the different conditions of the tidal waters on the south and north coast of the district under consideration, that heights taken from high water on one coast would not coincide with those taken from high water on the other.

It has been generally considered that low water is the best time of tide to take as a level whence to calculate heights on land, it being supposed that the sea is then more equally distributed amid shoals and along shores than when driven over the former, or along the latter, by the force of a flood-tide, or during the run of the ebb; and consequently heights on land, surrounded by tidal seas, are generally computed from low-water mark.

Of late, chiefly in consequence of the observations of Mr. Walker, Assistant-Master Attendant in her Majesty's Dock-yard, Devonport, and of Captain Denham, R.N., much attention has been called to the subject of half-tide as being the level of least variation on tidal coasts, inasmuch as in the same place the high water of any tide rises as much above the line of half-tide as low water falls beneath it. It has, therefore, been supposed that the half-tide levels along the coast would coincide with each other, due precaution being taken not to include those estuary tides among them, where low-water mark on the sea coast is often considerably under the low-water level in such situations, the waters running out on the inclined surface of the bottom, in the manner of a common inland river. The greater portion of the Bristol Channel would probably be considered merely as an estuary, the ebb running out in the manner of a river over its bottom.

In his researches on tides, Mr. Whewell has noticed that the mean heights of the sea at Singapore and Plymouth are nearly constant,† and we understand that by tidal observations made under his direction at the extremities of the line levelled, at the

* Philosophical Transactions, 1836, pl. xxv.

† Philosophical Transactions, 1837, p. 83.

charge of the British Association for the Advancement of Science, between the English and Bristol Channels, it has been ascertained that the level of mean tide at both ends of the line is the same within a small fractional part of an inch.

Mr. Walker, who has long devoted much time to tidal phenomena, considering that half-tide levels on oceanic shores, such as a large part of those of Cornwall and Devon may be regarded, give the equilibrium level of the sea, proposes a simple method—given in the note beneath *—for readily obtaining it, which, whatever opinion may be entertained of the general value of half-tide levels, affords very considerable facility in ascertaining that level at any given place.

Mr. Walker has observed, with respect to the influence of the pressure of the atmosphere upon the tidal waters on the shores of Cornwall and Devon, that a fall of one inch of the mercury in the barometer corresponds with a rise of sixteen inches in the level of the sea, more than would otherwise happen at the same time, under the other general conditions; a rise in the barometer of one inch marking a corresponding fall in the sea-level of sixteen inches. This he has found to be the usual rate of such alterations in level; but *very sudden* changes in the pressure of the atmosphere are accompanied by elevations and depressions equal to twenty inches of sea-water for one inch of mercury in the barometer. Regarding the whole pressure of the atmosphere over the globe as a constant quantity, all local changes in its weight merely transfer a part of the whole pressure from one place to another; and hence he concludes that the subjacent water only flows into, or is displaced from, those areas, where, for the time, the atmospheric pressure is either less or greater than its mean state, in accordance with the laws which would govern the condition of two fluids situated in the manner of the atmosphere and sea.† We might account for the difference observed by Mr. Walker, in the amount of depression or elevation of sea-level pro-

* "When the barometer stands at its mean annual height, and the air is calm and still, set up a tide-pole (or select a rock) in some sheltered corner on the coast. Mark upon it the low and high-water levels, and half way between these points will be found the mean level of the sea. Under the above conditions a single observation will give the mean level *very nearly;* but numerous observations are necessary when great accuracy is required."—Walker's MSS. Mr. Walker most obligingly communicated his notes to us, to be used in any way which might appear best calculated to promote the progress of science.

† Walker, MSS.

duced by sudden changes in atmospheric pressure, by considering that a sudden impulse given to the particles of water, either by suddenly-increased or diminished weight in the atmosphere, would cause a perpendicular rise or fall in the manner of a wave beyond the height or depth strictly due to the mere change of weight itself.*

As regards the influence of the winds on the mean level upon the south coast of Cornwall and Devon, Mr. Walker observes that east and west winds scarcely affect it, but that southerly winds raise the sea above it from one to ten inches, and off-shore winds depress the water beneath it as much, according to their force. On the morning of the 29th November, 1836, when the velocity of the wind was estimated at about one hundred feet per second, the sea at Plymouth was raised three feet six and a half inches above the mean level, the greatest height above the equilibrium level he has seen. The hurricane began at S.W., and the barometer was very low; therefore this great increase in height is due both to the wind and diminished atmospheric pressure. A gale of wind from the southward, a low barometer, and a high spring-tide concurring, cause damage and inundations on the southern coast of Cornwall and Devon. From the form of the Bristol Channel, and the absence of a free passage for the waters, such as exists at the Straits of Dover, in the English Channel, westerly winds force up and *sustain* a great body of water, thereby raising the sea above the mean level several feet. It appears from an account of the great storm of the 26th November, 1703, that the tide flowed *over* the top of Chepstow bridge, inundating all the low lands on both sides of the Severn, washing away farm-

* A circumstance connected with this subject, of considerable practical value, has been noticed by Mr. Walker during his long-continued observations. He has found that changes in the height of the water's surface, resulting from changes in the pressure of the atmosphere, are often noticed on a good tide-gauge *before* the barometer gives notice of any change. Perhaps something may be due in these cases observed by Mr. Walker to the friction of the mercury in the barometer-tube, as it is well known that in taking careful barometrical observations it is necessary to tap the instrument frequently and carefully, to obtain the measure of the true weight of the atmosphere at a given time and place. The practical value of the observation is, however, not the less, be the cause of the phenomenon what it may; for if tide-gauges at important dock-yards show that a sudden change of sea-level has taken place, indicative of suddenly-decreased atmospheric weight, before the barometer has given notice of the same change, all that time which elapses between the notices given by the tide-gauge and barometer is so much gained; and those engaged with shipping know the value of even a few minutes before the burst of an approaching hurricane.

yards, drowning cattle, &c.; and it is worthy of remark that the barometer is recorded to have then fallen lower than had ever been previously noticed.*

It will be obvious that while in a hurricane, such as that of November, 1836, noticed by Mr. Walker, the level of the sea was raised on the south coast of Cornwall and Devon; it was also depressed on the north coast of those counties; so that the difference in the sea level on the two coasts thus caused would be the sum of the elevation and depression produced on each coast respectively. It will also be obvious, from the form of the Bristol Channel, that the sea-level on the two coasts will not be the same with westerly winds, and the difference will be in proportion to the force of such winds. With easterly winds also this level will be disturbed; for while such winds act as an off-shore wind in the Bristol Channel, forcing the waters outwards, on the south coasts of Cornwall and Devon there will be little or no effect produced from this cause (as proved by the observations of Mr. Walker), because there is a supply of waters from the eastward. It would, therefore, appear that around the shores of the district under consideration, when the winds which traverse it have considerable force, the levels which would obtain in calms are considerably disturbed, and consequently minor effects of the same kind are caused by less powerful winds, according to their velocity. To obtain, therefore, true heights in this district above the sea, which should correspond above a level in both channels, supposing such level to exist, calm weather is essential for accuracy.

The following tables afford a more extended view of the general relief or inequalities of the district than has been above attempted, and it is hoped that, in connexion with the Ordnance Maps of the same district, they may be found useful. The heights in the first table, obtained with every care by the officers in charge of the trigonometrical survey, during the progress of the great triangulation for that national work, have long been before the public. The heights in the second table are now first given, and those in the third, obtained during the progress of the geological survey in Cornwall, are also new. The heights in the fourth table are from the Admiralty charts of the British Channel, by Captain Denham, R.N.; and those in the fifth are selected from the heights given by Mr. Thomas, in the memoir accompanying his Geological Map

* Walker's MSS.

of the Mining District of Camborne, Redruth, Gwennap, &c., in Cornwall, heights which, it is understood, have been ascertained with great care.

Heights above the level of the sea, of several places in Cornwall, Devon, and West Somerset.

Heights obtained in the Trigonometrical Survey.

	Feet.
Sennen (Trigl. Station) Land's End, Cornwall	387
St. Buryan	415
Pertinney Hill, St. Just	689
Carnminnis Hill, N.W. from Towednack	805
Carn Bonellis, or Menelez, near Stithians	822
St. Agnes' Beacon, St. Agnes	621
Deadman Head, near Mevagissey	379
Hensbarrow Hill, near St. Austell	1034
Trevose Head (Trigl. Station)	274
Bodmin Down, Bodmin	645
Cadon Barrow, near Camelford	1011
Brown Willy, near Camelford	1368
Caraton Hill, near Liskeard	1208
Bin Down, near East Looe	658
Lansalloes, near Fowey	514
Kit Hill, near Callington	1067
St. Stephen's Down, Launceston	605
Maker Heights, near Plymouth, Devon	402
Black Down, near Tavistock	1160
Bolt Head	430
Butterton Hill, Dartmoor	1203
Rippon Tor, Dartmoor	1549
Cawsand Beacon, Dartmoor	1792
Furland Hill, near Dartmouth	589
Little Haldon Hill, near Teignmouth	818
Charlton Common (near Lyme Regis)	582
Dumpdon Hill, near Honiton	879
Dunkery Beacon, near Porlock, Somerset	1668
Wills Neck Hill, Quantock Hills	1270

Approximative heights in Devon, principally in Dartmoor, deduced by Mr. M'Lauchlan from data obtained during the Trigonometrical Survey.

	Feet.
Yes Tor, near Cawsand Beacon (4 miles west)	2050
Amicombe Hill, the summit (3 miles east of Bridestow)	2000
Newlake Hill (4 miles south of Cawsand Beacon)	1925
Fur Tor (5 miles east of Lidford)	2000
Brent Tor (4 miles north of Tavistock)	1100
Morwell Down (3 miles south of Tavistock)	715
Cocks Tor (3 miles N.E. of Tavistock)	1472
Great Mis Tor (5 miles N.E. of Tavistock)	1760
North Hessary Tor (near the Prison Barracks)	1730
Pen Beacon (3 miles east of Shaugh Prior)	1470
Shell Top (1 mile north of Pen Beacon)	1600
Hill, half a mile north of Shell Top	1650
Hemerdon Ball (3 miles N.E. of Plympton)	810
Three Barrow Tor (2 miles north of Butterton Hill)	1510
Peter's Stone, Holne Ridge (6 miles west of Ashburton)	1785
Hamilton Down (4 miles N.W. of Rippon Tor)	1738
Broadbury Castle (west from Okehampton)	874
Chapman Barrows, Exmoor (east from Paracombe)	1540
Barrows, South end of North Molton Ridge, Exmoor	1413
Span Head, Exmoor (Division of Devon and Somerset)	1610

*Approximative Heights in Cornwall, obtained during the Geological Survey by Mr. M'Lauchlan and Mr. Still.**

	Feet.
M. Sawah, between Sennen and St. Levan (Land's-End District)	305
M. Trenthrennan, near St. Levan	311

* The heights observed by Mr. M'Lauchlan are preceded by M.; those by Mr. Still by S.

		Feet.
M.	Hill close to St. Lena, near St. Buryan	314
M.	Hill above Merthen Point, near St. Buryan	254
M.	Chapel Carn Brea, N.E. from Sennen	640
M.	Hill between Tregiffian and Gorland, White-Sand Bay, Land's End	248
M.	Lecha, above Polpry Point, St. Just	275
M.	Bullowhall, near Cape Cornwall	265
M.	Carn on hill south from St. Just (Carn Bosavern)	472
M.	Carnidjack, near St. Just	640
M.	Carn on the north of Carnidjack	595
M.	Beacon Hill, Sancreed	* 531
S.	Trannack Downs, near Sancreed	660
M.	Tregurno Hill, on west of Lemorna Cove, near Mousehole	247
M.	Kimniel Wartha Hill, above Carn Du Point, near Mousehole	375
M.	Hill on the west of Paul, near Penzance	350
S.	Madron, near Penzance	370
S.	Hill near Forest Carn, N.W. from Madron	600
S.	Castle an Dinas, N.E. from Penzance	735
S.	Trerobben Hill, S.W. from Lelant	550
S.	Trink Hill, west from Lelant	652
S.	Lelant Church	110
S.	Base of Knill's Monument, near St. Ives	545
S.	St. Michael's Mount	195
S.	Marazion Mines, near Marazion	148
S.	Wheal Fortune, on the north of Marazion	90
S.	St. Hilary	190
S.	Penberthy Cross, near St. Hilary	148
S.	Hill, half mile east from St. Erth	200
S.	Wheal Alfred, near Hayle	210
S.	Hill south from Wheal Alfred	320
S.	No-Man's-Land, near St. Erth	300
S.	Pooleys	260
S.	Wheal Herland, near Gwinear	236
S.	Gwinear Church	240
S.	Conner Downs, near Gwinear	180
S.	Binner Downs, near Clowance	240
S.	Leeds Town, near Binner Downs	250
S.	Water Course at Godolphin Bridge	100
S.	Great Works Mine, near Godolphin Hill	215
S.	Godolphin Hill	495
S.	Tregonning Hill (north side)	596
S.	——————— (south side)	578
S.	Caerleon	250
S.	Breage	300
S.	Sithney, near Helston	230
S.	Crowan Beacon, Crowan	850
S.	Wendron, near Helston	400
S.	Hill, one mile west from Wendron	540
S.	Cury, south from Helston	250
S.	Mullion	285
S.	Pradanack Down, Lizard District	310
S.	Windmill, near Ruan Major Lizard	295
S.	Grade, Lizard	250
S.	Lizard Town	236
S.	Base of Lizard Light House	186
S.	Ruan Minor, Lizard	205
S.	Black Head Signal House, Lizard	220
S.	Cross Roads on hill north from Coverack Cove	360

* Mr. Still, by independent observations, gives this hill an elevation of 530 feet, so that this height probably is not far from the truth.

		Feet.
S.	St. Keverne, Lizard	290
S.	Dry Tree, Goonhilly Downs, Lizard	367
S.	Roscreage Beacon, near St. Keverne	380
S.	Penare Hill, Nare Point, near Manaccan	203
S.	Dennis Head Camp, St. Anthony, Helford River	160
S.	Mawnan, north entrance to Helford River	200
S.	Constantine	390
S.	Mewdon	230
S.	Hill near Penrose	220
S.	Budock, near Falmouth	280
S.	Pendennis Castle (entrance), Falmouth	198
S.	——————— (signal staff)	178
S.	Pelastine Rocks, near Mabe	700
S.	Maen Rock, S.W. from Mabe	690
S.	Hill above Burnt House, west from Penryn	680
S.	Plantations near Carnhingey, west from Penryn	500
S.	Stithians	390
M.	Carclew Park, east from House	266
M.	Killaganoon, between Perran Arworthal and Truro	335
M.	Tregothnan, near Truro	314
M.	Tolvorn, west from Philleigh	300
M.	Tregear, south from Philleigh	240
M.	Mill above St. Just, Falmouth Estuary	282
M.	Hill near Bohortha, between St. Mawes Harbour and Porth Mellin Head	277
M.	Trewince, south from Gerran	207
M.	Gerran	261
M.	Carne Beacon, near Veryan	370
M.	Nare Head, south from Veryan	338
M.	Probus	305
M.	Jenkins Barrow, near Mitchel, or St. Michael	457
M.	Cubert	280
M.	Penhale Point, near Cubert	217
M.	Point opposite the Chick, west from Crantock	142
M.	Point on south of entrance into the Ganel, Grantock	146
M.	Pentire Point, north of entrance into the Ganel	150
M.	Towan Head, near New Quay	120
M.	Look-out Hill, on north of New Quay	165
M.	Trevelga Barrow, near St. Columb Minor	240
M.	Castle an Dinas, near St. Columb Major	729
M.	Belovely Beacon, on east from Castle an Dinas	765
M.	Roche Rock	680
M.	St. Dennis	674
M.	Carliquoita Rock, on east from St. Enoder (summit of hill)	690
M.	St. Enoder	307
M.	Near Caryinack, west from St. Enoder	334
M.	Barrows-on-hill, two miles north from Ladock	376
M.	Burthy Hill, east from St. Enoder	607
M.	Hill, east from Burthy Hill, and north from Meledore	553
M.	Hill near Trevascoe, S.W. from St. Dennis	534
M.	St. Dennis Down, S.E. from St. Dennis	815
M.	Killivreth Down, west from Hensbarrow	1000
M.	Rosewallon, north from St. Stephen's	495
M.	St. Stephen's Beacon, St. Stephen's	700
M.	St. Stephen's	296
M.	Watch Hill, west from St. Stephen's Beacon	850
M.	Menacuddle, on north of St. Austell	404
M.	Carclaze Mine, on north of St. Austell	665
M.	St. Mewan Hill, N.E. from St. Mewan, near St. Austell	385
M.	Mulvra Hill, south from St. Austell	313
M.	Sticker Down, S.W. from St. Austell	364
M.	Lodge, north entrance to Heligan, near Mevagissey	286

		Feet.
M.	The Black Head, north of Mevagissey Bay	153
M.	N.E. corner of Penrice Grounds, near St. Austell	343
M.	Hill on west of Charlestown, near St. Austell	254
M.	Merthen Hill, near Par Pier	310
M.	Hill on S.W. from St. Blazey	364
M.	Hill above Restinas, near St. Blazey	502
M.	Prideaux Warren, near St. Blazey	435
M.	Helmen Tor, south from Bodmin	687
M.	Great Stone, St. Breock's Down, south from St. Breock	739
M.	Barrow on north of Scotland Corner, St. Breock's Down	670
M.	Line of Barrows on Bogee Downs, west from St. Breock's Downs	567
M.	St. Eval	326
M.	Park Point Hill, N.W. from St. Eval	180
M.	Gunver Head, N.W. from Padstow	174
M.	Base of the Beacon, Stepper Point, near Padstow	227
M.	Cant Hill, east from Padstow, Carmel River	223
M.	St. Minver Windmill, south from St. Minver	296
M.	Bray Hill, on west above St. Enodock, Padstow Harbour	209
M.	Pentire Point Hill, north from Padstow	256
M.	Hill one mile north from St. Minver	250
M.	Endellyon	417
M.	Killan Head, N.W. from Endellyon	209
M.	Varley Head, on west of entrance to Port Isaac	228
M.	St. Mabyn	295
M.	Cardinham Bury, near Cardinham	840
M.	Carbarrow, north from Warleggon	915
M.	Goldhill Barrows, N.E. from Warleggon	883
M.	Bellarmine Tor, north from Cardinham	884
M.	Greenbarrow, west from Temple	874
M.	Temple Tor, Temple	900
M.	Hill above Durfold, east from Blisland	690
M.	Penvorder, south from St. Breward	681
M.	Carbilley Tor, N.W. from Temple Tor	860
M.	Hawks Tor, north from Temple Tor	900
M.	Brocka Barrow, N.E. from Temple Tor	1000
M.	Hill above St. Breward	727
M.	Hill above Leasa, east from St. Breward	911
M.	Arthur's Hall, east from St. Breward	890
M.	Garrah, S.W. from Brown Willy	1060
M.	Alex's Tor, west from Garrah	940
M.	Michaelstow Beacon, near Michaelstow	684
M.	Hill one mile east from Michaelstow	762
M.	Rough Tor, N.W. from Brown Willy	1296
M.	Hill above Puckwalls, E.S.E. from Camelford	830
M.	Delameer Down, north from St. Teath	709
M.	Davidstow Moor, above Butterwell, south from Davidstow	959
M.	Corner of Davidstow Moor, above Penhale	1005
M.	St. Kitt's, west from Davidstow	985
M.	Titch Beacon, on North of Davidstow	1010
M.	Cross Roads on Hill, west from Otterham	758
M.	Fire-Beacon Point, north from Boscastle	492
M.	Barrow, near Newton Corner, Tresparret Downs	843
M.	High Cliff, north from Tresparret Downs	735
M.	Hill above Tremoutha, St. Gennis	420
M.	Carnbeack Point, near St. Gennis	333
M.	St. Gennis Hill, west from Church	431
M.	Cliff above East Dazard, north from St. Gennis	541
M.	Jacobstow Beacon, Jacobstow	590
M.	Hill above Millhooks Saddle, coast near Pounstock	385
M.	Cliff on west of Wescot, near Moorwinstow	420
M.	Littermouth Hill, north from Moorwinstow	404

		Feet.
M.	Ancient Camp above Warbstow	820
M.	Near Hallworthy, Wilsey Down, west from Trenegloss	910
M.	Brey Down, south from St. Clether	1125
M.	Beacon above Tresillon, east from Brown Willy	1174
M.	Tober Tor, N.W. from the Jamaica Inn, Bodmin Moor	1122
M.	Dozmere Pool, S.S.E. from the Jamaica Inn	890
M.	Trewartha Tor, westward from Hawks Tor (North Hill)	1050
M.	Kilmar, S.W. from North Hill	1277
M.	Sharp Point Tor, south from Kilmar	1200
M.	Newel Tor, west from Sharp Point Tor	1177
M.	Brown Gilly, south from Dozmere Pool	1100
M.	Bury Down, N.E. from St. Neot	925
M.	Carboul Tor, north from Bury Down	670
M.	Drains Down, N.E. from Bury Down	926
M.	Down close to St. Cleer, on the south	753
M.	Down near Mennaclew, N.N.E. from St. Cleer	1124
M.	Gribbin Head, near Fowey	267
M.	Whitley Hill, north of Pencarra Point, near Fowey	439
M.	Signal Staff, near Nealand, west from Polperro	421
M.	Elevation on west of the Signal Staff	435
M.	Hill east from Polperro	335
M.	Hill above Talland	445
M.	Ore Stone Point, near Talland	310
M.	Top of Looe Island, near Looe	170
M.	Signal Staff, near Penhale, on east of East Looe	498
M.	Hill above Seaton, on east of East Looe	465
M.	St. German's Beacon, south from St. German's, in Whitesand Bay	513

Heights on the Coast of North Devon and Somerset, from the Admiralty Charts, by Captain Denham, R.N.

		Feet.
Hartland Point	*Devon.*	350
Gallantry Bower, near Clovelly		387
Lundy Island Lighthouse		567
Coddan Hill, south from Barnstaple		623
Down End, near Baggy Point		511
Slade Down, near Ilfracombe		693
Helesbrow, or Hillsborough Hill, Ilfracombe		447
Little Hangman Hill, near Combe Martin		756
Great Hangman Hill		1083
Hill on west of Trenteshoe Barrow (named Great Hangman in the Chart)		1187
High Weer, near Martinhoe		850
Holiday Hill, Linton		818
Foreland Head, near Countesbury		734
Hall Hill, Countesbury		1145
Glenthorn Barrow, east from Hall Hill		1165
Culbone Hill, Culbone	*Somerset.*	1211
Bossington Beacon, Porlock		801
Grabbest Hill, south from Minehead		990
North Hill, Minehead		1059
Worle Hill, Weston-super-Mare		306

*Some of the Heights in the Great Mining District of Camborne, Redruth, Gwennap, &c., Cornwall, contained in the Report on the Survey of that District, by Mr. Thomas, Civil Engineer.**

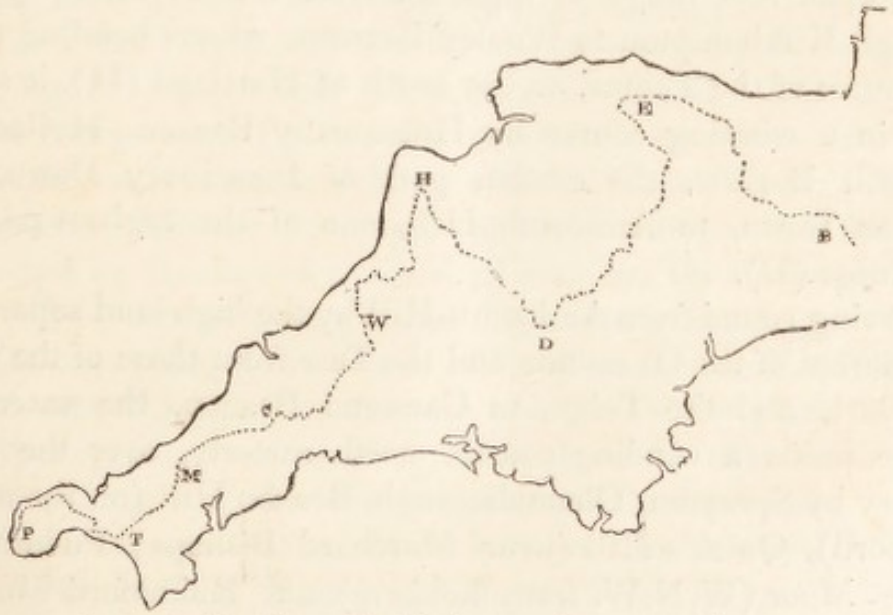
	Feet.		Feet.
Blackwater Hill	377	Carnarthen Hill	534
Cal Downs (highest part)	634	Carn Brea (highest rocks)	740

* The heights obtained by Mr. Thomas, of which those here given only form a portion, were determined by levelling from *high water* mark of great spring tides in Restronget Creek, Falmouth Estuary, and the results were proved by levelling from *high-water* mark at Portreath on the adjoining north coast of Cornwall.

	Feet.
Carn Entral	585
Carn Kie Beacon	780
Carn Marth (top of stone in Eastern Barrow)	757
Cosgarne Downs	366
Creegbroaze Hill	390
Glebe Crofts (half a mile south-east of Redruth Church)	560
Goonarle Downs	426
Hill east of Chacewater Mine	367
Hill south-west of Scorrier House	435
Illogan Downs	287
Lanner Beacon	757
Nancekuke Downs	285
Redruth Church (ground)	356
St. Day (south part)	388
Scorrier House (ground)	330
Trefula Beacon	599
Treloweth Downs	303
Trevarth Common (south-east corner)	323
Barncoose Mine	380
Chacewater Mine (engine shaft)	303
Cook's Kitchen Mine	360
Dolcoath Mine	370
North Roskeere Mine	304
Poldice Mine (Adit shaft)	377
Tin Croft Mine	372
Ting Tang Mine (engine shaft)	320
Tresavean Mine (William's shaft)	558
Treskerby Mine (Cook's engine shaft)	384
United Mines	288
Wheal Beauchamp	557
Wheal Damsel (engine shaft)	354
Wheal Druid	430
Wheal Gorland	400
Wheal Jewel (engine shaft)	407
Wheal Peever	385
Wheel Sparnon (engine shaft)	434
Wheal Squire	250
Wheal Virgin, Consols (ground at Compting House)	260

The water-shed line of the district takes a very tortuous course from W.S.W. to E.N.E., as will be seen by reference to the annexed figure (Fig. 1), where it is represented by the dotted line P, T, M, C, W, H, D, E, and B.

Fig. I.



Commencing at the Land's End, on the west, it passes over the high land of Castle Carn Brea, Pertinney Hill (P) Bosullo Down, Carnminnis (N.W. from Towednack), and Trink Hill, to the lower country on the left bank of the Hayle River, near St. Erth. It then strikes about S.E. to Relubbas, near St. Hilary,

making a bend to the sea on the south coast near Perranuthno. It continues hence eastward to Tregonning Hill (T), after which it holds its course across the comparatively depressed and intervening land to Crowan Beacon, in the elevated country of the Carn Menelez district, upon which it runs to Carn Marth (M). It afterwards approaches towards the north coast (at Prince's Common), but subsequently bends inland from it by Newton Downs, and the high land of Mitchell, St. Enoder, and Fat-Work Hill, to Castle-an-Dinas (C), traversing the Tregoss Moors, near the latter hill. From Castle-an-Dinas the water-shed holds a zigzag course on the north of the highest lands of the Hensborough district without passing over the latter, thence traversing the country near Bodmin in a N.E. direction to the elevated land of the Brown Willy district (W). After one or two minor curves between Temple and Brown Willy, it runs northward in a winding line over Davidstow Moor, Titch Beacon, and Otterham Downs, to Tresparret Down, where it closely approaches the shores of the Bristol Channel. These, however, it soon quits by a tortuous course in an eastern direction for the range of high land near Whitstone (on the E.N.E. of Week St. Mary), which carries the high road from Launceston to Kilkhampton. It continues northward upon this range of high land for several miles, passing through Kilkhampton to Wooley Barrows, where, bending round the source of the Tamar, on the south of Hartland (H), it strikes S.E. in a winding course by Holsworthy Beacon, Hollacomb, Hallwill Barrow, the eastern part of Broadbury Down, and Sourton Down, to Amicomb Hill, one of the highest parts of Dartmoor (D).

Curving round from Amicomb Hill by the high land separating the sources of the Okements and the Taw from those of the Tavy, the Dart, and the Teign, to Cawsand Beacon, the water-shed thence holds a winding course, north-easterly, over the lower country by Spreyton, Clannaborough, Beacon Hill (on the west of Sandford), Quick's Hill (near Morchard Bishops), Puddington, Gibbet Moor (W.N.W. from Loxbere), and Rakenford Moor, to Anstey Hill, on Exmoor.

From Anstey Hill it ranges along the south-western part of Exmoor by the high land of Molland Down and North Molton Ridge to the Span Head, where, coming round the western part of the Moor (E) by Moles Chamber and Ex-Head Hill, it holds a

course about E.S.E. by Black Barrow Down, Dunkery Beacon, and Lype Hill, to Wiveliscombe Barrow on Brendon Hill. It then strikes southerly over-land with very variable heights, across the direction of the general range of the hills, in a winding manner by Sperry Moor, Heydon Down, and Clayhanger, to Hockworthy, whence it crosses by the stripe of land pierced by the tunnel for the Taunton and Tiverton Canal, and by Banger Hill and Nicholshayes (on the E. of Burlescombe), to the Blackdown Hills (B), along the northern frontier of which the water-shed ranges by Beacon Hill, Noons Barrows, and Staple Hill, to Castle Neroche, whence, curving southerly by Combe Beacon to Chard, it passes easterly out of the district.

It will readily be observed, by reference to Fig. 1, that the largest part of the area has a southern drainage. If, however, the district had comprised more land to the eastward, and had taken in the country drained by the Parrett, the Brue, and the Axe, the embouchures of which only now come within it, the difference in this respect would not appear so marked, and the area would have been found to contribute more largely to that mass of river waters which is poured into the Bristol Channel. The main drains of the district are the Taw and Torridge on the north, pouring their united waters into Barnstaple Bay; and the Tamar, the Dart, the Teign, and the Ex on the south; the Tamar discharging its waters into Plymouth Sound, the Dart into its deep estuary near Dartmouth, and the two others into their shallow estuaries communicating with the Great Western Bay.

However different in height or various in position the lands connected by the line of water-shed may be, the drainage is the mere fall of waters from general higher to general lower levels, with the exception of the course of the Tamar near Kit Hill, and the Ex near Tiverton and Exeter. At the former place the river cuts through lands of much greater elevation than those at its source, and the Ex, after draining a generally descending country from its head, cuts through lands between Tiverton and Silverton, and on the north of Exeter, which would bar its course in those directions, if the continuity of the ranges of hills traversed were restored. With respect to the Ex, if the valley on the south of Tiverton were closed, the natural drainage would be in a direction towards the valley of the Culm; and, if the valley near Cowley Bridge were stopped, the drainage would be in the

direction of the Clist river. Connected with the drainage of the district, we may notice the basin-shaped cavity in North Devon, near Merton, Petrockstow, and Meath, generally known as Merton and Berry Moors, which would be converted into a lake, if the valley between Merton and Huish were stopped, through which the waters which either rise in, or fall upon it, now escape to the Torridge.

The following tables will afford a general view of the lengths of the principal valleys through which the main drainage of the district passes, and the distances to which the tidal waters flow up most of them will exhibit the general level at which they are cut by the sea:—

Names and Courses of the principal Rivers and Streams of Cornwall, Devon, and West Somerset.

CORNWALL.

Name.	Rises.	Flows into.	Total Length.	Tidal for
			Miles.	Miles.
Hayle River	Near Crowan	The Bristol Channel, near Hayle	11	2¼
Helston River	Hangman's Barrow, near Carn Menelez	The English Channel, near Helston	10	0*
Gweek River	At Buttris, N.W. from Wendron	The English Channel, near Mawnan	9½	5
Ladock River	Near St. Enoder	The Falmouth Estuary	11½	3
The Fal	Near Hensbarrow Hill	The Falmouth Estuary	19½	4
The Ganel	Near St. Enoder	The Bristol Channel, near Crantock	9½	2¾
The Camel	Near Davidstow	The Bristol Channel, near Padstow	29	9
The Par River	Near Roche	The English Channel, at Par Harbour	9	0
The Fowey	At Fowey Well, near Brown Willy	The English Channel, near Fowey	30	6½
The Looe River	Near St. Cleer	The English Channel, at Looe	10	1¾
The Inny	Near Davidstow	The Tamar River, at Innys Foot	19	0
The Lynher	At Beacon Hill, near Five Lanes	The Tamar, at Hamoaze	27	6½

* Is prevented from being tidal by the Looe Bar, a bank of shingle thrown up by the sea at the mouth of the valley converting the inner portion into a lake.

DEVON.

Name.	Rises.	Flows into.	Total Length.	Tidal for
			Miles.	Miles.
The Tamar *	At Wooley Barrows, 5 miles S. from Hartland.	Plymouth Sound, at Mount Edgcumbe	59	17½
The Tavy	At Okement Hill, Dartmoor	The Tamar, near Tamerton Foliot	23	3
The Plym	At the Plym Head, Cater's Beam, Dartmoor	Plymouth Sound, at Mount Batten	16	3
The Lyd	Branscombe Loaf, Dartmoor	The Tamar, near Lifton	13½	0
The Yealm	At Yealm Head, Dartmoor	The English Channel, at Yealm Mouth	14	3¾
The Erme	At Erme Head, Cater's Beam, Dartmoor	The English Channel, at Bigbury Bay	14½	2½
The Avon, or Aune	At Aune Head, Cater's Beam, Dartmoor	The English Channel, at Bigbury Bay	23	3½
The Dart	At Dart Head, Dartmoor	The English Channel, near Dartmouth	36	10½
The Teign	Near Siddaford Tor, Dartmoor	The English Channel, at Teignmouth	33	5
The Ex	At Ex Head, Exmoor	The English Channel, at Exmouth	54½	7
The Culm	Near Church Staunton, in the Black Down Hills	The Ex River, near Stoke Cannon	25½	0
The Otter	Near Otterford, in the Black Down Hills	The English Channel, near Budleigh Salterton	26	1½
The Axe	At Axnoller, near Beaminster, Dorset	The English Channel, near Axmouth	23	1¾
The Yart	Near Otterford, in the Black Down Hills	The Axe, near Kilmington	14	0
The Torridge	At the Ditchen Hills, near Clovelly	The Bristol Channel, near Appledore	53	9
The Okement	At Craumere Pool, Okement Hill, Dartmoor	The Torridge, near Meeth	18	0
The Taw	At the Taw Head, Okement Hill, Dartmoor	The Bristol Channel, near Appledore	48	11½
The Little Dart	On Rakenford Moor, Rakenford	The Taw, near Chumleigh	15	0
The Yeo	Near East Anstey	The Taw, near Newnham Bridge	19	0
The Bray River	Near Chapman Barrows, Exmoor	The Yeo, near Saterleigh	15	0
The Lyne	On Black Barrow Down, Exmoor	The Bristol Channel, at Lynmouth	11	0

* This may almost equally be considered a Cornish river, as it separates Cornwall from Devon for nearly its whole course.

WEST SOMERSET.

Name.	Rises.	Flows into.	Total Length.	Tidal for
			Miles.	Miles.
The Barle .	Near Moles Chamber, Exmoor .	The Ex, near Dulverton .	19½	0
The Tone .	At Tone Head, Brendon Hill . .	The Parrett, at Borough and Stanmore Bridges .	34	0
The Parrett .	Near South Parrott, S.E. from Crewkerne . .	The Bristol Channel, in Bridgwater Bay .	42	20*
The Brue .	At Brewham Lodge, near South Brewham . .	The Parrett, near Hemtspill	28	1†
The Ax .	In the Mendip Hills, near Ebber Rocks	The Bristol Channel, near Brean Down . .	25	6¼‡

The general configuration of the coasts will readily be seen by reference to the map (plate 1): those in the north and south, after approaching to within thirty-four miles of each other, between Bridgewater Bay and Lyme Regis, separate to the distance of seventy-one miles, between the Foreland, near Linton, and the Prawle Point. They thence approximate westward, and eventually join to form the boot-like termination of Cornwall towards the Land's End. The lines of different depths of sea adjoining the coast will serve to show the slope of the solid ground beneath it; a slope in general so trifling, that, if the waters of the English and Bristol Channels were removed, the present dry land would seem to rise above one vast plain, so small is the general angle which the solid ground beneath the sea makes with its level at the coast line. There may be places where, from our usually exaggerated ideas respecting the depth of any depression covered by water, we may consider the coast to be bounded by a deep sea, and it is apparent that deeper water approaches the western than the eastern part of the district, but if true proportional sections be constructed, and many miles distant from the land be included in them, the plain-like character of the floor of the sea adjoining such coasts as those of this district becomes very striking.

The southern shores of the district are in general bounded by

* This distance is reckoned from Bridgewater Bar. The Parrett runs only for 21½ miles within the district; but, as its embouchure and those of the two following rivers are within it, it appeared useful to notice the courses of the three.

† The Brue flows for only 4½ miles within the district.

‡ The Ax has its course for only 6¼ miles in the district.

cliffs, the sandy or shingle beaches at the mouths of the Axe, the Sid, the Ex, the Teign, the Par, and the Helston Rivers, and at the bottom of Tor, the Start, and Mount's Bays forming the chief, and, with reference to the total length of each, not very important exceptions. Of these beaches, those at the bottom of the Start Bay and at the mouth of the Helston River deserve notice, inasmuch as they both obstruct the drainage of the country behind them, causing fresh-water lakes. The superabundant waters of these lakes generally percolate through the beaches into the sea, which occasionally breaks through the shingly barrier in tempestuous weather, and opens a space through which the lake waters are let out upon the ebb-tide, again closing up the breach by its subsequent action. The lake behind the beach in Start Bay is now so much filled up that its area is by no means so considerable as it must have formerly been, even within historical times. The Looe Pool, as it is termed, near Helston, forms a handsome sheet of water several miles in circumference, above which the hills of the valley which has been thus closed rise high on both sides.

Though the northern coast is also in general bounded by rocky cliffs, we in several places find large accumulations of sand, which are not observable on the south, the sands of Gunwalloe in the Lizard district being comparatively unimportant. These sands may be considered to commence at Whitesand Bay on the north of the Land's End, where a patch occurs, partly covering up the adjoining hilly ground. On the east side of St. Ives Bay there is a large tract of sand hills extending about three miles and a half from Pencobben Farms to the mouth of the Hayle River, on the left bank of which, near Lelant, the country is also covered by sand. This sandy tract is nearly a mile broad between Treeve and the coast. The sand has been accumulated upon a hill of slate adjoining the sea, as is seen by occasional cliffs on the shore, particularly on the N.E., and by mining operations beneath the sand-hills.

Another considerable tract of sand-hills is found on the bottom of Piran Bay, extending from Piran Porth on the south towards Penhayle Point on the north, being nearly a mile and a half broad between Treworten and the sea. These sands also rest on hills of solid rock, as can readily be observed in the cliffs on the north and south, and at the several mines which have been

worked beneath them. A mass of sand occurs on the coast on the west of New Quay, and a far more considerable mass covers the shores and a large tract of country inland near Trevose Head. Sands also cover the country on the right bank of the Camel, opposite Padstow. At Braunton Barrows, near Barnstaple, the sand-hills and sandy country on the north of the united embouchures of the Taw and the Torridge occupy an area of about five square miles.

The greatest length of coast which occurs without rocky cliffs is that which extends about sixteen miles northward from the hills near Stockland Bristol, and Otterhampton, on the left of the embouchure of the Parrett, to Middle Hope Hill, on the north of Wick St. Laurence, broken only by the cliffs of the island-like hills of Brean Down and Worle Hill, near Weston-super-Mare. This low coast, formed either of shingle beach or sand-hills, ranges in front of the extensive flat lands, commonly known as the Bridgewater Levels, on the south-west of the Mendip Hills, and of another flat tract on the north-west of the same hills.

A limited portion only of the flat land extending up to Glastonbury on the south of the Mendips, and towards Wrington on the north of the same range, comes within the district under consideration. It differs materially in its physical features from the usual character of other parts of it. Instead of a very constant succession of hill and valley, we have an extensive plain, from which several hills emerge in the manner of islands in a sea, the western part of the Mendip range advancing into it like a promontory. One of the most conspicuous of the island-hills is Brent Knoll, a somewhat conical eminence seen far around the neighbouring levels. The lower island-hills of Pawlet and Chedzoy, and the promontory of Puriton and Cossington, rise out of the plain near Bridgewater. Worle Hill, near Weston-super-Mare (306 feet above the sea), forms a conspicuous object above it on the north. The area occupied by this flat land, if we take its ramifications into account, may be roughly estimated at about eighty square miles, forming part only of a far more extensive area of level land on the eastward of our district.

CHAPTER II.

MICA SLATE, HORNBLENDE SLATE, AND ASSOCIATED ROCKS.

HAVING sketched the general physical features of the district, we proceed to consider its geological structure, commencing with those rocks which appear to be the most ancient, and ascending to those which are most modern, noticing finally those geological changes which are now taking place on the surface of the land, and in the bed of the adjoining sea.

The most southern portion of Devonshire, comprised within the coast from Hope, near the Bolt Tail, to Hall Sands, near the Start Point, and a line connecting these points on the coast through South Pool and Marlborough, is chiefly composed of mica slate, chlorite slate, and chlorite rock. Mica slate is the predominant substance; it occurs in various parts of the area, but is most abundant on the south, where indeed it sometimes passes into a gneiss by the addition of felspar to its ordinary constituent minerals, mica and quartz. The gneiss is chiefly observable near the Prawle Point, and the mica slate best seen in the vicinity of the Bolt Head. True chlorite slate is not very abundant, but a compound of quartz and an ambiguous mineral much resembling chlorite occurs, intermingled with a chloritic and thick-bedded rock, very frequently towards the northern part of this area.

The chloritic rock has not unfrequently a somewhat arenaceous aspect, and the same appearance is observable in red rocks associated with it and the accompanying mica slates. These rocks can be well studied in the cliffs on both sides of the channel between the Molt and Salcombe. Hornblende is a rare mineral among the rocks from the Bolt Tail to the Start Point, but can be seen intermingled with the mica slate and chloritic series near the former place, forming part of some of those mineral compounds to which it is so difficult to assign names in rocks of this age.

If we consider the lamination of the mica and chlorite slates to

represent surfaces corresponding with those of beds, the mica and chlorite slate system of this part of Devonshire is much contorted, with a prevailing dip to the north and north-west. It might at first be considered that the beds possessing an arenaceous appearance would afford conclusive evidence on this head, but upon close inspection it becomes very difficult to determine if this appearance be really due to the aggregation of detrital matter, or to the rapid separation of substances from a fluid by chemical changes in it, which should render them no longer soluble. Taking, however, these beds as guides, we arrive at nearly the same results as to contortion and dip for this mass of rocks.

The natural sections of the junction of these rocks with the grauwacke on the north are in general somewhat obscure as regards the superposition of the latter. The best section occurs on the cliffs near Hope, where a series of red and grey argillaceous slates, apparently forming a part of the great grauwacke series of Devon and Cornwall, terminates somewhat suddenly at a little cove on the north of the village, becoming much traversed by quartz veins as it approaches the rocks on the south, but still preserving a very distinct character from them. A very soft argillaceous slate intervenes between these beds and the system of mica and chloritic slates on the south for a few feet, and is nearly concealed by shingle beach. A hard red rock, with a somewhat arenaceous aspect, then appears intermingled with mica slate on the south, and similar red rocks, often micaceous, and mingled with mica and chloritic slates, are well exposed at low water for about half a mile on the coast at Hope Cove. There is much irregularity in the manner in which these rocks are mixed with each other, and they are also so cut by divisional planes, having different directions, that it becomes no easy task to assign any prevalent dip to the mass.

The sections in the low cliffs of the Kingsbridge estuary, where in its range the northern boundary of these rocks cuts across it, are still less instructive. It is true that the laminæ of the argillaceous slates on the north dip northerly, away from the mica and chloritic slate system on the south, and that the mineral characters of the two masses are marked and distinct, and, therefore, in the absence of more direct evidence as to the superposition of the argillaceous slate system, we might infer that the one did rest upon the other at a moderate angle, the plane of lamination in

the argillaceous slate being inclined at a moderate angle near the junction, though it afterwards becomes perpendicular.

The sections near the Start Point are also somewhat obscure, and those inland particularly uninstructive, so that, though we may consider that the system of mica and chloritic slates of South Devon belongs to a class which existed prior to the grauwacke series, the evidence of its northern boundary having formed a surface from which detrital matter may have been derived for the production of the grauwacke near it, is by no means so good as could be desired.

In the Lizard district in Cornwall we again find mica slates, somewhat talcose perhaps, but still rocks of very different characters from those which constitute the great schistose systems of Cornwall, Devon, and West Somerset. They occupy a very limited area near the Lizard Head, and have been noticed by the various writers on this part of Cornwall, among whom some diversity of opinion seems to prevail, whether they should be termed mica or talcose slates, the principal mineral partaking of the united characters of mica and talc, a circumstance which has been noticed in several localities, more especially in the Alps. Mr. Magendie notices them as mica slates, observing that, under the slate at the Old Lizard Head, thick alternating beds of compact felspar and green talc are found.* Dr. Boase considers that talcose slates would be the preferable name for them, and remarks that they contain short irregular veins of quartz, and of this mineral united with calcareous spar, and that the slate passes on the south into a hard grey rock, containing minute particles of calcareous spar.†

Above, and indeed to a certain extent, interstratified with these talco-micaceous slates of the Lizard, we find well characterised hornblende slate, occasionally intermingled with beds which have the same mineral composition, but not the same schistose structure. It is a compound of hornblende and felspar, in the mass in nearly equal proportions, but occasionally the one or the other predominating in different localities. The rock is for the most part remarkable for the lustre of the hornblende, which gives it a character that the eye readily seizes as distinct from those combinations of hornblende and felspar, commonly

* Transactions of the Geological Society of Cornwall, vol. i. p. 34 (1818).

† Transactions of the Geological Society of Cornwall, vol. iv. p. 341 (1832).

termed greenstone, leading us to suppose that the mineral named hornblende in both can scarcely be exactly the same.

The hornblende slate seems intimately connected with the talco-micaceous slates above noticed, as may be seen near Poltreath, on the west of Lizard town. It supports the great mass of the Lizard serpentine, with an apparent passage of the one into the other in many places—an apparent passage somewhat embarrassing, inasmuch as there is reason to conclude, from the grauwacke conglomerate at the Nare Point in the north part of the Lizard district, that hornblende slates were in existence, forming a surface from which large portions were abraded by the action of water, while the serpentine and diallage rocks of the Lizard were not formed, for rounded pieces of the hornblende slate, though rare, are found in the conglomerate, while no trace has yet been discovered of either serpentine or diallage rock, though the latter especially is of great hardness, and therefore quite as likely as the hornblende rock to resist comminution into fine sand, and the two former are nearer to the conglomerate than the latter.

Whatever the cause of this apparent passage may have been, it is very readily seen at Mullion Cove, at Pradanack Cove, at the coast west of the Lizard town, and at several places on the east coast between Landewednack and Kennick Cove, more particularly under the Balk, near Landewednack, and at the remarkable cavern and open cavity named the Frying Pan, near Cadgwith. It will generally be found that, at this apparent passage of the one rock into the other, there is calcareous matter, and a tendency to more red colour in the serpentine near its base than elsewhere.

In contradiction to this apparent passage, we find a mass of serpentine amid the hornblende slate between Dranna Point and Porthalla, on the north of the principal mass of serpentine, which has every appearance of having been thrust up among the hornblende slate, twisting and contorting the laminæ adjoining it in directions which we should consider consistent with the passage of the serpentine in a state of igneous fusion through them. As a whole, however, the hornblende slate and rock seem to have formed a basin into which the serpentine and diallage rock have been poured in a state of fusion.

On the south, taking the laminæ for guides, the dip of the hornblende slate is in various directions beneath the serpentine; on

the north the prevailing dip is northerly and north-west, opposed to that of the grauwacke near it, which has a general southerly dip, with minor modifications. At Bellurian Cove, near Mullion, the junction of the hornblende rocks with the argillaceous slates on the north is marked by the presence of a conglomerate with a calcareo-magnesian cement, containing sprigs of copper and iron pyrites. In this conglomerate are portions of limestone, similar to that which occurs in Betsey's Cove, north of Porthalla, in the grauwacke, and also fragments which appear to have been derived from an arenaceous part of the same series. We were unable to detect any fragment of the adjacent hornblende slate and rock, which, indeed, seem to rest upon this conglomerate. The hornblende slate and rock contain veins of calcareous spar and siliceous matter, principally the former, in their lower part, the siliceous matter sometimes taking an agatiform character, showing that the cracks had been gradually filled. It is very difficult to trace this conglomerate up the cliff, where, indeed, though the ground is obscure, there may be a fault, but it can readily be observed in a line of rocks running seaward, at low water. On the north of the conglomerate we find argillaceous slate and arenaceous grauwacke, among which there is calcareous matter.*

If we trace the hornblende rocks from hence along the northern frontier of the serpentine and diallage rock, by Trelowarren to St. Keverne, we find extreme difficulty in marking its boundary against the grauwacke, more particularly on the east of Trelowarren. Well-characterised hornblende slate is found in many places near the serpentine, but it is also so mixed with ordinary greenstone rocks towards Roscreage Beacon, that to attempt a separation would appear a violation of a natural union between them, so that in the map we have been compelled to include the common greenstone rocks among the hornblende slates in this part of the country.

It will be observed that the mica and chloritic slate country in the southern part of Devon possesses little in common with the rocks in the Lizard district, if we except the talco-micaceous slates

* The presence of copper and iron pyrites in the conglomerate might lead to the opinion that it merely formed the substance of a lode which dipped beneath the hornblende rocks, and this view would be strengthened if the present obscure portion of the cliff were removed, and a fault should be traced upwards. As appearances stood, however, when we visited the spot, they would rather lead to the supposition that it was a conglomerate formed in the manner of a bed.

of the Lizard Head. The rock on which the Eddystone lighthouse is built, being, however, a variety of gneiss similar to some occurring near the Prawle Point, a kind of connecting link is obtained between one district and the other, which would give a W.S.W. and E.N.E. direction for the general bearing of the rocks of the Bolt Head and the Lizard, supposing them to be of the same geological age.

Around the granite of Devon and Cornwall we have abundant evidence of the alteration of the various rocks in contact with it, such alterations depending in a great measure on their original mineral structure. Similar facts have been observed elsewhere, and are now so multiplied that some geologists have even supposed, because many altered rocks assume the appearance of gneiss, mica slate, and others of that character, that all the crystalline and subcrystalline rocks, commonly considered to have been formed under a condition of the earth's surface, different from, and antecedent to, that which was fitted for the existence of animal and vegetable life, may be nothing more than altered detrital rocks, which having been buried beneath thick sedimentary accumulations, became exposed to long-continued heat, and were subsequently again brought to the surface by those geological changes which break up the crust of the earth and remove superincumbent matter.

When we term rocks detrital we suppose the pre-existence of solid mineral matter, whence their component parts may be derived by some abrading power; hence, we also consider that solid rocks of some kind must have preceded their formation on the earth's surface. The question then arises, whether there is any class of rocks which, as far as we yet know, does not contain the remains of animal and vegetable life, and which also possesses certain general and marked mineral characters different from another class of rocks which does contain the remains of animal and vegetable life, the former class occurring beneath the latter. Our present knowledge leads us to consider that there are two such classes, the one having a general crystalline or subcrystalline character, the other being without this character, except under particular conditions.

The hypothesis that detrital rocks, being buried beneath thick sedimentary accumulations, then become exposed to conditions which render them crystalline, chiefly from a movement of the

earth's heat upwards, in consequence of this sedimentary covering, also supposes pre-existing heat in the earth, a radiation of that heat into the surrounding planetary space, and, consequently, a general cooling of the earth by time, if no cause for a constant supply of the heat radiated exist in the earth itself, or be derived from bodies around it.

If we consider our planet as a cooling mass of matter, the present condition of its surface being chiefly due to such a loss of its original heat by long-continued radiation into the surrounding space, that, from having been wholly gaseous, then fluid and gaseous, and subsequently solid, fluid, and gaseous, the surface at last became so reduced in temperature, and so little affected by the remaining internal heat, as to have its temperature chiefly regulated by the sun, there must have been a time when solid rock was first formed, and also a time when heated fluids rested upon it. The latter would be conditions highly favourable to the production of crystalline substances, and the state of the earth's surface would then be so totally different from that which now exists, that mineral matter, even abraded from any part of the earth's crust which may have been solid, would be placed under very different conditions at these different periods. We could scarcely expect that there would not be a mass of crystalline rocks produced at first, which, however they may vary in minor points, should still preserve a general character and aspect, the result of the first changes of fluid into solid matter, crystalline and sub-crystalline substances prevailing, intermingled with detrital portions of the same substances, abraded by the movements of the heated and first-formed aqueous fluids.

In the gneiss, mica slate, chlorite slate, and other rocks of the same kind associated together in great masses, and covering large areas in various parts of the world, we seem to have those mineral bodies which were first formed supporting others in some localities, such as the northern parts of Europe and America, which contain, as far as we yet know, the remains of animals and plants created when the surface of our planet was first fitted for their existence.

The theory of a cooling globe, such as our planet, supposes a transition from a state of things highly favourable to the production of crystalline rocks to one in which masses of these rocks would be more rarely formed. Hence we could never expect to draw fine lines of demarcation between the products of one state of things and those of the other; and, consequently, if organic re-

mains should be detected in rocks associated with mica slates and others of that general character; or these rocks found alternating with the lower part of the grauwacke series, one in which, as far as geological researches have yet extended, the earliest traces of organic life have hitherto been detected; such facts would not be at variance with the theory of a gradually cooling globe, but would be in accordance with it, viewing the subject on the large scale.

Although we may feel inclined to doubt the sweeping hypothesis that all the crystalline rocks, such as mica slate, gneiss, and the like, are sedimentary deposits altered by the means above noticed, we should be careful to guard ourselves from undervaluing the influence of conditions which may alter detrital accumulations to greater distances from heated mineral matter, brought by any geological changes in contact with them, than we may at first sight consider probable. We shall have, as above stated, to notice several alterations produced by granite in the district under consideration, all of which, however, seem comparatively very limited; but there are facts connected with the hornblende slate of the Lizard which require consideration, with the view of seeing how far a fair explanation may be afforded by the supposition that they are altered rocks.

We have seen that it is extremely difficult to separate the hornblende slate by a marked line on the north, and we have also seen that a conglomerate composed of limestone and grauwacke seems to support the hornblende rock and slate at Bellurian Cove, near Mullion. Now these are facts very difficult to consider in accordance with the opinion that the hornblende slate was a rock of far greater antiquity than the adjoining grauwacke. On the other hand, the occurrence of hornblende slate in the grauwacke conglomerate of the Nare Point leads us to suppose that the former must have been a first-formed and consolidated rock. The serpentine of the district seems to pass gradually into the hornblende rock in many places, but cuts through it near Porthalla. If it were not for the occurrence of the hornblende slate in the conglomerate of the Nare Point, we might suppose that it was a mass of that trappean or ancient volcanic ash which is detected so abundantly amid the grauwacke of Devon and Cornwall (to be hereafter described), upon which the mass of serpentine and diallage rock, now nearly covering it up, has been

poured in a melted state; and that, being thus retained long beneath it in a heated condition, the water amid its loose laminæ prevented from escape upwards by the hot rock above, the hornblendic and felspathic particles of which it was composed arranged themselves into crystalline forms, the mass retaining its original laminated structure. This hypothesis would also serve to explain the apparent passage of the serpentine into the hornblende slate in so many places, and its intrusion amid the latter, with marks of force, near Porthalla. The serpentine at the latter place, detached from the main mass on the south, may have been thrown up subsequently to it; and we shall have occasion to show that the igneous rocks of the Lizard bear evidence of having been ejected at different times. It must, however, be confessed that, unless we suppose the hornblende slate, in the conglomerate of the Nare Point, to be derived from some other source, this explanation is not so good as could be desired; neither does it account for the apparent passage of the hornblende slate into the talco-micaceous slates of the Lizard Head, unless we suppose that they also are altered rocks.

The mica and chloritic slates of South Devon possess much of the character of similar rocks which cover considerable areas in various parts of the world. Unlike the hornblende slates of the Lizard district, we find no massive igneous rocks near them which may enable us to try the value of an explanation of their origin, founded on their relative mode of occurrence with such rocks, and thus endeavour to see how far they may be altered substances. It would be pure conjecture to suppose them immediately based on such rocks. The sea cuts off all view of their connection with other mineral masses on the south, which is the more unfortunate, as these rocks would appear to rise in that direction. Although there may be some obscurity as to the mode in which the red and grey argillaceous slates on the north come into contact with the mica and chloritic slates, the line which separates them from each other may be considered as well marked. There appears no passage of one into the other which would authorise the supposition that both were merely portions of a larger mass, one having been exposed to different conditions from the other, subsequently to their original formation, by which its first mineral character became changed. Neither does there appear any mode in which we could consider the one portion to have been buried beneath detrital

accumulations, and then changed, according to the hypothesis above noticed, without the adjoining mass having been subjected to like conditions. If the one be an altered portion of a larger mass, of which the other constituted a part, it could scarcely have been by this process. In the absence of any contradictory evidence, it would appear fair to infer that these rocks belong to that class which is more ancient than the grauwacke series; and though the mica and chloritic slates of the district may be associated with rocks possessing an arenaceous aspect, even supposing they may be detrital, that they form no part of that series which adjoins them on the north.

CHAPTER III.

GRAUWACKE GROUP.

This group of rocks, as developed in Cornwall, Devon, and West Somerset, is chiefly composed of sedimentary deposits, varying from the finest roofing slate to conglomerates, some of the component parts of the latter weighing more than half a ton. With these sedimentary accumulations, which seem due to the abrasion of pre-existing solid rocks by the action of water, or by meteoric influences, and the subsequent transport by water of the abraded substances to their present relative situations, we discover igneous products in parts of the area; a portion of which may also be termed sedimentary, inasmuch as it would seem to have been deposited in beds, among contemporaneous rocks of the former description, by the agency of water, after having been ejected from fissures or craters in the shape of ashes and cinders, precisely as we may now expect would happen with the ashes and cinders ejected from volcanos, particularly insular and littoral volcanos, into the sea. In the districts where this sedimentary ash is common, we also detect beds of greenstone and other solid trappean rocks, which seem to have formed sheets or streams of melted rock, amid the mud, silt, sand, or gravel, then in the course of accumulation, and which now constitute associated beds of slate, sandstone, and conglomerates. In the districts marked by such igneous action, there are also other greenstone and trappean rocks, but as they cut through beds of sedimentary matter, it is difficult to determine whether they acquired their present position, relatively to the mass of the grauwacke group, during the progress of the sedimentary accumulations, piercing through those which were previously consolidated, and being covered by the mud, silt, and gravel afterwards strewed over the area, or whether they were ejected through fissures after the formation and consolidation of the whole grauwacke series of Devon and Cornwall.

As large masses of sedimentary rocks, marking, for the most part, tranquil deposits of mud and sand during a long lapse of

time over a widely-extended area, seem seldom to occur without an accumulation of calcareous matter in different places sufficient to constitute limestones, the result either of deposits from water charged with carbonate of lime, coral reefs, or beds of shells or other animal remains of which carbonate of lime constitutes a large component part, so in this district we find limestones associated with the sedimentary parts of the grauwacke group, and calcareous matter very frequently prevailing where organic remains are most abundant.

Objections have lately been taken to the term grauwacke, and names have been invented to supply the place of that which it has been thought, by some geologists, desirable to remove from geological nomenclature. In a rapidly-advancing science, like geology, in which many theoretical points are of necessity extremely unsettled, it seems desirable to retain names for groups of rocks which, while they serve to assist our memories in classifying the deposits of given epochs in given areas, do not carry with them any particular hypothesis, or prematurely generalise local facts; for the hypothesis first framed may not eventually turn out the most tenable, and the local facts prematurely generalised may prove exceptions to a rule and not the rule itself. Hence if names such as grauwacke, lias, chalk, and others of the like kind, have, by accidental circumstances, obtained currency, and the geological epochs they may be said to represent are well understood, it seems an abandonment of terms of great convenience to change them for others involving hypotheses which may not eventually prove tenable, or which may prematurely generalise local facts.

Our geological nomenclature is certainly not at present in the most desirable state, being a compound of names added from time to time as geology has advanced, without regard to any fixed principle. In this respect it does not differ from the early nomenclature of most sciences, and we are far from wishing to resist changes in it; on the contrary, we fully admit that it would be highly advantageous that groups should be formed and names given to them which should be capable of embracing large portions of the earth's surface. We merely desire that this should be accomplished on fixed principles, and the nomenclature founded on large views of the earth's general structure, derived from a knowledge of facts over widely-extended areas. If

we calmly view our existing knowledge, it can scarcely be considered that the true relative structure of extensive portions of the earth's surface are yet sufficiently understood to frame a nomenclature of this order. The general knowledge required is advancing rapidly, and the inconvenience of the present nomenclature is beginning to press, more particularly when the geological structure of distant parts of the world is brought into comparison with that of the European area. We may anticipate that at no very distant period, when such comparisons shall become disentangled from the relics of the old doctrine of universal formations which now so frequently lurk in them, and embarrass useful generalisation, a state of knowledge will exist highly favourable for the formation of a good geological nomenclature. If the names 'Cambrian and Silurian Systems,' which have lately been suggested in England to supply the place of the term grauwacke, be merely employed as provisional, or because convenient for local description, they would be far from objectionable, it being understood that these systems form portions of a general mass of matter deposited at a given geological period over widely different parts of the earth's surface, bearing some general name which does not carry with it the inference that a system of deposits in one part of the general area is necessarily, though contemporaneous, the system of deposits in another. It is immaterial what that general name may be, provided that by it we understand the deposits of a given geological epoch, without presupposing a given system common to all.

To extend these names, as has already been done, to any series of beds in other localities without proof that the systems correspond with each other in the order and kind of their constituent rocks, and in the contained organic remains, merely from a supposition that they correspond in date, is prematurely to generalise local facts, and something like a return to the old doctrine of universal formations. It also supposes, in the case of sedimentary deposits, that detrital matter has been strewed exactly in the same manner, enveloping exactly the same organic remains, over all parts of the world, where deposits were taking place at the same time, otherwise a sedimentary system in one place could not be taken as a model of the sedimentary systems of equal geological date over all parts of the world.

It would be far from difficult to show that the extended use of

local names has, in many instances, greatly impeded the progress of geology, more particularly when authors, deeply imbued with the opinion that given organic remains can only be found in one system of rocks, and even in minute portions of that system, have carried their local names to different parts of the earth's surface, as if every accumulation of mud, silt, sand, gravel, or calcareous matter, must be continuous over it, tenanted by the same creatures, or enveloping the same drifted animals and plants, without for a moment considering the physical causes to which such accumulations must be due.

In thus objecting to the names Cambrian and Silurian Systems, as those given to the upper and lower portions of the detrital accumulations of a given geological epoch, to the exclusion of any general name applicable to the whole, and endeavouring to show that we already possess one which may be conveniently, in the present state of science, retained for the latter purpose, we are particularly anxious to avoid any seeming disrespect to the labours themselves on which these names have been founded. The value of the Cambrian and Silurian researches of Professor Sedgwick and Mr. Murchison cannot be doubted; that these researches will most materially advance our knowledge of the series of rocks under consideration is equally unquestionable; the latter geologist has dedicated several years to the detailed study of the upper part of the grauwacke group, which was either previously misunderstood or unknown, and the importance of the facts thus brought to light is undeniable. It is precisely because we do consider these researches important that we are desirous of seeing the names proposed restricted to the rocks in the countries which give rise to them, employing the facts brought to light as a well-ascertained local series, with which we may compare those observable in other countries, without, by affixing a local name to a series of rocks in those other countries, leading our attention away from the general conditions which may have influenced the deposits of more widely extended masses, and of which that whence the local name was derived may only constitute a part.

If it be objected to the term grauwacke, that originally it was merely the German miner's name for a particular kind of arenaceous rock occurring on the Harz, and that subseqently the name was applied to the mass of rocks of a given epoch among which

the original rock formed a subordinate and component part, the like objection would hold good with regard to the names lias, cretaceous rocks, oolitic series, and many others; for lias was only the name of the Somersetshire quarrymen for the argillaceous limestone beds forming a part of the rocks to which the term lias is now applied, being frequently limited by the quarrymen to two or three of those beds, and being also sometimes extended to other limestones, such as those of the carbonaceous series at Holcomb Rogus and Westleigh, in Devonshire. Actual chalk constitutes only a portion of the cretaceous series, which in some countries does not even afford this particular kind of carbonate of lime. Sands, clays, and compact limestones constitute the major portion of the oolitic series even in the countries where the oolitic limestones are well developed, and the oolitic character is moreover absent in some districts which contain the equivalent of that series, while the same character exists in rocks both older and more modern than it. Objections of this kind are objections to this order of nomenclature generally, and to many existing geological names, and therefore should be considered collectively with all the others similarly circumstanced.*

The grauwacke of Cornwall, Devon, and West Somerset would appear to bear considerable general resemblance to equivalent rocks in Normandy and Brittany, divided by MM. Elie de Beaumont and Dufrénoy into superior and inferior transition rocks; descriptions of which, with those of other deposits considered equivalent to either the one or the other of these divisions, were published by M. Burat in 1834.† This kind of classification merely requires that at a given geological epoch sedimentary deposits of various kinds, in some localities intermingled with contemporaneous igneous products, were accumulated in different parts of the earth's surface. As regards those portions now seen in Europe, they are merely, for convenience, divided into two parts, an upper and a lower, without pre-

* It has been objected to grauwacke, regarded solely as a word, that it jars harshly on the ear. If this be a sufficient reason to constitute a fatal objection to scientific names, and that all which do no not sound harmoniously are to be swept away, the number which in that case must be removed would materially abridge scientific dictionaries, more particularly if those compounds are included in which parts of two or three languages are often strangely and not over-harmoniously mixed together in one word.

† D'Aubuisson's Traité de Géognosie, 2de édition, tom. ii., par Amédée Burat, 1834.

supposing that the system of accumulations in one part of even the European area is of necessity the same with that in another; much less that it must correspond with any accumulations which may have taken place in more distant parts of the world. Thus leaving it to be determined how far any local causes may have produced corresponding effects horizontally, and permitting us by unbiassed researches to trace the varied condition of the earth's surface at given times, by such evidence as the present dry land can afford us.

In 1814 the Rev. J. J. Conybeare pointed out the general mineralogical difference between a large portion of the rocks in North Devon and those of other parts of Cornwall and Devon.* In 1823 the same author commenced a more detailed account of the slate rocks of Devon and Cornwall, which he did not live to complete.† He divided these rocks into—

I. Metalliferous, or, more strictly speaking, cupriferous and stanniferous slate, including various porphyritic and felspathic rocks (elvans), and occasionally greenstone. This he terms the *inferior* slate.

II. Slate which he terms *superior*, containing no elvans, but abounding much more in greenstone, especially its obscurer varieties, and in dark-coloured limestones. Sparingly metalliferous, containing no tin, and more productive of lead than the inferior. Occasionally containing organic remains.

III. Stratified rock; exhibiting the general character of a conglomerate or sandstone, alternating with tender slate, and occasionally associated with coralline or shelly limestone. It contains no metallic veins, and few, if any, rocks of the greenstone kind. "This rock might, perhaps," he remarks, "be regarded as forming the upper part of No. 2, and both would probably, by most geologists, be termed grauwacke."

In 1830 and 1831 Dr. Boase, in his 'Contributions towards a Knowledge of the Geology of Cornwall,'‡ adopts Mr. J. Conybeare's twofold division of the Cornish slates, proposing, however, the names of *porphyritic* and *calcareous*, instead of those of inferior and superior. "Most of the rocks of the calcareous

* Memoranda relatively to Clovelly, North Devon.—Geol. Transactions, vol. iii. p. 498, 1814.

† On the Geology of Devon and Cornwall.—Annals of Philosophy, 1823.

‡ Transactions, Geol. Soc. of Cornwall, vol. iv. p. 383.

series," this author remarks, in 1834, "appear to be referrible to the older portion of that class which is intermediate between the primary and the secondary; commonly known by the name of transition."*

In 1836 Professor Sedgwick and Mr. Murchison read a memoir before the meeting of the British Association for the Advancement of Science, held that year at Bristol, in which they separated the upper mass of rocks of North Devon which had hitherto been termed grauwacke from the lower, stated that these rocks rested in a trough-like cavity extending east and west, and concluded that they had been improperly classed with the lower series; inasmuch as they considered these rocks to be equivalent to the beds usually termed coal measures. The inferior rocks they divided into five subordinate groups.†

In 1837 the same authors read a communication to the Geological Society of London, on the physical structure of Devonshire, and on the subdivisions and geological relations of its older stratified deposits. In this memoir, Professor Sedgwick and Mr. Murchison notice the slates and associated rocks of both North and South Devon, and state their views respecting the identity of certain minor groups in each. They conclude that these minor groups of North and South Devon are *newer* than the rocks of Snowdon and Central Cumberland (lowest part of the Cambrian System of Professor Sedgwick), and *older*, with a very limited exception in North Devon, than the Silurian System (of Mr. Murchison): they therefore place them in the upper and middle parts of the Cambrian System; from the more ordinary appearance of which they consider them chiefly distinguished by the greater abundance of calcareous matter and fossils. The rocks of the centre of North Devon are described as coal measures, and divided into two minor groups.‡

Before we proceed more fully to notice the minor divisions of the grauwacke group, it is necessary to advert to the difficulty frequently experienced in parts of the area under consideration of being certain of the true direction and inclination of the beds,

* Treatise on Primary Geology, p. 38.

† Classification of the old slate rocks of the north of Devonshire, and on the true position of the Culm Deposits in the central portion of that county.– Reports of the Meeting of the British Association, vol. v. p. 95.

‡ Proceedings of the Geological Society of London, vol. ii. p. 556.

more particularly where extensive tracts of argillaceous slate prevail, in consequence of those divisional planes to which the terms lamination and cleavage have been given. These lamination planes vary from a perfect parallelism with the planes of the beds to very considerable angles with them, and are sometimes constant in their direction and dip while the beds they traverse are much contorted. This fact is not new, similar facts have been noticed by Professor Sedgwick,* but it is one which greatly embarrasses a correct judgment of the true dips of the beds themselves, where sections of neither cliffs, ravines, nor deep artificial excavations can be obtained. The accompanying section (Fig. 2) of part of the cliffs between Morte and Bull Points, near Ilfracombe, will illustrate the constancy of the lamination in

Fig. 2.

direction and dip, while the beds themselves are contorted; so that, while the planes of the former are sometimes parallel to the latter, at others they are at right angles to it, every intermediate angle being found according to the meeting of the variable curves of contortion and the constant planes of lamination. The thin diagonal lines in the figure represent the lamination, the thick lines the divisions of the contorted beds†.

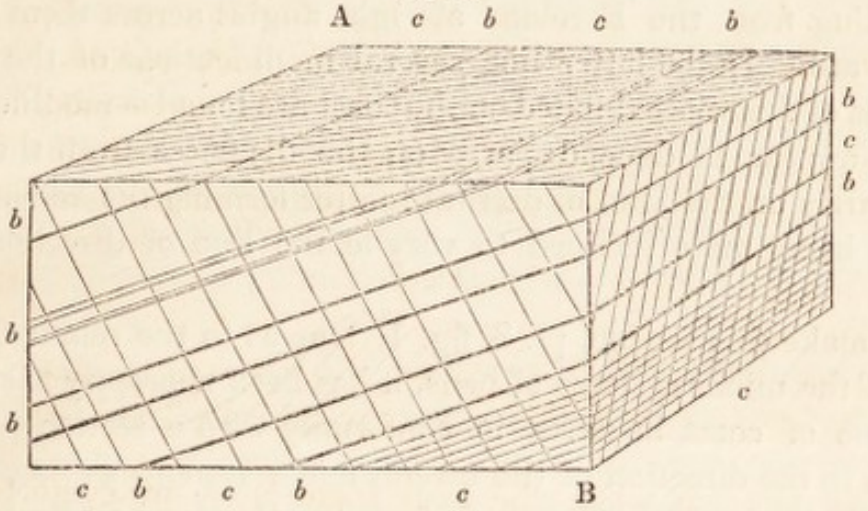
There is also another embarrassing circumstance connected with this subject, which is merely here mentioned to show the difficulty which sometimes attends the true determination of the dip and direction of the grauwacke beds, as we shall have to notice it more at large in another place, in connection with other divisional planes in rocks. While the planes of lamination for the most part coincide in direction with those of the beds, at whatever angle they may cut them vertically, they do not always do so. The most striking fact of this kind with which we are acquainted in the district is one occurring at Sharkham Point, near Brixham,

* Remarks on the Structure of large Mineral Masses, Geol. Trans. 2nd Series vol. iii. p. 470, 476, and Figs. 4, 4*a*, and 5.

† Dr. Boase has remarked on the difficulty of distinguishing true beds in the slates of Cornwall, in consequence of the divisional planes in the same rocks, caused, probably, he considers, by a kind of crystalline arrangement of parts.—Treatise on Primary Geology, chaps. vi. and xii. (1834.)

Devon, which was pointed out to us by Mr. Austen. Beds of limestone, resting on slate, are there seen to dip at a moderate angle about west-south-west, while they are traversed by lamination planes, rendering the whole schistose in one direction, dipping at a high angle to about south-east. It is difficult to represent this fact on paper, but the following sketch (Fig. 3) may assist in making it understood. Let A B represent a block of large

Fig. 3.



dimensions cut out of the hill, the lines marked *b* showing the planes of the true beds, traceable by lines of organic remains, and an interstratified slate bed, and those marked *c* representing the planes of lamination, planes rendering the limestone schistose in a direction different from that of the real beds, yet coinciding with similar planes in the adjoining slate. The liability to arrive at erroneous conclusions respecting the direction and dip of the beds will, in this case, be readily understood, more particularly when it is further stated that the lamination is a striking feature, and the beds comparatively obscure.*

Although the grauwacke of South Devon and Cornwall forms a more continuous mass, as regards surface, than the equivalent rocks in North Devon and Somerset, the latter present far greater facilities for study, inasmuch as, though often much contorted at right angles to the line of direction of the constituent beds, a certain general succession of minor sedimentary deposits, sparingly

* All notice of those other divisional planes, usually termed joints, which also cut through these rocks, has been purposely omitted, as it was considered that the figure would have been so confused by their insertion as to have been rendered altogether unintelligible.

intermingled with calcareous matter in sufficient quantity to constitute limestones, may there be easily traced, particularly by the aid of the coast section extending from the Foreland, near Linton, to Fremington, between Bideford and Barnstaple, on the tidal part of the Taw. The section, pl. 3, fig. 1, will show the succession of beds as seen on this coast. It must, however, be stated, that this section does not altogether afford a true view of the mineralogical character of the various and successive beds in a line extending from the Foreland at right angles across them to the southward. In the latter line several modifications of the minor systems of deposits exhibited on the coast are found—modifications which appear to depend partly on the distances from the coast and partly on the kind of detrital matter forming the beds, sandstones being more inclined to vary in the line of direction than slates.

To make this section, pl. 3, fig. 1, true as to the relative thickness of the minor systems of beds, it has been necessary to shorten the line of coast in parts, in conformity with a section at right angles to the direction of the several minor systems as they arrive at it. Thus, as the coast section from the Foreland to Bull Point, near Morthoe, a distance of about twenty-one miles (including the larger irregularities, but not the minor bays and points), is longer by about six miles and a half than the whole inland section of the grauwacke from the Foreland to its southern boundary near South Moulton, it is made to accord with about so much of the whole section as would correspond with the thickness of the constituent beds between the Foreland and the vicinity of South Moulton. From Bull Point to the headland on the north of Braunton Burrows, the greater part of the coast section is sufficiently at right angles to the bearing of the beds to be represented as it actually occurs. From the latter headland to Fremington, much of the section requires to be treated as that from the Foreland to Bull Point. Although such a section does not give a true view of that at right angles to the direction of the beds from the Foreland to the southward, it is nevertheless highly useful, by affording a general idea of the succession of the various deposits, the modifications of which can afterwards be traced across other parts of the country. The section, pl. 3, fig. 1, is proportional, that is, the scale of heights and distances are the same, and about four inches to the mile.

Commencing with the Foreland on the north, we find a series of sandstones, very frequently coarse-grained, and most commonly siliceous, in beds of variable thickness, some being schistose. The sandstones are associated with argillaceous slates, and the whole is of various tints of red, grey, and brown. From the variable indurations of these beds they have been unequally decomposed or removed by the united action of the atmosphere and sea, as is more particularly observable on the western side of the Foreland, which is exposed to the strong prevalent winds and the consequent destructive action of the breakers. The contortions are remarkable, and much care has been taken to represent them correctly in the section as seen from a boat. Notwithstanding the minor contortions, the beds make a general curve, and form an irregular arch, those which plunge at a high angle to the north towards the Foreland Point itself having a reverse dip towards the interior.

The red beds are very distinctly seen to rise from beneath the grey, to be next noticed, near Watersmeet, and the system of reddish sandstones which occurs above the Linton grey beds, in the ascending order, does not approach nearer to the valley of the Lyne, on the southward, than Cherriton, about a mile and a half distant, whence its northern boundary can be traced in the line of its strike by Dean and Six Acres to Woodabay, approaching there towards Lee Cove.

The red beds can also be seen to emerge from beneath the grey under Linton, the one seeming to pass into the other by alternations, and the red being sometimes somewhat calcareous. They are both much broken by faults in the valley, as can readily be observed along the new road, and still better to the west of the harbour at Lynemouth. This line of fault or faults seems to coincide with the general bearing of the valley from Lynemouth to Watersmeet.

The grey beds vary from a coarse argillaceous slate to a sandstone, most commonly schistose. They are often impregnated with calcareous matter, which is most prevalent in the vicinity of those seams which contain casts of broken vertebral columns of encrinites, and of productæ, spirifers, and corals—fossils few of which we found in a determinable condition. These beds can be well studied in the Valley of Rocks near Linton ; but, as the coast trends for some distance along the direction of the beds, care

must be taken not to confound the undulations along the line of strike for the true dip. This, though occasionally very slight, can be best seen at the coves to the east and west of Lee, and on the rocky ground on the south of the Valley of Rocks.

These grey calciferous grits and schists pass upwards into another minor system, apparently of considerable thickness, composed of red, claret-coloured, brown, and grey sandstones and slates, the former greatly predominating. From the small angle at which the line of direction of these beds meets that of the coast from the east part of Woodabay to the Little Hangman Hill near Combe Martin, they form the cliffs for about seven miles, their characters but slightly varying during the distance.

A very excellent natural section is afforded, on the western cliff of the Little Hangman Hill, of the upper part of this system of grits and slates, which is succeeded in the ascending order by grey and claret-coloured argillaceous slates, resting upon highly-inclined beds of red sandstone beneath them. Grey predominates in the upper part of these slates, and among them are seen sandstone beds, the whole covered by brown and red grit, partly schistose, and not very different in general character from those of the Hangman Hills.

We now arrive, in the ascending order, at grey argillaceous slates, generally of a fine grain, which contain the argentiferous lead-mines of Combe Martin, lead and copper also occurring partly in the grits beneath them at Knap Down. If we were to split up the mass of rocks into arbitrary divisions, the slates might be regarded as the lower part of a series comprising the Combe Martin limestones and grey argillaceous slates, with intermingled grits (that are sometimes calcareous and fossiliferous), which extends a short distance beyond Ilfracombe.

The Combe Martin limestones do not, as has been supposed, form regular bands continuous for considerable distances through the country. They seem to constitute lenticular masses of variable size, developed amid argillaceous slates, some fining off very gradually, others more abruptly. In the vicinity of Combe Martin they are more numerous than towards Ilfracombe on the W.N.W., or towards Kentisbury on the E.S.E., and sections across these and the accompanying beds, taken a mile apart from each other, would not give the same number of limestone patches. The limestones and their accompanying slates are occasionally fossil-

iferous, encrinites, as usual among these grauwacke limestones, being not unfrequent. The limestones are principally schistose, and of a dark grey colour, sometimes approaching black, and then, perhaps, being somewhat carbonaceous. As might be expected, siliceous rocks being associated with them, they are sometimes traversed by quartz veins.

From the vicinity of Ilfracombe, argillaceous slates, principally grey, intermingled in an irregular manner with grits, which are most frequently schistose, form the coast to Bull Point, near Mortehoe. From this point to Woolacombe, fine-grained argillaceous slate is the prevailing and almost sole rock. It is much traversed by quartz veins at Morte Point, and between Mortehoe and Woolacombe, the dark ground of the slate, and the white of the quartz veins having a marked appearance. These beds seem to have been subjected to considerable force, as shown by the quartz veins and the contortions of the beds. We have above (p. 44) called attention to some contortions traversed by cleavage lines between Bull Point and Morte Point. In part of the little cove where the section of these contortions is best seen, a long line of broken ground filled by quartz, runs out to sea from the cliff to the westward, and it is worthy of remark, that large blocks of porphyry, similar to the Cornish *elvans*, are found on the beach, too numerous and of too large a size to have been brought there by man. Though we were unable to detect any porphyry or elvan dyke in place, the end of such a dyke may, nevertheless, be visible at very low spring tides.

The argillaceous slates are succeeded by red, brown, and grey arenaceous beds, mingled with some argillaceous slates of the same colours, of which the actual coast section is concealed by blown sands, piled up against that which appears to have been a low cliff at the bottom of Morte Bay. Near Vention, on the south side of Woolacombe Sands, the upper beds become visible on the coast, and here grey, greenish blue, and claret-coloured arenaceous strata of variable thickness may be seen, the irregular decomposition of which is worthy of observation. These beds contain strings of manganese ore mingled with quartz.

Upon these beds are other arenaceous rocks, generally grey or brown, and for the most part schistose and micaceous. They are fossiliferous in part, and contain casts of shells much resembling

those of a cucullæa. In the upper part of these arenaceous rocks, more particularly in the eastern continuation of this part of the general series in a direction towards Barnstaple, we find the remains of plants, noticed by the Rev. D. Williams in his paper on the grauwacke of North Devon and Somerset, read before the British Association held at Liverpool in 1837. According to Professor Lindley, those which he has examined much resemble species detected in the coal-measures. Among them is *Stigmaria ficoides* (Ad. Broug.), one of the commonest of the fossil plants found in the true coal measures of Great Britain, and of the Continent of Europe, and which is also obtained from the upper grauwacke of Brittany, at St. Georges Chatellaison, and Montrelais, and occurs in the grauwacke of Bitschweiler (Department du Haut Rhin). There would also appear to be a *Bothrodendron*, somewhat resembling *B. punctatum*, found in the Newcastle coal-field, and a *Knorria*, like *Kn. Sellonii* (Sternberg), obtained from the grauwacke of Magdebourg, and from Felling colliery. With these are other plants, the species of which are not altogether so determinable, but possessing the general characters of the genera Lepidodendron and Stigmaria, so commonly found in the coal-measures. Like most fossil plants preserved in arenaceous deposits, they are commonly not much compressed.

The upper arenaceous rocks constitute Baggy Point, and are succeeded, in the ascending order, by argillaceous slates on the north side of Croyde Bay. Intermingled with the argillaceous slates, which are generally coarse, we find more gritty beds, and occasionally seams of a rotten ferruginous substance, among which are numerous casts of trilobites, encrinites, productæ, spirifers, &c.

These beds graduate upwards into slates, which contain more calcareous matter, sandstones being occasionally intermingled with them. The abundant remains of trilobites have been detected in them by Major Harding and the Rev. D. Williams.

Professor Phillips observes respecting the fossils from these beds, collected by Major Harding in the vicinity of Barnstaple, and kindly lent to us, that they consist of—

Zoophyta . .	Crinoidea . . .	Stems undeterminable as to genera.
	Retepora . . .	Obscure traces of.
Conchifera . .	Plagimyona . . .	*Nucula?* and several unknown forms.

	Mesomyona . .	*Pterinea.*
	Brachiopoda . .	*Leptæna;* a small species resembling *L. lata* of the Upper Ludlow Rock, Silurian system.
		Producta, offering analogy to *P. depressa* of the Wenlock limestone, Silurian system.
		Terebratula didyma? Dalman.
		Terebratula, analogous to *T. plicatella* of Dalman.
Mollusca . .	Gasteropoda . .	*Pleurotomaria.*
	Cephalopoda . .	*Orthoceratites.*
Crustacea . .	A beautiful tribolite, extremely similar to *Calymene macropthalma* (Dalman).	

The last-mentioned rocks pass gradually upwards into argillaceous slates, among which we find lenticular masses and nodules of limestone, for the most part containing organic remains, generally encrinites. The natural section is then concealed by the Taw, but on the east of Barnstaple these beds are seen to form a portion of a minor system, of which the argillaceous slates on the south side of the Taw near Fremington constitute a part. Between Fremington Point and Fremington Pill there is a very excellent coast section, in which these beds are seen to graduate insensibly into those deposits which, for convenience, we have separated from them under the head of carbonaceous series, a passage that will be more particularly noticed in the sequel.

If we consider this section with attention, there is nothing from the Foreland near Linton to Fremington Pill, which marks anything beyond a somewhat tranquil deposit of mud, silt, and sand, scantily mingled with calcareous matter, the sedimentary part of the deposit having been derived from pre-existing rocks, which have undergone various degrees of comminution, either the supply of detrital matter or the means of transport having been irregular, so that not only have sands, silts, and mud become interstratified with each other on the small scale, but the whole may be divided into larger constituent masses, some marked by a greater accumulation of mud or clay, and others by a predominant proportion of sand. Whatever might have been the numerical amount of the creatures, which from analogy we consider to have been marine, that tenanted the waters in which the deposit of these detrital rocks were effected, the remains of those now seen amid this mass of sedimentary matter, constitute a very minute portion of it, therein

differing from many thick rocks of more modern date, the greater proportion of which is not unfrequently formed of the accumulated remains of organised bodies. The frequent abundance of such remains in particular seams, and the larger proportion of such seams in one locality more than in another, might lead to the supposition that fossil organised bodies constituted a more important part of the mass than is really the case. Some localities may even be termed rich in such remains; but if we look at the cubic contents of the whole, organic remains form a very minute part of it.

Notwithstanding the diagonal character of the section from the Foreland to Fremington, that portion which extends from Bull Point to the southward is sufficiently far from a line of section commencing at the Foreland and extending nearly to South Moulton, about seventeen miles, to judge of any modification which the rocks may have sustained in the line of their direction for that distance to the eastward.

From the general tranquil character of the causes which have apparently produced the various rocks above noticed, no very remarkable general modification would be expected in a distance of seventeen miles along their line of strike; and accordingly we find a very general resemblance in the two sections. There may probably be a little more sandstone in one portion of one general section, than in a corresponding part in the other, but on the whole there is much uniformity. Thus, though there may be, near Challacombe, more of a union of the argillaceous slates and associated calcareous matter of Combe Martin with the grits and argillaceous slate-beds of the west of Ilfracombe, the fine argillaceous slates of Mortehoe seem to come nearly in their places at, and to the southward of, Challacombe, forming also the northern part of Breddon Down. The grey and brown sandstones, chiefly schistose, of the principal part of Breddon Down, appear to represent the grits of Pickwell Down, above Morte Bay. The lighter brown, and frequently schistose grits, between Stoke Rivers and High Bray, and of the adjacent country, come in the place of the Baggy Point sandstones.

If we take another section from the neighbourhood of Wiveliscombe to the north and south, which will be about twenty miles from the last, and consequently about thirty-eight miles from part of the first section from Bull Point to Braunton Burrows, we still

perceive certain generalities bearing much resemblance to each other. Thus, considering the grits of Croydon Hill to represent the sandstones of the Hangman Hills and Martinhoe; the Luxborough and Treborough limestones, curving round them on the eastward, to occupy the place of the limestones of Combe Martin; the grits and slates of Brendon Hill to correspond in position with those of the country between Ilfracombe and Bull Point; the fine argillaceous slates of Clatworthy to represent those of Morthoe; the red sandstones of Main Down, near Wiveliscombe, to come in the place of the red and brown sandstones behind Woolacombe Sands, there is a correspondence of certain generalities which is sufficiently marked and striking. The various rocks which occur above the red sandstones of Main Down, and the inferior portion of the carbonaceous series near Stawley and Clayhanger, do not certainly agree very closely in mineral character with those observable near Baggy Point, Braunton, and Barnstaple, and perhaps, with the exception of some argillaceous slates intermingled with arenaceous matter, containing seams of a rotten and ferruginous substance, full of organic remains, similar to those which are found near Barnstaple, there is little mineralogical resemblance between them. If we even take the red and claret-coloured slates resting upon the red sandstones of Main Down to represent the variegated grits of the southern part of Morte Bay and the rocks of Baggy Point, the very marked red sandstones and slates on the north of Stawley and Clayhanger cannot be likened to any portion, viewed mineralogically, of the rocks between Baggy Point and Fremington Pill.

From the manner in which we suppose any extended area to be covered by a succession of varying sedimentary deposits, it could scarcely be expected that great modifications—that is, variable mixtures of mud, silt, sand, and gravel, would not be found in different parts of it, so that, though the whole area has been covered with detrital matter by the action of general causes, those general causes have been subject to minor modifications producing corresponding effects.

The Quantock Hills, which emerge from the mantle of red sandstone and conglomerates that cover up the eastern end of the grauwacke beds of which we have been treating, form a continuation of the latter rocks. In the reddish and other sandstones of West Quantock's Head, Bicknoller, and other northern por-

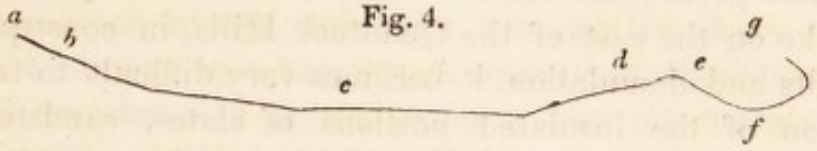
tions of the same hill, we seem to recognise the sandstones and associated rocks of Croydon Hill, and the Hangman's, while in the limestones of Doddington, Over Stowey, Asholt, and Cothelstone Park, we have the representatives of the Luxborough and Treborough limestones mantling round them. The limestones, which point away from Asholt and Cothelstone Park, are continued in the direction of Enmore and Higher Heathcombe, being covered on the southward by a series of slates, with accompanying grit beds, reminding us of the rocks of Brendon Hill, and of the north of Clatworthy.

It will not fail to have been observed, by reference to the sections (plate 3, figs. 1 and 2), that, however tranquil we may suppose the deposits of the various muds, silts, and sands (the original conditions of the different slates and sandstones now composing the lower grauwacke of North Devon and West Somerset) to have been, the beds have subsequently suffered from the action of some powerful force which has twisted and contorted them, so that probably not a single bed occupies exactly the same position in which it was first formed. What that force may probably have been will be noticed in another place; at present we merely advert to the fact. The extent to which the slates have been twisted is not always very evident, their real beds being often traced with great difficulty, while the lines of lamination or cleavage are so strongly marked, as almost to obliterate all traces of them.

These contortions are principally in lines at right angles to the lines of bearing, or strike, as it has been termed, of the various rocks; but they are not, as indeed it could scarcely be expected they would be, confined to that direction, undulations being also found in the course of the strike itself, as can readily be seen on any extended line of coast section cutting the line of strike at a small angle. Not only are minor undulations thus observable, but the whole mass seems to have received some very powerful contortions in a horizontal direction, to which the contortions at right angles to the bearing of the beds and the undulations along such line of general strike may be considered subordinate. By tracing the line of Combe Martin limestones, or rather the band of argillaceous slates in which they are here and there developed, the form of a great contortion will be readily seen, and may be represented by the subjoined sketch (fig. 4), *a* being Ilfra-

combe, *b* Combe Martin, *c* Simonsbath, Exmoor, *d* Cutcombe, *e* Luxborough, *f* Treborough, and *g* Withycombe. And if we be

Fig. 4.



right in referring the limestone of the Quantock Hills to the same band, this great contortion is carried round by Doddington, Asholt, and Cothestone Park, the connection being concealed by the red sandstone series, the lias, and the sea. As where we have so many similar sandstones and slates, and organic remains have not yet been fairly found to distinguish the various larger bands of these rocks, it is far from easy to identify the component parts of contorted masses, when the connection between them is concealed by more modern beds; this view of the connection of the Quantock Hill limestones with those mantling round Croydon Hill, might perhaps be doubted, and the former supposed to be some continuous portion of the band, which is so frequently calcareous, extending from Barnstaple to the vicinity of Dulverton, and which having ceased to be calcareous for some distance, again became so before it emerged from the red sandstone series near Cothelstone Park. On this hypothesis the slates and grits extending from Broomfield to Thurloxton would represent the lower portion of the carbonaceous series, still more changed in its course westward than it is found near Holcomb Rogus and Ashbrittle. Whatever opinion may be entertained on this head, compact grey limestones, similar to those under notice, probably occur beneath the red sandstone series near Sampford Brett and Stogumber; for red conglomerates there worked for lime abound in rounded stones and pebbles of a similar grey compact limestone, intermingled with other grauwacke rocks of the vicinity. Indeed a large proportion of the lime so worked is obtained from these rounded stones.

To determine the place which the Cannington Park limestone, near Bridgewater, occupies in the grauwacke series of North Devon and West Somerset, is difficult. The limestone is so surrounded by red sandstone, that its clear connection with the rocks of the Quantock Hills cannot be traced satisfactorily. At Cannington itself, on the south of this limestone, the lamination of the slate

has a southern dip; and if this should coincide with that of the true beds, the slate would appear to rest upon the limestone, unless some great fault should occur. From the exposure of the grauwacke on the east of the Quantock Hills, in consequence of both faults and denudation, it becomes very difficult to trace the connection of the insulated portions of slates, sandstones, or limestones, as the case may be, which occur (see map) at Cannington Park, Cannington, Ashford, Charlinch, and Radlet; and the difficulty is not a little increased by the possibility that contortions of these rocks may take place beneath their covering of red sandstone and lias.

Quitting North Devon and West Somerset, and traversing the rocks which are more modern than the lower grauwacke above noticed, we arrive, in Cornwall and South Devon, at a series of slates and sandstones, occasionally intermingled, more particularly in the latter locality, with grey compact limestones. These rocks are generally considered to have been formed at the same geological epoch as the grauwacke of which we have been hitherto treating. It therefore becomes highly important to ascertain how far the two masses may agree or disagree as regards the mode of occurrence of their constituent parts, their general mineral structure, and organic character. For this purpose it is desirable to examine a portion of the southern rocks, as undisturbed as we can find them, rising from beneath the superincumbent carbonaceous beds, should such be found.

With this object in view, we proceed to consider the rocks on the coast of Cornwall near Boscastle, Trevelga, and Tintagel, where grauwacke slates and grits emerge from beneath the carbonaceous system of North Devon, and where the beds of the former are merely forced seaward in a great curve by the protrusion of the neighbouring granite at a subsequent period. Beneath the carbonaceous grits and slates of Boscastle (pl. 4, fig. 1) we find argillaceous slates, much of which is of sufficiently fine grain to be worked as roofing-slates, the dip being northerly and under the carbonaceous grits and slates. In consequence of the great horizontal curve of the beds, the slates are brought round by Tintagel (where the roofing-slates are also worked) to the celebrated Delabole slate-quarries. In tracing this minor system of slates, we soon perceive that we have rocks intermingled with it of which there is no trace in North Devon and West Somerset.

They consist of schistose beds, strongly reminding us of the substance of greenstone, finely comminuted and permitted to settle in water, in which calcareous matter was occasionally present. The principal mineral substance has, as Dr. Boase observes*, an external character between hornblende and chlorite. These rocks form part of a general series of variable appearance, being sometimes slightly coherent, reminding us of the volcanic ash of modern times; at others vesicular, or even graduating into greenstone and other trappean rocks, some of which seem to have been in a condition of pumice prior to the infiltration of carbonate of lime and other substances into the cells, which has now rendered the whole a solid mass.

These schistose trappean rocks so graduate into the slates of Trevelga and its vicinity, as shown in the cliffs, that the change is almost imperceptible. They form the continuation of beds of far greater thickness in the direction of Davidstow and St. Clether, the run of which will be best seen by reference to the maps. Much of the vesicular kind, commonly known in Devonshire by the name of *honeycomb dun*, occurs above the church at St. Clether, with a dip about N.N.W. Large-grained greenstone, of a character to which the name syenite is sometimes applied, occurs on the hill above Davidstow, evidently associated with a continuation of the schistose trappean rocks above noticed. Greenstone, but generally of a finer grain, is found near Titch Beacon, on the north of Davidstow, the strike of which comes upon a variety of the schistose trappean rock which is impregnated with calcareous matter near Grylls, on the south of Lesnewth, where a fruitless attempt was once made to burn it for lime. On the south side of Trebarwith Strand, where the new sanding-road comes down to the beach, a similar rock is also found. Greenstones, some large-grained, occur near Tintagel, and the trappean schistose rock is also discovered mingled with them, particularly towards Bossiney. There is in fact so intimate a mixture of compact and schistose trappean rocks with the argillaceous slates, that the whole may be regarded as one system, the two kinds of trappean rocks having probably been erupted, one in the state of igneous fusion, and the other in that of ash during the time that the mud, now forming slates, was deposited, the mixtures being irregular

* Contributions towards a Knowledge of the Geology of Cornwall, Trans. Geol. Soc. of Cornwall, vol iv. p. 175.

from the irregular action of the respective causes which produced them; so that though the one may have been derived from igneous action, and the other from the ordinary abrasion of pre-existing solid rocks, they were geologically contemporaneous.

Dr. Boase, while describing the Delabole roofing-slate quarries, has seized the connection of these various rocks, though probably he would refer them to a different origin from that above suggested. He observes that "throughout the whole of the quarry there are insulated patches which are not regularly foliated, but which break into thick, coarse fragments, with a conchoidal fracture. These patches are not homogeneous. In one part they resemble the roofing-slate; but in others they contain a considerable portion of a dark green foliated hornblende (precisely similar to that which has been already noticed as occurring in conjunction with calcareous spar in the rock at Grylls) and a mineral in the form of white streaks, which may be seen on a close examination between the laminæ of the hornblende, and which on being tested proved to be carbonate of lime. This fact is very interesting; for it seems to point out that this slate (the Delabole) is connected with, or at least forms a member of, the same series of rocks to which the calcareous rocks of Grylls belongs."*

From the general coincidence between the curve of beds and the bend of the coast from Boscastle to Trebarwith Strand, a coast section of rocks beneath those above noticed is not obtained; but proceeding inland, a fine-grained arenaceous and micaceous rock, resembling a micaceous silt turned into slate, is seen to succeed them, curving round from the Vicarage, near Davidstow, by Cadon Barrow. These arenaceous and micaceous slates vary somewhat in the mass, are here and there mingled with true argillaceous slates, and more rarely with dark flinty slates, as at Hurrygulter, on the north, and at Helstone, on the south, of Camelford. When these beds approach the granite they become altered, as will be noticed under the head of altered rocks.

Proceeding from the vicinity of Camelford, Tintagel, Boscastle, and Davidstow towards St. Clether, Alternan, and Trewen, we find a continuation of the same series of beds. And it should be here noticed that the schistose trappean rock is highly charged with calcareous matter near St. Clether, on the Trebasil side of the river, matter accompanying the southern side of the same band

* Trans. Geol. Soc. of Cornwall, vol. iv. p. 183, 184.

of rock from thence to Trevenn. The association of carbonate of lime with the greenstones, trappean ash, and argillaceous slates, is a marked character of this part of the series—one which becomes more prominent as we advance eastward from Trewen to South Petherwin. Whether or not a band of limestone which there appears, though frequently interrupted in its course, be or be not a higher bed than any observable near Boscastle and Tintagel, the series having been slightly overlapped at the former place by the carbonaceous system above it, it is still intimately connected with the calcareo-trappean system which has been above noticed. In parts of these limestones and their associated slates we discover abundant organic remains. Between Trewen and Alternan there is much greenstone and schistose trappean ash; as also between the former place and Lawannack. Near Pollaphant there is a kind of potstone, which has been noticed by Dr. Boase*, who states that not long before he wrote (1830 and 1831), several vessels formed of this stone had been discovered under the rubbish of an old quarry about a quarter of a mile distant.

The limestones and associated slates of South Petherwin, after dipping northward (pl. 4, fig. 2) beneath the more modern beds of Launceston, arch over to the south; and a thin bed of limestone near Trewarlet (north from Lezant) may be a continuation of the calcareous portion of them. The South Petherwin beds, which consist of a mixture of limestone, sometimes schistose, with slates sometimes calciferous, at others possessing the ordinary argillaceous character, are extremely interesting from the abundant fossils they contain. Professor Phillips remarks on those which we obtained during the survey (chiefly through the exertions of Mr. Holl, at that time an active volunteer upon it), and on those in the collection from the same localities kindly lent us by Mr. S. Pattison of Launceston, that they consist of—

Zoophyta, Polyparia. .	A species of *Turbinolia*.
	Retepora, two species.
	Amplexus, one small species.
Crinoidea.	Stems.
Conchifera, Plagimyona.	*Cypricardia?* a species which in shape resembles *Axinus obscurus* of the magnesian limestone.
	Nucula?

* Trans. Geol. Soc. of Cornwall, vol. iv. p. 224.

Conchifera, Mesomyona.	*Avicula.* Two species very distinct in character; both supposed to be new.
	Pecten.
	Pterinea.
, Brachiopoda.	*Lingula?* It might be mistaken for a *Posidonia*, but is quite different from the Barnstaple shell.
	Terebratula. One resembling *T. plicatella* (Dalman), which occurs in Gottland and Ostrogothia. One resembling *T. didyma* (Dalman), which occurs in Gottland.
	Atrypa. One species somewhat resembling *A. cassidea* (Dalman), which occurs in Ostrogothia.
	Spirifera (Sow.) There are many species. One of the most remarkable has the cardinal line extended into long conical ears, as in *Sp. attenuata* (Sowerby), which occurs in the carboniferous limestone. Another has the aspect of *Sp. oblata* of that limestone, but is really distinct.
	Producta (Sow.) There are several species. One resembles, but is certainly distinct from, *P. rarispina* (Phillips), which occurs in carboniferous limestone.
Mollusca, Gasteropoda.	*Pleurotomaria.* Two or three very distinct species. Professor Phillips is not aware that they are described.
	Natica. Analogous to *N. ampliata* (Phillips), which belongs to carboniferous limestone. It is however distinct.
	Melania. Two species of the same group as *M. sulculosa* (Phillips), which belongs to carboniferous limestone. They are not identical with it.
	Genus? Several other spiral shells. One of them is a beautiful reversed specimen.
Cephalopoda.	*Clymenia lævigata* (Munster). There are at least four other species which, with the advantage of mature consideration, can certainly be determined. They undoubtedly belong to the same group as those described by Count Munster from the Fichtelgebirge.
	Goniatites. Two species, one of which belongs certainly to the group described by Munster from the Fichtelgebirge; but without more specimens it would be imprudent to attempt to name it. The other is of a new type.
	Orthoceratites. Several species; one very large.
Crustacea.	*Asaphus?*

In the valley of the Inny, between Trekellern and Trecarrell

bridges, there is much trappean rock, both schistose and compact, intermingled with argillaceous slate and a scanty portion of true limestone. Calcareous matter is however abundant in the schistose trappean ash; and some of this rock has been successfully worked for limestone, by selecting the more calcareous portions, and watching the first appearance of any slag in the kilns. On the right bank of the river, between Trecarrell Bridge and a place marked Mill in the Ordnance Map, calcareous matter has been infiltrated into a trappean rock which must closely have resembled pumice before the vesicles were filled by carbonate of lime; for if a piece of this rock be placed in dilute hydrochloric acid, the calcareous matter will be removed, and the remainder have all the character of a pumice. Although we have often seen the trappean rocks of Devon and Cornwall approach this character, we have never observed the vesicles so numerous and the trappean parting of the cells so thin as in this locality.

From hence the beds trend eastward towards Tavistock, where the obscurity of determining those which may be referred to the grauwacke, or the carbonaceous series, is so great, that it would be difficult to say how far the calcareo-trappean system above noticed may extend in that direction. In the descent of the road from Tavistock to Longford, calcareous matter is found among the trappean ash there cut through, and even nodules of limestone occur at the cutting near Longford.

On the left bank of the Tavy, immediately opposite the remains of Tavistock Abbey, there are quarries in which we find a considerable mixture of calcareous matter with the trappean ash; and it may here be noticed, that in an adjoining quarry, which might almost be considered as part of the same, a mineral resembling mountain leather fills the joints of the trappean ash.

On the new road from Launceston to Callington, and on the south of Landue, there appears a very decided example of unconformable position between the carbonaceous series and grauwacke, as will be more particularly noticed in the sequel, and seams with calcareous matter containing many organic remains, apparently similar to those detected at South Pitherwin, occur in the older rock. In the ascent thence towards Winfork, a somewhat arenaceous rock comes in, apparently a continuation of that which occurs at Innys Foot near Endsleigh, where, though curved, the beds generally have a southward dip. These beds are continued

in the direction of Leigh Ball, where schistose trappean ash is mingled with them, and the rocks are more argillaceous. Argillaceous slate prevails in the direction of South Sydenham, the laminæ of which dip southwards. Roofing-slate is worked near Horse Bridge, on the left bank of the Tamar, and at Mill Hill Quarry, near Tavistock. These may be continuous portions of the same band, as there is much similar rock between them, notwithstanding that the principal laminæ of the former dip south, and those of the latter to the north-west. In the vicinity of Tavistock the laminæ dip in such a variety of directions that it is difficult to decide which prevails; probably a southern dip may be most general. Near Wheal Franco copper-mine the laminæ are nearly horizontal.

If we take the mass of the slate country southwards from a line through Lezant, South Sydenham, Morwell Down, and Buckland Monachorum, to a line from St. Ive (near Liskeard), through St. Mellion, Beer Ferrers, to Bickley, and trust to the planes of general lamination alone, the whole, where not immediately near granites, elvans, or greenstone, would be considered to dip to the south. We have seen (p. 44), that to trust to this evidence alone would be highly dangerous; therefore, whether there may be numerous contortions of the actual beds, or the whole mass may dip quietly to the south, it would be difficult to determine without better evidence. Calcareous slate occurs near Cotele.

Continuing our course to the southward, and taking the banks of the Tamar as the best natural section, we find the shores near Landulph and Tamerton Foliot principally composed of argillaceous slate, a rock which continues with a southern dip of the constituent laminæ nearly to Saltash. We here arrive at bands of vesicular and schistose trap, mixed with slate of a sufficiently fine grain to be worked, an apparent continuation of the roofing-slates of Cann Quarries to the eastward. The section along shore at low tide, from Saltash to Hen Point on the coast, is particularly instructive as regards the association of sedimentary beds with the greenstones and trappean rocks of various kinds, schistose, vesicular, and compact, which may be there seen. Near this point the cliff and the shore (at low water) exhibit both vertical and horizontal sections of the mode in which the trappean rocks are there intermingled with the grauwacke. The annexed sketches (figs. 5 & 6) represent a part of this intermix-

Fig. 5.

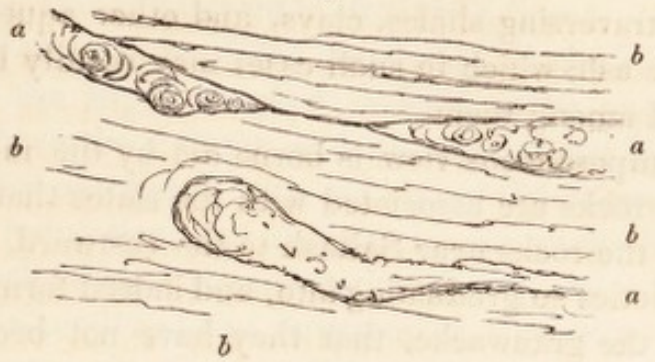
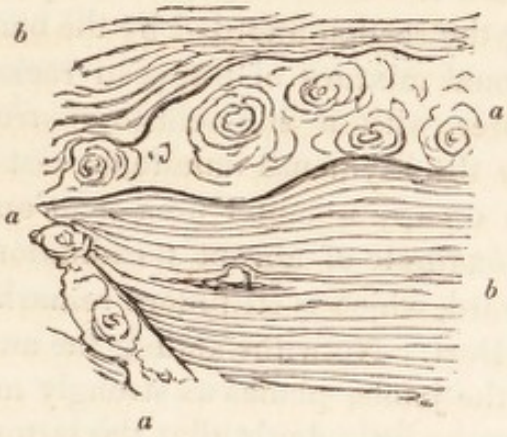


Fig. 6.



ture; fig. 5 affording a horizontal view at low water, and fig. 6 representing a vertical section in the adjacent cliff, *a* being trap, for the most part concretionary, and *b* grauwacke in both sketches.

Though there is such an abundant mixture of trappean rocks and grauwacke (the latter occasionally arenaceous) in the vicinity of Saltash and St. Stephen, and thence across the Tamar to St. Budeaux on the east, and towards St. Urney on the west, and good coast sections are exposed on the banks of the Tamar, and in the creeks which run up from the Lyhner to Manaton Castle and St. Urney, it is somewhat difficult to determine whether or not the whole of the trappean rocks were contemporaneous (in the sense formerly employed, p. 57) with the accompanying grauwacke. The schistose varieties certainly seem to be so, and if the greenstones and other compact trap rocks have sometimes the appearance of having been introduced into cracks produced in the slates subsequently to at least their partial consolidation, this appearance may be due to the filling of cracks and fissures, analogous to those which are produced in the beds of ash and filled by

lava on the flanks of volcanos (in cases where the latter are partly submarine), traversing shales, clays, and other aqueous deposits, as well as the ash, which in such cases may readily have become interstratified among them.

The contemporaneous view is borne out by the mode in which the trappean rocks are associated with the slates that form a continuation of the rocks near Saltash to the eastward, many of the schistose varieties so graduating into, and indeed forming so small a portion of the grauwacke, that they have not been noticed in the map, an example of which can be easily seen on the high road from Plymouth to Tavistock, near Widey.

Still continuing the section afforded by the banks of the Tamar, we find an occasional mixture of trappean rocks, both solid and vesicular, the latter with a sub-schistose structure, nearly to Devonport, where the Plymouth limestones rest upon the whole. These limestones occupy a larger area than any above noticed, and afford us an example of abrupt termination in the direction of the beds westward, which is still more remarkably exhibited on the banks of the Dart. Notwithstanding the ambiguity produced by the planes of the joints, planes as strongly marked as those of the beds, there can be little doubt that the latter dip to the southward, supporting the rocks which form the east and west shores of Plymouth Sound.

The limestones are generally of various shades of grey, and occasionally sufficiently dark coloured to afford black marbles. They are much traversed by veins of calcareous spar, and contain many organic remains, for the knowledge of which we are chiefly indebted to the Rev. R. Hennah, chaplain to the forces at Plymouth.* Among the shells are, *Spirifer cuspidatus*, Sow.; *Sp. distans*, Sow.; *Sp. octoplicatus*, Sow.; *Terebratula Pugnus*, Sow.; *T. imbricata*, Sow.; *T. platyloba* (*jun.*), Sow.; *Atrypa reticularis* (Wahl.); *Producta depressa* (Sow.); *Cardium alæforme*, Sow.; *Pileopsis vetusta*, Sow.; *Nerita spirata?* Sow.; *Cirrus acutus*, Sow.; *Pleurotomaria cirriformis*, Sow.; *Turbo Tiara*, Sow.; *Murex? Harpula*, Sow.; *Buccinum spinosum*,

* Playfair seems to have been the first to notice organic remains in the Plymouth limestones. He speaks in his Illustrations of the Huttonian Theory, p. 164 (1803), of having obtained a fossil shell from them. Subsequently, De Luc and others threw doubts upon the fossiliferous character of these limestones, and it was not till the labours of Mr. Hennah cleared up the subject that this character was fully admitted.

Sow.; *B. acutum*, Sow.; *B. imbricatum*, Sow.; *Bellerophon costatus*, Sow.; and *Orthocerates circularis*, Sow.*

A kind of alternation of the upper part of the Plymouth limestones with the superincumbent slates may be seen near Mount Batten. Above these slates, on both sides of the Sound, we find red sandstones associated with red slates, the former of variable degrees of induration, but frequently extremely hard. These beds are much twisted, the contortions being probably due to the causes which produced the intrusion of a porphyritic rock that occurs in mass on the north of Cawsand, and is intermingled with the contorted and broken beds along the shore thence towards Redding Point, cutting through and running among them in various ways. It has, however, a general leading direction for the curved and contorted beds on the north of Staddon Point. At Cawsand, variegated slates, among which red beds are very prevalent, form the upper part of these red rocks, and are succeeded in the ascending order by grey slates towards Penlee Point and the Rame Head. Similar beds rest upon the red grits and slates of Staddon Point, and are found to be fossiliferous on the south of Bovey Sand bay, where Lieutenant-Colonel Mudge, R.E., has detected calciferous beds containing organic remains.

The main mass of the Plymouth limestones, here and there intermingled with argillaceous slate, are continued eastward by the northern part of Plymstock to Gore, near which place, and West Sherford, they terminate amid the slates. A small portion of limestone occurs on the south of the main mass, near Goosewell, included in the argillaceous slates, a continuation, not improbably, of the beds amid which a much larger mass is developed at Kitley Park and Yealmpton. This last patch of limestone is greatly intermingled with a variety of dolomite, generally subcrystalline, and flesh, or roseate coloured, and black carbonaceous slate is found on the south of it in Kitley Park.

Viewing the subject in the large scale, we have a system of beds extending from the neighbourhood of Plymouth (including in that neighbourhood the country around Plympton, Brixton, and Yealmpton) to Buckfastleigh, Broadhempston, Ashburton, and Bickington, in which there is a very variable intermixture of

* These shells were determined by Mr. Sowerby from specimens which the Rev. R. Hennah was kind enough to lend us several years since, to complete some lists of organic remains for another work.

calcareous matter, argillaceous slates, and trappean rocks, the latter occurring sometimes solid, at others vesicular, and not unfrequently schistose. If we include the limestones of Ditsham, on the Dart, and the bands of Harberton Ford, and the vicinity of Cornworthy, in the same system, as probably ought to be done, we have a breadth of about eleven miles, on the east, gradually diminishing to about two miles on the west, near Plymouth. Taken as a whole, the beds on the banks of the Dart, from Buckfastleigh to Ditsham, rest upon each other in an ascending order, so that the limestones of the latter would occupy a higher part of the series than those at Buckfastleigh. There can be little doubt that the Bickington, Ashburton, and Buckfastleigh beds form portions of the same band of calcareous matter, extending nearly to Dean Church, where it terminates. There would also appear little reason to doubt that the limestones of Broadhempston, Woolston Green, and Paytor, are intermediate between the first band of calcareous matter and the bands near Cornworthy and Ditsham.

In the section exhibited on the Tamar, the Plymouth limestones were the first calcareous masses found in the ascending order. If we take the run of rocks of which they form a part, and trace them eastward, we first find limestones at Dunwell and Shilstone, on the south of Ugborough, at about eight miles distant from the eastern termination of the Plymouth limestones near Gore. These patches of limestone are very small, and are included amid a mixture of argillaceous slates and trappean rocks. We may hence trace the calcareous rocks by a small patch of limestone near Ugborough, and another at Fowelscombe, to North Hewish, where a larger band of limestone is detected. How far we may consider the patches of limestone near Langford and Paytor as a continuation of the same minor series of beds is not so clear. If, however, we take them to represent a prolongation of the Plymouth band, we may consider it still further continued to Dartington and Broadhempston. It must, however, be confessed that the evidence on this head is not so complete as could be desired.

If we take the Yealmpton limestones as somewhat higher in the series than the Plymouth beds, we find a band carrying on that line near Sequers Bridge. After this, however, calcareous matter does not appear in the line of strike for a considerable

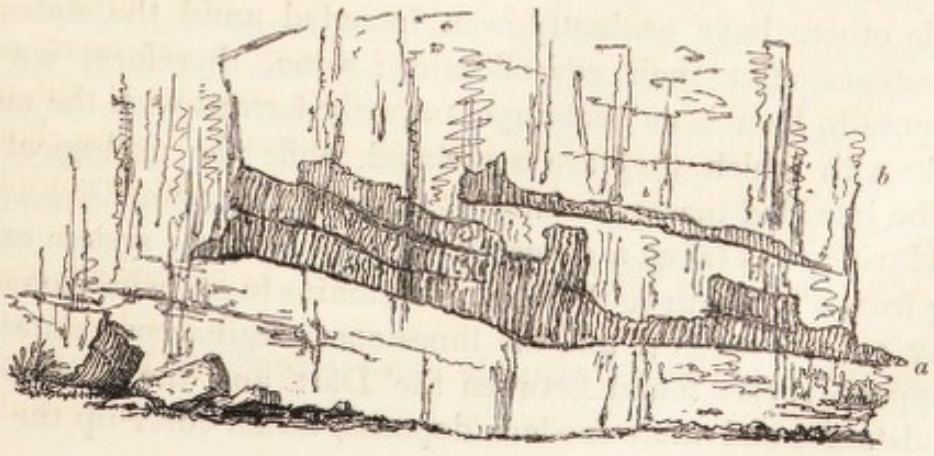
distance. If we suppose the limestone at Harberton Ford to be a continuation of the same minor system of rocks, there would be an interval of nine miles and a half between any development of actual limestone in it.

It will be observed, by reference to the maps, that in the area occupied by these limestones there is much trappean rock; and that, while this rock sometimes occurs in lines, at others it is found in isolated portions.

The other principal rocks of the same area are chiefly varieties of argillaceous slate, some being sufficiently fine grained to be worked for roofing slate. The true bedding of this slate is for the most part very seldom seen, the planes of lamination and perpendicular joints being chiefly observable. It therefore becomes exceedingly difficult to determine how far the main mass may be contorted, and how far the beds may rest at a small angle in one place, and be highly inclined in another. The limestones on the west of the Dart occur too sparingly to afford much evidence on this head; but if we regard the rocks near Plymouth to represent the system of beds extending along the banks of the Dart, from Buckfastleigh to Ditsham, it would seem reasonable to conclude, unless we suppose a very considerable decrease in the general thickness of this system, that the mass is much less inclined on the east than on the west.

With regard to the trappean rocks, the intrusion of many amid the slates and limestones, after the consolidation of the latter deposits, is very evident. The example beneath (fig. 7), taken from Luscombe's Quarry, North-street, Ashburton, as it appeared in 1832, is as good, probably, as we can select. Frag-

Fig. 7.



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ments of limestone, *a*, fractured portions of the band extending from Bickington, are caught up amid the trappean rock, *b*, which appears to have burst through the slates and limestones after their consolidation. Fine examples, also, of the intrusion of trappean rocks among the slates occur near High Week and Newton Bushell, and in the vicinity of Bickington; which will most probably be described in detail by Mr. Austen, in his memoir on that part of the country. The trappean rocks would appear to have been driven in among the limestones near Buckfastleigh. The section obtained on the Avon near Diptford would lead to the supposition that the trap rocks had there also in part been thrust in among the slates after their consolidation. There are appearances around the large trappean masses near Yealmpton, and at Hearstone and Southwood, which lead us to consider their intrusion also as probable. At the same time, however, several vesicular varieties of trap, approaching the ash, previously noticed, may be here and there found, intermingled with the slates and hard greenstone rocks between Totnes and Plymouth.

Upon the whole, we have a system of rocks extending from the Dart to the Tamar, principally consisting of argillaceous slates, among which limestones are found in bands of variable breadth and length, some occurring in lines which we may consider were formed at equal geological times, employing the term in an extended sense, seeming to mark a prevalence of conditions more favourable for their production at such times than at others, though, from the occurrence of calcareous matter in some of the slates out of these lines, and the relative positions of the minor patches in the supposed lines, such conditions must have been very variable. Among these slates and limestones we find trappean rocks, a few possessing the ashy character above noticed, while others have evidently been intruded amid the slates and limestones after their consolidation; some, therefore, we may suppose to have been contemporaneously formed with the mass of rocks with which they are associated, while the geological date of the intruded masses and dykes is more uncertain.

Having thus taken a general view of this minor system extending from Plymouth to the Dart, it remains to see what connexion may exist between it and the limestones, argillaceous slates, and trappean rocks, found between the Dart and the mass of red sandstones, and more modern deposits, which cover up the grau-

wacke on the eastward. A very satisfactory section can readily be obtained from the Bickington band of limestone (the continuation of that of Ashburton and Buckfastleigh) to the mass of limestone which occupies a comparatively extensive area at Ogwell, Denbury, Ipplepen, and Torbryan (pl. 4, fig. 5).

Mr. Austen, who has examined this district in great detail, and to whom we are principally indebted for the lines on this part of the map of Devon, assigns the name of "Lowest band of limestone" to the Bickington beds, and of "Great and Rag limestones" to those of Ogwell, Denbury, and Ipplepen. Notwithstanding the interruption from trappean rocks, the intermediate slates, which are not unfrequently claret-coloured, are perfectly conformable, as far at least as general lamination may be trusted, to both the limestones above and beneath them. There is nothing in the section to show that any of the beds have formed a surface from which portions have been abraded during the formation of the general mass. On the contrary, the various parts apparently graduate into each other in the manner of those deposits which are considered to have been produced during the same geological epoch. The passage of the higher parts of the slates into the superincumbent limestone, and their fossiliferous character under those circumstances, is noticed by Mr. Austen,* and can be well seen in the neighbourhood of Ogwell House.

From near Ogwell House to Ipplepen this upper limestone forms a table with minor undulations, and is continued to Oxhill and New House, cut into near Denbury, Torbryan, and Ipplepen, by valleys, which expose the slates beneath it. In attempting to bring this mass into connexion with the slates and limestones in the direction of Broadhempston and Staverton, we are embarrassed by the want of evidence as to the true bedding of the slates. If we take lamination as a guide, the slates dip beneath it. The limestone extending from Abbot's Kerswell towards Dainton, trending thence round to King's Kerswell, may readily be a continuation of the Denbury and Ipplepen beds bent over an intermediate arch of subjacent slate, the latter being probably also affected by the continuation of the fault which brings the

* Proceedings of the Geological Society of London (December 13 1837), vol. ii. p. 586.

limestone of Connator Hill in vertical contact with carbonaceous beds (pl. 4, fig. 5).

If we take the lamination of the slates in the deep cut of the Totnes and Newton Bushell road, descending from Bow Hill to Bow Bridge, to represent the planes of the beds, these slates would appear to rest upon the Ipplepen limestones, and support those which are found between Bully Barton and Bow Hill. This lamination coincides with the dip of that in its line of strike at Buckyatt and Dartington. It may still, however, not agree with the true bedding, so deceptive is lamination.

The older rocks between the limestones on the west of Bully Barton and those of Marldon are concealed by a mass of red sandstones and conglomerates, and it is difficult to determine the relations, as to relative age, in which they stand to each other. The like difficulty arises with respect to the minor patches at Compton, Gallows Gate, and North Whilborough, from the same cause. Probably the limestones at Arton, Loventor, Marldon, and Compton, are portions of the same series of beds. If so, we may consider them as distinct from the Ipplepen limestones, and separated from them by intermediate slates, a section of which may be obtained, on the west of the covering of red sandstone, between Berry Pomeroy Park, and Newhouse. Upon this supposition, the band of limestone at Little Hempston would be developed in a continuation of the intermediate slates.

In the indentation and exposure of the subjacent rocks among the Denbury and Ogwell limestones near East Ogwell, Mr. Austen has discovered organic remains in the trappean ash immediately beneath the limestones. A very interesting fact, as it tends to confirm the view we have formerly taken of the subaqueous deposit of similar ash beds. This ash, associated with some more solid trappean rocks, seems to have formed a floor on which the calcareous beds were deposited. Mr. Austen has traced similar ash, though I believe he has not detected organic remains in it, beneath the limestones winding round near Dainton from Abbot's Kerswell to King's Kerswell, and also beneath the limestones near Tor Moham.

The older rocks are unfortunately concealed beneath a mantle of red sandstone and conglomerate between the Mary Church and King's Kerswell limestones. A small patch of limestone rises

indeed through the red sandstone series on the hill between King's Kerswell and Barton Cross; but in a district where limestones occur so irregularly amid the slates, when the whole is unconcealed by more modern deposits, this patch affords us little aid.

The Torquay, Tor Moham, and Babbacombe limestones have been much contorted,* and the subjacent rock thrust up from Mead Foot sands in a north-west direction to Upham. Among these subjacent rocks we find sandstones frequently red, which, perhaps, may assist our inquiries respecting the relative superposition of the limestones of this part of the country.

Returning to the Dart, we perceive that the limestones on the north of Bunker's Hill, near Totnes, rest upon argillaceous slates in which arenaceous beds are very sparingly intermixed. Though claret-coloured rocks are found among them, grey is the predominant tint. On the east of Totnes, in the direction of Langcombe, we find an abundance of red sandstones (evidently forming a part of the rocks under consideration), in which limestone bands are included, the longest band not exceeding a mile in the direction of its strike. Whether the limestone, which extends from Berry Pomeroy by Gatcombe House, and thence round Bunker's Hill to Boston, does, or does not, form a continuous part of that which stretches from Bridge Town eastward to Langcombe Cross, is somewhat uncertain. Faults may have thrown two separate masses of limestone against each other. The mass of slates between Berry Pomeroy and Langcombe Cross are red, and the same red slates are continued to Beacon Hill. This red argillaceous slate seems to support the red sandstones on the south of it. If, therefore, the red rocks near Blagdon Cross and Beacon Hill rest, as they appear to do, upon the Berry Pomeroy, Loventor, and Marldon limestones, and the bands of limestones between Langcombe and Ash are included in red sandstones still higher in the series, the latter would be clearly more modern than the former.

On the eastward of Blagdon the older rocks are again concealed by beds of the new red sandstone series, but the continuation of the red sandstones of Langcombe and Ash is found in the line of strike near Cockington. From another covering of new red sandstones and conglomerates, the continuation of the Cockington red

* See sketches accompanying a paper on the Geology of Tor and Babbacombe Bays, Devon. Trans. Geol. Society, Second Series, vol. iii.

sandstones is concealed, and it becomes difficult to determine whether these sandstones are higher in the series than the Torquay and Tor Moham limestones, or whether we may consider them represented by the red sandstones occurring amid the beds, inferior to those limestones, which extend from Mead Foot Sands to Upham.

With the limestones which form the southern part of Torbay we have not the same difficulty. Above the red slates and sandstones extending from Ash by the Windmill Hill to Collaton, the singularly-shaped patch of limestone stretching from the vicinity of the Dart to Higher Yalberton seems clearly to rest. Indeed this patch may be said to be dove-tailed into its highest part, for the thin band of limestone which is seen included among the slates in the descent from the Windmill Hill to Higher Yalberton gradually swells out in its course to the south-west, and there unites with another and inferior band which commences at the latter village, and in a similar manner swells out towards the south-west, both, after their union, being suddenly cut off near Duncannon, their geological continuation consisting of slate.

Another mass of limestone, commencing about half a mile from Higher Yalberton, near the turnpike-road from Paington to Brixham, after swelling out considerably (see map), again terminates near Sandridge upon the Dart, the cliffs on the line of strike on the river exhibiting, however, no appearance of it, its geological continuation consisting of slate, sandstone, or conglomerate. The dip of these limestones is conformable to the slates with which they are associated, and they would appear mere calcareous patches developed amid them.

Still continuing the section across the strike of the beds, we find a considerable mass of vesicular trap and schistose ash to the eastward of the limestone at Higher and Lower Yalberton, a small band of limestone crossing the turnpike-road being apparently included in it. This vesicular trap and schistose ash is associated with a conglomerate in which the quartz pebbles sometimes attain the size of a nut. With it also there is more compact trap, as is seen on the north of Watton Court. These trappean and common sedimentary rocks appear interposed between the Yalberton beds and the mass of limestone extending to Churston Ferrers and Brixham; and it is worthy of remark, that at Saltern Cove in Torbay the limestone is seen to rest upon trappean rocks of a generally similar character, constituting the floor upon which

the calcareous matter was deposited, the whole having been contorted by subsequent pressure.

Sandstones and slates chiefly replace the trappean rocks of the north of Watton Court in their continuation on the line of strike to the Dart. The limestone of Galmpton rests upon the slates and sandstones of Watton Court, apparently dipping beneath the argillaceous slates and associated rocks on the south of Galmpton Creek. At Mudstone Sands near Brixham, and around Sharkham Point, where an isolated patch of limestone is found, there are equivocal appearances arising both from the strike of the lamination, which does not always coincide with the beds, (p. 45, fig. 3,) and from the manner in which the limestone seems to terminate, a manner not confined to this locality, but which is observable very commonly on the western sides of the various limestone patches that occur from Ogwell to Galmpton Creek. Allowing, however, that the geological continuation of the limestones may be argillaceous slate at Mudstone Sands and Sharkham Point, and that the limestone does not clearly dip beneath the slate at the latter locality, the mass, of which they each respectively constitute subordinate parts, plunges beneath arenaceous rocks on the south, the continuation, apparently, of sandstones intermingled with slates which bound the calciferous country from Modbury to and beyond the Dart; this arenaceous series being, however, very variable in its general characters, sometimes running into quartz rock, as at Black Down on the east of Modbury, and at Morleigh Down, on the south of Morleigh, while at others it is greatly intermingled with argillaceous slates, as on the banks of the Dart.

The geological structure of the country between Chudleigh and Kingsteignton is such, the older beds being so overlaid by several more modern deposits, and generally bearing such marks of disturbance and dislocation where visible, that the connexion between the limestones which occur at Chudleigh, Ugbrook Park, Orchard Well, Ideford, Rock Hill, and between Lyndridge and Kingsteignton, and those before noticed, have not as yet been satisfactorily ascertained. The band of limestone which commences on the west near Lower Herkley, on the south of Chudleigh, and passes thence by Grayleigh to the lower part of the Haldon Hills, along which it ranges in a northern direction to Whiteway House, curves in so remarkable a manner in conformity with the general

bend of rocks produced by the intrusion of the granite on the west, that there is some difficulty in referring its position, relatively to the carbonaceous rocks with which it is in contact, to a fault ranging from Bickington on the south-west, and concealed between Lower Herkley and Ash Hill by more modern rocks. The dip of the carbonaceous rocks on the east of this band is in a direction beneath it, and it is covered by the carbonaceous rocks of Ugbrook resting upon it. Viewed by itself, this band has much the appearance of being included in the carbonaceous system in the manner of the Holcomb Rogus beds on the north, to be hereafter noticed. At Waddon Barton the limestones rest upon fine argillaceous slates, differing from the general mass of carbonaceous slates around them; and we might here suppose that the limestone and this slate formed an island of the older grauwacke rocks, a continuation of the Bickington band, surrounded by carbonaceous rocks of more modern deposit. Organic remains will go far to determine this point. At present the species of corals, the chief fossils detected in it, are considered to be the same with those found near Ogwell and Newton Bushell; but when we reflect what careful examination these fossils require, it would probably be premature to form any opinion founded on this supposition without more complete evidence than we now possess.

There is the same difficulty attending the limestones of Ugbrook Park, Orchard Well, Ideford, and Lyndridge. They have been for the most part violently dislocated, and the rents filled by crystals of carbonate of lime of large size, and most frequently in layers above each other parallel to the walls of the fissures, in the manner so frequently seen in limestone districts. The fissures so filled are often large enough to remind us of the great cross courses filled by layers of quartz in the metalliferous districts of Cornwall and Devon. If we consider the various patches of limestone from Chudleigh to Kingsteignton to be the bared portions of a series of grauwacke beds (the continuation of those between Bickington and Abbot's Kerswell) covered up by patches of more modern deposits, including among the latter the carbonaceous beds of Ugbrook Park, Hestow, and Lower Wear, we might suppose, from the direction of the western part of the Chudleigh band, that it was a continuation of the Bickington limestones, while the beds between Lyndridge and Kingsteignton belonged to the limestone series of Newton Bushell,

Ogwell, and Ipplepen. These latter support a series of carbonaceous beds very similar to those of Ugbrook Park and Hestow Farm, possessing characters that may however be local and accidental, but which nevertheless may be regarded in a complicated country, such as that under notice, where the older deposits are covered up so irregularly by more modern rocks, and the whole is broken by faults, among which may be instanced that at Connator Quarry, between East Ogwell and Abbot's Kerswell.

To render the subject still more complicated, organic remains have been detected, more particularly near Newton Bushell and Ogwell, among which many shells bear so great a resemblance to others detected in the true carboniferous or mountain limestone, that at a first glance they might be considered of the same species. How far they may bear that careful scrutiny to which they will probably be subjected remains to be seen. In the mean time, however, the near approximation to form, supposing, for the sake of the argument, that it is merely a near approximation of these shells to species well known in the true carboniferous limestone, is a subject of considerable interest.

From the sections on the Dart and the structure of the country around Woodland, Broadhempston, Torbryan, Staverton, and Little Hempston, there would appear no reason to conclude that the limestones, slates, and sandstones on the east are not continuous portions of the beds before noticed between the Dart and Tamar. On the contrary, the Dart sections show that the mass of which the limestones merely form a constituent part continues across in its general line of strike.

We should expect, if the Plymouth limestones formed portions of the same minor series of rocks with the limestones observed between Bickington and Brixham, and between Chudleigh and Torquay, that there would be some organic remains common to both. Hitherto the organic remains of South Devon have not received that careful examination to which they will, it is hoped, be soon subjected: it therefore would be premature to attempt a general conclusion on this head. It may however be stated, that, having submitted the shells in the Rev. R. Hennah's collection at Plymouth, a few years since, to Mr. Sowerby, he found, having previously examined a collection we transmitted from Torquay, and Bradley near Newton Bushell, that *Terebratula Pugnus, Cardium alæforme, Murex? Harpula, Buccinum imbri-*

catum, and *Buc. spinosum*, were common to both: a small list certainly, yet useful, inasmuch as the shells sent from both localities were also few. The two former are also carboniferous limestone shells. The other shells obtained from Newton Bushell were, according to Mr. Sowerby, *Spirifer rotundatus* (Sow.), *Sp. decurrens* (Sow.), *Terebratula porrecta* (Sow.), *Megalodon cucullatus* (Sow.), *Turritella abreviata* (Sow.), *Buccinum breve* (Sow.), and *Bellerophon tenuifascia* (Sow.).

Among the shells of the Plymouth limestones, *Spirifer distans*, *Sp. cuspidatus*, *Sp. octoplicatus*, *Terebratula imbricata*, *T. platyloba*, *Nerita spirata*, *Turbo Tiara*, *Buccinum acutum*, and *Bellerophon costatus* are British carboniferous limestone shells, and *Producta depressa* and *Pileopsis vetusta* have been stated to occur in the same rock at Liege and Ratingen. Of the list of twenty species of shells, therefore, found in the Plymouth limestones, nine were referred by Mr. Sowerby to species found in the true carboniferous limestone; and if to these we should add the two other species, the number would amount to eleven.

There is nothing therefore in the shells found in the Plymouth limestones which should prevent us from considering them a continuation of the beds of Newton Bushell and Torquay, even though, as it is believed has been done by Mr. Austen, many more species resembling those found in the true carboniferous limestone should be detected in the latter. On the contrary, an approach to, if not an identity with, forms of shells discovered generally in the true carboniferous limestone, seems characteristic of the two localities. Now, whatever doubt may exist as to the true age of the Newton Bushell and Torquay limestones, the position of the Plymouth limestones is clearly amid the slates and sandstones of South Devon, and whatever geological age be assigned to the latter would appear common also to the former.

The band of arenaceous rocks ranging on the south of the calciferous country above noticed may, perhaps, particularly on the eastward, be considered as a mere extension of the sandstones beyond those in which the limestones are developed between Totnes and Galmpton Creek, rather than as forming a total change in the mineralogical character of the country. In several places the beds are red and grey, mingled with argillaceous slates of the same tints, as on the south of Modbury; in others they are light-coloured and micaceous, as near Morleigh Down. They run

into beds of quartz rock, as before noticed, at Black Down and Morleigh Down. The band is in fact very variable in its general character, and hard lines of demarcation can rarely be drawn between it and the rocks on the north and south, while it often partakes of the characters of both.

A mass of argillaceous slate, generally fine-grained, and in many places red or claret-coloured, rests on the arenaceous band. Not that arenaceous rocks are absent from it, but such rocks are scarce, and for the most part are found on its northern side. The eastern part of the mass is far more red than the western, though this colour is sufficiently abundant in that direction; and there is little difficulty in perceiving that many minor masses which are red in the Start Bay section are grey in that exposed at Bigbury Bay. Hitherto no organic remains have been detected in this slate.

Much difficulty attends an examination into the true bedding of this mass of red and grey argillaceous slate, notwithstanding the coast sections afforded by Start and Bigbury Bays, on the east and west; inasmuch as we cannot be certain of the extent to which the lamination may be trusted as representing the planes of the beds. If we were to regard the lamination planes as truly giving those of the surfaces on which the constituent detrital matter has been thrown down during its deposit, we get a thickness so great, as the lamination is so frequently either perpendicular or highly inclined, that we are led to doubt the enormous depth we thus obtain. Great contortions may indeed be traced by aid of the lamination; yet even then there is difficulty in arranging all the parts satisfactorily.

Taking lamination as a guide, and supposing it to coincide with the surfaces of beds, the latter would dip southerly, near Dartmouth. Between Stoke Fleming and Street the dip would be reversed, but would again become southerly near Slapton Sands. Near Stokenham it would again be northerly, and continue so, though very highly inclined, to the mica and chloritic slate system on the south. Employing the same aid on the west, in Bigbury Bay, we obtain a much more constant dip of the beds to the south, with more vertical strata. There are reverse dips, and they would give undulations, as on the eastern section; but it may be doubted whether they would give so many. Confused lamination may at different places be also seen on the coast,

particularly between Avon Mouth and Hope. Upon the whole, we may probably be not far wrong if we consider these slates as forming an undulating and contorted mass between the mica slate system on the south and the arenaceous band on the north, though far from possessing that thickness which measurements across the lamination would give it.

Near Erme Mouth we find rocks, part of which are arenaceous, that range up, somewhat out of the general strike of the beds of the country, towards the grits and quartz rock of Black Down, near Modbury. With them is a rock which we have ventured, though with some hesitation, to class as an elvan, as it is so extremely quartzose in part of its course, particularly near Torr and Sherlangston, where it more approaches the character of quartz rock, though near Modbury it is formed of a granitoid mixture of quartz and felspar.

If we consider this run of rocks as a continuation of the Black Down beds, the variegated slates which occur between Yealm Mouth and Erme Mouth would be separated from the mass between the Start and Bigbury Bays, and would be thrown into an equivalent of the calciferous country of Ditsham and Brixham on the east. Consequently, the red grits of Staddon Point would not constitute a continuation of the sandstones and quartz rocks of Black and Morleigh Downs, but would agree more in geological age with the red sandstones between Yalberton and Totnes and the hard red grits of Cockington. It must be confessed that there is difficulty in making good the connexion of the Staddon Point grits and the sandstones of Black Down. There is such a constant chance of the development of minor patches of sandstone, as near Torbay and the Dart, amid the red and grey slates, that the continuity of any supposed range of arenaceous deposits is very difficult to trace, more particularly when their mineralogical characters are so similar.

The sandstones and slates on the east side of Plymouth Sound cut across the land on the west, in their range in that direction, as has been above noticed, the Plymouth limestones terminating somewhat abruptly near Cremil Passage and Empacombe. On the coast between Trewinnow and Tregantle, in Whitesand Bay, west of the Rame Head, calcareous beds, containing organic remains, are found intermingled with argillaceous slate. The fossils are ill preserved, but, in a collection presented by Mr.

Johns, Professor Phillips found more than one species of *Spirifera*; parts of a *Trilobite*, a species of *Turbinolia*; two species of *Calamopora*, and many parts of *Crinoidea*, consisting of the columnar joints and plates of the pelvis of perhaps two species. Amid a system of detrital rocks, in which limestones so irregularly appear, it would be hazardous to conclude that these calcareous deposits are the actual continuation of the Plymouth beds. They, however, are sufficiently in the line of strike to render this inference probable.

In the direction of Looe, calcareous beds are found intermingled with the slate, which, if we take their general strike, would occupy a lower part of the series under consideration than the Plymouth rocks. Two patches of limestone, one on the south of Hessen Ford, and the other at Millaton, between Trerule and Treskelly, give a continuation of the Looe beds towards St. Germans, beyond which, on the eastward, the calciferous deposits seem to be merged in the intermixture of trappean rocks, arenaceous beds, and argillaceous slates of St. Stephen's and Saltash. There are calcareous rocks near the latter place, but, towards Dartmoor, we detect no calcareous line carrying on these beds on the north of the Plymouth limestones. If, from the limestone of Hessen Ford, a section be made northerly to Quethiock, a mixture of arenaceous beds and argillaceous slates are traversed, among which we find a great variety of trappean rocks, some of them possessing the schistose character so frequently noticed. The compact kinds are generally greenstones, but, a short distance out of the line of section, in the direction of the ordinary trappean masses, serpentine is found at Clicker Tor, apparently included among the slates.

If instead of this line we take another three or four miles more westward, up the Looe river, to the granite on the north, not a trappean rock is to be found until we arrive near the latter, in the vicinity of St. Cleer. The intermixture of trappean rocks, many of them schistose and ashy, which has characterised the argillaceous slates and sandstones, from St. Cleer, Liskeard, and Menheniot, by Saltash, Plymouth, Yealmpton, and Ugborough, to Ashburton and Torbay, is no longer found. The trappean rocks themselves become gradually mingled with a lower part of the general series from Saltash to St. Cleer, a circumstance which would be by no means remarkable if they all bore evidence of having been intruded after the consolidation of the slates and

sandstones, as we might then merely consider that the force, producing the apertures through which the trappean rocks were ejected, acted diagonally across the strike of the beds, and, finding planes of least resistance in these lines, burst them asunder for short distances along their main line of direction.

In the section up the Looe river, after passing the calciferous rocks near the towns of Looe, arenaceous beds and argillaceous slate are found dipping southerly beneath the former; and on the north of Sandplace the quartzose rocks, running from Bin Down to High Tredinick, cross the line of section with a southern dip. Hence to the northward there is an intermixture of sandstones and slates until near the line of Liskeard we arrive at the arenaceous beds among which quarries of building-stone are common. The general dip of these beds, due attention being paid to minor undulations, is to the southward.

On the coast to the south-west of Looe, towards the Oar Stone and Talland, we find red and variegated slate beds, which, trusting to the lines of colour and lamination, with the occasional presence of something like true beds, dip to the N.N.W. Now, if we consider these red and variegated beds to be the continuation of those to the eastward of Looe, the rocks have suffered from some force which has turned them up, forming a depression between them. Proceeding along the coast from Talland to Fowey, we find this reversed dip to continue, and calcareous rocks to appear from beneath the mass of variegated slates at Pencarra Point, whence they strike across the Fowey Harbour near Polruan. The calcareous rocks of Pencarra Point and Fowey Harbour would therefore appear to form a continuation of those of Looe, supporting a mass of red and variegated slates.

The variegated slates may easily be traced from Talland and Polperro, where they extend more than a mile to the northward, by Lansalloes, Gregon, and the vicinity of Tywardreth, to the granite near St. Blazey. Their dip, as a whole, is about N.N.W. Taking the section along the Fowey river to Clift and Prinsey, and thence up its tributary to and beyond Boconnoc, we find a mass of argillaceous slates, generally grey, resting upon the variegated slates, and finally above them a system of arenaceous rocks, some beds very compact and thick, constituting a patch of country which extends round from Bury Down, by Bucka Burrows, Boconnoc, Rye Downs, Four and Five Barrow Hills, to Broad-

oak Common. The northern dip continues beyond the Fowey river in the direction of St. Neot's, where, approaching the granite, it becomes reversed, without, however, the reappearance of the marked beds on the south. We thus obtain a kind of irregularly-shaped mass, the basin-shaped form of which on the north may be caused by the protrusion of the granite in that direction (pl. 2, fig. 2). A glance at the maps will show the curve of some dips round Pelynt, where they gradually coincide with those found in the valley extending from Looe to Herrots Foot and St. Pinnock.

If we consider the calcareous and fossiliferous beds of Pencarra Point and Fowey Harbour to represent the Looe beds, which are also fossiliferous, and the latter to be geologically older than the Plymouth limestones and their associated beds, the variegated and grey slates may agree in geological position, though they do not in mineral character, with the Plymouth rocks, more resembling the latter in their course round the south of Dartmoor, if we abstract the trappean beds there mixed with them. This would bring the grits and slates of Bury Down, Broadoak Common, and Five Barrow Hill, into a parallel with the sandstones and associated rocks of Black Down, near Modbury. It should, however, be observed, respecting the general dip of the sandstones of Bury Down and the surrounding district, that they may be seen much contorted in a few quarries, so that, though we have northerly dips principally exposed, there may be so much contortion and even prevalent though concealed dip in other directions, that great caution is necessary, particularly as there is much obscurity in the relative positions of these grits and of the country around Bodmin.

Whatever obscurity may hang over the arenaceous rocks above noticed, there is none attending the course of the red and variegated slates on the south. In Fowey Harbour, as has been seen, they rest on calciferous rocks, which contain the remains of shells, those which we have obtained being not very determinable, and a coral which Professor Phillips refers, with doubt, to the genus *Turbinolia*. Between Fowey and the Gribbin Head the beds are arched, or rather a dislocation—well exhibited at Combe Haune—probably a continuation of one of those in which copper and tin is worked in the direction of the Charlestown, Pembroke,

and Crinnis mines—has thrown the beds over in opposite directions, the rocks at the Gribbin Head dipping southerly.

The red and variegated beds are easily traced from the vicinity of Tywardreth by Tregehan to St. Austell, the turnpike section near which, in the direction of Grampound, affords an excellent view of them. From St. Austell they strike away to St. Stephen's on the west, apparently not much turned up by the granite on the north, against which they seem rather to abut in some places, as if a fault brought them in contact. At the Van, near the Black Head, S.S.E. from St. Austell, there are calcareous slates, and in them organic remains, chiefly *encrinites* and *corals*. The greenstone of the Black Head, and the ramifications of the same mass in the direction of Pencarra, somewhat interfere with the general dip of the beds, so slightly, however, that the main mass of slates and grits with which these rocks are associated are seen to descend as a whole to the N.N.E. Rocks of the schistose trappean order come in near Porthpean, a continuation of those which occur at Tregorrick, the dip still northerly. At Duporth there is another trappean rock, for the most part in a decomposed state, apparently a compound of felspar and hornblende, traversed by veins of an asbestiform mineral, and possessing an irregular concretionary structure. This rock appears to form a continuous portion with the mass of greenstone of St. Mewan Hill, near St. Austell, as connecting patches can be traced in many places. The broken condition of the partly fossiliferous beds between Charlestown and Par Sands, traversed by many lodes, prevents that clear view of the connection between the calcareous rocks near the Black Head and the red and variegated slates of the mining country of Crinnis which could be desired. If however we take the general evidence of the mode in which the red and variegated beds were dipping before their course was interrupted by the St. Austell granite, and the general range and dip of the slate and other beds near the Black Head, the calciferous rocks of the latter would appear to dip under the variegated slates on the north, and therefore correspond in general position with the calciferous rocks of Polruan and Fowey Harbour, brought up again in a line south of the Gribbin Head.

If we take a section in the line of the coast, which runs across the general strike of the rocks, from the Black Head to the Dod-

man Point, we find that the dip again becomes reversed on the south, with a mass of contorted and perpendicular beds between Pentewan and Portmellion. An arenaceous rock, almost approaching a fine-grained conglomerate, is found on the south of the river near Pentewan, a continuation of similar beds near Grampound. On the south of these beds, argillaceous slates, intermingled very sparingly with sandstone, are found dipping in various directions, much contorted, and very frequently vertical, near Mevagissey. These argillaceous slates can be traced towards Probus, apparently always occupying the same position relatively to the coarse sandstones on the north, which can be observed well characterised in the quarries near Thorn, and on the descent of the new road from Probus to Grampound.

Continuing our coast section, arenaceous and argillaceous slates are found, with a southern dip, in the cliffs near Bodragan and towards Chapel Point. On the south of Turbot Point, hard quartz rock appears, forming the height known as the Great Carn, and becomes a very useful aid in tracing the beds from Mevagissey Bay and Gorran Haven to Veryan Bay. Limestone associated with slate, and some very remarkable rocks with a semi-porphyritic character, occur on the north of Gorran Haven. Mr. Peach* was the first to detect organic remains in the arenaceous rocks near the Great Carn. Among those which he kindly presented to the Survey, Professor Phillips found a species of *Orthis* and another of *Atrypa*. The calcareous rocks of Gorran Haven are continued to the Guineas or Gwinges, rocks rising above the sea about a mile distant from the coast in the line of strike. Near Hemmick Cove, in Veryan Bay, calciferous slates appear as the continuation of the Gorran Haven limestones. Argillaceous slate reposes on the calcareous beds, graduating into arenaceous slate, which becomes micaceous and more hard in the direction of the Dodman Point.

If we consider the calcareous beds of Gorran Haven to be the continuation of those at the Van near the Black Head, and these to occupy the same place in the general series as the rocks at Looe, beds inferior to the Plymouth limestones run out to sea between the Dodman Point and the Greeb Point in Veryan Bay.

* Riding-officer of her Majesty's Customs at Gorran Haven, who dedicates the little time not occupied by his duties to the pursuit of natural history with a zeal and intelligence for which we could wish him a fairer field and more leisure.

The general line of coast of Veryan Bay, from the Dodman Point to Portholland, cuts the direction of the beds in a manner highly favourable for the study of the various rocks which, in the line of strike, run south-westward into the sea on this part of Cornwall. Commencing with the slates of the Dodman, we have the following rocks in the descending order, the dip of the whole being about south-east :—

1. Micaceous and arenaceous slate of the Dodman.
2. Arenaceous slate.
3. Argillaceous slates, often calciferous. (Continuation of the Gorran Haven limestones.)
4. White micaceous, siliceous and felspathic schistose rock, with iron pyrites.
5. Argillaceous slate, calciferous in part.
6. Quartz rock.
7. Argillaceous slate.
8. Siliceous slate.
9. Conglomerate, sometimes coarse, with argillaceous slate.
10. Quartz rock.
11. Conglomerate, containing rounded pieces of sandstone and slates, some of them as large as a man's head.
12. Trap rock, intermingled with the conglomerate.
13. Conglomerate, some of the rounded fragments of pre-existing rocks of large size.
14. Argillaceous slate.
15. Finer-grained conglomerate.
16. Argillaceous slate.

This section, compared with that from the Dodman Point to Mevagissey, is remarkable as showing a great increase in the size of the constituent detrital matter in a short distance ; for there can be little doubt that the mass of beds exposed in this part of Veryan Bay is a continuation of that cut by the coast from the Dodman to Portmellion.

From Portholland to the Nare Head the coast keeps very nearly the line of strike of the beds. Even this, however, is interesting, inasmuch as we are enabled to see how any change or modification may be exhibited for that distance in the character of such beds. The association of trappean rock with the conglomerate near Carhayes would lead us to suspect some local cause of disturbance during the formation of this part of the series. The whole coast from Portholland to the Nare Head bears out this view, for we find greenstone and a trappean conglomerate so intermingled with each other and with accompanying argillaceous slate, that it is difficult to separate them. These rocks are well seen around Nare Head, where we not only find the more common modifications of the trappean rocks of the district, and schistose conglomerates with a trappean cement, but serpentine and diallage rock,

mixed in a manner with the others, which would seem to mark local igneous action during the formation of this part of the general series, accompanied by a small upburst of serpentine and diallage rock, both of which resemble the same rocks in the Lizard district, and are well characterised.

The serpentine and diallage rock are not continued to the coast in Gerran's Bay, neither are they found in the general line of strike beyond the cove under Penare Barn, where they are intermingled with a talcose kind of slate passing into common argillaceous slate. The trappean conglomerate intermixed with greenstone is continued to and beyond Porthloe, losing its trappean character to the north-east, becoming fine-grained, and eventually merging into arenaceous beds and argillaceous slate, which dip beneath the beds previously noticed between the Dodman and Portholland.

Continuing the descending section afforded by the coast from Portholland to the Nare Head, and thence round to Gerran's Bay, we obtain the following rocks in the descending order :—

17. Trappean rocks and conglomerates, among which are serpentine and diallage rock, occupying a very limited area, the whole intermingled with common arenaceous beds and argillaceous slates, which predominate in the line of strike to the north-east.
18. Conglomerate beds, not thick.
19. Arenaceous beds intermingled with argillaceous slates.
20. Quartz rock, continued by Carne inland.
21. Sandstones.
22. Grey compact limestones, traversed by small veins of calcareous spar, and by larger veins of quartz.
23. Argillaceous slates, among which, a short distance inland, there is limestone similar to No. 22. These limestones appear, by the line of strike, to be developed in the same run of rocks with those passing through Veryan.* Limestone also occurs in the argillaceous slates near Gwendra.

It will be clear that the limestones of Veryan are lower in the general series than those of Gorran Haven, as indeed is also seen by continuing the coast section from the Dodman to Portholland up the valley to Polgrain, where limestones are found intermingled with the slate continued from Veryan. The Veryan limestones would, therefore, according to the views above taken, be also lower than the calciferous beds of Fowey and Looe.

* The Veryan limestones are described by the Rev. S. Trist in the Transactions of the Geological Society of Cornwall, vol. i. p. 107, a memoir to which the Rev. Canon Rogers added an appendix with a notice of other Cornish limestones.

From Pendowa (in Gerran's Bay) the beds are curved round with a southern strike to the Cabe and the Greeb, so that the argillaceous slates, mixed occasionally with arenaceous beds, inferior to those above noticed, become exposed at the Zoze Point on the east of the entrance to Falmouth Harbour. Though the general dip of the beds is to the east and east-south-east, the edges of still lower beds are exhibited up the Falmouth estuary to Mesack Point, where red and variegated slates appear in the descending order, dipping beneath grey argillaceous slates.

Returning to the red and variegated slates stretching on the south of the granite from St. Austell to St. Stephen's, and which, if the section above noticed be correct, are higher in the series than those found in the Falmouth estuary, we experience considerable difficulty in tracing them satisfactorily to the westward, and this difficulty is much increased by finding red and variegated slates in several places round the granite of the Hensborough district, beds which, though mineralogically alike, may readily occupy different situations in the general series.

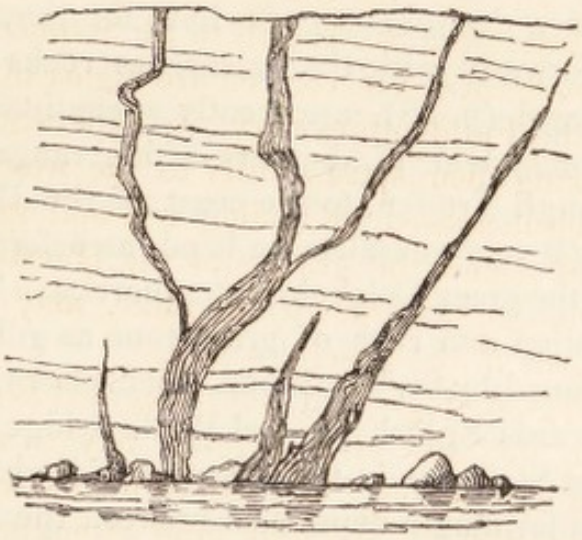
From the Tregoss Moors, red and variegated beds can be traced to the cliffs on the west at Watergate Bay, where a very fine section of them is exhibited; they dip to the south, and thus rise to the arenaceous rocks of the high land extending from St. Eval to St. Breock's Down. Unfortunately the schistose country between St. Columb Major and Lanivet is so mixed with granite and elvan, and rocks which appear altered in the line of strike, that the red and variegated slates are not easily traced for that distance, and the line of direction afterwards comes upon beds disturbed by the protrusion of the granite of Bodmin Downs on the one side, and that of the Hensborough district on the other.

Returning to the coast section at Watergate Bay, where a north and south dyke of granitic elvan cuts through the variegated beds, we find calcareous rocks resting upon these beds at Porth Island, Lower St. Columb Porth. The calcareous rocks are fossiliferous, and among them is a bed containing broken organic remains, some of which Professor Phillips considers to be parts of *fish*. In a few places the calcareous rock, which is developed somewhat irregularly, contains large quantities of *Crinoideal stems*. The calcareous slates between New Quay and Towan Head, which, if they be not precisely a continuation of the same beds, are closely associated with them, are also fossiliferous, and Professor Phillips

considers that there is a *fish tooth* among the specimens we there collected. The other organic remains from the same locality are parts of *Crinoidea, Calamopora,* and a species of *Turbinolia?*

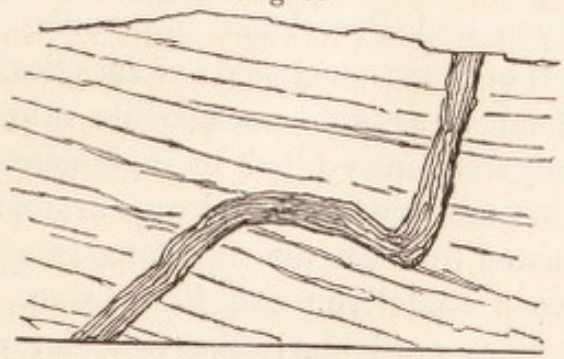
Near New Quay and Crantock, the argillaceous slates, in which the calcareous beds are found near Towan Head, and another small patch occurs on the north of Trevemper, are much cut by trap rocks, evidently intrusive, and not unfrequently running across the direction of the beds. The sketch beneath (fig. 8) shows the manner in which the trap has been ejected into cracks formed

Fig. 8.



in the schistose rocks near Towan Head, at a cove on the south, where organic remains are common, the dark parts in the cliff representing the trap veins. Fig. 9 is a section at Towan Head, where a trap dyke cuts partly through the beds and partly runs

Fig. 9.



with them, the force forming the fissure having broken occasionally through lines of least resistance in the planes of stratification. Trap dykes cut through the slates across the Ganel, and trap, amid confused strata, is well exhibited on the cliff between the Chick Rock and Holywell Bay.

Away from these local causes of disturbance, the main mass of grey argillaceous slate that succeeds the variegated slates of Watergate Bay, and which contains calcareous slates, and even limestone beds, in its lower part, may be seen to dip southward, if we can trust to lines of lamination. Near Ligger Point, on the north of Piran Bay, the beds dip south. Unfortunately the coast is covered by sand at the bottom of Piran Bay, precisely where a good natural line of section would be valuable.

Having noticed the red and variegated slates of Watergate Bay, and the calcareous rocks of Lower St. Columb Porth and New Quay, it becomes desirable to see how far they are connected along North Cornwall with the calcareous rocks previously noticed near Tintagel (p. 58), apparently a continuous portion of the same minor system of deposits which ranges from South Petherwin through Trewen, to the coast of the Bristol Channel. The beds make a very considerable bend, as before stated, round by Tintagel to the great Delabole slate-quarries. Taking general lines of lamination and runs of greenstone as guides, these beds would be continued by St. Teath and Michaelstow, St. Tudy and St. Mabyn, towards Egloshayle and Wade Bridge, a branch being thrown off from St. Teath in the direction of Endellyon and Pentire Point, thus forming a depression between the ranges in which more modern beds occur, among them a mass of variegated slates extending across the country from St. Kew and St. Minver to Padstow Harbour.

Numerous bands of greenstone and other trappean rocks are found in the strike of the beds from Pentire Point and Hell Bay, through Endellyon and Port Isaac eastward. Some of these bands are formed of greenstone, some of varieties to which it is, as usual, more difficult to assign names, while others are vesicular, the vesicles being frequently filled by carbonate of lime, an interesting fact, inasmuch as it would appear to show calcareous matter disseminated through the associated mass. These rocks are found between Endellyon and Port Isaac. While some of the trap rocks, more particularly the vesicular varieties, remind us of the contemporaneous igneous products, so often previously noticed, others break through the slates in a manner to show that the latter were consolidated before the igneous matter was intruded among them. Examples of intrusion are well exhibited near Porthqueen, and at Kellan Head fragments of slate are

caught up in the trap, where they have apparently been much altered by their imprisonment in the igneous mass. There is, however, notwithstanding the clear intrusion of part of the trap, so much vesicular rock in some places, that we might consider igneous rocks to have flowed during the general deposit of the accompanying sedimentary beds.

A conglomerate composed of fragments of slate, cemented by argillo-calcareous matter, occurs near Roscarrock, interstratified with the general mass of rocks, which, with a few minor reverse dips, plunges to the southward, apparently supporting the red and variegated slates of St. Kew and St. Minver. The latter are mixed with trappean rocks in the direction of St. Enodock, the red and variegated character becoming more rare to the westward; so that in the strike of the beds in that direction across Padstow Harbour it is less conspicuous. There is much disturbed country on the coast between Stepper Point and Trevose Head, and on the north and west sides of the latter trappean rocks are singularly mixed with arenaceous beds and argillaceous slates. A range of trappean rock runs eastward from Permizen, where it comes into contact with limestone, generally stated to be fossiliferous. How far this limestone may be continuous with a small portion among the schistose rocks near Padstow it would be difficult to say, from the occurrence of the trap. It is however not far from the general strike of the Rock beds, which are found on the east side of Padstow Harbour, and are at least closely-allied beds in the general series. Organic remains are found in the slates of Permizen Bay, and abundantly in the slates associated with calcareous beds near Dinas Cove, on the south of Padstow. Those in the latter locality are chiefly one kind of coral, which Mr. Lonsdale considers referrible to the genus *Turbinolopsis* of Lamouroux. On the south of Dinas Hill a conglomerate occurs resembling that of Roscarrock, and dark-coloured limestone is found at Lower Dinham.

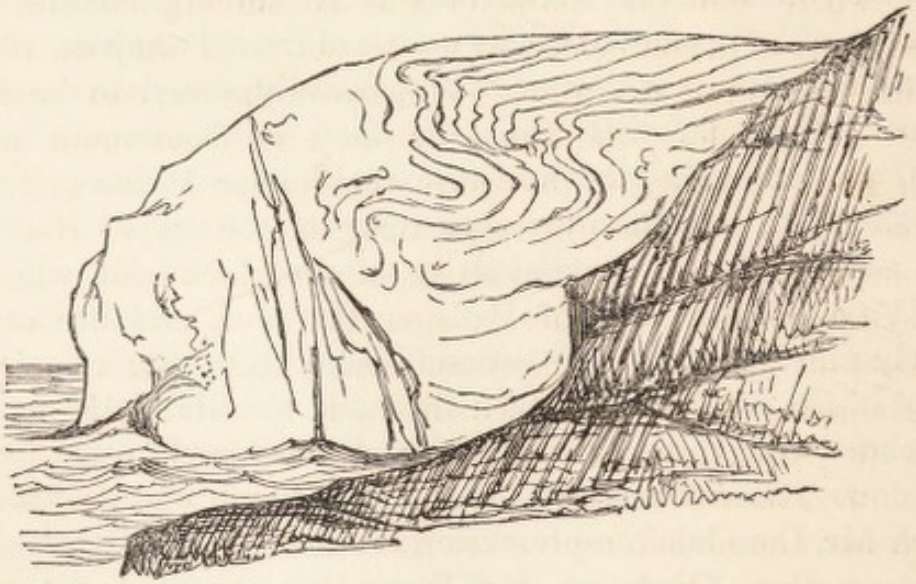
If we take the lamination of the slate as a guide, a trough extends from Constantine Bay on the west across to Dinas Hill and Cove, on the Camel, near Padstow. It then would appear to pass up the valley of the Camel to Trewornan, striking thence to St. Kew, beyond which the supporting beds unite and range to St. Teath, Delabole, and Tintagel. Calcareous rocks dipping north are found in Bodeeve Cove, near Wade Bridge, and may represent the Rock or Dinham limestones turned up on the south.

Corals of the same species as those occurring near Dinas Cove are found on the Camel, near the roofing-slate quarries of Penquean.

The patches of trap rock, elongated in the strike of the beds between St. Teath and Egloshayle, terminate somewhat abruptly near the Camel, and the slates in which they occurred are continued without them by St. Breock and St. Ervan to the sea on the west, trappean rocks reappearing among them at Park Head. Although argillaceous slate is the predominant rock, arenaceous matter is sometimes found among it, and even black carbonaceous slates are seen, as near Denham's Bridge. Though this mass seems to undulate on the north of the high land of St. Breock's Downs and in its continuation to the sea, it rises as a whole to it.

The high land of the range last mentioned is chiefly composed of arenaceous rocks, many of the beds approaching quartz rock, and some being micaceous. They seem to have been subjected to great force, which has squeezed them up in the line of direction.

Fig. 10.



The annexed sketch (fig. 10) of High Cove, from Trenance Point, exhibits a section of the contortions of these arenaceous beds on the west, where the sandstones would appear to be less abundant than in the direction of St. Breock's Downs. In that direction the arenaceous beds are traversed by numerous quartz veins cementing fragments of the sandstones that appear to have been much shattered.

The arenaceous and quartzose rocks of St. Breock's Downs are not continued far with the same characters across the Camel to the eastward. There are arenaceous beds in the line of strike,

but they are not generally so highly quartzose as those of the Downs. Should this veined and highly quartzose character be due to fracture, as we have above supposed, the change would be accounted for by the less broken state of the rocks in their line of bearing to the eastward towards Baron Down, beyond Bodmin.

Where great contortions exist it is extremely hazardous to trust to dips when the latter are not frequently exposed; and therefore much obscurity prevails between St. Breock's Downs and the country east from Bodmin. From Ruthern Bridge to Huslyn Down (an eastern part of St. Breock's Down) the dip is northerly; and the same inclination is seen in the valley near Tregoon. It is more variable in the line of strike on Nantallan Down. At Bodmin Down and Castle Canyke the want of good sections, when we examined that country, was much felt, occurring as their component arenaceous rocks do between the sandstone range of St. Breock's Downs and the arenaceous beds of Five Barrow Down; so that it became exceedingly difficult to determine, where mineral character was so similar, whether they formed part of a continuous series or not.* If they do, the dip obtained by aid of the lamination between the red and variegated slates of Lansalloes, the Fowey River, and Tywardreth, on the south, is deceptive; and though the lamination of the grey argillaceous slates continues the same, the true beds must rise up to the northward before they reach the sandstones of Boconnoc and Five Barrow Hill. Be this as it may, the slates of Watergate Bay rest on the sandstones of St. Eval and St. Breock's Down; and the red and variegated beds of St. Kew and St. Minver seem to be the same with the red and variegated beds of Watergate Bay; the calcareous rocks of Lower St. Columb Porth, New Quay, and the Ganel, representing in a general manner the limestones of Rock, Padstow, and Permizen. Not that in a district such as Cornwall and Devon, where calcareous matter is so irregularly developed amid the slates and sandstones, we should expect to find patches to correspond in exact relative position on both sides of a great fold of beds.

Having thus endeavoured to trace the minor systems of the grauwacke of Devon and Cornwall westward to a line drawn from Piran Bay to St. Stephen's, and thence along the course of the Fal to Falmouth Harbour, it must be confessed we experience

* Encrinital remains, discovered by Dr. Potts, occur in the quarries near the Lunatic Asylum at Bodmin.

considerable difficulty in following them still further westward, so as to join the rocks on the north and south satisfactorily with each other. The fine conglomerates which are mingled with the rocks near Grampound are in the line of similar rocks, approaching however nearly to common sandstones, that are found near Pentewan, on the northern side of the great undulation which throws the red and variegated beds of St. Austell to the northward. The fine-grained conglomerates near Grampound dip as a whole northerly, supporting grey argillaceous slates on which the red and variegated beds of St. Stephen's rest.

Taking this arenaceous or conglomerate rock, from the general scarcity of such deposits in the district, as a guide, we can follow it between Ladock and Probus, after which the sections are indifferent in the line of strike: still similar beds may from time to time be seen in the direction of Trevalsa and Zealla, on the north-west of St. Allen. Near the former place it is well characterised, and some of the constituent detritus of the size of shot and peas. Here it dips southerly, resting upon and apparently connected with the arenaceous beds and argillaceous slates of Newlyn Downs, rocks which, from their prevalent dip, seem to rest upon the slates, at the lower part of which we find the calcareous rocks of New Quay and Lower St. Columb Porth.

If these fine conglomerates do really constitute parts of the same continuous minor series, the dip has become reversed between Grampound and Trevalsa, and the beds have arched over in the intermediate distance, and the upper beds must have gradually been thrown out, so that the red and variegated slates ought to have disappeared gradually. The red colour, however, as we have seen in South Devon, is not always continued along the same beds; we may, therefore, have slates continued westward from St. Stephen's which are not red, and consequently we may too hastily assume that they have disappeared—a point the more embarrassing, as the protruded granite near the red beds of St. Stephen's also supports the red and variegated beds extending from Watergate Bay to the eastward.

The country is so cut up by lodes and elvan dykes between St. Agnes and the Falmouth estuary, that the relative positions of the constituent beds are difficult to determine. Arenaceous rocks, mixed with argillaceous slates, extend from the sea near Portreath, by Prince's Common, to Penhallow Downs, continuing thence in a direction towards the coarser detrital deposits near Trevalsa,

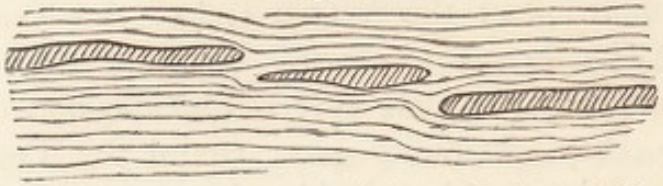
and the mixed arenaceous and slate beds on the north of it, the line of strike having made a great bend in conformity to the general range of the land. Red and variegated slates are found in the mines of Gwennap and Redruth. In the vicinity of Truro there is a contortion at the eastern end of the elvan dykes, extending from Gwennap towards it. The dips then radiate outwards (see map), but become reversed on the north towards St. Allen, while they gradually pass round by Pencalenick to Merther, where they again coincide with the general south-west strike coming from Tregony.

From the general direction of the beds, the red and variegated slates strike through Falmouth Harbour, from the vicinity of St. Just, to the southern part of Falmouth. They can be well studied on the beach, at low water, between Pendennis Castle and Swan Pool, where the irregular manner in which arenaceous rocks are mingled with the mass is very instructive. Indeed the red rocks are in many places seen to be almost altogether arenaceous. These beds are supported by gray or brown argillaceous slates that range from the skirts of the granite, where they have been much altered, by Falmouth, Milor, and Restronget, to Feock, beyond which, on the north, the red or variegated beds curve from the Falmouth estuary, round between Kea church and Truro, towards St. Day.

However obscure the structure of the country comprised within a line drawn from Truro to Tregony, Grampound, and Ladock, and continued thence by Michell, St. Agnes, and Gwennap, back to Truro, may be, the continuity of the rocks from Falmouth to the sea near Helston can easily be traced. The variegated beds between Swan Pool and Pendennis Castle seem to occupy the same relative position with the red and variegated slates near Gweek, a connection between them being found in several intermediate places. A run of more common grey argillaceous slates, mingled with a few arenaceous beds, rests upon them; and there is little difficulty in seeing that the rocks of Rosemullion and Mawnan are continuous portions of those at St. Anthony and Borhortha Point on the north-east. On the cliff on the south of Mawnan church a trap dyke cuts through the range of the beds, disturbing and rending them, the rents so made being now filled with quartz. There are other dykes of trap, near Mawnan, and one or two on the opposite side of the Helford river.

In one place in the ledge of rocks near Mawnan church, dry at low tide, we see the singular intermixture of trap and slate represented beneath (fig. 11). The dark shaded part represent-

Fig. 11.



ing the trap, which has apparently been injected in an irregular manner amid the laminæ of the slate, forming a continuous mass beneath, it having merely so happened that the plane of the ledge cuts the junction of the two rocks, so as to produce this appearance. The trap probably forms a portion of a dyke, which in the adjoining cliff runs partly among the beds, and partly cuts through them, in one place including a large piece of the rock which it traverses.

Following the line of coast on the south of the Helford river, we find argillaceous slate dipping southerly at St. Anthony. At Flushing a conglomerate, some of the pebbles in which are of large size, appears in beds dipping to the south, rising therefore to the argillaceous slates on the north. The pebbles chiefly consist of rounded pieces of slates and sandstones, portions of older grauwacke rocks. Schistose rocks rest on this conglomerate, and are again covered by another conglomerate well exposed between Gillin and the Nare Point. The rounded portions of rock included in this last are occasionally of large size, some even weighing nearly a quarter of a ton. They consist of sandstones and slates, quartz, and of portions of a rock which bears, though generally decomposed, a strong resemblance to some varieties of the hornblende rock and slate previously noticed on the south. The cementing matter is chiefly arenaceous.

Continuing our course to the south, grey argillaceous slates, with a few seams of conglomerate cemented by the matter of the rock, are seen to cover the last-mentioned beds, and to contain some calcareous matter. This is again succeeded, in the ascending order, by another mass of conglomerate, in which, though the included and rounded fragments of pre-existing rocks are occasionally large, they do not often exceed the size of the fist. This mass can be well studied at Carnmere, on the south of Nare Point. Argillaceous slates cover this conglomerate, and we

have thus three principal masses of coarse conglomerate included in the general series. They can easily be traced inland by Manaccan to Trelowarren, where they are brought nearly into contact with the serpentine, becoming, however, much less coarse in their range westward, and partaking more of the characters of a trappean conglomerate, similar to that of the Nare Head on the south of Veryan. In the vicinity of Carne and Tregea, near Manaccan, sandstones and dark shales are associated with the conglomerate series in a manner strongly reminding us of the mixture of such rocks in carbonaceous deposits, such as the coal measures. Sections of these rocks are found on the road from Carne to Gillinwartha, and on the opposite side of the estuary near the former place. Professor Sedgwick, in 1820, noticed the clear connection of the conglomerate near the Nare Point with the slate system of the country.*

That the conglomerates of Trelowarren, Menaccan, and the Nare Point, near St. Anthony, form the geological continuation of the conglomerates of the Nare Head, near Veryan, and Carhayes Cove, in Veryan Bay, is very probable; not that we are to suppose the conglomerate always continuous between these places, but as occurring more probably in patches on the line, fining off somewhat suddenly, as we see towards Gorran, and on the west of Trelowarren, the causes which produced them having acted at the same time. Trappean rocks of a vesicular and contemporaneous character are found near the conglomerate at Trelowarren, reminding us of the association of trappean rocks with conglomerate at the Nare Head, near Veryan, and at Carhayes Cove.

On the south of the Nare Point, proceeding towards Porthalla, quartz rock is observed, similar to the quartz rocks which succeed the conglomerate in the ascending order between Carhayes Cove and the Dodman Point. It can be traced inland, with a southern dip, by Trewothack, Trezebal, and Trevaddra, towards St. Martin. To it succeed slates, in which there is calcareous matter, and even grey limestone in Betsey's Cove, north of Porthalla, beds corresponding with the calciferous slates of Hemmick Cove, in Veryan Bay, and the limestones of Gorran Haven.† Con-

* Trans. of the Cambridge Philosophical Society, vol. i. p. 295.

† The limestone on the north of Porthalla was noticed by the Rev. Canon Rogers in 1822. Trans. Geol. Soc. of Cornwall, vol. ii. p. 417.

sequently, if the views we have previously taken be correct, they form a continuation of the calcareous rocks of Looe. Coarse beds of slate and arenaceous rocks succeed these limestones, and the whole series, dipping south, comes into contact with hornblende slates and serpentine near Porthalla in an obscure manner. In their western continuation inland, greenstone and vesicular trap are mingled with the slates in a way so often noticed as showing a contemporaneous origin with regard to geological date.

The conglomerates fine off on the west of Trelowarren, and arenaceous rocks are continued in their line of direction to the western coast, mixed with argillaceous slates, and dipping as a mass to the south-south-east, though bent round so as to take an eastern dip near Trenoweth and Pengwinion Head. A mixture of arenaceous beds and argillaceous slate continues to Bellurian Cove before mentioned, with a general dip, allowance being made for minor undulations and deviations, to the southward and south-east, the dip on the coast being more easterly than in the interior.

At Clicker Tor, on the south of Liskeard, we find serpentine among slates somewhat older than the calcareous rocks of Looe, and near Veryan we discover it associated with diallage rock in nearly the same geological position, the physical structure of the locality rather pointing to an ejection of these rocks during the time that the trappean conglomerate and accompanying greenstones were formed, than to an eruption of igneous matter long subsequent to the common conglomerate, sandstones, and argillaceous slates with which they are associated. Among the detrital rocks on the north of the run of the Looe beds between the Lizard serpentine and the granite of the Carn Menelez district, serpentine is not detected, and no immediate connexion of the diallage rock and the serpentine of the Lizard with these sedimentary deposits has yet been found. In noticing the serpentine and the diallage rock of the Lizard in this place, therefore, under the supposition that they were vomited forth at a period not very distant from, though somewhat later than, geologically speaking, the same rocks near Veryan, we do so for convenience, being unable to produce direct proof of that which we are inclined to believe probable. In examining the contents of the conglomerate of the Nare Point and Menaccan, we did not detect either diallage rock or serpentine; and hence, though it may be hazardous to assert that this is proof that the serpentine and diallage rock did not exist, as

the drift of pebbles may not have been from that direction, we may take this negative evidence as useful in showing an absence of proof that the serpentine and diallage rock are more ancient than the sedimentary deposits between them and the granite on the north.

The areas respectively occupied by the diallage rock and serpentine will be best seen by reference to the maps, and it only remains for us to point out the circumstances connected with their relative geological positions. In treating of the hornblende rock and slate we have endeavoured to show (p. 30) their mode of occurrence relatively to the serpentine, and the general fact that the latter rests upon them. The serpentine varies as usual in tints, but the predominant colour is a dark green, with a very frequent mixture of diallage. Dr. Boase considers this serpentine to be a compound of diallage and felspar,* and enumerates many varieties and the localities where they are found.†

A rock so variable as the serpentine of the Lizard can scarcely be expected to retain any given chemical composition for long distances, but careful analyses of the more important varieties would be useful in showing the substances that enter generally into its composition. Part of it, like the dark green rock, commonly termed serpentine, of Harzburg, in the Harz, may be nearly of the same chemical composition as the diallage contained in it.‡

Steatite veins are found traversing the serpentine in several places, as near Coverack Cove and between the Black Head and Pedn Boar, but the largest are those near Mullion and Gue Grease, near Kinance, which have been worked for profitable purposes, particularly the latter. How far some of these veins may have been contemporaneously produced with the serpentine

* Treatise on Primary Geology, p. 46.

† Contributions towards a Knowledge of the Geology of Cornwall; Trans. Geol. Society of Cornwall, vol. iv. p. 329—331, and 334—344.

‡ Dr. Köhler gives the following analyses of the diallage or schiller spar of Harzburg, and of the rock containing it:—

	Diallage.	Rock.
Silica	43·900	42·364
Magnesia	25·856	28·903
Protoxide of iron and chromium	13·021	13·268
Protoxide of manganese	0·535	0·853
Lime	2·642	0·627
Alumina	1·280	2·176
Water	12·426	12·071 *

* Thomson's Mineralogy, &c., vol. i. p. 174, 175.

itself, it is difficult to say; others, however, cementing fragments of serpentine in lines of fracture have been clearly formed subsequently to the consolidation of that rock, and sometimes contain native copper, as at the mines between Pradanack and Mullion, and at that of Dowgas, between Pedn Boar and Careglooz. Such veins not unfrequently also contain carbonate of lime mingled with the serpentine fragments, the copper, and steatite.

At the junction of the diallage rock of Crousa Downs and St. Keverne with the serpentine at Coverack Cove, veins of the former are seen to cut through the latter, so as to impress us with a belief that the diallage rock has been last formed, a view strengthened by observing the connexion of the serpentine and diallage rock extending from Careglooz through Gwinter towards Goonhilly Downs, the latter rock seeming to have cut through and disturbed the former. Near Landewednack also diallage rock appears to cut through the serpentine, rising from beneath hornblende slate.

The veins of diallage rock in the serpentine between the rivulet in Coverack Cove and the Pier at the village are highly interesting. Some of them are formed of large crystals of diallage, mingled with a variety, apparently, of saussurite. Dr. Boase has remarked upon the changeable character of the latter mineral at Coverack Cove,* and the difficulty of assigning it a name, and this observation applies to other localities, as, for example, Careglooz.† The serpentine, among which some of the veins of the diallage rock run, is much decomposed in some places. Veins of trap rock also traverse the serpentine in Coverack Cove. At Careglooz Point some of the diallage rock is schistose, though clearly connected with the more massive variety which seems to have broken through the serpentine, sending veins into it on the east side of the point.

Mr. Majendie considers that the rock extending from Coverack Cove to St. Keverne is a compound of felspar, hornblende, and diallage.‡ Minerals both resembling hornblende and diallage

* Trans. Geol. Society of Cornwall, vol. iv. p. 330.

† Dr. Thomson gives the following analysis of this Lizard saussurite, (Outlines of Mineralogy, &c., vol. i. p. 391):—

Silica	82·168	Lime	5·520
Alumina	5·072	Magnesia	4·520
Protoxide of iron with some manganese	2·880	Potash—a trace.	

‡ Sketch of the Geology of the Lizard District, Trans. Geol. Society of Cornwall, vol. i. p. 36.

occur with the felspar, and perhaps pass into each other; so that while in many localities it appears a true diallage rock, in others it more resembles a coarse mixture of hornblende and felspar, the diallage rock however predominating. At Porthoustock, veins of diallage rock cut through greenstone, and further south, near Ruten Point, a vein of a large-grained variety of the same rock traverses a porphyritic greenstone. A trappean porphyry traverses the country between Penhale and Bochin; but its connection with the serpentine on both sides of it is not well exhibited: probably it cuts through the latter. Serpentine appears to have risen through the hornblende slate and greenstone rocks near Porthalla, as previously noticed; and near them is a small portion of serpentine rising through slate, somewhat talcose, at Pencarrock, the serpentine appearing an intruded mass with a north and south direction.

Upon the whole, it seems to us far from improbable that the serpentine of the Lizard was ejected at an epoch corresponding with the deposit of some of the sedimentary rocks of South Devon and Cornwall—perhaps at one not far different from, though somewhat posterior to, that when the diallage rock and serpentine near Veryan became associated with the trappean rocks and conglomerate of the Nare Head. Whatever objection there may be to this view, there seems fair evidence whence to infer that the serpentine was produced before the diallage rock, and anterior to certain granitic veins, to be hereafter noticed, which not only cut through it, but the diallage rock also.

Quitting the Lizard district, argillaceous slates, intermixed with trappean rocks in their general line of strike, rise from beneath the red and variegated beds near Gweek. Arenaceous and quartzose beds are found on Helston Downs and in the line of direction to the north-east, gradually merging into more argillaceous rocks towards the south-west. While some of the trappean rocks are hard and seem contemporaneously intrusive (if we may employ the term), others are somewhat schistose, more combining the appearance also of sedimentary deposits of trappean matter, the latter being however rare. Good sections of hard trappean rocks and of their mode of occurrence amid the slates will be obtained on the coast near Porthleven, where some are observed to be concretionary.

The granite extending from Godolphin Hill to Trewarvas Head

disturbs the schistose rocks in their course to the westward, protruding through them; and little satisfactory can be observed among the lodes and cross courses between Breage and Clowance. On the west of the Trewarvas granite, we find argillaceous slates intermixed with trap rock, some, particularly those at Cuddan Point, possessing the contemporaneous character so often noticed, while others are beautiful greenstones less clearly ejected at the same period with the formation of the sedimentary rocks with which they are associated. These and the slates have a strike to the north-east and north-north-east. The country is however so cut to pieces by lodes, cross courses, and elvan dykes, that little is accomplished in tracing them in the direction to which they point, though probably they are connected with the line of slates and trappean rocks which range from Camborne to St. Erth.

The arenaceous rocks and argillaceous slates, noticed above, near Portreath, as an apparent prolongation of the beds of Princes Common and Penhallow Downs, are continued with a south-west strike by Tehidy, Trewithan Down, Gwythian, and Connor Down, to Hayle, extending to the coast on the north, and apparently supporting a line of slates, intermingled with trappean rocks, for the most part hard greenstones, which runs from Redruth by Camborne and Gwinear to St. Erth. Continuing the line of strike, there is an absence of trappean rocks in the slates between St. Erth and Ludgvan, but they reappear thence round by Penzance and Newlyn to the sea near Mousehole. The trappean rocks near Penzance are extremely interesting from the contemporaneous manner in which they are associated with the accompanying argillaceous slates. Dr. Forbes has given a detailed mineralogical account of these rocks, and notices the intimate mixture of the slates with them.* The relative proportion of felspar and hornblende frequently varies in the trappean rocks; so that sometimes they become nearly felspar rock, while at others they are loaded with hornblende. The rocks which skirt the Land's End on the north may be a portion of this series turned up by the protrusion of the granite. As mineral compounds and in the relative occurrence of their constituent parts they closely agree with the rocks near Penzance.

* On the Geology of the Land's End District, Trans. Geol. Society of Cornwall, vol. ii. p. 265, &c.

CHAPTER IV.

CARBONACEOUS DEPOSITS.

UNDER this head we have provisionally classed, for convenience, certain carbonaceous rocks, chiefly consisting of sandstones and shales, respecting the geological age of which a difference of opinion at present exists. It appeared more desirable thus separately to treat of facts which may bear upon the age of the whole or any part of these beds than, by prematurely assigning them names supposed to mark given geological epochs, assist in prejudging, or retard a correct view of, the place they may be eventually found to occupy in the great series of European sedimentary deposits. This plan moreover enables us to include these carbonaceous rocks in a general view of the sedimentary deposits of the district, anterior to the red sandstone series, without unfairly mixing up a description of any portion of them with other detrital beds, with which it may not be generally admitted that they are intimately connected: thus leaving the subject unclogged by this kind of entanglement, and open to fair and unprejudiced discussion.

The various slates, sandstones, and calcareous beds noticed in the preceding chapter as occurring in North Devon are succeeded, in the ascending order, by a series of shales, slates, and sandstones, which have been deposited under general conditions different from those under which the former have been produced, inasmuch as the higher sedimentary mass differs as a whole from that on which it rests.

Though there are many slates, sandstones, and other rocks, the mineralogical character of which may be common to the two accumulations of sedimentary matter, there is a marked distinction in this character between them, which the eye of an observer will not fail to detect. One of the chief differences in the two masses, mineralogically speaking, is the far more frequent occurrence of carbon in the one than in the other. Although carbonaceous matter is not absent from the lower series, it is far less abundant in it than in the rocks under consideration. It must

not however be hence inferred that carbonaceous matter can be detected in all parts of the upper series. So far from this being the fact, considerable areas are occupied by light-coloured sandstones and slates or shales, with no appearance of carbon in them. It is merely intended to state that carbon not unfrequently occurs in parts of the general series, and that in several localities the carbonaceous character of the deposits is very marked.

In the first place, it is desirable to ascertain if, at the lines of junction of these lower and higher systems of rocks, any facts can be brought to light by which we can detect a surface that has been exposed to the destructive action of meteoric influences, or to that of moving water, prior to the deposit of the first or lower beds of the higher system, as this would mark the lapse of some interval of time between the two deposits which might be considerable. We should also search for unconformable superposition in the lower part of the superincumbent system, by which we might learn that the inferior rocks had been subjected to disturbance before the higher beds were formed.

If with these objects in view we examine the northern boundary of the upper system of rocks, extending from the coast near Fremington (between Barnstaple and Bideford) eastward by Swimbridge, Castle Hill, the north of South Moulton, Brushford (near Dulverton), Hockley Bridge (near Bampton), Clayhanger, and Kittisford, to the red sandstone rocks which there conceal its continuation eastward, we neither find an upper surface of the lower rocks bearing marks of having been eroded by water or decomposed by meteoric influences, nor the unconformable deposit of the higher system upon the lower. On the contrary, we constantly find a passage of the one system into the other; so that, in order to define the limits of the systems upon the accompanying Ordnance Maps, it has been necessary to take a mean distance between the marked portions of the two where they adjoin each other, and there trace an imaginary line for the sake of convenience—one nevertheless which nature has not traced.

The mode in which the two systems pass into each other is much the same throughout the whole length of the line above noticed, the variations in this respect being merely minor modifications of a general fact. At Fremington the cliffs, though low, afford an excellent section of the junction of the two systems; but to study it properly it is essential that the tide be out, and that both sides of Fremington Pill be visited, as the one side

exhibits some points which are not so clearly seen on the other.* This section will be best understood by reference to plate 3, fig. 1, where it forms part of a more general section of a portion of North Devon. At the point of land opposite Heanton Court, and beneath the raised beach of the ancient estuary which there occurs, calcareo-argillaceous slates, among which are seams, generally in a decomposed state, containing encrinites, corals, productæ, spirifers, &c., the whole constituting the upper part of the grauwacke beneath, is well exposed. Proceeding southwards by the side of the cliff, these argillaceous slates, which dip southward, are here and there seen to contain nodules of grey limestone, and still further southward small seams and flattened nodules of grits are observable; seams, in a decomposing state, containing similar fossils with those above mentioned, being still intermingled with the whole. Further southward, the argillaceous slates become gradually more and more intermingled with sandstone, and finally the latter forms thick beds, and the argillaceous slates themselves acquire a different character from that which they previously possessed, here and there becoming carbonaceous. Ascending the Pill to Muddlebridge, black carbonaceous slates (containing a great abundance of posidoniæ) and carbonaceous limestones are found, and are succeeded by shales and slates, occasionally carbonaceous, mingled with some grits.

The passage of the one system into the other is here as complete as we have ever had occasion to observe. Indeed, several of the changes of the minor systems of arenaceous rocks into argillaceous slates, such as have been noticed under the head of the grauwacke of North Devon, are often far more abrupt.

At Hockley Bridge, near Bampton, another good section is afforded of the passage of the two systems into each other, the new line of road between Wiveliscombe and Bampton, and the cross-lanes which cut deep into the rock, affording evidence as clear as could be afforded by sea-cliffs (plate 3, fig. 3). This passage is effected without intervening arenaceous beds. Argillaceous slates, with a mere trace of calcareous matter in some localities, containing decomposed seams, in which the same kinds

* This is the more necessary, as the back of a contortion cut by the nearly horizontal plane of the eastern shore might otherwise mislead the observer respecting the true direction of the component beds of part of the section.

of encrinites, corals, and shells are found as previously noticed near Fremington and Barnstaple, occupy a band of country for about a mile to the north of Hockley, which can be readily traced continuously to Barnstaple and Fremington. Approaching Hockley Bridge, the slates gradually acquire a tint of black, and finally, at a quarry near the bridge, pass into a hard and somewhat arenaceous rock, extensively worked for roads and other purposes. This passage can also be very satisfactorily traced on the side of the high road on the east of the bridge, and the same section can be verified in the lane between Shillingford and Dadyscombe.

Continuing the section from Hockley Bridge to the southward, sandstones and shales, containing much carbonaceous matter, succeed to the beds seen in the immediate vicinity of the bridge, and on the east side of Bampton, limestones, there extensively quarried, are found included among the sandstones and shales. These limestones, which frequently contain much siliceous matter, intermingled with the more pure carbonate of lime, are, for the most part, black and carbonaceous, the shales intermingled with them presenting the same characters, and containing in some places an abundance of posidoniæ, of the same species as those previously noticed as having been obtained near Fremington. In one of the quarries a part of the limestone series is not carbonaceous, but presents the ordinary grey appearance of grauwacke limestones, and is, moreover, accompanied by reddish shales. This fact is deserving of attention, inasmuch as it is the first instance, proceeding eastward along the northern frontier of the upper system of rocks under consideration, in which we find a marked carbonaceous character absent, thus preparing us for a still greater absence of this character more eastward.

Taking another section, still further east, of the junction of the two systems, near the line where this junction becomes marked by the red sandstone rocks, from Wiveliscombe to Holcombe Rogus, the difficulty of drawing an imaginary line between them becomes still more increased. It will be seen by fig. 2, plate 3, that to the mass of red grits and slates above Stawley* succeeds the very constant system of argillaceous slates with decomposed seams, containing the same fossils as those found at Fremington

* This red series constitutes a marked feature in the grauwacke from thence westward across the new road from Bampton to Wiveliscombe above Shillingford.

and Barnstaple. This system can be better seen on the north of Clayhanger, where there are quarries in the continuation of the beds at Stawley. Above it we find grey clay-slates intermingled with blackish slates and some grits, after which dark-coloured roofing slates and shales appear; then reddish shales supporting grey limestones, which, though evidently occupying the same geological horizon as the black carbonaceous limestones to the westward, are neither black nor carbonaceous, but present the usual characters of grey grauwacke limestone, such as occurs at Plymouth and other places in Devon.

This limestone, with its associated reddish shale and slate beds, is made to appear and disappear by the contortions which the beds in general have suffered; but a very satisfactory section of them may be obtained near Westleigh, and in the cutting for the canal near the tunnel at White Town, where the absence of all carbonaceous matter is particularly remarkable when these limestones are contrasted with the equivalent calcareous beds to the westward. It would appear that the distribution of carbonaceous matter, probably derived from plants, was not so extensive in this part of the area occupied by the upper system of rocks, and that the general conditions accompanying the production of calcareous deposits and slates was more like those under which the lower system was formed. The absence of carbonaceous matter would seem also to have been favourable to the reappearance of animals of the kinds which were entombed in the lower series, for we find an abundance of encrinites in the limestones of Holcombe Rogus and Westleigh, constituting the greater part of some beds. The posidoniæ, which seem to have thriven amid the carbonaceous waters to the westward, have not been detected in these limestones, but a goniatite found associated in the carbonaceous limestone of Swimbridge (near Barnstaple) with posidoniæ is found at Westleigh.

Unfortunately the red sandstone series conceals any increase of change which we might infer would continue to take place eastward from that which has been noticed as having been effected between Bampton and Holcombe Rogus. It may be here remarked that this apparent decrease of carbonaceous matter, as we proceed eastward in the area occupied by this upper system of North Devon, is also borne out by the fact, to which we shall again allude, that the highly carbonaceous beds to the westward,

those which produce anthracite near Bideford, Alverdiscot, and Chittlehampton, disappear in proceeding eastward. It would therefore appear that, throughout the northern boundary of the great system of detrital rocks to which we have assigned the provisional name of carbonaceous deposits, there is no marked natural line of separation between it and the grauwacke beneath. Neither does there seem to be any evidence which might lead us to consider that the one succeeded the other after the lapse of any great interval of time during which extensive arenaceous and calcareous deposits were effected, such as we now see at only the distance of thirty-five miles in the Mendip Hills, where the old red sandstone, as it is termed, and the carboniferous limestone, are so extensively developed.

Proceeding now to the southern boundary-line of this system, for the same purposes as those with which the northern boundary was examined, we find that the upper series rests upon the lower near Boscastle, Cornwall, in a bay between the Meachard Rock and Short Island.* Here, though the one rests conformably upon the other, as represented, plate 4, fig. 1, there is no passage of the one system into the other. On the contrary, there is a marked line between the carbonaceous slates and arenaceous rocks above and the clay-slates passing into roofing-slate beneath, the latter forming a portion of the Tintagel roofing-slate series (among which the remains of shells have long been known), which constitutes part of the grauwacke of Cornwall.

Quitting Boscastle, a boundary-line, for the most part somewhat marked, may be traced between the upper and lower rocks by Lesnewth, Wilsey Down, Coose Moor, and Laneast Down, towards South Petherwin. Near the latter place, however, it becomes difficult to fix upon an exact boundary for the two systems, reminding us in this particular of the northern line in the vicinity of Barnstaple. To the clay slates and the associated limestones of this place, which contain an abundance of organic remains previously enumerated (p. 59), and among which fossil plants are

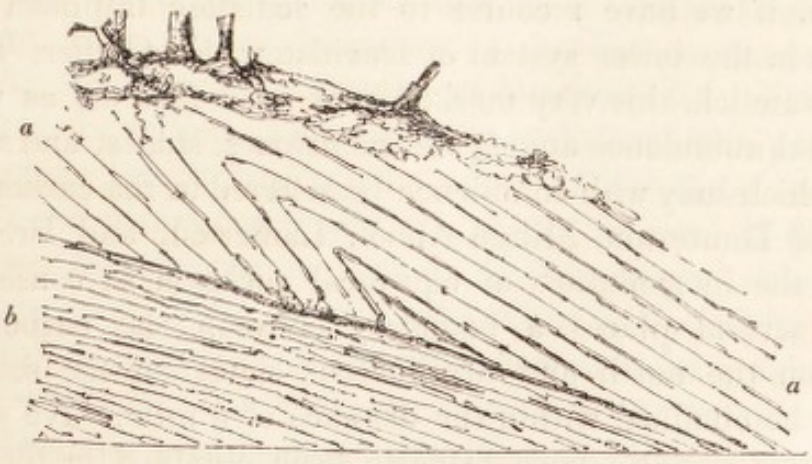
* Dr. Boase notices the occurrence of a carbonaceous mineral, apparently a variety of anthracite, at Wallapark Cliff, a little to the westward of Forrabury church (Boscastle), and states that Mr. William Petherick sought for it here in consequence of the resemblance the accompanying rocks bore to those which contained the Devon anthracite, probably alluding to that discovered near Bideford.—Trans. Geol. Soc. of Cornwall, vol. iv. p. 189.

detected at the quarry at the bottom of the hill, succeed slates that are at first grey and argillaceous, but which finally appear to graduate into more carbonaceous beds, with some grits, surmounted by dark slates that have been extensively worked as roofing-slates, and which contain posidoniæ and fossil plants. There is at this point an extreme difficulty in deciding where to draw a line of separation.

The same uncertainty continues in the curve taken by the beds from South Petherwin round to Trewarlet, where it is clear that the sandstones and slates of the upper rest on the argillaceous slates of the lower system; but, whereas at South Petherwin the beds dip northward, at Trewarlet they dip southward, and the limestone band worked at the latter place may be a curved continuation of the Petherwin limestones. Be this as it may, upon the descent of the hill from Trewarlet towards Lezant, a good section is presented, and in it the lower argillaceous slates have much the appearance of passing into the upper slates in a gradual manner.

Near Landue Mill, and on the old road from Launceston to Callington, the section is not clear; but on ascending the new road to Callington from the same place we obtain a section where the upper rocks are seen clearly above the lower in an unconformable position, shown in the annexed sketch, fig. 12, as the cutting for the road appeared in September, 1837.*

Fig. 12.



* This sketch was taken in company with Mr. Pattison of Launceston, and Mr. Holl, at the time mentioned in the text. Upon a visit to the same place about two months subsequently, we found that the quarry-men, who work the upper rocks for the roads, had much altered the appearance of the section, though similar contortions to those represented in the figure were still discernible.

From the contorted manner in which the upper rocks *a a* rest upon the lower beds *b*, it would appear as if the former were to a certain extent forced over the latter, and contorted at the same time. The lower rocks *b*, as has been previously noticed (p. 61), contain seams of calcareous matter with abundant organic remains.

Continuing to trace the boundary-line eastward, we obtain a fair section in the lane leading from Resair to Howley Bridge, and near the latter place. At the junction both systems dip southward, so that if the rocks on the south be really older than the carbonaceous series on the north, we must suppose a fault, giving the false appearance of the latter dipping beneath the former. There are, however, some equivocal beds at Innys Foot, near Endsleigh, continued across the Tamar to the westward, which would appear to give a dip for the carbonaceous system beneath the clay slates on the south, if the lamination of the latter can be trusted as affording a true view of the bedding.

From the Tamar to the granite of Dartmoor, near Tavistock, the difficulty of obtaining a boundary-line between the two systems is extreme; if carbonaceous beds be taken for guides, they will be found far to the southward of where it would seem right to trace the line; if grey argillaceous slates be selected, such as are so common in the lower series, these also fail us, as they are found amid beds which there can be little hesitation in referring to the upper carbonaceous system.

Again, if we have recourse to the schistose trappean ash so common in the lower system of Davidstow, St. Clither, Trewen, and Lawannick, this very marked rock also fails us, as we find it in equal abundance among the sandstones, shales, and slates of rocks, which may with confidence be referred to the carbonaceous system of Dunterton, Milton Abbot, Lamerton, and Brent Tor. In fact, the intermixture of equivocal rocks is so considerable, that in several places a boundary between the carbonaceous system on the north and argillaceous slates on the south can scarcely be obtained within the distance of a mile. No distinctive organic remains have hitherto been obtained in the neighbourhood of Tavistock to assist the inquiry; the only fossil known by the Survey to have been found there being the fragment of a plant, apparently a calamite, discovered near Wringworthy, in rocks which seem referrible to the carbonaceous system. At

first sight, the bunches of manganese, so common in the carbonaceous series near Launceston and Tavistock, might seem to assist in distinguishing the systems; the bunches of manganese are not, however, confined to the carbonaceous series, being found near Lawannick, Linkinghorne, and other places; and it is worthy of observation that they are so found under general conditions, such as the frequent proximity of schistose trappean ash, or compact trappean rocks, which correspond with those under which they are detected in the carbonaceous system.

Under these perplexing circumstances, it being necessary to distinguish the two masses from each other by some kind of boundary on the map, a line has been traced by weighing such evidence as could be obtained, and deciding upon the most probable course the line may in consequence be supposed to take. The obscurity on this head becomes more than usually great near Mary Tavy and Peter Tavy, in consequence of the alteration of the various slates, sandstones, and trappean rocks in the vicinity of the granite. The great copper lode of Wheal Friendship would appear clearly to cut through the carbonaceous system, inasmuch as its walls are partly formed of black carbonaceous slate, and thin seams of anthracite, not thicker than a shilling, are found among the harder and more arenaceous beds through which it passes. The lead and silver mine of Wheal Betsey is certainly in the carbonaceous system, as is also the tin lode of Wheal Jewel.

From the vicinity of Tavistock to that of Holne Chase, near Ashburton, the southern boundary of the carbonaceous system runs along the edge of the granite of Dartmoor for a distance of about forty-six miles. Throughout this distance the protrusion of the granite has thrown up the edges of the beds, rendering them in a few places nearly vertical, as can be seen on the high road from Okehampton to Exeter, at Ramsleigh, near South Zeal, where the cutting on the side of the hill exhibits a good section of these beds close to their junction with the granite.

When we proceed to trace the boundary of the rocks under consideration eastward from the granite near Holne, along a line separating them from the grauwacke of Buckfastleigh, Ashburton, Ogwell, and Newton Bushell, on the south, it is not without considerable surprise that we find them dip upon this line to the southward or south-eastward; a dip which gives them the appear-

ance of passing beneath the grauwacke on the south, as will be seen by reference to the sections, pl. 4, figs. 5, 6. Now, if the limestones of Bickington, Ashburton, and Buckfastleigh, form part, as there seems good reason to conclude they do, of a series of beds among which the limestones of Plymouth are developed, and there constitute a portion of the grauwacke, the apparent constancy of this dip on the southern boundary of this part of the carbonaceous system is not without its embarrassment, if we consider the carbonaceous beds as the more modern rocks.

After traversing the sands and clays of Bovey Heathfield, which mask the older rocks, and conceal the junction-line above noticed near New Inn, we find the Chudleigh limestones occupying a very equivocal position. From the more south-western lime-quarries to near Whiteway House, and on the north-west side of the brook, which flows into the Teign near Chudleigh Bridge, the upper series of rocks appears with its ordinary characters, the dip, however, of the beds being in a direction which would give them the appearance of plunging beneath the band of Chudleigh limestones extending from Lower Herkley by Grayleigh, Waddon Barton, and Lower Uppercot, in a curved line to Whiteway. At Waddon Barton these limestones are clearly associated with grey and red argillaceous slates, a continuation of which is cut through on the first ascent of Haldon Hill, towards Exeter, above Kesswells.

Upon the Chudleigh limestones we find a series of sandstones, shales, and conglomerates, containing the remains of calamites and other plants, and much carbonaceous matter. These beds are well exhibited in Ugbrooke Park, where they appear to dip, for the most part, towards the east-south-east, though probably they are in general much contorted, judging at least from the section obtained by the cutting on the southward of Chudleigh Bridge on the road to Newton Bushell. From the confusion which prevails among the rocks on the southern part of Ugbrooke Park and in the vicinity of Orchard Well, in some of the quarries near which limestone has been traversed by great fissures now filled by successive coatings of calcareous spar, crystallised on the large scale, there is much difficulty in tracing the true relations of the conglomerates, grits, and shales, with the compact grey limestones and argillaceous slate associated with them, and this difficulty is augmented by the overlap of red sandstone rocks which conceals

these older strata on the one hand, and supports the green sand of Haldon Hill on the other (fig. 8, plate 4).

It is by no means improbable that many faults traverse this country, added to which we have evidence in the ridge that extends from Higher Wear, near Kingsteignton, to Rowdown Cross on the north-east, that trappean rocks have burst through the limestones, and probably also the adjacent grits and shales, breaking them into fragments, some of which are caught up in the ejected trap rock.

A detached patch of conglomerates, grits, and shales, containing fossil plants and carbonaceous matter, occurs to the west and south-west of East Ogwell, evidently resting upon the limestones of that locality. It is traversed by two principal north and south faults (see map and plate, 4, fig. 5), which throw up the country to the eastward, so that the limestone rises at Connator Quarry and the line of hill of which it forms a part, and is again brought up in the line of the high road from Newton Bushell to Totnes. Near the latter spot Mr. Austen pointed out to us the non-conformable position of shales, which probably form part of the neighbouring carbonaceous rocks, upon the limestones of the Connator Quarry Hill, a kind of conglomerate, chiefly composed of pieces of the subjacent limestone, some of large size, mixed with quartz, and loosely cemented by sand, occurring beneath the shales. How far this may be the general character of the lower part of this patch of carbonaceous rocks, it would be difficult to say, as the country is deficient in good natural sections of its base, and faults seem common.

It should be noticed that the patch of carbonaceous rocks last mentioned, and those which occur at Ugbrooke Park, around Hestow Farm, and extend from Kingsteignton to Bishopsteignton, possess a common character in the coarseness of the arenaceous beds, and in the presence of conglomerates—one very distinct from that of the mass of carbonaceous rocks on the north, and, moreover, that the conglomerates contain rounded pieces of certain siliceous rocks, approaching Lydian stone, very characteristic and abundant in the latter, and which do not occur in the carbonaceous rocks associated with the conglomerates. In fact the Ugbrooke Park, Ogwell, Hestow Farm, and Kingsteignton carbonaceous rocks differ mineralogically in the coarseness of their beds from the great mass of the carbonaceous deposits on

the north, part of the detritus of which they are formed being probably derived from that mass. Rounded pieces of black carbonaceous rocks, the origin of which may be more questionable, are also detected in these conglomerates.*

Ascending the Teign from Chudleigh Bridge to Crocomb Bridge, we at first meet with sandstones which agree mineralogically with those of Ugbrooke Park, but higher up the valley the ordinary character of the sedimentary beds of the great carbonaceous deposit of Devon prevails, and nodules of calcareous matter are found intermingled with the slates in the deep cutting for the new road between Highner and Cannonteign. Between Chudleigh and Dunsford, trap rocks, generally greenstone, are found associated with the carbonaceous system, and the concretionary character of some masses, as, for instance, that near Ashton, is well worthy of attention. Near Highner, veins of calcareous spar are found in the greenstone, the calcareous matter infiltrated probably into cracks, and derived from the neighbouring slates, among which there are concretions of limestone, as above noticed.

Upon a review of the various facts connected with the boundaries of the carbonaceous deposits under consideration, we perceive that along the northern line extending from Fremington to Kittisford there is an apparent passage from them into the subjacent rocks; no surface is found marking abrasion during a long lapse of time between the systems. The whole of this passage seems to afford evidence of a gradual increase in the amount of arenaceous matter brought down and deposited with clay or mud in an area where the latter previously prevailed (a circumstance frequently observable in rocks of different ages); this change in the transported detritus having been accompanied by, and perhaps being the effect of, some physical change in the adjoining solid ground, by which terrestrial vegetation was more abundantly transported and entombed than before, for we have seen (p. 50) that plants were transported and entombed previously, though only for a short time, an intermediate collection of clay, mud, and calcareous matter, having been accumulated between

* The extent to which these carbonaceous beds occur beneath the red sandstone rocks of Teignmouth is probably considerable. The former plunge beneath the latter on the line of the Haldon Hills, and under the red conglomerate and sandstones of Combe in Teignhead, Coffinswell, and Abbot's Kerswell.

this first effort, if we may employ the term, and the final triumph of the causes which produced so considerable a change in the kind of organic substances embedded among the detritus.

From the occurrence of vegetable remains in the higher part of the undisputed grauwacke of North Devon, and from the species of plants there entombed being at least very analogous to plants found in those more modern sedimentary deposits termed coal measures, we necessarily feel little surprise that another rock above it, either still higher in the grauwacke series, or equivalent to the old red sandstone of English geologists, or to the carboniferous limestone, should contain vegetable remains, neither are we unprepared to find that plants detected in these rocks should correspond in general character, and perhaps often be of the same species, with those found in the older grauwacke beneath, or in the coal measures above.

On the contrary, if within so limited an area, so small a portion of the earth's surface, as that which constitutes South-west England and South Wales, we should detect certain kinds of plants both in a lower portion of the grauwacke and in the coal measures, ought we not to feel considerable surprise if in rocks within the same area, and geologically intermediate between these two masses of sedimentary matter, we did not find similar plants, in the event of plants being entombed at all in the detritus of the intermediate period? Great physical changes might indeed have caused a transport of the plants of a different kind of vegetation, supposing that they have been borne down from regions the elevation of which favoured the growth of those of a different character, and assuming that elevation then as now produced such differences; but under ordinary similar circumstances we should anticipate that, if plants entombed in the lower grauwacke and coal measures possessed common general characters, plants detected in detrital rocks produced during the intermediate period would also possess similar characters.

The day is fortunately passed when it became necessary, upon questions relating to the occurrence of anthracite and coal, to adduce arguments in favour of their vegetable origin. Neither is argument now required to show that vegetable substances have been accumulated at different geological periods on the earth's surface under conditions which have subsequently converted such accumulations into coal. It will now be very generally admitted

that an anthracite or coal bed has required an accumulation of plants to produce it, and that the thicker the bed the greater the bulk of vegetable matter necessary to form it. All other things therefore being equal, the chances are in favour of a more varied amount of any given vegetation, whence the plants were transported, being discovered in connexion with thick or numerous beds of anthracite or coal, than where such beds are either thin or scarce. For the same reason, in a series of sedimentary beds throughout which plants, or their fragments, are more or less dispersed, we should regard the vicinity of anthracite or coal beds, if such there be, as the most probable localities for detecting the greatest variety of plants.

The occurrence of vegetable remains and anthracite or coal associated with sandstones, shales, and slates, merely shows that during the drift and deposit of the sands, mud, and clay, forming the latter, geological conditions were favourable to either the transport or entombment of vegetable substances, drifted into, or merely covered up in, that locality, it being borne in mind that all the plants so brought into, or originally growing in the area upon which the sands, clay, and mud, were carried, are not necessarily buried among the other deposits, some totally perishing in the waters, as Dr. Lindley's experiments have shown, before they could be finally entombed, while others were partially or wholly preserved.* The greater or less extent of such carbonaceous deposits exhibits also that of the conditions under which they have been effected, it being understood that neither denudation on the one hand, nor overlapping beds on the other, so diminish or mask the original area as to render any fair appreciation of its probable extent impracticable.

When we discover any series of rocks composed of sandstones, shales, and slates, intermingled with carbonaceous beds, the whole evidently produced by deposits of various transported substances, and find the subjacent rocks on which this series reposes also to exhibit the necessary evidence of mechanical origin, the remains of vegetables being abundant in the former, constituting its chief organic character, while fossil plants are rare in the latter, corals, encrinites, and a variety of shells, being the chief organic remains detected, we at once perceive that, in the area where such facts are observable, the general geological conditions

* Fossil Flora of Great Britain, vol. iii. p. 4, &c.

could not have been precisely the same during the production of both series.

Now this alteration in the general organic character of the two masses of detrital matter may either have been the result of gradual changes in the consecutive order of geological events, effected in part of the area common to both, or considerable time may have elapsed between the deposit of the upper part of the inferior series and the lower part of the upper series, during which extensive masses of other rocks may have been produced, which either were never formed in this particular area, or, having been formed, were removed by denuding causes prior to the deposit of the upper series in that locality.

If the carbonaceous rocks under consideration be characterised, as they are, by the presence of vegetable remains, sometimes widely scattered, at others accumulated into layers, and these now and then sufficiently thick (as near Bideford) to have produced seams and beds of anthracite, it will be evident that the general conditions under which they have been formed must have been different as a whole from those in which the sandstones, slates, and calcareous rocks bounding them on the north, were deposited. We have endeavoured to examine whether this change was gradual or sudden, and whether there is any evidence of a long intervening lapse of time between the two deposits. That examination would lead us to infer that there had not been any great lapse of time between the deposits, neither is there any evidence to show that it was sudden, while the appearance of a passage along so considerable a distance, and the general uniform succession of beds, mere modifications taking place in the line of strike, would lead us to infer that the higher quietly succeeded the lower beds in the general order of geological deposits. Supposing this view correct, still it may be said that, as rocks have been often developed on the small scale in one locality, while their thickness is comparatively enormous in another, this passage of the carbonaceous rocks into the grauwacke beneath may correspond in age with the upper grauwacke of other places, and the whole of the old red sandstone series.

If we consider the various facts connected with the southern boundary of the carbonaceous system under consideration, there is much which at first sight appears contradictory. On the west of Dartmoor, particularly towards the Boscastle coast, the general

mass of beds dip northward, resting on argillaceous slates and other associated rocks, thus giving a section across to the northern boundary-line near Barnstaple (due allowance being made for multiplied intermediate contortions), which has the character of a trough occupied by the carbonaceous rocks. The boundary is certainly unsatisfactory between the Tamar and the granite near Tavistock, yet, as a whole, the carbonaceous system appears to dip northward, and there seems no very clear evidence of a turn over of the mass beneath the grauwacke slates and sandstones on the south, whatever ambiguity may arise from the southern dip of the rocks extending from Innys-foot to the east and west.

As a whole, a general northern dip of the carbonaceous deposits is continued round Dartmoor, by Okehampton and Drewsteignton, to Dunsford, whence a line extends by Holcombe Burnel to Exeter, on the north of which a general northern dip is still found. If sections be taken from a line extending from Boscastle through Okehampton and Dunsford to Exeter on the south, to the northern boundary from Fremington to Kittisford on the north, due allowance being made for contortions, the mass of carbonaceous grits and shales, included between these lines, seems to repose in a trough-like cavity extending east and west. On the southward, however, of Dunsford and Holcombe Burnel, due allowance being still made for contortion, a southern dip prevails down towards Chudleigh, Ashburton, and Buckfastleigh, as if the mass of carbonaceous deposits was folded over an anticlinal line running from the skirts of Dartmoor, near Dunsford, to Exeter, and bringing the upper beds gradually to the southward. The protrusion of the adjacent granite has, no doubt, modified the position of the beds, but it will be merely necessary to examine the manner in which the granite cuts across the general mass of sedimentary rocks to see that the prevalent southern dip is not altogether due to this cause. If this view be correct, we should expect to see the carbonaceous deposits covered by some rocks of the general series, if the whole were not masked by much more modern beds. Now, precisely in this position, and with a dip away from the carbonaceous rocks, we find the band of slates and limestones extending from Bickington to Buckfastleigh, the limestones containing seams of anthracite near Ashburton, with marks which appear to be the traces of fossil plants in such seams.

Carbonaceous limestones are found along the northern boundary of the carbonaceous rocks at Fremington, at Lake and New

House (near Barnstaple), at Marsh and Swimbridge, at Rock Farm, South Aller, and Hacche Mill (near South Moulton), at Upcots and Hele (near Brushford), and at Wonham, and other places in the vicinity of Bampton, near which latter place the limestones, as before noticed (p. 104), begin to lose their carbonaceous character, so that their continuation near Holcomb Rogus and Westleigh does not possess it. It is worthy of attention that, during the greatest interval between portions of limestone along the line for about eleven miles from Hacche Mill, near South Moulton, to Upcots, near Brushford, the immediately subjacent portion of grauwacke becomes very calcareous, even containing beds of limestone, a character which it only loses near Dulverton.

Respecting the shell found so frequently in the line of carbonaceous limestones, and commonly considered to belong to the genus *Posidonia*, Professor Phillips observes, upon specimens from Venn Quarry and Swimbridge, lent to us by Major Harding, that they are insufficient to determine what relation the two species he has detected bear to *Posidonia Becheri*, a shell which occurs in the grauwacke slate of Nassau, or to those which are found in the 'Calp' of Ireland.

With respect to the *Goniatites* from the same localities, and in Major Harding's collection, Professor Phillips observes, that one is so extremely similar to *G. Henslowi*, from the carboniferous limestone of the Isle of Man, that, unless more perfect specimens should disclose some difference, he should give it that name. Another species, he observes, is very closely related to *G. sphæricus* (Sowerby), *G. truncatus* (Phillips), &c., which belong to the carboniferous limestone. It is certainly, he considers, of that group, but without more specimens he would not venture to assign it a specific name.

Along the southern boundary-line, carbonaceous limestones, similar to those on the north, occur at Newchurch Farm, near Launceston (though very sparingly in that locality at a quarry formerly worked for roofing-slates), on both sides of the Tamar, near Lifton; at Stowford; at Thraselton; at Leigh, near Mary Stow; at Poleleet Corner, and Cury Park, near Coryton; at Lew Trenchard; at Alder and Point Bridge, on the high road between Lew Down and Bridestow; at Stone and Millaton, to the east of Bridestow, and also on the west of the same place; in the valley

of the West Okement, under Elmdon, near Okehampton; at South Tawton; at the turnpike-gate on Whiddon Down; and at Drewsteignton, beyond which, to the eastward, this line of carbonaceous limestones has not been found. Notwithstanding that the contortions to which these beds have been subjected, in common with the grits and shales of the series, may bring them up in more places than one on the line, there are probably two lines in the minor district of Mary Stow, Coryton, Lew Trenchard, Stowford, and Thraselton, uniting in their progress to the eastward in the direction of Bridestow, unless, indeed, we suppose an irregularly-shaped deposit of limestone to be so contorted that the various parts cut by the general horizontal exposure should present this appearance.

That calcareous beds should be carbonaceous and black in any part of a series, or in any series of rocks where carbonaceous matter is abundant, would not be remarkable; therefore, this circumstance in itself would be of little value, unless indeed we relied on that part of the old discarded doctrine of universal formations which still lurks in geology, and which supposes that every limestone or other marked bed which dips beneath the surface, among a series of rocks, must of necessity reappear, if an equivalent of the same series should again come to that surface. The calcareous matter on the north boundary-line runs for the most part not far distant from the edge of that line, on the other side of which are beds impregnated with the same matter, amounting sometimes to limestones, so that the upper part of the lower series, and the lower part of the higher series, are more or less calcareous along a considerable portion, particularly the western portion, of the north boundary-line. On the south, though calcareous matter is sufficiently abundant, more particularly near Trewen and South Petherwin, from Boscastle to Launceston, in the upper portion of the lower system of rocks, the same matter is not observable at the base of the upper series for the same distance, until near Lamerton. A section from South Petherwin to Lower Truscott, on the north (pl. 4, fig. 2), would give the nearest actual limestones to each other (one being in the higher system and the other in the lower) of any on the south boundary-line between Boscastle and Dartmoor, the distance between the calcareous beds being about one mile and three quarters, measured over the surface of the country.

From this point, while the line of limestone patches extends towards Okehampton, the south boundary-line of the whole series curves away from it to the southward in the direction of Dunterton, Milton Abbot, Lamerton, and Mary Tavy, leaving about four miles horizontal distance between the most southern patch of carbonaceous limestones near Mary Stow and the boundary-line near Lamerton. Though calcareous matter in sufficient quantity to form limestone thus recedes from the extreme edge of the whole system in this direction, calcareous matter is not absent from that edge. It occurs among the shales on the east side of the Tamar, near Grayston Bridge, and in the cutting for the high road from Tavistock to Launceston through the trappean ash near Longford, a trappean ash, which may be referred to either the upper or lower systems, not only contains calcareous matter, but also nodules of limestone. Carbonate of lime is also found mingled with the other substances in the lode of Wheal Friendship, derived from the adjoining rocks.

The great characteristic of the southern boundary of the upper series from Boscastle to Tavistock, wherein it differs very essentially from the northern boundary, is the intermixture of schistose trappean ash among the other beds. Herein it closely agrees with the grauwacke on the southward of it, and on which it appears to rest. Commencing on the west with Willapark Point cliff near Boscastle, we find a thin bed of this rock interstratified with the black slates and grits of the mass of the hill. Proceeding eastward it becomes difficult to assign the same rocks near Lesnewth more to one system than to the other, and there is the like difficulty with the trappean ash extending thence along the boundary to Hallworthy.

Greenstone occurs among the grits and shales at Minwonnet, near Trewen, at Trewithick, near Launceston, and in the town of Launceston itself, while schistose trappean ash occurs at Tregadillack, and on the top of the hill rising on the south of Launceston. Doubts may be entertained as to the date of the greenstone, but none can exist respecting the ash, which has evidently been contemporaneously deposited with the sandstones, shales, and slates with which it is associated.

In the country near Dunterton, Milton Abbot, Lamerton, Brentor, Mary Tavy, Peter Tavy, and Tavistock, the mass of schistose ash accompanied by greenstone and other trappean rocks

is very considerable. In this district also the geological date of the solid trappean rocks may be questioned, but that of the schistose ash is clearly the same with the various grits and shales, it being merely doubtful to which of the two great systems of rocks some of the beds may be referred near Milton Abbot, Lamerton, and Tavistock. Some perfectly similar rocks occur in both, and the boundary between them, as has been above noticed, is not clearly defined.

A principal and well-marked band of volcanic trappean ash commences near Dunterton, passes by Milton Abbot (its breadth being considerable near that place, including the village and Endsleigh), Foghanger, Lower Hay, and Churlhanger, thence skirting and plunging beneath the sandstone and slate series of Heath Field Down, by Pillands, Grendon, and Burnford Farm. There can be little doubt that the principal band is included in the upper series, as it can be seen to rest upon very characteristic rocks of that series. With a more southern band of a similar ash commencing with Endsleigh, and which is well exhibited in some quarries on the line near Combe, continuing thence by Lamerton and Kilworthy to Sowtentown, there is not the same certainty, as will be seen by the section, pl. 4, fig. 4. Still more questionable is the band which crosses the high road from Tavistock to Launceston, and, as already noticed, contains calcareous matter, among which some volcanic cinders are sometimes, though sparingly, observable.

If doubt should exist respecting the origin of these schistose ash beds, both in the rocks under consideration and in the adjacent grauwacke, it would be removed by an examination of Brent Tor Hill itself, which, as we had occasion to notice a few years since,* bore unequivocal evidence of the volcanic origin of its conglomerate. Although cinders may occasionally be observed in the schistose ash, they are so sparingly distributed that the evidence as regards them would be imperfect without the mass which occurs at Brentor. Those who have examined the conglomerates of a modern volcano, where cinders of varied dimensions and porosity are mingled with pieces of lava, more or less rounded by the attrition they have undergone during those periods when solid fragments of it are ground against each other by the minor explosions in a crater, will be much struck with

* Researches in Theoretical Geology, 1834, p. 385.

the general resemblance, allowing for difference of induration in the masses, which the one bears to the other. Most of the vesicles of the cinders at Brentor are indeed filled up by siliceous and other infiltrations, the result of the conditions to which they have been exposed during the time which has elapsed since they were formed and deposited; but, as in many cases, particularly near the surface, the contents of the vesicles have again disappeared, and the original character of the vesicular rock has been in a great measure restored, the resemblance to a modern volcanic cinder is frequently striking.

Associated with these cinders, some of which so abound in vesicles as to approach pumice, are portions of trappean rocks of various kinds, the solid portions probably of contemporaneous lavas, with occasionally a few fragments more resembling altered sandstones, the whole united by a cement of rather variable character, being more arenaceous in some places than in others, upon the whole resembling a substance composed of finely-comminuted volcanic matter consolidated. Greenstone appears by the side of the high road on the west of the Tor, apparently associated, as so frequently happens, with the ancient volcanic ash and cinders. A siliceous conglomerate, composed of somewhat jaspery fragments cemented by a similar substance, occurs on the east of the hill, where also thick fragments and blocks of roseate jasper are dispersed.

A mixture of compact trappean rock, principally greenstone with ash, occurs about a mile from Brentor, at Wick, on the north-west, part of a band which becomes entirely ash in the direction of Upperton. Greenstone is also found near Bowden, more on the north of the Tor, which is associated with ash in the continuation of the same band towards Barcomb. A long and frequently broad band of greenstone extends from the Tamar, a short distance south of Grayston Bridge, to Rams Down, where it makes a sharp bend round to the south by Willersley and Whittor, the continuation of the original direction of this band, where it makes this sharp bend, being formed of trappean ash, which is again replaced by greenstone towards Quether.* A very marked band of ash, in which there are cinders, occurs on

* Calcareous veins, or rather seams in the joints, are found in part of this band among the greenstone exposed in the descent of the road from Dunterton to Grayston Bridge.

the east of Brentor, from near North Brentor to South Brentor, and is clearly seen to form a contemporaneous portion of the grits and shales among which it appears.

When we attentively consider these facts, the idea that in the vicinity of Brentor a volcano had been in action, producing effects similar to those produced by active volcanos from a similarity of causes, forcibly presents itself. That this volcano ejected ashes, which, falling into adjacent water, became interstratified with the mud, silt, and sand there depositing, seems probable. That greenstones and other solid trappean rocks constituted the lavas of that period and locality, here and there intermingled with the ash, appears also a reasonable hypothesis. Upon the whole, there seems as good evidence as could be expected that to the north and north-west of Tavistock, ash, cinders, and liquid melted rocks were ejected and became intermingled with mud, silt, and sand during this ancient geological epoch, corresponding with the phenomena exhibited in connexion with volcanos of the present day, more particularly when they adjoin or are situated in the sea, or other waters, where ejected ashes, cinders, and lava can be intermingled with ordinary mud, silt, and sands.

Independently of other trappean rocks which have not been noticed as occurring in the vicinity of Brentor, very large masses of trappean rock present themselves on the eastward, forming the elevated lands of Horndon, White Tor, Smear Ridge, and Cock's Tor. Though there is much greenstone among these masses, generally of a large grain, there is also much that has a character approaching to hypersthene rock, one so frequently observable where greenstone comes into contact with granite in Cornwall and Devon.

A glance at the maps will show that bands of trappean rock skirt the granite of Dartmoor on the north-west, bending in conformity with the granitic outline, as if they had been thrust out of their original position by the protrusion of the granite. When we obtain sections of these bands, as we do in the ravines of the West and East Okement and Taw Rivers, near Okehampton, they seem included, like any other massive beds, among the grits and slates with which they are associated; so that we might readily consider them as sections of inclined tabular masses of the greenstones of which they are principally composed, such

masses being igneous rocks that have flowed during the accumulation of the sedimentary deposits which accompany them.

On the north-east of Dartmoor, near Bridford, Christow, Ashton, Hennock, and Trusham, trappean rocks, similar to those on the west of the moor, are found, and like them seem to have been in a great measure contemporaneously produced with the grits, shales, and slates of the carbonaceous series. The manner in which these bands are cut off by the granite on the west is very striking, and the alteration in the grain of the greenstones as they approach it is not less so.

Having thus endeavoured to trace the leading characteristics of this higher system of rocks on its northern and southern boundaries, we proceed to consider the principal facts exhibited in the country situated between them. Notwithstanding the size of the area in which they are comprised, the uniformity of the larger part of the carbonaceous rocks, viewed generally, is one of the most remarkable circumstances connected with them, and from which we may infer considerable uniformity in the general conditions under which their constituent mud, silt, sands, and vegetable remains have been accumulated.

The whole of the beds have suffered great contortion; so that their aggregate thickness becomes very questionable, if even we proceeded in the old way of measuring such thickness across the various beds, under the assumption that such beds must be continuous, or nearly so, throughout. These varied contortions are extremely well exhibited on the line of cliffs, extending from Boscastle to the Barnstaple estuary, which bounds the visible part of this system to the westward. North and south lines of section

Hut-like contortion near Cockington Head, Bideford Bay.

taken across the beds between the west coast and the boundary of red sandstone rocks on the east will show that the whole is ridged, furrowed, and twisted in lines which, when not much affected by the granite bosses, have a general direction from a few degrees north of west to a few degrees south of east.

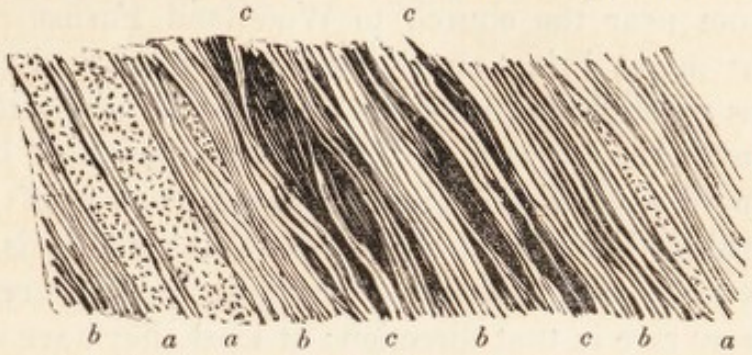
The mineralogical character of the beds of which the great carbonaceous series is composed cannot be considered as very varied. Sandstones, for the most part siliceous, occasionally with an argillaceous cement varying in colour from almost white to black, and shales, also of various tints, compose the bulk of the rocks. The sandstones and shales are very irregularly interstratified with each other, or rather one is often found to fine off amid a more largely-developed mass of the other. Coarser rocks, as we have seen, characterise the carbonaceous deposits of Ogwell, Ugbrooke Park, and Kingsteignton.

Roofing-slates and flagstones have been worked in some places, such as on the coast near Tremoutha, near Launceston, and in other localities ; but the produce, except for flagstones, cannot be considered of good quality. The occurrence of these beds is however sufficient to show that the deposit has occasionally been very fine-grained.

In the direction of Monkleigh, on the south of Bideford, and extending thence towards Orleigh Court, Alwington, and Fairy Cross, there is much red sandstone, and on the coast near Portledge Mouth conglomerate, of the red sandstone series, is seen to rest upon the red sandstones of the carbonaceous deposits of North Devon. Red sandstone is also very common among the carbonaceous series near Tiverton; but generally speaking red is not a common colour, and seldom moreover occurs except in the vicinity of the red sandstone series, or where we can consider the latter to have once reposed, and to have been subsequently removed by denuding causes.

Anthracite, or culm, occurs in a few beds, of very variable thickness, between Greenacliff, on the coast west from Bideford, and Hawkridge Wood, on the right bank of the Taw, near Chittlehampton, a distance of about twelve miles and a half. These beds, the importance of which has been most remarkably magnified, are generally accompanied by black shales, among some of which are found the abundant remains of plants. The anthracite

is mixed with these shales in the manner represented beneath;



a, sandstones; *b*, shales; and *c*, culm or anthracite.

so that the culm itself seems the result of irregular accumulations of vegetable matter intermingled with mud and sand. As so frequently happens with carbonaceous deposits of this kind, nodules of argillaceous ironstone are often found in the same localities with the shale and anthracite, reminding us of the intermixture of iron ores and vegetable matter in the bogs and morasses of the present day.

The occurrence of anthracite near Bideford has been long known; and Mr. Greenough, in his 'Geological Map of England and Wales,' published in 1819, noticed the fossil plants and clay ironstone near Clovelly, a portion of the series of beds which near Bideford contain anthracite. Between Shebberton Cliff and Cockington Head the beds associated with the anthracite consist of argillaceous shales and slates intermingled with sandstones, the latter not being so abundant as the former. Notwithstanding the faults by which the strata have been broken on this coast, and the contortions which they have suffered, the shale with vegetable compressions and ironstone nodules on the north side of Cockington Head seems somewhat higher in the series than the anthracite beds of Greenacliff, being perhaps a continuation of the beds that occur at Clovelly, and which are seen contorted from thence in different parts of the coast to Hartland Point.

The Greenacliff anthracite is continued in an east direction through the town of Bideford, two beds being there observable, which are more fully developed about a mile inland on the right bank of the Torridge. These beds are accompanied by shales, containing numerous fossil plants, on both banks of the Torridge, near Bideford. From Greenacliff to Eastacot a few marked sandstone strata occur not far beneath the anthracite and its associated beds, inclined at a very high angle with the horizon.

Near Alverdiscot a bed of anthracite has been traced for about a mile from near the church to Woodland Farms. Although contortions might bring up the more northern bed (see map), which runs parallel with it at the distance of nearly three-quarters of a mile, the absence of the marked sandstone beds above noticed would seem to place it in a higher portion of the series. At Hawkridge Wood, on the Taw, the anthracite beds terminate to the eastward; and it would appear that vegetable remains also become more rare in that direction: at least they have been as yet very sparingly detected near Hawkridge Wood.

It has been somewhat prematurely considered that the plants detected in this range of carbonaceous rocks from Bideford Bay to Hawkridge Wood were all of species well known in the coal measures. Dr. Lindley, who has examined such plants from this run of beds as we were enabled to place before him, informs us that, though the general form of the plants resembles that of the vegetation observed in the coal-measures, many species, and even one genus, were entirely new to him, and were different from any he had noticed among the plants of the coal-measures. Leaves of monocotyledonous plants of three or four species, hitherto undescribed, constitute the great proportion of the vegetation entombed along this carbonaceous range of rocks, and probably contributed most materially to the formation of the anthracite; for we find them most intermingled with that substance. The other plants occur much more irregularly, calamites and ferns being intermingled in patches with the principal body of this fossil vegetation. Amid these other plants Dr. Lindley recognised *Pecopteris Serlii* (Ad. Broug.), *P. lonchitica* (Ad. Broug.), *Neuropteris Loshii* (Ad. Broug.), *Neuropteris heterophylla* (Ad. Broug.), and *Sphenopteris acuta* (Ad. Broug.). Among the calamites there is probably also *C. nodosus*, and one which somewhat resembles *C. Steinhauri*. There were several species, unknown to Dr. Lindley, of the genera *Pecopteris*, *Asterophyllites*, *Sphenophyllum*, *Lepidodendron*, and *Poacites*. Indeed, a large proportion of the mass of plants entombed along this line would appear to belong to species not yet known to occur in the true coal-measures; and probably one-half of the same mass is made up of the leaves of plants of which the genera have not been determined. A minor portion consists of species which appear the same as those which have been detected in the coal-measures.

CHAPTER V.

GENERAL VIEW OF THE GRAUWACKE AND CARBONACEOUS ROCKS OF THE DISTRICT.

When we take a general view of the mass of sedimentary beds noticed in the two preceding chapters, we are forcibly struck with the necessity of reducing many cubic miles of pre-existing solid rock into sand and a still finer comminuted slate, to account for their existence. Many of the upper beds may indeed have been formed from a partial destruction of the lower after the first formation of the latter; but this does not diminish the necessity of deriving the whole from a general body of pre-existing solid mineral matter which has been worn into sand and still finer detritus to an extent at least equal to the cubic contents of the detrital rocks under consideration. There can be little doubt that these rocks merely constitute the visible portion of still more extensive masses of similar beds, some parts of which appear on the surface in other localities, while others are concealed by more modern rocks, the detrital portions of which may have been derived from a partial destruction of these beds. We neither see the extent of these rocks nor do we know the amount of matter which has been abraded from them, constituting new rocks, since their original formation. When we look around for the remains of more ancient mineral masses whence this great amount of sand, silt, and mud has been abraded, we find nothing in the district, nor indeed at considerable distances from it, except the mica slates and chloritic rocks of the extreme south of Devon, and perhaps some rocks in the Lizard district, remaining, of any older mineral masses from whence the detrital rocks of the grauwacke and carbonaceous series may have been derived.

If we attempt to trace the direction whence any part or the whole of this sedimentary mass may have been transported by water, we find ourselves foiled by the finely-comminuted condition of the component detritus and by the contortions to which

its constituent beds have been subjected. We can neither trace, except in the case of a few very subordinate conglomerates in South Devon and Cornwall, any remains of the structure of the rocks which have furnished the sedimentary matter, nor can we, from the mode in which the beds occur relatively to each other, form a safe conclusion of the manner in which the general drift of detritus was effected.

North Devon presents us with a series of beds so resting upon each other that there can be little doubt the more ancient deposits are found on the north and the more modern on the south, the slates and calcareous rocks of Barnstaple being the highest of the undisputed grauwacke of that district, while the Foreland red sandstones are the lowest. The latter are chiefly consolidated sands, intermingled with minor portions of silt and mud, deposited under some conditions which either permitted iron in a state of peroxide to be intimately mixed with the detritus, or left such intermingled iron in a state to be readily converted into a peroxide afterwards.

Calcareous matter subsequently became intermixed with the silt and mud; and either the carbonate of lime secreted by living creatures furnished this matter, or a facility of procuring this substance, present in the area from other causes, enabled living creatures so secreting carbonate of lime to exist; for we find seams of organic remains, among which single vertebral columns of encrinites are common, in patches which differ little in character from similar patches of dead and living marine creatures, so common on sea-coasts of the present day.

Above this we have evidence of a return of the conditions under which the lowest red sandstones and slates were accumulated, in the red and variegated consolidated sands, silt, and mud of Trentishoe and the Hangman Hills, with their continuation into Exmoor. Hitherto sand has been the prevailing substance; for even the calciferous grey beds of Linton more partake of the character of consolidated silt than mud. A considerable change seems however to have taken place in the character of the deposit above the Trentishoe beds, and drifted mud appears to have become the predominant substance, sands and silts being subordinate for at least a considerable time. In the lower part of this mud or clay we find calcareous matter in sufficient abundance to produce limestones. And it becomes interesting to inquire

how far facts may justify us in supposing the carbonate of lime thrown down from a solution, or how far accumulations of organic bodies may have produced it.

When we find a limestone thinning off to very fine edges, forming an irregularly-extended sheet of matter, its thickness, however it may vary in parts, inconsiderable when compared with its breadth, and few or no traces of organic remains to be detected, it seems not unreasonable to infer that there may have been a solution of carbonate of lime in a fluid, and that the substance thus in solution was precipitated by some chemical change in the fluid. When we observe seams of calcareous matter replete with organic remains, we are led to conclude that these remains have chiefly formed the limestone, being merely consolidated by calcareous matter which may in a great measure have been derived from the organic remains themselves. Where we find limestones terminating abruptly against slates, and corals form a large portion of such limestones, we may be led to infer that the limestones were formed in the manner of modern coral reefs, mud and silt having accumulated against them laterally; so that, when the whole in after ages became split by joints and divided by great planes of lamination and cleavage, the continuation of the limestones would appear to be slates or sandstones, as the case may be, and the limestones would seem to abut very suddenly in their line of strike against dissimilar rocks.

If we apply these views to the limestones extending from Combe Martin, in irregular patches amid the slates, by Challacombe to Treborough and Luxborough on the east, we find that while some beds fine off very gradually, others terminate more abruptly, and that organic remains do not constitute any large proportion of them. Even those which terminate somewhat abruptly do not contain many organic remains. They appear more the result of a deposit of carbonate of lime from a solution superincumbent on a surface of mud, so slowly that marine creatures were enabled to live and prosper at the time, than of accumulated banks of organic bodies, or of a series of coral reefs extending along a line of coast. If we suppose the carbonate of lime to be derived from local calciferous springs, there seems no reason why these should only have produced limestones at one epoch more than among the prior deposits, unless indeed we imagine that the causes which threw down the carbonate of lime

in solution only occurred at intervals. We should rather infer that there was some general cause acting at this period which either rendered the mud drifted more calcareous, or caused the deposit of carbonate of lime from the superjacent waters.

Subsequently to the formation of this calciferous portion of the series, silty matter was drifted with the mud, but finally mud alone was deposited, forming the great band of slates extending from Morte to Clatworthy, near Wiveliscombe. Arenaceous rocks succeed, the causes which produced the red colour of the lowest beds again appearing to have partially acted, though not in any great force; and the whole series is crowned by silt and mud, chiefly the latter, both being not unfrequently calciferous, and containing seams of organic remains, reminding us, in their mode of occurrence, of similar seams near Linton. The lower part of this last part of the series, or the upper part of the arenaceous rocks beneath it—for there is little physical separation between them—contain the remains of plants considered terrestrial: a fact of great interest, showing the existence of dry land with vegetation upon it within some reasonable distance, anterior to the formation of the beds extending from Barnstaple by Anstey (near Dulverton) to Bathealton and Kittisford. To the variable character of some of the upper beds of this grauwacke series, showing modifications in the causes producing contemporaneous deposits, we have previously alluded (p. 53).*

* In 1836, as above noticed (p. 43), Professor Sedgwick and Mr. Murchison divided the grauwacke of North Devon into five subordinate groups.

At the meeting of the British Association for the Advancement of Science, held at Liverpool in 1837, the Rev. D. Williams divided this grauwacke into seven minor groups:—1. Limestone of Cannington Park. 2. Sandstones of the Foreland, &c. 3. Calcareous slates of Linton. 4. Red slates and laminated sandstone of Trentishoe and the Great Hangman. 5. Limestones of Combe Martin and Ilfracombe with the Morte roofing-slates. 6. Woolacombe flag and sandstones (including the Baggy Point sandstones). 7. Trilobite slates. He pointed out that the upper part of the Woolacombe sandstones contained fossil plants, and that the Trilobite slates (No. 7) passed into an upper group (8) of Wavellite schistus and black limestones, supporting a still higher group (9), which he names the culmiferous and floriferous shales and sandstones. The Rev. D. Williams considered the groups 8 and 9 as forming at least part of the upper grauwacke. He observes that he stated the fact of the carbonaceous rocks occurring in a trough, bounded by the ridge of Exmoor on the north and the granite of Dartmoor and the slates of Forrabury and Boscastle on the south, at the meeting of the British Association held at Dublin in 1835.—(Report of the Proceedings of the British Association, Athenæum, October 7, 1837.)

Hitherto we have noticed beds which it seems agreed should be referred to the group usually termed grauwacke. With the rocks to be next mentioned the case is however different. We have seen that, conformably with the range of the southern boundary of the undisputed grauwacke of North Devon and West Somerset, we have the northern boundary of a great carbonaceous system, and that it was extremely difficult to draw fine lines of demarcation between the two great systems, supposing them to be clearly separable.

When we regard the various facts observable between these systems, we perceive nothing which would lead us to consider that any geological interval had elapsed between the last-formed beds of the one and the first-formed beds of the other. On the contrary, we find that shading or passage of one into the other which is usually regarded as affording evidence of a continued mechanical deposit, alterations of some of the conditions under which the sedimentary matter was accumulated causing corresponding changes and alterations in the character of the sand, silt, and mud brought to rest.

Little doubt would probably have been thrown on the conclusion that the carbonaceous series was merely a portion of a great system of tranquil deposits passing into each other, if certain fossil plants collected by us in the vicinity of Bideford, and presented to the Geological Society of London, had not been regarded as of the same species with plants detected in the coal-measures. Under the supposition that the species of plants detected in the coal-measures must be limited to them, it has been considered anomalous that species resembling them should be found entombed among the mud, silt, and sand of an earlier date, notwithstanding that the general organic character of the various sedimentary deposits, from the grauwacke to the coal-

In January, 1838, Mr. Weaver read a paper to the Geological Society of London on the Geological Relations of North Devon, in which he subdivided the rocks of the district as follows:—1. Foreland sandstone. 2. Linton calcareous slates. 3. Trentishoe quartzy slates and sandstones, including the Combe Martin limestone. 4. Morte slates. 5. Woolacombe sandstones, flagstones, and slates. 6. Trilobite slates. 7. Wavellite schistus and limestone. 8. Culmiferous shales. He concludes "that the strata from 1 to 6 belong to a system distinct from that which includes the beds 7 and 8, the former constituting a *peculiar transition group*, and the latter belonging to the true coal-measures of England, the old red sandstone being alone wanting."—(Proceedings of the Geological Society of London, vol. ii. p. 589, 590.)

measures, both inclusive, offers so much family resemblance that it may be well doubted if the classification which includes them in one great group—a classification that has often been adopted by continental geologists, and more recently employed by Professor Buckland in his Bridgewater Treatise—is not most conformable to a natural division of rocks.

The accidental occurrence in the undisputed grauwacke of Barnstaple of plants analogous to those detected in the coal-measures destroys any importance which might be attached to the presence of such plants among the grits and shales of the carbonaceous series of Devon and Cornwall. That it should have been considered an anomaly, as has been done in England, to discover plants in an earlier rock, analogous to those so abundantly found in the coal-measures, is the more remarkable when we reflect that it has for some time been held by continental geologists that plants similar to those in the coal-measures are discovered in grauwacke. And it should be recollected that this opinion has been held, not by geologists who, as formerly, made no distinctions between coal-measures and grauwacke, but by those who did make, and well understood, such distinctions.

M. Burat said in 1834, when speaking of the grauwacke series, "Fossil vegetables are not abundant in it: nevertheless the upper part of the system sometimes contains them in great quantity. They consist of ferns and reeds analogous to those found in the coal-measures. The frequency of these vegetables is generally in proportion to the abundance of carbon which forms masses and beds of anthracite and even of coal."* When treating of the upper grauwacke of Brittany, part of Normandy, le Maine, and Anjou, the same author observes that this group is composed of alternating beds of grey, black, and red slates; of very shelly limestones; of quartzose sandstones, often passing into compact quartz, grey and white; and of carbonaceous matter forming anthracite and even coal-beds. "The abundance of carbon is in fact its most striking character; for not only are the slates carbonaceous, but they are also associated with beds of anthracite and coal attaining even a metre† in thickness. This character at one time led to the supposition that a part of this country belonged to the coal-measures. The beds of carbon are worked

* Traité de Géognosie, par D'Aubuisson, seconde ed., tom. ii. p. 212.

† A French metre is equal to 3 feet 3·37 inches English.

at St. Georges Châtelaison, Montrelais, Mouzeil, Nort, Languin, &c., where they are generally included among black slates, alternating with compact limestones, more or less shelly, grey, black, or reddish, with talcose slates, and sandstones either pure or ferruginous. At Montrelais four beds of anthracite are associated with micaceous sandstones containing nodules of quartz, and alternating with slates and quartz rock.

"The beds of this district are often highly inclined, sometimes vertical, curved, and undulating, as may be seen in the coal-mines and among the roofing-slate of Angers. . . . .

"This formation, which resembles the coal-measures in the abundance of its carbonaceous beds and in its vegetable remains, nevertheless essentially differs from it in its other fossils (shells and corals), in its mode of occurrence, which has no resemblance to basin deposits, and lastly in its unconformable position to that rock. In fact, small basins which really do belong to the coal-measures occur in the same country, the nearly horizontal beds of these real coal-measures resting on the basset edges of the inclined beds of slate, limestone, sandstone, and anthracite. It resembles the inferior transition rock in its composition, but differs from it by the abundance of carbon, by the presence of certain fossils (Bellerophons, Ammonites, &c.), and by the unconformability of its stratification. The lower transition rocks form, in fact, observes M. Elie de Beaumont, gibbosities round which the upper transition beds mantle. The older schistose beds have generally a direction from N.E. ¼ E. to S.W. ¼ W., while the carbonaceous beds have a general strike between a line east and west, and another W. 15° N. and E. 15° S., leading us to infer that the lower transition beds had been forced into one direction before the deposit of the upper transition rocks, which were themselves compelled to follow another before the deposit of the coal-measures."*

That the opinion as regards anomaly should be entertained is still more remarkable, when we consider that M. Adolphe Brongniart, no mean authority on such subjects, remarks, when speaking of grauwacke or transition rocks, "These rocks, so rich in madrepores and other classes of inferior animals, are very poor in fossil vegetables. In some places beds have been found, which many distinguished geologists refer to these rocks, that

* Traité de Géognosie, par D'Aubuisson, tom. ii. p. 256, &c.

contain plants perfectly resembling those of the coal-measures. Thus the Museum of Strasbourg possesses many specimens of plants which accompany the anthracites of Berghaupten and Zundsweiler, in Baden, and others which are found in the transition rocks of Bitschweiler (dep. of the Haut Rhine). M. Voltz considers these formations as belonging to the transition series, and as consequently more ancient than the coal. M. Omalins d'Halloy also cites the remains of plants, analogous to those found in the coal-measures, as occurring among the slates of the Ardennes, which appear to have been contemporaneous with transition limestone."

In a more recent memoir on the nature of the plants which have existed on the surface of the earth at different epochs, M. Adolphe Brongniart observes that "The terrestrial plants which occur in the beds more ancient than the coal-measures, the transition rocks, for example, are not numerous, and scarcely, if at all, differ from those contained in that formation. There does not appear to me," he continues, "more difference in the fossil plants of the two epochs than between those in the upper and lower beds of the same deposit of coal-measures."*

M. Voltz observes that the Bitschweiler beds above noticed "occupy the valleys of Saint-Amarin, Mazevaux, and Guebwiller, and the bottom of those of Munster and of other parts of the Vosges; that they are composed of transition slates, grauwacke, and porphyry; that their stratification is nearly vertical; and that they also contain some beds of anthracite, anthracitic grit, and a much-divided petrosiliceous rock."†

"M. Elie de Beaumont points out the valley of Thann, in the Vosges, as an example of the upper transition series. It is composed of slates and sandstones, which, like those of St. Georges Châtelaison, frequently become felspathic near the interstratified petrosiliceous rocks. These slates are often carbonaceous, and contain beds of anthracite with vegetable impressions. The general direction of the beds is not the same with that of the slates and grauwacke of the central part of the Vosges; and these two directions stand in the same relation as those of the formations in Brittany. The prolongation, moreover, of these

* Considérations sur la Nature des Végétaux qui ont couvert la Surface de la Terre aux diverses Epoques de sa Formation. Par M. Adolphe Brongniart. Académie Royale des Sciences. Lués dans la séance publique, 11 Septembre, 1837.

† Histoire des Végétaux Fossiles, par Adolphe Brongniart, tom. i. p. 123.

carbonaceous beds occurs on the other side of the Rhine, in the mass of the Swartzwald, constituting a formation under the same conditions. The anthracite found in it is worked at Zundsweiler. These facts, joined to the absence of shells, have led M. Elie de Beaumont to consider that these upper transition beds have been deposited in a lake elongated in a direction from Thann to Zundsweiler, and that in fact this carbonaceous system (which offers no analogy with the coal-measures worked near there, at Ronchamp) forms a true basin-shaped deposit." *

The works above cited have not been selected because they alone contain these views, which is far from being the case, but because they are so readily accessible that probably few geological libraries are without them.

It may be useful, in addition, to state that, prior to 1833, MM. Elie de Beaumont and Dufrénoy examined the district of Brittany and Normandy while occupied on the government geological map of France, and that in the beginning of 1833 the former geologist described the facts noticed by them in that district in his lectures at the College de France, from which lectures, we believe, M. Burat's descriptions were principally taken. M. Elie de Beaumont informed me, in a communication dated December, 1834, that he and M. Dufrénoy completed and verified their observations in that year. He observes that the peninsula of Brittany (which, geologically speaking, comprises the Bocage of Normandy, La Vendée, and a part of the departments of the Sarthe and others) presents three different systems of rocks anterior to the new red sandstone, as distinct from each other as the oolites, the chalk, and the calcaire grossier. The first is the lower transition system, consisting of slate and grauwacke passing into mica slate and gneiss, penetrated by granite. The second is the upper transition system, composed of sandstones and conglomerates, of granular and compact quartz rock (Mai, near Caen), of limestones (Fuguerolles, near Caen), and of grauwacke and different slates (slates of Angers, &c.), more or less carbonaceous, the latter containing vegetable impressions and beds of anthracite in many places, the anthracite being sufficiently thick in some to be worked. (St. Georges Châtelaison, Montrelais, &c.) The third is the carboniferous system, represented by the small coal-basins of Litry

* D'Aubuisson's Traité de Géognosie, par Amédée Burat, 1834, tom. ii. p. 260, 261.

(Calvados), of Plessis (Manche), of Saint-Pierre-Lacour (La Mayenne), and of Quimper (Finisterre).

M. Elie de Beaumont proceeds to observe that there cannot be the slightest doubt that the carbonaceous trilobite slates of Angers are of the same formation as the anthracite beds which are worked for profitable purposes, and that vegetable impressions are frequent in all the slate and arenaceous beds of the upper transition system, being more particularly abundant in the rocks which form the roofs and floors of the anthracite beds. Numerous specimens were procured by M. Dufrénoy and himself, both among the anthracite mines and among the slates and grauwacke traversed by the argentiferous lead lode of Huelgoat, near Poullouen (Finisterre). M. Adolphe Brongniart, who has examined these impressions, finds that, while some of the species are yet unknown in the coal-measures, others are identical with those found in that rock.*

So far, therefore, from there being any anomaly in detecting the so-called coal-measure plants in grauwacke, previous knowledge would lead us to expect, if there should be any accumulation of vegetable remains in that rock, and more particularly if such accumulations should have been sufficient to form the materials for coal or anthracite beds, that such plants would have the same general character, and for the most part be of the same species, as those detected in the coal-measures themselves.

Accumulations of plants sufficient to form beds of coal or anthracite at different geological periods merely show that similar conditions proper for such accumulations have obtained at these respective epochs. Perhaps there are few things in geology which have less advanced beyond the old doctrine of universal formations than the coal-measures. The name itself of coal-measures has probably not a little contributed to the supposition that this system of rocks must have been an accumulation of similar plants amid similar sands, silts, and mud, if not over the whole face of the globe, over at least a very considerable portion of it. It seems to have been difficult to consider that the carbonaceous accumulations, to which the term coal-measures has been so exclusively applied, merely constituted a portion, and probably a minor portion, of the sedimentary deposits effected at that geological epoch, and that their equivalents in age, where the neces-

* Elie de Beaumont, MS.

sary conditions for such carbonaceous accumulations did not obtain, were marked by the presence of shells, corals, and other remains of animal life, among which the fragments of a terrestrial plant were of the greatest rarity.

We learn from the geological structure of Brittany and Normandy that a series of detrital beds were there deposited during the grauwacke epoch under conditions that permitted so considerable an accumulation of vegetable matter, that in several instances beds of coal and anthracite were the result; and we also learn that the plants therein entombed were generally of the same species with those found in rocks higher in the geological series. We infer, therefore, similar physical conditions for the accumulation of the vegetable matter at these different geological epochs, and a similar vegetation to have existed in the lands where the terrestrial plants which produced it grew.

When we inquire closely into the nature of the evidence on which the supposed equality in geological date of numerous deposits in Europe, termed coal-measures, is founded, it being understood by the name coal-measures that the beds were formed of sedimentary matter deposited after the carboniferous limestone of England and Belgium, we find that this geological parallelism is founded on the occurrence of certain fossil plants, a few of which may be common to all; but not a few are common to merely two or three, or three or four, of these carbonaceous deposits. Now, if the views of M. Adolphe Brongniart be correct, and the plants found in the grauwacke and coal-measures (above the carboniferous limestone) be so generally similar, we may have many deposits referred to the same epoch, which are, in fact, of different geological ages, ranging from the grauwacke to the true coal-measures, both inclusive.*

That conditions should obtain over a considerable area, such

* M. Ad. Brongniart seems to treat all this period as included under one epoch of vegetation, which he terms the primitive vegetation of the globe, designating the coal-deposits formed during that period by the general term "terrains houillers." He regards it as having commenced as soon as emerged portions of the earth's surface become covered by a few plants; feeble and scarce at first, however, not attaining its maximum development until towards the end of the coal period (période houillére). He further observes that during this long period the vegetation seems to have suffered notable changes as to species, while it preserved the same essential characters. (Considérations sur la Nature des Végétaux qui ont couvert la Surface de la Terre, &c., p. 5.)

as that of Europe, at various periods, and in different places, favourable to carbonaceous deposits, during all that time which must have elapsed while the mass of detrital and other rocks, known as grauwacke, old red sandstone, carboniferous limestone, and coal-measures, was accumulating, seems an hypothesis far more reasonable than that of a sudden contemporaneous deposit of carbonaceous rocks over the same area. The one opinion is in accordance with facts observable in other deposits, such as the oolitic, cretaceous, and supracretaceous series, and with the manner in which materials for future rocks are accumulated at the present day, while the other is little else than the old doctrine of the "Independent Coal Formation" of the Wernerian school.

As far as the evidence of the mode of superposition extends, and as far as that of the fossil plants detected in the carbonaceous series of North Devon is concerned, and we have seen the proportion of known fossil plants there supposed to bear to the unknown (p. 126), these carbonaceous beds may be an upper part of the same series of tranquil deposits of which the various sandstones, slates, and calcareous beds on the north of them, constitute the lower. Professor Phillips considers, indeed, that the *goniatites* discovered in the black limestones, running near the north boundary of the carbonaceous series, are of species corresponding with those found in the carboniferous or mountain limestone. Considering this determination to be correct, it would no doubt weigh much with those who suppose every minor geological epoch well marked by fossils peculiar to it, and that conditions could not obtain within reasonable limits (admitting that great changes in animal life have taken place from the earliest to the most recent epochs) which should be favourable to the existence of creatures of the same kinds earlier in one locality than in another. We should have for the goniatites of the black limestone above noticed conditions which may, for convenience, be termed carbonaceous conditions.

Now there appears nothing unreasonable in the supposition that carbonaceous conditions, at the epoch of the grauwacke, would have animal life adjusted to it different from that which was fitted for non-carbonaceous conditions at the same time, and therefore there would be nothing remarkable in not discovering the remains of animals, commonly entombed in deposits effected under non-carbonaceous conditions, amid the mud, silt, or

sand, contemporaneously brought to rest beneath carbonaceous waters, and a mass of transported vegetation, half of it probably in a decomposing state, in other localities. If we suppose the carbonaceous deposits of the grauwacke and coal-measures of a large part of Europe to have been effected under similar physical conditions, and the vegetation entombed be of the same general kind, indicative of growth in similar climates, we obtain like general temperature and physical conditions for the deposits at those respective times in that area. Hence, if animal and vegetable life has always been adjusted to conditions, as we now invariably find it to be, analogous animal life may have existed during the respective deposits of the carbonaceous grauwacke and the coal-measures, and amid the carbonaceous deposits of the intermediate time. If therefore we detect a group of shells possessing a certain form, such as a group of goniatites, amid limestones in carbonaceous grauwacke, which is also found in limestones formed when like carbonaceous conditions were prevailing at a somewhat more recent epoch, yet still one when the general forms of animals, judging at least from the remains known to us, was much the same, there would appear nothing in it contrary to the adjustment of life to similar physical conditions.*

We have seen that along the southern boundary of this carbonaceous series its beds repose on older rocks from Boscastle to South Petherwin. There is little to show at present either that these lower rocks correspond in age with, or are different from, the range of calcareous and argillaceous slates which bound the carbonaceous series on the north. One marked difference exists between the southern and northern beds in the trappean ash and vesicular igneous rocks which are associated with the former and deficient in the latter. This may be merely a local difference, but still it is one which may have greatly influenced the conditions under which animal life existed in the two localities, supposing them, for illustration, to be contemporaneous. Professor Phillips considers that a *Terebratula*, analogous to *T. plicatella* of Dal-

* We are too apt to regard the carboniferous or mountain limestone as separable from the carbonaceous rocks which it supports. The two are intimately blended with each other in the north of England, and coal is stated to be even found beneath the whole of the limestone in the old red sandstone of Dumfries. In such situations, at least, and perhaps also in parts of Ireland, the mountain limestone was formed under circumstances indicative of a great prevalence of carbonaceous conditions.

man, is found in both, as also another *Terebratula* resembling *T. didyma* of the same author, both shells occurring in rocks considered as upper grauwacke in Gottland and Ostrogothia. Several species of the remarkable genus *Clymenia*, of Munster, occur at South Petherwin, no trace of which has yet been discovered in the north. These may, however, be mere local variations due to local causes. There is much difficulty in separating the carbonaceous system from the South Petherwin rocks, and we can readily conceive a newer rock mantling round part of an older deposit, so that, while it should graduate into beds beneath it in one place, it may overlap, and even rest upon the edges of upturned strata in another. Now the mode in which the trappean ash, vesicular rocks, and solid greenstones, are associated with the series of which the South Petherwin beds form a part, is sufficient to show that volcanic disturbances may have been frequent during its formation. Hence we could scarcely expect that quiet succession of deposits which might take place contemporaneously in a less disturbed part of the area, such, for example, as North Devon, and we might obtain consecutive deposits, sometimes reposing conformably upon, at others resting against, broken or uplifted edges of beds formed immediately before them.

This intermixture of productions, which bear great analogy to those of existing volcanos, is common to the line of junction between the carbonaceous system and the slates and grits bounding it on the south, from Boscastle to the granite near Tavistock, and for a considerable part of that distance obscures the junction so much, that a line separating them is purely arbitrary. The whole has greatly the character of a line of coast, or shallow water agitated by volcanic action, a great change having been effected in an area comprising North Devon, which, while it did not interrupt the volcanic eruptions on the south, brought a large part of this area into a trough-like form, so that carbonaceous matter and plants were accumulated, and the volcanic vents through which ashes, cinders, and solid lava were ejected during the non-carbonaceous time, continued to supply the same materials after the change, these materials being then associated with the carbonaceous deposits.

If this be supposed, for the moment, a correct view, we could scarcely expect the same mineralogical succession of beds on the

south as on the north, inasmuch as the conditions of the sides of the area would be widely different. Tranquillity would characterize the northern deposits, disturbance from igneous causes the southern.

The mass of Dartmoor granite unfortunately occurs where a point of great interest would have to be determined. Near Tavistock the connexion of the carbonaceous beds and the mass of non-carbonaceous slates and sandstones on the south becomes extremely equivocal, so that in the vicinity of the town it would be difficult to say if there was not a tendency of the carbonaceous series to pass under the rocks to the south of them.

After passing round the granite of Dartmoor we arrive at the carbonaceous beds associated with trap near Bridford, Cristow, and Doddiscombleigh. If we consider these beds a continuation of those of Heathfield, Brentor, Cock's Tor, and other places near Tavistock, partly shoved northward, and partly broken through by the granite at the time of its protrusion, we have the lower beds of the carbonaceous series as they are exhibited in that locality. This would make the beds of an anticlinal line from Dartmoor to Exeter nearly the lowest in the series. Supposing this correct, the fall of this line would bring in the higher beds of the same series, and we might expect to discover rocks resting upon them on the south if a general dip of beds continued in that direction. If the beds of the calciferous country on the south rest, as they appear to do, on the carbonaceous series from Buckfastleigh by Ashburton to Bickington, then they are rocks higher in the general series than the carbonaceous deposits extending to North Devon.

If this view be taken it may be asked why a continuation of the carbonaceous series is not clearly found on the west of Dartmoor supporting the Plymouth range of rocks. It must be confessed that this is a question not easily answered unless we suppose that the carbonaceous series was beginning only to mantle round older rocks, where interrupted by the granite of Dartmoor, near Tavistock, and that these older rocks were so situated as to be uncovered by carbonaceous beds in the direction of Plymouth, so that, when the calciferous system of Ashburton and Buckfastleigh was deposited, it passed round and rested upon these older rocks in the same manner as the green sand extends over the area occupied by the wealden rocks, and overlaps in succession the oolitic and red sandstone series, the beds of which, during the epoch of

the wealden deposits, were not so situated as to be covered by them.

When we have to consider carbonaceous deposits, principally characterised by the presence of terrestrial plants, or beds, such as we suppose the wealden rocks to have been, we have to regard them as due to particular conditions, different from those under which great marine deposits were effected at the same periods. We view such deposits as of a local kind, forming irregularly-distributed local patches amid the general sedimentary accumulations of their epochs. We consider a change of conditions, perhaps a difference in the relative levels of sea and land, necessary to allow a larger area to be covered by marine detrital deposits (such as that occupied by the cretaceous series of England), a small portion of which was alone previously in a condition to be so covered, and that only in a manner which may lead us to infer the near presence of land or the bounding shores of an estuary or of lakes (such as we infer has been the case with the wealden rocks).

Let us suppose the carbonaceous deposits of Devon to have been bounded on the west by rocks not under conditions to be covered by them, the relative general levels of the older slates and grits and of the carbonaceous series to have been somewhat as at present, and that a change of conditions so altered the character of the sedimentary deposits, that, from being characterised by the abundant presence of carbon and terrestrial plants, they were no longer so characterised, but bore evidence of having been accumulated over marine shells and amid coral reefs. We can readily conceive that these older rocks may have been relatively so lowered respecting the level of the sea, as we consider may have been the case with the red sandstone and oolitic groups of Devon and Dorset at the time of their overlap by the green sand, that the newer beds should overlap the older slate rocks of Devon in a manner to be scarcely separable from them, and that fine lines of demarcation could not be drawn between the Plymouth range of slates, sandstones, and limestones, and the older rocks between them and South Petherwin.

Let us suppose also that, while the carbonaceous series was beginning to mantle round the older rocks near Tavistock, deposits were effected in the direction of Callington and Liskeard under different conditions from those on the north of Tavistock; that, in fact, instead of an estuary or confined basin, open sea occurred after

rounding this point. Under these conditions we could scarcely expect to obtain the same carbonaceous deposits, and we might, therefore, have in that direction accumulations of sands, silt, and mud, very differently characterised from those thrown down in the estuary or basin. If the slope of the older rocks round which this differently-characterised, but contemporaneous, deposit mantled was southward, there would be great difficulty in distinguishing it from the rocks on which it rested to the westward, and thus we might have, in the direction of Cornwall, slates and sandstones very similar to those above and beneath, occupying an intermediate position between the Plymouth range of rocks and older beds on the northward. Whether this hypothesis be tenable or not as regards the area under consideration, if we consider deposits to have been effected in estuaries, there must always have been contemporaneous deposits out of the estuaries in the adjoining open sea, which would be very differently characterised, particularly by organic remains, from those effected at the same time in them.

The general character of the great carbonaceous deposit of Devon and the adjacent part of Cornwall is that of drifted matter, vegetable remains included. In this respect it appears unlike the coal deposit of Northumberland and Durham, of which a valuable general sketch is given in the "Fossil Flora of Great Britain,"* and much, and as it appears to us, good evidence adduced to show the probable growth of the principal mass of entombed plants in the localities where they are now found, a character probably also common to the South Wales coal-measures.† The irregular manner in which the anthracite near Bideford and along the same geological line (p. 125, fig. 14) is mingled with the shales, seems very characteristic of drifted vegetable matter entangled amid mud. Broken pieces of plants are frequently distributed among the sandstones and shales of the series, the fragments sometimes thickly accumulated, at others occurring far apart, indicative of

* Vol. ii. Preface.

† Mr. Logan has lately discovered some beautiful examples of upright Sigillariæ piercing through these coal-measures in a deep valley at Melin-glyn-llech near Capel-Coelbren, branching from the higher part of the Swansea Valley. Four stems, one of which is two feet in diameter, and one thirteen feet and a half high, are exposed to open day near the mill. By clearing away the shale which enveloped two of them, we found that they had grown from that which now forms a bed of coal. They seem to constitute a portion of a subterraneous forest of the epoch of the lower part of the South Wales coal-measures.

an irregular mode of drift. We should hence infer a transport of plants and their fragments into a lake or estuary by means of rivers traversing the adjoining land, and not first a growth of plants over a flat, a sinking of that flat from physical causes, and a subsequent accumulation of detritus upon it, permitting another growth of vegetation, followed by another depression of land beneath water, and so on irregularly, precisely as we find many of those vegetable accumulations termed submarine forests, now covered by mud, silt, or sand, and a vegetation upon the latter, sometimes not much differing from that entombed beneath it.*

We have now to notice the carbonaceous deposits occurring at Ugbrooke Park, Hestow, Kingsteignton, and between East Ogwell and Abbots Kerswell. If these be contemporaneous with those above noticed, and the rocks they rest upon be higher in the general series than the Barnstaple calciferous slates and grits, the view above taken of the relative age of the great carbonaceous series of Devon must be abandoned, and its passage into the north Devon grauwacke, its intermixture with the older slates near Tavistock, and its apparent dip beneath the calciferous band of Buckfastleigh, Ashburton, and Bickington, be considered fallacious. If the rocks these beds rest upon be of equal or of greater age than the Barnstaple deposits, we should then have to consider that beds which passed into the latter on the north overlapped rocks unconformably on the south, the respective floors on which the sedimentary matter was thrown down having been under different conditions during the general deposit, the northern boundary having remained quiet while the southern was convulsed by volcanic action, which threw the older beds into positions that ren-

* The opinion that the vegetation entombed in the coal-measures has chiefly grown in the localities where we now find it seems gradually becoming more prevalent. M. Adolphe Brongniart, after alluding to the opinion advanced by De Luc, and which he also had long supported, that the coal-measures were formed in the same manner as the great peat deposits of the present day (due reference being made to the differences which the nature of the vegetation would then cause, and other necessary conditions), states that his later studies of coal deposits and peat districts, and the examination of the plants they contain and their mode of occurrence, have only tended to confirm him in his first opinions. (Considérations sur la Nature des Végétaux qui ont couvert la surface de la Terre, 1838, p. 6.) It has always appeared to us difficult to account for many of the phenomena connected with the plants in the coal-measures and some other rocks, without the supposition of successive depressions of the land on which the vegetation grew.—Geological Manual, 3rd edit., p. 408; and, Researches in Theoretical Geology, p. 320.

dered any deposit upon them unconformable, though such deposits may have been merely interrupted by the time occupied by the volcanic action. In this case we should have only to consider the apparent dip of the carbonaceous beds from Bickington to Buckfastleigh as fallacious.

It has been previously stated (p. 111) that the carbonaceous beds of Ugbrooke Park, &c., are frequently coarse grained, and that the conglomerates contain portions of marked rocks of the great carbonaceous series on the north. They rest clearly upon the limestones of Chudleigh and Ogwell, which would not have precisely the same age if the former be a continuation of the Bickington band, as there is an intermediate mass of slate ranging between that band and the Ogwell beds. Supposing the limestones somewhat different in age, these carbonaceous deposits would have an overlapping character, and may, therefore, as well overlap the carbonaceous rocks on the north as any other beds, and there would be great difficulty in separating the two, as there is sometimes in separating the red sandstones termed old and new, when the mineral character of both is, as sometimes occurs, not very distinct, and unconformable position not very apparent. Now, if we take the general dip of the beds near Chudleigh, one series of carbonaceous rocks seems to pass under the Chudleigh limestones (pl. 4, fig. 7), while another rests upon them, and the upper overlaps the end of these limestones near Lower Herkley, passing on and either overlapping a higher portion of the great carbonaceous series of the north near Chudleigh Bridge, or merging into it and forming the upper part of its beds.

The apparent dip of the carbonaceous beds beneath the Chudleigh limestones would, if the Ugbrooke beds merge into those on the north, be fallacious, and these limestones may merely have been ridges upon which this part of the general carbonaceous series was deposited, the lower part of the great carbonaceous system having furnished fragments which, being rounded by attrition, then formed a portion of the upper part, in the same manner that any lower beds of a general series may furnish materials for upper deposits. Whatever view be taken of this subject, the range of the Chudleigh beds and the apparent dip of carbonaceous rocks beneath them, and the course and anthracitic character of the Buckfastleigh and Ashburton band with a similar apparent dip, however fallacious these dips may be, are

circumstances well worthy of attention, more particularly when we regard the general line of the two limestones (supposing them to be continuous portions of each other), conformably to the line of the Dartmoor granite on the north-west.

On the south of the great mass of the carbonaceous series of Devon, and supporting those coarser deposits we have last noticed as occurring at Ugbrooke Park, Kingsteignton, and between East Ogwell and King's Kerswell, we find the band of calciferous country which has been shown to extend from the district of Ashburton, Newton Bushell, and Torbay by Plymouth, the Looes, Fowey, the vicinity of St. Austell, Gorran Haven, and Veryan to Porthalla, in the Lizard district. It is covered in the South Hams of Devon by arenaceous beds, separating it from a mass of red and grey argillaceous slates that seems to repose upon the mica slate and chloritic series of the district, which extends from the Bolt Tail to the Start Point.

This band of deposits is highly calcareous at its eastern extremity before it becomes covered by the mantle of red sandstone and conglomerates that bounds it in that direction. Though limestone patches keep up the calciferous character of the band between the Dart and the Yealm, it is chiefly between the latter and the Tamar that the limestones are again somewhat abundant. After passing the Tamar calcareous matter becomes more scarce, and is only occasionally in sufficient quantity to form limestones.

The limestones of the Torquay and Newton Bushell district are marked by the presence of organic remains which closely approach, if they be not varieties of, certain fossils detected in the limestone to which the name carboniferous has been of late so exclusively given. Similar fossils, though in less numbers, are found in the limestone of Plymouth. Organic remains of the like character have not as yet been discovered in the continuation of the same line of rocks in Cornwall, and very rarely in the range of rocks intermediate between the Plymouth limestones and those of Newton Bushell and Torquay. Now, assuming it to be true, as we consider it to be, that the band of rocks we have endeavoured to trace from the Newton Bushell and Torbay district to the Lizard district is one geologically continuous and contemporaneous, we have what was once mud, silt, sand, and calcareous matter variously intermingled with each other, carbonate of lime

somewhat predominating on the east, sparingly occurring afterwards to the westward, though somewhat more abundant near Yealmpton and Plymouth, and finally constituting a very subordinate part of the series in its range on the south of Cornwall.

Now, if we couple conditions favourable to the existence of molluscous and conchiferous creatures and corals with the production of limestones, as seems justifiable from geological facts, the district of Newton Bushell, Totnes, and Torbay, and that of Yealmpton and Plymouth, would appear to have been more favourable for the existence of such animal life than those parts of the range of the general series in which limestones are either sparingly developed or altogether absent. When we come to examine the localities where the limestones are more prevalent, we are forcibly struck with the abundance of corals found and the large proportion they bear to the masses of limestones, more particularly apparent in those places where the limestones are employed for marbles. To those who have seen coral reefs, and remarked the manner in which the organic structure of the original architects of such masses is sometimes obliterated and at others preserved, and the mode in which the shells of molluscs and conchifers are intermingled and bound up with the calcareous whole, the limestones of the eastern part of this range of deposits offer very striking analogies. We have often merely to suppose an absence of cleavage and joints, and a change of colour from grey to white, to have something very like a raised coral reef before us. The bedding is the chief difference: one, however, not altogether absent in coral reefs; for we have observed traces of it in the raised coral reef which skirts a large portion of Jamaica.

Mr. S. Stutchbury, in his excellent paper on the Formation and Growth of Coral Reefs and Islands,* in accounting for the production of the compact parts of a coral reef, "as dense as any limestone rock," suggests that, when the coral animals die, the animal matter decomposes, and that the carbonate of lime forming the solid part of the coral is taken up and held in solution, becoming again precipitated upon shells, corals, fish, &c.; so that eventually the mass "closely resembles the limestones in which the fossil remains of corals, shells, &c. are so often found; cemented," as Mr. Stutchbury believes, "by a paste composed of the

* The West of England Journal of Science and Literature, p. 45, &c.

lime derived from their congeners."* To take up the carbonate of lime of the corals, water charged with carbonic acid, derived from the decomposition of the animal matter of the corals, would, we should suppose, be not unfrequently present among the numerous interstices of a coral reef, other dead creatures adding to the free carbonic acid in situations where the latter could not escape upwards to the surface. To deposit the carbonate of lime thus supposed to be held in solution, it would be merely requisite that the water containing it should be placed under circumstances where the free carbonic acid would escape—circumstances not difficult to conceive in the tidal seas of a hot climate.

Mr. Stutchbury remarks that among coral islands "it is not uncommon to see extensive beds or strata of particular species of shells deposited along the shores in the most regular order, with comparatively little or no admixture of other substances;" and he states that at Bow Island, in the Pacific, he has observed "beds of *Cardium fragum*, from six to eight feet thick, and more than two miles in extent, without even the broken portion of any other shells being deposited in the same stratum."† When we take these and all the other facts connected with coral reefs and islands into consideration, we find so many points of analogy between them and the kind of limestones under consideration, that we are led to conclude they must have had a somewhat common origin. And it should be recollected that the limestones of South Devon, if we suppose a large proportion of them to have been coral reefs, would collectively form a group exceedingly insignificant when compared with the coral reefs and islands which occur in so many parts of the world at the present day. Mr. Austen has been so struck with the resemblance of the Dartington band of limestone to a coral reef, that he considers it to have been a coral reef encircling a bank, thus accounting for its otherwise singular shape.‡

The sudden manner in which some of these limestones terminate, and the apparent prolongation of the line of strike by means of slates, remind us of a coral reef against which mud has been drifted or quietly accumulated. We can readily imagine that for a time conditions were favourable to these coral reefs, and that subsequently the increase of mud around them gradually retarded their progress, and that finally they became

* West of England Journal, p. 50. † Ib., p. 47. ‡ Austen, MS.

so overwhelmed by it or drifted sand as to be included in a body of transported detritus. Creatures may readily have flourished amid the coral reefs which were unable to do so, from their habits, when the whole area became covered by mud or fine sand; and we should expect that this would be more especially the case with those kinds which delighted in rocky places.

Hence, if we found shells in argillaceous slates in the line of strike with these limestones not observed in the latter, or species among the limestones not discovered in the slates, we should merely detect the remains of creatures which had different habits in their respective habitats, it being assumed that the remains have not been drifted from other localities. When we cease to find certain shells, supposed to be analogous to some characteristic of the carboniferous or mountain limestone, in the slates on the line of general strike of the Newton Bushell and Torquay limestones, or in that of the Plymouth limestones, we seem to see that the creatures of which these shells are the remains could live consistently with their habits amid the corals and calcareous masses in the one locality, while the mud and sand of the other places, then forming the floor of the waters in which they existed, were not suited to them. Among the slates of Whitesand Bay, near Plymouth, we appear not to find the marked shells and corals of the limestones at the latter place, merely because conditions were not suited to their existence. When more attention becomes paid to the physical conditions under which different parts of those masses which we suppose to have been geologically contemporaneous, and group for convenience under some given name, have been placed, and organic remains be studied in connexion with such varied conditions, general views may perhaps be obtained of the kind of seas and shores in and on which large detrital masses have been accumulated.

If we suppose the band of rocks under consideration to be above the great carbonaceous system of Devon, and that this rests in its turn upon the Barnstaple grauwacke, the calciferous band extending from Torbay, &c. into South Cornwall would be a higher part of the grauwacke series, and might be even equivalent to the beds known as the old red sandstone;* for we are

* We see no advantage in separating the beds termed old red sandstone from the grauwacke group except for local purposes, as we employ the term green-sand. In the district under consideration we have examples of great accumulations of

not to suppose that over even the western European area the sandstones so named are always red, or that equivalents of them may not be argillaceous slates and large masses of compact limestones. Dismissing, however, any supposed evidence of the carbonaceous rocks (that is, the great North Devon mass, and not the patches of Ugbrooke Park, Kingsteignton, and Ogwell, which clearly rest upon them) dipping beneath the calciferous country of Newton Bushell, &c., and considering such carbonaceous rocks, for the sake of illustration, as altogether more modern than any grauwacke rocks or old red sandstone, those who rely very exclusively on the character of organic remains would probably feel disposed to consider the Torbay and Plymouth beds as equivalent to some such rock as the old red sandstone.

We do not pretend to enter into the question of what a species may be, or how far local causes may produce modifications in the calcareous parts of shells or corals, parts from which fossil species are necessarily determined, but the near approach of many shells, and we understand that Mr. Austen has obtained far more than we have enumerated (p. 76), to species detected in the carboniferous limestone, is certainly a remarkable fact. It may be asked, if the carbonaceous deposits, or at least those which are found between Ogwell and King's Kerswell, &c., be equivalent to true coal-measures, why true carboniferous limestone may not be found in the district also. It must be confessed that if such did occur it would be no easy matter to separate it from the other limestones, so covered up are parts of the country by (new) red sandstone and conglomerate, and so broken and disturbed has it been. However this view might apply to the Torbay district, the Plymouth limestones are certainly not so situated, so that, if the latter contain shells analogous to those found in true carboniferous limestone, as it has been supposed they do, the case, as regards the occurrence of these fossils in a rock which can

red sandstones much older than the old red sandstone. It would seem desirable that this name and that of new red sandstone should be removed from geological nomenclature. When they were first employed there were supposed to be only two great masses of red sandstone, to one of which the term new was applied and to the other that of old. Now that we are becoming acquainted with larger portions of the earth's surface, and are aware that there are many red sandstones newer than the new red sandstone, and many older than the old red sandstone, it seems time to change them for others. Mr. Conybeare has suggested the name *Poicilitic* for the new red sandstone group.

scarcely be regarded as carboniferous limestone, unless, indeed, the argillaceous slates and sandstones above them be considered as non-carbonaceous equivalents of the coal-measures, remains the same.

Now when we turn our attention to the area upon which the belief has been founded that we cannot expect to detect animal forms in the grauwacke, even in the higher part of that group, analogous to forms in the true carboniferous or mountain limestone, we find it of comparatively small extent; and we are led to inquire if too much stress has not been laid upon the evidence afforded by this somewhat limited area, let that evidence be as clear as can be desired. When we see that constant and beautiful adaptation of animal and vegetable life to physical conditions everywhere exhibited around us, we infer a change of physical conditions when a change of such life takes place over a given area.

If we imagine a cooling globe, its earlier habitable conditions, judging, at least, from the kind of life now known to us, would be favourable to considerable uniformity of marine creatures, reference being made to equal depth of water, and consequent proportion of light, temperature, and pressure, and to the kinds of bottom inhabited, whether rocky, sandy, or muddy. There would be, however, important modifications of equal general conditions as to temperature; and when to these we add the different conditions under which animals requiring light would be placed at the poles and the equator, the necessity of dry land to afford the terrestrial vegetation then entombed, and the consequent probability of coasts unequally exposed to the action of tides and winds, the chances of estuaries, and of salt and fresh water lakes, we have the elements of very important physical differences, and could scarcely expect, though animal and vegetable life may have had a common general character, that it would not be composed of parts modified to suit these various conditions. One condition may have prevailed in one area, another in one adjoining it, so that a mass of coral reefs and islands in one locality might be tenanted by creatures the larger part of which did not exist in a great tract of sandy and muddy bottom adjoining it. Physical changes may subsequently have caused the coral district to be overwhelmed by deposits of mud and sand, while the sandy and muddy

bottom became in a condition to be covered by corals. The creatures entombed in the two adjoining districts might therefore be so in a different order within a given geological epoch, the remains of the coral-frequenting animals being lowest in the one and highest in the other, and so also with the mud and sand-loving creatures. Admitting a general change of animal life from the earliest periods when the earth was habitable to the present time, such changes as these during those minor periods, which we term, for convenience, geological epochs, must be expected.*

Having previously noticed the run of some of the minor divisions of the grauwacke of South Devon and Cornwall, we shall merely here remark on the difficulty of identifying this mass with the grauwacke of North Devon. The chief difference between them is the intermixture of trappean rocks, a large proportion of which appears contemporaneous, employing the term in an extended geological sense, in the former, while they are absent in the latter. Here and there in South Devon and Cornwall minor areas may be without these trappean rocks, as, for example, between Polperro, Fowey, and St. Neots, and between St. Columb Major and Padstow; but, as a whole, the slates and sandstones are intermingled with the trappean rocks in a way to show that there must have been considerable igneous action, during which

* We can readily understand that a gradual change in the saline or other contents of the sea, from the earliest habitable periods of our planet to the present times, would be productive of a series of conditions gradually destructive of the animals originally created to accord with the earlier habitable state of the earth, and that, in conformity with the design everywhere manifested, new animals would be created to accord with the new conditions as they gradually appeared. If we suppose some great change in this respect, and couple it with a cooling globe, we have two important causes for a gradual change in marine animal life. If we adopt the theory of a cooling globe, and a gradual change from a general and equal external temperature to the present state of the earth's surface under the influence of the sun, there must have been a time when the whole surface was under the present temperature of the tropics. Now this temperature would last to the present day in the tropics, while the surface of the globe would gradually become colder towards the poles, until it arrived at the state we now find it. If no change in the saline contents of the sea took place in the latter period, there seems no physical reason, all other things being equal, why the marine creatures in the tropics should not have continued the same during this lapse of time, while those in the colder regions became gradually extinct, to be replaced by new creations. Hence rocks formed in the tropics may, during all this time, have entombed the remains of similar animals, while the deposits in the colder regions would have enveloped the exuviæ of creatures exhibiting a gradual change, and be different from those entombed in the tropics.

ashes, and vesicular lavas, showing little pressure, were ejected, contemporaneously with the deposit of slates and sandstones, along a line extending from the east of Dartmoor nearly to the Land's End. Even supposing that the grauwacke of North and South Devon may have been contemporaneously produced in part, if not as a whole, these igneous conditions on the south are sufficient to account for great differences in general physical structure. No trace is found in the north of such coarse conglomerates as those of Menaccan and the Nare Point near St. Anthony, of the Nare Head near Veryan, or of those of Carhayes Cove. These conglomerates mark a power to grind the large masses into rounded boulders and minor pebbles, of which we find no trace on the north. Being associated with trappean matter, and even hard igneous rocks, we can imagine great local disturbance from igneous action, throwing bodies of water into local agitation sufficient to produce these conglomerates, a mass of ash being showered among the agitated waters during the explosions, thus forming the trappean portion of the cementing matter. The conglomerates have not much the character of old beaches piled upon the coasts of those ancient seas in which the mud, silt, and sand associated with them were drifted.

It would be premature, before the organic remains found in the grauwacke of the district shall have been examined with that attention they will probably soon receive, to generalize on this subject; but it may be remarked that, while marine remains analogous to those in the carboniferous or mountain limestone have not been detected in any bed beneath the carbonaceous series in North Devon, we find a *Melania* and *Natica*, analogous to *M. sulculosa* and *N. ampliata* (Phillips), *Spiriferæ*, analogous to *Sp. attenuata* (Sow.), and *Sp. oblata*, and a *Producta*, analogous to *P. rarispina* (Phillips), shells usually detected in the true carboniferous limestone, in the Petherwin beds, which are continued into Cornwall, appearing at Padstow, Lower St. Columb Porth, and New Quay. The shells resembling those in the true carboniferous limestone are more numerous in the Newton Bushell and Torquay district, and in the Plymouth limestones. This may be merely due to the greater development of the limestones in those localities, or, in other words, the conditions for the existence of particular creatures have been more favourable in those localities. When we leave the Petherwin limestones, and follow the run of

rocks of which they form a part westward, we in like manner seem to quit the conditions which have been favourable to the existence of the *Clymeniæ, Goniatites, Melaniæ, Naticæ, Spiriferæ, Productæ*, &c.: a few crinoidal stems, and a coral, which appears not to have been attached by a calcareous foot to the rocks of its habitat, being the chief organic remains which have yet been detected in that direction.

Judging, therefore, from the localities where conditions for the existence for numerous creatures, supposed marine, were most favourable in North Devon and West Somerset, and in South Devon and Cornwall, there is little organic correspondence between the deposits on the north and south of the great carbonaceous series. If these rocks be considered of the same relative geological age, the conditions for the existence of animal life have been very different in these two portions of the district at the same time, while, if there has been a general change in the kind of animal life which has existed in the north and south portions of the area during the deposit of these sedimentary rocks in it, we should consider the southern rocks to have been last formed, inasmuch as the animal life entombed in them more resembles, as a whole, that which we find in the carboniferous limestone of a large portion of England and Ireland.

The great carbonaceous series certainly seems to rest upon beds containing a few of these kinds of fossils near South Petherwin, while it has more the appearance of dipping beneath rocks containing them far more abundantly in the Ogwell, Torbay, and Ashburton districts. If we even imagine, for the sake of illustration, that the latter appearance is fallacious, and that the carbonaceous beds all belong to one epoch, so as to include the carbonaceous deposits between Ogwell and King's Kerswell, at Ugbrooke Park, &c., in one great series, still the general resemblance of so many shells, supposing even that they are not varieties of species detected in the true carboniferous limestone, but distinct, though closely-approximating species, the presence of these forms where limestones are abundant in the southern rocks, their disappearance, or at least rarity, where calcareous matter becomes comparatively scarce in the same subordinate groups, the occurrence of at least some of these forms in the southern rocks when calcareous matter is somewhat abundant adjoining, if they be not connected with, the carbonaceous deposits,

the presence of anthracite in some of these limestones, and the absence, or at least scarcity of these forms, where the carbonaceous series seems to graduate into the northern rocks, are all points of great interest when we study the probable physical conditions under which animal life may have existed at a given geological epoch. Even if we consider the mass of the carbonaceous rocks to be of intermediate deposit between the undisputed grauwacke of North Devon and a portion of the South Devon beds, the resemblance of organic forms detected under certain conditions in the latter to those of shells found in the true carboniferous limestone in other parts of England, the disappearance, or, at least, great scarcity, not only of these forms, but of organic remains at all, in the prolongation of the subordinate groups of the southern rocks of Devon to the westward, and the occurrence of some of these forms in beds which certainly support the carbonaceous series near South Petherwin, are all points of considerable interest connected with the distribution of animal life according to physical conditions.

CHAPTER VI.

GRANITE AND ELVAN.

A GLANCE at the index map (plate 1.) will show six principal masses of granite, including that of the Scilly Islands, occurring in the district, while smaller patches of the same rocks are found in several localities, as at St. Michael's Mount, Tregonning and Godolphin Hills, Carn Brea and Carn Marth (near Redruth), Cligga Point (near St. Agnes), Castle an Dinas and Belovely Beacon (near St. Columb Major and Roche), Kit Hill and Hingston Down (near Callington), and at Lundy Island in the Bristol Channel. A substance so remarkable and so easily distinguished as granite, was not likely to escape the earliest geological researches in Cornwall and Devon, and accordingly, in the oldest works which in any way relate to the physical structure of the country, we find notices of this rock. The isolated character of the principal masses is pointed out in Mr. William Smith's Geological Map of England and Wales (1815), and in more detail in Mr. Grenough's Geological Map of England and Wales (1819). A very good map of the area occupied by the Land's End granite, with an account of the general mineralogical structure of that mass, was published by Dr. Forbes in 1822,* and the granite portions of Cornwall were pointed out by Dr. Boase in 1832,† in the map which accompanied his Contributions towards a Knowledge of the Geology of Cornwall. Mr. Carne gave a detailed description of the Land's End granite in 1827, and Dr. Boase published detailed accounts and general views of the Cornish granites in 1832‡ and 1836.§

Taken as a whole, the range of the principal masses of granite, including Dartmoor and the Scilly Islands, is about east 24°

* Trans. Geol. Soc. of Cornwall, vol. ii. p. 248, pl. 6. The paper was read in 1819.

† *Ibid.* vol. iv. pl. 2. ‡ *Ibid.* vol. iv. § Primary Geology, p. 15—23.

north, and west 24° south, and the composition of the rock, though subject to minor variations, very generally the same, being commonly a mixture of quartz, mica, and felspar, the latter not unfrequently prevalent, and often occurring in crystals, usually large, in the more common aggregate of the three minerals, thus rendering the granite porphyritic. Schorl is also so frequently found in it that it may, as has been remarked by Dr. Boase, be considered to characterise a large portion of it. This character is, however, chiefly exhibited at the confines of the various masses.

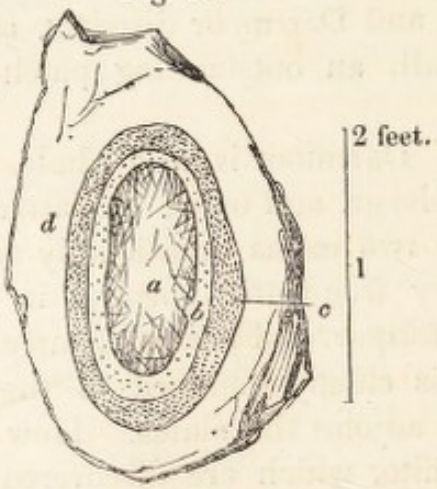
The smaller exposed bodies of granite, if we except those of Cligga Point and Lundy Island, may be regarded as mere outstanding patches of the nearest principal masses, or as forming connecting links between them. Thus, the granite patches of St. Michael's Mount, and Tregonning and Godolphin Hills, may be considered as connecting links between the granite bosses of the Land's End and Carn Menelez districts, while the granites of Carn Brea and Carn Marth seem outstanding portions of the latter district, a comparatively slender covering of slate converting them into insular patches. In like manner the granites of Kit Hill and Hingston Down appear to form connecting links between the Brown Willy and Dartmoor districts, and the granitic island of Hemerdon Ball, an outstanding patch on the south of the latter.

The granite of Dartmoor is, as a whole, a coarse-grained mixture of quartz, felspar, and mica, the latter sometimes white, at others black, the two micas occasionally occurring in the same mass. It is very frequently porphyritic from the presence of large crystals of felspar, and here and there schorlaceous, but the latter character is chiefly confined to the outskirts where the Dartmoor granite adjoins the slates. How far those portions of schorlaceous granite, which are discovered more in the interior, may also have formed the outside of the protruded mass, it would be difficult to say, as we can form no opinion as to the amount of superincumbent matter which may have been removed by denuding causes since the granite was first erupted. The schorl not unfrequently occurs in radiating nests of variable size and abundance. A complete passage may generally be traced between the compound of schorl and quartz, usually termed schorl rock, and the ordinary granite. The mica usually disappears as the schorl begins to be abundant, but sometimes, though not very commonly

beyond limited areas, the granite rock is a mixture of mica, schorl, felspar, and quartz, in nearly equal proportions. After the absence of mica, the next mineral which commonly disappears is the felspar, leaving the compound a mixture of schorl and quartz, the former sometimes occurring in radiating nests in the latter, but more commonly the two minerals form an aggregate in nearly equal proportions.

Good examples of nests of schorl radiating among quartz may be seen in the blocks of schorl rock above Bowdley, near Ashburton. Schorl rocks are found at Holne Lee and at various other places on the eastern side of the moor. The granite on the west of Buckfastleigh frequently contains small nests of schorl, which often increase in abundance until finally this mineral with quartz constitutes schorl rock towards the adjoining slates. Schorl rock containing large crystals of felspar occurs under Ugborough Beacon. Schorlaceous granite and schorl rock may also be often seen on the south of Dartmoor. We observed the following not very common mode of the occurrence of schorl among the granite in a block (fig. 15) near Blatchford, Cornwood, brought down from

Fig. 15.



schorlaceous granite in the adjoining moor: *a* is a cavity not quite filled by numerous long crystals of schorl crossing in many oblique directions, with a general tendency towards the interior; *b* is a zone of schorl and quartz, the latter predominating; *c* black compact schorl rock, and *d* light flesh-coloured granite, the felspar predominating. Some very interesting mixtures of schorl, felspar, and quartz, may also be observed on the western side of Dartmoor, more particularly near Tavistock. Even the compounds of quartz, felspar, and mica would seem more variable

towards the outskirts of the mass than in the interior, and schorlaceous veins and veins of finer granite appear more frequent under such circumstances.

The granite of the Brown Willy district is very similar to that of Dartmoor, its principal mass being a mixture of quartz, felspar, and the two micas above noticed, and being frequently porphyritic from the occurrence of large crystals of felspar disseminated through this aggregate. As a whole, it is not particularly schorlaceous, though here and there schorl may be discovered in small crystals in the mass. It appears chiefly so towards the south. Near St. Cleer, as has been noticed by Dr. Boase, there are some interesting schorlaceous rocks composed of quartz, schorl, mica, and felspar.*

The granitic district of Hensborough or St. Austell is far more variable, and considerably more schorlaceous than those of Brown Willy and Dartmoor. On the eastern part of this mass we find granite differing little from that forming the chief part of those districts, the mineral composition being nearly the same, and the porphyritic character frequent; but on the west the mica becomes scarce and often absent, replaced by a steatitic or talcose mineral, and schorl. Dr. Boase, who has given a very excellent account of this granite, considers that schorl is "not entirely wanting in any part of the mass, though in some of the hard crystalline varieties it is in very minute quantities," and notices the occasional substitution of this mineral for mica, and that it appears to become gradually more abundant towards the confines of the granite.†

Schorlaceous veins are abundant in the St. Austell granite, more particularly among the western and central portions, which are also remarkable for their liability to decomposition—a decomposition extending to very variable depths in different localties, but often so considerable as to embarrass mining operations, from the difficulty of keeping up the sides of the shafts and galleries. The great proportion of the western part of the district, studded with china-clay works, is composed of this kind of granite. In many places the felspar of this variety is only partially decomposed, and the rock is employed for economic purposes when schorl is absent from the mixture of quartz, steatite, or talc, and

* Trans. Geol. Soc. of Cornwall, vol. iv. p. 209.

† *Ibid.* vol. iv. p. 240.

of partly-decomposed felspar, of which it is otherwise formed; but it is carefully rejected, as Dr. Boase has observed, when that mineral is present.

This decomposed and semi-decomposed granite is extremely schorlaceous on its confines, adjoining the slates, from St. Mewan's Beacon, by Step-aside, Calliquoiter Rock, and St. Dennis, to Roche, certain elongated stripes proceeding from the mass into the slates, being composed of complete schorl rock, mixtures of schorl and quartz; as at the stripes extending from Watch Hill to Long Lane, the two on the north and south of Burthy Row, near St. Enoder, and the long-celebrated Roche Rock, at Roche; all of which have a common general character. In places, as near Meladore, the schorl rock (schorl and quartz) contains large crystals of felspar, some of which have been decomposed, and the cavity partly filled by schorl. At Calliquoiter Rock there are variable mixtures of schorl, with quartz, felspar, and mica, the compound nearest the slate country being an aggregate of schorl and quartz. The granite of St. Dennis Hill is a compound of quartz, schorl, felspar, and mica, and a variety is found composed of a large proportion of the latter mineral. A remarkable and often thick vein of dark mica traverses the granite of St. Dennis Down.

The Carn Menelez granite more approaches the general character of that of Brown Willy and Dartmoor, as has been noticed by Dr. Boase.* Schorl is far from abundant in it, though it sometimes occurs, especially on the confines of the mass, and then very commonly in veins. This granite is occasionally porphyritic, from the presence of separate felspar crystals. In the neighbourhood of Mabe and Constantine it is of a very beautiful grain, in consequence of which large quantities of it are exported.

The granite of the Land's End district contains much schorl, the common compound of quartz, felspar, and mica, often porphyritic, being, however, sufficiently abundant. On the eastern side of Trecobben Hill, and at Laity, near Lelant, there are some good examples of schorlaceous granite and schorl rock, as also on the skirts of the mass on the westward of Penzance. Schorl rock is likewise well exposed in Penledeen Cove, near Cape Cornwall. A very beautiful variety of schorl rock, composed of a base of schorl and quartz, containing large crystals of felspar, is seen on the skirts

* Trans. Geol. Society, Cornwall, vol. iv. p. 290.

of the granitic mass close to Trevalgan, near St. Ives. In some parts of it the felspar crystals have been removed by decomposition, and the cavities filled by crystals of schorl, crossing each other in various directions. In such cases the schorl rock base adjoining these refilled, or nearly refilled, cavities contains less schorl than around the crystals of felspar which have not been decomposed. A granite composed of felspar, quartz, schorl, and an abundance of mica, occurs at Tregender, near Ludgvan. Radiated nests of schorl in the granite are common in many places where that mineral is abundant, the largest which we have seen being in the vicinity of Wicca Cove, near Zennor. Numerous schorlaceous veins are found in this granite, and are generally well exhibited on the coasts; some, several inches in thickness, are composed of little else than crystals of schorl, radiating from different centres, and crossing or pressing against each other: of this kind some good examples are seen at Trevalgan, near St. Ives, and at Rosemergy, near Morvah. Schorl may be observed between and approaching the joints of the granite in many places, a fact well exhibited between Castle Trereen (long known for its Logan stone) and Pedn-mean-anmear. Much pinite is mingled with the granite near the Land's End.

The granite of the Scilly Islands is usually a somewhat coarse compound of quartz, felspar, and mica, both dark-coloured and silvery, and a finer-grained granite is not unfrequently detected in it in the form of veins. Schorl appears rare: a rock, however, formed of quartz, felspar, mica, and schorl, occurs above St. Martin's Bay, in St. Martin's.

Regarding the smaller patches, the granite of Hingston Down and Kit Hill is much like that of the two masses between which it is situated. Schorlaceous veins occur on Kit Hill. The granite of Belovely Beacon, between Roche and St. Wenn, partakes of the character of the Hensborough mass on its southern side, graduating into schorl rock on the north. Northward from this hill, and extending from Small Money, on the west, to the brook above the place marked Mill on the Ordnance map, there is an elongated patch of schorl rock, composed of a base of nearly equal parts of schorl and quartz, with larger detached portions of the latter, a variety which may occasionally be seen among the schorl rocks of Cornwall and Devon. The small portion of granite exposed upon the adjoining hill of Castle-an-Dinas is not generally large

grained. From the fragments scattered about, schorlaceous rocks are probably concealed beneath the turf on this hill.

The granite of Cligga Point, which has been found by mining operations to abut against the slate on the east in the manner of a dyke, is chiefly composed of quartz, light-coloured felspar, and black mica, with disseminated crystals of roseate and white felspar. Though much of this granite is sufficiently hard to be worked for economic purposes, many portions are considerably decomposed and worn away by the action of the sea.

On the west side of St. Agnes Beacon there is a patch of granitic rock, which we have not observed elsewhere in the district. In the northern part of it we find a mottled base of quartz and felspar, containing large crystals of flesh-coloured felspar and semi-crystallized quartz, a compound that becomes, on the south, a fine-grained mixture of mica, quartz, and felspar, with numerous semi-formed crystals of quartz, which give a very quartzose character to the body of the rock: the whole has been much traversed by small veins and strings of the black oxide of tin, which have been worked out. The granite of the outstanding patches of Carn Marth and Carn Brea, near Redruth, resembles that of the adjoining mass of Carn Menelez. A compound of schorl, quartz, and a little felspar is found on the skirt of the Carn Marth granite, near St. Day.

The granite extending from Trewarvas Head to Godolphin Hill is of a somewhat variable character. On the coast, more particularly where the granite adjoins the slate, a general compound of quartz, felspar, and a talcose mineral, with occasional specks of mica, is often marked by lines of felspar crystals, these lines varying from one to several inches in thickness. At Tregonning Hill we find a mixture resembling the China-stone of St. Stephen's, some of it being sufficiently decomposed to be worked for China-clay. The granite of Godolphin Hill forms another variety, part of it differing somewhat from the common Cornish granite, as Dr. Boase observes*, in having a base of felspar, in which white crystals of felspar, nodules of clear quartz, and black mica, are thickly embedded: schorlaceous veins are common in it.

The granite of St. Michael's Mount is generally fine grained, and a compound of felspar and quartz, with a somewhat small proportion of mica.

* Trans. Geol. Society of Cornwall, vol. iv. p. 349.

A very general structure prevails throughout these granites, and is more particularly observable in the larger masses. This structure consists in a division of the granite into portions resembling beds, which form tabular sheets of matter in the central parts of the masses, when they are extensive, the edges bending beneath the adjoining schistose rocks, and conforming to the surface of the junction between them. The whole, therefore, has the general character of a stratified mass, one which we have endeavoured to represent in the sections, where they pass through granite (pl. 2, figs. 1, 2, 3, 4, 5, 6, and 7; and pl. 4, figs. 5 and 6). As we have had occasion some time since to observe, this tendency to be divided or cleave in a stratiform manner is highly deceptive, and has probably given rise to the opinion, so frequently expressed at one time, that granite was stratified*. Though often continuous for long distances, this stratiform cleavage is in some places extremely imperfect, as represented in the annexed sketch, fig. 16; a common appearance in several of the frontier

Fig. 16.

tors of Dartmoor. There are few ravines or coast sections of the granite at its junction with the slate, through which it has been protruded, in which this tendency to divide into stratiform bodies is not observable. Dr. Boase has noticed this structure in the Cornish granites; and has observed that, wherever the granite "is exposed by quarries on the sides of hills, near the junction with slate (as at Kit Hill, and in the parishes of Mabe and Constantine), the surface of the rock has not only a rounded form, but is also traversed superficially by curved fissures or joints†."

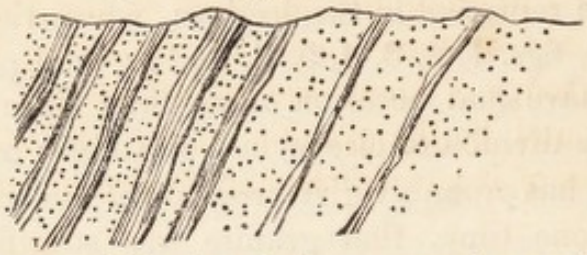
This variety of cleavage may be regarded as a kind of thick laminated structure pervading the masses on the large scale, probably agreeing in form with that of their original surfaces after protrusion. In the entrance to a quarry of very hard granite,

* Researches in Theoretical Geology (1834), p. 103.

† Treatise on Primary Geology (1834), p. 96.

worked in Hingston Down, near some cottages on the road from Gunislake to Callington, alternations of a decomposed and hard granite are observed, constituting stratiform bodies, which seem to coincide with the dip of the granite beneath the adjoining slate. This difference of original structure may be due to a tendency of the whole to arrange itself in false beds coinciding with the surface of the erupted mass. At Cligga Point, however, we observe

Fig. 17.



similar alternations of hard and decomposed granite, represented above (fig. 17), which seem to run at right angles to the bearing of the patch of granite which there occurs, as far, at least, as can be determined from the natural sections presented. The alternations of schorl rock and granite, forming stratiform bodies of marked dark and light-coloured rocks, observable in a cutting on the south of Carglaze tin-mine, near St. Austell, seem an arrangement of parts according to different affinities in force during the cooling of the whole mass after protrusion.

It is the intersection of the more or less perpendicular joints or divisional planes, to be noticed hereafter, with this stratiform structure in the Cornish and Devon granite which gives it the appearance of being composed of a multitude of rectangular blocks, block being piled upon block, so that in good exposures, as on the sea-coast of the Land's End district, the cliffs seem almost artificial. The massive quadrangular columns thus formed on this coast are very striking; and many of the best localities for observing them have been noticed by Mr. Carne, who particularly points out the small promontory of Chair Ledder as a good example of the prismatic and cubical forms united*. The granite at Pardenick Point, and some other places near the Land's End, bears a great resemblance in form to a collection of huge basaltic columns.

As the principal granitic bosses range in the direction above

* On the granite of the western part of Cornwall. Trans. Geol. Society of Cornwall, vol. iii p. 209.

noticed from the Scilly Islands to Dartmoor, we are led to infer either that the force which threw them up acted with greater intensity on that line, more especially upon points in it, or that the resistance of the crust of previously-existing rocks was less in that direction than in other parts of a wider area, supposing the whole exposed to a common force acting upwards at the same time. That the various slates, sandstones, calcareous and trappean rocks, which at present bound these granite bosses and smaller patches, existed prior to the intrusion of the granite is shown by the displacement of these rocks by the latter, by the mode in which minor groups of them are sometimes cut off by it on the line of strike, and by the granitic matter which has been driven from the bodies of it into cracks and fissures formed in these adjoining rocks.

From their general mode of occurrence few geologists would probably think of separating the chief granitic masses from each other as regards geological age. Now the intrusion of the Dartmoor mass was certainly after the deposit of the carbonaceous series of North Devon, be the age of that series what it may: it thrusts the southern portion of this series northwards to Okehampton, cuts off the ends of trappean bands and of associated beds of grit and shale near Cristow and Bridford, and sends veins into it in the valley of the Dart, at the junction of the two masses of rock. In the valley of the Erme, near Ivy Bridge, the granite of Dartmoor sends veins into the calciferous and fossiliferous band of country which ranges from Ashburton and Newton Bushell to Plymouth and the Tamar, apparently, also, displacing and cutting off some of the beds.

The Brown Willy granite shoves the calcareo-trappean and fossiliferous country of South Petherwin and Padstow to the northward at Tintagel, veins proceeding from the mass of granite, across some subjacent beds, almost up to this system at Blisland and near St. Mabyn. The Hensborough or St. Austell granite has partly been thrust up through beds above the fossiliferous rocks of Fowey and Looe, which are somewhat lower in the series than the Plymouth limestones, and partly through rocks continued from beds associated with the fossiliferous country of St. Columb Minor and New Quay, sending veins into the latter near Roche*. The

* Beautiful veins of granite in slate were found in the workings of Roche Rock mine.

Carn Menelez granite has been protruded through beds, some of which appear to be higher in the general series than the fossiliferous rocks of New Quay and Lower St. Columb Porth, and veins proceed from it near Constantine* into beds associated with the run of rocks which traverse Falmouth Harbour, and undoubtedly belong to part of the great grauwacke series ranging to the eastward. Fine examples of granite veins cut through beds, on the east of Trewarvas Head, of about the same age as those traversed by similar veins near Constantine; and the granite of the Land's End has been thrust up through the grauwacke beds which range down from Penhallow Downs, Redruth, and Camborne, sending numerous veins into them in various localities, which are chiefly observable where its junction with the slate is well exposed on the sea-cliffs. The rocks traversed by granite veins at St. Michael's Mount seem part of the same subordinate series.

As a whole, the chief granitic masses of Cornwall and Devon may be considered to have been protruded after, at least, the deposit of the upper part of the grauwacke series. Indeed, the evidence of the Dartmoor granite having occupied its present relative position anterior to the early part of the (new) red sandstone is not always so clear as could be desired; for, among all the pebbles of the red conglomerate extending from Torbay to Exeter, we have not been able to detect any portions of it, though the granite ranges so near that part of the red conglomerate. In the tongue of red sandstone and conglomerate which runs from Crediton amid the carbonaceous series by North Tawton and Sampford Courtney to Jacobstow, we have, however, detected pebbles like some varieties of Dartmoor granite. Moreover, if we are to refer the present bent and contorted conditions of the carbonaceous and other slate rocks around Dartmoor to the intrusion of its granite, and we find, as we do, the red sandstone series resting quietly upon the basset edges of these upturned beds, and on their contortions, it would appear fair to infer that the Dartmoor granite was formed anterior to the new red sandstone series. Those who consider the great carbonaceous series of Devon as equivalent to the coal-measures, will of course refer the intrusion of the Dartmoor granite to an epoch posterior to the

* These veins, which occur near the mill at Polwheverill, and are extremely interesting, were pointed out to us by the Rev. Canon Rogers.

deposit of that rock, and even this view may be maintained by those who only consider the Ugbrooke beds equivalent, or nearly so, to the coal-measures, overlapping the older carbonaceous rocks near Chudleigh Bridge, for these beds are tilted up as if lifted by the granitic mass near them on the west.

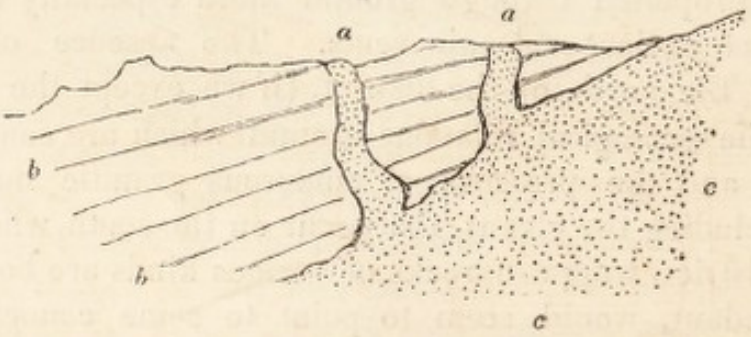
As a whole also, the granitic masses have pierced through a district which had previously been exposed to igneous action, as shown by those trappean rocks of various kinds which we have considered to be geologically contemporaneous with the sandstones and slates among which they occur, and by those other trappean rocks that cut through these sedimentary beds, and of which the age is not so determinable, though they must have been erupted prior to the granite, inasmuch as the latter often cuts off their continuity, and is never traversed by them. We are therefore led to infer that this mixed igneous and sedimentary range may have offered a line of least resistance to a body of granite impelled upwards by some great force acting on the area under consideration, and to suspect that the granite of the great bosses has been propelled through ground more especially weakened, perhaps as ancient volcanic vents. The absence of granitic masses in the north of the district, (if we except the granite of Lundy, the geological relations around which are concealed by the sea,) and the presence of numerous granitic masses and dykes, including the elvans, that occur on the south, where, alone, in this district, trappean rocks of various kinds are both present and abundant, would seem to point to some connexion, with regard to facilities of eruption, between these products, however different they may mineralogically be, which can scarcely be disregarded.

We can readily suppose volcanic vents, existing in a general line from the Haldon Hills to the western part of Cornwall, to have vomited forth the various hornblendic and igneous products we now find intermingled with the consolidated mud, silt, sand, and gravel of that period, the line or lines being due to dislocations and their ramifications among the solid crust of the globe on which these igneous products, and their associated detrital deposits, were accumulated. We can also readily consider the causes for this minor igneous action to have ceased, and the weakened crust to be rent by one of those great adjustments of

the solidified surface of the earth to subjacent hot fluid rock, which it has been supposed would result from the radiation of the earth's original heat into the surrounding planetary space. We can imagine that the fluid granite would thus be squeezed through the weakened crust, more especially taking its course through the parts of still less resistance, displacing the accumulated, and probably consolidated mud, silt, sand, and trappean ash and lava, which had covered over the general surface.

From the minute strings in which the granite veins proceeding from the granites of this district often terminate, we may be led to infer very considerable fluidity on the part of the erupted masses in, at least, many portions of their confines. These veins are frequently very tortuous, cutting through the adjoining slate in various directions. The annexed sketch (plate 5) will afford a general idea of the mode of occurrence of some granite veins in slate at Wicca Cove, or Pool, near Zennor, and the accompanying sectional view (fig. 18) will show the connexion of

Fig. 18.



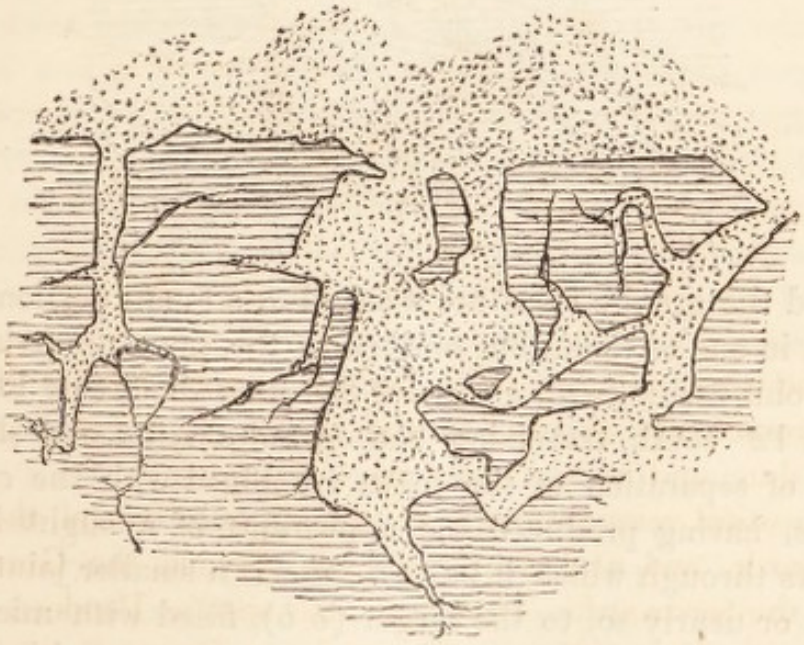
two of these veins with the main body of granite behind the face of rock prominently exposed in the sketch; *a a* being granite veins, *b b* slate, and *c c* the main mass of granite.

Very beautiful veins are seen on the opposite side of the cove at Carnyvarth, and at Porthmear Cove, beyond the Gurnard's Head, to the westward. They are also seen at Pendeen Cove, at Chycornish Carn (Botallack), at Cape Cornwall, at Whitsand Cove (near Pedn-maen-du Point, Land's End), at Tetterdu Point, or the Bucks, and at Mousehole, all around the Land's End mass of granite, and cutting into the slate rocks adjoining them. In some, as at Wicca Pool, and at Porthmear (or Polmear, as it is not unfrequently called), included portions of the slate are caught up in the veins. At Wheal Providence mine, near

St. Ives, granite veins are found in the workings, so that the whole mass seems to send veins into the rocks around it, as do probably also most of the granite masses, their appearance being more common round part of the Land's End granite, merely because conditions for the exposure of the junction lines with the adjoining rocks are there more favourable; a view long since taken by Mr. Carne*.

The granite veins of St. Michael's Mount, easily accessible, and readily seen at low tide, being clearly observed to proceed from the main mass of the granite, and to include detached portions of the slate into which they penetrate, while at the same time the main mass of granite, the slate, and the granite veins were cut by veins of quartz, of mica, &c., a very hot controversy was, some years since, carried on upon the subject of their relative antiquity to the slate in which they were found. The following plan (fig. 19) of the contact of the slate and granite, at a spot on the

Fig. 19.



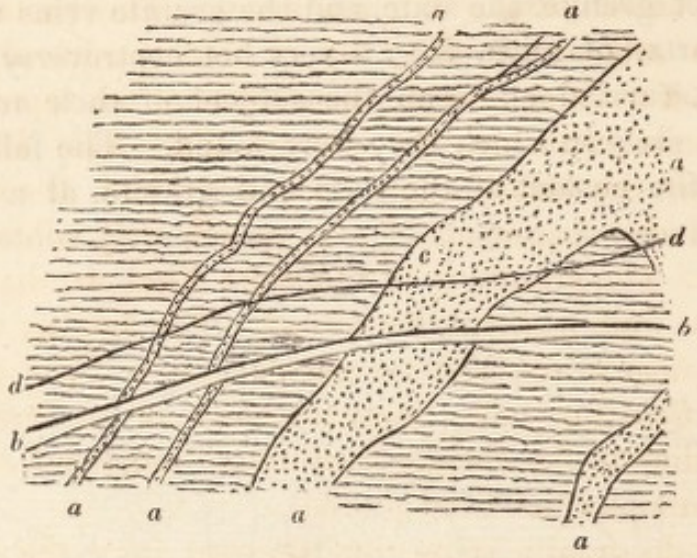
north-east side of the mount, will afford a view of the more massive junction of the two rocks, one strongly marking the force

* Trans. Geol. Society of Cornwall, vol. ii. (1822), p. 76. Mr. Carne observes that, "from the occurrence of granite veins in slate, wherever the junction of the two rocks has been discovered on the coast, and from their probable existence in the mines in which both the rocks occur, it is very likely that, if the lines of their junction could possibly be laid open to view, granite veins would be seen traversing the slate at almost every point." (On the Veins of Cornwall, read October, 1818.)

with which the granite has been thrust through the previously-existing slate, the shaded part of the plan representing the latter,* and the dotted portion the granite.

The veins which seem to have complicated the subject, before the joints or divisional planes of rocks received attention, are merely joint, or divisional plane, fissures, filled by quartz or other mineral substances, which are seen in the continuation of the same, or similar fissures in the mass of the adjoining granite. The annexed plan (fig. 20), taken not far from the last (fig. 19), will serve to illustrate this point. In it the shaded part is

Fig. 20.



slate, and the granite veins are marked *a*, a small portion of slate included in one of them, but omitted in the plan, occurring at *c*. *b b* is a joint fissure, with a general direction about east 12° north, and west 12° south, traversing both granite veins and slate, the amount of separation of the joint, combined with the course of the veins, having produced the appearance of a slight heave of the rocks through which it passes. *d d* is a smaller joint fissure, parallel, or nearly so, to the larger (*b b*), filled with mica where it traverses the slate, but containing more quartz, and being even altogether filled by that mineral, where the joint fissure traverses the granite veins.

The general direction of the perpendicular joints, or divisional planes, of the granite of St. Michael's Mount is about east 10°

* It may, perhaps, be necessary to state that these lines do not represent those of lamination, but are simply intended to give a distinctive shading to the slates in the figure.

north, and west 10° south, giving the western end of the mass the appearance of numerous vertical beds of granite, a character which has been noticed by Dr. Forbes*. The facts connected with the veins of St. Michael's Mount, and which have been considered contradictory, seem simply to be, that the granite veins were ejected into cracks of the grauwacke when this granite was protruded through it, and that, subsequently, after an alteration of the original mineral character of the grauwacke adjoining the granite, in consequence of the new conditions to which its particles were then exposed, joints or divisional planes were formed through the whole mass, as has been a very common case throughout Cornwall and Devon under similar circumstances. The partings of these joints were afterwards filled by different mineral substances, among which we find quartz, mica, oxide of tin, topaz, &c.

The granite veins on the east of Trewarvas Head are remarkable for the small angle they make with the horizon, and for the included fragments of slate which they contain in one or two places. The granite is of the same kind as that of the adjoining mass from which they proceed. The smaller veins are, as usual, of a finer grain, and the central parts of the larger more crystalline than the sides: facts indicative of an arrangement of parts according to the cooling conditions under which the same igneous compound has been placed.

Not only do granite veins thus proceed from the masses into the cracks formed in the rocks through which they have been protruded, as may readily be expected; but the granitic masses themselves are cut by similar veins, showing that, during the consolidation of the first-erupted portions, cracks were formed, and into these cracks melted granite was forced, in the manner we sometimes see veins of trappean rock cutting through larger masses. There are very few of the larger masses in which these veins are not observable. They are not unfrequent in the granite of the Scilly Islands, at Trescow, Bryers, St. Martin's, St. Mary's, and St. Agnes. Mr. Carne†, and Messrs. Oyenhausen and Von Dechen‡, have noticed many veins of this kind in the granite of the Land's End district. The former observes that their chief

* Trans. Geol, Society of Cornwall, vol. ii. p. 370.

† Ibid., vol. iii. p. 216.

‡ On the junction of the granite and killas rocks of Cornwall, Phil. Mag., and Annals of Philosophy, new series (1829), vol. v. p. 161, 241.

localities are at Tol-Pedn-Penwith, and on the east side of Lamorna Cove. Similar veins occur in the other masses, and are not very unfrequent in parts of Dartmoor. As distinguished from the granitic dykes, termed elvans, these veins are tortuous in their courses, and in general form resemble those on the outskirts of granitic masses intruding into the slates.

As might be expected, a few of these veins are observed to traverse both the granite and slate, to account for which it would be merely necessary that the cracks into which the matter of the veins has been injected should have occasionally passed out of the granitic mass (consolidated at its surface) into the adjoining slate. A vein of this kind is seen at Carn Silver, near Rosemodris, long since pointed out by Mr. Carne*. Many of the schorlaceous veins in granite may probably be classed under the same head with these veins. The granitic veins that traverse slate, and which we suppose of an earlier date because they proceed from the main body of granitic masses, are sometimes schorlaceous, and the change in the courses of such veins from schorlaceous to non-schorlaceous granite is frequently very interesting. The granite veins at Mousehole offer good instances of this fact.

Some of the granite veins in granite may be due to a separation of parts during consolidation; but those to which we have more particularly alluded above seem rather referrible to the cause which we have assigned them—a view in a great measure borne out by the continuation of some of these veins into the adjoining slates, which there can be little doubt are altered portions of sedimentary rocks.

The granitic veins which occur in the serpentine of the Lizard, and even in the hornblende slate of the same district, may either be referred to the date of the intrusion of the granite masses, to periods when cracks were produced in them after such first intrusion, or to that of the elvan courses to be next noticed. Their date may be uncertain, but they would appear to be formed of granitic matter ejected into cracks which were formed in the rocks among which they are found. They resemble both elvan dykes and the veins above noticed in their general characters. The vein at the long-celebrated Kynance Cove descends the cliff in the manner of a dyke, afterwards taking a course between

* Trans. Geol. Society of Cornwall, vol. ii. p. 67 (1822). In a paper read October, 1818.

Asparagus Island and the main land, much resembling some trappean dykes. The granitic vein which descends the cliff on the north of the Balk, near Landewednack, also possesses a dyke-like character, though it afterwards divides out into branches very similar to the granitic veins above noticed. The granitic veins between Innis Head and Kernick Cove have also a very dyke-like character. This granitic compound runs sometimes also in very thin veins, as may be well seen at the rock of hornblende slate in the centre of the landing-cove at Landewednack. These veins are generally a compound of felspar and quartz, and many of them have been long noticed by the various writers on the Lizard district. They are difficult to trace inland, though similar rocks may be there found, appearing to take very tortuous courses, as might indeed be readily inferred from their mode of occurrence on the coast. One large dyke seems to hold a somewhat permanent course from Cugar, a few degrees south of east, to the sea near Kernick Cove; and some between Innis Head and Poltesca appear not far out of that direction. Dr. Boase remarks that the rock of this kind which occurs on the east of Kernick Cove runs north-east and south-west, dipping at a considerable angle to the north of east, and traversing red serpentine*. The vein or dyke in the north of the Balk (Landewednack) partly cuts through diallage rock; and there is much of this granitic compound under the diallage rock and serpentine in the cliffs in the same vicinity: whether part of a mass or the prolonged portion of a large vein running horizontally it is difficult to say†.

In addition to the masses, minor patches, and veins of granite above noticed, we find long lines of granitic and felspar-porphyritic rocks, provincially termed *elvans*, cutting the slates and granites, occasionally traversing both in one continuous body of rock, which in their general mode of occurrence strongly remind us of trap dykes, and from which they chiefly differ in mineral composition. That those elvans (to adopt this very useful term) which traverse the granite and slates are of an age posterior to

* Trans. Geol. Society of Cornwall, vol. iv. p. 336.

† Mr. Still was enabled to trace this granitic rock for a considerable distance, under favourable circumstances, along the line of the sea. It should be observed that many of the sections afforded by the cliffs of the Lizard, which are highly interesting, can only be seen in boats during fine weather; those, therefore, on the west more especially, only during a few days in the year.

the consolidation of, at least, that portion of the granite which they cut through will be evident. With respect, however, to those which only traverse the slate, the time of their formation, or rather of the fissures into which the igneous matter of which they are composed was injected, is not so clear. Some may have been formed at the epoch of the intrusion of the great masses, while others may even have been produced after the elvans which traverse the granite and slate.

These elvan dykes vary from a few to 300 or 400 feet in breadth, and, though comparatively narrow, many can be traced satisfactorily for several miles. One of the longest hitherto determined is that which runs from Wheal Darlington, near Marazion, for twelve miles, by Wheal Fortune, Corbus, Treganhorn, Cayle, Herland Mine (Gwinnear), Roseworthy, and Camborne, to Pool, sending off a branch near Cayle about five miles long, which passes by Carnhell Green, Cassawson, and Tregear, into the Carnbrea granite, cutting into the latter on the west of Camborne Beacon. How far this elvan may extend to the south-westward it would be difficult to say. That which runs along with Penzance Pier, and is continued by the Wherry Mine, is not far out of the line.

The elvans which occur in the granite, especially when they are granitic, are often difficult to trace, as might be expected, while the courses of those which traverse the slates are more easily distinguished, particularly where quarries for building-stone are opened upon them, as is very frequently the case.

Commencing on the west, we have found only one instance in the Scilly Islands of an elvan dyke. It seems to run across the northern part of St. Mary's, near the Telegraph, and has a grey felspatho-quartzose base containing crystals of light-coloured felspar and quartz. Other elvans may exist, but if granitic, as above noticed, they would be very difficult to trace in these islands. That above mentioned, which appears to cut through the granite, has a course about east 25° north, and west 25° south.

From fragments which are scattered over parts of the Land's End granite, there are evidently more elvans traversing it than we have been successful in finding, from the want of exposed portions of them in place. At Maen, or Mayon, near the Land's End, a rock composed of a small-grained mixture of felspar and

quartz, with larger disseminated portions of schorl, seems to cut the granite in the manner of an elvan, holding a north-western course towards the west of Chapel Carn Brea. From Sancreed towards Ludgvan we obtain a course of elvan varying somewhat in mineralogical character, as is often the case with elvans, of a more decided kind, cutting through both granite and slate. It has chiefly a quartzo-felspathic base with crystals of felspar: schorl is also sometimes observable. The same line of elvan is probably continued in the course we find extending from Tregellas and Colurrian across the road near Roseangrouz.

A glance at the maps will show that lines of elvans somewhat radiate in their directions eastward from the courses of Penzance Pier and the Long Rock, in Mount's Bay. Not that they actually spring from these elvans, but they point down in that direction from the eastward. While the elvan course above noticed as running from Wheal Darlington to Camborne and the Carn Brea granite takes a north-western direction, as also another elvan on the north of it, passing from Rosevidney by St. Erth through Wheal Alfred, an elvan on the north of Marazion, after running in the direction of Tregurtha, bends round to the southward by Goldzithney, and passes into the sea on the west side of Pra Sand. Another elvan, which passes through the Marazion mines, seems to divide on the north of Tregurtha, one branch running near Trevarthian to Gurlyn, while the other crosses through St. Hilary to the east-south-east. Generally speaking, these elvans are composed of a felspatho-quartzose base with crystals of felspar or of quartz, and occasionally of both these minerals in the same rock. They sometimes acquire a more granitic structure in the central parts of the dyke. The elvan which runs through St. Hilary towards Tregonning Hill, and also that which cuts through the country from Tregurtha, near Marazion, to Pra Sands, are both remarkable, more particularly in parts of their courses, for containing a multitude of pinite crystals; so that in some localities, as on the west of St. Hilary, the rock is thickly studded with them and with crystals of felspar, occasionally large. Numerous schorl veins with oxide of tin traverse the elvan near Tregurtha Tin-mine. An excellent example of the change of structure in the same mineral compound may be seen in the elvan near the Pra Sands, the sides almost passing into compact quartzo-felspathic rock, while the interior

is more crystalline. In the pinitiferous elvan between St. Hilary and Bostrase the outsides of the dyke are more compact and porphyritic than the interior, which is more granitic, with disseminated large crystals of felspar.

We must refer to the maps for the situation and direction of the elvans which occur near Great Binner, Clowance, Wheal Crenver, Copper Bottom, and other places in that part of the county, which run more or less parallel with those on the north, and bring on the general strike of the mass of elvans that occur in the great mining districts of Redruth and Gwennap. Elvans with the same line of strike will be seen occurring near Breague, on the south, running among the lodes of Wheal Vor. Most of these elvans have the common character above noticed.

It will be observed that the elvans near Camborne, Redruth, and Gwennap, if they hold their courses up to the granite, seem to cut into it. The mining section (pl. 9) shows three elvans seen in the workings in the contre lode in Dolcoath mine; one traversing the slate alone, another cutting through slate and granite, and the third running solely through granite; all having a somewhat converging character downwards, as if they sprung from the same mass in depth. It will be seen that some elvans split in their courses to the eastward, and some spring from elongated masses, as near Trevarth, on the west of Gwennap, and near Frogpool, on the east of the same place. One elvan traverses greenstone near Burncoose, passing westward by Trewedna Water and above Carnon Gate to the downs on the west of Killaganoon, where suddenly a branch from it turns to the southward, pointing to some elvans, which, after cutting through granite by Trevathes, Laity, Menke, Roscrow, Trelever, Penryn, and other places in that district, turn up in part by Enys, Garrick, Gluvias, and Milor Bridge, towards the north and north-east. The elvan which crosses the Restronget Creek from Lower Deveron to Carclew is parallel to this branch, as is also another intermediate dyke. That which seems to curve round from Daniel's Point, under the creek, by the west of Restronget, seems also to show a tendency of the elvan courses of the vicinity of Penryn to run up to the eastern part of those that extend from Gwennap to the neighbourhood of Truro.

These elvans have, for the most part, a common mineral character, being chiefly composed of a felspathic, perhaps often a

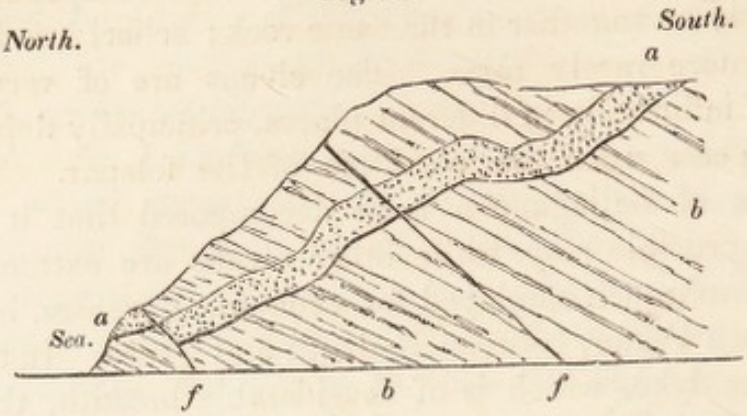
quartzo-felspathic base, containing crystals of felspar and quartz, either singly or together in the same rock; schorl less frequently, and still more rarely mica. The elvans are of very variable degrees of induration in different places, principally depending, it would appear, upon the condition of the felspar. The elvan on the west of Killaganoon is so decomposed that it has been worked as crucible clay, while other elvans are extremely hard. A hard elvan, much employed for economic purposes, is quarried near Seveoch Water, between Redruth and Truro. In the central parts of the dyke, which is of considerable breadth, the rock is granitic, containing small roseate crystals of felspar, and isolated and radiated nests of schorl, the outer portions being far less crystalline and more hard than the central. At Newham quarry, near Truro, at the termination of a long dyke extending about nine miles from the westward of Penstruthal, where it cuts through granite, even the porphyritic character becomes lost, and we have a substance not unlike some arenaceous rocks*. It is white and rather friable—a fine-grained compound of quartz and felspar. A short distance west, however, the elvan is a well-characterized porphyry†. Even marked colours are seen to change in short distances. As an example, we may note the Creegbroaz quarries near Chasewater, where, at only fifty yards asunder, one part of the mass is of a greenish hue, while another has a beautiful roseate tint. They are both granitic porphyries, felspathic matter prevailing.

Near St. Agnes we have the advantage of seeing an elvan cut in several places in its course by the line of sea-cliff. It is first observed westward on the south of St. Agnes' Head, whence it traverses the country for about a mile to the coast on the west of Trevaunance Porth. It then disappears beneath the sea for about three-quarters of a mile, and is afterwards seen rising up the cliffs, with a northern dip, cutting through the slate beds. In the next cove on the west, sometimes termed Trevellas Cove, we have the elvan dyke as represented in the annexed section (fig. 21), in which *a a* is the elvan dyke, *b b* the slates which it cuts across,

* It should be observed that when elvans are decomposed, and many are so, they not unfrequently appear sandy or gravelly at the surface.

† At Penstruthal, the elvan is a porphyry formed of a fine-grained quartzo-felspathic base, with disseminated crystals of schorl.

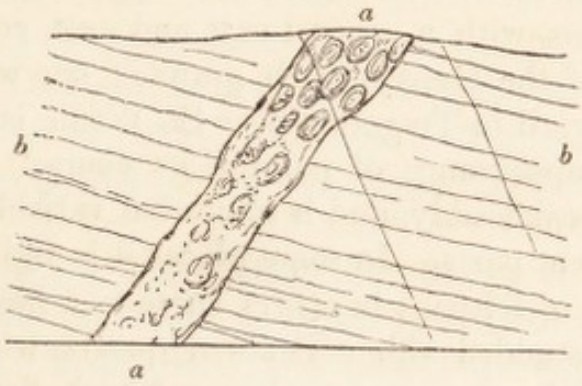
Fig. 21.



and *f f* are faults, that on the north having heaved the dyke about its own thickness, while the other has scarcely moved it. The same elvan afterwards runs to Wheal Prudence, and apparently enters the granite of Cligga Point, if, indeed, the granite of this point be not the main mass from which it springs, sending out two other elvans to the eastward. The line of the St. Agnes elvan is at all events carried on upon the south of Great St. George Mine and Wheal Leisure to Penkaronow, near Piran Porth, after which it is continued by Piran Round, and the south of Wheal Hope, towards Wheal Deer Park. About this place it has not been traced continuously, but on the same line of strike an elvan is found at Nanhellan and at Trevilson, near Newlyn. Other elvans occur near Piran Porth and Cubert, which seem to take courses somewhat parallel to the last-mentioned dyke, those near Cubert being, however, more nearly east and west. The Cubert and Trebellen elvans evidently pass under the blown Piran sands to the sea, where they are well exposed, the latter appearing at Carnhaut. At this place the cutting character of the elvan, where a small portion of the slate it traverses appears from beneath the sands, is well exhibited, as also the more developed crystallization of the central part of the dyke. It is a quartzo-felspathic porphyry, containing crystals of felspar, quartz, and schorl. The central part of the continuation of the Cubert elvan is more granitic, being a compound of quartz, felspar, and mica (the latter rare), containing disseminated crystals of felspar and schorl. The outer portions of this dyke, where they approach the containing slate, also exhibit a less crystalline arrangement of the constituent parts, being there more porphyritic, with a more compact base.

Proceeding northward to Watergate Bay, we observe a fine example of a dyke traversing the grauwacke beds nearly at right angles to their strike, these beds being in part a continuation of the fossiliferous deposits of Lower St. Columb Porth and New Quay. The annexed wood-cut (fig. 22) is a section of the dyke,

Fig. 22.



where it appears at Watergate Bay, somewhat obliquely to the run of the coast, *a a* being the elvan dyke, and *b b* slates. This elvan is very granitic, being a compound of quartz, felspar, and mica, containing crystals of felspar. The upper portion, which is inaccessible, seemed to have a concretionary structure when viewed through a telescope. The dyke continues in its general course across a variety of beds in a north and south direction from Watergate Bay by Lower St. Columb Porth, Chapel, Trerice, and Pollamounter, to the west of Jenkins Barrow, near Mitchell. This granitic elvan preserves its general mineral character for long distances, not varying much in this respect during its whole course. Near St. Columb Minor the sides of the dyke are more porphyritic and less granitic than in the central portions. Indeed, the granitic structure, as frequently happens with the granitic elvans, entirely disappears towards the outer walls.

The elvans which stretch up to this north and south course from the eastward, have a different direction from those which run towards it on the west side, and neither on the one side nor on the other have we been able to detect the junction of any one of these elvans with it. Such a junction would, however, appear very probable, more particularly near Chapel, where the elvan running from Coosewell Mill, about west 20° north, to Penlane, approaches close to this north and south course; and

also near Trevilson, where that ranging up from Nanhellan, near Newlyn, seems to approximate still closer. The elvan near Penlane is much decomposed, sufficiently so to be employed as crucible clay; and if the two elvans should hereafter be found, by better artificial sections than could be obtained when we were there, to come into contact, it would be highly interesting to see whether the one cut the other, or both merged into the same dyke.

Several elvans, with a general east and west course, are found on the north of the Hensborough granite; one which runs from Tremore westward to Tregotha, near St. Wenn, is remarkable for the beautiful appearance of parts of its course. Near Tremore it swells out considerably, and is somewhat variable in the colours of its component parts. In some places it is light-coloured with white crystals of felspar; in others there is a flesh-coloured felspathic base, studded with crystals of quartz, white felspar, and some schorl. Another variety has a brown flesh-coloured felspathic base, with light pink crystals of felspar, crystals of quartz, and some schorl. On the south of St. Wenn this dyke becomes much decomposed, forming a white clay, with disseminated crystals of felspar in it. An elvan not far from Lower Woodley, near Lanivet, has a quartzo-felspathic base, containing crystals of quartz, schorl, and mica.

It is difficult to say whether the lines of granitic rock which run from the granite in the neighbourhood of Blisland should be considered in the light of elvans or of veins injected into the adjoining slate when the granite mass was first protruded. Their parallelism and general range would lead us to refer them to the former; their mineralogical character, however, if they be elvans, prevents their being traceable in the granite. Elvans, indeed, occur near Temple, which may constitute continuous portions of them, but, if so, they are more granitic in the slates than in the granite. At Hellagon, on the north of Helland, the dyke or vein is composed of a base of felspar and quartz, in which are crystals of felspar and schorl. At Kernick, also near Helland, the termination of another of these granitic lines is a granite composed of felspar, quartz, and mica, the latter being somewhat rare. Where the latter line approaches the granite near the London Inn on the road from Bodmin to Launceston, we find a hard base of quartz and felspar containing plates of black mica and crystals of white felspar.

These dykes or veins run parallel to others that occur in the vicinity of Cardinham and St. Neots, and which also partially communicate with the adjacent granite in a manner to render it doubtful whether they were formed subsequently to, or at the time of, the protrusion of the latter. Some of these granitic lines are certainly detached from it, as far as exposure on the surface is concerned. They have generally the character of elvans, possessing much the same mineral structure as those near Gwennap and other places, and should probably be referred to that class of granitic rocks. At Higher Hill, south-west from Cardinham, iron pyrites occurs among one of the common porphyritic elvans.

An elvan stretches down from the vicinity of Camelford to Tregreenwell, near St. Teath, at which latter place it has a base of light-coloured felspar, quartz, and mica, containing disseminated crystals of light-coloured felspar. Nearer Camelford the same elvan dyke, instead of being granitic, as at Tregreenwell, becomes a porphyry with a grey-white quartzo-felspathic base, containing crystals of quartz and specks of mica. At Trecligoe, near Camelford, the rock is formed of a light-grey felspathic base, containing crystals of quartz, flesh-coloured felspar, and plates of mica. In the line of strike near St. Teath we did not detect elvan in place, though perhaps some fortunate artificial section may eventually disclose a continuation of it; but in the direction of the line of strike at Treburget, beyond St. Teath, we find a rock composed of a grey quartzo-felspathic base, with imperfect crystals of lighter-coloured felspar and points of iron pyrites This latter rock can be traced by the neighbourhood of Trelill, St. Kew (where it is formed of a felspathic base containing disseminated quartz and imperfect crystals of felspar, the whole having a granitic appearance), Trewethern, Hensdon Mill, and Keiroe, towards Lower Penmaen.

Elvans are found in the granite near Rough Tor, and a few other places in the district of Brown Willy, but from the want of well-exposed ground we have been unable to trace them with the precision necessary for insertion in the maps.

Returning to the south we find a group of elvans near St. Austell and on the south of St. Stephen's, of which the general direction may be taken at about west 20° north, and east 20°

south, though portions of them vary considerably from that direction, as for examples, the Pentuan branch running from Sticker Down to the sea at about east 30° south, there sending off a shoot to the north-east; and the elvan extending from Trembear (near St. Austell) to Nanphisick, which takes a south-west and north-east course, allowing for the bend, and the faults by which it heaved. The main direction of these St. Austell elvans corresponds, therefore, with the strike of those which occur between Fatworth Hill (near the Indian Queen) and Quintrel Downs, and differs about 44° from the general run of the Redruth and Gwennap elvans, which may be regarded, on a whole, as having a direction of east 24° north, and west 24° south.

In general mineralogical composition these elvans resemble the mass of those previously noticed. They are sometimes granitic, and at others more porphyritic, the same course often changing its character in this respect, the sides being generally more compact and less crystalline than the interior parts of the dykes. Granitic and porphyritic elvans are seen near Polgooth, where the one which cuts through the old Mulvra Mine in its course from Trelyon Mill, near St. Stephen's, to Flat Rock Point, in St. Austell Bay, holds nests of yellow bi-sulphuret of copper, apparently isolated, and varying from even several tons to a few ounces in weight*. We have been informed that this elvan possessed a similar character in its course near Penrice, the lumps of bi-sulphuret of copper being there smaller.

The long-celebrated Pentuan elvan, or *Pentuan stone*, as it is generally termed, is a fine-grained compound of felspar and quartz, with crystals of mica, and is remarkable for containing fragments of the slate-rocks which it traverses, and occasionally, though very rarely, portions of quartz, which also seem to have been broken off and imprisoned in the matter of the elvan. The fragments, however, actually found in the main body of this elvan are rare compared with those which are detected in a branch it sends off from the cliff where it comes upon the sea, and which runs along the shore towards the Black Head. The fragments of

* My friend, Mr. Robert Were Fox, obtained small nests of plumbago, similarly dispersed, from one of the elvans near Deveron (Restronget Creek, Falmouth Estuary), the only instance, we believe, of the occurrence of this mineral which has been yet noticed in Cornwall.

the adjoining rocks contained in this branch are extremely numerous, decreasing in abundance from the sides of the dyke towards to the central part, where we rarely detect any.

The elvan of Sparnick Moor, near St. Austell, abounds with strings of schorl and quartz, among which oxide of tin is often in sufficient quantity to be profitably worked. It may be doubted, however, how far these strings are contemporaneous with the ejection of the elvan, and not joints in it subsequently filled. Pinite is found in the elvan which runs from Polgooth by Trewithan to Court Mill, more particularly in a decomposed part of it at Treloweth on the road from St. Austell to Grampound.

It will be observed, by reference to the maps, that two of the elvans near St. Austell divide in their courses, that which runs from Flat Rock Point through Polgooth tin-mine separating near Dowgas in its progress to the westward, while that from which the Pentuan elvan proceeds sends out another branch eastward by Towan to Trenarren. The cutting character of these elvans is well known in the mines of the district, and is particularly well exhibited in the deep excavation for the St. Austell and Grampound road near Bosinver, where a small elvan traverses it.

On the east side of the Brown Willy mass of granite we detect elvans between Linkinghorn and North Hill, and to the west and south-west of the latter place, possessing the same general mineralogical characters as the other common Cornish rocks of the same kind. Occurring as they do, nearly opposite similar lines of granitic rock on the west of the same mass of granite near Blisland, we may be led to consider that they form a part of a series of dykes running in an eastern and western direction across it, the lines being difficult to trace through the granite, in consequence of the frequent mineralogical resemblance they may bear to it. On the other hand, they may as readily have filled fissures produced during the eruption of the Brown Willy and Dartmoor masses of granite, such fissures taking the lines of least resistance among the beds of pre-existing grauwacke, while in one or two places bosses of granite have been forced through them, as upon Hingston Down. The occurrence of the elvans that traverse Morwell Downs, the southern of which nearly extends to Horrowbridge, there nearly meeting an irregular but detached line of granitic rocks which range from Dartmoor by

Walkhampton, would appear to support this view, if we did not find an elvan which seems to traverse the granite of Kit Hill. There seems certainly no reason why these granitic rocks may not have been of different geological ages, the whole tending to show that beneath, in that line, the granite has struggled to free itself through the superincumbent grauwacke, and to unite the masses of Brown Willy and Dartmoor above, as they are doubtless beneath. The elvans of Morwell Downs are cut by the tunnel of the Tavistock canal, and have been described by Mr. John Taylor in his notice of the rocks there traversed*.

The elvan, long known as the *Roborough stone*, traverses the Downs, from which it takes its name, in an east and west direction; it is chiefly a porphyry composed of a felspatho-quartzose base with crystals of quartz, formed of hexagonal pyramids, base to base, a very common shape in which crystals of quartz appear in the elvans of Cornwall and Devon, when this mineral occurs disseminated throughout a felspathic or quartzo-felspathic base, so that, where the base is liable to decomposition, these isolated crystals can be obtained in multitudes, by merely washing away the decomposed rock. The Roborough elvan can be well seen to cut through the slate-beds in the valley between Milton and Maristow.

On the south of Roborough we find a granitic elvan near Jump, and a porphyritic elvan extending from Cann slate-quarries, by Fursdon towards Knacker's Knole. The rock which runs in a line from the south of Modbury towards Erme Mouth, we have, as before stated (p. 78), referred with doubt to this class of rocks, and have mapped it as an elvan for convenience. On the north of Dartmoor we find two elvans in the carbonaceous series, one on the west of Arscot, near South Zeal, and the other running through Lidbridge and Lidleigh Ball, on the south-west of Hatherleigh. Dykes of this kind have not hitherto been detected on the east of Dartmoor.

It will readily be observed, by reference to the maps, that a connexion is in a great measure established between the principal masses and patches of granite in Cornwall and Devon by means of elvans. They may be considered as mere granite dykes, the

* Trans. of the Geological Society of London (vol. iv. 1817). The total length of the tunnel is 1270 fathoms.

chemical composition of which bears great analogy to that of the chief granitic masses in the vicinity of which they occur, their mineral structure considerably depending upon the conditions for cooling to which they have been exposed, their central portions being, therefore, often more generally crystalline than their sides. They would appear to occur somewhat in groups, though more straggling elvans are also detected. Thus a chief group may be considered to occur between Truro and Mounts Bay, including the elvans of Gwennap, Redruth, Camborne, Gwinnear, Crowan, St. Erth, St. Hilary, and Marazion, to which should probably be added those near Breague. Another group would include the elvans of St. Agnes, Piran Porth, Cubert, and Newlyn, with those of St. Enoder, St. Columb Major, St. Wenn, Withiel, and Roche, comprising the great north and south dyke which extends from Watergate Bay to Michell. Those of St. Austell and St. Stephen's would constitute a third group, and those of Blisland, St. Neots, North Hill, and Linkinghorn, with the elvans on the southern part of the Brown Willy granite, would form a fourth group, the elvans near Tavistock being considered to constitute an extension of it to the eastward. These divisions into groups are, no doubt, somewhat arbitrary, and connecting links may be considered to exist between them; but, from the frequency of elvan dykes in particular localities, the forces which produced the necessary cracks, and threw up the fluid granite into them, would appear there to have acted with greater intensity than in those situations where elvans are more rarely found. It will be observed, that the chief areas in which these granitic dykes are not detected occur between the Falmouth estuary extending to Truro, and the St. Stephen and St. Austell elvans, including the country stretching towards Michell; in the district on the north of St. Columb Major, St. Wenn, and Withiel, which runs up to Padstow, and is bounded by the sea on the west and the Camel on the east; and in the country extending from St. Austell, Lostwithiel, and the course of the Fowey River, to the Tamar. Whether these districts offered greater resistance to the protrusion of the granite, or the forces which ejected the latter acted with less intensity in those points, it would be difficult to say, though it may be noticed that hard sandstones or fine-grained conglomerates occur in variable proportions as a component part of all of them, and might offer much resistance to the production

of dykes in them. Connected with the subject of resistances to the production of the cracks or fissures in which the elvans occur, it is interesting to observe the manner in which the elvans run among the greenstones and slates near Penzance, and between St. Erth and Redruth, more particularly that in which an elvan passes between the beds near Cayle, separating and running on both sides of a mass of trappean rocks that extends from the vicinity of Wheal Herland to Camborne. Elvans, however, may be seen to traverse greenstones, when the latter occur across their courses, as between Marazion and the Greeb, at Burncoose near Gwennap, and at Burnthouse near Penryn.

Although the great mass of the granitic rocks in the district under consideration is to be found in Cornwall and South Devon, such rocks are not altogether confined to that portion of it. A patch of granite, the superficial extent of which beneath the waters of the Bristol Channel is unknown, occurs at Lundy Island; a few blocks of elvan, previously mentioned (p. 49), are to be seen at low water in a cove between Bull and Morte Points; and a granitic rock, long since noticed by Mr. Leonard Horner as a compound of dull flesh-coloured felspar, green mica, and a small quantity of quartz, is observed at Hestercombe, on the north of Taunton*. These three localities, supposing the elvan blocks between Bull and Morte Points to be really in place, would seem to occur in a line not far different from the general strike of the grauwacke and carbonaceous deposits of North Devon and that part of the Quantock range in which Hestercombe is situated. If we consider these granitic rocks to have been contemporaneously ejected, of which, however, we have no proof, and connect their occurrence with the rents subsequently filled by quartz infiltrated into them, and so conspicuously intermingled with the slate near Morthoe, and other places on the same line of strike, and also with the contorted character of the North Devon and West Somerset grauwacke and carbonaceous deposits in similar lines of strike, we seem to arrive at the effects of some force or forces exerted in the same general direction, which either

* Sketch of the Geology of the South-western Part of Somersetshire, Trans. Geol. Society of London, vol. iii. (1816).

Although the map appended to this excellent memoir by Mr. Horner is described by him as merely an approximation to the truth, and has now been published twenty-two years, it will be observed that the Ordnance Geological Maps of that district differ very slightly from it.

met with such resistance from the cohesion of the sedimentary covering that the latter was not sufficiently broken, except in one or two instances, to permit the intrusion of granite, or the forces were unaccompanied by the pressure of subjacent fluid granite upwards sufficient to displace the superincumbent detrital beds and form masses resembling those which occur in South Devon and Cornwall.

These granitic rocks of North Devon may, indeed, be mere patches or parts of dykes analogous to the elvans of Cornwall and South Devon, and may have been ejected, like them, after the sedimentary rocks they traverse have suffered great contortions and displacements; but if we regard the whole area under consideration with reference to the protrusion of the great granitic masses and the wrinkled and contorted state of the limestones, sandstones, slates, and other pre-existing rocks among which these masses have been so protruded, the probability that both are in some measure due to a common and geologically-contemporaneous cause would appear considerable.

If we adopt the theory of a cooling globe and the necessity of the solidified crust of one period, with its covering of sedimentary deposits, conforming to the reduced size of the earth at another, this solid crust with its detrital covering would be broken up, or wrinkled, or both, to conform to the new adjustment of parts. While great masses might be squeezed up against each other in some places, forming mountain ranges, less marked effects might take place in another. The wrinkled or fractured condition of the surface may there have been produced on a minor scale, and smaller masses of granite, or any subjacent fluid rock, have been squeezed up among the weaker parts by the pressure of the dislocated portions of the solid crust there adjusting themselves. In support of the hypothesis that lateral pressure may, under such conditions, have caused the contortions, not only of mountain chains, but also of districts such as that under consideration, it may be observed that if we, in imagination, unroll these contortions, and endeavour to restore them and the highly-inclined beds to even moderate angles (those in which we may consider the detrital accumulations to have been effected), the mountain chains of which the stratification has been fairly examined—such, for example, as that of the Alps—will be found to require far more lateral space

than is now occupied by these ranges*. Even in districts such as that under consideration, after due allowance is made for the areas occupied by the intruded granite, we find that it would be extremely difficult to replace the detrital beds and their associated trappean rocks in a flattened manner within the same space. Hence we may be led to infer that, although much of the contortion and displacement observed in the grauwacke and carbonaceous deposits of Cornwall, Devon, and West Somerset may be due to the intrusion of the granite, such intrusion is in itself insufficient to cause the effect observed, and that some greater geological cause productive of both the intrusion of the granite and of the great contortions of the pre-existing rocks must be sought; and this will be more especially necessary when we unite this district with the curvatures or highly-inclined strata observable in the detrital beds, from the coal-measures in the descending order downwards, which occur in Eastern Somerset, Gloucestershire, Monmouthshire, and Wales, the whole forming a very insignificant portion of the earth's surface.

We may probably regard the mass of the granites and elvans above noticed as of essentially the same chemical composition, subject only to minor variations chiefly arising from the presence or absence of schorl and of a steatitic mineral allied to talc. We have elsewhere calculated † that a very common variety of the Devon and Cornish granites, that in which large crystals of felspar are disseminated, assuming the rock to be formed of three-sixths felspar, two-sixths quartz, and one-sixth mica, would be composed of—

Silica . . .	73·04	Lime . . .	0·44
Alumina . .	18·83	Oxide of iron .	1·73
Potash . .	8·51	Oxide of manganese	0·10
Magnesia . .	0·83	Fluoric acid . .	0·18

And that another somewhat common granite, formed of two-fifths quartz, two-fifths felspar, and one-fifth mica, would be formed of—

* An easy method of illustrating this fact is by arranging paper according to the contortions and highly-inclined strata of mountains, as exhibited in careful sections, when it will be readily observed that we cannot restore the paper to a more flattened surface without extending the area which it occupied as a miniature representation of a mountain chain.

† Geological Manual, 3rd ed., p. 449.

Silica	74·84	Lime	0·37
Alumina	12·80	Oxide of iron	1·93
Potash	7·48	Oxide of manganese	0·12
Magnesia	0·99	Fluoric acid	0·21

These are, no doubt, somewhat rough approximations to the truth, but they will probably suffice to afford a general idea of the chemical compositions of such granites. It would appear, however, that a small proportion of lithia may not be unfrequently added as a constituent part of Cornish granite, since Dr. Turner has detected this substance in several of the micas contained in it. The following are his analyses of a brown and a grey mica from Cornwall:—

	Brown mica.	Grey mica.
Silica	40·06	50·82
Alumina	22·90	21·33
Protoxide of iron	27·06	9·08
Protoxide of manganese	1·79	
Fluoric acid	2·71	4·81
Potash	4·30	9.86
Lithia	2·00	4·05
	100·82	99·95*

If we take Gmelin's analysis of the Bovey tourmaline—silica 35·20, alumina 35·50, oxide of iron 17·86, oxide of manganese 0·43, boracic acid 4·11, soda 2·09, magnesia 0·70, lime 0·55—as giving, or at least closely approximating to, the chemical composition generally of Devon and Cornish schorl, we should have for the composition of schorl rock, formed of about equal portions of schorl and quartz, such as that of Roche and several other places:—

Silica	67·600	Boracic acid	2·055
Alumina	17·750	Soda	1·045
Oxide of iron	8·930	Magnesia	0·350
Oxide of manganese	0·215	Lime	0·275

Whether, therefore, we have schorl rock, the intermixture of this mineral with the more ordinary compounds of the granite, or the common granite itself, silica forms from 65 to 75 per cent. of the compound, and alumina from 12 to about 20 per cent., the other ingredients, potash, soda, magnesia, lime, lithia, oxide of iron, oxide of manganese, fluoric acid, and boracic acid, being in much smaller quantities.

* Brewster's Edinburgh Journal of Science (1823), vol. ii. p. 266.

Although boracic acid may only constitute about 2 per cent. of a schorl rock formed of equal portions of schorl and quartz (and this rock is rare compared with the mass of the common granitic rocks of which it constitutes a part), still, from the frequent occurrence of schorl in so much of the Devon and Cornish granite and in the veins by which it is traversed, there must as a whole be a vast body of boracic acid locked up in the Cornish and Devon granites and elvans.

If we consider the joints which traverse the granites and elvans to have been produced subsequently to the consolidation of those portions they cut through, the component parts of the granites and elvans have often arranged themselves differently adjoining these joints, more particularly on the outskirts of great masses, and when schorl is present, than between them, subsequently to such consolidation. In the schorl filling the cavities of large decomposed crystals of felspar in the schorl rock near Trevalgan (p. 161), we seem to have conclusive evidence that this mineral may be decomposed in one place and recomposed in another under given conditions,—transferred, as it were, from one situation to another. The frequent occurrence of schorl in the joints of some granites, more particularly in connexion with oxide of tin, as happens in the Hensborough mass, and the disposition of schorl in several places, as, for example, among the Land's End granite between Castle Trereen and Pedn-mean-anmear, and other localities, to accumulate towards the joints, would seem to show the like fugitive character of this mineral under similar conditions. What these conditions may have been it may be difficult to determine, but they would appear analogous to those under which schorl has been so frequently accumulated among tin veins in granite, and towards the walls of the smaller veins in which oxide of tin occurs, as, for example, those of Balieswhidden near St. Just.

The variable character of common granite itself near the joints may be observed in many localities, and is very conspicuous in that of St. Michael's Mount, which is generally far more quartzose towards the joints than in the intermediate spaces. An arrangement of parts which would appear to show a change in the position of the constituent chemical ingredients subsequently to the production of the joints, or perpendicular or highly-inclined divisional planes, and, therefore, an arrangement produced sub-

sequently to the consolidation of the rock, if the joints have been produced since such consolidation; and we should recollect, that whatever age is given to the joints in the granite of St. Michael's Mount will be common also to those in the adjoining slate, the same joints traversing both equally, no uncommon circumstance at the junction of the granite and schistose rocks of Devon and Cornwall, but one which may be frequently observed*.

It would appear, therefore, that the constituent portions of the granitic rocks of the district not only arranged themselves in a variable manner, more particularly on the outskirts of the masses before consolidation†, but also that, since their consolidation, conditions have arisen to modify portions of these rocks mineralogically, the divisions into joints, and the larger dislocations traversing them, having constituted part of such conditions, for into and adjoining them there appears to have been either a frequent movement of schorl and quartz, and occasionally of felspar, or substances were in solution in these fissures which modified the mineral structure of the granite adjoining them. The granitic rocks, elvans included, are much divided by joints; the great granitic masses are often cut by granite veins and elvans, and the whole is frequently traversed by dislocations of different ages, so

* Illustrations of this circumstance are given by Dr. Boase in his Treatise on Primary Geology, p. 126, fig. 6, and p. 127, fig. 7. After noticing the appearances visible at the junction of the granites and slates at Polmear Cove, St. Michael's Mount, Mousehole, Rosemodris, and Cape Cornwall, he observes, "In several spots at the places now referred to, the lines of structure are distinctly and regularly continued through both the granite and the slate."—P. 129.

† The relative fusibility of the different varieties of granite may often have caused their relative positions in the chief masses. This fusibility certainly seems to differ in the granites of the same masses, those containing the greatest quantity of mica without lithia being most refractory, while those with lithia-mica are far less so. In some experiments on the fusibility of rocks made jointly with Mr. L. Llewelyn Dillwyn, at the Cambrian Pottery, Swansea, we found that the Cornish granites and elvans were melted at a temperature about equal to that required for fusing malleable iron, those which contained the black non-lithia micas generally, however, presenting that mineral unfused. It is remarkable that the granites and elvans all become vesicular when first melted, the cause of which we have not yet ascertained. It may be interesting to notice, as showing the different fusibility of the Cornish and Devon granitic and trappean rocks, that in these and other experiments we have generally found the latter to enter into fusion at about the temperature at which copper melts. The difference in the heat required for melting of these granitic and trappean rocks is, therefore, considerable; for, according to Daniel, the point of fusion of copper is at 1996 Fahr., while the heat required for the fusion of malleable iron is the greatest which can be obtained in a smith's forge.

that there would appear no want of fissures into which water charged with matter derived from the granite might percolate, or from which aqueous solutions of different kinds might be infiltrated into the granite*.

* The decomposed granites of St. Stephen's, St. Austell, Roche, and Breague, form the more prominent examples of changes affected in the granite of this district. The change is particularly striking when we find hard lodes, as at St. Austell Hill mines, or the contents of joints or quartzo-schorlaceous portions adjoining them, as in Carglaze tin-mine, standing out in relief from amid the decomposed granite in which they were once included, the lodes and the substances actually between the joints having probably been fissures when the granite was solid on both sides of them.

CHAPTER VII.

RED SANDSTONE SERIES.

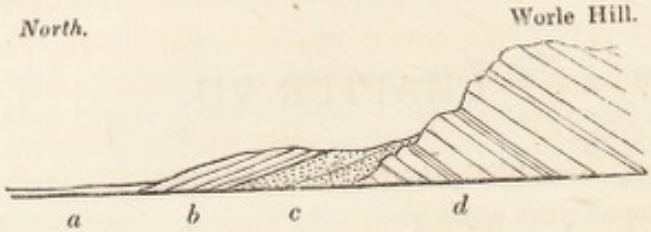
Resting upon the disturbed beds of the sedimentary deposits previously noticed, and upon the bent or uplifted strata of the carboniferous limestone which occurs on the borders of the Bristol Channel on the north of the district,* we find a series of beds of variable thickness, and as a mass extremely arenaceous, though the lower portions generally contain much breccia or conglomerate, and the upper parts principally consist of marls. The cementing matter of the conglomerates and sandstones is chiefly stained red, while the marls, though red in the inferior parts, are commonly variegated in the higher, where tints of blue, green, and several light colours prevail. To this series the name of new red sandstone has been long assigned by English geologists, to distinguish it, as previously noticed, from the old red sandstone, one very inappropriate in the present state of geological knowledge, instead of which, that of poicilitic has been suggested by Mr. Conybeare.

Commencing with the north of the district, we see on the northern side of Worle Hill, and near Kewstoke, as shown in the annexed section (fig. 23), a red marl and sandstone (*c*), principally the former, resting with a dip to the northward upon beds of carboniferous limestone (*d*), which dip to the south, a section

* Though small portions of carboniferous limestone occur at Middle Hope Hill (near Wick St. Laurence), Worle Hill (near Worle and Weston-super-Mare), Brean Down (near Uphill), and Bleadon Hill (between Hutton and Bleadon), in the north-east part of the district, it has been considered advisable to abstain from any detailed description of this rock in those localities, inasmuch as its relation to the group of which it forms a part, and that of the group itself to the general series of rocks developed in south-western England, could scarcely be rendered intelligible without an account of the carboniferous group of the district of the Mendip Hills and Bristol, of which these portions of carboniferous limestone geologically form a part. For descriptions of these localities in connection with that district, we refer to the very excellent memoir of the Rev. Dr. Buckland, and the Rev. W. D. Conybeare, on the South-western Coal District of England, Geological Transactions, 2nd series, vol. i. p. 210.

clearly showing that the latter were either tilted up prior to the deposit of the former, or were worn away, supposing them to

Fig. 23.



have been formed as highly inclined as we now find them, so that the red marl and sandstone were deposited on their abraded edges. Lias (*b*) reposes upon the red marl, and indeed seems to graduate into it, plunging beneath the alluvial flat (*a*), through and into which these and some other hills rise or project, like islands and promontories.

A short distance from the spot where this section is taken, concretions of a yellowish magnesian limestone begin to appear in the marl adjoining the subjacent carboniferous limestone, gradually increasing eastward, so that towards the eastern side of the hill it has acquired a fair thickness, and contains some fragments of the rock upon which it reposes. On the south of Worle Hill a line of this magnesio-calcareous rock extends along its base from Weston-super-Mare to Worle, plunging beneath the alluvial flat above mentioned Here also it sometimes cements fragments of the carboniferous limestone on which it rests.

On the north and south sides of Bleadon Hill we observe similar facts, with the exception that the arched position of the beds of carboniferous limestone there brings the superjacent deposits into a more conformable position with them. Here also the red marl and sandstone sometimes rest directly upon the carboniferous limestone, while at others they are separated from it by the magnesio-calcareous rock, or by a conglomerate or breccia, of which that rock forms the cement, as may be seen near Hutton, and at Shiplate and Shiplate Wood.

Several miles of flat country intervene between these red marls, sandstones, and magnesio-calcareous rocks and their next appearance above it in the direction of Bridgewater, where variegated and red marls, and red sandstones, are seen to emerge in several places above their alluvial covering, a main mass extending from the Parrett to the grauwacke of the Quantock Hills, upon

which it rests, running into little coves and round promontories, in the same manner that the alluvial flats near Bridgewater run into coves and round promontories formed of these red deposits themselves, and surrounding islands near Radlet and Cannington, in the same manner that islands of red marl, sandstone, and lias rise through the clay and sands of the Bridgewater levels at Chedzoy, Paulet, and Brent Knole. Indeed, the grauwacke of the Quantock Hills rises as an island above the red marl, sandstone, and conglomerate which surround it, being much indented by coves and bays on the east, with scattered outstanding islands of the same rocks off this imaginary coast, while more even lines mark the trough or channel of the red sandstone series that extends between the Quantocks on the east, and the grauwacke of the Exmoor district on the west, and from Ash Priors and Bishop's Lydeard on the south, to Williton on the north.

Though conglomerates are not absent, red sandstones and marls chiefly abound on the north-east side of the Quantocks, the marls being variegated in the higher part of the mass, where it passes into the lias that ranges from East Quantock's Head by Stokecourcy to Otterhampton on the east. In the trough or channel on the west of the Quantocks, the lower beds are principally formed of a claret-coloured sandstone, above which a conglomerate occurs, consisting of a magnesio-calcareous cement, uniting fragments or rounded portions of the adjacent grauwacke, and reminding us of the magnesio-calcareous beds near Worle Hill and Bleadon. Two lines of these conglomerates may be traced, though somewhat interrupted, on each side of this trough or channel of the red sandstone series, one on the west from near Williton by Capton, Vellow, Stogumber, Vexford, and Coleford Water, to Will, near Lydeard St. Laurence, the other from Lawford and Robbuck near Crowcombe, by Riches Holford and Yard Farm, towards West Combe, between Combe Florey and Cothelstone. These bands are readily traced, as the conglomerate is frequently worked for lime, more particularly when it contains pebbles of grauwacke limestone, which are found in it more especially between Stogumber and Williton. The beds which rest on these conglomerates are principally arenaceous, filling up the central parts of the trough or channel.

Similar conglomerates occupying similar geological positions

are observed in two or three situations where this channel of red sandstone rocks opens out on the north, and the line of the grauwacke trends away to Minehead. They may be seen at Beggcarn Huish and Tarr, on the south of Washford, and at Alcombe near Minehead. The conglomerates of the latter locality have been minutely described by Mr. Leonard Horner,* to which description, and an excellent account of the red sandstone of this part of Somerset, generally, we must refer for greater detail than the plan of this report would permit.

The mass of this series from Williton to Minehead is principally arenaceous or marly, the latter rock prevailing, and becoming variegated towards the covering of lias that extends on the north of it from Blue Anchor by St. Decumans and Watchet, towards St. Audries. Very instructive sections of the upper variegated marls, and of its passage into the superincumbent lias, may be observed on the coast from Blue Anchor to Watchet, and from thence to the cove on the north of Rydon, notwithstanding the great contortions and faults which are so common on it. A considerable abundance of gypsum, both red and white, principally the latter, characterizes these marls, sometimes occurring in veins, as represented in fig. 24, the chief veins

Fig. 24.

corresponding with the planes of the beds, the irregular and more upright strings communicating through the marls between them. The gypsum also occurs in isolated lumps in the marls without any immediate connection with other nodules or veins, and both the gypseous veins and nodules are more prevalent to the westward than to the eastward of Watchet.

In the gulf occupied by the red sandstone series, amid the grauwacke, from Porlock by Holnicote, Luckham, and Wotton

* In his valuable memoir on the Geology of South-western Somerset, Trans. Geol. Society of London, vol. iii. p. 358.

Courtney, towards Timberscombe, we again find a line of conglomerate with a magnesio-calcareous cement in sufficient quantity to make the rock worth working for lime (when the siliceous pebbles are removed), running from Doverhay by Luckham to Huntsgate, and two patches of similar conglomerates at Knoll and Well Farm. The lower portion of the series, on the southern side of this gulf, is also remarkable for the presence of red hæmatite iron in such abundance, that it is in some localities worked in the manner of a quarry for that ore, and profitably exported in the state in which it is thus roughly obtained, large patches in the body of the rock being wholly composed of it, and the hæmatite constituting as much a part of the beds as the sandstones and conglomerates with which it is associated. This ore is found on the east and west of Luckham and at Brockwell, and may be seen in other parts of the same line of rocks. Strings of rich black hæmatite may also be observed among the conglomerates and sandstones near Luckham.

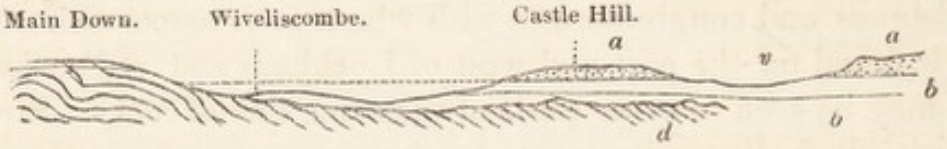
On the south of the channel of red sandstone and conglomerates between the Quantocks and the grauwacke of the Exmoor range, this series opens out widely from the Parrett on the east to Wiveliscombe on the west, passing round the southern part of the Quantock grauwacke, and being bounded by lias from West Sedgmoor to the vicinity of Blagdon near Pitminster, and by the green sand of the Black Down Hills from thence to the neighbourhood of Culmstock, supporting both these rocks, and leaving an exposed tract of red marl, sandstone, and conglomerate open between the western end of the Black Down Hills and the carbonaceous series of Holcomb Rogus.

If a line be drawn from Wiveliscombe, through Milverton, to the lias near Orchard Portman, Thurlbeer, and Stoke St. Mary, a fair section will be obtained of the red sandstone series as exhibited in the country commonly known as the Vale of Taunton. The general thickness of the series would probably not exceed a few hundred feet; for though the distance from the lowest part near Wiveliscombe to the highest, where it passes into lias near Stoke St. Mary, is between twelve and thirteen miles, the angle of dip, even omitting any additional length which may be acquired by faults letting down the country to the westward, is generally very moderate, in some places nearly approaching to

horizontality. From this small angle of dip the breadth of the conglomerate with the magnesio-calcareous cement that stretches down from Williton by Stogumber to Lydeard St. Laurence, is considerable between Pitbeer and Westleigh, and nearly two miles across between Ford (near Wiveliscombe) and its eastern boundary near Fitzhead.

This conglomerate, extensively worked for the lime in the cementing matter, is well seen near Wiveliscombe occupying the higher parts of hills which are cut by valleys of denudation. The following sketch, fig. 25, will serve to exhibit the mode of

Fig. 25.



occurrence of the various rocks, *a a* being the conglomerate, composed of portions of the adjoining and subjacent grauwacke cemented by magnesio-calcareous matter; *b b*, red sandstone, which may be about 140 or 180 feet thick, and *d d*, grauwacke upon which the whole rests unconformably. This section will be also useful in showing that the conglomerate may once have formed a continuous line of rock, not only across the small valley of denudation *v*, but also across the country between the Castle Hill and the grauwacke of Main Down Hill. Indeed the filling up of this space would appear necessary for the transport of the rolled pebbles from the grauwacke on the west to the portions of conglomerate still existing and dipping beneath more modern parts of the red sandstone series on the east, between Milverton and Combe Florey.

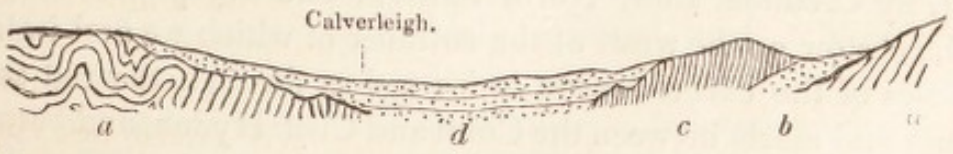
Above this conglomerate, which may be traced uninterruptedly by Milverton, Langford Budville, and Runnington to Thorn St. Margaret on the south, where it becomes thin and fines off by Thorn Farm towards Crossway House, red sandstones chiefly abound, mingled occasionally with some marls. A good section of part of these beds may be seen in the deep cutting of the high road from the White Ball Inn to Beam Bridge near Sampford Arundel. Approaching the lias the marls gradually prevail and become variegated where this series passes up into it. Good

sections of this passage and of the variegated marls may be seen on the hill side between Stoke St. Mary and Stoke Hill House, and along the escarpment capped by lias extending from Hatch Beauchamp towards Langport, and rising on the south of West Sedgemoor.

The red sandstone series, after passing round by Holcomb Rogus, runs into a gulf among the carbonaceous system of North Devon in the direction of Tiverton, isolating the limestone of Westleigh. From the outlying patches of red conglomerate and sandstone on the west of Hockworthy, and at Houndsmoor, on the north of Uploman, this series must once have more extensively covered the adjoining carbonaceous rocks than we now find it. In this direction we again meet with the magnesio-calcareous conglomerate near Sampford Peverell (where it is worked for lime), in the same relative position as is observed on the north, limestone such as that observed at Westleigh and Holcomb Rogus being found among the pebbles of which the conglomerate is composed.

Proceeding westward towards the end of this gulf we first find rocks of an igneous character associated with the red sandstone and conglomerate from Washfield, on the north of Tiverton, to Sidborough near Loxbere. These igneous rocks are of very variable character, being sometimes porphyritic, at others forming a more compact mass. The greater proportion of them are, however, scoriaceous, showing that the vapours or gases contained in them, while in a state of fusion, were not subjected to any very powerful pressure when they were erupted. A vesicular porphyry is not uncommon on the western side of the mass. The relative position of these rocks will be understood by means of the maps

Fig. 26.



and the annexed section, in which *a*, *a* represent beds of the carbonaceous series bounding this gulf on the north and south; *b*, a conglomerate wholly composed of portions of the subjacent carbonaceous rocks cemented by red sandstone and argillo-arenaceous matter, no fragment of the igneous rocks being observed in it; *c*, the igneous rocks; and *d*, conglomerates and sandstones, the

former containing fragments of the igneous rocks above noticed, or of others possessing a similar general character. Geological events, therefore, would appear to have succeeded each other in the following order in this locality :—

1. A subaqueous valley or depression in the carbonaceous series existing subsequently to the contortions which this series has suffered.

2. A deposit of detrital matter derived from the subjacent carbonaceous series.

3. The eruption of igneous rocks under somewhat moderate pressure.

4. The deposit of detrital matter derived in a great measure from the surrounding and subjacent carbonaceous grits and slates, mingled with the fragments of the igneous rocks, which were necessarily pre-existing.

In connexion with the eruption of the igneous rocks and the deposit of detrital matter subsequently to it, it remains to be noticed that along the range of the igneous rocks, particularly on the north, a sand occurs, here and there mingled with the more common red sandstone, which bears a very great resemblance to a volcanic product. Indeed the resemblance is so strong, and its occurrence among the ordinary red sandstone such, that we are led to infer that it may have been ejected in the manner of modern volcanic sand from a crater or fissure, and that falling into water it became intermingled with sands and other detritus then depositing at the bottom.

The facts here noticed in the Tiverton gulf are by no means confined to it, but are seen also at the eastern part of the long line of red sandstone and conglomerate which extends from Bradninch, Silverton, Kellerton, Broad Clist, and Huxham, on the east, by Crediton, Bow, North Tawton, and Sampford Courtney, to Jacobstow on the west, at the entrance of which we find isolated patches of the carbonaceous series rising through the red sandstones and marls between the Culm and Clist Hydon, and between Kellerton and St. Laurence Clist, Bray Down forming part of the latter. A large mass of these igneous rocks occupies the high ground in Kellerton Park, where they may be very advantageously studied, a long line extending from it by Budlake and Chiphele. Other patches are seen on the south of Kilnland and on the south of Spraydown House. The igneous rocks associated with the

red sandstone near Thorverton, and between Rew and Silverton, occur in east and west lines, resembling in that character lines of dykes. When, however, we examine carefully into their mode of occurrence, they rather appear sections of erupted igneous matter contemporaneously intermingled with the red sandstones and conglomerates with which they are associated, as if igneous action, the chief seat of which was at Kellerton Park, accompanied the deposit of this part of the red sandstone series, and these sections were something analogous to sections of lava currents.*

Including the large patch of these igneous rocks at Posbury Hill on the south-west of Crediton, and those on the west-north-west of the same place near Cross Farm, Wellgrove, Knole Lake, and Knole Farms, we find the harder parts of the various igneous products (frequently worked in large quarries) to descend in mass downwards, as if filling up some crater or fissure through which these rocks had been vomited, while the scoriaceous varieties run more horizontally away among the beds of red sandstone, fining off, however, under such conditions in a manner which modern lavas that flow in the atmosphere are not known to do. We can readily conceive that the same mineral compound would present very different appearances if in the one case it were retained to cool slowly in the pipe or fissure of a volcanic vent, the lower part under the pressure of the higher, while in the other it flowed in a comparatively thin sheet, pressed only by a moderate depth of water or by the atmosphere.

In the vicinity of Cadbury we find the red sandstone series capping the tops of high hills, and resting upon beds of the carbonaceous system: it also runs on high land in the direction of Sandford, near Crediton, continuing thence upon elevated ground to Sampford Courtney and Exbourn. At Hatherleigh also the outlying patch of red sandstone and conglomerate which there occurs is upon moderately elevated land. Nearly the whole of this stripe of red sandstone and conglomerate, extending about twenty-five miles from Bradninch to Jacobstow, dips to the south. This may arise from the detritus of which it is composed having been drifted from the northward, and thus, accumulations not having taken place on the south side of any gulf which may

* The intimate connexion of the igneous rocks of Thorverton and Silverton with the red sandstone series was pointed out in 1821 by the Rev. J. Conybeare.—Annals of Philosophy, new series, vol. ii. p. 161.

here have existed among the carbonaceous series, the inclined beds formed by a drift from the north may have been made to terminate suddenly without a reversed dip against the older rocks on the south. Be this as it may, the gulf-like form of the stripe is in part, at least, produced by a great east and west fault which can be traced from near Poltimore on the east by Huxham, Upton Pyne, and Woodleigh near St. Cyres, to the mass of igneous rocks at Posbury and Posbury Hill on the west, by which the edges of red sandstone beds dipping south, and those of the carbonaceous series dipping north, are brought suddenly into contact.

The chief rocks in this long stripe are conglomerates and sandstones, the former containing, besides rounded fragments of the adjoining carbonaceous sandstones and slates, pebbles of porphyritic rocks, and some which seem rolled fragments of Dartmoor granite. It becomes more arenaceous near Crediton, and even marls are mingled with it from thence to the Exe.

On the east of a line from Holcomb Rogus and Westleigh to Cullumpton, and thence round the isolated patches and projecting portions of carbonaceous sandstones, slates, and shales which occur near that town, Clist Hydon, and St. Laurence Clist, to Pinho near Exeter, a mass of red sandstone and marls extends towards the Black Down Hills, few conglomerates being intermingled with these rocks. The valleys of denudation that cut through the green sand which caps the Black Down Hills show that the red sandstone series is continued under them to the higher part of the valley of the Yart, where it becomes covered by lias. As lias is not detected in the higher part of the valley of the Otter, the boundary between it and the red sandstone series would appear to sweep round beneath the green sand of the Black Down Hills at Brown Down and Otterford, joining that which emerges from under the green sand of these hills on the south of Angers Leigh, where the lias is seen to rest upon the red and variegated marls.

Passing round the promontory of carbonaceous sandstones and slates which projects into the red sandstone series near Pinho, two patches of igneous rocks of the same character as those which occur at Thorverton and Kellerton are found at the base of that series, one near Poltimore, the other near West Clist on the high road from Broad Clist. Continuing a course thence to Exeter along

the boundary of the series, red sandstones and conglomerates are observed to rest upon the edges of the older rocks to that city, where another patch of similar igneous rock occurs, forming the hill on which Rougemont Castle is situated. Judging from the stones in the old walls of this castle, a large proportion of which were probably taken from the spot on which it is built, vesicular rocks must have been commonly quarried at that period on Rougemont, some of this rock being porphyritic from the dissemination of crystals of felspar through the mass. A good section of part of the igneous rocks of this hill was exhibited two or three years since, when a new road to Tiverton was cut through part of its base: much vesicular rock was seen, the vesicles often containing a green earthy mineral readily removed by atmospheric influences. The igneous rocks were also found to be singularly intermingled on the eastward with marl and sandstone. The principal base of these rocks would appear to be a dark reddish-brown siliceo-felspathic substance, similar to that which occurs at Thorverton, Silverton, and Kellerton.

At the deep cut through Pocombe Hill on the road from Exeter to Moreton Hamstead and Okehampton, igneous rocks of the same general character are observed to rest upon the edges of the slates of the carbonaceous system, and to support the red sandstones which occur on the hill towards Exeter. The Pocombe rock is chiefly a hard siliceo-felspathic compound with occasional though not numerous vesicles, and, being much employed for roads and buildings, good sections of it may readily be obtained. The vesicular character is more apparent in its continuation on the north at Little Barley than at the great quarry near the high road.

Judging from their frequent appearance from Exeter to Haldon Hill, igneous rocks would seem to occur abundantly at the base of the red sandstone series in this part of the area occupied by it. They may be well studied between Ide and Dunchideock, resting, as at Pocombe, on the edges of the slates or sandstones of the carbonaceous series. Near Western Town they will be observed intimately connected with the red conglomerates and sandstones above them, and apparently intermingled with red conglomerate near Ideston on the the north of Dunchideock. The harder varieties much resemble the Pocombe rock, being siliceo-felspathic and of a dark reddish-brown colour. Above Ideston and Knole we

find porphyries sometimes containing crystals of quartz, at others of felspar, and occasionally of both together—a very interesting fact, inasmuch as it is the only locality with which we are acquainted where any portion of those quartziferous porphyries, of which fragments are so commonly found in the red conglomerate between Exeter and Teignmouth, occurs in place. Igneous rocks seem to form the base of the red sandstone series from Dunchideock to its covering of green sand upon Haldon Hill, behind Haldon House, resting partly upon trappean rocks, which we have previously noticed (p. 112) as associated with the carbonaceous series of Ashton, Cristow, and Bridford. From the neighbourhood of Exeter to the sea on the south the lower part of the series under consideration is principally formed of conglomerates, composed of angular fragments and rolled portions of the various sandstones, slates, and limestones on which they rest, when the igneous rocks above mentioned are not interposed. The conglomerates of Heavitree were long since noticed by Dr. Berger,* and those of Dawlish and Teignmouth have been described in detail by the Rev. J. Conybeare.†

When we examine the fragments of igneous rocks in this conglomerate we do not find many portions of the trappean rocks associated with the beds near them, neither have we been able to detect any granite similar to that of Dartmoor among them, while fragments of other igneous rocks, chiefly porphyries, a large proportion of which are not known to occur in place, are extremely abundant, more particularly along the line of the Haldons and on the coast near Teignmouth. On the side of Little Haldon Hill there are blocks of quartziferous porphyry of more than a ton in weight; and large blocks are seen included among the conglomerate, apparently a continuation of the same part of the series, on the coast on the north of Teignmouth. Some of the fragments of porphyries contain large crystals of glassy felspar two or three inches in length. The chief part, however, is composed of a brown or reddish-coloured base with smaller crystals of felspar and disseminated crystals of quartz. Upon carefully examining the mode of occurrence of the rolled or fragmentary contents of these conglomerates, we find that they are not arranged according to specific gravities in the respective beds in

* Trans. Geological Society of London, vol. i. p. 99 (1811).

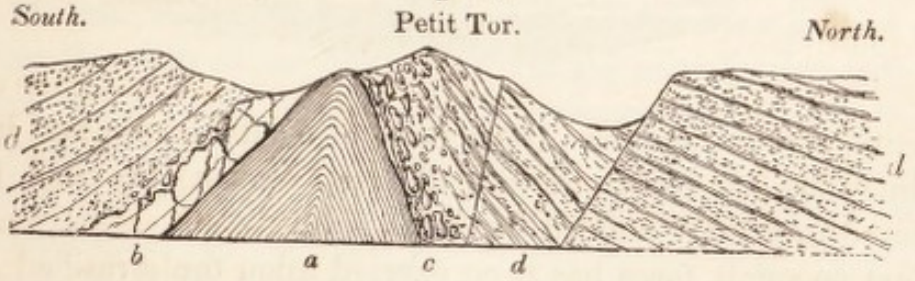
† Annals of Philosophy, new series, vol. i. p. 254 (1821).

which they occur, while the size of the fragments in the beds varies materially, a bed with large fragments occurring among others containing small fragments, and occasionally sandstones being interstratified with the conglomerates.

In Torbay and its vicinity we find a mixture of red conglomerates and sandstones, the former abundant, the latter comparatively rare, resting upon the pre-existing slates, sandstones, and limestones in an unconformable manner, the conglomerates being composed of the rocks on which they repose. Except where disturbed by faults, or so close to them that they have been contorted by the forces which have produced the dislocations, they rest at a moderate angle upon the subjacent beds, filling up inequalities which have existed among them prior to the deposit of the sandstones and conglomerates.

At Petit Tor, in Babbacombe Bay, we obtain the highly-interesting section represented beneath (fig. 27). An arch of slate (*a*) supports beds of limestone (*b*) on the south, which, though much

Fig. 27.



fractured, are still traceable as strata, while on the north the continuation of the same beds is so broken up that, except towards the higher part, huge fragments, forming the lower portion (*c*) of the red sandstone or poicilitic series, are all which remain of it. From the highly-inclined dip of the thick bed in which the great fragments of limestone, often weighing several tons, occur on the north of this arch, we are led to consider that its present acute form must have been due to the exertion of a disturbing force subsequently to the formation of this lowest accumulation of fragments; for both they and the contents of the conglomerates (*d*) immediately adjacent to them could scarcely have been accumulated at the high angle at which we now find them. As we are not to suppose that the contorted and disturbed condition of the grauwacke and carbonaceous series of the district was produced at

one single movement, but rather that the squeezing, rending, and adjustment of the beds to new conditions was the result of several movements, geologically contemporaneous, inasmuch as the cause which produced them acted at one geological period, the limestone on the outside of the arch may have been dislocated, and even reduced to large fragments, on the northern side, when the curvature was less, and the whole may have been squeezed into a more acute arch subsequently to the first deposit of conglomerates. Whenever the arch was produced, great pressure was

Fig. 28.

evidently exerted upon the rocks composing it; for we find blocks of limestone, as shown in the annexed sketch (fig. 28), fairly squeezed into the shales on the south side.

That no small force has been exerted upon the stratified rocks of this part of the district prior to, or during the production of, the lower part of the new red sandstone series can be readily seen in many places; and considerable dislocations of the limestones on which it rests can also be observed in the range of the Chudleigh limestone where this series reposes upon it on the west side of Haldon Hill, similar to those occurring at Petit Tor, the cracks produced at that time in both localities being partly filled with the finer matter of the conglomerate, where it has been able to penetrate, and by the usual coatings of carbonate of lime where it has not, both kinds of filling up being occasionally observable in the same fissure*. The contorted limestones of Hope's Nose

* A fissure filled by the matter of red conglomerate, and occurring in the limestone on the east side of the Petit Tor arch, is represented p. 363, fig. 93, of the Geological Manual, third edition.

and Torquay afford evidence that the great squeezing forces have not been confined to the beds of the carbonaceous series in this part of the district.*

The mode in which the red sandstone series overlies the pre-existing rocks in the vicinity of Torbay, and thence towards the Teign on the north, will be seen by reference to the maps, where it will be observed that the limestones, slates, sandstones, and trap rocks of Torquay, Tor Moham, and St. Mary Church form an island surrounded by this series, a triangular mass of the latter being wedged in it by the arch at Petit Tor and by the great fault near Babbacombe. A small portion of limestone rises through the covering of red conglomerate and sandstone between this island and the main body of older rocks that appears at Abbots Kerswell; and other small patches come up through this series at Gallows Gate and Compton, where the red sandstone and conglomerate stretch westward in a tongue to the high road from Totnes to Newton Bushell. The Paington beds communicate with the red sandstones and conglomerates of Tor Moham and King's Kerswell by means of a very narrow stripe skirting the cliffs at the bottom of Torbay near Livermead; and their unconformable position to the grauwacke beneath them is well exhibited near Collaton Kirkham. The rock of these minor districts is generally a conglomerate or breccia intermingled with red sandstone, the former prevailing, and composed of fragments or rounded pebbles of the older deposits: pebbles of red quartziferous porphyry or igneous rocks, of the kinds previously noticed as associated with the series under consideration, becoming more abundant in the conglomerate towards the Teign. At the Corbons rocks, in Torbay, and in the line of beds which crop out

* The whole coast from Hope's Nose to Petit Tor is one of considerable geological interest. At Hope's Nose, as noticed in the text, we have evidence of the great squeezing forces employed in the contortions there seen, and which we have elsewhere figured (Geol. Trans., vol. iii., second series). On the southern side of the same point there is an excellent example of a raised beach, discovered by Mr. Austen. At the Black Head we find a portion of trap rock overlying broken beds of slate and limestone (well seen in the cliff), the latter having been apparently altered by the heat of the superincumbent greenstone, the veins in which near the limestone are calcareous. Veins of trap are observed running in the slate beneath the limestone, including fragments of the slate at Babbacombe. A great fault occurs between Babbacombe and St. Mary Church, by which the red conglomerate and sandstone on the north are brought into vertical contact with limestone, slate, and trap on the south; and at Petit Tor we have the section described in the text.

between Holloway Hill and Watcombe, crystals of Murchisonite* occur somewhat frequently among the cement of the conglomerate.

The coast from Petit Tor to Culverhole Point, between Seaton and Lyme Regis, affords an excellent section of the red sandstone series, as developed in South Devon, from the lowest to the highest beds. If measured in the usual manner across the various strata, as they respectively rise on the coast, with every allowance for the prolongation of the series by means of numerous faults that, as a whole, throw the country down to the westward, again bringing beds to the level of the sea, which without these faults would have disappeared upwards, the collective thickness of the mass would be very considerable.

From Petit Tor to Dawlish, though red sandstones are occasionally mingled with the conglomerates, the latter greatly prevail, and the cementing matter is somewhat calcareous: so much so in the vicinity of the Parson and Clerk Rocks, between Teignmouth and Dawlish, that druses or small cavities in it are lined with crystals of carbonate of lime. This calcareous, or rather magnesio-calcareous cement (for carbonate of magnesia appears also mingled in it), is to be traced towards the conglomerate of Heavitree, near Exeter—not, however, very continuously, but by means of patches here and there exposed.

Near Dawlish, where the rocks are traversed by numerous faults, red sandstone begins to prevail in abundance, and increases, though here and there mingled with conglomerates, to Budleigh Salterton, beyond which, towards Sidmouth, red sandstone beds are chiefly found,† becoming gradually intermingled with red marl; so that at Branscombe the latter almost constitutes the sole rock, containing a small portion of gypsum. The red marls of Seaton may be regarded as the Branscombe beds again brought up by curvature under the chalk and green sand of Beer, and continued thence to the cliffs near Axmouth.

* This mineral contains, according to the analysis of Mr. R. Phillips—silica 68·6, alumina 16·6, and potash 14·8: a composition closely approximating to felspar; Murchisonite being represented, according to Dr. Thomson, by the formula $3AlS^{3\frac{1}{2}} + KS^{3\frac{1}{2}}$, and felspar by that of $3AlS^{3} + KS^{3}$.—(Outlines of Mineralogy, &c., vol. i. p. 289, 292.) The same mineral occurs in the conglomerate of Heavitree, near Exeter.

† Buff-coloured and yellow beds are sometimes intermingled with the red, as may be seen on the road between Starcross and Exeter; but such strata are not common.

From the Axe to Culverhole Point there is a fine exhibition of the upper part of the series, the red marls gradually becoming mixed with others that are blue, greenish, and of different light-coloured tints, and which crown the whole and support the lias. Unfortunately, masses of chalk and green sand, fallen from the higher part of the cliffs, conceal the junction of these two rocks, and it is not easy to see whether they do or do not graduate into each other in the manner observable near Watchet and Taunton. Judging, however, from that which can be observed at Culverhole Point and at Charlton Bay, still further east, where the upper variegated beds are brought in for a short distance by a fault, we should be disposed to consider that the red sandstone series and lias did here also pass into each other.

The inland section obtained from Exeter to the Black Down Hills, and among the valleys in those hills, agrees very closely, as might be expected, with that exhibited on the coast. It was formerly stated that in the northern part of one of those valleys, that of the Yart, the red sandstone series passed under the lias, showing the boundary between these rocks in that direction. For about four miles to the southward in the same valley, between Howley and Yarty House, the lias is not seen, and the boundary of the red sandstone series would appear to bend considerably to the eastward beneath the covering of green sand, as the lias has not been found in the tributary valley of Furley or Rocky, on the north of Membury. From Yarty House and Beckford the boundary of the red sandstone series may readily be seen to cross the valley of the Axe near Axminster, the variegated marls of the higher part being very conspicuous under the line of lias. Though the boundary-line is concealed on the south of Axminster by the overlap of the green sand of Trinity Hill, a small patch of lias, visible at the head of the Bruckland valley, near Combe Pyne, shows that it runs in a slightly undulating manner beneath its burden of green sand and chalk to Culverhole Point.

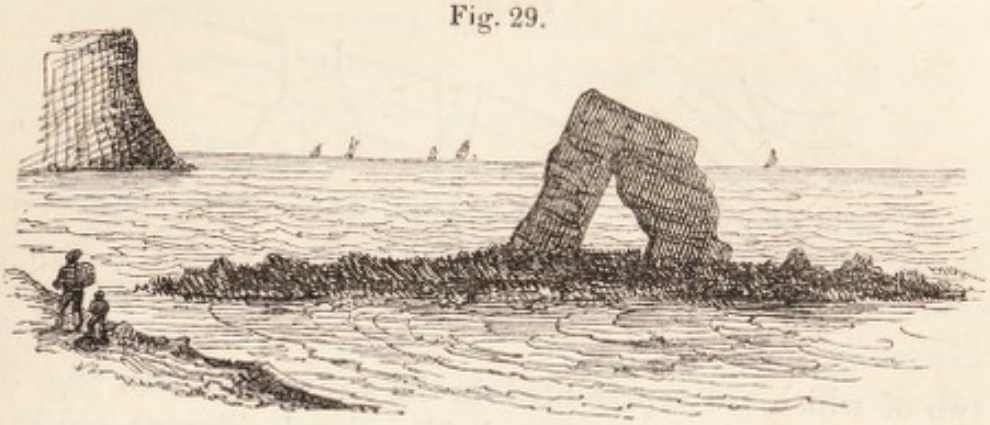
In addition to the mass of red conglomerates, red sandstones, and marls, both red and variegated, above noticed as sloping beneath lias on the east and resting upon a variety of rocks on the west, along a very irregular line from Torbay on the south to Minehead on the north, and in addition also, to the rocks occupying the gulf at Porlock and Holnicote, so near Minehead that

they may be considered to be connected with the main mass on the east, more particularly by the scattered patches of red conglomerate and sandstone in the valley between Dunster and Timberscombe, we find three detached portions of the red sandstone series (one on the north coast and two on the south coast of Devon), which become highly interesting, as they carry the original deposit much further westward in the district than we might otherwise suppose.

The northern patch occurs at Portledge Mouth and Peppercombe, in Bideford Bay, about sixteen miles from the nearest red sandstone and conglomerate at Hatherleigh (itself an outlying portion of the long stripe extending from Crediton to Jacobstow), and about thirty-three miles in a direct line from the red sandstone and conglomerate of Porlock. The area occupied by this patch is extremely limited, as will be observed by a glance at the maps, and is divided into two portions by a projecting point of the carbonaceous grits and shales on which it rests, and which are themselves chiefly red in this locality. The larger portion fills the valley from Portledge to the sea, and good sections of it are seen along the coast and in the course of the streams flowing to Portledge Mouth. The rock is principally a conglomerate composed of portions of the subjacent grits and slates, upon the edges of which it is seen to rest unconformably, the conglomerate filling up all the uneven edges of the older rocks. Towards Peppercombe yellow magnesian limestone is developed among these rocks, not forming regular beds, but separating from the mass in a concretionary manner in given lines: a fact of considerable value, as it exhibits a continuation of the magnesio-calcareous character of the lower part of the red sandstone series to the westward.

The two southern patches occur in the South Hams; one at Slapton, in Start Bay, and the other between the Bolt Tail and Thurlestone, in Bigbury Bay. It will be observed that these two small patches bear about east 10° north, and west 10° south from each other, and are eight miles apart. We have evidence in Thurlestone rock, represented in the next page (fig. 29), that the conglomerate of Bigbury Bay once extended further westward, above the level of the sea, than we now find it, this rock being formed of an isolated piece of red conglomerate of the same kind

Fig. 29.



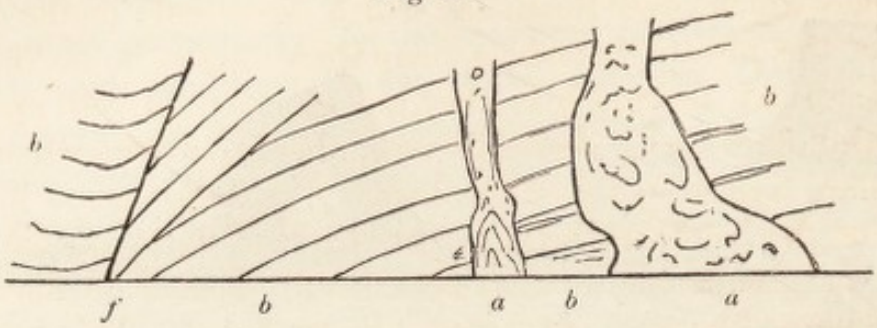
as that on the adjoining coast at the Garrats, left standing in the sea, with an arch through it, upon the highly-inclined edges of argillaceous slates of the grauwacke series. The Thurlestone Rock and Garrats red conglomerate dips seaward, and is seen to be traversed, where it rises upon the slates to the northward, by a double fault, letting down the conglomerate slightly.

The Slapton patch is chiefly arenaceous, and good sections of it are obtained in the west part of the village. It dips seaward at a moderate angle, and is observed to terminate somewhat abruptly against the argillaceous slate that bounds it inland on the top of the hill leading to Pool, and on the road to Watergate.

In addition to these outlying patches of the red sandstone series, a porphyritic rock occurs at Cawsand, in Plymouth Sound, ranging thence towards Redding Point, which in general aspect resembles some of the igneous rocks associated with this series in the neighbourhood of Exeter and Tiverton. It appears a somewhat earthy compound of felspar and quartz, containing crystals of mica, and more rarely of felspar, of a reddish colour in the mass, mixed with occasional blueish green spots. It is much traversed by joints, and has a coarsely-laminated structure towards the east, becoming as much laminated as the slates among which it runs in the veins, when the latter are small: in such cases changing its common red colour for a light brown, stained by oxide of iron.* That it has burst through the grauwacke red sandstones and slates among which it appears seems evident from the fractured and disturbed condition of the beds it traverses on the east of the chief mass, and from the fissures through them filled by

* One of these veins will be represented, in another part of the Report, under the head of divisional planes.

Fig. 30.



it, two of which are represented in the annexed section (fig. 30), *a*, *a* being dykes of this rock,* dividing hard siliceous red sandstone, *b*, *b*, *b*, *b*, in the face of the cliff under West Maker Church, cut also by a fault, *f*. Though unable to adduce direct proof, we are inclined to refer this porphyry, from its general character, to the date of the lower part of the red sandstone series, and to infer that it may be connected with a portion of that series beneath the sea in the direction of Bigbury Bay, on the coast of which, near Thurlestone, we find the patch above noticed.

Viewed in the mass, the red sandstone series of Devon and West Somerset rests on some great depression on the east, rising to and reposing upon various disturbed beds of older rocks on the west, so as to isolate various portions of them on the outskirts of the main mass, and running among them in a very irregular manner in that direction, sometimes being bounded by higher portions of the older deposits, at others being elevated above them.

When the detritus composing the conglomerates occurs in sufficiently large pieces there is little difficulty in perceiving that, with the exception of some fragments of igneous rocks in South Devon, it is derived from the adjacent and disturbed older beds, or from igneous rocks associated with the lower part of the series; and we infer that the finer portions are more comminuted parts of the same rocks.

It will be readily understood that in searching for the lower sedimentary beds deposited in a depression, the floor of which does not slope away at a moderate angle, but rises somewhat abruptly on the side whence the detritus was derived, the strata first formed, adjoining the abrupt boundary, may be concealed

* The rock in the dyke on the left has a tendency to a concretionary structure near the level of the beach.

by others which cover them, and which, seen only in the higher part of the abrupt boundary, may there appear to be the beds first deposited, inasmuch as they are observed to rest upon the disturbed older rocks, and to be covered only by those which have been since formed. This difficulty may, perhaps, occur in some parts of the boundary between the red sandstone and the older rocks, and conglomerates may occasionally appear to have been first deposited because sandstones are concealed. This would be the case near Wiveliscombe but for the valleys of denudation which cut into the lower sandstones; for if we fill up the valley represented in the section, fig. 25, p. 198, beds of conglomerate would cover up the sandstones and be seen resting, as apparently the lowest rocks in the series, upon the older and disturbed deposits. There may be, therefore, some ambiguity respecting the relative ages of some of the outlying conglomerates, such as those in Bigbury Bay, at Portledge, Hatherleigh, Slantycombe (near Hockworthy), and other places, and perhaps also of some beds in the long stripe between Crediton and Jacobstow; but, taking a variety of sections along the boundary of the main mass of the red sandstone series on the west, arenaceous beds prevail in the lowest parts (varying in depth from 20 or 30 to 180 or 200 feet), from the Bristol Channel, on the north of the district, to the vicinity of Holcombe Rogus, after which conglomerates generally constitute the lower beds to the southward.

From the Bristol Channel to Sampford Peverell, near Tiverton, the lowest beds, passing through the channel between the Quantocks and Exmoor, are covered by conglomerates, the cementing matter of which is generally magnesio-calcareous, and often abundant.* Between Sampford Peverell and Exeter the mode of occurrence of the red sandstone deposits along the irregular boundary-line on the west renders it difficult to trace the run of particular beds, and, therefore, though calcareous matter is occasionally detected, those beds in which it is found are not readily identified, in a satisfactory manner, with the magnesio-calcareous conglomerates that range from the north to Sampford Peverell. From the vicinity of Exeter to the Parson and Clerk Rocks, between Teignmouth and Dawlish, the deposits which

* The red conglomerates on the south and east of the Quantocks are by no means characterized by the presence of calcareous matter in their cement; it is, however, occasionally detected in it in very small quantities.

possess calcareous matter in their cement would agree in general position with the Wiveliscombe, Milverton, and Stogumber beds on the north.

Should the breccias and conglomerates with a magnesio-calcareous cement, and the beds composed of the matter of this cement alone, which rest upon Worle Hill, near Weston-super-Mare, and upon Bleadon Hill, and are known from the descriptions of Dr. Buckland and the Rev. W. D. Conybeare* to occur so frequently in connexion with the adjoining Mendip Hills and in the neighbourhood of Bristol, be equivalent to the conglomerates of Wiveliscombe, Milverton, Stogumber, Williton, and other places, some interval may have elapsed during which red sandstones and conglomerates were deposited in Devon and West Somerset before they were formed, these beds overlapping and concealing others accumulated in deeper situations.

It certainly does not follow that the mere presence of magnesio-calcareous cement should characterize a particular deposit of beds over this area, for it may readily have happened that the conditions for this cement existed first in the localities where calcareous rocks, many of which contain magnesia, constituted the floor on which the fragments now in the conglomerate were rolled about, such fragments being chiefly limestones. Whether the beds containing this cement are exactly contemporaneous or not, calcareous matter, associated with carbonate of magnesia, occurs among the conglomerates of the lower parts of the red sandstone series in so many parts of this district that it becomes a circumstance worthy of attention.†

Above the beds characterized by the presence of magnesio-calcareous matter, in sufficient quantity to be worthy of notice, arenaceous deposits become more prevalent throughout the whole area occupied by the red sandstone series of the district, passing into red marls, which are throughout crowned by variegated marls, the higher part of the red marls being gypseous in places.

* Observations on the South-western Coal District of England, Trans. Geol. Society of London, second series, vol. i.

† In general the conglomerate, commonly termed dolomitic conglomerate (on account of the mineral character of its cement), in the Mendip Hills and Bristol district, contains the largest and commonly rolled fragments in the lowest parts, the included pebbles or fragments becoming smaller in the higher part. The matter of the cement, when free from pebbles or fragments, forms beds named dolomitic or magnesian limestone.

Though only noticed in a few localities, this latter character may be more common than is suspected, for, without the coast sections on the Bristol and English Channels, it is not very observable, even near Watchet, where the gypsum is most abundantly detected. Scarcely a suspicion that gypsum occurred in the red marl of South Devon would exist without the coast section near Branscombe, so relatively small is the quantity there found.

Judging from the sections obtained from the base of the series to the lias in the vicinity of Williton on the north, and from Babbacombe Bay to Culverhole Point on the south, making a fair allowance for faults, the thickness of the whole deposit is far more considerable on the south than on the north. And this seems equally true if we take the thickness of the beds on the east of the Quantocks instead of those opening out of the trough near Williton. Considering that the whole deposit occupied a given time in forming, it would appear that less detritus was accumulated in portions of that given time on the north than on the south, which not only shows that there may have been a greater depression ready to receive it on the south, but also that more detrital matter was from some cause drifted into it.

The chief difference in the mass is exhibited towards its base. Among the lower beds on the north we alone find portions of the pre-existing and adjoining sedimentary rocks when the fragments or pebbles are sufficiently large to show whence they may have been derived, while on the south we see fragments of quartziferous porphyries, and of the igneous rocks previously noticed, mingled with pebbles or angular fragments of the adjacent older rocks. Not only do we find such fragments, but also igneous rocks themselves in places associated with the conglomerates and sandstones, in a manner indicative of their eruption at the time during which the accompanying detrital rocks were formed. Near Tiverton the igneous rocks would appear to have been ejected after a certain thickness of conglomerate had been accumulated, the igneous action having subsequently commenced. Near Exeter, igneous action seems to have accompanied the earliest deposits, for not only do we there find the igneous rocks resting unconformably upon the carbonaceous system, and apparently supporting the mass of the red sandstone series, which may, however, merely have arisen from the molten liquid rock

overflowing and overlapping some previously formed detrital beds; but the lower conglomerates also in that direction generally contain fragments of similar igneous rocks, which have not been found isolated among the older adjacent rocks from Torbay to Tiverton, though they must have burst up through them, and therefore, from denudation, might be exposed without any immediate visible connexion with the red sandstone series, a circumstance which we suspect has occurred at Cawsand.

It will be observed, by reference to the maps, that the igneous rocks associated with the lower part of the red sandstone series near Exeter, Crediton, Thorverton, Kellerton, Silverton, and even near Tiverton, occur in the prolonged direction of the granitic bosses and elvans extending from the Scilly Islands to Dartmoor, themselves apparently ranging in a line through which trappean matter had been previously erupted.

We have seen that in the district under consideration the carboniferous limestones on the north, and the carbonaceous deposits and grauwacke of Devon and West Somerset are covered unconformably on the east, after having been bent, contorted, and tilted up, by the conglomerates, sandstones, and marls of the red sandstone series, and we have inferred that the granitic eruptions of Cornwall and Devon accompanied, and may in part have produced, by displacement, some of the bends, contortions, and upliftings of their constituent beds. We are consequently led to inquire if the forces which caused the granitic eruptions and disturbed the pre-existing sedimentary accumulations may not have produced conditions under which the lower part, at least, of the red sandstone series was formed.

If we imagine the pre-existing sedimentary beds to have been thus disturbed beneath water, it could scarcely happen but that such water would have been violently agitated, and even supposing that the granitic eruptions, and the disturbance of the sedimentary beds with their associated trappean rocks occurred chiefly beneath the atmosphere, the neighbouring seas must also have been thrown into violent motion. The destructive effects caused by waves, produced during common earthquakes, are sufficient to show the power of water thrown upon land under conditions insignificant when compared with those we have supposed to have existed. If such effects be combined with the abrading power of

a weighty body of water thus disturbed upon the bottom supporting it, the mass of detritus formed, and mechanically suspended, would be considerable.

We have seen that there were at least two periods of granitic eruptions in Devon and Cornwall, and it is by no means certain that there may not have been a long period during which granite may have continued to have been protruded at intervals through the grauwacke and carbonaceous series. Even, therefore, if we suppose that the igneous rocks associated with the lower part of the red sandstone series were ejected during this period, we feel at a loss to refer their eruption to any particular part of it. The matter of these rocks seems to differ little but in the mode of crystallization from the granitic rocks on the westward; indeed, the quartziferous porphyry near Dunchideock closely resembles some elvans in all except colour, which may readily have been derived from the iron of the associated red sandstones and conglomerates. It may be supposed that the glassy felspar contained soda, as many glassy felspars are found to do; but it has not yet been ascertained by analysis whether the large crystals in some of the fragments of porphyry included in the conglomerates may not be Murchisonite felspar, which does not contain soda. The crystals of Murchisonite disseminated through the cement of the conglomerate near St. Mary Church and other places much resemble it. Even supposing that it should contain soda, we are yet uncertain that the granitic rocks of Devon and Cornwall may not also include soda felspars mingled with the others.

With regard to the porphyries with large crystals of felspar which we do not find in place, they may readily have formed portions of igneous masses covered up by the red sandstone series, and it is by no means improbable that such masses are thus concealed. They may also have been ejected in the manner in which large rocks are now often thrown out from volcanos during eruptions, becoming intermingled with fragments of the igneous rocks, parts of which are still uncovered, and with the detritus of the adjacent and subjacent older and disturbed sedimentary deposits, the earthquakes and rending of rocks accompanying the eruptions adding, by the action produced in the water, very considerably to the rolling and dispersion of the detritus in mechanical suspension at different times. The successive deposits, as shown in the respective beds, would appear to have been

drifted by variable forces, sometimes large fragments of porphyry and other igneous rocks associated with rolled or angular fragments of the older beds seem to have been violently driven forward, the pebbles and fragments occurring in the beds without regard to specific gravity; at others more order in the latter respect is observable, and even beds of fine detritus intervene, all apparently pointing to very different velocities of water as dispersive power, such as might readily arise from igneous explosions of variable intensity at different intervals near or beneath the water, or from the variable agitation produced by movements of the earth on the large scale.

From the absence of pebbles of granite resembling that of Dartmoor, and the occurrence of rocks of the same general composition, though crystallized differently, in masses and even beds, and the association of the latter with sands not unlike volcanic sands, we are led to infer that the granite of Dartmoor may not have been covered by water when the red sandstone series of the district was formed and the igneous rocks associated with it ejected; that the igneous rocks of the lower part of the red sandstone series were erupted beneath water adjoining land, through which the granitic rocks of Devon and Cornwall were protruded, and that the disturbance caused by these protrusions and during the fracture of the country when the fissures filled by elvans were formed, were the earliest causes of the movement of waters which ground down the rocks into at least a large portion of the conglomerates and sandstones in the lower parts of the red sandstone series. Subsequent geological events may indeed have so altered the relative levels that it may now be difficult even to approximate towards a view of the area which may have then been dry land; but when we recollect that the coal-measures, the rock which immediately precedes the red sandstone series in the succession of beds in the adjoining districts of South Wales and Bristol, are marked by the presence of an abundant terrestrial vegetation, probably the extent of dry land may have been considerable on the north, even anterior to the protrusion of the Cornish and Devon granites.

Though from the mass of matter which has been removed from the face of the red sandstone series where now exposed in the district, and from the outlying patches of it here and there observable, we cannot be well satisfied that the area now occupied

by this series even approximates towards that once covered by it; yet when we regard the mode in which it surrounds the Quantock Hills and other isolated minor portions of older rocks, and note the trough-like manner in which it runs in a channel between the Quantocks and Exmoor, or into gulfs at Porlock, Tiverton, and some other places, we seem to perceive that it may have been formed in waters bounded on the west by a coast with outlying islands. When we include the range of the Mendip Hills and Worle Hill, and the mode of occurrence of the red sandstone series at their bases, we seem to find the remains of other isolated lands in that direction which rose above the waters in which this series may have been formed, while the outstanding patches of Portledge on the north, and Thurlestone and Slapton on the south, would lead us to suspect that it may be continued beneath the waters of the Bristol and English Channels for a considerable distance on the flanks of, if not around, the grauwacke, carbonaceous system, and granite on the west.

The absence of organic remains throughout the red sandstone series of this district is one of its marked characteristics. With the exception of a few fish-scales and some pieces of fossil-wood in the higher part of the variegated marls near Culverhole Point and Charlton Bay, close under the lias, in which, as is well known, fossils are very abundant, we have not found any organic remains either animal or vegetable, or heard of any having been discovered in it. Not far from the district, however, on the east of Durdham Down near Bristol, the remains of Saurians (Thecodontosaurus and Palæosaurus), have been obtained by Dr. Riley and Mr. Stutchbury in the conglomerate with the magnesio-calcareous cement, several of the bones being in actual contact with, others one or two feet above, the subjacent carboniferous limestone; and it is stated that the fragments entering into the composition of the conglomerate "are of considerable size, angular, and without any appearance of having travelled far."*

As far, therefore, as the evidence extends, reptiles which existed prior to the production of the magnesio-calcareous conglomerates near Bristol, and fish that lived in the waters and plants drifted from land when the conditions under which it was formed were about to cease, are the only remains of life yet known to have been

* West of England Journal of Science and Literature, 1835—6, p. 85.

entombed in the red sandstone series within the district under consideration, or in that adjoining it on the north-east. We can readily conceive that the reptiles sported on the shores formed of pre-existing rocks, and that the fish in the higher beds were among the first of those so abundantly enveloped afterwards by the mud of the lias above them, the plants being merely drifted from dry land, which we have considered to have existed at no great distance during the deposit of the whole series. It may, indeed, be premature to infer, because they have not been hitherto detected, that organic remains may not hereafter be discovered by some fortunate section in some thin obscure beds in great numbers; and it certainly does not follow because such remains are not found, that animal and vegetable life did not exist in the waters or on the adjacent dry land within the district, since we know that fossil plants, zoophytes, conchifers, molluscs, fishes, and a saurian, have been discovered in the continuation of the same series in Central and Northern England, and that vegetable and animal remains occur far more abundantly in it in the continental parts of Western Europe; these remains may not be detected, because conditions for their preservation have been unfavourable.

In like manner we must not too hastily infer, because conglomerates characterize by their presence the lowest deposits, sandstone the central, and marls the upper beds, that the whole is a mere settlement of a great mass of detritus drifted about in agitated water, the power of which, to keep it suspended, gradually diminished from a return to a tranquil state, the finer parts being last deposited, and that, therefore, no comparatively great length of time would be required for the settlement of the whole; for in parts of Western Europe, where we have a continuation of the same series, and the accumulated detritus has even been thicker than in Central England, we have evidence, more particularly in the calcareous deposits named muschelkalk and zechstein (the latter considered as an equivalent of the magnesian limestone of Central and Northern England), that various animals were created and became in part entombed in a manner pointing to a long lapse of time.

Whatever length of time may have been required for the accumulation of the great red sandstone series of Europe, taken as a whole, and though in many places within the area occupied by it a variety of animals lived at different times in the waters beneath which it

was accumulated, and that in several localities it graduates downwards conformably into older beds, marking an absence of disturbance in the subjacent rocks in such localities, all the older deposits have been contorted, bent, or otherwise disturbed in the district under consideration prior to the formation of the red sandstone series in it; and this series occurs among them in a manner which would lead us to suppose that in the waters wherein it was formed animal life was, at least, extremely rare, and that while a large portion of the existing dry land was covered by these waters other portions rose above them as islands of various sizes, igneous products having been vomited forth during the earlier deposits of the series on the south-east side of the land on the west, while similar eruptions did not occur on the north-east or north.

CHAPTER VIII.

LIAS AND INFERIOR OOLITE. CRETACEOUS SERIES. SUPRACRETACEOUS ROCKS.

Lias.

THE argillaceous and calcareous deposits known as the *lias*, succeed the variegated marls of the red sandstone series in the ascending order, and are so generally uniform in the composition and relative arrangement of their constituent parts, that a section of a portion of them in one part of the district will nearly represent that in another.

The most instructive section of these deposits is to be obtained near Lyme Regis, inasmuch as in the vicinity of that place we find their whole thickness included between the variegated marls on which they rest and the sands of the inferior oolite by which they are covered. This section is not fully seen within the district strictly under consideration, but it is readily obtained by means of the cliffs between Culverhole Point, on the west of Lyme Regis, and Bridport Harbour, a distance which includes a small portion of country on the east of it. The sandy beds of the inferior oolite are, indeed, observed near Ilminster, Chard, Ford Abbey, and Hawkchurch, resting upon lias within the district, but from the manner in which they are covered up by a great overlap of chalk and green sand, and from the generally obscure natural sections presented, the detail cannot be well studied.

The following is a general section of the lias in the vicinity of Lyme Regis, with a portion of the beds on which it rests and by which it is covered :—

		Feet.
Part of the Inferior Oolite.	*a.* Ferruginous yellow sand and sandstone . .	180
	b. Bed of grey marl	
	c. Ferruginous yellow sand and sandstones with mica.	

		Feet.
Lias.	*a.* Marls and slaty marls, with several beds of indurated marl and earthy limestone in the lower part, micaceous in the higher	350
	b. Irregular bed of limestone, with nodular concretions, frequently containing *Ammonites*	2
	c. Slaty marls, with several thin beds of indurated marl	67
	d. Slaty marls, containing small crystals of selenite	32
	e. Indurated marl, containing small plicated *Terebratulæ*	4
	f. Slaty marls	18
	g. Sixty-five grey limestone beds, from two to ten inches in thickness, and varying from earthy to compact, alternating with marls and slaty marls, from the thinnest seam to four or five feet in thickness	75
	h. Four thin beds of yellowish white limestone, alternating with thin seams of marl of the same colour	2
	i. Yellowish white limestone, earthy, marly, and compact, in obscurely divided beds	18
	k. Three beds of dark-coloured marl and slaty marl, alternating with three beds of grey limestone	12
	l. Dark slaty marl	7
Upper part of the Variegated Marls.	*a.* Light blueish green marl	8
	b. Alternations of dark-coloured marls with light-coloured indurated marl, some of the latter being calciferous	13
	c. Light-coloured marl with gypsum	8
	d. Dark-coloured marl	2
	e. Alternations of light blueish green marls, with light-coloured marls	15
	f. Indurated marl, the top and bottom of the bed of a red tint	2
	g. Alternations of blueish green and light-coloured marls, becoming mixed with beds of red marls in the descending section	30

The lias of Lyme Regis contains a great variety of organic remains, of which the following is a list of such as have come to our knowledge :—

PLANTS.

Otopteris obtusa . . . . Lindley and Hutton, Fossil Flora, vol. ii. pl. 128.
Cycadeoidea pygmæa . . L. & H., Foss. Flora, vol. ii. pl. 143.
Araucania peregrina. . . L. & H., Foss. Flora, vol. ii. pl. 88.
Strobilites elongata . . . L. & H. Foss. Flora, vol. ii. pl. 89.
Also several other plants which have not been described.

CORALS.

A few casts of one or two undetermined species have been found in the white lias of Pinhay Bay.

RADIARIA.

Cidaris Bechei . . . . . Broderip, Geol. Trans., 2nd series, vol. v. p. 174, and vol. ii. pl. 4, fig. 5.
Pentacrinites subangularis . Miller, Nat. Hist. Crinoidea, p. 59.
——— *Briareus* . . Miller, Nat. Hist. Crinoidea, p. 56.
——— *basaltiformis* . Miller, Nat. Hist. Crinoidea, p. 62.

ANNULATA.

Serpula . . . . . Rare. We have seen a specimen upon a *Belemnite*.

CONCHIFERA.

Spirifer Walcotii. . . . Sowerby, Mineral Conchology, pl. 377.
Terebratula crumena. . . Sow., Min. Con., pl. 83, fig. 3.
——— *serrata* . . . Sow., Min. Con., pl. 503, fig. 2.
Gryphæa incurva. . . . Sow., Min. Con., pl. 112, figs. 1, 2.
——— *Maccullochii* . . Sow., Min. Con., pl. 547, figs. 1—3.
——— *obliquata* . . . Sow., Min. Con., pl. 112, fig. 3.
Plicatula spinosa. . . . Sow., Min. Con., pl. 245.
Plagiostoma giganteum . . Sow., Min. Con., pl. 77.
——— *Hermanii* . . Voltz.
Avicula inæquivalvis. . . Sow., Min. Con., pl. 244.
——— *lanceolata* . . . Sow., Min. Con., pl. 512.
Modiola Scalprum . . . Sow., Min. Con., pl. 248, fig. 2.
——— *Hillana* . . . . Sow., Min. Con., pl. 212, fig. 2.
——— *lævis*. . . . . Sow., Min. Con., pl. 8.

Undetermined species of *Pinna*, *Ostrea*, *Cucullæa*, *Unio*, *Astarte*, *Pecten*, and *Nucula*.

MOLLUSCA.

Rotella expansa . . . Sow., Min. Con., pl. 273.
Pleurotomaria Anglica . . Sow., Min. Con., pl. 142.
Trochus imbricatus . . . Sow., Min. Con., pl. 272, fig. 3, 4.
Belemnites aduncatus . . Miller, Geol. Trans., 2nd series, vol. ii. pl. 8, fig. 6, 7, 8.
——— *elongatus* . . Miller, G. S. 2nd series, vol ii. pl. 7, figs. 6, 7, 8.
——— *longispinus* . Miller, G. S. 2nd series, vol ii. pl. 8, figs. 1, 2.
Orthoceratites? elongatus . De la B , Geol. Trans., 2nd series, vol. ii. pl. 4, fig. 4.
Nautilus intermedius . . Sow., Min. Con., pl. 125.
——— *striatus* . . . Sow., Min. Con., pl. 182.
Ammonites heterophyllus . Sow., Min. Con., pl. 266.
——— *Henleii* . . . Sow., Min. Con., pl. 172.
——— *communis* . . Sow., Min. Con., pl. 107, figs. 2, 3.
——— *planicostatus* . . Sow., Min. Con., pl. 73.
——— *fimbriatus* . . Sow., Min. Con., pl. 164.
——— *Bucklandi* . . Sow., Min. Con., pl. 130.
——— *obtusus* . . . Sow., Min Con., pl. 167.
——— *Walcottii* . . Sow., Min. Con., pl. 106.
——— *armatus* . . , Sow., Min. Con., pl. 95.
——— *Brookii* . . . Sow., Min. Con., pl. 190.
——— *Bechei* . . . Sow , Min. Con., pl. 280.
——— *stellaris* . . . Sow., Min. Con., pl. 93.
——— *Greenovii* . . Sow., Min. Con., pl. 132.
——— *Loscombi* . . Sow., Min. Con., pl. 183.
——— *Davæi* . . . Sow., Min. Con., pl. 350.
——— *Birchii* . . . Sow., Mem. Con.. pl. 267.

Ammonites lævigatus . . Sow., Min. Con., pl. 570, fig. 3.
——— *latæcostatus* . . Sow., Min. Con., pl. 556.
Sepia, ... Remains of, with ink-bags preserved.
——— . . . . . Beaks of.

CRUSTACEA.

Colëia antiqua . . . . Broderip. Geol. Trans. 2nd series, vol. v., pl. 12, figs. 1 and 2.

A macrourous decapod, allied to the Salicoques of Latreille.—Broderip, Geol. Trans., 2nd series, vol. v., p. 172, pl. 12, figs. 3 and 4.

Other indescribed crustaceans.

FISH.

These have lately been found by M. Agassiz to be of numerous species. The following list has been kindly prepared for us by Sir Philip Grey Egerton, Bart., from the notes of M. Agassiz, either published or still in MS., upon specimens in Sir Philip Grey Egerton's own collection, in that of Viscount Cole, or in those of the Misses Phillpot and Mr. Marder, of Lyme Regis.

ORDER I. THE PLACOIDS.

The Cestracionts.

Acrodus gibberulus . . .	MSS.	C. P.*
——— *latus*	MSS.	P.
——— *nobilis*	Agassiz, Poissons Fossiles, tom. 3, tab. 21.	C. P. E.
——— *undulatus* . . .	MSS.	P.
——— *another species* .	MSS. (not yet named)	C. E.
Leptacanthus tenuispinus	Ag., P. F., tom. 3, tab. 27. . . .	C.
Myriacanthus paradoxus	Ag., P. F., tom. 3, tab. 38. . . .	C. E. P.
——— *retrorsus* .	Ag., P. F., tom. 3, tab. 39. . . .	P.
——— *granulatus*	Ag., P. F., tom. 3. tab. 40. . . .	Marder.

The Hybodonts.

Hybodus carinatus . . .	Ag., P. F., tom. 3, tab. 52. . . .	P.
——— *crassispinus* . .	Ag., P. F., tom. 3, tab. 48. . . .	Marder.
——— *curtus*	Ag., P. F., tom. 3, tab. 49. . . .	C. P. E.
——— *ensatus* . . .	Ag., P. F., tom. 3, tab. 51. . . .	P.
——— *formosus* . . .	Ag., P. F., tom. 3, tab. 51. . . .	
——— *grossispinus* . .	Ag., MSS.	C. P. E.
——— *homoprion* . . .	Ag., MSS.	P.
——— *incurvus* . . .	Ag., P. F., tom. 3, tab. 50. . . .	C. P. E.
——— *medius* . . .	Ag., MSS.	P.
——— *pachyprion* . .	Ag., MSS.	P.
——— *reticulatus* . .	Ag., P. F., tom. 3, tab. 50. . . .	C. P. E.
Sphenonchus	Ag., MSS.	P.

The Sharks.

The Vertebræ of a new Genus, Ag., MSS.		P.

The Rays.

Spinacorhinus polyspondylus	Ag., P. F., tom. 3, tab. 42. 43 . . .	C. P. E.

ORDER II. THE GANOIDS.

The Lepidoids.

Dapedius Colei	Ag., P. F., tom. 2, p. 195. . . .	C. P. E.
——— *granulatus* . .	Ag., P. F., tom. 2, p. 190. . . .	C. P. E.

* P shows that a specimen of the species named is in Miss Phillpot's collection, C that it is found in that of Viscount Cole, and E that Sir Philip Egerton possesses it.

Dapedius politus	Ag., P. F., tom. 2, p. 185.	C. P. E.
——— *punctatus*	Ag., P. F., tom. 2, p. 192.	C. P. E.
Tetragonolepis confluens	Ag., P. F., tom. 2, p. 199.	C. P.
——— *heteroderma*	Ag., P. F., tom. 2, p. 206.	C. E.
——— *Leachii*	Ag., P. F., tom. 2, p. 203.	C. P. E.
——— *leiosomus*	Ag., P. F., tom. 2, p. 202.	C. E.
——— *pholidotus*	Ag., P. F., tom. 2, p. 207.	C. P .E.
——— *pustulatus*	Ag., P. F., tom. 2, p. 201.	C.
——— *radiatus*	Ag., P. F., tom. 2, p. 201.	E.
——— *striatus*	Ag., MSS.	P.
——— *speciosus*	Ag., P. F., tom. 2, p. 199.	C. E.
Amblyurus macrostomus	Ag., P. F., tom. 2, p. 220.	P.
Semionotus rhombifer	Ag., P. F., tom. 2, p. 228.	C. E.
Lepidotus fimbriatus	Ag., P. F., tom. 2, p. 247.	C. E.
——— *rugosus*	Ag., P. F., tom. 2, p. 246.	P.
Pholidophorus Bechei	Ag., P. F., tom. 2, tab. 39.	C. P. E.
——— *latiusculus*	Ag., P. F., tom. 2, p. 9.	C. P. E.
——— *limbatus*	Ag., P. F., tom. 2, p. 9.	C. E.
——— *onychyus*	Ag., P. F., tom. 2, tab. 39.	C. P. E.

The Sauroids.

Gyrosteus mirabilis	Ag., MSS.	C. E.
Ptycholepis bollensis	Ag., P. F. tom. 2, p. 11.	C.
Sauropsis (species not named)	Ag., MSS.	P.
Pachycormus heterurus	Ag., MSS.	P.
——— *leptosteus*	Ag., MSS.	P.
——— *macrurus*	Ag., MSS.	P.
Leptolepis Bronnii	Ag., P. F. tom. 2, p. 13.	C. P.E.
——— *caudalis*	Ag., MSS.	C. P.E.
Eugnathus cheirotes	Ag., MSS.	C. P.
——— *leptodus*	Ag., MSS.	P.
——— *mandibularis*	Ag., MSS.	P.
——— *minor*	Ag., MSS.	C. P.
——— *ornatus*	Ag., MSS.	C. P. E.
——— *polyodon*	Ag., MSS.	P.
——— *spinosus*	Ag, MSS.	P.

The Acipensirids.

Cyclarthrus macropterus	Ag., P. F. tom. 3, tab. 44, fig. 1.	C. P. E.

Also, the teeth of an undescribed genus of an undescribed family.

REPTILIA.

Pterodactylus macronyx	Buckland, Geol. Trans., 2nd series, vol. iii., pl. 27.
Plesiosaurus dolichodeirus	Conybeare, Geol. Trans., 2nd series, vol. i., pl. 48.
——— *macrocephalus*	Conybeare.
Icthyosaurus communis	De la B., Geol. Trans., 2nd series, vol. i., p. 43 and 108, pl. 15, fig. 8.
——— *platyodon*	De la B., Geol. Trans., 2nd series, vol. i., p. 43 and 108, pl. 15, fig. 7.
——— *tenuirostris*	De la B., Geol. Trans., 2nd series, vol. i., p. 43 and 108, pl. 15, fig. 10.
——— *intermedius*	Conyb., Geol. Trans., 2nd series, vol. i., p. 108, pl. 15, fig. 9.

Crocodilus?

These organic remains are not equally distributed through the mass of the lias so that we might expect to discover any species in any part of its thickness. On the contrary, the higher portions differ much in their organic contents from the lower. Thus, *Pleurotomaria anglica*, *Trochus imbricatus*, *Ammonites Greenovii*, *A. Bechei*, *Pentacrinites subangularis*, *Cidaris Bechei*, and the remains of *Ichthyosaurus tenuirostris*, most prevail in, if the shells be not almost confined to, the upper beds. *Belemnites* also are far more common in the higher marls, and even are so numerous beneath those which are micaceous, that seams composed of little else than their remains are seen on ledges dry at low tide, at the foot of Golden Cap Cliff, on the east of Lyme Regis. Ammonites are common in the nodular concretions noticed in the section (p. 223) as containing them. *Gryphæa incurva* and *Plagiostoma giganteum* most abound towards the lower part, among the alternations of the lias limestones with marls, and the greatest amount of Saurian remains seems to occur in the marls not far above the lias limestones, and in the higher and central parts of the latter.

The organic remains in the lias of Lyme Regis are not only numerous as regards the species found, but they are abundant also as respects the individuals detected in it, thus presenting a marked contrast with the red sandstone series previously noticed. The sediment deposited during the formation of the higher part of the latter series seems as fine as that thrown down during the production of the lower part of the lias, and we observe nothing indicative of a change in the transporting power of the water, supposing the sedimentary matter to have been all transported during the deposit of both. A difference, therefore, in the velocity of any moving waters which may have carried sedimentary matter, now constituting the higher part of the red sandstone series or the lower part of the lias near Lyme Regis, would not appear to have been included in the causes which have produced so marked a difference in the fossiliferous characters of the two rocks.

The mode of occurrence of the gypsum among the variegated marls would seem to show that the latter may partly, at least, have been deposited chemically. There is much also in their general structure which would not oppose the supposition that they have been partly produced in the manner of chemical precipitates. For the lias limestones also, and their alternating seams and beds of marls, a semi-chemical, semi-mechanical

origin may be considered necessary. Chemical changes in the waters in which both rocks were formed may readily have taken place, producing very different conditions for the existence of animal life in them at different times. Now, though the peroxide of iron which appears, combined with red oxide of manganese, to have coloured so much of the red sandstone series, may not have been soluble in the waters beneath which that series was produced, the iron of the peroxide may readily have existed in a soluble state in them under other combinations, and have been rendered insoluble by chemical changes, so that it was thrown down as a peroxide among the detrital and sedimentary matter then accumulating. Waters in which peroxide of iron was abundantly forming, and thrown down to the bottom, would scarcely, we should conceive, supposing even that no other chemical condition in them was noxious, be favourable to the existence of animal life, more particularly of that which made the bottom of the sea, or the sands and mud immediately beneath, its habitat.

When the lias of Lyme Regis was formed, iron in a state of peroxide was no longer intermingled with the strata then deposited. The beds so strongly marked by it and the red oxide of manganese gradually disappeared, so that the upper deposits of the variegated marls became light-coloured and interstratified with black shale, the light-coloured marls containing a small portion of carbonate of lime. A great abundance of calcareous matter then succeeded, mingled with mud; and no sooner does this calcareous matter appear than we detect organic remains, so that we are forcibly struck with the probability that a change of chemical conditions, in the waters beneath which the red sandstone series and the lias of the district were accumulated, was among the chief causes of their fitness for the animal life created to suit the condition of this part of the earth's surface at that geological epoch.

When we examine into the mode in which the organic remains occur in the lias of Lyme Regis, we soon perceive reason to conclude, as we have elsewhere observed,* that the mass of argillo-calcareous matter of which it is composed has not been suddenly accumulated. The general difference in the organic contents of the higher and lower parts of the rock, and the manner in which

* Geological Manual, 3rd edit. p. 347 (1833).

groups of fossils, often of the same species and of various sizes, occur in seams parallel to the general stratification, show not only that new creations may have taken place during the general deposit of the mass, but also that there were different times during the production of the lias, when marine creatures lived and died, arranged in horizontal groups, as many marine creatures are known to be at the present day, upon matter which then constituted the bottom of the sea, deposit succeeding deposit during intervals in which many marine creatures made the temporary bottoms their habitats. That temporary bottoms from time to time existed, seems also proved by the *coprolites*, or fossil-fæcal bodies, brought to light by the labours of Dr. Buckland,* which sometimes occur in seams at different heights in the lias, showing the surfaces upon which they were dropped. The coprolites also frequently occur isolated in the marls, as if let fall from above during the periods when muddy matter was accumulating upon these temporary bottoms, the creatures from which they proceeded continuing to swim freely in the superincumbent waters both during the accession of muddy matter to the bottom, and when that matter ceased for a time to be accumulated.†

From the manner in which the saurian remains occur, many of the dead animals may be inferred to have remained sufficiently long at the bottom to have had their bones somewhat dispersed, in part, perhaps, the result of removal by the fish and other animals feeding upon the flesh. In a large proportion of cases, however, as we have elsewhere observed,‡ these remains are so beautifully preserved, their bones so well connected, with even the contents of their intestines between their ribs, and with traces of skin upon them,§ that many Ichthyosauri and Plesiosauri must

* For an account of Coprolites and their contents, we refer to Dr. Buckland's memoir upon them in the Geological Transactions, 2nd series, vol. iii. Part i. 1829, and his Bridgewater Treatise, 1836, vol. i. p. 188—197.

† Dr. Buckland observes, in addition to the proof of the intervals between the deposits of the component parts of the lias afforded by many beds having become the repository of coprolites, dispersed singly and irregularly at intervals far distant from each other, "that those surfaces *only* of the coprolites which lay *uppermost* at the bottom of the sea, have often suffered partial destruction from the action of water before they were covered and protected by the muddy sediment that has afterwards permanently enveloped them." Bridgewater Treatise, vol. i., note, p. 307.

‡ Geological Manual, 3rd edit. (1833), p. 346.

§ Magnified representations of the skin of an Ichthyosaurus from the lias of Barrow-on-Soar, Leicestershire, are given in Dr. Buckland's Bridgewater Treatise, vol. ii. pl. 10, figs. A. 2, 3, 4.

have been suddenly enveloped alive, or immediately after death, by the matter of the rock now enclosing them, so that neither their decomposition took place in the water, nor the predaceous animals existing in the same seas had access to their bodies. Fish also are so frequently found entire that we would adopt the same conclusions respecting their remains, so that, while we suppose the lias to have been gradually accumulated, minor accessions to the mass from time to time may have been more suddenly caused. The numbers of Ammonites found under conditions from which we may suspect that the animal was alive and retreated into its shell when overwhelmed with mud, are considerable.

From the structure of the Pterodactyle found in this rock near Lyme Regis, we learn that dry land must have existed sufficiently near to have permitted this singular animal to have flown upon its bat-like wings until it fell into the water, and became buried in mud so speedily that the voracious creatures abounding in the waters beneath which it was entombed did not devour it.* That the animals which inhabited these waters were voracious, we have abundant evidence in the coprolites included in the same deposits with, and even existing amid, the bones of their skeletons, since these coprolites not only contain the indigested scales of the fish, the remains of which are found included in the same beds with the Ichthyosauri and Plesiosauri,† but also the bones of young Ichthyosauri and Plesiosauri, so that the larger animals of the first genus, for the latter could scarcely have swallowed them, must have fed upon the young of their own kind.

We must refer to works dedicated to an account of the anatomical structure of the Pterodactylus, Plesiosaurus, and Ichthyosaurus, for a description of the probable adaptation of the parts of these creatures to particular purposes.‡ It is sufficient for our

* A detailed description, by Dr. Buckland, of the Pterodactylus macronyx, above alluded to, will be found in the Geological Transactions, 2nd series, vol. iii. He considers that this species of singular saurians adapted for flight may have been about the size of a raven.

† "According to Professor Agassiz, the scales of *Pholidophorus limbatus*, a species very frequent among the fossils of the lias, are more abundant than those of any other fish in the coprolites found in that formation at Lyme Regis, and show that this species was the principal food of these reptiles (Ichthyosauri). Buckland's Bridgewater Treatise, vol. i. p. 191.

‡ An excellent summary of the anatomical structure of these creatures, and of the probable adaptation of their parts to particular purposes, will be found in Dr. Buckland's Bridgewater Treatise.

object to know that they all must have breathed air, that the first required dry land to live upon, that the second was adapted rather to live in water in sheltered places than to buffet the waves of a stormy sea, and that the last was a genus of powerful reptiles, some far exceeding in size any saurian with which we are now acquainted, capable of keeping the open waters and seeking its prey among waves as easily as numerous cetaceous animals now do.

The presence of the Pterodactyles and the Plesiosauri, and the occurrence of terrestrial plants, some of which, from the state in which they occur, could scarcely have suffered a long transport from their place of growth, would induce us to consider that dry land may not have been far distant from this lias.

Quitting the vicinity of Lyme Regis and proceeding northwards, we can trace the area occupied by the lias under the Black Down Hills, and in the country extending from Axminster to Chard, prior to the overspread of chalk and green sand in that part of the district, by means of the valleys of denudation which have been cut through the latter rocks. Between Axminster and Chard we indeed see more lias than was exposed at the time of this overlap, inasmuch as the valley of denudation between these two places has laid bare that rock beneath the sands of the inferior oolite, which probably extended over the lias in that locality when the green sand and chalk were deposited.

Emerging from beneath the green sand of the Black Down Hills, fronting the Vale of Taunton, and continued from beneath the inferior oolite near Chard and Ilminster, the lias forms a tract of country occupying several square miles, the continuation of the beds which occur in the direction of Somerton. By making sections across this lias from Stoke Mary and Hatch Beauchamp to Ilminster, it is not difficult to see that there is a very general correspondence with that obtained at Lyme Regis, though the opportunities of studying it in detail are not frequent, nor from the want of natural or artificial exposure are the organic remains so readily obtained. Though much broken by faults, the mass of this lias may be considered to dip towards the south-east.

Near Bridgewater we find lias which rises from beneath the Huntspill levels on the north, and rests upon variegated marls on the south, dipping northward, and extending from Cossington to Walpole. The sands and clays of the levels then cover it up so that its continuation at Pawlet is isolated. Proceeding west-

ward, the sands and clays again conceal the lias, which however reappears at Stockland Bristol, and Otterhampton, extending thence by Stokecourcy and Kilton to East Quantock's Head. Beyond this, in the same direction, its connexion with the Watchet patches of lias are concealed by the sea; and, though the whole is broken by faults, so that intervening portions of the inferior rock are brought to view among the lias (St. Decuman and Rydon), we may regard the lias observable from Cossington to Blue Anchor, on the west of Watchet, as the southern exposed portion of a large mass which occurs beneath the Huntspill and Burnham levels (rising above them at Brent Knole), and extends under the Bristol Channel to the opposite south coast of Glamorganshire, spreading on the east to the northern side of the Mendip Hills, the patches which occur at Culm and Newton, near Wick St. Laurence, and at Lorking, emerging from the sand and clays of the levels, being continuations of it in that direction.

The general characters of the lias in the northern part of the district are much the same as those we have noticed on the south; the limestones may occasionally be less thick, and more marls may here and there prevail, but as a whole there is considerable resemblance between them. Where so much depends upon natural or artificial exposure it would be hazardous to form an opinion, unless these conditions were nearly equal, respecting any differences which may exist in the abundance of organic remains in various situations. In all probability the lias differs in this respect, and in the number of the individuals of the species entombed in different localities, even when those species may not be altogether absent. We may expect that species found in some places may not be discovered in others, since we can scarcely anticipate that it would be otherwise, or that all the creatures existing even upon a moderately-sized area in the waters beneath which this mass of calcareous matter and mud was accumulated would be found in one locality.*

When we search for the dry land on which the plants may have grown, and the Pterodactyles lived, the remains of which are detected in the lias in the district, and near the coasts of which the Plesiosauri may have lurked in watch for their prey, we are somewhat at a loss to know, even approximatively, the distance to

* *Ammonites planorbis*, and *A. Johnstonii*, found at Watchet, have not yet been detected, we believe, on the south.

which the lias extended over the present exposed portions of the adjoining red sandstone series. In parts of the Mendip Hills, on the opposite parts of Glamorganshire, and also within the district between Porlock and Minehead, we find the lias resting upon rocks older than the red sandstone series, and hence we cannot be certain that it may not have covered a very considerable portion of the area now occupied by that series, having been carried away by the various denuding causes which have removed solid matter from that area since the deposit of the lias to the present day. There is an evident disposition in the outline and dip of the lias to conform to the range of grauwacke and carbonaceous rocks on the west, making due allowance for the faults by which it has been broken, and the denudation which it has suffered. From the vicinity of Lyme Regis it ranges northerly to the neighbourhood of Taunton. It then curves away conformably with the projection of the Quantock Hills towards the south-east, and sweeps round the same hills towards Dunster, more closely approaching their northern part near East Quantock's Head and St. Audries. It seems clearly again to conform to the outline of the western parts of the Mendips, and to have run among the outstanding hills of Worle and Middle Hope, on the north.

Taking the levels where it overlaps the red sandstone series near Porlock, on the Mendips, and in Glamorganshire, and allowing for the changes caused by faults, we appear to have a depression above which the Mendip Hills, the Quantocks, Exmoor, and other high land ranging to the southward, were raised, and may readily have formed parts of the dry land from which the vegetation was drifted, and on which the Pterodactyles lived. This higher land may or may not have risen immediately above the waters in which the lias was deposited. When we regard the gradually-diminishing areas in which the various members of the oolitic series seem to have been formed, and consider that upon its highest part, the Portland oolite, we find evidence of the existence of dry land supporting vegetation before the rocks next in the general series were produced, we may probably infer a gradual rise of the whole southern part of England, and probably also of a far more extended area, so that the seas became more and more confined, the lower deposits gradually rising into dry land while the upper were forming. Low shores would thus constantly present themselves, tenanted by the various creatures

which were in part buried beneath the various accumulations that then successively took place.

Adopting the view of gradually-diminishing areas of sea, and the formation of dry land by such decrease, until a portion of western Europe, composed of a large part of the oolitic series and of older rocks, disturbed only prior to its deposit, may have risen above the sea, a large part of the red sandstone series of our district may have formed low land extending from the shores of the coasts against which it was deposited to the margin of the sea on which the lias was formed, the Mendip Hills, the Quantocks, and Exmoor, and the other western high land rising above the low country, as the lias itself and other rocks now rise above the great Bridgewater, Glastonbury, Hutton, and King Seymour levels.

Inferior Oolite.

The only part of this rock which comes within our district consists of the inferior sands, which, resting on lias, emerge from beneath the green sand and chalk of the neighbouring hills between Hawkchurch (near Axminster) and Ilminster, where it spreads to the eastward, out of the area under consideration.

The best sections of these sands are seen near Ilminster, and will be found to correspond with those obtained near Lyme Regis and Bridport, where the beds are much better exposed on the cliffs (p. 222).

The oolitic rock from which this deposit acquires its name does not occur in the district, as it does not extend eastward sufficiently far to include it; but it can be readily seen to advantage on Chideock Hill, between Lyme Regis and Bridport, where a coarse oolitic limestone is found with irregularly-interspersed grains of hydrate of iron, and a light brown limestone is worked. Irregular beds of calcareo-siliceous sandstone occur in the brown and yellow micaceous sands beneath this limestone, which, it should be observed, contains a great variety of organic remains, as do its equivalents in so many localities, among which Dundry near Bristol, and Bayeux in Normandy, are particularly remarkable.

The passage of these beds into the lias beneath is so gradual that any divisional line between them is purely arbitrary. To mud has succeeded sand, and this again became covered by limestone. The causes which produced the mud, generally calcareous, of the

lias ceased, sands were accumulated on, at least, the shores* of the seas in which they were drifted, and new creatures succeeded those the remains of which were buried beneath the mud and calcareous matter of the lias. These sands, if they were abundantly tenanted or covered by marine animals, have not preserved many of their exuviæ, for organic remains are scarce in them, compared with those we find in the lias. Among those which have been preserved the *Ophiura Egertoni* (Broderip, Geol. Trans., 2nd series, vol. v. pl. 12, fig. 5) seems prevalent in the lower sandstones.

Chalk and Green Sand.

By reference to the maps it will be observed, that the higher parts of the Black Down Hills, and of others which rise on the coast near Sidmouth, Seaton, and Lyme Regis, and in the interior near Axminster and Chard, are covered by green sand, occasionally surmounted by chalk. Outlying portions of green sand will be seen also to occupy the higher parts of the Haldon Hills between Exeter and the coast, and to occur in the lower land between Chudleigh and Newton Bushell, rising upon Milber Down near the latter place. An isolated patch is also found upon Black Hill, near Exmouth, forming a connecting link between the green sand of the Haldons and that of the heights near Sidmouth.

From their mode of occurrence there will be little difficulty in conceiving that a far wider area was once overspread by green sand and chalk in the district than is now covered by them; that, in fact, the green sands of the Haldons and the Black Down Hills were once united, forming continuous portions of a great arenaceous deposit, the intermediate portions of which have been removed by denuding causes that have not only borne away the connecting sands, but have also scooped deeply into the supporting and older rocks. Such an extensive destruction of a deposit,

* In company with Dr. Buckland, we observed a fact among the stony masses of the middle region of the inferior oolite which would appear to mark the presence of shallow water, if not of a shore, during the accumulation of this rock. Beneath Down Cliff (on the west of Bridport) there is a breccia or conglomerate of rolled fragments of coarse oolite, not differing in character from the strata of which they form a part. The fragments have been pierced by small Lithodomous animals before they were included in the conglomerate, resembling the limestone pebbles often thus pierced on many coasts. Geol. Trans., 2nd series, vol. iv. p. 31.

which certainly, from its slight state of cohesion, would afford no great resistance to denuding forces exerted upon them, would prepare us for outlying patches still further distant from the main body of chalk and green sand which occurs so extensively, either exposed on the surface or covered by more modern deposits, over a large portion of England. Our surprise is therefore less than it would otherwise be to detect a very small portion of green sand, few acres in area, isolated at Orleigh Court, near Bideford,* forty-three miles and a half from the green sand of the Black Down Hills, and thirty-six miles from that of Great Haldon Hill, which is the nearest to it.

When we examine narrowly into the mode in which the green sand rests upon older rocks in the Black Down Hills, and in the adjoining country on the east and south, we find it much broken by faults, so that the levels at which it comes into contact with them are very different. In addition to which, we discover the chalk and green sand resting upon red marls, occupying a depression near Beer, which, whether formed by a disturbance of the subjacent beds posterior or anterior to the deposit of the former, brings down the chalk to the present level of the sea at Beer Head. This depression may either have been due to disturbance of the beds subsequently to the formation of the chalk and green sand, or the latter may have filled up an inequality existing in the older rocks at the time of their accumulation. Be this as it may, this depression leads us to consider that the basin of green sand which appears to support a large part of the supracretaceous Bovey deposit, between Chudleigh and Newton Bushell, and which has recently been brought to light by the labours of Mr. Austen, may readily be the continuation of the Haldon green sand into an adjoining depression on the west, and that the difference of level between the deposits, though considerable, may have been produced in a similar manner, even without the aid of great faults. As faults are, however, abundant in the vicinity, probably a combination of them and of a depression produced either previous or subsequently to the deposit of the green sand may best explain the phenomena observed.

The situation of the various patches of chalk will be seen by reference to the maps. They are sometimes isolated by denudation, at others partly by denudation and partly by faults. The

* This remarkable patch was pointed out to us by the Rev. W. Bilton.

patches between Sidmouth and Lyme Regis; at Brice Moor, near Otterford, in the Black Down Hills; at White Stanton and at Northay, near the latter place; above Clanger, near Combe St. Nicholas; and at Whitemoor Hill, on the east of Chard, belong to the former class, while those of Widworthy and Membury, with that extending from Combe St. Nicholas to Chardstock, are referable to the latter.

The following is a general section of the chalk and green sand near Lyme Regis, in the descending order :—

1. Chalk with flints.

   The upper part cut off by denuding causes. Flints very numerous and in layers for about one hundred feet, occasionally mixed with continuous seams of the same substance. In the lower part, for about fifty feet, the flints more rare, gradually losing the appearance of being distributed in layers, finally occurring as detached pieces, without order, in the mass of chalk.

2. Chalk without flints.

   In general tolerably hard, and from thirty to forty feet thick.

3. Chalk with quartz grains.

   This division gradually acquires small irregularly-rounded grains of white quartz, and ends by becoming thickly studded with them, thence acquiring considerable hardness. Thickness, from twenty to thirty feet. At the bottom there is usually a very hard compact bed, three feet thick, in which the quartz and siliceous matter greatly predominate.

4. Yellowish-brown sandstone with chert seams.

   Upper part, for about twelve feet, does not contain chert in regular seams, but in detached pieces. Here and there green earth, with thin veins and specks of oxide of iron. To this succeeds compact and yellowish-brown siliceous sandstone with regular chert seams, several inches thick, cavities in them affording fine specimens of chalcedony. Layers of broken shells among the chert seams. Thickness of this division about seventy or eighty feet.

5. Yellowish-brown sand (termed *fox-mould*).

   Yellowish-brown sand, slightly aggregated, of various intensity of tint,—contains green earth at its base, where it graduates into the next division. Thickness about seventy or eighty feet. Organic remains rare.

6. Green sand and sandstone.

   Composed of a mixture of green earth (silicate of iron) and siliceous sand, with occasionally some argillaceous matter. Contains indurated nodules and seams in its lower part, known locally by the name of *Cow Stones*. These sometimes contain mica and calcareous matter. The whole division is about forty or fifty feet thick, and abounds in organic remains.

The chalk with flints does not appear so fossiliferous as it is in the more eastern parts of England; the organic remains detected in it seem to be the same with those so well known to occur in it in that direction. The most abundant fossils of the chalk without flints would appear to be *Catillus Cuvieri* (Brongniart, Env. de

Paris, pl. iv. fig. 10.—*Inoceramus Cuvieri,* Sowerby), and the *Mytiloides labiatus* (Brong. Env. de Paris, pl. iii, fig. 4.—*Inoceramus mytiloides,* Sow.). The chalk with quartz grains is extremely fossiliferous. Among the organic remains are the following:—RADIARIA, *Cidaris varioralis* (Brongniart), *Echinus areolatus* (Wahl.), *Galerites albo-galerus* (Lamark), *Echinoneus lampas* (De la B.);—CONCHIFERA, *Ostrea vesicularis* (Lam.), *Pachymya Gigas* (Sowerby);—MOLLUSCA, *Trochus Rhodani* (Brong.), *Belemnites, Nautilus* (two species), *Scaphites* (two species), *Ammonites varians* (Sow.), *A. Hippocastanum* (Sow.), *Turrilites.* With *Alcyonia,* encrinal remains, and fish teeth and palates.

In the upper part of the yellowish-brown sandstone with chert seams we find an abundance of broken shells, among which fragments of oysters and pectens are distinguishable. The vertebræ, scales, and teeth of fish are also obtained from it. In the lower part the *Exogyra digitata* (Sow.) is common, and apparently fragments of it form a portion of the layers of broken shells which occur in this division. Fossil dicotyledonous wood occurs in it, frequently much bored by some animal, the holes generally filled with chalcedony. A few scattered fragments of shells are only observable in the yellowish-brown sand, but the green sand and sandstone beneath is full of organic remains, among which may be enumerated—

PLANTÆ.

Abies oblonga . . . . Lindley and Hutton, Fossil Flora, vol. ii. pl. 137.
Other plants not yet determined.

ANNULATA.

Serpula antiquata . . . Sow., Min. Con. pl. 598, fig. 4.

CONCHIFERA.

Terebratula biplicata . . . Sow., Min. Conchology, pl. 90.
Ostrea carinata . . . . Lamarck—figured Min. Con. pl. 365.
Gryphæa canaliculata . . Sow., Min. Con., pl. 26.
Pecten quinquecostatus . · Sow., Min. Con., pl. 56.
——— *asper* . . . . . Sow., Min. Con., pl. 370.
——— *orbicularis* . . . Sow., Min. Con., pl. 186.
Inoceramus gryphæoides . . Sow., Min. Con., pl. 584, fig. 1.
——— *concentricus* . . Sow., Min. Con., pl. 305.
Gervillia aviculoides . . . Sow., Min. Con., pl. 511, figs. 1—4.
——— *solenoides* . . . Sow., Min. Con., pl. 510, figs. 1—4.
Mylilus lanceolatus . . . Sow., Min. Con., 439, fig. 2.
Trigonia alæformis . . . Sow., Min. Con., pl. 215.
——— *spinosa* . . . . Sow., Min. Con., pl. 86.
Nucula pectinata . . . . Sow., Min. Con., pl. 192, figs. 6, 7.

Pectunculus sublævis . . Sow., Min. Con., pl. 472, fig. 4.
Arca rotundata . . . . Sow., Geol. Trans., vol. iv. pl. 17, fig. 8.
Cucullæa glabra . . . . Sow., Min. Con., pl. 67.
——— *costellata* . . . Sow., Min. Con. pl. 447, fig. 2.
——— *decussata* . . . Sow., Min. Con., pl. 206, figs. 3, 4.
Cardium Hillanum . . . Sow., Min. Con., pl. 14.
Astarte striata . . . . Sow., Min. Con., pl. 137, fig. 2.
Thetis minor . . . . . Sow., Min. Con., pl. 513, figs. 5, 6.
Venus ? submersa . . . Sow., Geol. Trans., 2nd series, vol. iv. pl. 17, fig. 4.
Cytherea parva . . . . Sow., Min. Con., pl. 518.
——— *plana* . . . . Sow., Min. Con., pl. 20.
——— *caperata* . . . Sow., Min. Con., pl. 518, fig. 1.
Tellina inæqualis . . . Sow., Min. Con., pl. 456, fig. 2.
——— *striatula* . . . . Sow., Min. Con., pl. 456, fig. 1.
Lutraria striata . . . . Sow., Min. Con., pl. 534, fig. 1.
Panopæa plicata . . . . Sow., Min. Con., pl. 419.
Mya mandibula . . . . Sow., Min. Con., pl. 43.

MOLLUSCA.

Auricula incrassata . . . Sow., Min. Con., pl. 163, figs. 1, 2, 3.
Vermetus concavus . . . Sow., Geol. Trans., vol. iv. pl. 18, fig. 10.
Rostellaria . . . . . .
Nautilus simplex . . . Sow., Min. Con., pl. 122.
——— *elegans* . . . . Sow., Min. Con., pl. 116.
Ammonites Goodhalli . . . Sow., Min. Con., pl. 255.
——— *splendens* . . Sow., Min. Con., pl. 103.
——— *varians* . . . Sow., Min. Con., pl. 176.

CRUSTACEA.

Astacus longimanus . . . Sow., Zoological Journal, vol. ii., pl. 17., figs. 1, 2.

The following is a section of the chalk and green sand at White Cliff Beer :—

1. Chalk with numerous flints, generally in layers.
2. Chalk in which flints are more rare, and disseminated through the mass.
3. Compact bed containing much siliceous matter, equivalent to the chalk with quartz grains near Lyme Regis.

(The chalk near Beer is probably about the same thickness as in the vicinity of Lyme Regis.)

4. *a.* Yellowish-white sandstone.
   b. Nodules of compact light-coloured sandstone, connected by sandstone containing green earth.
   c. Yellowish-brown sandstone containing chert seams.
   d. Yellowish sandstone with some green earth and numerous quartz grains.
   e. Nodules of chert in yellowish-brown sandstone.
   f. Sandstone abounding in green earth, intermixed with nodules of light-coloured sandstone.
   g. Yellowish-brown sandstone with chert seams.
   h. Large-grained sandstone, containing the teeth and vertebræ of fish, with broken shells, &c.
   i. Yellowish-brown sandstone with chert seams.

5. Greenish-yellow and brown sands, (equivalent to the *fox-mould* of the Lyme Regis section.)
   Contain chert nodules. The upper parts of these sands of various shades of colour.
6. Green sands and sandstones, the latter in concretionary layers. Contains many organic remains.

The chief difference between this section and that near Lyme Regis consists in the greater development of the subdivision No. 4, and in the presence of chert nodules and a larger quantity of green earth in the subdivision No. 5, near Beer.

Within the neighbourhood of that village there is also another modification in the series effected within the distance of about a mile. At Beer Cove the compact bed at the base of the chalk may be seen at low water to make a basin-shaped curve, dipping from White Cliff on the east, and rising towards the line of cliffs extending to Beer Head on the west. At the Beer-stone quarries on the west of the village, beds of white calcareous rock of variable hardness occur immediately beneath the chalk without flints. Through them are partially disseminated brilliant fascets of carbonate of lime, and some green earth,—they also contain argillaceous and siliceous matter, the different beds varying in this respect. There are eight of these beds, forming a thickness of twelve feet four inches, resting upon a hard white calcareous rock five or six feet thick, which reposes upon sandstones.

The Beer-stone extends towards Branscombe Cliff, where a shaft has been sunk upon the hill, and a level driven from the cliff. The section here obtained would be as follows, employing the same general subdivisions as in the other sections.

1. Chalk with flints.
2. Chalk without flints—indurated.
3. Beer-stone ; including the hard calcareous bed beneath it.
4. *a.* Light-coloured compact sandstone.
   b. Sandstone with quartzose grains.
   c. Compact beds of the same.
   d. Sandstone with green earth : a compact bed and ferruginous portions in the higher part.
   e. Sandstone with chert seams.

The remainder of the section, in the descending order, is nearly the same as at White Cliff.

Dr. Fitton enumerates *Thetis major*, *Inoceramus sulcatus*, *Pecten* (a new species), *Gryphæa vesiculosa*, *Exogyra conica*, *E.*

lævigata, and Ostrea macroptera,* as found in the sands beneath the chalk at Beer Head.†

As far as the sections of the chalk and green sand can be determined in the direction of Membury and Chard, they would appear to correspond, excepting in a few minor points, with those obtained near Lyme Regis.‡ Broken by faults, and probably also resting upon an uneven surface of lias, red and variegated marls, and red sandstone, the green sands (employing the usual term for those beneath the chalk and above the Wealden rocks) are seen to be covered westward, upon the Black Down Hills, as far as Brice Moor near Otterford on the north, near Widworthy on the south, and still further in the same direction on the coast between Sidmouth and Weston Mouth, by patches of chalk. From the prevalence of unrolled chalk flints above the green sand over a large portion of the Black Down Hills, upon Haldon Hills, the adjoining depression of Bovey, and even upon the small isolated patch of green sand at Orleigh Court near Bideford, it is clear that this rock has once overspread Devonshire very extensively. From the mode in which the upper surface of the chalk has been furrowed before the deposit of the plastic clay series, to be next noticed, so that the minor outlying patches, as can be well seen at Dunscombe on the east of Sidmouth, seem mere portions which have remained after the erosion which then took place, a great denudation of the chalk in this district appears to have been effected before the production of the beds that now constitute a large portion of the dry land of Europe, though it seems probable, as we find the remains of the plastic clay series, also isolated in patches, generally crowning those of green sand and chalk, that no small portion of the chalk may have been removed by the same causes which carried away so large a portion of the detrital matter that constituted that series.

From these denuding causes, the apparently uneven surface of older rocks upon which the cretaceous series (chalk and green sand) was deposited, and the faults by which the beds are

* In the soft agglutinated sand abounding in green particles which constitutes the lowest part of the green sands at Beer Head.

† Observations on some of the strata between the chalk and the Oxford oolite, in the south-east of England, Geol. Trans., 2nd series, vol. iv., pp. 240, 241, 242.

‡ Near Chardstock the organic remains in the lower beds of the chalk, usually containing quartz grains, are very numerous.

traversed, masses of chalk and green sand of very unequal thickness occur on the Black Down Hills, and upon their continuation to the southward.

The sands capping the hills which face the lower lands on the west are not above one hundred feet in depth. They are apparently the remains of the beds of which the equivalents occur beneath the sands and sandstones with chert seams, marked No. 4, in the preceding sections near Lyme Regis and Beer, the destruction of the latter having furnished the abundant fragments of chert with which they are usually covered.

As Dr. Fitton has observed, the western escarpment of the Black Down Hills from Punchey Down to Upcot Pen is marked by an almost continuous horizontal stripe of white, formed by the refuse thrown from levels driven into the hills in search of the concretions of the green sands which are there extensively worked for sithe-stones. More interrupted lines may also be seen in the escarpment facing Broadhembury, and the continuance of the same concretions may be traced by the refuse heaps in several other places. These concretions, which are of a very irregular form, occur in layers of variable thickness in looser sand. Four of the layers afford the sithe-stones, and the whole occupies, as has been noticed by Dr. Fitton, a thickness varying from twelve to eighteen feet.* Beneath these concretionary layers there appears to be a depth of about twenty feet of brown or light-brown sand, and above them a thickness of fifty or sixty feet of similar sands with a slightly different tint.

From these workings very numerous organic remains have been obtained, generally in fine preservation, and easily separable from the sands or sandstones containing them, being chiefly converted into chalcedony. As this locality is important with regard to the evidence of the kind of animal life which existed in the seas over that part of the district when the cretaceous series was accumulating, we have extracted the following list of the fossils that have been obtained from thence which is given in Dr. Fitton's valuable memoir on the strata between the chalk and Oxford oolite in the south-east of England, merely adding some localities in Sussex, on the authority of Dr. Mantell's works, and others on the continent, where it has been stated that some of the same species have been found.

* Geol. Trans., 2nd series, vol. iv. p. 237.

POLYPARIA.

Siphonia pyriformis.	Goldfuss	*Oolite series.* Streitberg (Goldf.).

RADIARIA.

Spatangus Bufo	Brongniart	*Chalk,* Meudon, Havre (Brong.); Sussex (Mant.); Aix-la-Chapelle; Maestricht (Goldf.); *Bacuclite limestone,* Normandy (Desn.)
—— (Another species probably new)		

ANNULATA.

Serpula ampullacea	Sowerby	*Chalk,* Sussex (Mant.); Norfolk (Barnes).
—— *antiquata*	——	*U. G. S.* Kent and Dorset. *L. G. S.* Kent (F.) †
—— *carinella*	——	
* —— *filiformis*	——	
—— *plexus ?*	——	*Chalk,* Sussex (Mant.)
* —— *tuba*	——	
* —— *Vermes.*	——	

CIRRIPEDA.

* *Pollicipes lævis*	Sowerby	*G.,* Kent, (F.)

CONCHIFERA.

Pholas prisca.	Sowerby	*L. G. S.,* Kent (F.)
* *Panopæa ovalis*	——	
* *Mya læviuscula.*	——	
Lutraria ? striata	——	
* *Mactra angula*	——	
* *Amphidesma tenuistriatum*	——	
Corbula elegans	——	
—— *gigantea*	——	*L. G. S.,* Hampshire (F.)
—— *lævigata*	——	
—— *truncata*	——	
* *Petricola canaliculata*	——	
* —— —— *nuciformis*	——	

† The abbreviations employed in this list are as follows :—

U. G. S.	Upper green sand.	*Her.*	Herault.
G.	Gault.	*Lons.*	Lonsdale.
L. G. S.	Lower green sand.	*Mant.*	Mantell.
F.	Fitton.	*Nils.*	Nilsson.
Brong.	Al. Brongniart.	*Pas.*	Passy.
Desn.	Desnoyers.	*Phil.*	Phillips.
Dufr.	Dufrénoy.	*Sedg.*	Sedgwick.
Dum.	Dumont.	*Von D.*	Von Dechen.
Goldf.	Goldfuss.		

Where an * is prefixed to the name of the species, it is figured in the plates attached to Dr. Fitton's memoir, Geol. Trans., 2nd series, vol. iv.

**Psammobia? gracilis*	Sowerby	
Tellina inæqualis	———	*L. G. S.*, Sussex (Mant.)
——— *striatula*	———	
**Lucina Pisum*	———	
**——— ? orbicularis*	———	
**Astarte concinna*	———	
——— *cuneata*	———	*Portland stone*, South Wilts, Oxfordshire, Buckinghamshire. *Kimmeridge clay* and *Oxford oolite*, Dorset (F.)
**——— formosa*	———	
**——— impolita*	———	
——— *lineata*	———	
**——— multistriata*	———	
——— *striata*	———	
Cyprina angulata	———	*L. G. S.*, Kent and Sussex (F.)
**——— cuneata*	———	
**——— rostrata*	———	
Cytherea caperata	———	
——— *lineolata*	———	
**——— subrotunda*	———	
**——— parva*	———	G., Kent and South Wilts. *L. G. S.*, Sussex and Hampshire (F.)
——— *plana*	———	
Venus Faba	———	*L. G. S.*, Sussex and Norfolk (F.)
**——— ? immersa*	———	
**——— sublævis*	———	
**——— ? truncata*	———	
Thetis major ?	———	*U. G. S.*, Hampshire. *L. G. S.*, Kent, Sussex, and the Isle of Wight (F.)
——— *minor*	———	*L. G. S.*, Sussex, Hampshire, I. of Wight, and North Wilts (F.)
Cardium Hillanum	———	*Cretaceous series*, Env. of Pont St. Esprit; Gourdon (Dufr.)
——— *proboscideum*	———	
Cucullæa carinata	———	*Green sand*, Aix-la-Chapelle (Von D.); Rouen (Pas.)
——— *decussata*	———	*U. G. S.*, I. of Wight. *L. G. S.*, Kent and Sussex (F.) *Chalk*, Rouen (Brong.)
——— *fibrosa*	———	
**——— formosa*	———	
**Arca rotundata*	———	
Pectunculus sublævis	———	*Cret. series*, Paderborn, Quedlinburg (Von D.)
——— *umbonatus*	———	*G.*, South Wilts. *L. G. S.*, Kent (F.); *Green sand*, Rouen (Pas.)
Nucula angulata	———	
——— *antiquata*	———	*L. G. S.*, Sussex (F.)
**——— apiculata*	———	
——— *impressa*	———	*L. G. S.*, Sussex (F.)
**——— lineata*	———	
**——— obtusa*	———	
Trigonia affinis	———	

Trigonia alæformis	Sowerby.	*G.*, South Wilts. *L. G. S.*, Kent, Hampshire, Sussex, and I. of Wight (F.); *Cret. series*, Gourdon (Dufr.); Aix-la-Chapelle, Quedlinburg (Von D.); Ocher, Normandy (Pas.)
——— *dædalea*	Parkinson	*L. G. S.*, Sussex (F.); *Cret. series*, Env. of Pont St. Esprit (Dufr.)
*——— *quadrata*	Sowerby	
——— *spectabilis*	———	
**Modiola reversa*	———	
**Mytilus inæquivalvis*	———	
——— *lanceolatus*	———	*L. G. S.*, Sussex (F.)
*——— *prælongus*	———	
*——— *tridens*	———	
Pinna tetragona	———	*L.G.S*, Kent, Sussex, and I. of Wight (F.); *Green sand*, Pirna, Aix-la-Chapelle, Bochum, Maestricht (Von D.)
**Perna rostrata*	———	
**Avicula anomala*	———	
Gervillia solenöides	Defrance.	*L. G. S.*, Sussex and I. of Wight (F.); *U. G. S.*, Aix-la-Chapelle (Dum.); *Baculite limestone*, Normandy (Desn.)
**Lima semisulcata*	Sowerby	
*——— *subovalis*	———	
Pecten asper	Lamarck	*U. G. S.*, Hampshire and Dorset (F.); Wilts (Lons.); *Chalk*, Lublin, Poland (Pusch.); *Green sand*, Calvados (Her.); Lillebonne (Pas.); Maestricht (Von D.)
*——— *compositus*	Sowerby	
*——— *Millerii*	———	
——— *orbicularis*	———	*U. G. S.*, Hampshire, I. of White, Dorset, and South Wilts; *G.*, I. of Wight and South Wilts; *L. G. S.*, Kent and Sussex; *Portland-stone*, Oxfordshire and Buckinghamshire (F.); *Chalk, G., L. G. S.*, Sussex (Mant.); *Green sand*, Lillebonne (Pas.)
*——— *Stutchburiensis*	———	
Podopsis striatus	———	*Chalk*, Sussex (Mant.); Havre (Brong.); Dieppe (Pas.); Yorkshire (Phil.)
Gryphæa canaliculata	———	*U. G. S.*, I. of Wight (F.)
Exogyra halyotöidea?	———	*U. G. S.*, Wilts (Lons.); *Chalk*, Lillebonne (Pas.); Kjuge, Balsberg; Mörby (Nils.)
——— *undata*	———	*U. G. S.*, I. of Wight (F.)
Terebratula biplicata	———	*G.*, Kent and Norfolk; *L. G. S.*, Kent and I. of Wight (F.); *U.G.S.*, Sussex (Mant.). Cambridge (Sedg.); Rouen, Havre (Pas); *Green sand*, Calvados (Her.) †

† This shell is also stated to be found in the oolitic series at Papenheim (Von D.), in the Kimmeridge clay of the Bernese Jura (Thurria), and in the Oxford clay, forest marble, and great oolite of Normandy (Herault).

Terebratula depressa	Sowerby	*U. G. S.*, I. of Wight; *L. G. S.*, Sussex (F.)
*——— *dilatata*	———	
——— *latissima*	———	*L. G. S.*, Kent, I. of Wight, and North Wilts (F.)
——— *Lyra*	———	*U. G. S.*, Wilts (Lons.); Havre (Pas.)
*——— *megatrema*	———	
——— *Pisum*	———	*U. G. S.*, I. of Wight (F.)
——— *striatula*	———	

MOLLUSCA.

Dentalium ellipticum	Sowerby	*G.*, Kent and South Wilts (F.); Rouen (Pas.)
*——— *medium*	———	
Auricula? incrassata	———	*U. G. S.*, Norfolk (F.); *Chalk*, Sussex (Mant.)
**Natica canaliculata*	———	*G*, Kent and Sussex (F.)
*——— *? carinata*	———	
*——— *granosa*	———	
**Tornatella? affinis*	———	
Vermetus radiatus	———	
**Scalaria pulchra*	———	
**Solarium conöideum*	———	*U. G. S.*, I. of Wight; *G.*, Kent and South Wilts (F.); *G.*, Sussex (Mant.)
Littorina conica	———	*L. G. S.*, I. of Wight (F.)
*——— *gracilis*	———	
——— *monilifera*	———	
*——— *pungens*	———	
——— *rotundata*	———	*L. G. S.*, Sussex and I. of Wight (F.)
**Phasianella formosa*	———	
*——— *pusilla*	———	
*——— *striata*	———	
Turritella costata	———	
——— *excavata*	———	*Portland-stone*, South Wilts (F.); *Green sand* Perte du Rhone (Brong.)
——— *granulata*	———	*U. G. S.*, South Wilts? *L. G. S.*, Sussex, and Norfolk (F.)
**Fusus clathratus*	———	
*—— *quadratus*	———	
*—— *rigidus*	———	
*—— *rusticus*	———	
**Pyrula Brightii*	———	
*——— *depressa*	———	
Murex Calcar	———	*G.*, Kent (F.)
Rostellaria calcarata	———	*G.*, Kent.; *L. G. S.*, Sussex, I. of Wight, and Norfolk (F.)
*——— *macrostoma*	———	
——— *Parkinsonii*	Mantell	*G.*, Kent; *L. G. S.*, Sussex and I. of Wight (F.); *Chalk*, Sussex (Mant.); *Green sand*, Lillebonne (Pas.)
*——— *retusa*	Sowerby	
**Nassa costellata*	———	
*—— *lineata*	———	

Ammonites auritus . .	Sowerby . .	*G.*, Kent and South Wilts (F.); Sussex (Mant.); Havre (Pas.)
——— *denarius*. .	——— . .	
——— *dentatus* . .	——— . .	*U. G. S.*, North Wilts; *G.*, Kent, Norfolk, and South Wilts; *L. G. S.*, Sussex (F.)
——— *falcatus*. .	Mantell . .	*Chalk*, Sussex (Mant.); Rouen (Brong.)
——— *Goodhallii* .	Sowerby . .	
——— *lautus* . .	Parkinson .	*U. G.S.*, Oxfordshire; *G.*, Kent, Cambridgeshire, and South Wilts (F.); Sussex (Mant.)
*——— *triserialis* .	Sowerby . .	
——— *tuberculatus* .	——— . .	*G.*, Kent and South Wilts (F.); Sussex (Mant.)
——— *varicosus* .	——— . .	*G.*, Kent, South Wilts, and Cambridgeshire (F.)
Hamites tenuis . . .	——— . .	*G.*, Sussex (Mant.). Rouen (Pas.)
Turrilites tuberculatus .	——— . .	*Chalk*, Sussex (Mant.)
Nautilus inæqualis . .	——— . .	*G.*, Sussex (Mant.). Rouen (Pas.)

The green sand of the Haldon Hills is so much masked by flint and chert gravel, and good sections are so seldom exposed, that it is difficult to obtain a correct idea of its character in this direction without the aid of wells or pits. The following is a section of a well not long since sunk by Sir R. Newman on Little Haldon, for which we are indebted to Mr. Thomas Newman and Mr. Abraham :—

	Ft.	Ins.
a. Small flints	4	0
b. Brown sand	10	0
c. Flints (chert ?) large enough for building purposes. .	8	0
d. White sand, much prized for making stucco . . .	11	0
e. Red sand.	1	0
f. Fine-grained dark-coloured sand	14	0
g. Green sand	9	0
h. Large flint (chert ?) mixed with light-coloured sand .	13	0
i. Fine brown sand	15	0
k. Red sand	4	0
l. Pipe-clay—very white	1	0
m. Rounded gravel, like brook or river gravel . . .	1	6
n. Red rock	4	0
	95	6

In this section, *n* is certainly part of the red sandstone series upon which the green sand of Little Haldon chiefly rests, and *a*, *b*, and *c*, probably form the superficial gravel and the remains of supracretaceous rocks, leaving about 90 feet for the thickness of the green sand of Little Haldon at a point where the parishes of Ashcombe and Dawlish meet.

The green sand of Milber Down and of the depression on which the Bovey deposits rest, is generally light-coloured, and sometimes intermingled with indurated bands passing into chert. The sands must be thick beneath these deposits, for Mr. Hole of Park, near Bovey Tracey, informed Mr. Austen that, when a boring was made near the Pottery in Bovey Heathfield, several years since, they penetrated nearly 300 feet through sands resembling those on Haldon. Some parts were very compact, and the borer worked with difficulty through them. The search not having been rewarded with the discovery of lignite (Bovey coal), which it was thought would be obtained, further boring was given up at that depth. The thickness, therefore, of the green sands beneath, still remains unknown.* A good section of the sands of this depression is obtained on the road from Sandy Gate (near Kingsteignton) to Ugbrooke Park. By turning off from the high road and descending the lane towards Combe Farm, the green sands will be observed to rest unconformably upon the carbonaceous series, fragments of the latter being mixed in a breccia forming their lowest part.

The organic remains of the Haldons have not hitherto been described in detail, a deficiency which it is hoped will soon be supplied by Mr. Austen. *Exogyra conica, Cardium Hillanum,* and *Pecten quinquecostatus* would appear somewhat common, and Dr. Fitton mentions *Pecten quadricostatus, Pectunculus umbonatus,* and *Terebratula dimidiata,* as there found†.

For the following list of organic remains from the green sands of Milber Down and the Bovey depression, we are indebted to Mr. Austen :—

Fucoides	Impressions between the lines of deposit of Lindridge Hill.
Wood	In chert from Lindridge Hill.
Siphonia	
Cellepora	
Orbitalites conica	The largest, three-fourths of an inch indiameter. Occurs with *Or. plana* at Staple and Milber Down Hills, and forms entire beds at Lindridge Hill.
——— *plana*	
Cidarites	Small, circular, and depressed. White beds, Staple Hill.
———	Large spines, in the same beds.
Nucleolites depressa	Sandstone of Staple Hill.
Serpula	Several species—numerous in several localities.

* Austen, MSS.

† Geol. Trans. 2nd series, vol. iv. p. 242.

Orbicula	Numerous at Lindridge Hill.
Spherulites	
Exogyra conica	Very common everywhere.
——— *halyotoidea*. . .	Lindridge Hill.
Pecten quinquecostatus . .	Staple Hill and Lindridge Hill; numerous, but all smaller than those of Haldon.
—— *Boissyi*	
Inoceramus Cuvieri . . .	Lindridge Hill.
——— *concentricus* .	Not uncommon—Lindridge Hill.
Trigonia scabra	Lindridge Hill.
——— *alæformis* . . .	Lindridge Hill, Milber Down.
——— *eccentrica* . . .	Staple Hill, Staple Hill.

The sands of the far-outlying patch of Orleigh Court, near Bideford, very closely resemble those termed *fox mould* near Lyme Regis. Organic remains seem rare in them, but in the flints and chert composing the superincumbent gravel, and reminding us of that on the Haldons and Black Downs, *Galerites albogalerus, Spatangus Cor-anguinum,* and some other organic remains, usually occurring in the cretaceous series, are found. These sands rest unconformably upon the edges and contortions of the carbonaceous series of that part of Devon.

Viewing the chalk and sands above noticed as a whole, we readily perceive that very different conditions must have obtained during the formation of the higher and lower parts of it, and we also see that some great change must have taken place in the relative general levels of sea and land, so that, from matter having been accumulated in gradually diminishing areas during the oolitic period, a great overspread of sedimentary substances took place, enveloping creatures which we, from analogy, infer to have been marine. Taking a wider range than southern England will afford us, we find the same overlapping character of the cretaceous series in the opposite parts of France, after the oolitic system had there also been formed within gradually diminishing areas, so that probably a considerable portion of western Europe was subjected to the same change of conditions that permitted the great overspread of the cretaceous series which now constitutes a marked feature in it.

On the east of our district there is evidence, as is now well known, of dry land having been submerged after the formation of the Portland beds, and their elevation above the sea, so that the mass of detrital matter known as the Wealden was de-

posited in fresh or brackish water, the presence of certain genera of animals analagous to those detected in fresh-water lakes or estuaries of the present day being held to prove that point. The change which again covered this area with marine deposits is considered by Dr. Fitton to have been a "sudden or rapid depression of the entire Wealden, to such a depth as to be covered by salt water; proved by the sudden and exclusive appearance of marine productions and fossils, above and in immediate apposition with strata containing only fresh-water fossils, though mineralogically of the same composition."*

Although the depression may have been, and probably was, sudden, the amount of the change in the relative levels of sea and land need only have been trifling, judging at least from the facility with which fresh-water creatures are destroyed when the sea makes an inroad *suddenly* into pieces of fresh water defended usually from it by sand-banks. A change of level of a few feet might have been quite sufficient for the purpose. From the kind of deposits which have succeeded the Wealden rocks, as much comparatively quiet accumulation of sedimentary matter took place subsequently as previously to the change, and we have no coarse detrital beds resting upon upturned Wealden deposits to show that any change in the relative levels of sea and land, which may then have been effected, was accompanied by great violence.

Upon the whole we are led to suppose that the change may, geologically speaking, have been gradual; and that, subsequently to the gradual rise of a portion of western Europe, which brought a part, at least, of the oolitic series above the sea, a gradual depression took place which permitted the chalk and green sand to overspread a wide area, covering up a variety of older rocks. Under this view we should expect the beds forming the lowest portion of the green sand to be best developed where the depression beneath the sea was first effected, and that consequently the higher beds would be most continuous over the area subsequently occupied by the whole cretaceous series, due allowance being made, more particularly as to the sands and clays, for variations caused by the operation of modifying conditions in horizontal distances. Supposing this view correct, we might expect in our district, not only considerable modifications from distance between

* Geol. Trans., 2nd series, vol. iv. p. 321.

the green sand in it and in the east of England, but also that several of the lowest deposits may be absent, considering the relative levels of sea and land to have been such, that while the lowest beds of the green sands were accumulating in the east of England, dry land still existed in the west.

When we refer to Dr. Fitton's list (p. 243) of the organic remains found at the Whetstone quarries on the west side of the Black Downs, and add a few localities for species from Dr. Mantell's catalogues of the fossils from Sussex, we find that six species are found in the chalk of more eastern parts of England, one in the chalk and upper green sand, one in the chalk, gault, and lower green sand, five in the upper green sand, two in the upper green sand and gault, five in the upper and lower green sands, nine in the gault, four in the gault and lower green sand, fifteen in the lower green sand and three in the upper green sand, gault, and lower green sand, while ninety-one species have not been yet found in the cretaceous series of the same parts of England. Of these ninety-one species, one has been noticed in the cretaceous series of the environs of Pont St. Esprit and Gourdon, one in the green sands of Rouen and Aix-la-Chapelle, one in the green sands of the Perte du Rhone and in the Portland-stone of South Wilts, one in the oolitic series of Streitberg, and one in the Portland-stone of South Wilts, Oxfordshire, and Buckinghamshire, and in the Kimmeridge clay and Oxford oolite of Dorset.

Assuming the determination of these species to have been correct, and it is believed that more than usual labour has been bestowed on Dr. Fitton's lists to render them useful, we might conclude that certain animals considered marine (*Spatangus Bufo, Serpula ampullacea, S. plexus? Podopsis striatus*, and *Ammonites falcatus*), were enveloped by the sands of the Black Downs before the chalk of Sussex was formed; that four species (*Siphonia pyriformis, Astarte cuneata, Pecten orbicularis*, and *Turritella excavata*), which lived during the deposit of the higher members of the oolitic series, survived up to the time when these sands were accumulating; and that other species, which would appear to be found in particular subdivisions of the green sand to the eastward in England, are here found together in a manner leading us to consider that they existed at the same time in the same place.

With regard to species found equally in the oolitic and cretaceous

series, Dr. Fitton's lists inform us that *Cardium dissimile* is discovered in the lower green sand of Kent and in the Portland-stone of Wilts, and in the Portland-stone and sand of Oxfordshire and Bucks; that *Trigonia clavellata* is found in the lower green sand of Kent and in the Portland-stone of Oxfordshire, the Portland-sand of Dorset, Wilts, and Bucks, and in the Kimmeridge clay and Oxford oolite of Dorset; that *Trigonia gibbosa* occurs in the lower green sand of Wilts and in the Portland-stone and sand of several localities; that *Gervillia aviculoides* is found in the green sand near Lyme, in the Portland-stone of Oxfordshire, the Kimmeridge clay of Dorset, and the Oxford oolite of Oxford and Cambridgeshire; and that *Ammonites circularis* is discovered in the green sand of Kent and in the Oxford oolite of Dorsetshire.

That we should find some species of animal remains common to the upper portions of the oolitic and the lower portions of the cretaceous series would appear no more remarkable, among a system of deposits which do not show any interruptions from violent dislocations of the earth's surface, in a given area, during the time of their accumulation, than that we should find species among the animal remains entombed in the lowest supracretaceous or tertiary rocks which now exist, and which have continued to live from that period to the present amid a considerable general modification and change of animal life upon the earth's surface.

A very considerable break may have taken place in an area embracing southern England and northern France, from the presence of dry land over a considerable portion of it, and no greater interruption can be well imagined; and according to the time which may have elapsed between the rise of the land above the level of the sea and its subsequent submersion, supposing a general modification or change of animal life then in progress, would depend the amount of difference that might be observed, all other conditions being equal. In the marine equivalents of the Wealden a greater mixture of some of the creatures which existed during the deposit of the upper part of the oolitic series with some of those which lived when the lower beds of the cretaceous series were forming may be expected, some marine creatures which lived only at the Wealden period being confined to the marine equivalents of that epoch, and not discovered in the cretaceous and oolitic series above and beneath.

From the mixture of species observed in the Black Down sands,

and the presence of several which occur in the upper portion of the green sand to the eastward, we may be led to infer, upon the supposition of a gradually-extending area for cretaceous deposits, that many species which preferred shallow waters and the proximity of land migrated from their original localities when the waters became deeper or dry land more remote, so that the deposits continuing as a whole, the upper beds adjoining the remaining dry land, or thrown down in the shallower waters towards the outer edges of the general deposit, enveloped not only creatures which were called into existence during the progress of the general accumulation of detrital matter, but also others which had escaped from conditions no longer favourable to their existence to those situations which were still suited to them. Whether this view be correct or not, as regards the Black Down sands, which are particularly interesting, as all the organic remains above enumerated occur within the depth of a few feet, under conditions leading us to suppose that they all existed about the same time, such modifications as those supposed must have occurred extensively during the more quiet and gradual extensions of deposits which we consider to have taken place by the more tranquil subsidencies of parts of the earth's surface, such as may now be in progress in different parts of the world.

That the arenaceous deposits termed green sands were liable to many local modifications, the sections above given will show; and it will be observed that no trace of the great mud deposit, known as the *gault*, extends into the district under consideration. The occurrence of this mud marks a modification of the causes that transported and brought detrital matter to rest during the deposit of the sands beneath the chalk, and the area over which it took place was considerable. Dr. Fitton observes that the almost constant presence of this distinct band of clay between the chalk and lower green sand, considering its small relative thickness, is remarkable. The same author states that he has seen it in its place in the lower Boulonnois, in the vicinity of Aix-la-Chapelle, and in the country between that place and Liege. If however the sands of the Black Downs be upper beds of the great arenaceous deposit beneath the chalk—and Dr. Fitton seems to consider it more probable that they are a continuation of the lower part of the *upper* green sand from the Vale of Wardour—they were formed subsequently to the gault.

If the cretaceous sands of Devonshire, including those near Lyme Regis and Chard, be equivalent to the upper green sands of the eastern counties, they are far thicker and more developed than the equivalent deposits in that direction. Now this would be in accordance with the hypothesis of a wider area for the deposit of the upper portions of the green sands than the lower; for, adjoining the supposed dry land, whence we may suppose some of the detritus to have been drifted, we should expect a greater accumulation of comminuted matter than in places far distant from it. We may here remark that the presence of the gault would seem to show an extensive mud deposit, such as we now find so frequently at distances from land, and therefore some of the Devon sands may have been arenaceous equivalents nearer the shores of dry land.

Prior to the deposit of the chalk near Lyme Regis and Chard, some drift of detritus of a larger size than ordinary took place, as shown by the quartz grains, and subsequently a considerable change was effected in the nature of the deposits, a great mass of chalk having overspread the previous sandy accumulations, showing a very material alteration in the conditions under which rocky matter was then accumulated, one, judging from the area over which chalk occurs with certain common general characters, extending over a considerable portion of Europe and certain adjoining parts of Asia.

It would be foreign to the plan of this report to enter further into the probable origin of the chalk, observations on which would more properly accompany descriptions of other districts to the eastward of that under consideration; but we may observe, that the tranquillity which seems to have prevailed during this great accumulation of siliceo-calcareous matter, whether it may have been a deposit from water in which it was mechanically suspended, partly the work of living creatures, or in a great measure chemical, is very remarkable. The presence also of green silicate of iron so frequently in the sands beneath (whence the distinctive name), and its disappearance in the chalk after the passage of the latter into these sands, where both white carbonate of lime and green silicate of iron are intermingled with each other, is another fact worthy of attention, more particularly as the green silicate of iron appears as much like a drifted product as one chemically produced in the sands among which it is found.

Supracretaceous or Tertiary Deposits.

Coextensive with the chalk and green sand above noticed, we find a covering of either chalk-flints or fragments of green sand chert, or both, even on the outstanding patch of Orleigh Court, near Bideford. The furrows and indentations filled by these flints and chert correspond with those which are well known to exist on the surface of the chalk of England and France very extensively, and which appear to have been formed anterior to the clays, sands, and gravels, known as the *plastic clay*, inasmuch as the same furrows are commonly found upon the surface of the chalk on which these detrital deposits rest.

Judging from the accumulation of flints in several places, the quantity of chalk once existing over parts of this district, where green sand, and frequently a reduced portion of that deposit only, now remain, must have been considerable. From the unrolled condition of a large proportion of the flints in the neighbourhood of Lyme Regis, Sidmouth, Chard, and many parts of the Black Downs, we are led to suppose that the chalk in which they were once embedded may have been quietly removed from among them, and that these flints have been let down nearly in places above which they occurred in the chalk.

It would appear that, subsequently to the deposit of the cretaceous series, its upper surface became worn away, even through the whole depth of the chalk, in parts of Devonshire, so that the deposits were afterwards formed upon an uneven base, sometimes of chalk, at others of green sand, and often of both. A very instructive example of a mass of unrolled chalk flints, resting upon large isolated masses of chalk left upon the green sand before these flints were accumulated, is observed at Dunscombe Hill, near Sidmouth. The flints, which are unrolled, piled upon each other, and intermixed with loose sand or clay, rest upon both the green sand and chalk, the latter rising upwards among the flints in irregular forms.*

A very plastic yellow clay is not unfrequently mixed up with the flints, filling up the furrows in the chalk, but is more rare in the furrows of the green sand. This may be well observed in the

* On the Geology of the neighbourhood of Weymouth and the adjacent parts of the coast of Dorset. Buckland and De la Beche. Geol. Trans., vol. iv., 2nd series, p. 6.

cliffs between Lyme and Sidmouth, and generally where any natural or artificial sections can be obtained.

As has been elsewhere observed,* angular chert gravel may be seen resting upon the remains of the chert beds from which it has been derived, parts of the beds being still in place and shivered into fragments, so there can be no doubt that the fragments immediately adjoining are but slightly removed from their original situation as parts of the bed. A good example of this fact may be observed in the cliffs at Black Venn, between Charmouth and Lyme Regis

The accumulation of chalk flints surmounting the chalk, and of chalk flints and chert fragments covering the green sand of the district, may be probably referrible to more epochs than one; indeed, the appearance of the highest gravels on the east, which occasionally contain rounded pebbles of quartz, and on the Haldons, where they are mixed with rounded pieces of granite, porphyry, and other older rocks in the vicinity, seem to prove this. That the plastic clay of western England has, like the cretaceous rocks which it usually covers, suffered considerable destruction, we have abundant evidence. Two isolated patches of it may be observed near Weymouth, one on Came Down, on the Ridgeway, and the other at Black Down. Great blocks also of siliceous breccia or puddingstone, composed of chalk flints with the rare fragments of green sand chert, are scattered over parts of that county, the remains of supracretaceous beds which have been destroyed.†

It appears to us that all the lower portions of the chalk and chert gravels upon the hills near Lyme Regis, Sidmouth, and Chard, upon the Black Downs and the Haldons, may be referred to the plastic clay series, the mass of sands, gravels, and clay, which probably once covered them having been removed by denudation. With the exception of some marls upon the chalk above Ridge, on the south-west of Chard, the clays, sands, and lignite, deposited in the Bovey depression on the west of the Haldons, are the only beds of importance which have yet been observed above these lower flint and chert gravels.

Upon the undisturbed green sand of this depression we find a

* On the Geology of the neighbourhood of Weymouth and the adjacent parts of the coast of Dorset. Buckland and De la Beche. Geol. Trans., vol. iv., 2nd series, p. 7.

† Geol. Trans., 2nd series, vol. iv. p. 5.

gravel of chalk flints and chert resembling the lower gravels above noticed, particularly those on the Haldons, being like them slightly rounded. Upon these the clay and sands of the Bovey deposit may be seen to rest, and there can be no doubt that the flints and chert were reduced to the condition in which we find them before the Bovey beds were formed. Mr. Austen has found a white clay resting upon similar gravel upon Great Haldon (pits near the race-course, &c.), which cannot be distinguished from the Bovey clay, and may have been formed at the same time, though, as that clay has been furrowed and removed prior to the deposit of a 'head' of gravel corresponding with the higher gravels on Haldon, the white clay there situated might be a resettlement of the Bovey clay.

With the exception of a thick bed of lignite, which occurs near the Pottery on the south of Bovey Tracey, the lignite of Aller Mills, and portions of the same substance, sometimes mixed with the clay in various parts of the deposit, organic remains have not hitherto been detected in it. We are therefore deprived of any aid which animal exuviæ might have afforded us in referring the Bovey clays and sands to any particular geological date. The examinations to which the lignite has been subjected have not tended to clear up this point, further than, if the woods be, as has been sometimes supposed, analogous to oak and other existing trees, we should suppose the Bovey beds to have been formed towards the later part of the supracretaceous period.

From the manner in which the Bovey deposit conforms to the valleys adjoining it, the character of the clays and sands, and the greater purity of the clays towards Kingsteignton and away from the granite of Dartmoor, we may be led to infer that, prior to the production of the Bovey beds, a depression was formed in this locality, subsequently to the destruction of the mass of chalk and a considerable portion of green sand which there once existed, and that the materials for this deposit were chiefly derived from decomposed parts of the adjoining granite gradually carried down by streams, the quartzose parts forming the sands, and being sooner brought to rest than the decomposed felspar, which was borne onwards until it could quietly settle, in the same manner that similar china-clay is now artificially prepared in the south part of Dartmoor, and in Cornwall, by turning streams of water upon decomposed granite.

Judging from the existence of trout and shell-bearing animals in the white waters of several streams in Cornwall, particularly near St. Austell, descending through china-clay works, and still containing much decomposed felspar in mechanical suspension, we should not be prepared to expect an absence of animal life in the waters in which the china-clay of the Bovey deposit was formed from that cause. Even supposing that the detritus was chiefly derived from decomposed granite, and the waters charged with decomposed felspar were injurious to animal life, yet, as many lateral streams may have poured more pure waters into the lake, only carrying before them into the common receptacle the more usual drift, supposing the depression to have formed a fresh-water lake bounded by dry land, we should expect to have discovered some animal remains up the lateral valleys, leading from the general depression. We may now, however, merely have in the Bovey depression the lower parts of a considerable and more widely-distributed deposit which overspread the country, for we find clays and sands, that appear to be continuous portions of the Bovey beds, occupying far greater elevation than in the vale beneath, and resting upon beds of the carbonaceous series above Soldridge on the west of the village of Bovey Tracey. There has evidently been a considerable removal of some arenaceous deposits up the valley between Bovey Tracey and Lustleigh, and the present river course is beneath the level at which those deposits must have existed. Part of them may be referrible to the green sand, and, if so, that rock may probably have once extended over a portion of the adjoining granite of Dartmoor. A very good section of these beds may be seen in the road between Bullbrook and Letford Bridge.

Some remarkable beds of sands and clays nearly encircle the higher parts of St. Agnes Beacon, Cornwall, which we are disposed to believe may be the remnant of some supracretaceous deposit. They occur at an elevation of between 300 and 400 feet above the level of the sea,* resting upon the slates of the hill, and partly also on a small portion of the granite rock which there occurs, the granitic rock and slates being traversed by several tin lodes. From its proximity to the sea and the form in which it occurs on three sides of the Beacon, the first impression is, that

* Mr. Hawkins gives 375 feet as the height of these sands and clays above the level of the sea. Trans. Geol. Soc. of Cornwall, vol. iv. p. 136.

we have before us one of those raised beaches, so common in Cornwall, elevated far higher than usual. That the Beacon rose as an island above waters which formed cliffs on its side and ground the rocks into pebbles at its base, seems very probable from the cliff-like sections which the tinners affirm they have obtained when working the tin in the gravel of the lower part of the deposit. Moreover, the waterworn hollows on which this gravel is accumulated, by the same accounts, perfectly coincide with a rocky shore among which beach is accumulated. The tin stones are minerals which we should expect on the shores of an island traversed by numerous tin lodes. They are chiefly found on the eastern side of the Beacon, and arranged in a manner we should expect, if washed about by the action of the waves, the heaviest bodies finally becoming the lowest in the gravel.

With the cliff and rocky waterworn floor supporting the tin stones and other gravel composed of the rocks of the hill, the resemblance to the raised beaches appears to terminate, and we have a succession of sands and clays resembling the overspread of a more general deposit, the whole presenting much the same appearance as the islands of red sandstone and lias which now rise from the Bridgewater levels would offer, if the clays and sands of those levels were washed away nearly up to the former islands and to the beaches which sometimes occur on them, leaving only small remnants to mark their previous existence. From the descriptions of various sections, noticed by Mr. Hawkins and Dr. Boase, and as has indeed been remarked by the latter*, the thickness of the beds and their number vary considerably. The following is a section we were enabled to make on the north-east side:—

	Feet.
Head of rubble, derived from the hill above, and named *Cobb*.	3
Yellow sand	2
Brownish sand, with numerous planes (apparently those of deposit) dipping at an angle of 45°.	11
Light-coloured mining-clay	2
Blue clay	9
Yellow sand	4
White sand	4
Yellow sand	3
Pebbles, resting upon an uneven surface of slate	variable.

This isolated deposit has not hitherto been found to contain organic remains, with the exception of some traces of plants that have the appearance of *Fucoids*. In no other part of Cornwall have any deposits resembling these beds been detected, and the

* Trans. Geol. Soc. of Cornwall, vol. iv. p. 298.

only sands and clays which they even mineralogically approach are those of Bovey. Such a resemblance is, however, of little value, from the distance between them, when we possess no other information as to their relative geological ages. They both probably belong to a class of deposits that may once have covered a considerable portion of the district under consideration, and which have been since removed, with a large mass of pre-existing rocks, to form that varied surface we now see, and which is still undergoing different modifications.

CHAPTER IX.

ALTERATION IN THE MINERAL CHARACTER OF ROCKS.—DIVISIONAL PLANES.

Alteration in the Mineral Character of Rocks.

The various solid masses above noticed would appear to have undergone some change since they were either ejected in a state of igneous fusion, thrown down as chemical precipitates, deposited from fluids in which their chief component parts were mechanically suspended, or were accumulated by the simple drift of detrital matter by means of moving water.

These changes have been of various kinds: some rocks are simply formed of detrital matter consolidated by a cementing substance; others by chemical action have become disintegrated after having been solid; in some, portions have separated from a general deposit and formed nodules and even crystalline substances; others have suffered alterations in their general characters where they have been exposed to the influence of protruded and heated masses of igneous rocks: divisional planes, different from those of stratification, traverse a large proportion at various angles nearly approaching to the vertical, and many have been split into thin laminæ in a regular manner over large areas.

As we have elsewhere* observed, we can scarcely conceive that detritus, particularly when finely comminuted, can be kept in juxta-position, moist, and even wet, for long periods of time, without suffering some chemical change. Into the beds through which water easily percolated soluble matter, derived from other rocks, may readily have been introduced, and, combining there with substances for which it possessed affinity, form new compounds. Even in the first instance deposits effected in the sea may have the original condition of part of their component detritus, such as that which has been transported by fresh water from the land into it, greatly modified by juxta-position, while kept moist or wet by a solution of the salts usually found in the sea.

* Researches in Theoretical Geology, p. 91.

In the sandstones we find the cohesion of the original grains of sand very unequal. In some the cementing matter is as hard as the grains themselves. In the grauwacke and carbonaceous series of the district this is frequent, and we find siliceous grains, generally of quartz, cemented by matter which closely approaches chalcedony or chert, much intermingled with peroxide of iron in the red sandstone of those rocks. In the poicilitic or red sandstone series the cohesion is rarely considerable, and we find the cementing substance chiefly consisting of alumina, peroxide of iron, and the red oxide of manganese, the rock being harder when calcareous matter forms any considerable portion of the cement. In some of the beds of the green sand there is very little cohesion among the grains, so that they become readily disintegrated by exposure to atmospheric influences.

Probably the unequal consolidation of the same deposit is nowhere better exhibited in the district than among the sands with chert of the green sand near Lyme Regis. Intermingled with arenaceous beds of comparatively slight cohesion we find layers consolidated by chalcedony or chert, the siliceous matter having infiltrated while in solution into cavities, and being there deposited in a stalactiform manner. The movement of silica in solution can in these cases scarcely be doubted, and there is every reason to consider that it occurred after the deposit of the arenaceous strata in which the chert is found, unless we suppose that during their production a chemical deposit of chalcedonic or cherty matter was effected, such matter being now represented by the chert beds which occur in the same arenaceous accumulations.

That chalcedonic matter in solution was in movement among these arenaceous beds is best shown by its substitution for the carbonate of lime of organic remains, some shells having been wholly replaced by it, showing that, after the accumulation of the sands over the shells, the carbonate of lime of the latter was removed in solution, and chalcedony by infiltration deposited in its place.

Perhaps by the movement of silica in solution combined with alumina and a few other substances we may account for the unequal consolidation of beds of sandstones and slates among the grauwacke and carbonaceous series, the former being often extremely compact, while the latter are sometimes comparatively soft. When we observe a mixture of sands and clays in more modern beds we see that water freely percolates through the former

while it passes with difficulty through the latter, so that, if from any cause cherty or chalcedonic matter in solution was percolating among the mixed beds, it would enter more freely among the sands than the clays, filling up the interstices among the grains in the same manner that deposits from similar solutions have filled up the vesicles and cavities of many trappean rocks. Judging from the innumerable siliceous veins, generally of quartz, among the detrital beds of the carbonaceous series and grauwacke, silica must have been a very common substance in solution among them after their general consolidation.

The consolidation of the mud and clay into slates was probably due to causes similar to those which converted the sands into hard bodies, chemical changes having probably been more easily effected in the one than in the other from the finer comminuted state of its component parts, even supposing the detritus to have merely differed in the fineness of the grain, though probably it varied also in other respects, being composed of abraded mineral substances most readily worn down by the detrital forces which produced both the sands and mud. The power of bodies to crystallize freely in some of the slates is shown by the cubes of iron pyrites found among them. They were then probably in a state of clay, a substance in which crystals of iron pyrites are often found; if so, this chemical change in the arrangement of some of the component parts was effected before the subsequent general modification which produced the consolidation of the rock.

In the calcareous nodules (p. 223) among the marls of the lias of Lyme Regis we have good examples of the aggregation of matter of the same kind from among the mass through which it was originally dispersed, without the lines of general deposit having been destroyed. At first sight they appear concentric concretions, but when fractured they are found laminated, the planes of the laminæ coinciding with those of the beds of the lias, and being continuous with those in the surrounding marls, from which the calcareous matter of the nodules would appear to have separated so tranquilly that the lines of deposit were preserved, unless, indeed, the whole has been laminated after the formation of the nodules. As organic remains generally occur in these nodules, often occupying their central parts, we may infer that these exuviæ constituted points upon which the separated matter directed itself.

Probably the flints in the chalk afford as good evidence as could be desired of the change effected in the mass of a rock after its deposit as we can find in the district. It has been long considered by many geologists that these flints have been formed by siliceous infiltrations into the places they now occupy. Dr. Berger states that such was Werner's opinion.*

If we suppose, as has been done, that animal bodies without bones or hard shells were enveloped in lines as the chalk was from time to time deposited, when decomposition of the animal matter took place, cavities would be left into which siliceous matter could infiltrate. This view seems borne out by the alcyonic and other spongiform remains which are now found in many of these flints, their fibres beautifully preserved as if the zoophytes had been tranquilly covered by the matter of the chalk, their animal matter removed and replaced by a siliceous infiltration, while the chalky case permitted the undecomposed parts to remain uncompressed in the cavity.

Throughout the district also the organic remains, where they are found, show the modifying influences which have been in action since the original deposit of the rocks in which they occur.† In many situations, as amid the slates of Linton and Barnstaple, the carbonate of lime of shells, encrinites, and corals, once strewed in partial patches over the bottom of the sea, has been removed, and we merely have the impressions of those hard bodies preserved in the silt or mud, now consolidated, which enveloped them during the deposit of the grauwacke series. Even in limestones such as those of Plymouth, Torquay, and other places, if we suppose that we have the original carbonate of lime of the shells and encrinites, in some of these remains it would appear far too crystalline not to have undergone some new arrangement of the component particles. The substitution of chalcedony for the original carbonate of lime of shells is best exhibited in the green sands of the Black Downs at the Whetstone pits (p. 242), though it is by no means confined to the green sands of that particular locality. While the bones of the saurians and fish entombed in the lias have undergone considerable modification, bisulphurate of iron having even penetrated into their pores, the phosphate of lime seems to

* Geological Transactions, vol. i. (1811).

† The substitution of iron pyrites for shells in the lias of Lyme Regis is on this account particularly interesting.

have remained, thus, being a very insoluble substance, affording evidence by its presence and the change of the other parts of the bones, of the general modification which the rocks containing these remains have suffered since the deposit of the matter composing them.*

Without attempting to extend the evidence further, these facts will be sufficient to show that the sedimentary deposits of the district, from the chalk downwards, may have suffered considerable modification in the condition of their component parts since they were first accumulated, preparing to expect that, if any conditions should arise which might disturb the arrangement of such parts at any subsequent period, other modifications might take place. We could scarcely suppose, therefore, that great masses of granite in a state of igneous fusion could be protruded through the rocks, composing the grauwacke and carbonaceous series, without producing a change, within reasonable distances, in the beds brought into contact with them, and remaining heated for long periods of time.

When these igneous masses were thrust up, it seems fair to suppose that water was disseminated through the pores and between the strata of pre-existing beds in the manner we so constantly find rocks impregnated with it at the present day. One of the earlier effects produced upon the beds of the upturned and fractured sedimentary rocks would, therefore, be to drive the water in a heated condition through the matter of those rocks, thus rendering it capable of taking up several substances in solution that its previous temperature rendered it unable to remove; and leaving the interstices previously filled by the water open for the admission of any vapours which might be driven off from the surface of the fluid hot granite in contact with the beds. We may readily conceive that this circumstance might not only cause many modifications in the arrangement of the original particles composing the sedimentary beds, but also that new mineral matter might be introduced in a state of vapour, which, combining with substances originally present in the sedimentary deposits,

* Dr. Turner found 29 per cent. of phospate of lime still forming part of a vertebra of Ichthyosaurus from the lias of Lyme Regis, while in a rib and tooth forming part of the same fossil skeleton the phospate of lime amounted to 50 per cent. In the scales of a specimen of *Dapedius politus*, from the lias of the same locality, he obtained 19 per cent. of the same substance.

or with each other, produced mineral compounds different from those existing in the detrital beds before they were subjected to these new conditions.

As has been observed by Professor Hausman, the heat of furnaces often produces lasting changes on stones contained in them perfectly analogous to those observed in rocks which have been brought into contact with igneous masses. He states that "clay slate which was used in constructing a blast furnace at Mägdesprung, in the Anhalt territory, had, from the long operation of heat, without becoming fluid, acquired an aspect like siliceous slate, in appearance very much resembling the rock which is often found in the vicinity of greenstone, where that rock is in contact with clay-slate."* The same author also notices the changes produced by heat on sandstones which have lined or formed the base of furnaces, and the analogy of the altered substances to sandstone rocks in contact with igneous masses. Though there could be little doubt that the changed character of many rocks in contact with igneous masses was produced by the application of heat to them, often long continued, observations of this kind are always important, inasmuch as they may be considered in the light of experiments made to try the value of the explanation usually given. The silicates which have been obtained by heat, in experiments instituted for the purpose, and accidentally in furnaces, are most important, more particularly the crystals of mica noticed by M. Mitscherlich, and the substance resembling felspar, mentioned by M. Hausman as having been formed by a condensation of vapour in the copper furnaces of Sangerhausen.†

* Jameson's Edinburgh New Philosophical Journal, January, 1838, p. 81.

† The condensation of vapours, and the formation of mineral substances from them, which resemble natural products, have scarcely yet received the consideration which they deserve in explanation of many geological phenomena. Von Buch long since called attention to the probability that many dolomites were limestones altered by vapours which had entered through cracks and interstices in them. The decomposing effects produced upon the granite of Auvergne by the passage of carbonic acid through it has also been long known and pointed out, and Mr. Lyell, who notices several instances of the modifying influences of gases, has called attention to the great alterations which may be thus produced. (Principles of Geology, 5th ed., vol. iv., p. 374.)

Various facts illustrative of the formation of metallic sulphurets and oxides by vapours are observed in furnaces. M. Hausman notices the crystallizations of oxide of zinc in iron blast furnaces, sometimes accompanied by chloride of potassium, and the sulphurets of zinc and lead in the walls of lead, silver, and copper furnaces. (On Metallurgic Phenomena as illustrative of Geology, Jameson's Edinburgh New Philosophical Journal, Jan., 1838.) Several products from vapour have been ob-

The instances in the district in which heated igneous rocks may have produced a change in the mineralogical structure of sedimentary beds, anterior to the protrusion of the granite, are not numerous, at least as regards any material modification. At the Black Head near Torquay, slate would appear to have become hardened, and calcareous beds rendered more crystalline by an overflow of greenstone in fusion upon them. The fragments of limestone would appear to have had their original structure modified when caught up in the trap rocks at Ashburton. Some of the slates in the vicinity of Port Isaac in Cornwall, on which greenstones rest, would appear somewhat modified, and, as previously noticed (p. 89), the fragments of them included in the greenstone of Kellan Head have a porcelanic appearance.

These examples, and a few others which might be adduced, are, however, all insignificant compared with the altered condition of the various rocks brought into contact with the granitic masses of Devon and Cornwall. From the variable mineralogical character of the beds through which the granite of Dartmoor has been thrust, the altered rocks around it are particularly instructive, inasmuch as we find them changed in accordance with their original structure. Thus, where the grits of the carbonaceous series closely approach the granite on the north-west of Dartmoor, as at White Hill near Lidford, we find them taking the character of quartz rock, and other instances of the same kind may be observed from thence round by Okehampton. Wherever slates come into contact with this granite, they become changed in appearance, some having been rendered flinty; and this is rather a common circumstance with the shales and slates of the carbonaceous series, in which silica is often abundant. Where very fine clay-slate skirts the moor in some places between South Brent and the Western Beacon on the south, it becomes a felspathic rock, striped of different colours in the original structural lines of the slate. In numerous localities we find the coarser slates converted into rocks resembling mica-slate and gneiss, a fact particularly well exhibited in the neighbourhood of Meavy, on the south-east of Tavistock. Where greenstones approximate,

served by Mr. Logan in the copper-works belonging to him and Mr. Benson at Swansea. Pure copper seems to be thus produced in the form of dust upon the roofs of the furnace-houses, particularly in the neighbourhood of the refinery, from which, when it rains, it is washed into troughs prepared to receive it and convey it to a reservoir to be resmelted.

or come into contact with the granite, the crystallization has become large near it, and even a modification of the arrangement of the component particles seems to have been produced, so that the hornblende resembles hypersthene ;—examples of this kind are observable at Cocks Tor, near Tavistock, and in the trappean masses near Bridford, Cristow, and Hennock, on the east of the moor.*

Round the various granitic masses of Cornwall the alterations are equally apparent. Near Camelford we observe a fine arenaceous and micaceous grauwacke turned into a rock resembling mica-slate near the granite; and some of the trappean rocks and ash become modified in the vicinity of Davidstow and St. Clether, where they approach the same rock. A very interesting variety of altered slates is found at Fatworth Hill, and upon Castle-an-Dinas, near St. Columb Major, schorl having been introduced among the laminæ.

It would be uselessly occupying time to attempt a description of all the altered rocks which occur in Cornwall, inasmuch as the varieties are as considerable as the composition of the rocks brought under the necessary conditions. The slates not unfrequently become extremely hard, and of a dark colour—dark purple is by no means an uncommon tint. Another common variety consists of a glossy grey slate often containing disseminated and imperfect crystals of a mineral resembling chiastolite.

The coast from St. Ives to Penzance affords a good opportunity of studying the alteration of fine-grained greenstones and ordinary grauwacke slates, portions of these rocks occurring on the outskirts of the Land's End granite in a manner to render the junction of the two classes of rocks very accessible. Granite veins not unfrequently penetrate into the altered slate, while the greenstones appear to have offered more resistance to the forces which broke through the former. The mineralogical structure of these altered rocks has been well described by Dr. Forbes, who notices the felspathic character of a large portion of them, and has given a

* From Dr. Muir's analyses of hypersthene from the Isle of Skye and from Labrador (Thomson's "Outlines of Mineralogy, &c."), and Bonsdorf's analyses of hornblende from Nordmark, Vogelsberg, and Pargas, which show that the constituent parts of the minerals to which these names are given vary considerably in their relative proportions, it would appear that hypersthene chiefly differs from hornblende in being free from fluoric acid, in containing somewhat more magnesia and silica, and less lime and alumina.

detailed section of the Gurnard's Head.* Veins of actinolite are very common among the greenstones of this coast, and veins of schorl also are found among the same rock near St. Ives. Near the latter place the greenstone, as it approaches the granite, becomes large grained, agreeing with similar alterations in numerous other places. Near Mousehole some of the altered slates resemble gneiss, a variety, with others having the appearance of mica-slates, not uncommon in other parts of Cornwall near the granite. In the vicinity of Penryn the gradual change of common into mica-slates may be advantageously seen on the ascent of the road from that place to Constantine, the deep cutting affording a better section than can be usually obtained inland, if we except the shafts, adits, and levels in the mines.

In these various modifications we often appear to have mineral matter introduced among the constituent parts of the original rock, as, for instance, in the case of the schorlaceous slates upon Fatwork Hill and Castle-an-Dinas. That schorl is a mineral which may be decomposed in one place, and, under favourable conditions, recomposed in another, we have evidence in the schorl rocks of Trevalgan, near St. Ives (p. 161), so that in the schorlaceous slates of Fatwork Hill and Castle-an-Dinas we may suppose the schorl to have been introduced among the ordinary grauwacke slates, of which they constitute a continuous part, subsequently to the intrusion of the adjoining schorlaceous granites. The mica also in many cases appears to have been formed in the altered rock from matter received from the adjoining granite, more particularly when the latter is very micaceous, and the felspar in the gneiss-like variety may have been often added in the same manner; and that these minerals may have thus been introduced is rendered far from improbable, from the artificial formation of minerals resembling mica and felspar in the manner above noticed (p. 266).

As, however, the sedimentary beds which are thus altered are frequently made up of matter so finely comminuted that the minerals from which such detritus was originally derived are no longer distinguishable, there is great difficulty in ascertaining, without careful analyses of the altered or unaltered parts of the rocks, whether the former are due to a mere re-arrangement of

* Trans. Geol. Soc. of Cornwall, vol. ii. p. 260, pl. 5.

particles in conformity with the new conditions to which they have been exposed, or matter derived from the adjoining granite has been added to them. If the comminuted parts of a granitic compound have not been much separated since they were transported from the parent rock, and brought into contact with a heated mass of granite, we might readily expect to see a rock like gneiss produced where conditions may have been favourable to the rearrangement of the original crystalline parts, a compound like mica-slate where the particles of quartz and mica have alone remained together, and a compact felspathic rock where the lighter particles of felspar have so drifted from the parent rock, that they have first formed clay, have afterwards been converted into slates, and have been subsequently brought into contact with the hot fluid rock. Be this as it may, it is difficult to conceive that nothing should have escaped from the hot fluid granite in the shape of vapour into the pores and cracks of the adjoining disrupted beds, or that, when the mass was sufficiently cool to allow water to permeate among both rocks at a high temperature, some modifying combinations were not then produced.*

Divisional Planes.

When we thus perceive that a mass of rocks has been greatly modified in its mineral structure, and recollect that the igneous portion of it, that which has been in a state of fusion, has had its component parts arranged in as crystalline a manner as the conditions under which it has been placed would permit, we are somewhat prepared to find that these varied changes in the condition of the whole may have been accompanied by some still

* While on the subject of altered rocks we should notice the lines of a quartzo-felspathic substance occurring among the slates, and apparently dipping conformably with their beds, between St. Columb Major and Bodmin. As they are found among beds which do not appear to have been subjected to a change in their mineral structure from the contact of igneous rocks, since they were consolidated, it is difficult to suppose, though they much resemble some of the slates altered into felspathic rocks near the granite of the south-east of Dartmoor, and a few other places, that they are sedimentary beds which have suffered change from heat. They may therefore be igneous rocks which have been formed during the deposit of the sedimentary matter among which they occur, in the manner of the contemporaneous greenstones and other trappean rocks so situated in other localities. At Rosevanion, near St. Columb Major, one of these bands of rock exhibits traces of lamination in the direction of the dip.

more general modification in its constituent parts, from being brought within the powerful influence of laws that tended to render the general mass crystalliform. When, therefore, we see two series of divisional planes, independent of the bedding in the detrital beds, alike traversing igneous rocks and sedimentary deposits, one series being either vertical or very highly inclined, the planes varying from a few inches to several feet apart, and the other series, not so generally common, having the planes so close as often to divide the rock into thin laminæ, we are led to suppose that powerful forces tending to render the mass crystalliform have been in action, and that these two kinds of divisional planes are their effects.

In 1811 Dr. Berger observed that the grauwacke of the cliffs of Whitesand Bay, near Plymouth, separated into "very regular rhomboidal joints." * In 1821 Professor Sedgwick observed that, "whenever any natural section of the country (Devon and Cornwall) exposes an extended surface of the granite, we find portions of it divided by fissures, which often, for a considerable extent, preserve an exact parallelism among themselves." He further adds that "these masses are not unfrequently subdivided by a second system of fissures, nearly perpendicular to the former, in consequence of which structure the whole aggregate becomes separated into blocks of rhomboidal form." † In 1833 Mr. Enys stated that the vertical divisional planes or joints of the granite near Penryn took a general direction from N.N.W. to S.S.E., varying but a few degrees from those points;‡ and in 1834 we had occasion to remark that "the cleavage of the Devon and Cornwall granite is frequently in given directions over considerable areas, showing that the causes producing it have acted on the large scale," adding that the most general direction was from N.N.W. to S.S.E., agreeing with that observed in the granite near Penryn,§ and that the granite on the northern part of Dartmoor was not only cleaved perpendicularly in this direction, but also in lines at right angles, or nearly so, to it.‖

Though the general direction of these lines, which may be

* Geological Transactions, vol. i.

† Cambridge Philosophical Transactions, vol. i.

‡ On the granite district near Penryn, Cornwall. London and Edinburgh Phil. Mag. May, 1833.

§ Researches in Theoretical Geology, p. 103.

‖ *Ibid.* p. 104.

termed great divisional planes, to distinguish them from the cleavage lamination to be presently noticed, may be N.N.W. and S.S.E., varying only a few degrees from those points, these planes are by no means confined to it; on the contrary, there are many exceptions to it in the granite districts of Cornwall and Devon. To show an average amount of local variation in this respect, we will select the coast between Pedn-maen-du and Pedn-maen-an-mear, which includes the Land's End, as it is easily visited and the great divisional planes well seen. Commencing with the north, they run as follows :—

At Pedn-maen-du . . .	325°*	Carn Mellyn	328°
Near Carn Clog . . .	325° & 242°	Tol-pedn-penwith . . .	316° & 218°
Near Carn Creis . . .	318°	On west of Porth Chapel.	328° & 225°
Nanjisal, or Mill Bay .	316°	Pedn-maen-anmear . .	320°
Carn Barra.	318°		

Taking the present magnetic north to be about 335° at the Land's End, the leading great cleavage of Pedn-maen-du and Carn Clog would differ from it 10°; that of Carn Creis and Carn Barra, 17°; that of Mill Bay and Tol-pedn-penwith, 19°; that of Carn Mellyn and Porth Chapel, 7°; and that of Pedn-maen-anmear, 15°, the average of the whole differing from it between 13° and 14°. It will be observed that the cross great cleavage is not always sufficiently well characterised to be noticed, and that it varies more considerably than the north and south cleavage, the cross cleavage planes at Carn Clog and Tol-pedn-penwith differing 24° in direction. The line of cross cleavage makes an angle of 83° with the main cleavage at Carn Clog, of 98° at Tol-pedn-penwith, and of 103° near Porth Chapel, the angle being measured on the west.

The above will convey a fair idea of the general variations in the directions of the great divisional planes of the granite in Cornwall and Devon, the results of many hundred observations on which would give about 80 per cent. of instances in which the great divisional planes differed only 14° from the present magnetic meridian in the district, and about 15 per cent. of cases in which they differed between 14° and 20°, leaving about 5 per cent. of instances in which the north and south lines approximate the cross planes.

* In these directions the degrees of the circle are reckoned round by the east, 90° representing that point, 180° the south, and 270° the west. The second numbers in the list represent the directions of the cross great divisional planes.

The same numbers may be nearly taken to represent the proportion of cases in which the latter approximate to within a few degrees of a right angle to the other main planes.

While a large proportion of the great divisional planes in the serpentine of the Lizard have a direction approaching the present magnetic meridian, we find several exceptions to it. The following will serve to show the prevailing direction in the serpentine of different parts of that district:—

Henscarth Rock (Mullion)	335° & 225°	Lankidden Cove	290° & 211°
Mullion Cove (S. side)	355°	Black Head	287° & 197°
Between Vellan Head and Gue Graze	335° & 230°	Porthbeer Cove	312° & 198°
Rill Head	295°	Goonhilly Downs, N. of Trelowarren	335°
On N. of Kynance Cove	340°		

It will be observed, that, while the prevailing direction, with the exception of the local variations at Rill Head and on the south side of Mullion, is in, or within a few degrees of, the magnetic meridian, from Kynance Cove to Goonhilly Downs, the main divisional planes between Kennack and Coverack Coves differ between 23° to 48° from it. While on the subject of the Lizard, it may be observed, that the great divisional planes which traverse the hornblende slate in it do not appear to have any strongly-marked and prevailing direction throughout. Near the lighthouses they hold a course of 263°, and somewhat further west, towards Penolver Point, one of 322°. Perhaps as a whole, the divisional planes of the hornblende slate are more frequently within a few degrees of true east and west than in other directions. At Porthalla they have a direction of about 268°.

Great divisional planes are common throughout the varied rocks of the grauwacke and carbonaceous series. In the limestones they generally run at right angles to the dip of the beds, good examples of which may be seen in the vicinity of Plymouth. In very numerous instances also in the carbonaceous series of Devon and Cornwall, they hold the same course relatively to the planes of deposit. Among the slates of the grauwacke, particularly the finer varieties, a direction of 325° is very common, the direction being estimated by the average run of the lines for at least some yards, for on the small scale great divisional planes often cut others at acute angles for short distances, disturbing the general parallelism and rendering it difficult, when limited natural, or

artificial sections are alone exposed, to determine the direction of the chief planes within several degrees. It may be here observed, that the crossing of divisional planes, so as frequently to show three series cutting each other, is not confined to the slates of the grauwacke, but is frequently observable in the granites, the arenaceous grauwacke, and carbonaceous series, the chief planes, however, being usually found well marked, and to prevail in one direction, or at most in two, when we do not confine our view to a limited area.

How far the direction of the great divisional planes at right angles, or nearly so, to the planes of deposits over a large part of Devon and Cornwall, may be caused by the accidental circumstance of the beds having a strike which would produce this appearance if the general course of the divisional planes had a northern tendency, it would be difficult to say. Probably this circumstance may have some influence on the general appearance, inasmuch as, at the contact with the granitic masses, where the beds of the grauwacke and carbonaceous series become altered, the great planes coming out of the granite and cutting through the adjoining sedimentary rocks appear often to traverse the planes of stratification obliquely, the beds having been thrown out of their general strike by the protrusion of the granite.

In the red sandstone series great divisional planes are not so frequent as in the older rocks: such planes do however occur, and are found for the most part to range in northerly and southerly directions. In the lias of the neighbourhood of Watchet they are common, dividing the limestone beds into cuboidal and prismatic portions. In that of Lyme Regis they are more rare. In one or two beds of slaty lias, on the west of the church cliffs at the latter place, divisional planes have caused a regular appearance resembling planks on a floor. The greater proportion of the great divisional planes in the lias also take directions among which those which do not vary many degrees from the magnetic meridian, or which run at right angles to it, are not uncommon.

As a whole the great divisional planes of the district may be said to prevail more in directions from N. to N.W. and from S. to S.E. than in others, the greatest number holding their courses within a few degrees of N.N.W. and S.S.E., these lines being cut by others, which chiefly form angles from 70° to 90° with them. When we compare these directions with those which have been

observed elsewhere, we find so much coincidence that we can scarcely consider it accidental, but rather due to some law governing the arrangement of the component parts of rocks, both igneous and sedimentary, on the large scale. Professor Phillips's diagram of the divisional planes in the carboniferous limestone of Northern England* would, with only a few modifications, represent the course of those in the district under consideration; and, from information which we have obtained respecting the prevalent direction of similar divisional planes, more particularly in granites and grauwacke, of several localities in other parts of England, and in France, there would appear to be a coincidence in such prevalent directions which can scarcely be supposed accidental, though no doubt great modifications may be expected from the chemical and mineral character of rocks traversed by these planes, as has been remarked by Professor Phillips.†

In addition to these great divisional planes, many slates in the grauwacke, a few of those in the carbonaceous series, with some sandstones and calcareous rocks in the former, are traversed by planes of lamination due apparently to powerful forces which have divided the rock into thin plates. We have above (p. 43) alluded to the difficulty caused by these planes of lamination in distinguishing the true beds in several localities, and that they remain constant in their direction through contorted beds, so that they sometimes coincide with the planes of deposit, and at others occur at right angles to them (p. 44, fig. 2). We have moreover observed that these planes of lamination sometimes cut those of deposit obliquely (p. 45, fig. 3). It remains therefore to state that, while in some districts, such as North Devon, West Somerset, Southern Devon, and some parts of Cornwall, these lamination planes clearly cut those of deposit, so as to show that they are the effect of some great re-arrangement of the mineral matter composing the rocks since their component parts were brought to rest, in some parts of Cornwall, more particularly on the south, there is great difficulty in considering the schistose structure of the slate to have been produced otherwise than by original deposit.

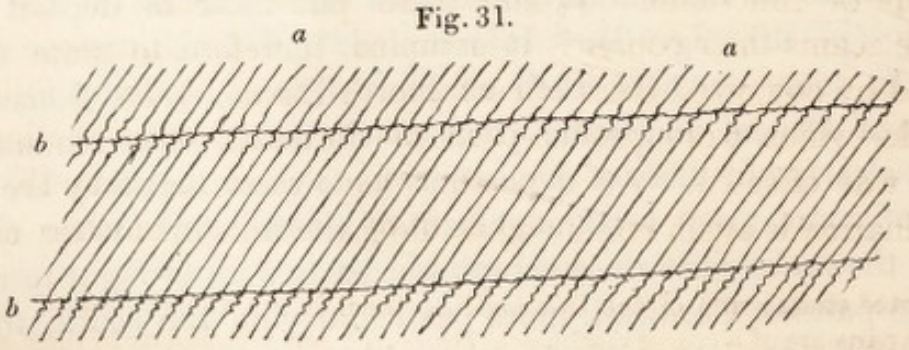
The schistose character of the grauwacke of North Devon and West Somerset would appear to have been frequently produced by planes of lamination, which have traversed the original beds

* Treatise on Geology (Lardner's Cabinet Cyclopædia), p. 65.
† *Ib.* p. 66.

of mud and clay either during or subsequently to their consolidation. A great prevailing direction, having a southern dip, runs through a large portion of them.* The range of the Morthoe slates from the coast to Clatworthy would seem to afford examples of these circumstances. In other places again, as at Linton and the range of the Barnstaple beds, the schistose structure so agrees with seams of organic remains, that we are led to consider it due to original deposit, more particularly as, in some contortions on the coast, the schistose planes are bent conformably with the seams of organic beds, and the whole agrees with the true bedding. We very often observe a few beds cut obliquely by planes of lamination among others which bear no traces of having had their parts arranged by laminating forces, and this is particularly observable when sandstones are interstratified with fine-grained slates, seeming to show that, while the fine particles of the mud or clay were arranged by these forces, the sand had not been acted upon sufficiently to produce any marked effect; probably also the different mineral composition of the beds, should it be different, may have been variously acted upon, independently of the facility with which small particles may, compared with the larger, have obeyed a force tending to move and rearrange them.

When the planes of lamination traverse different beds, interruptions of the even course of the laminæ are often, though not always, observable, as in the subjoined section (fig. 31), in which

Fig. 31.



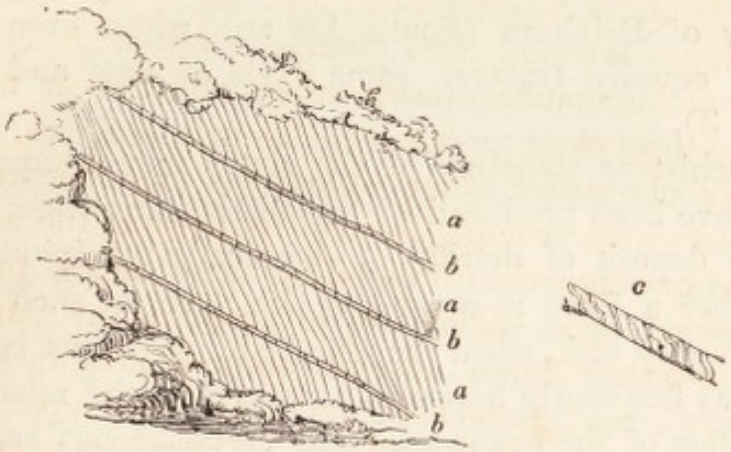
it will be seen that they are bent and undulate where they meet the beds, *a a* being the laminæ and *b b* the beds. It would

* The following description by Professor Sedgwick, of the lamination planes which are observable in the country stretching from the gorge of the Wye, above Rhaiadr, to the upper gorges of the Eolan and the Towy, with the exception of that which relates to the coarser beds and to the exact direction of the planes, is applicable to much of North Devon. "The whole region," he observes, "is made up of

appear as if the laminating forces had suffered interruption where they encountered the open space between the beds, filled probably with water, containing, as usual, mineral matter in solution.

It would appear also that the general planes of lamination have sometimes suffered interruption from thin seams of limestone. The following (fig. 32) is a sketch of the mode of the occurrence of argillaceous slate and thin seams of limestone at a quarry on the road to Combe Martin, on the east of Hillsborough

Fig. 32.



Hill, near Ilfracombe. Argillaceous slates *a a a* alternate with limestone seams *b b b*, about two or three inches thick. The schistose structure of the slates seems entirely due to planes of lamination which have traversed them with a southern dip, the plane of deposit and the true bedding being marked by the seams of limestone. Where these planes arrive at the limestone seams their course is interrupted, and the limestone is divided by contorted veins of carbonate of lime, no doubt filling up cracks which were produced in the limestone when the lamination was effected. After passing the limestone seam the even lamination is again continued to the next limestone, where similar

contorted strata; and of the true bedding there is not the shadow of a doubt. Many parts are of a coarse mechanical structure; but subordinate to them are fine, crystalline, chloritic slates. But the coarser beds and the finer, the twisted and the straight, have all been subjected to one change. Crystalline forces have rearranged whole mountain masses of them, producing a beautiful crystalline cleavage, passing alike through all the strata. And again, through all this region, whatever be the contortions of the rocks, the planes of cleavage pass on, generally without deviation, running in parallel lines from one end to the other, and inclining at a great angle, to a point only a few degrees west of magnetic north." (On the Structure of large Mineral Masses, Geol. Trans., 2nd series, vol. iii. p. 477.)

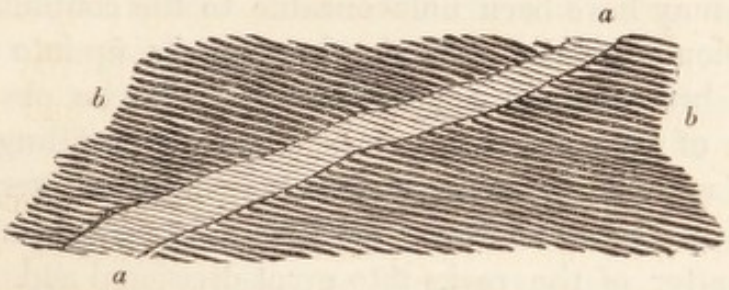
appearances are repeated. The divisions in the limestone are represented on a larger scale at *c*, where it will be observed that, though contorted (more so in reality than they could conveniently be represented in the figure), they still conform to the general planes of lamination traversing the whole rock.

Though it would thus appear that the forces producing lamination did not in this case traverse the limestone so as to produce even plane surfaces, but apparently broke through the seams in an irregular manner, this is not always the case with respect to beds of limestone in contact with slates, as may be well seen in the vicinity of Brixham (South Devon), where even planes of lamination equally traverse some beds of slate and limestone (p. 45, fig. 3).

If the schistose structure of the slates may, as appears to be the case, have been produced by two dissimilar causes, one being the simple deposit of detrital or chemically-precipitated matter, and the other a force re-arranging the parts of such matter, it becomes no easy task, when the true bedding cannot be well determined, as frequently happens, to ascertain the relative age of the lamination of the grauwacke and carbonaceous series of the district, as regards the intrusion of the granite of several parts of Devon and Cornwall, solely from the actual contact of the laminæ of slate with the granite. We see that this lamination took place after the contortion of the rocks in North Devon and West Somerset, so that, if we could be certain that these beds only became so contorted at the epoch when the granite was protruded, the lamination of the grauwacke of that part of the district took place after the granite was thrown up. There certainly seems no reason why we should consider all lamination which occurs in the planes of deposit as due to the latter alone, for it may readily have so happened that the direction of the laminating forces may have been in those planes, as has taken place among the contorted beds of North Devon and West Somerset, where the contortions have brought the beds in the direction of such planes. Still, as we find many little seams of coarser materials in the planes of deposits in various localities, and other circumstances indicative of the schistose structure having been produced by deposit, we should require good proof that the schistose structure was produced by cleavage lamination where it coincides with the great planes of deposit.

Among the veins of porphyritic rock previously noticed as intruded among the grauwacke between Cawsand and Redding Point, Plymouth Sound (p. 211), we seem to obtain evidence respecting the date of the lamination of the slate among which these igneous products have been thrust, inasmuch as the lamination passes through both the slate and some of the thinner veins, rendering the whole equally schistose, as is represented in the annexed sketch (fig. 33), in which *a a* is a vein rendered

Fig. 33.



schistose, and *b b* the including slate. It should be observed that the mineral structure of these veins appears to have been modified by the action of the powerful forces which have rendered the whole laminated. So much is this the case in some, that it would be only by tracing the gradual change from the arrangement of the component parts of the porphyry in the mass, where it becomes thickly laminated on the outskirts towards the east, to those places where the rock has become altogether schistose, that an observer would feel assured these veins formed part of ejected igneous rocks.

If we have been right in inferring (p. 211) that this porphyritic rock may be of the age of the igneous rocks of the red sandstone series, (and it may be observed that other good examples of thickly laminated igneous rocks of that age are to be found at Hazel Barton, near Kellerton, and on the ascent of Beacon Hill, near Crediton,) the lamination of the slate adjoining it would appear contemporaneous with the early part of that series. If it be of the age of the elvans generally, we might at least infer that lamination took place in the grauwacke near Plymouth after the intrusion of the granite, unless we suppose the schistose character of the veins to have been produced by some influence which the laminated condition of the adjoining rock may have exerted upon them.

It is quite clear that the schistose structure of a large portion

of the grauwacke and carbonaceous series existed anterior to the production of the red sandstone series, inasmuch as abundant fragments of the slaty beds of those deposits are intermingled with the breccias and conglomerates so common in its lower part; and it would appear equally evident that great divisional planes traversed the grauwacke and carbonaceous series prior to the same period, as the lower beds of the red sandstone series cover up inequalities in them which have often been modified in their form by these divisional planes; and, lest it may be inferred that the conditions may have been unfavourable to the continuance of the great divisional planes from the lower rocks up into the superincumbent breccias and conglomerates, it may be observed that the matter of the latter may occasionally be seen filling the upper portions of widened great divisional planes in the lower rocks.

In addition to these two marked arrangements of the constituent matter of the rocks into great divisional and lamination planes, we sometimes find it split into a multitude of bodies of a rhomboidal or prismatic form, bearing a close resemblance to crystals, some being more imperfect than others. In many of the beds of the grauwacke and carbonaceous series these bodies would appear to be formed by the intersection of the three planes of deposit, cleavage, lamination, and great divisions; and upon the angles at which they meet the greater or less regularity of the figures would appear to depend. As some arenaceous beds placed between others of slate are divided into a multitude of these bodies, while the slates are not, and cases occur where the slates are split into these bodies, while sandstone beds are merely separated into the great divisional planes, it would appear that this crystalliform arrangement of parts was often confined to particular beds from local causes. These facts are so common, that it would be useless to notice the various localities in which they may be seen; but it may be observed that the carbonaceous series has a greater tendency to be so split up than the grauwacke, and that often, both in the one and in the other, a few blows with the hammer will subdivide some of these bodies into still smaller portions, having the same shape with original rhomboidal or prismatic pieces of rocks. In many instances, also, particularly among slaty beds, a thin film of quartz is interposed between some of these crystalliform bodies, showing that, in the arrangement of the particles of the rock to produce them, there has been a

certain diminution of bulk permitting interstices between which siliceous matter has been subsequently infiltrated.

This subdivision of rocks into small crystalliform bodies is not confined to the sandstones and slates of the grauwacke and carbonaceous rocks of the district; it is observable, though rarely, among the trap rocks, among the best instances of which we may notice the greenstone near Toppleundy Hole, a cavern on the coast near Padstow, between Trefan Head and Carnweather Point. The fine-grained granite also of Castle-an-Dinas, near St. Columb Major, is thus subdivided where it occurs in laminæ of an inch or two thick in the old encampment.

When we regard the prevalence of the great divisional planes in particular directions crossed by others nearly at right angles to them, producing solids to a certain extent symmetrical, and consider the mineral modifications which the sedimentary beds have generally undergone since they were deposited, we are led to suspect not only that the lamination planes, commonly termed cleavage, are, as has been supposed by some authors, due to polar forces, but also that the great divisional planes have been equally caused by them, as has been considered probable by others.*

Although the direction of the present magnetic meridian in the district may be merely temporary, and the approximation of so many great divisional planes to it therefore accidental, still their great prevalence, both in the igneous rocks and sedimentary deposits, in that direction, leads us to suppose that polar forces may have considerably governed the arrangement of the component matter of the rocks they traverse during consolidation, either from the cooling of the former, or the chemical changes which have taken place in the latter. If we imagine a constant tendency of such polar forces to arrange the component matter of rocks during consolidation in given areas, we can the more readily account for the frequency of nearly similar directions in the great divisional planes of rocks of different ages in them, some of which

* Dr. Boase remarks upon this subject, that in rocks, as in crystals, the integrant particles are combined and arranged into forms more or less geometrical, and that, if the rocks do not exhibit such symmetrical figures as perfect crystals, it may be accounted for by their more complicated composition; "so that their forms are not the simple result of the aggregation of similar particles, but the balance of different powers, each tending to produce a different form." (Treatise on Primary Geology, p. 254.)

have clearly been consolidated before the others were formed, inasmuch as we find solid portions of them forming either rocks of intermediate age, or component parts of the beds thus divided by planes having similar or nearly similar directions. Thus, instead of supposing that these great divisional planes were formed only at one time, we have merely to consider that, during the various periods when rocks were consolidating, the matter composing them was brought within the influence of forces tending to divide the masses in directions which deviated slightly from each other, when viewed on the large scale, though many minor modifications may have been produced by the conditions existing during the consolidation of each rock. How far such polar forces may be due to electricity, it may be difficult to say in the present state of our knowledge; but if we suppose, with M. Ampere, that electrical currents exist in the crust of the globe traversing it from east to west, and producing terrestrial magnetism, we can readily conceive that they may be intimately connected with it.*

* The experiments of Mr. Robert Were Fox, in which he produced lamination in clay by means of long-continued voltaic action, the planes of the laminæ being formed at right angles to the electric forces, possess great interest from their bearing upon great divisional and lamination planes in rocks. He considers that the general laminated structure of the clay in these experiments appeared to indicate that a series of voltaic poles were produced throughout the clay, the symmetrical arrangement of which had a corresponding effect on the structure of the clay, and that this view was confirmed by the occurrence, in several instances, of veins, or rather laminæ of oxide of iron, or oxide of copper, according to the manner in which the experiments were conducted.

Mr. Fox points out the bearing of these experiments upon the cleavage or lamination planes of rocks, and "considers the prevailing directions of the electrical forces, depending often on local causes, to have determined that of cleavage, and the more or less heterogeneous nature of the rock to have modified the extent of their influence."—Report of the Polytechnic Society of Cornwall for 1837, pp. 20—21, and 68—69.

CHAPTER X.

MINERAL VEINS AND FAULTS.

When we regard the Ordnance geological maps of the district with reference to the ores of the useful metals discovered within the area represented by them, we readily perceive that the chief metalliferous country occurs from Dartmoor on the east to the Land's End on the west, such ores being sparingly scattered over other parts of the district under consideration. It will also be perceived that, with the exception of iron ore in the red sandstone series, seldom of any value, excepting near Porlock, Somersetshire, of manganese at Upton Pyne, and other places on the same lode or mineral vein in the red sandstone series near Exeter, and of carbonate of zinc (calamine) in the carboniferous limestone near Weston-super-Mare, the ores of the useful metals in Cornwall, Devon, and West Somerset, are either in the carbonaceous series, in grauwacke with its associated greenstone, serpentine, and other igneous rocks, or in granite or elvan.

It will be next observed that the various veins containing these ores are not distributed equally over the chief metalliferous country above noticed, but are, in a great measure, arranged in groups in still minor districts. Thus we have the metalliferous district of Tavistock (including therein Dartmoor, and the mining country of Callington and Linkinghorne), that of St. Austell (including therein the granitic mass of Hensbarrow and its grauwacke skirts), the metalliferous district of St. Agnes; that of Gwennap, Redruth, and Camborne; that of Breague, Marazion, and Gwinear, and the mining district of St. Just and St. Ives (comprising the mineral veins in the granitic country between the two latter places). There are no doubt many mineral veins not included in these groups, but the occurrence of those which have afforded large quantities of the useful metals in groups is a somewhat marked feature in the geological structure of the country.

The chief metalliferous country, taken as a whole, may therefore be conveniently subdivided into six minor districts. Dartmoor, considered as a portion of the Tavistock division, is stanniferous; the mines around the town of Tavistock are principally

cupriferous ; on the north are the lead lodes of Wheal Betsey and Lidford, and on the south the argentiferous lead-mines of Beer Alston. On the north also are numerous manganese mines, and manganese has been obtained near Calstock on the south, and near Linkinghorn on the east. The neighbourhood of Callington is both stanniferous and cupriferous, and as true silver-lodes are found in it, it may also be termed argentiferous. The Tavistock district, therefore, viewed as a whole, is of a mixed metalliferous character, its component parts being somewhat marked.

The St. Austell district is principally stanniferous, the copper-lodes being chiefly confined to its south-eastern side, including the present very productive mine of Fowey Consols, and the Crinnis lodes, from which much valuable copper ore has been extracted. The St. Agnes district is for the most part stanniferous, particularly near the town and Beacon, the principal exception being the Great St. George and Wheal Leisure mines near Piran Porth to the eastward, and Wheal Towan and some other mines on the south-west.

The great mining district of Gwennap, Redruth, and Camborne, is chiefly cupriferous, tin ore being comparatively rare, except near the latter place. Silver ores were once raised in sufficient quantities in Dolcoath mine to be profitable, and cobalt at Wheal Sparnon, near Redruth. The Breague, Marazion, and Gwinnear district, is of a mixed stanniferous and cupriferous character,* the Gwinnear subdivision being argentiferous as far as regards Wheal Herland, from which mine muriate of silver and other silver ores were obtained in profitable quantities. The St. Just and St. Ives district is principally stanniferous.

Independently of the principal groups above noticed, lead occurs on the north of Truro, at Garras; and at Wheal Rose, near Newlyn, considerable quantities of the same ore have been obtained. In the latter vicinity there are also other lead-mines, as well as in the country extending thence towards Penhale Point and New Quay. Lead-mines have also been worked at St. Merryn, St. Issey, Pentire (north of St. Minver), and near St. Teath. Antimony is found at St. Merryn, Endellion, and between the latter place and St. Teath, on the north, and near Mevagissy, and between St. Germains and Landrake, on the south.

* The Breague subdivision is also to a certain extent plombiferous, as lead is obtained near Porthlieven and Penrose.

Quitting the principal metalliferous country, and following the skirts of Dartmoor round by Okehampton and Ashburton to the neighbourhood of Plymouth, a few lodes* are discovered, principally of copper, and of comparatively little value, at least as far as researches have been yet made among them, with the exception of that at Bottle Hill Mine, near Hemerdon Ball, from which both tin and copper have been raised in fair quantities. The other localities will be best seen by reference to the maps. Valuable manganese mines have been worked on the east of Dartmoor, at Doddiscombleigh and Ashton, and fine iron ore is found near Ilsington. In the stripe of the carbonaceous series which runs to the north of Exeter, lead ore has been raised near Newton St. Cyres, and the valuable manganese lode running near the latter place, Upton Pyne, and Huxham, has already been noticed.

Proceeding to the north of Devon the country is non-metalliferous, with the exception of some clay-iron ore, mixed with the anthracite of Bideford, and its continuation to the eastward, until we reach the range of land beyond Barnstaple, where manganese is found at West Down and a few other places, the returns from which, however, are generally unimportant.† At Combe Martin large quantities of argentiferous lead have at various times been raised, and from these mines much silver was at one time extracted.‡ Iron ore is also obtained in the same vicinity. Copper ore has been sparingly found in the country on the south of Minehead, and in the Quantock Hills and its vicinity; in quantities, however, that would be scarcely noticed in the mining districts of Cornwall and Devon. Proceeding still further to the north-east extremity of the area to be noticed in this report, the carbonate of zinc is seen to occur in the carboniferous limestone of Worle Hill, near Weston-super-Mare, and of Bleadon Hill, near Bleadon, a part of the Mendip range from which much calamine has at different times been raised.

If we now regard the maps with reference to any connexion which may exist between the geological structure of the area represented and the abundance or scarcity of the useful metals

* Lode is a term employed in Cornwall and Devon for a mineral vein.

† Mr. Robert Were Fox informs us that, in a ferruginous lode in the neighbourhood of North Tawton, gold was found in small quantities.

‡ These lodes also contain bi-sulphuret of copper.

found in such area, we shall soon perceive that granite, or its modification, elvan, occurs near, or at, all the localities where tin and copper ores so abound as to be worked and produce good mines, while lead, antimony, manganese, iron, and zinc, are discovered in sufficient quantities to be profitably raised at a distance from granite or elvan. Hence we might infer that the presence of granite or elvan has had considerable influence in promoting the presence of tin or copper ores which either occur in them or in other rocks in their vicinity, while the granitic influence, if we may use the expression, was not essential to the accumulation of the ores of lead, antimony, manganese, zinc, or iron, in bunches or veins, as the case may be, in quantities to be profitably worked. So far from the ores of lead appearing abundantly in granite, elvan, or in the schistose rocks contiguous to them, the occurrence of such ores, in quantities sufficient to repay the miner for his labours, is very rarely under such conditions in Cornwall and Devon, being on the contrary generally removed from them. As far as the two counties above mentioned are concerned, the conditions favourable for tin and copper ores seem unfavourable to those of lead.

The antimony ores appear chiefly to be obtained in fair abundance in those portions of the grauwacke of the district which are much associated with trappean rocks, as for instance, near Endellyon and Port Isaac, on the north of Cornwall, and near St. Germains, on the south-east. The manganese ores are also much associated with the same rocks, occurring very abundantly in the mixture of them with the carbonaceous series and grauwacke which extends from the neighbourhood of Laneast Down, near Launceston, towards Bridestow, curving southward between those places by North Hill and Linkinghorn towards Tavistock. In this minor area the oxides of manganese frequently occur in bunches, the best bunches being, for the most part, those which are contiguous to the trappean rocks. The rich bunches of manganese which are found at Doddiscombleigh and Ashton, on the west of Dartmoor, occur under similar conditions. The manganese ores of North Devon are, however, unassociated with trappean rocks, so also are some manganese ores in the St. Austell mining district, and the valuable lode of Upton Pyne, with its continuation on the east and west, is without visible trappean rocks of importance near it.

The sulphuret of zinc (the *Black Jack* of the Cornish miners) occurs very abundantly in the mineral veins of Cornwall, being, however, more frequently associated with the ores of copper than with those of tin. The conditions favourable to the production of tin and copper lodes have been favourable also to the appearance of sulphuret of zinc (blende), the latter, however, frequently occurring in the continuation of tin or copper lodes far beyond those localities where the tin or copper can be profitably raised. Viewed on the large scale, blende is one of the most widely distributed ores in Cornwall. The carbonate of zinc, or calamine, is a very rare ore in Cornwall or Devon, so much so that, considered as one which could, under favourable conditions, as regards demand, be profitably raised, it is confined to the carboniferous limestone in the north-east corner of the district under consideration.

It has been above stated that lead does not occur in quantities sufficient to repay the labours of the miner in those localities in Cornwall and Devon where tin and copper can be profitably raised. As a connexion has often been observed in various parts of the world between sulphuret of lead and calcareous rocks, it may be proper to observe that the argentiferous lead-lodes of Combe Martin occur in beds immediately beneath the slates in which limestones are found at the same place, that the celebrated argentiferous lead-lodes of Beer Alston cut through slates which are in part (those of Cotele) calcareous, and that the continuation of the South Petherwin calciferous series is plombiferous near St. Teath, at Pentire (near Padstow), at St. Issey, St. Merryn, and New Quay; in several other localities, however, as will readily be observed, the lead ores do not occur in calciferous rocks.

From our knowledge of the occurrence of iron under very various geological conditions, we should not expect to find its useful ores limited to any one in the area under consideration, and accordingly we perceive that the conditions under which it is found vary considerably. Red hæmatite iron occurs as part of a mechanical rock, the new red sandstone, mixed with sandstone and conglomerate, and is worked at open day at a quarry near Wotton Courtney, and at Luckham, and Porlock (Somerset). This iron has been, and I believe still is, extensively shipped at Minehead for the Welsh iron-works. It constitutes nearly the lowest beds of the new red sandstone of that part of the country,

and it should be noticed that the grauwacke on which this rock rests contains veins of brown hæmatite iron near Porlock, so that the red hæmatite in the new red sandstone may in a great measure have been derived from the hæmatite in the grauwacke beneath. The most marked occurrence of iron in Cornwall and Devon is in lodes as brown hæmatite, often rich and of excellent quality. It is thus found at Combe Martin, in North Devon, at Ilsington, on the east of Dartmoor. In Cornwall it occurs in the same manner near Lostwithiel, Bodmin, St. Stephen's, Ladock, and Cubert, and in the St. Just mining-district, chiefly in grauwacke. A lode of magnetic iron ore occurs at Lower Treluswell, near Penryn, crossing trap rocks associated with the same series.

Cobalt is a rare ore in the district under consideration, and does not seem to be accompanied by any marked geological conditions, as far as regards its occurrence in any particular class or kind of rock. Nickel is still more rare, and has only been detected in any profitable quantity near St. Austell. Bismuth is not a common metal, and does not seem confined to any particular rock or combination of rocks.

The silver of Devon and Cornwall has for the most part been obtained from argentiferous galena, of which the general mode of occurrence has been already noticed. Silver ores proper have also been obtained in several mines in Cornwall, and hitherto in lodes or cross courses in the grauwacke. The ores so found have been chiefly native silver, sulphuret of silver, arsenical silver, and black oxide of silver; and, judging from the localities where they have been detected, those lodes or cross courses where the schistose rocks are near granite or elvan have been the most productive. Thus in Herland mine, near Gwinnear, where elvans traverse the grauwacke, silver ores to the value of 8000*l.* were raised.* At Dolcoath mine, which is partly in granite and traversed by elvan courses, silver ores to the amount of about 2,000*l.* were obtained. Mr. Carne states that at Wheal Duchy, near Callington, which is near granite, and at the ten-fathom level, a course of silver ores accompanied by native silver occurred for three fathoms in length, yielding about 200*l.* per fathom.† The value of the silver at one time raised was about 3,000*l.*, and the mine has lately been

* Carne, Trans. Geological Society of Cornwall, vol. i. p. 122.

† *Ib.* p. 123.

worked, and more silver ores have been obtained, but of what value we have not learned.

Although gold has not been obtained in veins, except in one case near North Tawton, Devon,* there is good evidence in the rolled pieces found in the tin stream-works in Cornwall that it has occurred in strings, branches, or lodes, in the rocks of the district. Judging from the stream-works, the gold has often been brought down from granite, as for instance in the St. Just mining district. The gold occurs in such a manner with the stream tin near Ladock as to give rise to the supposition that a lode from whence such gold has been derived crosses the river in the grauwacke not far from that place; for, though grains of this metal have been detected on the south of that line down the course of the river, they have not been found above it. Some of the largest pieces of native gold have, we believe, been obtained from the Carnon stream-works.

If we now turn our attention from the general geological conditions under which the ores of the useful metals are found in Cornwall, Devon, and Western Somerset, and direct it to the lines representing mineral veins, as also to those which in the mining districts are termed cross courses, cross lodes, or iron leaders, according to different localities, it will readily be perceived, that, notwithstanding minor variations, marked and distinct directions are apparent. If the eye be carried to other parts of the maps, at a distance from the mining districts, it will also be seen that some of the directions above noticed are also common to the lines of dislocation, termed faults, there observable.

Commencing with the faults on the north-east of the area under consideration, a north and south line of dislocation occurs at Uphill, on the south of Weston-super-Mare, by which magnesian limestone, new red sandstone, and lias, on the east, are brought suddenly into vertical contact with carboniferous limestone on the west, and the amount of dislocation must be considerable. Alluvial land intervenes between this fault and Worle Hill on the north, concealing the rocks beneath it; but a fault seems to traverse the latter hill nearly in a line with that at Uphill, judging at least from a dislocation observable in the cliff on its north side. On the south the great alluvial tract of the Bridgewater levels conceals the continuation of the Uphill fault in that direction.

* Mr. Robert Were Fox, MS.

On the south-east, great leading faults, having general north and south directions, though somewhat bent in their courses, traverse the eastern side of the Blackdown Hills and their geological continuation towards the south. The most marked of these is that which cuts through Combe Beacon, near Combe St. Nicholas, where chalk is brought into vertical contact with green sand in such a manner that the eastern half of the beacon is composed of one rock, and the western half of another, as represented in fig. 34.

Fig. 34.

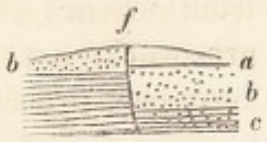
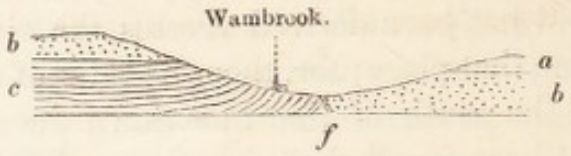


Fig. 35.



a, chalk; *b*, green sand; *c*, lias; and *f*, faults.

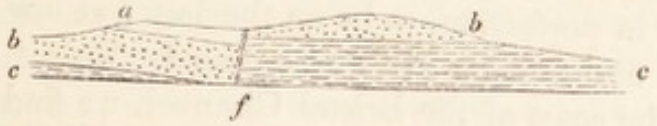
In its continuation to the southward this fault passes down the Wambrook valley, showing (the valley being one of denudation on the back of the fault) the lias brought into vertical contact with the green sand at Wambrook (fig. 35). The amount of vertical dislocation, independently of any lateral movement, must be more than 200 feet. Proceeding southward, this fault passes through the hill to the eastward of Axminster and down the Charmouth valley to the sea, letting down the green sand at Hawkchurch to a lower level than it would otherwise occupy. From the nature of the ground this fault is not easily traced to the northward, but there can be little doubt that it passes through the lias in that direction, and probably the manner in which the lias and red sandstone series occur on the north-west of Hatch Beauchamp is connected with its continuation there. The north and south fault by which the green sand at Chard is let down, probably falls into the fault above mentioned nearly where it traverses the Axe river.

It will be seen that other faults, having a general north and south bearing, occur in the same district, one, the Membury fault, bringing the green sand into vertical contact with the lias in such a manner that the chalk is almost on a level with the latter, the dislocation being about 300 feet, measured vertically. The Membury fault seems a branch of that which runs up the valley of the Yart. If the line of the Yart fault be prolonged southward, it

would run into the fault at Pinhay Bay, near Lyme Regis.* Of this, however, we have no good proof, the covering of chalk flints and fragments of green-sand chert on the high ground between Pinhay Bay and the valley of the Axe concealing all the minor detail essential to such proof. Another important fault passes northward up the Dalwood Valley, and can be seen to split into several branches on the road which traverses the valley between Stockland Hill and Rower Common, rising to Wyteh.

At Widworthy there is a north and south fault which brings chalk vertically against green sand, so that the former constitutes the lower part of a hill of which the latter forms the top (fig. 36).

Fig. 36.

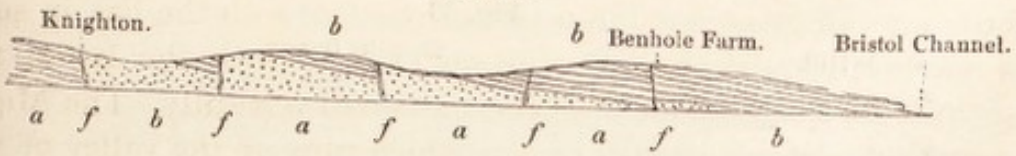


a, chalk; *b b*, green sand; *c c*, red sandstone and marl; and *f*, fault.

There are, no doubt, numerous minor faults with other directions, but these great north and south lines of dislocation are so marked that they cannot be overlooked, and we perceive that such main north and south lines can be observed between the coast of the Bristol Channel, near Weston-super-Mare, and the shores of the English Channel, near Lyme Regis and Axemouth.

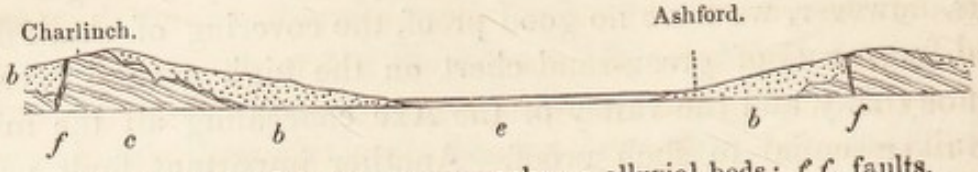
If we now return to the coast of the Bristol Channel and the adjacent country, we find numerous lines of dislocation near Watchet and Bridgewater. These for the most part have an east and west direction, and are consequently at right angles to those above noticed. Some of these faults bring in alternate lines of lias and red sandstone near Knighton, on the north of Stokecourcy (fig. 37), and throw up patches of grauwacke in the vicinity of Cannington and Charlinch, which would be otherwise concealed beneath the general level of the red sandstone series of the district (fig. 38). On

Fig. 37.



* See Geol. Trans. vol. i., 2nd series.

Fig. 38.

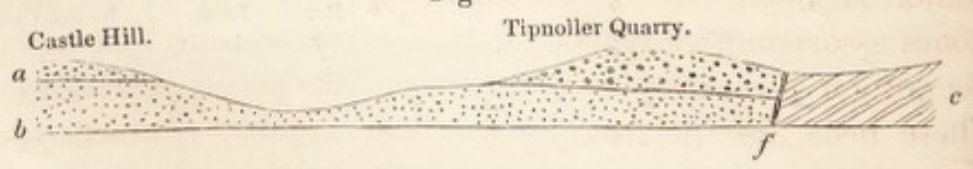


a, lias ; *b*, red sandstone ; *c*, grauwacke ; *e*, alluvial beds ; *f f*, faults.

the coast, from the vicinity of Watchet to that of Little Stoke, these faults will be seen to have been accompanied by much contortion, so that the various beds are thrown into every variety of position, affording, on the small scale, very beautiful illustrations of those greater disturbances on the surface of the earth to which many of the higher ranges of mountains, such as the Alps, Himalaya, &c., are due. It is necessary, in order to see the faults and contortions of this coast in perfection, to be on the latter at low water, when the fractures and flexures are well exposed.

Quitting the coast of the Bristol Channel, we find marked lines of east and west dislocations on the south and south-west. A considerable east and west fault traverses the south-west termination of the Quantock Hills, passing through Hestercombe, and by West Monkton into the country concealed by the great alluvial deposit of the Bridgewater levels. Where this dislocation cuts through the turnpike-road between Taunton and Bridgewater, near Adsboro Hill, the fault is well seen. An east and west fault is found in the direction of that of West Monkton, on the north of Wiveliscombe. It is difficult to prove that the latter is a continuation of the same fracture which passes through Hestercombe, as the nature of the country is such, both as regards the want of natural or artificial sections, and the difficulty of tracing faults through rocks which possess the same structure for considerable depths so great (similar mineral substances only being thus brought into contact), that we could not satisfactorily determine this point. At the fault on the north of Wiveliscombe, grauwacke is brought into vertical contact with red sandstone and magnesian conglomerate (fig. 39). There can be little doubt that this dislocation passes

Fig. 39.

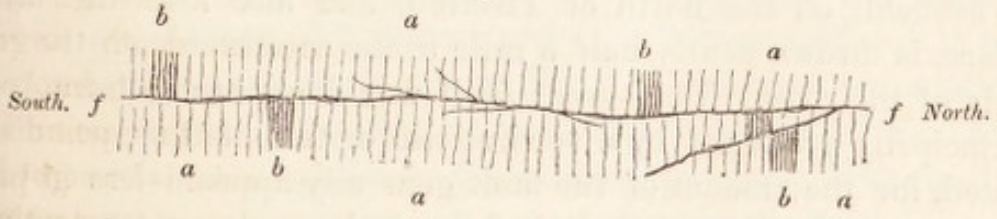


a, magnesian conglomerate ; *b*, red sandstone ; *c*, grauwacke ; and *f*, fault.

westward in the direction of Huish Champflower; but similar slates of the grauwacke series being alone brought into vertical contact with each other, it cannot be satisfactorily traced.

For this reason, though dislocations can be often observed in the river courses of North Devon and the adjacent part of Somerset, formed in grauwacke, and faults can be frequently seen in artificial sections, they cannot be satisfactorily followed, though the general evidence produces on the mind of the observer a strong conviction that two main lines of dislocation prevail, the one having a general tendency, notwithstanding minor variations, to the east and west, the other north and south. The coast necessarily presents the best evidence on this head, and, accordingly, we perceive that the country bounded by it is much broken by faults. Such being the case, we may fairly infer that the interior is not less dislocated; and wherever sections are favourable we see that such is the case. Many of these coast sections are highly interesting when viewed with reference to the dislocations which in Cornwall contain the ores of the useful metals, and are hence more especially denominated mineral veins. At low water the faults may be seen not only cutting the cliffs vertically, but also horizontally exposed among the ledges of rocks which on some coasts extend outwards sufficient distances to exhibit the lines of faults in considerable detail. The horizontal exposure of the range of a north and south fault under the cliffs at Cornborough, near Bideford, may be selected as showing the evidence to be thus obtained.

Fig. 40.



The rocks represented (fig. 40) form part of the carbonaceous series, and are fossiliferous, usually containing the remains of plants: *a*, being argillaceous shales, and *b*, compact siliceous sandstones associated with them; the dip of the various beds being, in the portion of coast represented, to the southward at a high angle. These beds are traversed by the dislocation, *f f*, which destroys the continuity of the rocks, so that the hard sandstones, *b b*, are

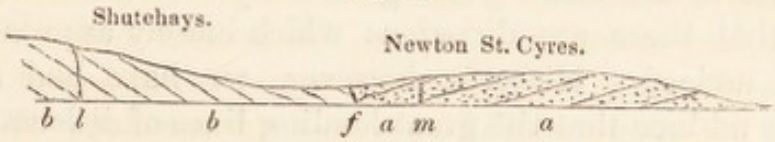
made to abut vertically against the shales, the greatest amount of horizontal heave so produced in the section being about one hundred yards. It will be perceived that on the north the fault is double, from a division in the dislocation. Independently of this main split in the fracture, smaller cracks (too small to be represented in the figure), leading into the great dislocation, are numerous, as might be expected in a fracture of rocks, and is very commonly seen. As is well understood, considerable horizontal movement may appear to have taken place in a dislocation when the planes of strata are inclined, and the movement has been merely vertical; in such cases the amount of apparent lateral dislocation increasing with the decrease of the dip. The whole of the apparent lateral heave of the beds at Cornborough cliffs may, therefore, be due to vertical dislocation. As, however, the dip of the strata is considerable, and beds are not brought into contact in such a manner as we may suppose would be the case if the movement had been alone vertical, probably a movement partly vertical, partly horizontal, in other words a diagonal motion, will best explain the facts there observable.

The valley of the Exe would appear to run upon a north and south fault for a considerable distance, as beds which ought to be continued across it in the line of strike are found to have been heaved out of their places. The boundary-line between the carbonaceous series and the grauwacke of North Devon, near Brushford (on the south of Dulverton), is heaved more than half a mile to the southward, on the left bank of the Exe, near Exe Bridge; and the junction-line of the red sandstone and carbonaceous series near Washfield, on the north of Tiverton, and also near the latter place, is thrown nearly half a mile to the southward, on the east side of the river. This great fault would appear to have been principally produced by a vertical rise or fall of the parts dislocated, for the amount of the fault generally appears less in proportion to the increased dip of the beds, and greater as their inclination becomes less.

Proceeding to South Devon, we find marked lines of east and west dislocation on the northward of Exeter. They are readily traced at Spray Downs and Bere, near Kellerton Park, where the carbonaceous series is brought into vertical contact with red sandstone. The great fault, bringing the red sandstone series on the north into vertical contact with the carbonaceous series on

the south, which can readily be traced ten miles from Poltimore on the east, to Venny Tedborn, near Posbury Hill, on the west, runs east and west, and is remarkable as having parallel to, and not far distant from it, another, but minor fault in the red sandstone, from which so much valuable manganese has been obtained at Huxham, Upton Pyne, and Newton St. Cyres, the latter being probably a mere split from the great fault, and uniting with it in depth.

Fig. 41.



a a, red sandstone; *b b*, carbonaceous series; *f*, great fault; *m*, smaller fault and manganese-lode; and *l*, lead-lode.

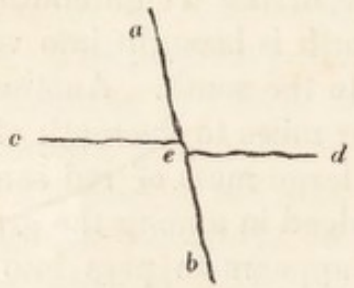
A multitude of faults are found on the coast composed of the red sandstone series in south Devon, particularly near Dawlish. Various artificial sections in the interior show that they are no less abundant there, but their very abundance renders them difficult to trace with accuracy, as it is only when red sandstone is brought into contact with some other rock that this can be satisfactorily accomplished. By this aid we find an east and west line of fault running on the north side of the Teignmouth estuary, by which red sandstone dipping north is brought into vertical contact with slates and grits dipping to the south. Another east and west line of fault occurs about four miles to the south of the latter, near St. Mary Church, so that a large mass of red sandstone and conglomerate is, as it were, wedged in among the grauwacke limestones and slates. This fault appears to pass into the red sandstone series on the west of Yeadown, and there becomes difficult to trace. Several faults are observable at Tor Bay, the most remarkable of which appears to be that on the north-east side of Tor Abbey sands, where red sandstone is brought into contact with the limestone, the former being much turned up near the line of junction.

Proceeding round the coast from Tor Bay to Plymouth, we perceive that it is very much broken by faults, but, as rocks of a similar mineralogical character are for the most part brought against each other, the amount of dislocation is not easily estimated in such cases; neither, as small portions only are exposed to view, can the true directions of the faults be easily determined; for, as is well known, faults not unfrequently have a zigzag direction on

the small scale, though their general directions are well marked, so much so, that, when laid down on the scale of an inch to a mile, the fault has the appearance of a straight line, the zigzag deviations from that line being then often inappreciable.

In the vicinity of Tavistock and Callington the operations of the miner have shown dislocations in two main directions, one set, viewing the subject generally, holding an eastern and western course, varying from due east and west, to west 25° south and east 25° north, the other crossing it nearly at angles. It will be observed that these are directions which closely approach those previously noticed. Hitherto, however, we have had no good evidence to adduce that the great leading lines of dislocation were not produced contemporaneously, or that one set was formed subsequently to the other. In the Tavistock and Callington district we become acquainted with a fact which holds true throughout the metalliferous districts of Devon and Cornwall; namely, that the lines of dislocation having a general tendency north and south have been produced subsequently to those which vary from west 30° south, and west 30° north, to east 30° north, and east 30° south. The proof of this consists not only in seeing that

Fig. 42.



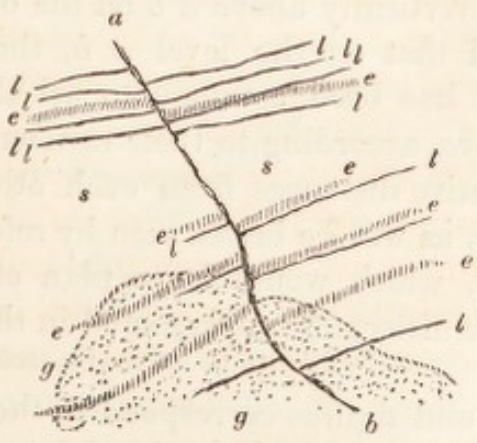
the line of dislocation *a b* (fig. 42) cuts through the line *c d* in such a manner that the continuity of *c d* is apparently destroyed at *e*, but also in the fact that the body of the country on the one side is seen to be so moved as not to coincide exactly with the mass of country on the other. The contents of the fissure *c d* are also found to be so similar where its continuity is destroyed at *e*, with minor modifications due to causes brought into action subsequently to the fracture, that no reasonable doubt can exist of the fissure *a b* having been the last formed, even in cases where the opposite sides of the pre-existing fissure are nearly in a line with each other.

As to the arrangement of the lines *a b* and *c d*, so that there

should be an apparent solution of the continuity of the latter at *e*, that in itself, independently of other evidence, would be insufficient to prove that a fissure, *a b*, was formed subsequently to another fissure, *c d*, inasmuch as the whole country may have been dislocated at one time, the arrangement of the lines having been solely caused by the fissures having been opened in the lines of least resistance; and there would appear little doubt that numerous apparent *heaves*, as the Cornish miners term these dislocations, are nothing more than contemporaneous fractures with a considerable shift among the various fragments, both great and small, produced at the same time. In such cases, however, the contents of the fissures crossing each other show a continuity very different from the appearance presented where mineral veins or lodes are suddenly cut off by a cross course, filled, for the most part, by substances dissimilar from them, the lodes exposing ends at the points of contact with the cross course of so marked a character, that a reasonable doubt can scarcely exist that they were once continuous portions of filled fissures which have been subsequently divided by the cross course.

The best evidence of the priority of one set of fissures to another consists in the general fact that the body of the country containing the one is so moved, where traversed by the other, that the one set merely occupies its general position in the country, like any particular beds or masses of rock in it, following the general shift, while the other set passes directly through all, cutting across, and destroying the continuity of, the contents of the other set, in common with the general rocks of the country. Thus, in the annexed figure (fig. 43), which represents a ge-

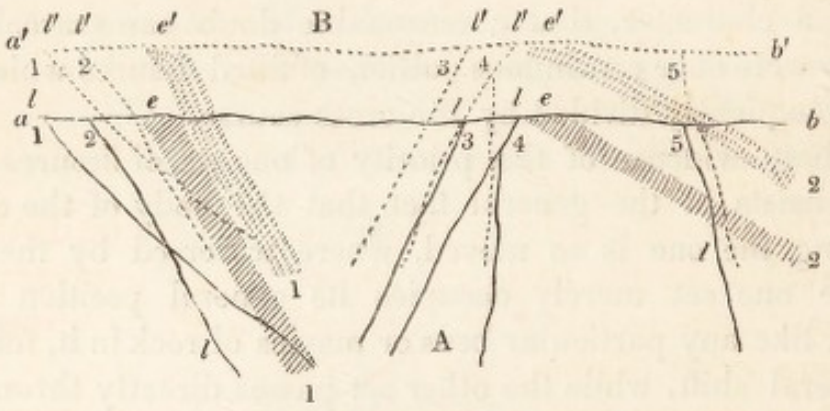
Fig. 43.



neral plan, on a scale of one inch to a mile, of part of the great cross course, *a b*, near Redruth, where it traverses the North Downs, all the lodes or mineral veins, *l l*, are moved with the body of the country, as shown by the heave of the elvan courses, *e e*, and of the junction-line of the granite, *g*, with the slate, *s*. In such a case it can scarcely be doubted that *a b* is a fissure formed subsequently to those marked *l l*.

While on this subject, and as this report may fall into the hands of those who have not directed their attention to the dislocation of one set of fissures by another formed at a subsequent period, and to the heaves which may be produced apparently contradictory to each other by the same movement, a word or two on this head may not perhaps be useless before we proceed with the general subject.

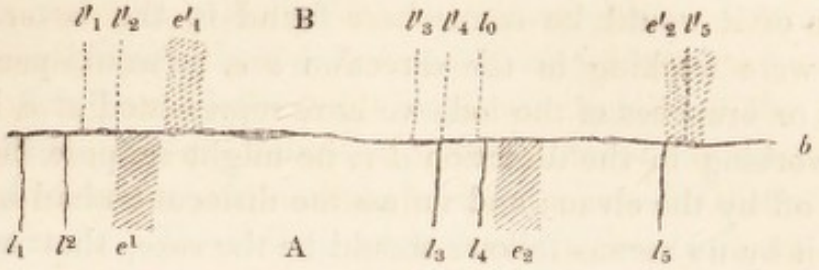
Fig. 44.



Let *a b*, in the above section (fig. 44), represent the surface of a country traversed by the elvan courses, *e e*, and by the lodes, *l l l*. Let us now suppose this country to be dislocated in a plane perpendicular to the section before us, so that *a' b'* on the one side be lifted vertically above *a b* on the other. It will readily be perceived that on the level *a b*, though the amount of vertical elevation has been common to all the lodes and elvan courses, these have, according to their various dips or underlies, very different relative distances from each other on the one side than on the other, as will be better seen by reference to the figure beneath (fig. 45), which would be a plan of the fault, on the level *a b*, after the dislocation represented in the section (fig. 44) had taken place.

As the letters and figures correspond in the section and plan, it will be seen that, while the lodes *l* 1, *l* 2, and the elvan *e* 1, are

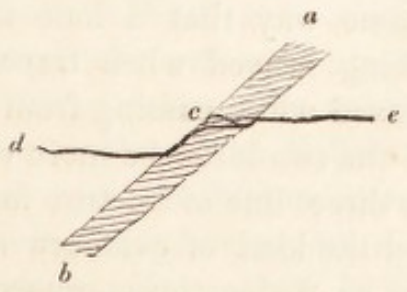
Fig. 45.



heaved to the right on the side of the dislocation marked B, the lodes *l* 3 and *l* 4 are heaved to the left, and in the latter case a lode, or branch from a lode, *l'* o, appears on the side B which was not at the surface on the side A, so that three lodes appear on the side B as continuations of the two lodes visible on the surface of the side A. The elvan *e* 2, which was close to the lode *l* 4 on the side A, is apparently removed far from it on the side B, and moreover contains the lode *l* 5 in the latter case, which was far removed from it on the side A. These figures will serve to illustrate the facts, apparently contradictory, which are often observable on the two sides of a dislocation when lodes, elvans, or other mineral bodies, dip at various angles or in opposite directions, and are traversed by it.

For the sake of more easy illustration we have made the movement vertical in the foregoing figures. Such movements, however, have been, as might be supposed, in all directions, which still more serves to complicate the results. It may be also necessary to observe that a lode may present the appearance of having been heaved by a hard body, such as an elvan, when in reality the fissure merely took a line of least resistance. Thus, let *a b*, in the annexed figure (fig. 46), represent an elvan, and *d e*

Fig. 46.



a lode, formed subsequently to it. Without due care and examination it might be assumed that the elvan *a b* was introduced into a fissure formed after the lode *d e*, heaving it at *c*. In the

case before us, if the lode were formed after the elvan a continuation of it would be somewhere found in the latter. If the miner were working in the direction *e c*, he would perceive the strings or branches of the lode we have represented at *c*, but, if he were working in the direction *d c*, he might suppose the lode to be cut off by the elvan; and unless the dislocation had been such, which it by no means follows should be the case, that an appreciable space, sufficient to show the continuation of the fracture, is apparent on the wall of the elvan on the side *d*, it might be considered that the elvan was formed after the lode, the latter having been heaved at the time of the dislocation into which the matter of the elvan has entered. Even in the case when the miner is working in the direction *e c*, equivocal appearances may present themselves. The strings at *e* need not be immediately in a line with the lode in that direction, for, according to the figure before us, the fissure was merely produced along the lines of least resistance, and the planes of separation, between the elvan and the slate or other rocks in which the latter is included, being easier to pass through, where the fissure came against the elvan, than the body of the elvan itself at that spot, the fracture of the elvan only took place where the forces so acted, that it became easier to produce a fracture through the elvan than along its walls. Now upon the structure of the elvan will depend the kind of fracture through it. If it be somewhat brittle it may be split into a multitude of fragments, while if it be tough a single rent may traverse it. Much also will depend on the divisional planes in the elvan, and elvans are generally much divided by such planes. If these be easily separated or numerous, the fracture forming the walls of the lode, though considerable out of the elvan, may be so divided up among the joints of the elvan itself as to be scarcely perceptible. In the same way that a lode may thus have the false appearance of being heaved when traversing an elvan, it may be apparently heaved while passing from slate into granite, if the junction-line of the two latter be more easily divided for a short distance than the direct line of fracture followed.

Having thus adduced the kind of evidence necessary to show that one set of fissures or dislocations crossed another set at a subsequent time, we may proceed with the direction of the various lines of mineral veins and cross courses observable in the great mining districts of Devon and Cornwall.

The direction of many lodes in the vicinity of Tavistock and Callington is upon points which do not vary considerably from east and west; those which differ considerably from that line being probably the Crowndale and Gunnislake lode and the Wheal Franco lodes. Wheal Friendship lode differs but a few degrees from east and west, as is also the case with Wheal Jewel tin-lode on the north of it. The lodes passing through Tavistock, on Plaster Down, on the south of the same Down, near Monk's Hill, at Wheal Robert, on Roborough Down, Morwell Down, on the banks of the Tamar above New Bridge (including the lode near the latter place), at Homebush, at Wheal St. Vincent, Wheal Brothers, and some other places near Callington, differ only a few degrees from east and west.

These lodes, varying from about W. 25° S. and W. 5° N. to E. 25° N. and E. 5° S., are traversed by numerous cross courses, cutting them generally at angles varying from 70° to 90°, very frequently approaching the latter. A very powerful cross course traverses Wheal Franco, heaving the lodes to the right, taking a direction thence towards the south-western part of Tavistock. The cross courses cutting through Wheal Friendship do so nearly at right angles, the argentiferous lead-lode of Wheal Betsey being a continuation of one or more of them, for at least two would appear to have a tendency to unite and fall into one in that direction; and it may readily happen that the north and south lead-lodes on the east of Lidford are the continuation of cross courses which traverse the country near Wheal Friendship; indeed they appear to take directions which would bring them close to Wheal Betsey.

The two great north and south argentiferous lead-lodes of the Beer Alston mines are cross courses, taking directions which would cut the Drake's Wall and other adjacent lodes. The cross course in Gunnislake can scarcely, however, be a continuation of either of them, unless they deviated from their courses near Calstock considerably. The N.N.E. and S.S.W. lead-lode of Red Wall mine, near Callington, seems another instance of the cross courses being plombiferous in this district.

The cross course running about N.N.W. and S.S.E. from Black Down, near which it traverses the western part of Wheal Friendship lode, to the east end of Whitechurch Down, near Tavistock, is well marked through the country, and the fissure ap-

pears to have been wide in places, judging at least from the quarry between Tavistock and Mary Tavy, where the quartz in it has been worked for the roads. Small cross courses seem very common: many traverse Drake's Wall mine, and some can be well seen in the upper part of that mine as in the face of a cliff, the lode having been laid open from the surface for a considerable depth.*

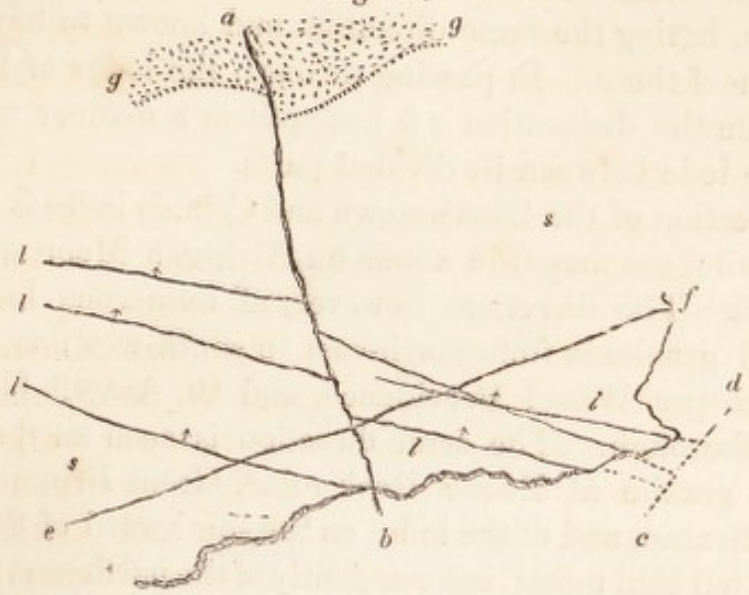
The lodes upon Dartmoor approximate considerably to east and west courses, and round its borders on the north, east, and south, where mines have been worked, the same direction in the lodes would generally appear. The chief exceptions seem some tin-lodes on both sides of Longstone Hill, near Okehampton, which would appear to take courses about W. 30° S. and E. 30° N.; such short parts of these lodes were however worked when we visited them, that these lines may merely have been some of the minor irregularities common to almost all lodes. Some eastern and western lodes between Belstone and Okehampton are cut by a N. and S. cross course, and a cross course, in which lead and silver ores have been found, traverses the Okement, near the Castle. The tin-lode at Owlecombe runs a few degrees south of west and north of east. A large iron-lode runs nearly east and west from Sharkham Point, near Brixham, to Upton, and was extensively worked towards the end of 1837. Bottle Hill lodes are within a few degrees of east and west. A lode on the west of them, on the south of Cann Slate Quarries, appears to run a few degrees more to the N. and S.

In the St. Austell district the general direction of the mineral veins and cross courses is to a great extent preserved. The main lodes at the Fowey Consols approximate a true east and west direction; there are others which run more W.N.W. and E.S.E., and E.N.E. and W.S.W., thus forming contre or counter lodes coming in from the N. and S., but, taken as a whole, the general tendency of the mass of fracture is as above. The direction of the main lodes which form the Charlestown, Pembroke,

* On this as well other accounts, Drake's Wall mine, on the south of Gunnislake, is well worthy of attention, inasmuch as it rarely happens that lodes can be seen at all by the light of day. At the Charlestown mines, near St. Austell, the upper part of the great tin-lode is also open to daylight for several fathoms, but by no means to the depth to which Drake's Wall lode is exhibited. The latter, being close to the high road from Tavistock to Callington, is easily accessible.

and Crinnis mines, is towards the W.N.W. and E.S.E. They are traversed by other dislocations, as is seen in the annexed figure (fig. 47), where *l l l* represent the main lodes, and *a b*, *c d*,

Fig. 47.



and *e f*, cross courses. When viewed with reference to itself only, the above seems sufficiently complicated, but, when taken as a part of a whole it is not so.

The main lodes, when viewed in connexion with those of Fowey Consols, and of the Great Hewas mine, which latter are nearly parallel to the Crinnis lodes, give a marked line of dislocation, having a direction a few degrees to the north of west and south of east. The line *a b* is that of a cross course, agreeing in its direction with the general direction of the north and south cross courses of Devon and Cornwall, and *c d*, notwithstanding its S.W. and N.E. direction near these mines, appears to constitute part of a north and south cross course, which, curving round by Tywardreth, runs northwards to Lostwithiel, and there forms the great iron-lode, so extensively worked near that place. The direction of the line *e f*, running at right angles to *a b*, is that of the principal lodes of the Gwennap, Redruth, and other districts to the westward. We have here at least two epochs of dislocation, if not three. The north and south lines, considering *c d* as part of one running probably into *a b* under the sea to the southward, traverse the copper and tin lodes, and heave not only them but also the junction-line of the granite and slate, so that the country is dislocated or moved, as regards surface, nearly the tenth of a mile. The dislocation in the line *e f* also heaves the lodes,

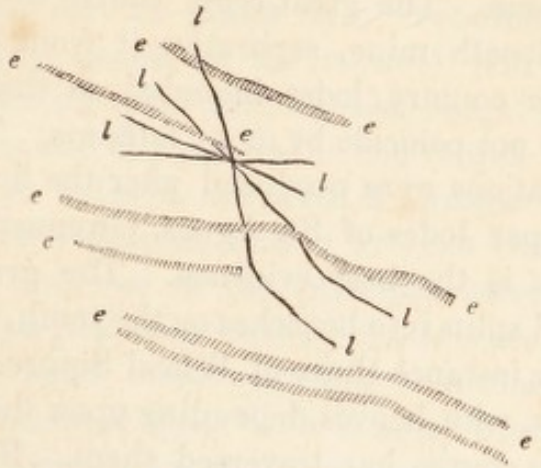
though in a minor degree, but it does not appear clear whether such dislocation was produced contemporaneously with *a b*, or subsequently or previously to it. It may, however, be remarked that at the Great Hewas mine a dislocation traverses the tin lodes there, having the same direction, and known to have heaved at least one of them. In passing through the lodes of Pembroke copper-mine the dislocation *a b* has split in a manner to include part of the lode between its divided parts.

The direction of the Charlestown and Crinnis lodes is preserved in the granite (see maps) in a lode on Alviggan Moor, and thence to Dubbers. The direction, however, of numerous lodes in the St. Austell granite is from north-east to south-west, as is seen at Wheal Prosper, Wheal Providence, and St. Austell Hill mines, near Hensborough. The same direction is seen on the skirts of the same granite at Roche Rock mine, Great Brin mine, near Belovely Beacon, and at the lodes on the southward of St. Enoder. At St. Austell Hill mines, independently of the north-east and south-west lodes, there is a north and south cross course, with a lode running at right angles to it. At Wheal Prosper, also, there are lines running north and south, nearly. At Treliver Mine, one lode is nearly east and west, and another, which must fall into the former, going eastward, runs to the northward of west, and south-east,—a cross course, holding manganese, and having a general north and south direction, traversing the west of the mine. This cross course runs southward to Toldish mine, where a lode parallel to it has been worked for tin, though not very profitably. Cross courses holding iron ore occur in a north and south direction at Nantallan Downs and Lanivet Downs near Bodmin, resembling that above noticed as traversing the country near Lostwithiel.

Taking the St. Austell district as a whole, the most marked lines of lodes are W.N.W. and E.S.E., thence inclining to true east and west in the slates on the south-east, and south-west and north-east in the granite and on its skirts on the north and north-east and east, large cross courses having a general north and south tendency occurring in various places. One mine, Polgooth, differs materially from the others in its vicinity, and indeed from the Cornish mines in general, for, instead of showing that parallelism of lodes so commonly seen in them, viewing the subject on the large scale, its lodes so cross each other nearly in one place as

to give the appearance of a star, as will be seen by reference to the annexed plan (fig. 48), in which *l l l* are lodes, as they appear on the surface, and *e e e* elvans.

Fig. 48.



The direction of the lodes in the St. Agnes district is, taken as a whole, W.S.W. and E.N.E., and considerable general parallelism can be observed among them. The lodes of Wheal Rose, &c., in Newlyn Downs form a kind of intermediate link between them and those on the north of the St. Austell district.

Parallel to the run of the lodes in the St. Agnes district we find the great mass of mineral veins of Gwennap, Redruth, and Camborne, the two districts being connected in this respect by the lodes on Princes Common and by other intermediate mineral veins. The general parallelism of the lodes in this part of Cornwall is remarkable, and presents a striking feature in its geological structure. There are, no doubt, many minor deviations from this parallelism, but, viewed as a whole, and in the mass, it is particularly striking. These lodes are more or less traversed by other lines of dislocation having a general tendency to run at right angles to the W.S.W. and E.N.E. lines. One of the more remarkable of these is termed the great cross course, and can readily be traced many miles from Gwennap to the sea on the north. During its course it heaves the country, lodes included, between seventy and eighty fathoms horizontally (see fig. 43 p. 297), so that the eastern side of the fracture is more to the south than the western, forming what the miner terms a "right hand heave," for, whether he be working from east to west or the reverse, the continuation of the lode he is following will be found to the right hand when hove by the cross course.

Many other great cross courses are seen in the St. Agnes and Gwennap, Redruth and Camborne districts, the apparent heave produced by which is in the same direction. One at Piran Porth is considered to shift the country on either side to the distance of ninety-two fathoms. The great cross course which traverses the east end of Dolcoath mine, separating it from Cook's Kitchen mine, heaves the country, lodes included, so that its once continuous parts do not coincide by many fathoms. That these north and south dislocations were produced after the fissures containing the tin and copper lodes of St. Agnes, Gwennap, Redruth, and Camborne, there is the best evidence. The great cross course above mentioned splits into branches on the south, so that the lodes traversed, as for instance those of Wheal Squire, are broken into numerous pieces, with heaves depending upon the mode in which the divided cross course has traversed them. By sections which represent the old workings at Poldory mine,* adjoining Wheal Squire, it would appear that the lodes run into each other vertically in a manner somewhat resembling that in which the lodes at the Fowey Consols are disposed relatively to each other (pl. 11), showing a complication of fissures. In this part of the Gwennap district, therefore, the country can be considered as little else than a mass of huge fragments cemented together by various mineral substances, the great dislocations having been produced at two different times at least, the last cutting off the continuity of numerous fissures, previously filled in part by the ores of the useful metals, in this case chiefly by those of copper.

Continuing our attention for the present to the direction of the lodes and cross courses, it will be seen that the W.S.W. and E.N.E. direction is continued from Camborne through the north part of Gwinnear into the granite on the north of Penzance, which has been previously termed for convenience the Land's End granite. The great leading lode of Wheal Alfred, those of Herland mine, and to a certain extent those of Relistian mine, have this direction, which is also preserved in some lodes near Gwythian. Near St. Ives the main lode of Wheal Trenwith and St. Ives Consols takes the same course, which may also be seen among Balnoon lodes. Proceeding along the coast from St. Ives to Morvah, many lodes are found coinciding with the same direction, and, in the interior, the two main lodes at Ding Dong tin-

* Kindly lent us by Mr. John Williams, of Scorrier House.

mine take the same course: so that the St. Agnes and Gwennap line of fissures may be traced nearly to Morvah.

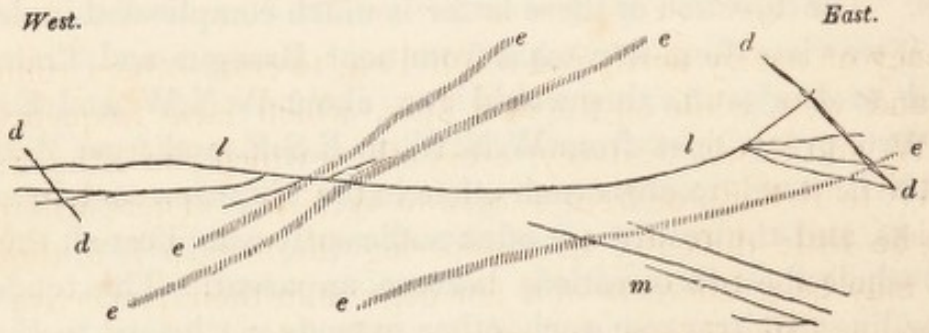
A W.S.W. and E.N.E. direction will be observed in the lodes at Penance Mill near Falmouth, Wheal Vyvyan near Constantine, and in several mines near Wendron, which serves to show the general course of the mineral vein fissures in those localities, connecting them with the Gwennap line of lodes. The same direction is also conspicuous in the Wheal Vor, Great Work, and several other lodes on the north of Breague. The great lode which runs from Godolphin Hill to Trevean Cove takes a similar course, as does also one of the principal lodes near Retallack. The Breague and Marazion country is however crossed by another line of principal lodes, more reminding us of that of the St. Austell lodes. The direction of these latter is much complicated in detail, but, if we view them in a mass from near Breague and Trewavas Head to Ludgvan, they would run about W.N.W. and E.S.E. The two great lines from W.N.W. to E.S.E. and from W.S.W. to E.N.E. tend to cross each other in the Marazion and Breague districts, and the results are often sufficiently complicated, though as a whole the two directions become apparent. This tendency of the lines to traverse each other extends northward to Binner Downs, and also to Copper Bottom mine between Clowance and Pendarves. The cross courses which coincide with the general run of those in St. Agnes and Gwennap, where they traverse the W.S.W. and E.N.E. line of fissures near Gwinnear, St. Erth, and St. Ives, become complicated in their directions near Germoe and Breague, some taking very nearly those of the W.N.W. and E.S.E. lodes, as for instance near Trescow and Wheal Vor.

It is very difficult to determine whether the lines from W.N.W. to E.S.E., or from W.S.W. to E.N.E., have been formed anterior or posterior to each other, as there exists much contradictory evidence on this head, it being sometimes stated that the former cut the latter, and at others that the latter cut the former. If we take the cross courses at Wheal Vor, those which are nearly parallel to the W.N.W. and E.S.E. lines, to have been formed contemporaneously with the latter, then it might be inferred that such were last formed, but it may readily have happened that the cross course fractures following lines of least resistance took a direction parallel to the W.N.W. and E.S.E. lodes. This point, which is one of considerable interest, can only be well cleared up by re-

cording more fully than has hitherto been done the working of the smaller mines, which would afford very valuable information not only on this but also on other heads alike important to science and its application to the useful purposes of life. Whether, however, these two main lines of lodes be or be not contemporaneous, as regards each other, there is good evidence that great lines of dislocation, having a N.N.W. and S.S.E. tendency, traverse the land, bending occasionally, as near the Marazion mines and Trescow, more into a W.N.W. and E.S.E. course.

Some good examples of split lodes are to be seen in the Marazion and Breague districts; of these, the most remarkable is the Wheal Fortune range of mines represented in the annexed plan

Fig. 49.

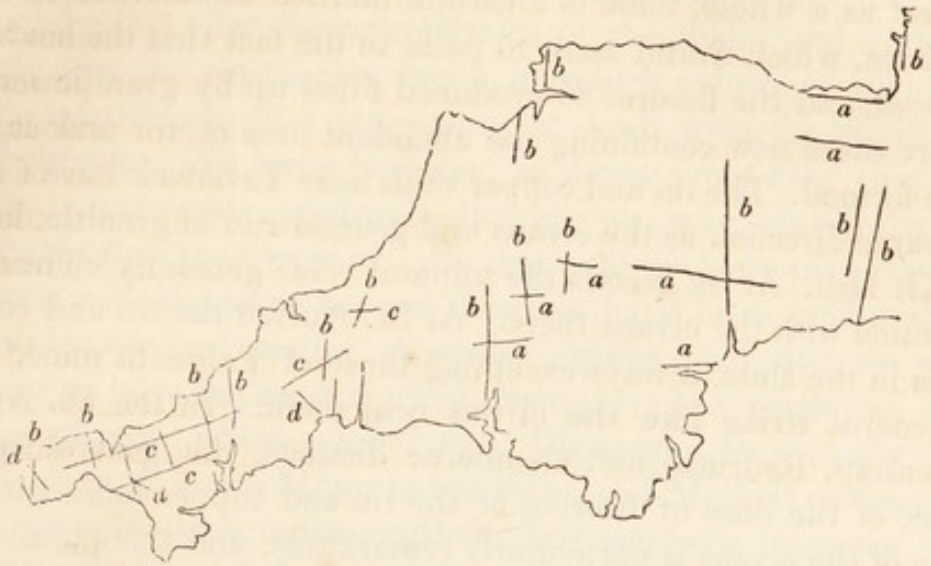


(fig. 49), on a scale of one inch to the mile, *l l* being the main lode, which splits east and west. A range of lodes, *m*, forming Wheal Frendship, would, if they be continued in the direction of the main Wheal Fortune lode, fall into the latter. These various lodes traverse three elvan courses, *e e e*, and are cut by cross courses, *d d*. There are also some curious examples of lodes parting and meeting again at the Marazion mines and at those on the Downs to the southward of St. Hilary. (See maps.)

Near St. Just some of the lodes have the same direction with many of those in the Marazion and Breague district, which run from W.N.W. to E.S.E., and from N.W. to S.E., nearly. Other lines run N.N.W. and S.S.E., thus corresponding with the general run of the cross courses more eastward. There are also cross-course lines more north and south. The St. Just mass of lodes may be considered to have a still more northerly direction than the W.N.W. and E.S.E. system of Breague and Marazion.

When we generalize, as in the annexed plan (fig. 50), the various facts connected with the directions of the common faults, mineral veins, and cross courses, above noticed, we find on the east a

Fig. 50.



tendency of nearly north and south lines to cross others running east and west, while on the west lines, which have frequently a N.N.W. and S.S.E. tendency, cross others which run either from W.S.W. to E.N.E., or from E.S.E. to W.N.W. There will probably be little difficulty in considering the lines *b b b*, though there may be a difference of a few degrees in their respective directions, as belonging to the same system of fissures, and it will be also seen by the preceding notices of them that many afford evidence of considerable dislocations in the country traversed.

It will also be seen that towards the great metalliferous district of Cornwall, the lines *c c c*, take a direction somewhat parallel to that of the general range of land, and we have to consider whether this may be a bend from the east and west lines on the eastward, or a portion of a separate system of dislocations. Looking at the subject in a general point of view, a bend in the general line of fissures produced by local causes would appear the better explanation, more particularly as the lines of north and south fissures also bend so as to traverse the change of line at right angles. How far local causes have produced the lines *d d d* (at St. Austell, Marazion, and St. Just), supposing them to a certain extent contemporaneously produced with the lines *a* and *c*, it is difficult to prove. One thing, however, can scarcely fail to strike the observer, and that is, the general coincidence between the lines of tin and copper veins and those of the elvan courses. It is not pretended that these mineral veins do not often cross the elvans: this they frequently do, and at Polgooth, near St. Austell, the

elvan is considered to traverse the mineral veins; but, viewing the subject as a whole, there is a certain marked coincidence between the lines, which would seem to point to the fact that the land was fissured, and the fissures so produced filled up by granitic matter before those now containing the abundant ores of tin and copper were formed. The tin and copper veins near Tavistock have nearly the same direction as the elvans and general run of granitic matter of Kit Hill. At St. Neotts the mineral veins generally coincide in direction with the elvans there. At St. Austell the tin and copper veins in the slate, always excepting those of Polgooth mine, have a general strike like the elvans near them. In the St. Agnes, Gwennap, Redruth, and Camborne districts, the general coincidence of the lines of bearing of the tin and copper lodes with the lines of the elvans is particularly remarkable, and this parallelism may be traced from the latter through part of Gwinnear, to St. Erth, and thence into a part of the Land's End granite. In the Wheal Vor part of the Breague district the same facts are observable; and when we regard the W.N.W. and E.S.E. lodes of the other part of the same district, and of Marazion, we find elvans with the same directions.

As for the most part we have direct evidence that the elvans generally were consolidated before the fissures containing the ores of tin and copper were formed, inasmuch as the latter are continued through the former in the same manner as through any other rock which they traverse, and it would appear probable that the fissures filled by elvans were chiefly produced after the consolidation of the granite, we have the various fissures which contain the greater portion of the copper and tin ores of Devon and Cornwall taking general directions coincident with lines of pre-existing fissures. Now, if granitic matter extends, as we have supposed, beneath a considerable part of the metalliferous districts of Devon and Cornwall, we have the lines of elvans and principal tin and copper lodes, upon a great back of pre-existing granite, at first taking a western course from Dartmoor to the Brown Willy and Hensborough bosses, then striking down W.S.W. to the Land's End and Scilly Island granites.

The north and south lines, *b b b*, present a marked feature in the plan before us (fig. 50), cutting through all, and are clearly seen in Cornwall to have been the last set of fissures, with the exception of east and west slides, which are exceedingly difficult

to trace on the surface. If these lines have been contemporaneously produced, we have evidence near Chard that they must certainly date after the consolidation of the chalk, and very probably after the plastic clay epoch, inasmuch as beds which appear to be referrible to that deposit are let down with the chalk near Wambrook. We have, however, no direct proof that they were contemporaneously produced, though we may consider it very probable that they were so. Be that as it may, we may infer that fissures with the same general direction have been produced and filled by mineral matter at earlier epochs. Of this we would appear to have the most marked example in the north and south range of elvan which extends from Watergate Bay on the north through St. Columb Minor to the vicinity of Michell on the south, and probably also in the northern and southern trappean dykes of the neighbourhood of New Quay, and in the vicinity of Truro.

In the dislocations termed, as above noticed, slides, there is evidence that lines of fracture were produced after the general north and south fissures; the geological date to which they can be assigned is however difficult to determine, further than if we suppose the Cornish cross courses to have been contemporaneous with the north and south faults of the Black Down Hills, it must have been during the supracretaceous or tertiary period, and anterior to the present configuration of the land as regards hill and valley, inasmuch as such dislocations are not more apparent on the surface than others of anterior date, and cause no more break in the general contour of the ground.

It may here be noticed that dislocations and lines of disturbance, in directions varying from W.N.W. and E.S.E. to W.S.W. and E.N.E., have taken place at different geological epochs, if we merely regard the part of England situated on the south of a line drawn from Bristol to London. The granite has probably so disturbed the slates through which it has protruded, that their original lines of bearing may be scarcely discernible; and, seeing that granite occurs at Lundy Island, the grauwacke of north Devon and Somerset, the strike of which we might otherwise have regarded as an example of an anterior direction of beds, may have been as readily ridged and furrowed at the time the granite was protruded as at any prior period. If we take as our guide the direction of these ridges and furrows, whatever their geological age may be, a line a few degrees N. of W. and S. of E.

would be that of the strike for the grauwacke rocks of North Devon. Taking the mass of the grauwacke and associated rocks of Devon and Eastern Cornwall, east and west would not far differ from the average direction of the beds, abstraction being made of those parts of the area more immediately and locally disturbed by granitic protrusions. The slates of Western Cornwall have so suffered from this more immediate cause of disturbance, that a general direction, further than that of the various granite bosses which are above the surface, cannot readily be traced. It may, however, be observed that, from Mevagissy towards Probus, an anticlinal line can be observed coinciding much with that from Croydon Hill, south of Minehead, to Linton. The anticlinal line of St. Breock's Downs, near Bodmin, extending thence through Bogee Downs to the sea, is nearly E. and W.

This general east and west direction of beds, whether caused by the protrusion of the granite or partly anterior to it, was produced prior to the deposit of the red sandstone series, for the latter rests quietly upon the edges of these disturbances, as may readily be seen where it comes in contact with the pre-existing rocks. In the Mendip range we find the carboniferous series ridged into an east and west anticlinal line, which may have been contemporaneously produced with the general strike of older beds in Devon and Cornwall. Be that as it may, the red sandstone series rests quietly on this previously-disturbed country.

We next observe the elvan courses, fissures filled with granitic matter, in part at least, certainly after the consolidation of the granite, inasmuch as elvan courses traverse that rock as well as grauwacke, the same fissure evidently running through both. The great mass of such granitic-filled fissures vary in direction from W.N.W. and E.S.E. to W.S.W. and E.N.E., many running true east and west. Whether or not these fissures were produced and filled with granitic matter, as previously observed (p. 217), at the time of the earlier deposit of the red sandstone series, it would be difficult to say, but at all events they were consolidated prior to the lodes which cross them at acute angles, while ranging in the same general direction.

We now come to the east and west lines of fracture through the red sandstone series, some of these faults being considerable, as that ranging near Upton Pyne and St. Newton Cyres, the fault near Kellerton, and others near Wiveliscombe and Taunton. There

will be no difficulty in considering the E. and W. lines of fracture traversing the lias and red sandstone series near Watchet as contemporaneous with these faults. In the area under consideration evidence of E. and W. faults of tolerable magnitude, such as may not be considered mere lateral breaks from the great north and south faults, have not yet been noticed, though probably some exist in the Black Down Hills. If we, however, extend our view beyond this area, we find considerable fractures with east and west directions near Bridport and Weymouth,* traversing chalk in the latter instance, so that such dislocations are carried into the supracretaceous or tertiary epoch. And of the like epoch will be the anticlinal line of the Wealden country, and of its probable continuation in the Vale of Wardour, as also of those of Kingscleer and other places noticed in Dr. Fitton's map of the south-east of England.† In the Isle of Wight there is direct evidence that an east and west line of disturbance was produced during the supracretaceous or tertiary period, after the deposit of the London clay, such line of disturbance extending a considerable distance through Purbeck, to and beyond Weymouth, and it may, for anything that appears to the contrary, be prolonged among the east and west faults affecting the red sandstone series in Devonshire.

If we attempt to connect these lines of dislocation and disturbance with those tin and copper lodes of Devon and Cornwall which have a general east and west tendency, there is considerable difficulty, inasmuch as the lines of many slides also take that direction. Now it should be recollected that, from the epoch of the red sandstone series upwards, vast deposits have been formed over the grauwacke, carboniferous series, and granite, and that we only see such portions of the latter rocks as have subsequently been denuded or have never been covered; consequently the fissures containing the tin and copper lodes may have been formed anterior to the deposits above named, and similar lodes be covered in abundance beneath them, the east and west cracks or dislocations traversing the superincumbent rocks being merely equivalent to those east and west fissures which are termed slides by the Cornish miners. With this view of the subject we have four

* Geol. Trans., 2nd series, vol. iv., plates 1 and 2.

† Fitton's Observations on some of the strata between the chalk and Oxford oolite on the south-east of England, Geol. Trans., vol. iv., 2nd series, pl. ix.

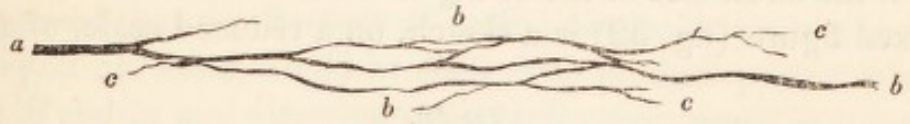
epochs of eastern and western disturbances in the south of England: 1. that either anterior to, or contemporaneous with, the great granitic intrusion; 2. that of the elvan courses, which traverse alike granite and disturbed beds; 3. that of the east and west tin and copper lodes, allowing considerable latitude to this term, the exact date of the lodes being uncertain; and 4. that of the east and west slides, which may coincide with the lines of disturbance produced during the supracretaceous or tertiary epoch in the more eastern part of southern England. If to this we add the north and south lines of elvan and trappean rocks in part of Cornwall, and the great cross courses and faults, there is no want of evidence to show that the solid rocks of the area before us have, at different epochs, been well contorted, bent, and broken, and it will be seen in the sequel that the consequences of such violent contortions and fractures have been of the greatest importance and value to man.

CHAPTER XI.

MINERAL VEINS AND FAULTS.

HAVING endeavoured to trace the great lines of dislocation, the minor lines of fracture and the present contents of the fissures, whether known by the names of common faults or mineral veins, are to be considered. It could scarcely be supposed that the great lines of fracture would be unaccompanied by smaller dislocations, running from them in various directions according to modifying resistances, which would depend upon the kinds of rock traversed by the great fractures, the direction in which they were carried through them as regards the bearing of their strata, should they be stratified, and other obvious causes. The great fractures would often also tend to split in various directions, and reunite into main lines, as in the annexed sketch (fig. 51), in which *a b*

Fig. 51.



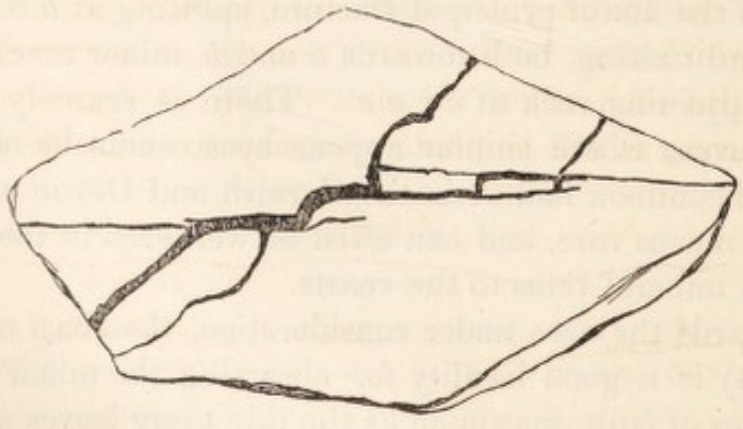
represents the line of principal fracture, splitting at *b b* from local causes, and uniting, both towards *a* and *b*, minor cracks running into the adjoining rock at *c c c c*. There is scarcely any long range of coast where similar appearances cannot be observed in the line of common faults: in the Cornish and Devon mines they are by no means rare, and can often be well seen in the continuation of the mineral veins to the coasts.

As regards the area under consideration, the coast of Watchet (Somerset) is a good locality for observing the minor complication of lines of fault, inasmuch as the tide there leaves a considerable extent of dislocated rocks bare at low water. On the coast between Marazion and the Greeb Point, Mounts Bay, there is a very beautiful display at low water of the back of a fault, traversing argillaceous slate, greenstone, and an elvan, the heave produced in the country by the fracture being well shown, as also all the minor ramifications, splits, and reunions.

The ramifications in mineral veins are commonly known to the miners as strings and branches, their very natural process of naming such parts being to regard the lode or mineral vein as a great leading body, and the country or rock including it an object of secondary consideration; and hence perhaps has in some measure arisen the somewhat remarkable hypothesis that the mineral veins of Cornwall were of contemporaneous production with the rocks containing them, which is to suppose—as the same mineral vein often traverses a variety of rocks, some clearly of fossiliferous systems, and mechanically formed through the agency of water, and others of crystalline structures and certainly due to different causes—that a body traversing others, formed at different epochs and through the agency of different causes, was contemporaneous with them all.

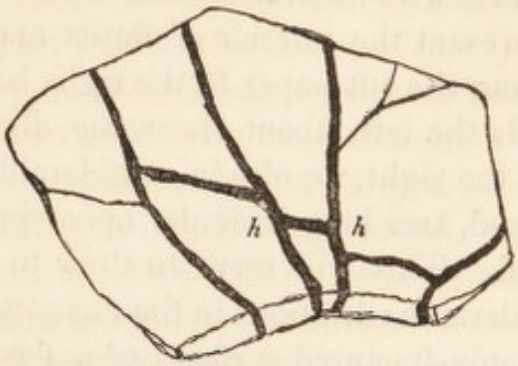
As the ramifications *c* (fig. 51), are merely cracks in the adjacent rocks formed while the greater dislocation *a b* was produced, it will follow that, whatever amount of heave there may be along a line of the main fault, supposing such heave to exist, which it by no means follows should be always the case, the sides of the strings or branches would generally coincide and fit exactly if the substance of the string or branch were removed. The annexed figure (fig. 52) is a sketch, on a reduced scale, of a specimen of slate containing strings of oxide of tin from St. Agnes, and illustrates a complicated minor fracture subsequently filled with a metallic oxide. These kinds of specimens are not uncommon, more particularly from St. Agnes, and some show an arrangement of parts which are improperly termed heaves, being nothing but numerous small fragments of slates, the results of

Fig. 52.



the minor fractures produced during a more considerable dislocation, cemented by mineral matter subsequently introduced, in a

Fig. 53.



manner well known to geologists to be common among fractured rocks. The above (fig. 53) is a sketch of another specimen of strings of oxide of tin in slate from St. Agnes, thought to be highly illustrative of such heaves at *h*, *h*.

The walls of a fault or a mineral vein are seldom parallel to each other for any considerable distance, and could not well be so except in cases where the fissure has been a mere opening in the containing rock, the relative position of the sides being otherwise unchanged as regards each other, for it can scarcely be supposed that the fracture of rocks, particularly when in beds of unequal hardness, would be such as to produce perfect planes, which, if slid in any direction upon each other, would still be parallel. On the contrary, the walls are generally found to be very irregular, which must be the case if two irregular sides of a fissure were slid upon each other, no matter in what direction, so that they be uneven, as will be readily seen by the annexed sketch.

Fig. 54.

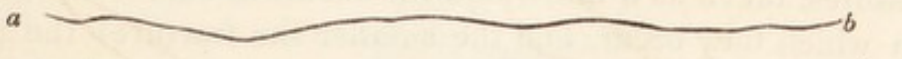


Fig. 55.

Fig. 56.

Let *a b*, fig. 54, be a line of fracture traversing a rock or rocks, and let *a b*, fig. 55, represent the same line; now, if we cut a piece of paper representing this line, and slide part of the

cut paper from *a* to *a'*, and from *b* to *b'*, so that the one side be pressed against the other at the points *o o o o o*, we obtain an irregular aperture at *d*, and isolated cavities at *c c c*, and, when we compare such figures with nature, we find that, with certain modifications, they represent the interior of faults and mineral veins. If, instead of sliding the cut paper to the right hand, we move the lower part towards the left, about the same distance that it was previously slid to the right, we obtain considerable variation in the cavities so produced, two long irregular open spaces, *c c* (fig. 56) being then formed. This will serve to show to what slight circumstances considerable variations in the character of an opening between the unevenly-fractured surfaces of a fissure may be due, such surfaces being moved upon each other so as to have numerous points of contact. The fractures would, of course, be more complicated among rocks than those above sketched, the irregularities of the sides being in all directions, and it being highly improbable that fragments of the shattered sides, of various dimensions, were not interposed between them, while others fell forwards into the fissures, producing a complication of cavities.

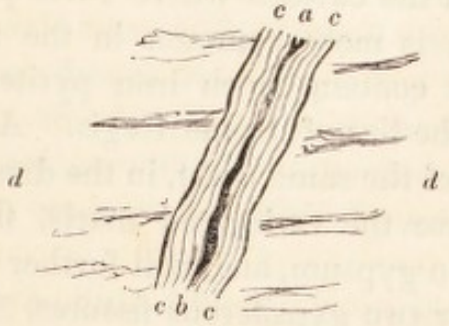
When we regard the general contents of fissures, whether they be known by the name of faults, mineral veins, branches, or strings, we are struck with the fact that the most abundant non-metallic mineral substances in them coincide with the principal mineral character of the mass of rocks traversed; thus, in districts where silica is the prevailing substance, such as in granites, a great variety of slates, &c., quartz is common; in calcareous countries carbonate of lime is abundant, and in gypsiferous districts selenite and common sulphate of lime are far from scarce. There is an evident connexion between the most abundant contents of fissures, taken as a mass, and the chemical character of the rocks in which they occur, and the smaller the fractures the more apparent this fact becomes, so that it would be a matter of considerable surprise to find carbonate of lime the most abundant substance in the small veins running through the granite of Cornwall and Devon, while it would cause equal surprise to see the small veins in the carboniferous limestone of Somersetshire, Derbyshire, and Yorkshire, principally composed of quartz. In districts where calcareous matter constitutes a small portion of the country traversed by a fissure, we should expect to find quartz veins traversing limestone, and accordingly, at Veryan and some

other places in Cornwall and Devon, where limestone occurs as a very subordinate portion of rocks chiefly formed of silicates, we find the principal veins traversing the limestone composed of quartz, while the smaller strings and branches are nearly altogether formed of carbonate of lime.

Modifications of various kinds would necessarily be produced from local causes, but, with the main facts before us, there can be little hesitation in considering that at least a large part of the non-mechanical and non-metallic contents of fissures, by whatever name the latter may be known, may be derived from the mass of adjacent rocks, the principal chemical character of which impresses a corresponding character upon them.

The contents of faults and fissures not worked for profitable purposes are, in the area under consideration, seldom well exhibited, except in the cliffs, where ample opportunities are afforded for observing them. In the cliffs of Middle Hope Hill, Worle Hill, and Brean Down, near Weston-super-Mare, numerous fissures in the carboniferous limestone are filled by calcareous spar. Galena has been worked for profitable purposes in the Mendip Hills, the geological continuation of those above mentioned, but hitherto no great quantities of lead have been raised. This ore is generally associated with carbonate of lime, which for the most part occurs in the plombiferous and other fissures, when they are not small cracks, in a series of layers of crystals parallel to their walls, occasionally leaving druses, or *vugs*, as the Cornish miners would term them, in the central parts, as is represented beneath

Fig. 57.



(fig. 57), *a b* being a line of fissure; *d d*, carboniferous limestone; and *c c*, layers of calcareous spar crystals, the axes of which are nearly perpendicular to the walls of the fissure.

At Worle Hill and Bleadon Hills, carbonate of zinc (calamine)

has been obtained in profitable quantities; but, as the working of this ore has for some time been discontinued, there is much difficulty in obtaining correct information as to its exact mode of occurrence. It is stated to be found in bunches in cavities of the limestone; but at Worle Hill, above Milton, and on Bleadon Hill, above Hutton Wood, such bunches have much the appearance of occurring in lines of mineral veins or lodes, running in a direction a few degrees to the S. of W. and N. of E.

In the faults on the coast near Little Stoke, which traverse lias, and in those near Watchet, which cross both lias and the upper beds of the red sandstone series, we find calcareous matter, more particularly in the lias, independently of clayey substances, usually washed out where the sea has free access to the faults, with a mixture of gypsum or selenite among those portions which traverse or are near the variegated or red marls. Sulphate of strontian is found, though very rarely, in the fissures of the variegated marls precisely as it occurs at Aust Passage, higher up the Bristol Channel.

On the southern coast the contents of the faults in the lias are highly instructive. Calcareous spar, as might be expected, is somewhat common, particularly in the small cracks, becoming crystallized in the cavities or vugs. Bisulphuret of iron (iron pyrites) is also not unfrequent, and its mode of occurrence reminds the geologist forcibly of that of the same mineral, and of bisulphuret of copper in the mineral veins of Cornwall, the one being a miniature representation of the other. The bisulphuret of iron occurs here and there in bunches in the little veins of the lias, crystallizing in the cavities where such present themselves. Bisulphuret of iron is more common in the fissures where the neighbouring rocks contain much iron pyrites, a very common mineral in part of the lias of Lyme Regis. Among the fissures and smaller cracks of the same coast, in the direction of Axmouth, where faults traverse the variegated marls, they contain much selenite and common gypsum, and, still further westward, celestine is detected in one or two gypsiferous fissures.

The faults, which are so numerous in the coast formed of the red sandstone series from Beer to St. Mary Church (Torquay), are chiefly filled by clayey or earthy substances, containing calcareous matter in a few places between Dawlish and Teignmouth. The fissures in the limestones near Torquay and on the southern side

of Torbay, are chiefly filled with carbonate of lime, so that a quartz vein at Saltern Cove, traversing shales, immediately beneath the limestones at that place, strikes the attention more than it would otherwise do.

From Minehead on the north, and Dartmouth on the south, the coasts to the westward are formed of little else than rocks composed of siliceous minerals, a few subordinate limestones included among them being the chief exceptions. Throughout this long line of coast, with the exception of the serpentine and diallage rock of the Lizard district, fissures of various dimensions, filled wholly or in part by quartz, are innumerable, sometimes cementing fragments of the adjoining rocks, sometimes extending from wall to wall, and at others forming a series of crystallised layers like the carbonate of lime, noticed above (p. 319) as occurring in the limestones of Weston-super-Mare and Torbay.

That water in the shape of springs is more or less charged with foreign matter is a fact too well known to be insisted on, and it is equally well understood that, if water percolate slowly through rocks, the foreign matter so contained in the spring waters will in a great measure agree with the principal soluble substances contained in the rock. Fissures being therefore formed in any rock of given chemical composition, the water in such fissures would contain foreign substances in it according to the chemical composition of the containing rock, and we should expect, from any cause which would produce a deposit from the water, that the substances thrown off on the walls of the cavity would be compounds of those contained in the adjoining rock, supposing the fissure to be so situated that water derived from other sources did not enter it. Much would necessarily depend upon the latter condition, so that in a large fissure traversing many rocks of different chemical compositions, the deposits in it might be very complicated, while in the respective different rocks the minor cracks in each would in a great measure be filled by substances derived from each alone.

There will probably be little difficulty in considering the non-mechanical contents of the various fissures and cavities, above noticed, as deposits from aqueous solutions contained within them, each deposit being characterised according to the conditions to which it has been exposed. Faults are well known to be generally so full of water that the lines of springs thrown out along

their courses afford the geologist considerable facilities in tracing them, and water is so disseminated through rocks that they may always be considered, while forming part of the solid ground, as in a moist state, some being more replete with moisture than others. Hence, by means of the porosity of rocks, and of the fissures that traverse them, and which vary from many feet in width to mere cracks, water containing a variety of substances in solution is intermingled with the solid parts of the earth's crust.

This is a state of things highly favourable to the transmission of mineral matter in solution from one place to another ; and also, as Mr. Fox observes, to electro-chemical action, the rocks "containing different saline solutions and metalliferous substances, in contact with water, charged in many instances with other salts."* Hence a variety of effects depending on electro-chemical action may be produced, and substances transferred from one part of a series of moistened rocks to another. We have, therefore, in a fissure filled by water among rocks a receptacle for a variety of mineral deposits, the character of which will depend upon the conditions under which the fissure exists.

When we direct our attention to the manner in which the contents of the mineral veins of Cornwall and Devon occur, we are soon struck with the general resemblance it bears, more particularly in the slate districts, to that observable in common fissures and faults. The layers parallel to the sides of the including fissure in some, the irregularly mixed substances in others, and the cavities of various sizes, usually lined by some crystalline mineral, at once recall to our attention the contents of non-metalliferous fissures and faults, and when to this we add the fragments of the adjoining rocks, cemented by the non-mechanical substances, the general resemblance becomes exceedingly striking.

The mechanical contents of the mineral veins of Cornwall and Devon are far more abundant than seems to be commonly supposed, for there are very few mines from which the Survey has not obtained proofs of their existence in the lodes worked. The slate and quartz pebbles of Relistran mine cemented by oxide of tin and bisulphuret of copper have long been known. Mr. Carne states that they occurred at the depth of 600 feet below the surface in the tin lode, the mass being about 12 feet in length, and

* Observations on Mineral Veins, Report of the Royal Polytechnic Society of Cornwall for 1836, published in 1837.

as many in width and thickness, scattered pebbles being found in the vein far beyond these boundaries.* It has been doubted that these are true pebbles; those specimens, however, which the Survey procured from various sources, some from Mr. Carne himself, can leave little doubt on the subject, more especially as rounded pebbles of quartz are mixed up with those of the slates, which are also most clearly seen to be such. In the Wheal Badger lode, near Relistran, pebbles of granite are mixed with others of slate and quartz;† and Mr. Carne mentions pebbles having been found in the tin lode of Ding Dong mine, near Penzance, and in the upper lode of Wheal Alfred, near Guinear.‡ Breccia lodes, or those in some parts of which angular fragments of the adjoining rocks are cemented by different substances, metallic or otherwise, are very common, and it is merely necessary to watch the contents of the lodes brought to the surface, or laying about the ground in the mines of Cornwall and Devon, to feel assured that they are so. Among the examples of brecciated lodes observed during the Survey may be noticed—Fragments of slate cemented by quartz and yellow copper ore from the principal lode at Consols mines, Gwennap; angular portions of slate cemented by yellow copper ore at the United mines, Gwennap; fragments of slates united by yellow copper ore and quartz, Wheal Trenwith, St. Ives; fragments of slate cemented by oxide of tin and yellow copper ore, Wheal Fortune, near Marazion; angular portions of slate joined by oxide of tin, Perranuthno Downs, near St. Hilary; fragments of slate cemented by yellow copper ore, Wheal Jane, near Helston; angular portions of slates united by yellow copper ore and quartz, Fowey Consols mines; fragments of slates joined by yellow copper ore at East Crinnis mine;§ angular portions of slate, yellow copper and sulphuret of zinc cemented by pearl spar or carbonate of iron, at Binner Downs mines, near Crowan, &c., &c. Among the various instances of the mixture of fragments of the adjoining country with ores in the lodes of Cornwall and Devon, which

* Carne, Trans. of Geol. Soc. of Cornwall, vol. iii. p. 238.

† Granite is found in this lode, or rather in its continuation.

‡ M. Fournel (Etudes sur les Dépots Métallifères. Daubuisson, Traité de Geognosie, tome iii., p. 411) notices pebbles of gneiss in the lode at Joachimsthal at 192 fathoms.

§ Captain Barrett states, in a communication to Mr. Fox, that in the lodes of East Crinnis portions of the adjoining rocks are mixed up with their other contents throughout every portion of them.

have come to the knowledge of the Survey, that which was observed in the Consols mines, Gwennap, in 1830 and 1832, is among the more remarkable. Captain William Penrose, who then worked at the back of the 135 fathom level, at Frances shaft, states to Mr. R. Fox that at that place for more than twenty-five fathoms in length and fifteen fathoms in height, the lode was from eight to twelve feet wide, and full of fragments and copper ore, some of the fragments of slate weighing several tons, and occurring, as to the position of their laminæ, in all directions. He also states that many of these masses and smaller stones had the appearance of having been washed by a flow of water. Above this mixed mass, and in the level above, a great cavity or vug was found many fathoms in length and height, from whence it was conjectured the fragments beneath had fallen. It is unfortunately not stated whether any copper ore actually cemented the fragments, or whether the copper ore so found, which was estimated at about 1600 tons, was altogether in fragments, the whole forming a comparatively modern condition of the lode.

Mr. John Rule describes a cavern in Dolcoath mine discovered in November, 1814, at the depth of 1020 feet from the surface. It was of an irregular form, from 100 to 120 feet long, 18 feet high, and from 4 to 9 feet wide; in the lower part fragments of rock were wedged together between the walls, the spaces between which communicated with other cavities beneath. There was much carbonic acid gas in the cavern which extinguished flame.*

It would appear from the general information we have received, that fragments of the adjoining rocks in the body of the lode are more frequently seen, as might be expected, when the dip of the fissure was somewhat inclined, than when the latter approached a vertical position. By attention to the position of some of the fragments in the large masses occasionally brought to the surface, it would appear clear that the fragments in a given lode were not introduced into it all at one time, since, though a complete breccia not unfrequently occurs, fragment touching fragment, the interstices only between them being filled by copper-ore, tin-ore, iron pyrites, quartz, or other substances, single fragments may not unfrequently be seen surrounded by such substances, without contact with any other fragment, as if it had dropped from the sides of the fissure while the quartz, the sulphurets of copper, iron, &c.,

* Trans. Geol. Soc., Cornwall, vol. i. p. 225.

were in the course of deposition, and one fragment may be sometimes seen above another as if it had fallen at a subsequent period. In addition to which, fragments are included between the nearly vertical plates of lodes, in a manner that, supposing such plates or *combs*, as they are often termed by the Cornish miners, to have been deposited at different times, the fragments in them must also have fallen at different times.

The other contents of lodes, which may for convenience be termed chemical in contradistinction to the mechanical parts above noticed, offer a great variety of character. As regards the metalliferous part, very erroneous impressions seem to prevail out of the mining districts of Cornwall and Devon respecting its mode of occurrence in those districts. Instead of forming lines in the metalliferous veins or lodes throughout their whole extent, they occur in what the miners term '*bunches*,' in patches of various sizes and shapes, very rarely for considerable distances even in rich lodes, when such are of tolerable width, occupying the whole space between the walls, but being mixed up with a variety of other substances, the principal part of which is frequently quartz. By reference to the accompanying sections of Dolcoath mine (plates 8 & 9) irregular dark-shaded portions, whence the bunches of ore have been extracted, will readily be seen, it being supposed in these sections that one wall of the lode is removed, and the contents of the lode itself as regards the occurrence of the ores sought, and those portions which are unprofitable, brought to view, the various adits and shafts, cut into the country and lode, to extract the useful part of these contents, being also represented. It will at once be observed that the proportion which the bunches of ore, even in this mine, whence such large quantities of ore have been extracted, bear to the unprofitable parts of the vein, are by no means so great as might at first be supposed. It may here be remarked, that if a great tabular view were prepared of the Cornish and Devon mines, excluding those which have been merely worked for the purpose of deceiving unwary adventurers, but including those which have once been profitable mines, though now valueless, a very different estimate of the proportion which the ores of the useful metals bear to the profitless part of mineral veins would prevail than now appears to be current.

Where the discovery of these 'bunches' is of so much import-

ance, it has necessarily become the study of the miner to ascertain those circumstances which may ordinarily accompany the lodes in which they are found, so that when he is in search of the really metalliferous portions of a lode both time and money may be directed with the best chance of success. A great variety of facts have in consequence been brought to light, highly important both as regards science and its applications. It has been found that the per centage of cases is considerable where an iron-ochreous substance, named '*Gossan*' prevails, and copper ore is connected with it, and it may be said that the instances are very rare where copper ore is found in fair quantity in a lode without gossan having been discovered on the '*back*' or upper part of that lode. This gossan, which is generally mixed with quartz and other mineral substances, among which the oxide of tin frequently occurs, differs much in general aspect, and the experienced eye of the miner readily detects that character which is most indicative of a good copper lode, though it is one that can scarcely be expressed in writing. Respecting the tin in the gossan, it is well known that the backs of many copper-lodes have in ancient times been worked for that metal, so that the upper part of many a copper-lode has been worked as a tin-lode. Mr. Carne notices Wheal Damsel and Wheal Spinster copper-mines as instances where the upper part of the lode was taken away for the tin which they contained. "The granite walls of the lode are still visible," he remarks, "at the surface and to the depth of three or four fathoms, having a space of about four feet between them. It is probable that if the rubbish were taken away the space would be found to extend to the depth perhaps of ten fathoms, or as deep as the ancient miners could go without being obstructed by water. From this space the fine gossan of the copper-lode was wholly taken away, and the tin-ore extracted from it."* The same author states that gossan has been worked for the sake of its tin, within the recollection of some of the oldest miners living, at the time he then wrote (1827).†

It thus appears that an oxide of iron, generally mixed with the oxide of tin, is found in the mineral veins of Cornwall and Devon very commonly above the copper-ores, which are usually

* Carne, on the Copper Mining of Cornwall, Trans. Geol. Soc. of Cornwall, vol. iii. p. 37.

† Ib.

sulphurets and bi-sulphurets, most frequently the latter, and it may be stated that for the most part the latter ores do not occur very near the surface, being covered by gossan, quartz, and other substances to the depth of many fathoms.

The bunches of tin-ore occur much in the same way as to their distribution among the quartzose and other parts of a lode as those of copper, and it may be said that though very valuable tin-mines have been worked in slate, as for instance, Wheal Vor, Polgooth, and at St. Agnes, the lodes in granite where tin occurs are more numerous than those where the same metal is found in the slates, particularly where the latter are not traversed by elvans. It is rarely that any thing which could be termed gossan is seen above a tin lode where copper does not occur in some abundance, but the connexion between schorl and the oxide of tin in the granitic districts is very marked, and schorl is a very common ingredient in tin-lodes in such localities, the minor strings and branches being often composed of quartz, schorl, and oxide of tin.

The sulphuret of zinc (black jack of Cornish miners) seems also to occur in bunches, being very frequently associated with the sulphuret and bi-sulphuret of copper, with the sulphuret of lead, and more rarely so with the oxide of tin. Not being an ore worth raising for profitable purposes at present, though it is one of the most abundant in Cornwall, its mode of occurrence when not associated with the ores of copper, tin, or lead, is less a matter of inquiry among the miners than it otherwise would be. The lead of Cornwall and Devon would appear also to occur in isolated patches in the fissures, whether they be termed lodes or cross courses, so that the ores of tin, copper, zinc, and lead, are not disseminated through all parts of the fissures in which they are found, but are gathered together in patches, commonly known by the name of "*bunches of ore*," the intervening portions between these bunches frequently containing strings and specks of ore, in quantities too small to be profitably worked, yet sufficient to keep up the metalliferous character of the fissure.

With regard to the occurrence of these bunches of ore, many facts have of necessity been brought to light where the search for them has been so constant and so long continued as in Cornwall.

We have before observed (p. 286) that the bunches of tin or copper are larger or more frequent in the lodes, generally, within

moderate distances of the junction of the slates and granites, or where the former are traversed by elvan courses. Various local causes, many of which it will require far more attention to the apparently minor circumstances in lodes than is now given fully to appreciate, have so acted that while the bunches of ore are sometimes more abundant in the granite, at others they are more abundant in the slate, even where the lodes in which these facts are observable are not far distant from each other. Of this, the tin mines of Wheal Vor and Great Work, near Breague, are often quoted as good examples. In both cases the fissures forming the lodes traverse the same granite and slate, are nearly parallel to each other, most probably belong to the same system of dislocations, and are only a mile apart; yet at Wheal Vor the lode which contained so much tin ore in the slates, held so little where it entered the granite, as not to be worth working, while at Great Work the lode which was so rich in the granite became worthless where it entered the slates. The principal difference in the two mines is that an elvan was traversed by the lode at Wheal Vor while in the slates, which did not happen in the slate near Great Work. The lode at Wheal Vor was improved in value where the elvan occurred, but there was an abundance of oxide of tin in it in other parts of the fissure. We should, however, with respect to the elvan, still recollect that it continued to run near the lode for a considerable distance.

When we advert to the little attention usually paid in the Cornish and Devon mines to those facts which are not very glaringly connected with profit, and the absence of any institution or establishment, such as a school of mines, where a variety of circumstances connected with the occurrence of ores in large masses, yet not strikingly obvious, can be chronicled and classified for future generalization, we shall not long remain surprised that the above and other supposed anomalies present themselves. Certain general views on the occurrence of the bunches of ore, founded on experience, and transmitted orally from generation to generation are disseminated among the miners; but hitherto there has been less of general science introduced from without into this mass of practical knowledge than might, at first sight, have been expected.

Not many years have elapsed since it was held good doctrine that no copper ore, in profitable quantity, could be found eastward of

Truro Bridge, and the existence of such mines as Crinnis has been, and Fowey Consols now is, would have been considered highly improbable, and, consequently, it would have been thought a wanton waste of capital to have embarked in the search for copper in that neighbourhood; yet a very ordinary amount of geological research would make it appear that the conditions accompanying many of the lodes near St. Austell were very similar to those in the great cupriferous district of Gwennap. To show how gradually even great leading facts become known, it may be stated that many of the miners of the present day remember the time when, although copper ores were ascertained to have been profitably worked in some mines in granite, such as Dolcoath, Cook's Kitchen, and others, still granite was not reckoned a good rock for copper ores, and many persons have stated to us that they would not, some years since, have thought very favourably of a copper lode in granite. Now, however, we find one of the best copper mines in Cornwall, Tresavean, wholly in this rock, the lode becoming, it is considered, profitless where it quits the granite and passes through the slate resting upon it. The mass of ore in this mine is found in the granite running beneath the junction line of the latter and the superincumbent slates, a fact also observable to a great extent at Wheal Jewel in the same neighbourhood.* In many other mines copper ore has been plentifully obtained in granite (Penstruthal, Carnbrea, Wheal Gorland, Gunnislake, &c.), though hitherto at no considerable distance from its junction with the slates, wherein it differs from tin ore, which has been profitably worked (Ding Dong, Beam mine, &c.) as regards horizontal exposure, in the interior of granitic masses.†

The connexion between bunches of tin and copper ore in fissures, and those places where the latter traverse the elvans is, viewing the subject on the large scale, of the most marked kind,

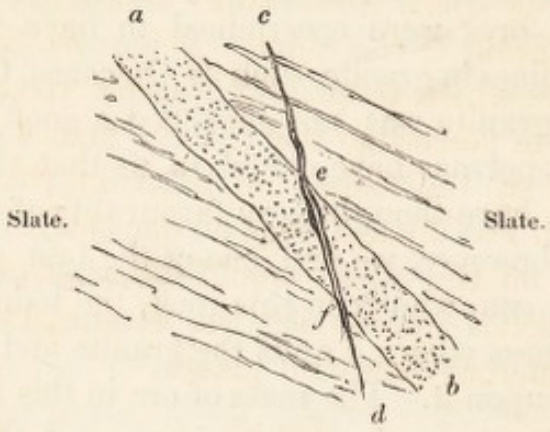
* 11,456 tons of copper ore, worth 86,010*l.*, were raised at Tresavean in the year ending 31st December, 1836, and 4,464 tons, worth 45,079*l.*, from Wheal Jewel in the same year.

† Mr. Carne states that in Treskerby and Wheal Gorland the copper lodes improved in value where they entered the granite, but that in Wheal Unity, Cook's Kitchen, and Dolcoath, scarcely any alteration was perceptible. The same author observes that in Botallack, Huel Cock, and other mines in St. Just, the copper lodes were more productive in the slate than in the granite, but they were richest in the line of junction, especially where one wall was granite and the other slate.—On the Veins of Cornwall, Trans. Geol. Soc. of Cornwall, vol. ii., p. 103.

and is well understood by the practical miners of Cornwall, though it has not hitherto received that attention among the scientific public that it requires. One of the most noted examples of this fact is that of Wheal Alfred, near Guinear. This mine is now abandoned, but the following are the principal facts connected with it.*

The Elvan dyke *a b* (fig. 58) is about three hundred feet thick, having a direction about N.E. and S.W., and dipping N.W. at an

Fig. 58.



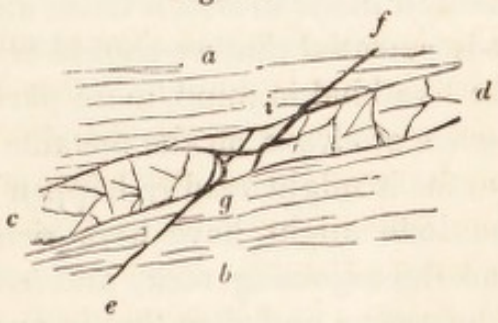
angle of 45°. The lode *c d*, which dips at an angle of 72° to the north, traverses the elvan obliquely in its descent at *e f*. This lode produced some ore while in the slate, but upon entering the elvan *a b* it became much richer, and increasing in value in the same rock, it yielded ore sufficient to afford a profit of 140,000*l*. to the adventurers. After quitting the elvan at *f*, and upon entering the slate or killas *f d*, the lode became poor, and eventually the mine was abandoned from poverty. The width of the lode was from six to nine feet in the slate above the elvan, increasing in the latter to twenty-five feet, but decreasing in the slate beneath to ten feet.

The value of elvan dykes in connexion with lodes can be well seen in the vicinity of Marazion, where the latter often cross the former, so that the localities where the traverses take place are well marked, and are generally found to be productive of the ores of copper and tin (Wheal Darlington, Marazion mines, Gwallon mine, Wheal Fortune, Tregurtha mine, &c.). By a glance at the map of Cornwall, numerous examples will be observed of the intersection of elvan dykes and lodes, and viewing the subject on

* Carne, Trans. Geol. Soc. of Cornwall, vol. i. p. 101.

the large scale the per-centage of cases is considerable in which such intersections are accompanied by bunches of ore in fair quantities. It is true that a lode is said sometimes to be split up into strings under such circumstances, and consequently from the admixture of fragments and masses of the elvan among the branches of the lode, it is then said to be impoverished. Such cases, when minutely inquired into, not unfrequently show that the ore itself is abundant, but being difficult to separate from the body of the rock without much cost, and consisting of numerous small strings, the whole is said to be deteriorated, because it is so as regards the profit of the mine. When we see the numerous divisional planes which frequently traverse elvan courses, there is little difficulty in perceiving that if these planes were formed prior to the fissures of the lodes, the latter in passing through the elvans, out of a less divided rock on one side to another similarly circumstanced on the other, would often cause a separation of many of the solids into which the elvans are divided by the meeting of numerous divisional planes.

Fig. 59.



Let *a b* (fig. 59) be a country composed of slate, and *c d* an elvan course with a very jointed structure, then a fracture being formed across both the rocks it would probably happen that when such fracture traversed the elvan at *g i*, there would be considerable division among the joints of the elvan in the line of dislocation, so that they might be opened from each other to the amount of the wider fracture in the adjacent rocks, and when the whole afterwards became filled with mineral substances, the lode *e f* would be apparently divided into numerous minor portions or strings in the elvan at *g i*.

It is always necessary to recollect, that elvans, for the most part, constitute great plates of granitic or porphyritic matter, filling a previously existing fissure, and that generally there is slight cohe-

sion between the walls of the containing rock and the elvan, so that the less the angle at which a line of fracture strikes the course of the elvan, the greater the probability that it may open out the wall of the elvan and the containing rock, holding its course between them until it found some resistance, leading it to take another line. Let *a b* (fig. 60) be an elvan traversing any given kind of rock,

Fig. 60.

and *c g* a fracture proceeding from the side *c*; then this line of dislocation when it reaches the elvan at *d* may readily take the line of the wall of elvan *d e*, as far as *e*, where supposing, from accidental circumstances, the resistance to be less in the direction *e g*, than in that of *e a*, we may consider the fracture to pass through the elvan in the line *e f*, and to be prolonged in the direction *f g*, if the line of least resistance should there present itself.

From the complicated mode in which lodes are sometimes mingled with elvans, it is essential that we should bear these and other circumstances of the like kind in mind, more particularly when the subject of the influence of elvans on the metallic contents of lodes is under discussion, for it might readily happen that in the above figure (fig. 60) the lode might have been rich from *d* to *e* between the elvan and the adjoining rock, and not particularly so in the elvan itself between *e* and *f*, so that in answer to a question whether the elvan improved the lode, the reply might be in the negative. Dowgas mine, near St. Austell, afforded an excellent example of a good lode between the walls of an elvan and the slate of the adjoining country. Great quantities of tin-ore were raised from the lode under these circumstances, which continued for a long distance, and it was remarkable as Captain Bennet of St. Mewan, who worked in the mine at the time the tin was extracted, informed us, that another lode ran for a considerable distance on the other side of the elvan, and it generally happened that when a good bunch of tin was found on the one side they also found one on the other opposite to it.

It would be difficult to select a district where, when elvans and tin and copper lodes occur together, the former are not found in

connexion as a whole with good mines. Captain Jeffery of Wheal Jewel has remarked, that "most of the ore in the principal mines in Gwennap (the great cupriferous parish of Cornwall) has been found in, or near, large elvan courses; for example, Huel Virgin, Huel Maid, Huel Fortune, Huel Squire, Poldory, Ale and Cakes, Ting Tang, Poldice, Huel Unity, Huel Unity Wood, and other mines."* The effect of elvan courses is not confined to those which cut through slates, though it is more obvious in such localities. Elvan is found in connexion with the great copper-lode in granite at Tresavean, and not unfrequently elvan courses in granite are accompanied by oxide of tin, such for instance as that of Penstruthal, on the south of the copper-lode at that mine, and at Porkellis, on the north of Wendron. Tin ore is indeed very frequently met with in connexion with elvans among slates, and the backs of these dykes may not unfrequently be seen to have been torn up in ancient times for the oxide of tin in connexion with them, when the ore was sufficiently near the surface to pay for working. This, however, rather belongs to the subject of tin-ore in joints of rocks, to be noticed in the sequel, though it is often difficult to say whether these apparent joints should be considered as minor fractures connected with a great dislocation, or divisional planes of rocks, properly so called. The south elvan in Wheal Bissy, or Chacewater mine, affords a good example of strings of copper, apparently occupying minute cracks, disseminated through that rock. At Tregurtha mine, near St. Hilary, a multitude of strings of oxide of tin occurred in the elvan traversed by the lode, apparently minute splits from the main fracture. Many of these strings are very interesting where the crystals of felspar are so divided by the crack, now filled by oxide of tin or quartz, that evidently these crystals were formed before the cracks which break their previous continuity.

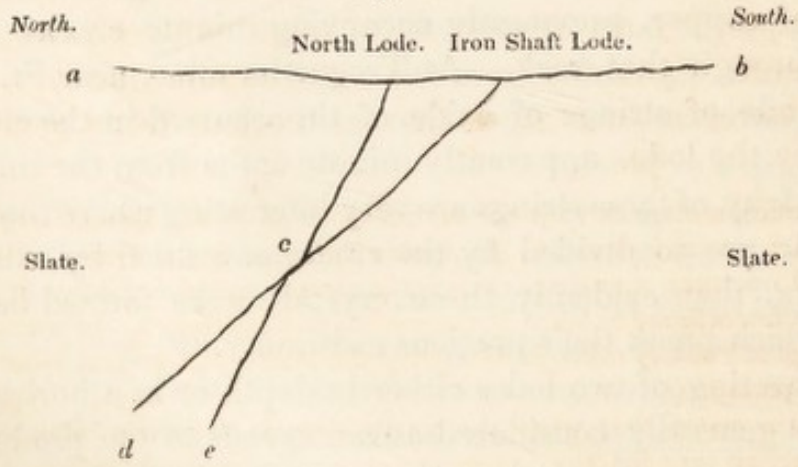
The meeting of two lodes either in depth or in a horizontal direction is generally considered advantageous to the production of ore, more particularly when the angle at which they so meet is not great. In endeavouring to classify facts connected with this subject, we soon find the want of the necessary information. The simple circumstance of the meeting of the lodes and the amount of the angle between them is of course well known, and whether

* Fox on Mineral Veins, Report of the Cornwall Polytechnic Society, for 1836, p. 96.

both lodes were fairly rich, or one only had that character, is also recorded; but the exact character of the lodes at their junction, and at short distances from it, with a variety of other attendant circumstances not usually observed, and which are nevertheless very important, are points very rarely to be obtained if these junctions have been worked some time previously, and the agents then in charge of the mine are either deceased or removed to other places. There is, therefore, much difficulty in approximating towards a reasonable cause for several apparent anomalies connected with the meeting of lodes at present, which will probably not attend enquiry on this head some years hence, when the value of records of mining phenomena shall be more fully appreciated, and a proper establishment instituted for their preservation, so that the mass of information existing at any given time, and this is always very considerable in Cornwall, shall be preserved, to be condensed and distributed among miners, again to be returned with the necessary increase of additional information.

As a leading fact, however, it is understood that the meeting of two lodes at a small angle is productive of good. The following sketch of part of East Crinnis mine, near St. Austell, for which we are indebted to Captain Barrett, will illustrate this point in its simplest form.

Fig. 61.



The section is vertical, representing the lodes in their descent from the surface *a b*, downwards. The iron shaft lode is considered, in the miner's language, to have been the *strongest*, and to have carried the north lode seven fathoms with it at *c*, where the bunch of ore occurred. Though the iron shaft lode may thus seem to have been subsequently formed and to have heaved the

north lode, it may readily have happened, as it is scarcely necessary to remind geologists, that both lodes have resulted from the same dislocation, the whole forming a complicated fault.*

The miners have observed with much care the kind of rocks, or *country* as they term them, in which the ores they seek are principally discovered, and from local practice they judge of the probability of finding such ores in given rocks when the other conditions are also favourable. It is well known that there is often much connexion between given rocks in particular districts and the productive mines in it, some rocks being considered more *kindly*, as the Cornish miners term it, than others. When a variety of beds is traversed by a lode, as often happens, particularly in a slate country, some are far greater favourites than others. In Gwennap, the more experienced miners seem to prefer those argillaceous slates which accompany the red or variegated slates of the district, and which have a fine grain and a blue-grey colour. Respecting the value of the red beds themselves opinions seem to differ.† In most mines the miners have their favourite kind of rock or country, so that the whole tendency of their great experience goes to prove that particular mineral structures, other circumstances being the same, are more favourable to the production of the ores sought than others. The principal lode at Fowey Consols mines would seem to afford a good example of ore accompanying a particular set of beds. The slate in this productive mine dips away from the granite of St. Blazey, on which it rests, towards the east, so that, as the lode has a general east

* The vertical section through the various lodes of Fowey Consols mines (plate 11), for which we are indebted to Mr. Austen Trefry, of Place, Fowey, will show the complicated fractures sometimes observed in mines, resembling some of the more complicated faults found to occur in the workings of coal-mines. In sections of the old workings of Poldory mine, in Gwennap, the meeting of several lodes produces a similar appearance.

† Mr. Carne states, that when the copper-lodes in Gwennap intersect the red beds they become unproductive, an immediate change generally taking place when the lodes pass beyond them into another slate. Trans. Geol. Soc., Cornwall, vol. iii. p. 81. Pryce, in his Mineralogia Cornubiensis, p. 74 (1778), mentions the mining properties of the different kinds of killas (slate). He states that the red "is well disposed for copper or tin lodes; the latter preferably. The yellow is indifferently disposed for either. The brown, which has various shades of lighter and deeper colours, is generally a hard stone, and contains lodes of tin more commonly than copper. But of all the killas, the cinereous or pale-blue is most desirable, as the enclosing stratum of a copper lode."

and west direction, the beds traversed by it on the lower part of the mine on the east rise to the surface on the western end, and it is found that the bunches of ore accompany this dip, viewing the subject on the large scale, so as to coincide with certain beds. It may, indeed, be said that the granite dips with the slate, and that its influence beneath the slate in a parallel plane, may have caused the false appearance of the principal bunches of ore accompanying a particular range of beds. That the proximity of the granite has had its influence on the contents of the lode may readily be allowed, but observations along the junction-line of the granite and slate in the vicinity, would appear to give a much higher angle for the plane of contact of the two rocks than the dip of the slate in the mine. The mode in which the "*gossan*" and other marks of the back, or higher part, of a copper-lode dip to the eastward with the beds in this mine is extremely interesting; gossan, with its very common accompaniments of native copper, and gray copper ores descending, above the bunches of the common yellow bisulphuret of copper, to the depth of about 600 feet from the surface on its eastern part.

It would be almost impossible to convey by words the precise character of the slate which the miner prefers for copper, though it is one which the eye readily seizes after a little practice. That which he prefers for tin has a different aspect, being generally more dull in its appearance, darker coloured, harder, and more resembling altered slate, which, in fact, it frequently seems to be. A piece of slate (killas) from the tin country of St. Agnes, and another from the best copper-mines of Gwennap, or St. Austell, generally differ from each other in a manner that the eye easily distinguishes after practice.

Respecting granite the miner seems commonly to prefer the somewhat decomposed kinds, in a state to which he applies the term *plumb*, one in much use in Cornwall, to express softness combined with a fair amount of resistance. A *plumb granite* or *elvan* is that most usually esteemed, particularly for tin, though the cases are by no means rare in which large bunches of copper and tin-ores are found in hard granite. Viewing the subject of hardness alone, however, this quality in rocks traversed by mineral veins may be stated as in no great repute with the Cornish miners, not only as regards the difficulty of working, but also as

respects the quantity of ore found under such circumstances. Greenstone, viewed as a whole in Cornwall and Devon, seems unfavourable to the ores of tin, copper, and lead, though the fissures traversing it are often large, and its condition, as to the proximity of granite, the intermixture with elvan dykes, and the intersection of cross courses, equal to that of the slates with which the greenstones are for the most part associated. At first sight the mines at St. Just may appear an exception to this remark, but the riches there found are very rarely detected in the greenstone itself, which appears to occupy, from its general dip, seaward, more of the solid mass of rock than it actually does; moreover, the altered slates there found are frequently mistaken for greenstone.

Respecting the change in the metallic contents of the Cornish lodes according to the mineral character of the adjoining rock, Mr. Carne observes, that "in Godolphin the lodes were rich where the killas (argillaceous slate) was of a bluish-white colour, but poor where it was black. In Poldice and Huel Fortune the lodes in the killas continued productive until they entered a stratum of blue hard killas, which *cut out* the riches. In Huel Squire the copper-lodes were very productive when in the soft light-blue killas; but a stratum of hard black killas underlying (dipping) rapidly met one lode at the depth of 44 fathoms and the other at 120 fathoms, under the adit, and at these levels both the lodes became poor. At Penstruthal copper-mine, the lode had been tried at various times in parts where the granite was hard, and the result was unsuccessful; a trial, however, has lately been made on the lode where the granite is soft, and it is now the most profitable mine in Cornwall."* Other instances might readily be added, which would be unnecessary, inasmuch as similar facts are well known in mining countries generally. M. Fournet observes, that commonly in Upper Hungary the largest copper-lodes are found in fine clay slates; in Saxony the silver ores occur in gneiss; and in the Hartz certain ores are intimately connected with grauwacke. The veins of Kongsberg, in Norway, are steril in mica-slate, and become very productive in

* Trans. Geol. Soc. Cornwall, vol. iii. p. 81.—1827. Since this date Penstruthal mine has been abandoned, after yielding considerable profit to the adventurers. It appears by the returns that, from 1826 to 1829 inclusive, copper-ore to the value of 132,186*l.* was raised from this mine.

the beds known by the name of *Faalbænder*. At Andreasberg, in the Hartz, the veins which pass from argillaceous slate into flinty slate lose their riches in the latter rock.*

The fact of the lead-lodes in Derbyshire, which traverse the limestone and toadstone (a variety of trappean rock), being productive in the former and unproductive in the latter, has long been known; and Mr. Burr states, that a knowledge of "this fact has been the foundation of some of the most important mining enterprises lately undertaken in that county, which have had for their object to penetrate through the toadstone, in order to make further trial of veins which had been formerly productive in the limestone above." The same author adds that "at the Crich Mine this trial was perfectly successful, a large quantity of lead ore having been raised from the continuation of the lode in the limestone beneath the toadstone, where it was small and unproductive."

Mr. Burr also notices facts in the north of England connected with the subject of variation in the contents of lodes, according to the nature of the including rocks, which are highly important both as regards science and its economic application. The mining districts are there composed of limestone (carboniferous), sandstone, and shale, in parallel beds, and the lodes produce ore in the two former, while they are unproductive in the shales. Such being the case, it is found of practical importance that the fault,

* Fournet, Etudes sur les Dépôts Métallifères, D'Aubuisson's Traité de Géognosie, 2de Ed. tom. iii. p. 431.

M. Fournet gives the following remarkable example of a lode varying in its contents according to the nature of the adjoining rock, furnished him by M. Voltz:—The Wenzel lode at Furstenburg runs nearly vertically from N. to S., across many beds of gneiss, about 60 feet thick, dipping east. Each of these beds forms a distinct variety of rock. The first is very micaceous; the second passes into argillaceous slate; the third is hornblendic, and in the fourth scarcely any mica can be detected. This lode is heaved in depth to the westward by several cross courses, and it was between two of these cross courses, distant from each other about forty fathoms, that it exhibited those riches for which it has become so celebrated. In the first bed of gneiss the lode merely formed a nearly imperceptible string of clay; in the second it suddenly acquired a thickness of from 12 to 18 inches, and was composed of sulphate of barytes, antimonial silver, red silver, and argentiferous grey copper. The antimonial silver is always found in large masses. In the third bed the thickness of the lode is preserved, and the sulphate of barytes is continued in it, but the silver ores disappear, and a little sulphuret of lead is the only ore found. In the fourth bed the silver ores become as abundant as in the second, but they gradually disappear in depth and are replaced by selenite, a little sulphuret of lead, and some traces of native sulphur.

between the sides of which the contents of the lode occur, should not have been considerable, the dislocation not having destroyed the level of the beds on either side, as regards each other, for more than a fathom or two, "so that the strata composing each *cheek* or wall of the vein should be similar, that is, limestone opposite limestone, gritstone opposite gritstone, &c." When the heave or amount of fault has been considerable, so that limestone or gritstone is opposite shales, the metallic produce of the lode is generally found to be deteriorated.*

When we attentively regard the minor facts connected with the tin and copper lodes of Cornwall and Devon, we soon observe circumstances which show that many of the fissures must have increased in size since the deposit of some of the substances in them, so that their present contents are due to a succession of openings in the same line of fissure. The contents of parts of several lodes consist of a succession of plates of mineral substances, varying much in their continuity, and to a certain extent parallel to the sides of the fissure, between the walls of which they are included. These vertical plates, which vary from a few lines to many inches in thickness, are known to the miners in Gwennap and many other parts of Cornwall as *combs*, and a lode is said to be a *comby lode* when composed of such vertical plates. In some of these comby lodes we have no evidence to show that there has been anything more than a succession of deposits against the sides of the fissure according to the substances in solution in it at the time, one plate or deposit succeeding another, and separable from it, from there having been a lapse of time between each deposit sufficient to allow of clayey matter having settled on the outer surface of the previously-formed plate or comb, so that when the succeeding comb was deposited there was no great cohesion between the upper surface of the one and the under surface of the other. In other comby lodes we find a succession of plates or combs, each composed of crystalline substances with the faces of the crystals turned inwards, the nature of which will be best understood by reference to the accompanying figures.

The first figure (62) represents part of the lode at Wheal Cathedral mine, one hitherto found to be of little value, in the granite of Carn Marth, near Redruth. All the combs or plates have the

* Burr, Observations on the Theory of the Formation of Mineral Veins. Mining Review, No. IX., new series, Feb., 1837, p. 64.

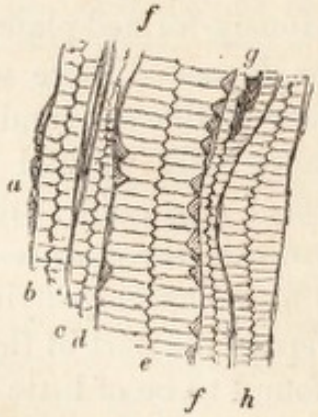
Fig. 62.

a, comb of quartz and purple fluor spar; *b*, quartz with a few *sprigs* of yellow copper ore; *c*, comb of quartz with yellow copper ore more abundant; *d*, quartz and purple fluor spar; *e*, quartz; and *f*, quartz with a few sprigs of yellow copper ore.

points of the crystalline substances of which they are composed turned inwards, and all are readily separable from each other by a moderate blow, along the surfaces 2, 3, 4, 5, and 6, which separate the combs, and are thinly covered by an ocreous indurated clayey substance. From all that we know respecting the filling of cracks by crystalline substances deposited from solutions in them, we should conclude that the breadth of each comb constituted the whole width of the fissure at the time the substances of which the comb is composed were crystallized upon both walls of the fissure as bases, so that the crystallization gradually met in the centre. If this be correct, we should have six consecutive openings of the fissure for the contents of the lode here represented, so that 1 and 7 constituted the walls of the lode, or the sides of the fissure, when the combs above noticed were all formed.

The subjoined figure (fig. 63) represents part of a lode at Wheal Julia, near Binner Downs, Crowan. In this we perceive

Fig. 63.

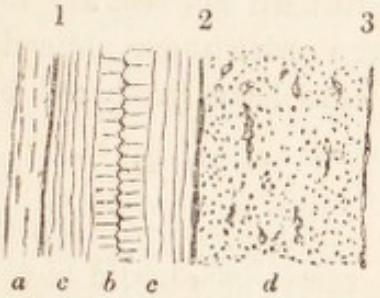


a, bisulphuret of copper and sulphuret of zinc; *b*, comb of quartz; *c*, wall of indurated argillaceous matter; *d*, comb of quartz; *e*, larger comb of quartz, with blende and yellow copper-ore, *f f*, on both sides; *g*, cavity, or *vug*, in another comb of quartz; *h*, more solid comb of quartz.

more irregularity than in the preceding figure, and in the comb *e*, we see that crystals of sulphuret of zinc, intermingled with bi-sulphuret of copper, were formed on each side before the quartz was deposited and met in crystallization in the centre of the comb. The *vug*, or cavity, also, at *g*, shows that the crystallization had not filled up the cavity in that direction, and the group of pointed crystals in it exhibits the general appearance of those parts of the fissure where the crystallization had not met from the sides, and, by interlocking, filled up the cavity.

The next figure (fig. 64) represents part of a lode at Godolphin Bridge mine, near Breague, where the combs have very parallel sides, and one of them is composed of the bi-sulphuret of copper intermingled with some quartz. The agatiform sides of the

Fig. 64.



a, small quartz comb; *b*, comb of quartz, crystalline towards the centre, agatiform on the sides *c c*; *d*, bisulphuret of copper, intermingled with a little quartz.

comb *b* are extremely interesting, reminding us of the gradual deposition of some agates on the sides of their containing cavities. They afterwards become more crystalline towards the centre of the comb, probably from the slower rate of deposition and the greater purity of the siliceous matter. Such a mode of occurrence as that of the comb *b* seems to afford decisive evidence that the quartz of which it is composed was gradually deposited on the sides 1 2, that space being open when the deposit first commenced. Whether the side 2 was then, as now, bounded by the copper comb, is of course difficult to determine, inasmuch as the copper ore at *d* may have been introduced into the fissure subsequently to the formation of the comb *b*, the surfaces 2 and 3 having been the walls of the cavity at the time of its deposit.

A close inspection of the quartz crystals forming combs, by interlocking towards their central parts, often shows the gradual increase the crystals have received in the direction of the axes of

the prisms, and sometimes small sprigs of copper-ore or blende may be seen entangled among them in lines corresponding with surfaces which existed during the formation of the comb, as if, while the crystallization of the quartz was effected, the siliceous solution sometimes contained the elements of the bi-sulpuret of copper, and was sometimes without them, or, if it always contained them, that conditions were often unfavourable for their deposition on the sides of the cavity holding the solution.

The combs are, as we have seen, sometimes composed of different substances, so that one of copper, of blende, of fluor spar, or other substances, should be included between others of quartz; but, unless there be crystallization in the comb, showing that the resulting solid has been formed by addition from the sides inward, in the manner above stated, when several combs of copper and blende, in uncrystallized masses, are interposed between two crystalline combs of the order above noticed, we cannot be certain that all such combs have been produced by successive openings

Fig. 65.

of the lode. Thus, if *a b* (fig. 65) be two combs crystallized towards their central portions, and *c*, *d*, *e*, *f*, and *g*, other combs of copper or blende, then there is no proof that such other combs have not been all formed when the whole distance was open between *a* and *b*, though we might be inclined in such a case to infer that they were each separately formed.

Much difficulty has been considered to attend the supposition that numerous contemporaneous fissures, not far distant from each other, could exist in the same district, such fissures having a general tendency to increase in width, it being supposed that the various masses into which the rocks would be divided could not stand in the necessary positions. It requires no very extended research among the mineral veins of Cornwall and Devon to see that many of them, even now, have numerous points of contact between the walls of the lodes, or, in other words, that the adjacent masses of rock touch each other in numerous places, so that,

if the contents of the lode were withdrawn, a long uneven cavity would be left, the walls or sides remaining where they now are. As the miner considers a lode as a leading body traversing rocks, regarded by him as of secondary importance, he terms such points or places of contact a *nipping-in* or *wringing-up* of the lode, and many a good bunch of ore has been cut by driving through spaces where the walls of the vein were in contact (a small string or crack alone showing the continuity of the lode in the direction worked upon) until the vein opened out into a larger space, and contained ore. Carn Brea mine is a recent instance of workings having been abandoned in consequence of the *wringing-up* of a lode, or, in other words, the close contact of the walls for some distance, and afterwards turning out a rich and profitable mine by continuing the workings through the space so *wrung-up*, until the lode again became larger, or, in other words, the original fissure became wider, where a rich bunch of ore was cut. This mine had been previously abandoned for poverty, the continuation of the lode where the walls were tightly pressed against each other having been regarded as a mere string.

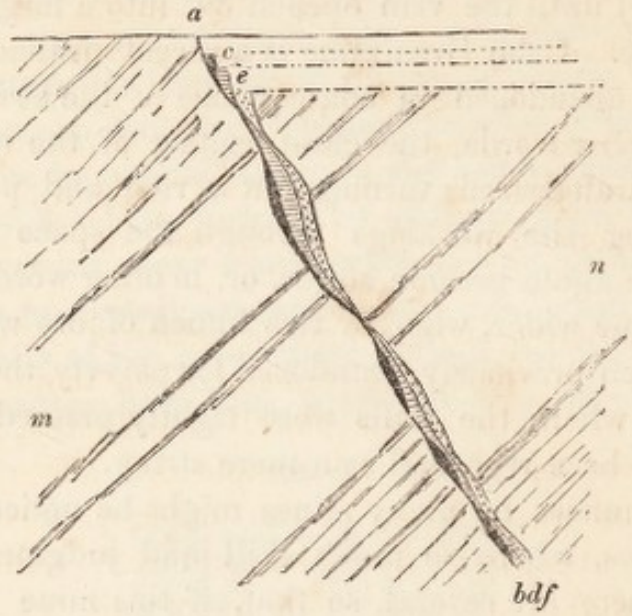
Minor instances in many mines might be noticed; in Fowey Consols mines, where so much skill and judgment have been exhibited, there are several, so that, if this mine had not been worked on the large scale which it has been, numerous rich bunches of ore never would have been cut.

In cases where the walls of the lodes now touch each other in various places, there is therefore no difficulty in perceiving that a multitude of contiguous fissures could exist, which should run and cross each other in all directions. So long as the points of contact were sufficiently numerous, the various broken masses of country could rest perfectly firm against each other, leaving the greater part of the spaces between them open fissures, the width of which would, of necessity, be extremely various. Independently, however, of those lodes, where the walls often touch each other in a sufficient number of points to insure permanence of position, even if the mineral substances now filling the fissures were removed, there are numerous lodes where for considerable distances the walls do not touch. When a fissure has been vertical, or nearly so, it can readily be understood that points of contact are not required to keep the walls of the fissure apart from each other, and that the fissure may become enlarged without requiring

them. This explanation would be insufficient when the lodes had much dip or underlie, so that, if the upper or *hanging* wall were unsupported, it would fall upon the lower or *foot* wall.

By combining the general inequality in the walls of lodes with the comby structure of their contents in numerous places, we have an explanation, which, at least, if it be not the true one, is sufficient to account for the phenomena observed. Let *a b* be a fissure pro-

Fig. 66.



duced by sliding two masses of fractured rock *m n* upon each other in the manner above noticed (p. 317), and let the fissure so formed be filled with mineral matter; then if another dislocation be effected along the line of the pre-existing fissure, so that, the walls being the lines of easiest separation, the rock on the side *n* is lowered, then the wall on that side would slide on the contents of the fissure *c d*, so that its points of contact would be no longer against the *foot* wall, but against the contents of the first-formed fissure; thus perfect support may be afforded to the hanging wall, and yet, if workings were carried on in the contents of the fissure, no points of contact would be observed between the two walls. If now this new-formed opening be filled with mineral substances, and we suppose the hanging wall again to slide some distance downwards, we have another cavity *e f* to be filled in those places where the hanging wall on the side *n* does not touch the contents of the two fissures before produced. In this case the hanging and foot walls will be still further removed from each other; and, if the *whole* contents were removed from the space occupied

between them, the two walls could not rest apart, as they would then exist relatively to each other.

For the sake of rendering the above explanation clear, we have considered the subject in its simplest form; but it would scarcely happen that often-repeated effects of the order here supposed could be produced in a multitude of fissures in so simple a manner. Though the walls of lodes would very frequently afford the line of least resistance, numerous other lines of least resistance may exist among the contents of the lodes themselves, or in the direction of cracks or branches from the main fissure previously formed, so that the general effects may be very complicated, though the principle remains the same, and the two walls of the lode become more separated from each other in proportion to the number of dislocations which the line of the same fissure may have suffered.

That numerous strings and branches of ore or other mineral substances run among the contents of the main lode, so that the continuity of the latter is evidently interrupted, is well known in many places, and, from the complicated effects thus produced, many arguments in favour of the contemporaneous nature of the whole contents of lodes have been adduced. All such effects are, however, well explained by the hypothesis that the first contents of lodes have often been dislocated, and that into the cracks and smaller fissures so caused various ores and other substances have been subsequently introduced.

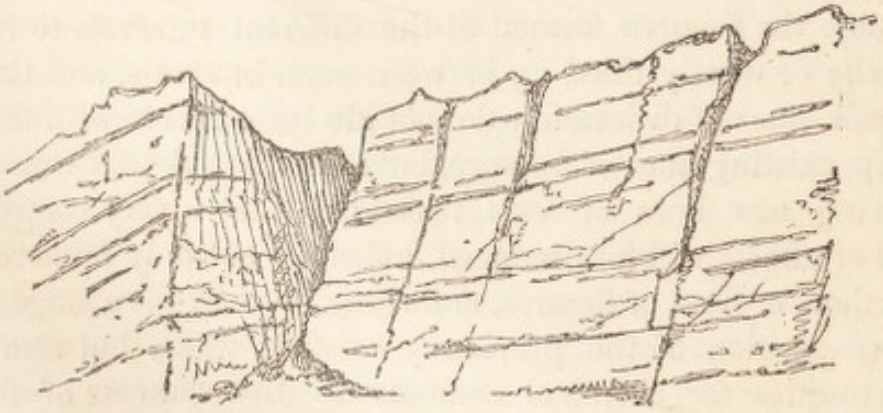
It will be obvious, if a series of fractures be effected along the same general lines, at distinct intervals of time, sufficiently long to enable the fissures formed at the different intervals to become partially or wholly filled up between such intervals, and that the different lines of dislocation do not always coincide with the previously-existing lines of fracture, but sometimes depart from them, following new lines of least resistance, that a very complicated series of effects will be produced, affording not only numerous intersections of lines of fissures, enlarging some by the change in the relative position of the previously-existing walls, but also many opportunities for chemical changes in the contents of fissures broken through or exposed to new conditions, by which such changes can be effected.

Independently of the lodes, properly so called, and of branches and strings proceeding from them, there are strings of ore, more

particularly in the granites and elvans, which cannot be well traced to any lode, and which cross each other in a very complicated manner. Upon close examination, such strings, which are rarely composed of other ores than the oxide of tin, coincide very frequently with lines of divisional planes or joints, and are commonly an intimate mixture of oxide of tin, schorl, and quartz. Of these the most remarkable is that of the long-celebrated and picturesque Carglaze mine, near St. Austell, which has been worked in open day, in the manner of a quarry, from time immemorial, a few workings having been driven into the body of the rock from the main open space. Like all the external portions of masses of granite in Cornwall and Devon, a main series of divisional planes or joints divides the granite, so that a series of beds are produced which dip outwards beneath the mass of adjacent slate-rocks. Those who have attentively studied the Cornish and Devon granites have soon perceived, more particularly near the outer boundary-lines adjacent to the slates, that, when schorl formed any part of the granite, there was a tendency of that mineral to occupy a position near the divisional planes, and that not unfrequently between the planes themselves schorl and quartz sometimes filled up the whole space.

In Carglaze mine the schorl is close to the joints, while the granite forming the remaining part of the mass is in an advanced state of decomposition. The schorl is often intermixed with oxide of tin, and both minerals, mingled with quartz, frequently occupy

Fig. 67.



Part of Carglaze Tin Mine.

the space near and between the divisional planes, so that the black lines thus produced present a marked contrast with the white

decomposed granite among which they run. A large portion of these lines dip southward under the neighbouring slates, as is usual under such conditions, and may be readily seen by taking up a position by which the eye can be brought to have a good sectional view, as represented above (fig. 67). These lines are crossed by many others, precisely as one series of divisional planes or joints traverses another, and the greater part of them are impregnated with oxide of tin, occurring either between the divisional planes or in the schorlaceous part of the granite adjacent to them. The tin-ore thus found is, for the most part, of excellent quality, but the cost of obtaining it is relatively considerable, in consequence of the quantity of granite to be removed in order to extract the strings of ore.

Numerous examples of the same kind seem to occur in the granite of which that of Carglaze forms a part; indeed a large proportion of the granite on the north of St. Austell, more particularly in the neighbourhood of Hensborough, contains strings of oxide of tin, generally intermingled with schorl, which often seem little else than lines of divisional planes, between or adjacent to the surfaces of which the tin is accumulated. The workings upon these strings and upon the tin-lodes proper, which traverse the same ground, have in ancient times been very extensive, so that a large proportion of the surface is covered by pits and small hillocks (technically termed *burrows*), formed by the "*old men*," an expressive term for those who in early times worked in the Cornish stream-works or mines.

The long-celebrated St. Michael's Mount, near Marazion, exhibits a useful illustration of the occurrence of ores between divisional planes, as for the most part the latter are very partially filled with metallic substances, and the whole of the rock containing them well exposed. On the west and south sides of the Mount, more especially, the granite of which the island is in a great measure composed is seen to be divided perpendicularly, as previously noticed (p. 170), by a multitude of vertical divisional planes having a direction about W. 10° N., and E. 10° S. The spaces between them are filled by a variety of mineral substances, among which quartz is the most abundant. Oxide of tin is also found in the same situations, as also wolfram (which may be traced in long lines), topazes, apatites, schorl, and various

other minerals, among which there is a kind of tin pyrites, for the analysis of which we are indebted to Professor Johnston of Durham, who found it to consist of

Tin	31·618
Copper	23·549
Zinc	10·113
Iron	4·79
Sulphur	29·929

CHAPTER XII.

THEORETICAL OBSERVATIONS ON THE FORMATION AND FILLING OF MINERAL VEINS AND COMMON FAULTS.

It has often been observed that there have been few subjects more fertile in theory than that of the formation of mineral veins, and it may be added that there have also been very few, the consideration of which have in general been productive of less satisfactory results. This has in a great measure arisen from the state of those sciences, at given times, by the aid of which endeavours have been made to arrive at somewhat like a satisfactory explanation of the phenomena observed. Hence, the greater the advance of those sciences, the greater the probability of employing them to advantage in the explanations sought, and, consequently, the less we should be surprised that hypotheses, framed when such sciences were in their infancy, should be unsatisfactory. It is, therefore, no reflection on the abilities of those who have paved the way for so much that is known, that they indulged in speculations which at present seem somewhat extravagant; they merely worked with the knowledge of the day, as we now do, and the results are different merely because that knowledge is different. In the same way, we have every reason to believe that existing information will be greatly inferior to that of a century hence, and, consequently, that many views now current will be abandoned. M. Fournet has well remarked that, "metals having become objects of the first necessity to man, he would, during all times, and in all places, attach great importance to their receptacles, and that it is to the study of their mode of occurrence, their connexion with adjoining substances, and their relation to the phenomena observable in the neighbouring country, that geology owes its birth."* The current of geological inquiry having of late years been more directed towards the

* Etudes sur les Dépôts Métallifères, D'Aubuisson's Traité de Géognosie, 2de ed., tom. iii. p. 383.

zoological and botanical character of deposits than to those points among which mineral veins occupy a conspicuous and important place, the consideration of their formation and of numerous circumstances connected with them have received comparatively minor attention, so that, though the study of phenomena in connexion with mineral veins may have given birth to geology, the geological theories of the day are less advanced on the formation and filling of mineral veins than on any other part of the general subject.

We must refer to works which treat of mineral veins in general for the history of the various opinions which have been formed respecting their origin, more particularly to the Etudes sur les Dépôts Métallifères of M. Fournet,* and the Report to the British Association for the Advancement of Science on the State of Knowledge respecting Mineral Veins, by Mr. John Taylor,† where fair and recent expositions of them will be found. It will be sufficient to state that the theories of the day divide themselves into, first, the contemporaneous formation of mineral veins with the rocks which enclose them; secondly, the filling of fissures formed in rocks by the sublimation of substances driven by heat from beneath upwards; and, thirdly, the filling of fissures in rocks by chemical deposits from substances in solution in the fissures, such deposits being greatly due to electro-chemical agency.

With regard to the first of these opinions, we have not observed any facts in Cornwall or Devon which would lead us to suppose that the mineral veins in those counties were contemporaneously produced with the rocks which enclose them. On the contrary, we may observe that the evidence is opposed to such an hypothesis, inasmuch as the same mineral veins or lodes often traverse rocks of different geological epochs, and which were in many instances formed by different causes, and hence, a body traversing others formed at different times, and often produced by different causes, cannot be contemporaneous with the bodies traversed, or be produced by the same cause with them. That the slates in which numerous mineral veins occur, and which are not known to pierce into adjoining masses of granite, are products

* Etudes sur les Dépôts Métallifères, D'Aubuisson's Traité de Géognosie, 2de ed., tom. iii. p. 383.

† Report of the Third Meeting of the British Association for the Advancement of Science, held at Cambridge in 1833, published 1834.

derived from the deposition of matter at different intervals of time, there is every reason to conclude; hence, lodes which traverse masses of matter not contemporaneously formed cannot be contemporaneous with such masses. The question of the contemporaneous formation of the mineral veins of Cornwall and Devon with the rocks containing them, can only be maintained with any show of probability when they occur solely in the granites, as then there is no evidence that the parts of the body traversed by the lode have been successively formed, and, consequently, as far as that argument goes, the vein may have been contemporaneous with the rock enclosing it. Independently, however, of the unphilosophical character of the reasoning required to maintain that the lodes which were only known to exist within the granitic areas, and which often run parallel to others that partly occur in granite and partly in slate, and which do not differ in any other respect from the portions of such lodes in the granite, were contemporaneous with the granite, the fragments of granite which often occur in them, and the mode of occurrence of the contents of the lodes themselves, will not bear out such an opinion. In the neighbourhood of St. Austell we have direct evidence that many of the tin and copper lodes of that vicinity traverse beds above fossiliferous rocks, and some can readily be seen to cut through the latter, so that organic remains may be procured close to the walls of the lode. The great Crinnis lode from which so much copper was once extracted, and from which large quantities of tin-ore are now obtained at the Charlestown mines, can readily be seen to cut through fossiliferous beds at the bay where it comes to the coast, and is itself cut off by a great cross course. In the same bay the Regency copper-lodes on the south of the Crinnis lode cut through the same beds, and organic remains may be obtained close to their walls.

With regard to the tin-strings which sometimes traverse the granites and elvans in a variety of directions, so that they frequently appear to cross each other, thus resembling that mode of occurrence to which the German miners have given the name of *Stockwerck*, we have not seen any which did not either take lines corresponding with those of divisional planes, or could be considered as minor fractures produced in the vicinity of greater dislocations, and would be open spaces formed before the metallic ores and other substances now in them were introduced.

With a few important exceptions, the present impression among the Cornish miners seems to be that lodes are contemporaneous with the rocks in which they are found. How long this opinion may have been prevalent it is difficult to ascertain; but its more general dissemination in Cornwall may perhaps be dated from the animated discussions which at one time prevailed respecting the geological date of the granite veins of that country, it being held by the supporters of one of the views taken, that the granites and slates of Cornwall were contemporaneous, and that the elvans, lodes, and cross courses were contemporaneous also, the differences of mineral structure and mode of occurrence having arisen from certain affinities, so that one aggregation of mineral matter took the character of granite, another that of slate, another of elvan, and so on, according to circumstances, the mineral veins being minor separations of matter from the greater masses.

Pryce, who published his Mineralogia Cornubiensis in 1778, makes no mention of this opinion, which, as he often cites those of his day on other subjects of the same kind, we may have expected him to have done, if it prevailed to any considerable extent at his time in Cornwall. He speaks of lodes as fissures in rocks, without any intimation that in this respect he differed from Cornishmen in general.

The opinion that mineral veins are fissures in rocks subsequently filled is, as is well known, very ancient, and will be found in various works from the time of Agricola down to the present day. Von Oppel, in the middle of the last century, seems, however, to have been the first who took a somewhat enlarged view of the subject. He supposes that after the rocks in which the veins occur were formed they suffered great desiccation, and were exposed to violent shocks. "In consequence of these changes the rocks and mountains, which formerly composed one continuous mass were split asunder; whilst this took place, it might easily happen that one of the rocks slipped from the other, leaving between them open spaces, which were afterwards filled up, in part at least, with different mineral substances." He afterwards remarks that "it is difficult to conceive how rents and openings of considerable size can be produced without some portion of the adjoining rock suffering such a strain as would form lateral chinks, so that the principal rent should terminate in several smaller ones. When these smaller rents are filled with the same matter as the principal

vein they are said to be branches of the principal vein; in this case the vein is said to ramify or divide into branches."

Von Oppel was also aware that the walls of a lode did not always coincide, so that the fissure was also a fault. He remarks—"It sometimes happens that, when a vein is formed in a stratified mountain, the vein not only traverses, but also deranges a stratum, that is to say, that one of the two parts of the intersected stratum changes its position, being elevated or depressed in relation to the other strata; so that in this case the strata are said to have shifted."*

Pryce was perfectly aware, in 1778, that evidence existed in Cornwall of successive dislocations of the rock containing the lodes, such dislocations having been "occasioned by so many shocks and subsidences;" adding, "that the strata were not unfooted, shaken, or brought to fall once only, or twice, but several times."† He particularlys point out the mechanical effects produced by cross courses, and observes that, "because cross gossans or cross flukans run through all veins of opposite directions, without the least interruption from them, it seems reasonable to conclude that the east and west veins were antecedent to cross veins."‡

The same author observes also that there are in Cornwall lodes "which frequently pass through all others except cross gossans, and are called by the name of contras. Such lodes direct east and west more nearly than any others; and, therefore, in their course run through many other lodes, intersecting them at very oblique angles. All veins crossing each other may be termed contras in respect of each other, as their courses are in opposition; but, from the best information I can procure, all those gossans which are direct east and west run through every other lode like cross gossans, but do not disorder them in the same manner; therefore I choose to fix the name contra, vulgarly called caunter, to these direct east and west lodes, of whose direction and fertility the great Huel Virgin is one notable instance." He particularly remarks that "the lode which separates and

* Anderson's translation of Werner's Theory of the Formation of Veins, pp. 33, 34, where Von Oppel's Anleitung zur Markscheidekunst (1749), and Bericht von Bergbau (1749) are quoted.

† Mineralogia Cornubiensis, p. 82.

‡ *Ib.* p. 101.

goes through another must have been formed subsequently to that which it divides and passes between." *

Pryce also particularly describes the faults, commonly termed slides, which traverse the lodes in their underlie, and notices the various shifts occasioned by this kind of dislocation, giving a section of Goon-laz and the Pink mine, in St. Agnes, in illustration of the subject.†

Werner in his new theory of veins, published at Freiberg in 1791, points out the relative ages of mineral veins by means of their intersections, stating that "every vein which intersects another is newer than the one traversed, and is of later formation than those which it traverses." He considered that he was the first to notice this circumstance, which, as we have above seen, was previously insisted upon by Pryce. In all probability, however, as Dr. Anderson observes, Werner was unacquainted with Pryce's Mineralogia Cornubiensis at the time he wrote, as, from the general fairness of his writings, he would have otherwise mentioned that work. Werner notices the frequency of those cases in which the hanging wall is found much lower down in the lode than the foot-wall, being the effect of a dislocation by which one side of the fissure is let down relatively to the other, and cites the tin-veins at Zinnwald as good examples of this fact. He seems the first to have observed that veins "have become larger and larger, perhaps during the very time they were filling up," and "that the greater number of the old rents were filled up, and consequently shut, at the time new ones, either having the direction of the old ones, or traversing them, were formed."‡

Both Pryce and Werner remarked upon the different directions of the veins of different ages in the countries known to them. The former pointed out that there were three kinds of lodes of different ages in Cornwall, the magnetic east and west veins (W. 25° S., and E. 25° N.), the contra-lodes (E. and W., nearly), and the cross courses (frequently about N. 25° W. and S. 25° E.); and Werner remarked that the N. and S. lodes of Freiberg were traversed by veins which vary in direction from E. and W. to S.E. and N.W. (six to nine o'clock veins.) He also observed that the tin-veins of the Ehrenfriedersdorf mining-district having a direction from E. and W. to S.E. and N.W. are always traversed by the

* Mineralogia Cornubiensis, p. 105.

† *Ib.* p. 106, &c., and pl. 1.

‡ Werner's Theory of Veins, Chap. v., § 53.

silver-veins, the direction of which varies from S.E. and N.W. to N.E. and S.W.* Werner further considered that, by the inclination and direction of the principal veins of the same formation in any one country, which are usually almost parallel, but still more so by those of any particular vein, we shall be able to determine with sufficient accuracy the place from whence the force which has cut the rock has proceeded, and also the direction it has taken. †

Mr. Carne, in a memoir on the relative age of the veins of Cornwall, published in 1822, divides the fissures, resulting from the successive dislocations of the rocks in which they occur, into eight epochs of formation, on the principle that the fissures of one epoch traverse all those of preceding epochs, and are only cut through by those which may be produced afterwards. By *east and west lodes*, Mr. Carne states he means "metalliferous veins whose direction is not more than 30° from those points: by *contra-lodes*, metalliferous veins whose direction is from 30° to 60° from east and west; and by *cross courses*, veins whose direction is not more than 30° from north and south. The eight epochs into which he divides the fissures are as follow:—1. The oldest tin-lodes. 2. The more recent tin-lodes. 3. The oldest east and west copper-lodes. 4. The contra copper-lodes. 5. Cross courses. 6. The more recent copper-lodes. 7. The cross flukans (cross courses filled wholly by clay). 8. The slides (faults, wholly filled with clay, having their most general direction parallel with the tin and copper lodes, and heaving such lodes in their underlie or dip).‡ The theory of these distinctions is, that fissures opened at different and succeeding times have to a certain extent been differently filled by mineral substances, and that the directions of the fissures have at certain times been different, each set of fissures possessing marked characteristics in this respect. Whatever may be thought of the necessity of some of the eight distinctions above made, the value of the memoir itself cannot be doubted, embodying as it does a great mass of facts, and having, as Mr. Robert Fox justly observes, formed an epoch in the records of Cornish mineral veins,§ in proof of which it is merely necessary to glance at what had been previously published on the subject, and the frequent use which has been subsequently made of it.

* Werner's Theory of Veins, Chap. iii., § 35. † *Ib.* Chap. v. § 57.

‡ Trans. Geol. Soc. of Cornwall, vol. ii. p. 85—119.

§ Observations on Mineral Veins, p. 1.

From the date of Mr Carne's paper, nothing further has been published respecting the relative date of the veins of Cornwall, as deduced from the dislocation of fissures with given directions by others which have different directions either horizontally or vertically. Before, however, we proceed to consider this point further, it will be necessary to give an abstract of the important researches of Mr. Hopkins into the directions which would be taken by fissures, under given conditions, either formed at the same time or at periods subsequently to each other; his object being to ascertain if the phenomena of anticlinal lines, faults, mineral veins, or by whatever name similar lines of disturbance or dislocation may be known, are not referrible to some "widely-diffused action of some simple cause, general in its nature with respect to every part of the globe, and general in its action, at least with respect to the whole of each district throughout which the phenomena are observed to approximate, without interruption, to the same geometric laws." *

With respect to the action of an elevating force, Mr. Hopkins sets out by hypotheses as simple, he conceives, as the nature of the subject will admit of. He says, "I assume this force to act under portions of the earth's crust of considerable extent at any assignable depth, either with uniform intensity at every point, or in some cases with a somewhat greater intensity at particular points; as, for instance, at points along the line of maximum elevation of an elevated range, or at other points where the actual phenomena seem to indicate a more than ordinary energy of this subterranean action. I suppose this elevatory force, whatever may be its origin, to act upon the lower surface of the uplifted mass through the medium of some fluid which may be conceived to be an elastic vapour, or in other cases a mass of matter in a state of fusion from heat." †

"The first effect of our elevatory force," observes the same author in continuation, "will of course be to raise the mass under which it acts, and to place it in a state of *extension*, and consequently of *tension*. The increase of intensity in the elevatory force might be so rapid as to give it the character of an impulsive force, in which case it would be impossible to calculate the dislocating effects of it." He therefore always assumes "this intensity and that

* Hopkins, Researches in Physical Geology, Transactions of the Cambridge Philosophical Society, vol. vi., part i.

† *Ib.*

of the consequent tensions to increase *continuously*, till the tension becomes sufficient to rupture the mass, thus producing fissures and dislocations," the nature and position of which it is the first object of his investigation to determine. "These will," he proceeds, "depend partly on the elevatory force, and partly on the resistance opposed to its action by the cohesive power of the mass. Our hypotheses respecting the constitution of the elevated mass are by no means restricted to that of perfect homogeneity; on the contrary, it will be seen that its cohesive power may vary in general, according to any continuous law; and, moreover, that this power, in descending along any vertical line, may vary according to any discontinuous law, so that the truth of our general results will be independent; for example, of any want of cohesion between contiguous horizontal beds of a stratified portion of the mass. Vertical or nearly vertical planes, however, along which the cohesion is much less than in the mass immediately on either side of them, may produce considerable modifications in the phenomena resulting from the action of an elevatory force. The existence of joints, for instance, or planes of cleavage, in the elevated mass, supposing the regularly jointed or slaty structure to prevail in it previously to its elevation, might affect in a most important degree the character of these phenomena." Mr. Hopkins further remarks that to a mass so constituted his investigations must not be considered as generally applicable, and that in them, "vertical or highly-inclined planes of least resistance will only be assumed to exist partially and irregularly in the elevated mass."

After considering the subject of the direction which fissures would take under a variety of circumstances in a thin lamina, this author states the impossibility of forming in succession parallel fissures not far distant from each other in a mass subjected to such tensions as he supposes acting upon such lamina. "In any system of parallel fissures," he says, "which are not remote from each other, the fissures could not have been formed in succession," though it is easy to understand how, in an assumed case "of two systems of tension perpendicular to each other, any number of parallel fissures may be formed simultaneously." He further remarks, as "evident, that, in whatever manner a system of parallel fissures may be produced, after their formation the only tension of the mass between them must be in a direction parallel to them. Consequently, should any other system be subsequently

formed, it must necessarily be in a direction perpendicular to that of the first system. No two systems of parallel fissures, not perpendicular to each other, could be formed by causes similar to those of which we have been investigating the effects."

Mr. Hopkins, in applying his investigations to a mass of three dimensions, deduces a series of important conclusions, among which are the following:

"If the mass be subjected to two systems of parallel tensions of which the directions are perpendicular to each other, two systems of parallel fissures may be produced, of which the directions will be perpendicular to each other. No two systems of parallel fissures could be thus formed, of which the directions should not be perpendicular to each other."

"If the fissures in either of these systems be near to each other, they could not be formed by such tensions as we have been considering, in succession. They must be formed simultaneously in each system. One system, however, might be formed at any time subsequently to the other."

Mr. Hopkins very carefully points out the modifications which may be produced by given conditions, especially the effects of more intense action of the elevatory force at particular points, so that, if this "be sufficiently great and exactly simultaneous with the elevatory force, it may modify materially the position of the longitudinal fissures." He moreover notices the sense in which the term parallelism should be regarded, observing that, "if the extent of the mass be comparatively small, and its boundary irregular, this property would altogether cease to characterise the phenomena," and that, "if the axis of the general elevation of indefinite length be not in a right line, the fissures of the longitudinal system (assuming them to be produced in the manner he indicates) will still be parallel to this axis (in the sense in which one curve line may be said to be parallel to another), and every fissure of the transverse system will be perpendicular to each fissure of the former system at the points of their intersections, and consequently the fissures of this transverse system will not be parallel. "Again, if we suppose the superficies of our elevated mass," he continues, "to be of finite length, and to be bounded, for instance, by a line approximating to the form of an elongated ellipse, the direction of the fissures in the transverse system, as we approach towards either extremity of the elevated range, will

gradually change from perpendicularity with the major axis (the axis of elevation) till they become parallel to it at the extremities of the ellipse, always preserving their approximative coincidence with the directions of the lines of greatest inclination of the general surface of the mass. The fissures of the other system will be approximately perpendicular to these lines. In this case, then, the two systems will be no longer characterised by any constant relations which their directions bear to that of the axis of elevation, and therefore the terms longitudinal and transverse will cease to designate them so correctly as in other cases." It is further observed, that, "if the elevated mass be of great superficial extent, partial irregularities in its boundary will have no appreciable effect in the directions of the fissures; and, though two remote fissures of the same system might, in such case, be inclined at any angle to each other, any two adjoining fissures would in general be approximately parallel."

Having thus endeavoured to present a general idea of the views of Mr. Hopkins, rendered alike necessary by the importance of the subject and of the researches themselves, we will now proceed to examine a few facts which may bear upon them, connected with the faults and mineral veins of the district under consideration.

In the first place, if the mass of country before us were now acted upon by an elevatory force, such force would not be exerted upon a mass possessing homogeneity, since it is composed of a variety of rocks not only of variable hardness and cohesion, but offering planes of less resistance of a very complicated order, some being divisional planes, and others planes of stratification; even supposing, for the sake of illustration, that the mass was unbroken by those numerous faults and other fissures of dislocation which now traverse it. Much of this variable character is due to time, during which additional matter, of very variable cohesion, has been accumulated upon the earliest consolidated rocks. The planes of stratification have necessarily become multiplied by the addition of new beds of stratified rocks, and divisional planes, unless we suppose all to have been formed at one given time (an hypothesis not very probable), were successively produced, so that, in the earlier geological ages of the area comprising Cornwall, Devon, and Western Somerset, we may assume more homogeneity in the solid matter forming the earth's crust

at that point than is now to be found, and consequently given causes acting upon such mass, all other things being equal, would then produce more uniform results, that should be mainly governed by homogeneity, than they could now, when other masses of mineral matter, possessing a very variable character, are wholly or in part accumulated upon it.

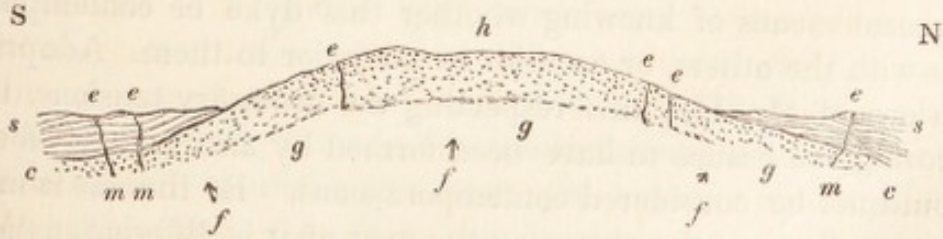
We have next to examine whether there is any geological evidence to show that an elevatory force has acted at all on the area before us, and, if there be evidence to that effect, then to see what geological date may be assigned to such force, and note how far any lines of fissure may coincide with any axis of elevation. There will be little difficulty in perceiving, from what has been previously stated, that there is evidence of an elevatory force or forces, and that among the effects resulting from it or them has been the protrusion of granite, which, judging from the bosses now exposed to view, would give an axis of elevation extending from about E.N.E. to W.S.W.; an accumulation of more modern rocks concealing the eastern continuation of it beyond Dartmoor, while the Atlantic covers its western portion beyond the Scilly Islands. There will be little difficulty in considering that the superficially isolated patches of granite in Devon and Cornwall are connected beneath the intervening slates, and that the latter have been borne up upon the back of the concealed and connecting granite masses in such a way that their constituent beds are seen to be more clearly turned out of their previous positions at the points where the granite, being impelled upwards with greater force, or meeting with less resistance, broke through them.

We have no good geological evidence to adduce that this elevatory movement (supposing for the sake of investigation that it was a single movement) was accompanied by any system of fissures, for we have to assume that the granite was fluid, and consequently could not be divided by fissures, so that if fissures had been formed in the slates they would have stopped at the granites. We have evidence, however, that the slates in immediate contact with the granite were greatly fractured, and that into them the fluid granite was forced. At first sight the elvan dykes would seem good evidences of fractures in the slates parallel to the axis of elevation, and filled by granite matter. When, however, we come carefully to examine into this subject, we find

that, when elvan dykes cut through slates, and can be traced up to granites, a very large portion of them can be distinctly observed to enter the granite, so that the fissures into which they have been forced have been formed equally in the granite and slate, and, consequently, that at least that part of the granite in which the fissures were produced must have been consolidated: hence they have been formed subsequently to the exact period of the first elevatory movement. The question now arises whether all the elvan dykes are of the same age; and here there is considerable difficulty. The elvans which do not clearly cut into the granites when they arrive at them, after having traversed adjoining slates, may have been injected into fissures formed at the epoch of first elevation; but of this we have no proof; and every geologist who endeavours to trace elvan dykes in granite knows how difficult it is to follow them under such circumstances, particularly when the elvan becomes more granitic than usual.

Quitting this uncertain ground, we have evidence in the elvans above noticed, as traversing alike granite and slates, that longitudinal fissures, corresponding with general lines, which may be readily considered as parts of the axis of elevation of the Devonian and Cornish granite, were formed after the consolidation of at least the higher portions of the granite now visible. These fissures must have been produced by tension of some kind, either by another elevatory effect of the same force which raised the granite in the first instance, or by the cooling of the granitic crust, which thus shrunk and formed fissures into which the inferior fluid granite rose, partly in consequence of the pressure of solid and heavier granite upon it. A minor repetition of the same force which originally elevated the body of granite and raised the slates with it, acting along a line in a great measure coinciding with the main axis of the first elevation, is the more simple hypothesis, and involves less difficulty than the other.

Fig. 68.



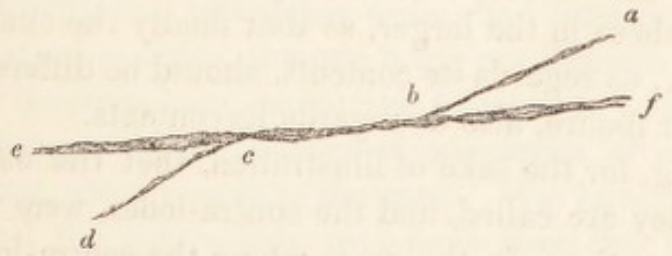
Let the annexed diagram (fig. 68) represent a section in which

s s are slates through which granite *g g g* has been protruded in a state of igneous fluidity, and that sufficient time has elapsed so that a crust of solid granite *c c* has been formed, thicker where uncovered by slate from the difference of cooling that would arise, the consolidated part covered by slate, a bad conductor of heat, being thinner than where the fluid granite was exposed to the atmosphere and the heat could radiate freely. In such a state of things it is easier to conceive that an elevatory force acting in the direction of the arrows *f f f*, and producing tension in the solid crust of rocks between S and N, should cause rents *e e e e e e*, into which fluid granite *g g g* should be impelled, than that rents should be produced in the crust between S and N by the contraction of such crust above the fluid granite *g g g*, into which the latter should rise. We should expect that, if there were an axis of elevation, as at *h*, though there might be contraction from consolidation and a tendency to form longitudinal fissures, the gravity of the separated parts would tend to keep them together. It may indeed be said, that, if cracks were formed at the points *m m m*, there would be all the pressure at *h* of both the fluid and consolidated granite to force up the former through any fissures then formed. The points *m m m*, however, would be those where fissures would be least likely to be produced from the cause supposed, inasmuch as the crust of consolidated granite would be there thin in proportion to the covering of non-conducting rocks, and the latter would offer considerable resistance to the progress of a fissure so caused, more particularly when they formed a covering of considerable thickness.

Having previously noticed the directions of the Devon and Cornish elvan dykes, we shall merely remark that the principal exception to the general coincidence with the undulating axis of elevation we have here supposed is the north and south elvan which holds its course from Watergate Bay, on the north coast of Cornwall, through Lower St. Columb to Mitchell. We have no present means of knowing whether this dyke be contemporaneous with the others, or anterior or posterior to them. Adopting the views of Mr. Hopkins respecting the necessary tensions, and supposing the fissure to have been formed by an elevatory force, it would not be considered contemporaneous. Be that as it may, the general run of the elvans on the west of it is different, as previously observed (p. 179), from that on the east.

We have previously noticed that the faults and veins of the district under consideration may be classed under three principal systems as regards directions, and that one crosses the others at considerable angles, often approaching a right angle, while the two others cross each other at angles between 30° and 60°. The first, or cross courses, evidently traverse the others having different directions, with the exception of those dislocations which are commonly, in Cornwall, termed slides. Leaving the consideration of the latter for the moment, we have to inquire whether, from any differences in the intensity of the elevatory force (supposing for the sake of the argument that such produced the fissures), or in the resistances to that force, could have produced this variation of direction, or crossing of fissures at the same time, or whether one set of fissures has preceded the other, the one set having been traversed by the other. In order to prove that the east and west lodes, as they are termed, because they in general approximated towards the present magnetic east and west, have been formed, as is supposed, prior to the contra, or *caunter* lodes, it is necessary to show that the latter traverse the former so that the contents of the contra-lode cut off the continuity of the lode considered to be traversed, the walls being partly composed of the contents of the east and west lode where the traverse is effected. This is a point upon which the survey has received the most contradictory information. The miners not unfrequently say that one lode throws out another, that the strongest carries the other with it for some distance, and that then each holds on its own course, as represented beneath (fig. 69), where it would be said that the larger lode *e f* carried the small lode *a d* with it from *b*

Fig. 69.



to *c*; but when inquiry is made into the facts necessary to show that one lode actually traverses the other, the answers are in general very unsatisfactory, records having been very rarely kept of, or attention directed to, the main facts relating to actual intersec-

tion; and, unless it should so happen that workings are carrying on upon parts of a mine, where such intersections may occur, during the examination of a country by the passing geologist, he cannot himself clear up these points.

If, as shown in the above diagram, *a b* and *c d* are parts of the same lode, the points *b* and *c* having been once joined, and the continuity of the parts *a b* and *c d* destroyed by the intersection of the fissure *e f*, the lode *a b* could not be said to be carried with the lode *e f* to *c*, since there would be nothing to carry, inasmuch as *b* and *c* are supposed to have been points forming adjacent portions of the lode broken through by the fissure *e f*. We can however readily understand that, *e f* being a fissure first formed, a subsequent fissure *a b* may be produced (the disrupting force acting in the direction from *a* to *b*), which, meeting with the line of least resistance *e f*, should follow that line from *b* to *c*, and should afterwards be continued in the direction *c d*, parallel or nearly so to its first course. In such a case the new fissure would pass along the line *a b c d*, and be readily traced by its contents (which however ought to be distinctly seen to traverse those of *e f*), and the contents of both fissures would occupy the space from *b* to *c*, though the conditions then arising might be highly favourable to the alteration of both lodes from electro-chemical agency, and in fact such intersections of lodes are often occupied by bunches of ore and other remarkable accumulations. There is no difficulty in supposing that, if *e f* be a large fissure and *a b c d* a smaller fissure formed contemporaneously, or nearly so, the difference in their directions might give rise to differences of deposit from a solution, at first of nearly uniform character, common to both, but which afterwards became modified, the changes in the smaller fissure varying, from variation of conditions from those in the larger, so that finally the character of the minor crack, as regards its contents, should be different from that of the larger fissure, also as regards its contents.

Supposing, for the sake of illustration, that the east and west lodes, as they are called, and the contra-lodes, were produced by distinct dislocations, in the cases where the contra-lode is said to have carried the great lode with it for some distance (at Wheal Alfred it is said to have done so for 480 feet), the probabilities are, unless the one can be distinctly seen to cut through the other, that the great lode was last formed. Mr. Carne observes

that the lodes were clearly distinguishable from each other when together in this mine.* In Wheal Crenver the contra-lode is stated to have been carried 420 feet in the direction of the great lode where it met the latter, and then to have resumed its old course: in this case, unless actual intersections should prove it otherwise, we might assume that the great lode was first formed. It should here, however, be observed, that the Crenver lode is, as regards its direction, a contra-lode to that at Wheal Alfred, and that moreover the Wheal Crenver lode turns up shortly after meeting with the contra-lode to the northward in a direction about 15° N. of true west, and the contra-lode runs about 35° to the N. of W., thus approximating towards the direction of some cross courses.

It may be here noticed that Cornish miners always give the name of a contra-lode, or caunter, to those veins which do not hold the directions of their main lodes, and that, therefore, what may be termed a contra-lode in one district coincides in direction with the true lodes of another; thus, the lodes of the southern part of the St. Austell district coincide with many contra-lodes in Gwennap, Camborne, &c.; and the direction of some contra-lodes in the former agree in direction with the true lodes of Gwennap, &c. Hence, when the terms of lodes and contra-lodes are employed without reference to their exact directions, we should be careful not to deduce consequences from them as regards any theory connected with their respective directions, without being fully aware of what those directions actually are.

That many of the lodes of Cornwall distinctly traverse each other there can be little doubt; but, assuming this to be the fact, it remains to be seen if a series of metalliferous veins, having a reasonable approximation to another series, had been formed antecedently to that other series, the one being cut through by the other. It therefore becomes very important to possess well ascertained facts, showing the clear passage of one series of mineral veins across another, should such be the case. We have seen that in Wheal Alfred the contra-lode may have been that first formed, and perhaps many other instances of a similar kind might be found. Mr. Robert Fox informs us that Harriett lode at Dolcoath mine clearly traverses the contra-lode, so that distinct walls are seen across the traversed contra-lode. The lodes in the

* Carne on the Veins of Cornwall, Trans. Geol. Soc. Cornwall, vol. ii. p. 98.

southern part of the St. Austell district are said to be crossed by others having the same direction as those at Gwennap, and one, having the same W.S.W. and E.N.E. direction, heaves the Great Hewas lode near that place.

In the present state of the inquiry there is much difficulty in arriving at conclusions respecting the priority of the two directions as regards the whole area before us; they, however, both so far coincide with the great axis of elevation previously alluded to, that we can readily consider them to do so in a general manner, the intensity of the points of action, or the resistance having been variable, causing local deviations and complicating the fractures.

In discussing this subject, it should be recollected that, after a series of fissures has been produced and filled up by mineral matter, the further elevation of the same mass, by another action of the elevatory force in the same direction, would be attended with other conditions than if it had been subjected to a similar action before the fissures were so filled. Some of these fissures have their walls so cemented together that the lode can with difficulty be separated from the containing rock, and even in cases where the walls of the lode are not so cemented with the rock, surfaces which might otherwise slide upon each other get wedged by the unequal solid matter constituting the contents of the lode, so that a very complicated series of fractures might be the result, some through the lode (partly parallel to the walls, partly across its contents), others extending across the adjoining country.

Having above noticed the directions of the various faults and lodes in Cornwall, Devon, and West Somerset (p. 309), we shall merely observe that there seems evidence that many lines of fracture have followed each other in similar or nearly similar directions. Thus, though, as near Marazion, lodes do not always hold their courses nearly parallel to the elvans in their vicinity, the cases in which they do not vary from it many degrees are numerous. If we have been correct in inferring that the lodes have sometimes suffered enlargement at different times, sufficient time having elapsed between each time to permit solid mineral matter to have been accumulated, fractures have been several times produced in the same or nearly similar lines. Whether or not the contra-lodes (true east and west lodes) have been always formed after the others, which vary in direction from them from 10° to 50°

(and indeed we have evidence to show that at Dolcoath, and on the western part of the Great Hewas lodes, near St. Austell, they have been cut by fissures taking directions coinciding nearly with the present magnetic east and west in Cornwall), these various dislocations took place prior to the great cross courses which traverse them in directions varying from 70° to 90°.

A glance at the maps, or at fig. 50 (p. 309), will show that the crossing of fissures varying from east and west to east 25° north and west 25° south, by others at considerable angles, often approaching right angles, constitutes the main feature in the dislocations of the district under consideration, the chief exceptions to these principal directions occurring near St. Austell, Marazion, and St. Just. When we observe these main facts, and possess evidence that the great leading lines of dislocation have a general tendency to parallelism, we are led to consider that, however little some of the phenomena observed may at first sight appear to coincide with Mr. Hopkins's views, such disagreement may in a great measure be due to modifying causes.

In the first place, the minor detail may have been extremely complicated by the divisional planes, as Hr. Hopkins has pointed out would be the case if they existed prior to the elevation of a rocky mass. The planes of stratification, more particularly where there has been much contortion, would also aid in modifying the results, and we have seen that the intrusion of the main masses of granite appear to have produced this effect. Homogeneity would not exist in the mass to be fractured, even omitting the divisional and bedding planes, inasmuch as it would be composed of substances very variably distributed, and of very different degrees of cohesion. The fissures may have been long producing, so that even mineral matter may have been introduced into the cracks first formed before the whole mass subjected to tension adjusted itself, resistances having been gradually overcome in one place before they were in another, so that, from the complication of these resistances, partial lines of fissures may appear to vary even 50° from each other. The effects of the first great fractures having been accomplished, we may consider that there was a state of rest, after which the whole was again subjected to tension, when the great cross courses were produced, in accordance with the views of Mr. Hopkins, at angles as much approaching right angles as the modifying circumstances would permit.

It being a well-ascertained point in Cornwall that the slides traverse the cross courses in directions coinciding, or nearly so, with the lodes cut by the cross courses themselves, and as we appear also to have evidence that lines of eastern and western dislocations may have been produced at different geological epochs in the district or its vicinity, and, for aught that can be adduced to the contrary, the like may have happened to the northern and southern faults, it may be right, before we consider these facts at variance with Mr. Hopkins's view, to consider whether they may not render it support. We can imagine that after the fissures have been formed they have been so cemented by mineral matter that one set may have been chiefly open when the necessary tension was produced, so that, with proper allowances for modifying circumstances, the new dislocations were at right angles to it. We can further readily suppose that there have been, during any time that the mass may have been placed under tension, very considerable differences in it from the variable manner in which the previous fissures have been so cemented by mineral matter, so that contemporaneous effects by the same elevating force may have sometimes produced fissures nearly coinciding with lines of previous dislocation in some places and not in others. Be this as it may, the tendency of so many fissures to be parallel to each other, viewing the subject on the large scale, and to be traversed by great lines of dislocation at considerable angles, is very remarkable ;* and, as Mr. Hopkins has offered us a theory which, under certain conditions, would explain similar facts, we seem bound rather to see how far apparently adverse phenomena may be explained by modifying circumstances, than, by regarding nothing else than the apparent exceptions, cease to take a fair view of the explanation of them afforded us, and, consequently, shut ourselves out from the truth to which it may lead us.

With regard to the filling of fissures by chemical means, Pryce has some observations that show considerable advance towards a due appreciation of a play of affinities by which substances may be carried in solution into a fissure, and afterwards arrange themselves there according to the new conditions to which they

* The great north and south dislocations of Devon and Cornwall are continued through South Wales, in which the northern and southern faults are abundant, and easily ascertained by means of the coal-mines. Some of the heaves produced by them are very considerable.

may become exposed. He says, "we may reasonably infer that water, in its passage through the earth to the principal fissures, imbibes, together with the natural salts and acids, the mineral and metallic particles with which the different strata are impregnated, and meeting in those fissures matters which have nearer affinities with the acid, of course disengage it, in whole or in part, from the metallic or mineral matter which it held dissolved, and which, on being so disengaged, by the natural attraction between its parts, forms different ores more or less homogeneous, and more or less rich, according to the different mixtures which the acid had held dissolved, and the nidus in which it is deposited. The acid, now impregnated with a new matter, passes on, till, meeting with some other convenient nidus, it lodges in that, and thereby acquires a fresh impregnation, perhaps, at last, totally unmetallic, or, for want of meeting with a proper nidus, appears at the surface weakly or strongly tinctured with those principles it had last imbibed."* Though this passage is, of necessity, marked by the chemical knowledge of the day, it shows that Pryce considered that the non-mechanical contents of veins, particularly the ores, might be introduced into the fissures by means of solutions which percolated through the adjoining rocks, and that then the various substances in solution in the fissures arranged themselves according to their affinities. He remarks on the occurrence of even small parts of lodes containing several different kinds of ore separated from each other by quartz, clay, and other substances, and asks how this could have been effected, "but by the agency of water to bring, and the power of attraction to arrest, such and such particles, and deposit each in its proper matrix or nidus."† He particularly notices the various kinds of lodes, as distinguished by the miners according to their contents, point-

* Mineralogia Cornubiensis, p. 6, 1778.

† Mineralogia Cornubiensis, p. 8. Pryce after this passage carries his opinion of the possible alteration of lodes so far as to suppose that they may even in a few centuries change their character so as to be rich at one time and poor at another, mineral substances being transferred from one part of a lode to another, "according to the solution and transmigration of their respective principles, which are deposited in some other magnetic nidus, whose power of retention, in process of time, may be again decayed, those principles again depart, and again be arrested *ad infinitum*." However little we may be disposed to agree with Pryce as to the time in which he supposes such changes can be produced, still we must allow him the credit due to the recognition of the possibility of change caused by alterations of the conditions to which the contents of lodes may be exposed; an opinion not in accordance with the views of his time.

ing out the difference between the *backs*, or upper parts, and the contents beneath. He describes a great variety of the *gossans*, observing that "the tender red gossan is very much inclined to produce copper-ore, especially if the gossan be spungy, cellular, and of a very red colour, like to a well-burned brick. When it is thus, and spotted, and tinctured with green copper-ore, like pieces of verdigris, it does not often deceive the proprietors. So, likewise, stones of blue or black copper-ore, or of yellow ore having a black or purple outside, are very hopeful to follow when mixed in this gossan."*

Although Agricola and others speak of the deposit of mineral substances in the veins from solutions in which they were held, Werner seems to have been the first to point out that the layers of substances which succeed each other in many lodes, and which present a general parallelism to the containing walls, are often different from each other, showing a difference of the solution or solutions from which the various substances were deposited.† He particularly notices a specimen from Segen-Gottes at Gersdorf, "in which, reckoning from the middle (which is composed of two beds of calcareous spar, in which small druses here and there occur), thirteen beds of different minerals are arranged in the same order on each side of the vein; these are fluor spar, calcareous spar, heavy spar, galena, &c. In the southern vein, Gregorius, the two beds which adhere to the sides of the vein are composed of crystallised quartz; next to that, on each side, is a bed of sulphuret of zinc, mixed with sulphuret of iron; this is followed by sulphuret of lead, carbonate of iron, sulphuret of lead, carbonate of silver, red silver ore, sulphuret of silver; the central part which, of course, is most recently formed is of calcareous spar." Although Werner does not mention the kind of arrangement of parts of a lode, noticed above (p. 339), and which we had occasion to adduce at the meeting of the British Association for the Advancement of Science, in 1836, as evidence that in many lodes of Cornwall successive openings or enlargements of the containing fissure have been separately filled, it is not improbable that he possessed some evidence of this order, since he observes that "we meet with distinct examples of new veins formed in the direction of those of older date

* Mineralogia Cornubiensis, p. 88. † Theory of Veins, chap. iv. § 52.

(either within their substance or by the side of them), forming with them the same individual substance."* Among the facts, however, which he adduces, the mere occurrence of different ores on different sides of the lode is insufficient to prove the point, as this fact is observable in Cornwall in some lodes or parts of lodes, which there is every reason to conclude were filled during only one condition of the fissure.

M. Fournet has observed that the extreme regularity noticed by Werner and others does not always take place, remarking that, "when, for example, the veins contain fragments of the adjacent rock imbedded in their mass, the ore has in preference attached itself around them, enveloping them in a bed of greater or less thickness."† He further states that this fact is frequent in the mines of the Hartz, whence the sulphuret of lead obtains the name of *ringertz*, or *ring-ore*.

The same author has presented us with a very interesting account of the evidence which exists of the successive openings of the mineral veins in the environs of Pontgibaud, where for five years he was director of the mines. He shows that successive dislocations not only broke through the previously-consolidated contents of the lode, but also that the complicated fractures frequently extended into the adjoining country, forming branches. Chemical deposits of different mineral substances, or modifications of such substances, are seen to characterise five of the six successive dislocations which M. Fournet has been enabled to trace in these lodes, the sixth being marked by the introduction of pebbles and sand from above, a continuation of that which still covers the country in many places, and which is itself covered by the lavas of the extinct volcanos of Louchadière and Pranal. From this latter circumstance the author observes that there would be nothing remarkable in finding the metalliferous veins cut or divided out

* Theory of Veins, chap. v. § 55.

† Etudes sur les Dépôts Métallifères, D'Aubuisson Traité de Géognosie, tom. iii. p. 523. Speaking of the regularity of the substances filling some fissures, M. Fournet mentions that M. D'Aubuisson notices a vein composed of differently-coloured beds of sulphate of barytes and fluate of lime placed upon each other with so much symmetry in all parts, that more could not be accomplished with a compass and ruler. M. D'Aubuisson observes that this structure is exactly that which would have taken place if the fissure had been filled with a solution, successive deposits from which had been thrown down on its sides; adding, that the section of some geodes, and some water-pipes, in which successive deposits have been effected, present analogous facts.

by basaltic dykes, a fact that seems to have occurred in the veins of Courgoul and Saurier, on the S.E. of the Monts Dores. It further appears that ferruginous and calcareous deposits are now effected in the open spaces which may present themselves in these veins, "so that, if after working out the lode the galleries be left shut during a long series of years, and the mass acquire a certain compactness from successive infiltrations, new workings could be carried on upon the siliciferous and calciferous hydrates of iron. The attle, or broken rubbish, is even found to be cemented by very compact ores of this kind, the mammillated surfaces of which have sometimes the same appearance as some of the hydrates of iron of old date."*

The whole of the evidence, both of successive coatings of different substances in veins where the fissures seem always to have retained the same width, and of the coatings and different modifications of the contained mineral substances in those veins which have suffered successive dislocations, goes to prove that chemical or electro-chemical conditions in the lodes have varied materially at different times, producing a corresponding variety in the arrangement and number of the various mineral substances contained in them, and causing aggregations of similar matter in some places, and repulsions of different matter in others. Apparent cases of the latter are particularly noticed by M. Fournet; among others, the disposition to avoid each other of the siliceous and barytic deposits in the mines near Pontgibaud during the filling up of the fissures caused by what he considers the fourth epoch of dislocation in those lodes.

If fissures were now produced in the Cornish rocks, they would not only traverse those of various kinds as regards geological age, but they would cut through substances which, though they may not differ very considerably in many instances in their chemical composition, do so with respect to the mode in which that composition is arranged, as may be instanced in the granites and elvans taken collectively. In a fissure traversing grauwacke, the carbonaceous series, and trappean rocks, there might be much diversity of chemical composition; in the two former more especially, beds of very variable chemical character presenting themselves, and in fissures which traversed granites, elvans, slates, sandstones, and trappean rocks, still more so. A great difference between them

* Etudes sur les Dépôts Métallifères, D'Aubuisson, &c., p. 543.

would likewise consist in the comparative facility with which water could percolate among them, and, consequently, the power with which mineral matter in solution might be thus transmitted through them. It may now be considered a well-ascertained fact that the temperature of mineral vein fissures would be different according to their depths, the lowest part being the hottest.* If, therefore, we had fissures now formed, they would traverse rocks of different kinds (the power of water to pass through which would be very variable), and the walls of the fissures would pos-

* This fact may be considered so well established in Cornwall by the labours of Mr. Robert Were Fox, Mr. Henwood, and others, that we have abstained from adducing the evidence which was formerly considered necessary to give it support.

To obtain a fair approximation, with due allowance for modifying causes, to the rate of the increase of heat with the depth in Cornwall and Devon, or to those lines which mark curves of equal temperature beneath the earth's surface, and to which Professor Bischoff has given the name of *chthonisothermal*, would appear to be now the proper object of inquiry, one, however, which can be only accomplished with great care, for water rising up the lodes, or percolating through the pores and crevices of the adjoining rocks, would always modify the temperature of particular portions of a mine. Pryce long since remarked that different jets of warm and cold waters occur in mines at short distances from each other (Mineralogia Cornubiensis, p. 12), and the fact has been so often observed that we might anticipate that an open deep mine, well drained, would have a tendency to be cooled by the percolation of cold waters from the surface, the warm waters which rise from beneath, and which would tend to raise the temperature of the adjacent rocks to their own, being pumped out.

Mr. Robert Were Fox, in noticing the fact observed by Mr. Henwood and himself, that the granite in the Cornish mines is found to be less warm, at equal depths, than the slates, observes that he had long attributed this difference to the facility afforded by lodes as compared with rocks, and of killas (slates) as compared with granite, for the ascending and descending currents of water.—(Observations on Mineral Veins, p. 29.)

Mr. Fox, considering that the high temperature of the lowest parts of deep mines is in a great degree independent of accidental or extraneous causes not existing in the earth itself, and that it is more often diminished by them than the reverse, caused thermometers to be placed at different depths in the rocks in Levant Mine and in the Consols Mines (Gwennap), the result of which was, that the deeper thermometers (four feet long) stood at a higher temperature than other thermometers placed near them, and buried only one inch in the rock. In Levant Mine the long thermometer, in granite, at 230 fathoms from the surface and 200 beneath the level of the sea, stood at 80°, while the short thermometer rose only to 78°·5. Placed in slate in the same mine at about 190 fathoms under the sea-level, and four feet from the lode, the former indicated 78° and the latter 72°·5. Results of a similar kind were obtained in Consols Mines, with the additional important information that, in a cross-cut in which the experiments were made, the temperature increased towards the lode, being in the latter much more considerable than in the cross-cut, an effect which Mr. Fox attributes to the greater facility afforded by it to the ascent of currents of hot water.

In Tresavean Mine, Captain Oats obtained the following results, experimenting at

sess higher temperatures in proportion to their distances from the surface, so that we should infer, if the cracks descended sufficiently deep, they might reach incandescent matter, assuming that the heat continues to increase downwards from the surface of the solid crust of the earth, until finally there is mineral matter kept fluid by heat.

We have supposed that the elvan dykes resulted from the forcing up of granitic matter into cracks, and consequently we assumed a propelling force equal to the effect required. The next series of fissures which traverse the elvans may or may not have extended down to the fluid mineral matter beneath. If they were produced by a continuance of the same elevatory action that caused the fissures into which the elvans were forced, we might expect that the granitic matter would still have been thrust up in

the request of Mr. Fox, with a thermometer (No. 1) buried two feet ten inches in the rock, and another (No. 2) one inch under the surface of the rock at the two stations:—

Depth in fathoms from surface.	Depth in fathoms from sea-level.		Experiments made. In air.	In the rock. No. 1.	In the rock. No. 2.
			°	°	°
26	...	In granite 15 fathoms N. of lode, and 40 fathoms from "killas"	53·3	57·	52·8
200	170	In the lode, rock do., "killas," and three fathoms from granite	77·2	76·	75·5
200	170	In do. 10 fathoms from do.	77·7	76·	75·5
250	196	In lode contained in granite, and 60 fathoms from "killas"	83·2	82·5	82·
262	208	In lode, do., in 7 fathoms from do., being the bottom of the mine	85·5	82·5	82·

Mr. Fox estimates a rate of increase of heat of one degree of Fahrenheit in 46 feet in Levant Mine, of one degree for 49·6 feet in Consols, and of one degree for 48 feet in Tresavean Mine, if calculated from the surface.—Report of some Experiments on the Electricity of Metallic Veins and the Temperature of Mines.—(Report of British Association for 1837, p. 133—137.) From the experiments made in Dolcoath Mine, when a thermometer four feet long was buried in rock 1380 feet from the surface, he inferred that there was a difference (taking the mean temperature of the mining district of Cambourne to be about 50°) of 25° for that depth, or at the rate of about 51 feet for 1°.

Professor Bischoff observes, respecting chthonisothermal lines, that the general inequalities of these lines would conform to the irregularities of surface, and gives instances to show that they rise in mountain-masses, among others that of Guanaxuato in Mexico, where the workmen find themselves at a depth of 1607 feet at a temperature of 98°·15, which is about 15°·75 higher than the temperature of the equator at the level of the sea, and yet this point is at a height of 4617 feet above the sea.—(On the Cause of the Temperature of Hot and Thermal Springs, Jameson's Journal, January, 1838, p. 146.)

them, in some cases rising high enough to fill up fissures in the first-formed elvans. Of this, however, we have no example, for the granite lode described as found in Herland Mine, about two feet thick and dipping nine inches in a fathom,* comes more under the head of elvan courses antecedent to lodes in that vicinity, running parallel, or nearly so, with the neighbouring elvan courses of Guinear.

If in any way we consider the fissures open to, or in, greatly-heated mineral matter, the water which would find its way into the fissure would encounter heat in the lowest parts of the crack, which would tend to vaporise it and drive it out again, the power to accomplish which would depend upon the quantity of water on the one hand, and the amount of heat on the other. Assuming for the sake of illustration that the fissure extended sufficiently deep, and that the amount of water which could find its way into it was not so abundant at any given time that it could not be vaporised readily by the heat of the lower parts of the fissure, steam mixed with any vapours or gases arising from the bottom of the fissure itself, and partly derived from matter carried down by the water, would be driven upwards through the rent, and of course be subjected to the laws of condensation according to circumstances. Although the walls of the higher parts of the fissures would become more heated than they were at the first dislocation of the rocks from the passage of heated vapours through them, still, as a whole, the fissures would be cooler in proportion as they approached the surface in contact with the atmosphere, and condensations of substances carried up in a state of vapour mixed with steam would be affected accordingly.

Upon the hypothesis that the heat at the bottom of fissures is supposed to be sufficient to vaporise water flowing into them, waters slowly oosing out of the pores and interstices of rocks into the cracks, heated at their surfaces by the ascent of vapours close to them, would have a tendency to be vaporised before they could trickle downwards towards the more heated parts of the fissures. Consequently mineral substances which they held in solution, and which could not be carried in vapour with the steam at the same heat, would be deposited on the sides of the fissures, on the same principle that we see carbonate of lime now deposited on the sides of fissures in many limestone countries from the eva-

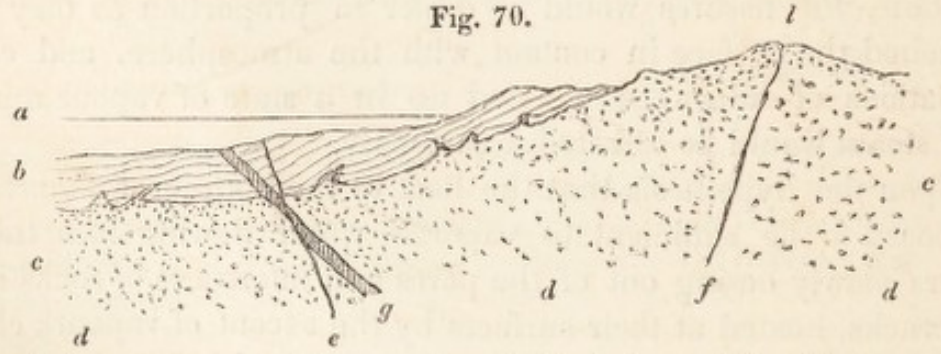
* Edmonds, Trans. Geol. Soc. Cornwall, vol. iii. p. 332.

poration of the water and loss of carbonic acid which held the carbonate of lime in solution, while the whole percolated through the adjacent rocks.

A state of things, such as above supposed, could only continue while the heat beneath was sufficient to vaporise the water, so that if this heat became less by degrees, and we assume the quantity of water introduced into the fissure to remain constant, a time would come when the water would remain in the cavity in a heated state, the evaporation being wholly carried on upon the surface of the crack, assuming that it opened out into the atmosphere. We have now a condition of the fissure and its contents highly favourable to depositions from solutions depending on temperature. As Mr. Robert Fox has observed respecting a fissure under this last condition, the difference of temperature in the higher and lower parts of the crack would cause ascending and descending currents of water, and substances which are soluble at high temperatures, and insoluble when such temperatures are reduced, would be deposited as the water ascended, and became gradually cooler.*

If the fissures were opened beneath great bodies of water, such as the sea, or were so situated that sufficient water could rush into them, filling them up, at least in their higher parts, the early condition of the crack would be different from that above alluded to. Let us suppose that *a* in the annexed section

Fig. 70.



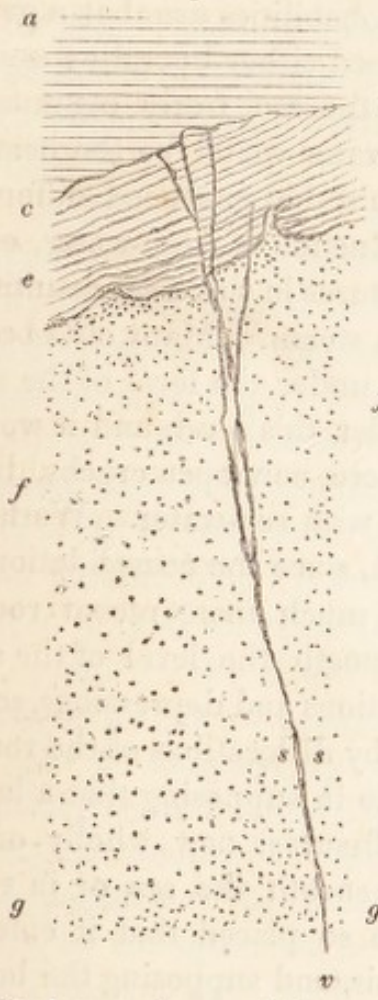
(fig. 70), represents the sea-level, *b* slates, rising from a considerable distance beneath that level to the dry land *l* above it, that *c c* is consolidated granite beneath the slates, becoming gradually hotter until at *d d d* it was in a state of incandescence from heat, and that *g* is an elvan course. If we now suppose that two cracks *e* and *f* are formed between the incandescent granite and the highest part of the solid crust above it, the two

* Fourth Report of the Royal Cornwall Polytechnic Society, p. 108.

fissures would be under different conditions. In the fissure *f* the heat in the lower part might at first be able to drive out the water that could percolate into it, as above noticed. In the fissure *e*, however, the moment it was opened the water of the sea above it would rush into it, and would fill it as far as the pressure of the column of water above and the heat of the fissure below would permit.

Under such conditions as that last noticed, the effects would be somewhat as follows:—

Fig. 71.



Let *a b* (fig. 71) be the sea-level, *a c* and *b d*, depths of water between the solid bottom and such level; *e e*, slates, resting on granite *f f*, becoming gradually hotter in depth, so that at *g g* it was at least incandescent, and *v* a fracture or fissure opened through all the rocks, then, upon the rush of water into the fissure, steam would be generated at *g g*, and may be supposed to exist to any given height, such as *s s* in the fissure, its state of condensation being dependent on the height of the column of water above it. We might thus have steam formed under great pressure in the lower part, and water of varying temperature upwards, through which the steam would strive to pass in the usual manner.

Under such conditions rapid currents of ascending hot water and descending cold water would be produced, the steam formed would tend to rush upwards and be converted into water when it arrived at temperatures less than the boiling-points of water under any given pressure. Any vapours also which might be driven off from the incandescent mass into which we have supposed the fissure to open would be forced upwards with the steam, and numerous chemical combinations might be effected

with their aid when they became intermingled with the waters above. The fissure would tend to be cooled by the entrance of the cold water from above, but it will be readily seen that under the conditions the rate of cooling would be so slow that long periods of time would elapse before any material change would be effected in the temperature of the fissure, supposing even that the chemical effects which would be produced did not materially influence any change of temperature that might arise.

When we see fissures, now forming lodes or faults, we are too apt to assume that they have been produced so as to be open only to the atmosphere, while the probabilities are that a great proportion of them at least were formed either beneath the sea, or in such situations that, when open, the sea freely communicated with them. In such cases sea-water would be the heated water in the fissures, and effects would be produced different from those caused by the mere introduction of fresh water, even supposing the latter to rush into the fractures in sufficient quantities to prevent its immediate conversion into steam. Many of the continuations of Cornish lodes now run under the level of the sea, and are even occasionally worked under this level, and it would necessarily follow that, if such lodes were now open cracks, they would be filled up to a certain height with sea-water. We have abundant evidence whence to infer that, since the consolidation of the granite and elvans, and indeed of much more recent rocks, the area under consideration was beneath the level of the sea, subject to oscillations that caused elevations and depressions, some of which may have been accompanied by dislocations of the rocks. There is therefore nothing unreasonable in supposing that a large proportion of the Cornish and Devon fissures, now wholly or in part filled up, were opened either beneath the sea or in such situations that portions of them were so placed that it entered freely into them. Upon this hypothesis, and supposing the lower part of the fissures to be greatly heated, we should expect, among other results, that there would be a disposition to form a concentrated solution of marine salts under some conditions, such for instance as in those situations where fissures communicated laterally with sea-water, some portions of the crack being exposed to the atmosphere.

Mr. Robert Fox found by experiment "that pieces of compact granite and killas (slate) taken out of a mine, and without any

apparent flaws in them, after having been placed in boiling water, in which a small quantity of some salt was dissolved, were rendered conductors of voltaic electricity, although they possessed this property in a feeble degree in comparison with the liquid solution itself." He observes that "it is evident from this experiment, and from others made in mines in which parallel lodes acted on each other through very large masses of rock, that rocks become conductors of electricity, especially at great depths, where the great pressure of the column of water, and the high temperature, combine to introduce moisture into them. If then," Mr. Fox says, "the rocks are thus rendered even feeble conductors of electricity, and contain different salts, they are necessarily exciters of it also; that is, if contiguous they become in opposite electrical states."*

Becquerel seems to have been the first to show that by slow secondary electrical action, caused by feeble currents, a variety of substances are produced which are not formed by common chemistry, disunited elements being presented to each other in a nascent state highly favourable to the production of such substances. He remarks that "for a long time it could not be conceived how, with apparently feeble electrical forces, strong affinities could be overcome, in order to decompose bodies and produce new combinations; it being considered that the action of currents more or less energetic should always be employed. As soon, however, as the electrical effects which take place in chemical actions had been analysed, it became clear that the same end might be obtained by skilfully employing these effects. It can readily be understood that, when any voltaic couple be plunged into a solution which reacts on one of the elements of this couple, the particles of this solution, the moment they are brought into play by the operation of chemical action, are then, since they are in a nascent state, in the most proper condition to obey the action of the electric current produced by the couple."†

M. Becquerel has, as is well known, obtained a variety of crystalized substances, such as the oxides of copper and zinc, the

* Fourth Annual Report of the Royal Polytechnic Society of Cornwall, p. 109, 110.

† Becquerel, Traité Expérimental de l'Electricité et du Magnétisme, tom. iii. p. 295. Paris, 1835.

sulphurets of silver, copper, tin, lead, iron, &c., by means of these secondary actions. Those experiments in which he employed a tube bent like an U, with moistened clay at the bottom of it, separating solutions, to be acted upon in the two branches, into which wires were introduced to form the voltaic circuit, and those in which he placed substances in a tube afterwards hermetically sealed, so that they formed voltaic circuits in the tube itself, are extremely interesting with respect to their applications to the filling of mineral veins. Substances commonly termed insoluble are stated to crystallize, because, the electrical action being very slow, and consequently the chemical action being slow also, the molecules have time to arrange themselves according to the laws of crystallization, an advantage which does not obtain when the chemical forces have a certain intensity.*

The action of bodies upon each other, so that, after the production and even crystallization of some substances by the continuance of feeble electrical influences, these substances are again decomposed by the new action then produced among them, is well shown by M. Becquerel's experiments, and seems well to explain some of those changes which have apparently taken place in mineral veins. He observes, after describing some substances obtained by these experiments, "that all the chemical actions which gave rise to these compositions, could only have arisen from certain electrical influences possessing little energy; for, if we operate with apparatus the action of which is too strong, all the elements are isolated, and no combination is possible."† He concludes, from the facts he is enabled to adduce, "that, to obtain an insoluble crystallized substance by electro-chemical reactions, it is sufficient to make it combine with another which is soluble, and afterwards operate by means of very slow decomposition.‡

* Becquerel, Traité de l'Electricité, tom. iii. p. 298. This author observes, respecting the truncation of crystals of the double chlorides obtained in some of his experiments, that in the beginning the crystals are perfectly formed; "but that, when the apparatus has been in action for a long time, truncations of the angles are gradually produced; whence it seems to follow that, when the particles of the crystallizing substance are less abundant, the force which determines the regular grouping of the particles has no longer sufficient energy to complete the crystal." He adds that he has often had occasion to make the same remark in the crystallization of products formed by the aid of electric forces derived from a single couple. *Ib.* tom. iii. p. 312.

† *Ib.* tom. iii. p. 309.

‡ *Ib.* tom. iii. p. 317.

M. Becquerel also adds that the same end may be attained, but with far more difficulty, by ordinary chemical means, and cites the following very interesting experiment in illustration of this point.

"Some clay, well divided and moistened with a solution of arseniate of potash, having been placed in a glass tube, a solution of nitrate of copper was poured upon it. The reaction of the two solutions took place rapidly at first, at the surface of contact of the clay and the solution of the nitrate of copper; but, the latter having penetrated by degrees into the mass of clay, a very slow reaction took place between the arseniate and the nitrate, a circumstance favourable to the crystallization of the arseniate of copper. At the end of some time crystals resembling the arseniate of copper of nature were observed in some of the open parts of the clay."*

Mr. Robert Fox appears for some time to have been impressed with the belief that electric action might not only "contribute to produce the extraordinary aggregation and position of homogeneous minerals in veins,"† but also that this action is still kept up in them; and accordingly he commenced a series of experiments on the electro-magnetic properties of mineral veins of Cornwall, which were published in 1830.‡ In 1837 he published Observations on Mineral Veins,§ which relate chiefly to those in Cornwall, and in which he treated the subject of the connexion of electricity with lodes more at length, and detailed some experiments he had been led to make to illustrate such connexion. Mr. Fox observes, on the subject of the present condition of mine-waters, that he finds, "by an examination of water taken from different mines, and from various parts of the same mine, that different varieties of saline solutions now exist in neighbouring strata." "In many instances," he proceeds, "the proportion of

* Becquerel, Traité de l'Electricité (1835), tom. iii. p. 318. In the Comptes Rendues hebdomadaires des Séances de l'Académie des Sciences, 12 Juin, 1837, M. Cagniard-Latour announces that, by means of various experiments founded on slow actions (apparently chemical), he has been enabled to form several substances similar to those found in nature. Those noticed were calcareous and siliceous, one among them, a crystallized substance, having the form and principal properties of felspar with a base of lime.

† Annals of Philosophy, 1822, vol. iv. p. 447.

‡ Philosophical Transactions, 1830.

§ Report of the Royal Polytechnic Society of Cornwall, for 1836, Falmouth, 1837.

foreign matter in the water was very small, whilst in others it was very considerable; but I have not yet tried any mine-water, that would not produce very decided electrical action, when the native sulphuret and bisulphuret of copper were plunged into it, and the voltaic circuit was completed. The very superior conducting power of the saline water in the fissures, in relation to the merely moistened rocks, would always tend to supersede the transfer of electricity, more or less, through the latter. The contact of large surfaces of rock, clay, &c., with water, differing in its saline contents from them, must also have been an efficient source of electrical excitement; and it should not be forgotten, that the circulation of the water would be liable to very frequent changes of velocity, in consequence of obstructions in the fissures, or their occasional enlargement, so that the contents, as well as the temperature of the water, would be subject to many modifications."*

Among the experiments made by Mr. Fox, the following may be selected as particularly illustrative of phenomena observable in lodes, more particularly their upper parts. In two cells, separated from each other by clay, the common yellow, or bisulphuret of copper being placed in one in a solution of sulphate of copper, and sulphuret of copper (grey ore of Cornish mines) in water or acidulated water in the other, the voltaic circuit between the ores being completed by copper wire, after some weeks the bisulphuret became covered by a thin coating resembling the sulphuret. "When zinc or iron was substituted for the sulphuret of copper in the water-cell, the bisulphuret of copper became coated with a considerable crust of the sulphuret, or rather it was changed into the latter to a greater or less depth, according to the duration of the experiment, in consequence of the abstraction of a portion of the sulphur, and probably also of some of the iron which it contained; and beautiful crystals of pure copper were abundantly deposited upon it, and likewise, in some instances, red oxide of copper."†

"When a solution of sulphate of iron was substituted for the sulphate of copper in the cell containing the copper-ore, the latter appeared at first to have on its surface a deposition of iron, and this, becoming oxidated, in time formed an incrustation which

* Report of the Cornwall Polytechnic Society, for 1836, Falmouth, 1837, p. 110.

† *Ib.* p. 115.

resembled *gossan*. When the water in the other cell was acidulated by sulphuric acid, and a plate of zinc or iron put into it, having a metallic connexion with the electro-negative copper or iron ore in the solution of sulphate of iron, (or sulphate of zinc, as the case might be,) sulphureted hydrogen was evolved from the latter, and sometimes in considerable abundance."*

"When chloride of tin in solution is placed in the voltaic circuit, part of the tin is deposited in a metallic state at the negative pole, and part at the positive one, in the state of peroxide, such as it occurs in our mines."†

The first experiment above noticed is considered by Mr. Fox to bear on the fact that neither native nor red oxide of copper occur in the Cornish mines in conjunction with the bisulphuret of copper (common yellow ore), while they frequently do so in connexion with the sulphuret or grey and black ores. From the second he infers that many sulphurets of metals might have been thrown down by sulphureted hydrogen, generated by the action of electricity on yellow copper-ore, the effects being modified by local circumstances; while the third experiment he thinks "may serve to explain why tin is found contiguous to, and intermixed with, copper-ore, and likewise separated from it in other parts of the same lodes, or in lodes situated near, or perhaps crossed by, the copper-lodes."

Adopting M. Ampère's inference, that the direction of the terrestrial magnetic meridian is due to the circulation of currents of electricity from east to west round the globe,‡ Mr. Fox con-

* Report of the Cornwall Polytechnic Society, for 1836, Falmouth, 1837, p. 115.

† *Ib.* p. 116.

‡ Becquerel considers that to a certain depth in the earth a multitude of electric currents exist, with very different directions, the general result of which would produce an action on the magnetic needle. He considers these currents would be caused by the permanent communication kept up by means of numerous fissures through which the sea-waters percolate either to the metals of the earths and alkalis or to metallic chlorides, causing the metals to take negative electricity, and the steam and other vapours positive electricity. One part of the latter electricity, he infers, would be carried into the atmosphere by volcanic eruptions, and the other would tend to combine with the negative electricity of the bases, by passing through all the conducting bodies which established the communication between the metals or their chlorides and the solid, liquid, or gaseous substances which filled the fissures. Hence, he observes, a number of partial electrical currents would circulate in the interior of the globe, producing electro-chemical reactions, of which we cannot appreciate the whole extent, but which certainly would give rise to numerous compounds. Traité de l'Electricité et du Magnétisme, tom. v. pp. 163, 164.

siders that, "if fissures happened to have opposite horizontal bearings, and were equally filled with water charged with saline matter, the electric currents would be determined in preference through such of them as nearly approximated to the magnetic east and west points at the time."* The consequence of such conditions would be, this author conceives, the decomposition of the saline substances, and the determination of the metals or base to the electro-negative rock, and the acids to the electro-positive rock. "However slow," he observes, "this process might, at first, have been, the deposition of the metals would cause it to become more and more energetic. The metals and metalliferous deposits would, likewise, react on each other, and give rise to new combinations and arrangements, till they arrived at a state of comparative equilibrium. This may be said to be very much the case with the lodes at present, as most of the ores which are capable of conducting electricity very nearly approximate to each other in the electrical scale, being more electro-negative than silver, and many of them as much so as platina; indeed, the grey oxide of manganese and the lodestone are electro-negative in a still higher degree. Arsenical pyrites, iron pyrites, and copper pyrites hold rather a high place in the scale, and are electro-negative with respect to purple copper and galena, but especially to the sulphuret or vitreous copper-ore, which will produce a very decided action on the galvanometer, when connected in the voltaic circuit with copper or iron pyrites, &c."†

Respecting the well-known fact above noticed (p. 335), that, in a lode traversing various kinds of rocks or modifications of rocks, some seem to have had the power to influence the deposits adjacent to them in preference to others, Mr. Fox observes that such facts "seem to bear a remarkable analogy to some of the results of voltaic action. It is well known," he continues, "that by its means the chemical affinities of bodies may be superseded, and even inverted; so that it may, and it does seem to have happened, that metallic and earthy substances were determined towards certain rocks, and deposited on them, according to the electric states of the latter. These states may have depended, either on the saline or metallic matter which the rocks contained, or on their positions and combinations with respect to other

* Report of the Polytechnic Society of Cornwall, for 1836, p. 112.

† *Ib.* p. 113.

rocks, modified, more or less, by their relative temperatures at the time, as well as by the prevalent direction of the electric currents in their vicinity, and by numerous other accidental circumstances."*

The marked effect produced in the Cornish tin and copper lodes by the proximity of granite or elvans, must be due to some cause acting on the great scale. The influence on the metalliferous contents of the fissures which traverse the country, when such fissures cut through the junctions of the slates and granites, or where elvans are mingled with the former, has been long known and practically acted upon in Cornwall.

The frequent presence of igneous rocks in metalliferous districts is a well-known fact, and abundant evidence on this head has been accumulated by Professor Necker, who has thence deduced inferences in favour of filling metalliferous veins by means of sublimation.† Among the rocks which are considered to have exercised considerable influence on the contents of lodes, granite and porphyry (the latter very frequently resembling the Cornish elvans,) hold distinguished places. M. Fournet has compared specimens of the porphyry, often termed metalliferous porphyry, with each other, and finds the most striking resemblance between them in different mining districts. He enumerates the porphyry observed by M. Boussingault in America, that which occurs in Britanny, especially near Poullaouen, the porphyry which occurs in the metalliferous parts of the Vosges, such as at Sainte-Marie-aux-mines, Giromagny, the Vallées de St. Amarin, Massevaux and la Brusche; the porphyry of part of Saxony, that of Joachimsthal in Bohemia; and lastly, the elvans of Cornwall.‡

If the occurrence of this particular kind of rock in mining countries is remarkable, it is not less so that the effects produced by it, where metalliferous veins either pass through or close to it, should also bear considerable general resemblance to each other, as far at least as regards the accumulation of ores in such situations. It may be useful to select from the various examples which might be adduced, the following sketch of some of the facts observable in the silver and cobalt mines of Joachimsthal in

* Report of the Polytechnic Society of Cornwall, for 1836, p. 114.

† Proceedings of the Geological Society of London, 28th March, 1832, vol. i. p. 392, and Jameson's Edinburgh New Philosophical Journal, 1833.

‡ Etudes, &c. Traité de Géognosie, tom. iii. p. 469.

the Erzgebirge, taken from an account by M. Mayer:—Porphyry dykes, which seem closely to agree in their general characters with Cornish elvans, occur in a mica slate system (that passes into clay slate) near the contact with granite adjoining this schistose system. The porphyry has the appearance of being in beds among the slates; it is, nevertheless, seen to occur in true dykes as they sometimes cut through the slate beds both in their dip and strike. The porphyry dykes have apparently exercised an influence not only on the metalliferous, but also on the non-metalliferous parts of the lodes. This is instanced more particularly in the case of the lode named the Rothe-Gang, consisting of clay where the lode is in mica-slate, and of red cavernous-quartz when it either passes through the porphyry or by its side. The porphyry and the lode have both a northern direction. "In the places where the Rothe-Gang quits the porphyry for some distance, as happens more particularly in its course towards the north, it contains no other ore than that of uranium, whilst in the vicinity of, or in immediate contact with the porphyry, it contains remarkable quantities of native silver, sulphuret of silver, brittle sulphuret of silver, arsenical cobalt, arsenical nickel, bismuth, uranium, pitch ore, some native arsenic, iron pyrites, and sulphuret of lead; in a word, all the ores which occur at Joachimsthal, with the single exception of red silver, which may be considered as the most common ore in the country." *

By carefully comparing the metalliferous localities with each other, where granite and the porphyry, or elvan occur together, we soon see reason to believe that there is much in the structure of these rocks which may have influenced the results observed. In Cornwall and Devon the miner prefers a *plumb* granite or elvan; in other words, granites or elvans which are in a greater or less state of decomposition, and are consequently porous. The china-clay districts of St. Austell are the most marked examples of decomposed granite, and the *plumb* elvans occur in so many places, and are so spread, that they cannot be said to be confined to any particular district. In some cases the elvans are sufficiently soft to be worked for crucible clay, and in others the felspathic matter has been so removed as to give the elvan the appearance of a coarse sandy rock.

* Mayer, as cited by Fournet, Etudes, &c. Traité de Géognosie, tom. iii. p. 501.

These decomposable granites and elvans seem to contain, or rather to have been once partly formed of, potash felspars. The extent to which some granites are decomposed in the depths has often been observed, and the fact that hard granite is often intermingled with the soft is also well known. Indeed, decomposed granite seems to have been found at all depths in the mines of Cornwall. The experiments of Professor Forchhammer, of Copenhagen, show us, though potash felspar may be exposed to the action of boiling water under the ordinary pressure of an atmosphere, without obtaining alkali from it, that when that pressure is considerably increased, and consequently also the temperature augmented, potash is obtained from it in solution, or in other words, the felspar is decomposed. Taking felspar to be represented by the formula $3Al\dot{S}^3 + K\dot{S}^3$ he would consider that, the tersilicate of potash being dissolved, the other constituent parts remained, and with water constituted Kaolin or china-clay. If, therefore, we assume a fissure to be formed and filled with water in granite, in which potash felspar enters in fair proportion as a constituent mineral, and that the heat increases downwards in the fracture, we have conditions highly favourable for the decomposition of the felspar of the granite forming the walls of the fissure, and consequently for the production of a soluble silicate of potash, which would form one of the substances in solution in it. When we consider this power of water highly heated under pressure to decompose felspar, so that a considerable quantity of silica, mixed with potash, can be transported in solution wherever such water may move, there is no difficulty in perceiving that silicious deposits may be effected in abundance in chinks and fissures, independently of the production of compounds into which silica and potash may both or singly enter.

Numerous elvans would be acted upon precisely in the same way as the granite above noticed, and not only elvans, but those detrital rocks also in which comminuted felspar formed a component part.*

If we suppose sea water to enter fissures formed in the earth's crust sufficiently deep to have their walls greatly heated, we should not only have effects caused by the application of greatly

* Dr. Forchhammer has informed us, that he could not perceive any appreciable effects produced on mica, by subjecting it to the same conditions as those to which he exposed felspar.

heated water under pressure, which may possess the power of acting upon mineral substances far beyond that which may be now supposed, but also numerous important effects produced by the saline contents of the sea itself under such conditions.

Taking the present salts in solution in the sea as guides, the sea water introduced into a fissure would contain about 2·5 per cent. of chloride of sodium, ·4 per cent. of sulphate of soda, a variable quantity of chloride of magnesium, and a small proportion of chloride of calcium. Not only would the water be acted upon by the great heat at the bottom of fissures, such as we suppose may have been formed in Cornwall and Devon, but these substances would also be placed under its influence, and we should have a variety of products and combinations which it would be difficult to foresee, inasmuch as the rocks traversed would be variable, and the substances laid open on the walls of the fractures be differently acted upon, independently of any vapourised matter which might, from exposure, proceed from them, or be driven upwards from beneath.

By this hypothesis we might obtain a variety of substances in solution in a fissure traversing rocks of variable mineral composition, the solutions under different conditions of pressure and heat according to their relative situations in the fracture. We can readily conceive that this would be a state of things in which granites, elvans, trappean rocks, slates, and sandstones, would be very differently acted upon according to circumstances, and that frequently two somewhat dissimilar rocks and the solutions might be so placed, that one might constitute a negative substance and the other a positive substance with respect to them, and that there would be a tendency to deposit certain bodies in solution near the junctions, viewing the subject generally, and under modifying conditions. Hence near the junctions of granites and slates, or of elvans and slates, deposits of particular kinds might be effected, which rarely took place elsewhere, and upon the same principle some slates and associated beds under similar conditions would be more favourable to the deposit of particular substances than others.

Independently of the substances directly introduced into the fractures by the sea water, and of the effects both the water and such substances carried down may produce on bodies brought into contact with it and them by the opening of the fissures, we

should have to consider that the percolation of water existing among the interstices of the rocks would also find its way into the cracks, so that there would be considerable variation of the compounds in solution in the fractures, placed under conditions very favourable to secondary actions and the production of insoluble compounds on the walls of the dislocations, more particularly in the higher and cooler parts.

Many fissures would in the end become mere channels for waters, which, according to circumstances, might either be thermal or lose their heat, before they flowed on the land, sufficiently to take the ordinary temperature of the springs of any given country; in either case often containing numerous substances in solution, such as silica, chloride of sodium, and numerous others,* and being also impregnated with gases, such as carbonic acid and sulphureted hydrogen,† and therefore capable of producing deposits in the fissures, or of altering their pre-existing contents should conditions be favourable.‡

* The amount of matter now brought to the surface through fissures in waters of different temperatures must be considerable, as Berzelius informs us, that 1,132,923 lbs. of sulphate of soda, and 746,884 lbs. of carbonate of soda are brought annually to the surface by the Carlsbad waters, without taking into account the other substances also contained in solution in them. Traité de Chimie, tom. i. p. 445.

† Carbonic acid has been found in waters even to the extent of 30 cubic inches in a wine pint, at Pouges. Twenty-six cubic inches of it are detected in the same measure at Pyrmont.

‡ In illustration of the changes which may be now in progress in the mineral contents of fissures, we may cite the circumstance noticed by M. Fournet, in one of the veins of the Pontgibaud mines. "A blast caused the violent escape of water charged with carbonic acid in a highly condensed state. The water was at first loaded with a white clayey matter, held in suspension. This water had traversed a mass of sulphate of barytes, which was altered to a certain thickness, in such a manner that the crystalline form of the barytes was laid open like a metallic moiré. These waters had also attacked the fragments of steachist imbedded in felspar. The decomposition was so complete, that the grains of quartz and the talcose laminæ alone remained." Becquerel, Traité de l'Electricité et du Magnétisme, tom. v. p. 180.

As bearing upon the subject under consideration, it may be noticed that a considerable connexion has been found to exist between the gases and substances in solution in the mineral springs of volcanic countries, and the gases evolved from, and substances sublimed in the volcanos themselves, so that we may consider the former as mere vents in which the aqueous vapours are condensed, and contain substances and gases which are either directly combined with the water, or produced by secondary actions in it or upon bodies brought into contact with the solutions in their passage upwards.

Pseudomorphous crystals have been adduced as evidence of the change which may have taken place in the condition of minerals in the veins where they are found. Mr. Haidinger has described many alterations, termed by him the parasitic formation of mineral species, depending upon gradual changes which take place in the interior of minerals while their external form remains the same. Under this head he has noticed the changes which have been produced on substances which have the same composition, and on others which contain copper, iron, lead, manganese, baryta, antimony, and the so-called earthy minerals, pointing out a variety of cases in which new compounds have taken the form of the original crystals, apparently by gradually displacing their constituent parts.*

Mr. Fox notices the yellow sulphuret of copper in the form of crystals of carbonate of iron, of oxide tin in that of crystals of felspar, the pseudomorphous crystals of quartz, and others of the like kind, as affording evidence of the reaction of substances upon each other in the veins of Cornwall, remarking that it could scarcely be doubted that under the conditions of the various substances in a fissure in the course of filling, those which were metallic must have reacted on each other, and pointing out that "a considerable accumulation of an electro-positive metal, such as zinc or iron, at an electro-negative rock, might, for a time at least, have changed or reversed the direction of the electric currents."†

M. Becquerel while noticing these changes adduces the following fact as being of a nature to show that all these decompositions arise from actions analogous to cementation, to which he attributes an electric origin. He states, that M. Darcet left a plate of steel during eight years in a case at the mint at Paris, in contact by means of one of its ends with a solution of nitrate of silver, which reached it very slowly from a fissure in the vessel containing it. One half of this steel plate was entirely changed into very pure silver, offering a resisting mass without the least trace of iron. The volume of the plate of silver was visibly the

* Transactions of the Royal Society of Edinburgh, vol. ix. p. 73. (1828.)

† Observations on Mineral Veins. Report of the Cornwall Polytechnic Society for 1836.

Mr. Fox has figured a six-sided prismatic crystal, part of which is sulphuret of lead, and the other part phosphate of lead (pl. vi. fig. 20.), the former having partly replaced the latter, as also a crystal of octohedral fluor spar in a great measure replaced by pseudo-hornstone (pl. vi. fig. 21).

same with that of the plate of steel. "This singular effect," continues M. Becquerel, "must have been produced by actions analogous to those which have converted antique bronze coins into the protoxide of copper."

Not only have these changes taken place, but we also very frequently find cavities in quartz and other substances from which the crystals over which they were formed have disappeared, leaving only their casts. Some very interesting specimens of this order were lately obtained in considerable quantity from the Virtuous Lady copper-mine, near Tavistock. Carbonate of iron had covered cubical crystals of some kind which had been formed on bisulphuret of copper, and had entirely disappeared, leaving cubical cavities produced by the crust of the carbonate of iron. In these cavities, some of which were large, quartz and bisulphuret of copper have crystallised, filling them up only in part. So that in this case the following events succeeded each other after the fissure or cavity was formed in which the whole occurred:—1st. the production of the bisulphuret of copper, often crystallised, in contact with the containing rock; 2dly. the crystallization of some mineral in cubical forms, perhaps fluor spar; 3dly. the incrustation of these crystals by carbonate of iron; 4thly. the disappearance of the cubic crystals by some cause which did not remove the carbonate of iron; and 5thly. the crystallization of quartz and bisulphuret of copper in the cubical cavities thus formed.*

Not only would changes of this order and the formation of pseudomorphous crystals arise from the reactions produced by various substances upon each other during the filling of a fissure by different mineral bodies, but also from the new conditions caused by fresh fractures through the first formed contents of the

* It would appear that under certain conditions crystals may be rendered hollow and still preserve their external form. Mr. Haidinger states, that during his stay at Berlin in 1826, Professor Mitscherlich "exposed crystals of hydrous protosulphate of iron, immersed in alcohol, to a degree of temperature equal to the boiling point of that liquid. Decomposition ensued, though the external shape of the crystal remained unchanged. On being taken out of the liquid and broken, each of them was found hollow, and presented a geode of bright crystals, deposited in the planes of the original ones. The crystals had the form of low eight-sided prisms, belonging to the prismatic system, and were proved by analysis to contain exactly half the quantity of water which is required in the mixture of the original species."—Trans. Royal Soc., Edinburgh, vol. xi. p. 79.

lode, either in the direction of the main fissure or across it in various others. From the workings on the Cornish and Devon lodes it is found, as might be expected, that while the walls touch, or almost touch in some places, they swell out from each other in others. The filling of such fissures must therefore have been very unequal, and cavities of various sizes here and there left isolated, as it were, amid the general accumulation of mineral matter in it, some of which have continued unfilled to the present day.* When new fractures were made through them, and they were laid open to the general conditions then produced, and probably new solutions of substances brought into contact with any crystallizations that might have been effected in them (and it should be recollected that these cavities would be very favourable to their production), we might expect that many modifications would be produced, some crystals being decomposed and removed, their constituent parts uniting in part or in whole with other substances, and forming other minerals, while such very gradual changes were effected in others, that new matter replaced or greatly modified that of the original crystals without changing their external form.

When we take a general view of the filling of the dislocations in the district, whether termed common faults, lodes, or cross courses, we see that it has depended upon conditions among which the mineral character of the adjacent rocks holds a prominent place. Upon this character seems to have greatly depended the nature of the chief mineral substances in them. Among the limestones we find carbonate of lime abundant, and among the silicious rocks, quartz. We therefore infer either that water charged with matter derived from the adjacent rocks has infiltrated into the fissures,† or that their liquid contents have acted on the adjoining rocks and dissolved a portion of them.

* These cavities are termed *vugs* by the Cornish miners, and are sometimes large. In November, 1814, a very large vug or cave was found in Dolcoath at the depth of 170 fathoms from the surface. Mr. Rule describes its form as very irregular, from eighteen to twenty fathoms in length, three fathoms high, and from four to nine feet wide. In the lower part blocks of rock were wedged in between the walls of the lode.—Trans. Geol. Soc. of Cornwall, vol. i. p. 225.

† Among the many instances of the power of water to filtrate through rocks even of great hardness, perhaps the case adduced by M. Fournet (D'Aubuisson's Traité de Géognosie, tom. iii., 2nd ed. p. 430), is as good as can be selected. Some blocks of hard compact basalt, which had remained partly under water in the vicinity of

Upon the mineral characters of the adjacent rocks seems also to have greatly depended the accumulation of the ores of the useful metals, it generally happening that when two or three dissimilar rocks are traversed by the same fissure they are most abundant.

By whatever cause these fissures were filled, an examination of their contents would appear to show that the mineral matter we now find in them was gradually accumulated, and that frequently during the time thus occupied new dislocations were effected through them, sometimes separating the walls from the mineral matter previously formed in them (p. 339), at others breaking through it in an irregular manner. In the one case, newly formed substances would arrange themselves a sort of plate often parallel to the walls of the fissure; in the other, they would be distributed among the previous contents of the lodes very irregularly. Sometimes the irregular cracks would extend into the adjoining rocks, so that the branches of similar substances may often appear to run into the heart of a lode, traversing the first formed minerals in it.

Though many lodes have the appearance of having been disturbed after a considerable accumulation of mineral matter in them, others bear no evidence of having been fractured since the original production of the fissure, and others again are so full of fragments of the adjoining rocks, that the quartz, oxide of tin, bisulphuret of copper, or whatever may have been the cementing substance, merely joins them together in the manner of a breccia.

The experiments of Becquerel, Fox, and Cross, have shown that great modifications of a mineral vein, and consequently of the contents of any common fault, may take place by the reaction of a variety of substances on each other, so that the whole may be greatly modified. Every new dislocation has produced new conditions for these changes, and we can readily conceive that those which cut across lodes at considerable angles may have produced different results from those which traverse them at an acute one, more particularly if we consider, with Mr. Fox, that currents of electricity passing round the globe from east to west, have in-

Pontgibaud, were found, when blasted with gunpowder, to have their cavities, where the rock was beneath the water, filled with liquid, a lining of little needles of mesotype having commenced within them; the cavities in the part of the rock above water having been empty.

fluenced the deposits from substances held in solution in the fissures.

The extent to which the contents of mineral veins and faults may be now modifying, we can scarcely judge, but when we recollect that the waters in them are all charged with mineral matter of some kind, we can readily conceive that any alteration of circumstances, which may produce a change in the nature of such matter, might also be productive of a change in them, however the component parts of substances in the fissures had arranged themselves for the time. The effect of atmospheric influences is well observed at the top of every mineral vein, and M. Becquerel has taken occasion to point out, from the atmosphere and the earth being generally in two different electrical conditions, so that they are assimilated to the two conductors of an electrical machine, charged with opposite electricity, and by the aid of which decompositions are effected, that "we should not in the present state of science neglect the electro-chemical action resulting from this circumstance in researches relative to the influence of atmospheric agents upon bodies on the surface of the earth, since it is demonstrated that free electricity, which is transmitted through saline solutions, causes their decomposition."*

* Traité de l'Electricité et de Magnétisme, tom. v. p. 202.

CHAPTER XIII.

STREAM TIN AND OLDER SUPERFICIAL DETRITUS. SUBMARINE FORESTS. RAISED BEACHES AND ESTUARIES.

Stream Tin and older superficial Detritus.

SCATTERED over various parts of the district we find gravels, sands, and clays, distributed in a manner which would lead us to consider that a large proportion of them had been brought to rest since the inequalities of its surface were much the same as we now find them, consequently after the various dislocations above noticed had been effected and the existing valleys formed.

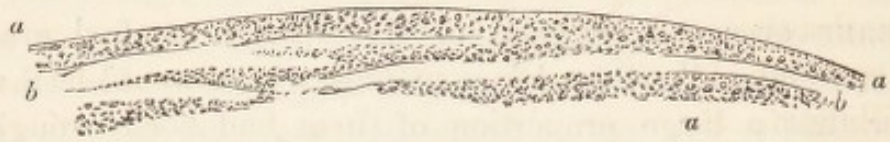
The higher gravels on the Black Down Hills, with their continuation to the southern coast, which contain rounded quartz pebbles, the gravels on the Haldon Hills in which pebbles of granite, porphyry, and other hard rocks of the surrounding country are mingled with chalk flints and chert, the rounded quartz pebbles of Crousa Downs, near St. Keverne (Lizard district), and the gravels and clays of Straightway Hill, between Exeter and Honiton, may belong to an epoch anterior to the production of the valleys in the district, since the inequalities of surface produced by these valleys cut off their continuity, and they are all found on high ground. They may, indeed, all be the remains of supracretaceous beds, which, with the exception of these gravels, have been removed during the formation of the valleys.

Dr. Buckland long since noticed the occurrence of quartz pebbles upon the summits of the hills surrounding the vale of Charmouth, and upon the highest parts of the Black Down Hills. These we might suppose were derived from the larger pieces of quartz in the chalk with quartz grains (p. 237), and to have been separated from the calcareous matter in the same manner that the flints have been, if we did not detect them above the mass of such flints, instead of at their lower part, as in that case they ought to have been.

In the absence of better evidence, we are inclined to refer these

superficial gravels to the same date as those which rest upon the top of the Haldon Hills, and in which pebbles of granite, porphyry, and other rocks, are, as above stated, mingled with green sand chert, and chalk flints. What the geological age of these gravels may be it may be difficult to determine, as may also be the case with the gravels on Straightway Hill, where we find pebbles derived exclusively from the red sandstone conglomerate on which they rest, mingled with some sands, in the manner represented in the following section, one exposed in a quarry near

Fig. 72.



the London road in 1834, *a a*, being pebbles derived from a disintegration of the subjacent conglomerate, and *b b*, sands irregularly intermingled with them. The disintegration of the red conglomerate may have been contemporaneous with the disintegration of the chalk and green sand, producing the lower part of the plastic clay series, which appears to have been afterwards so extensively removed in this district, the disintegrating causes having removed any green sand which may once have covered this part of the country, and having acted on the lower and older rocks, supposing such to have been once covered by the cretaceous series. In this case the Straightway Hill gravels would be older than those which form the highest parts of the Haldons and the Black Downs.

The like uncertainty as to geological date exists respecting the isolated patch of superficial gravel, composed of rounded quartz pebbles, upon Crousa Downs, or rather upon the high land upon which are situated the large blocks of diallage rock, known as the 'Brothers of Grugith.' This patch of gravel is perfectly isolated, occupies an area of about half a square mile, at a height of about 360 feet above the level of the sea, and resembles no other accumulation of superficial detritus within considerable distances.

Whatever difficulty may exist respecting the geological age of the superficial detritus above noticed, we are certain that the valleys in which the stream tin and its associated gravels are found, were produced anterior to the deposit of the former. The relative date of the production of the valleys is a subject of con-

siderable difficulty. It by no means follows because there is a very general resemblance in the characters of these valleys over a large proportion of the district that they have been all contemporaneously formed; on the contrary, we can readily suppose that they may have been produced by the operation of similar causes at various times. The valleys of the Black Downs seem to have been formed after the deposit of the plastic clay series, as it is termed, and those of a large portion of the eastern part of the district have probably been produced after the same epoch. If great faults have not so altered the level of strata that, up to the formation of the present character of the surface, no inferences can be drawn respecting the relative levels at which various deposits were effected, we might expect to find the more modern beds filling up the more ancient valleys in such a manner, that we could be certain of the great antiquity of some of them. Although the red sandstone series reposes on inequalities of the older rocks, and the cretaceous series in like manner appears to cover uneven surfaces of the beds on which it rests, we have been unable to trace any thing like a system of ancient valleys which may be thus concealed. Whether the valleys of the district may have been formed at various periods, or whether they may have been more especially produced since the earlier part of the supra-cretaceous epoch, those in which the stream tin and its associated gravel have been deposited have probably been much modified by the action of the waters which have drifted this detritus. If these valleys, previous to the drift of the tin stone pebbles, had been beneath the sea, and exposed to the action of tides and currents transporting detritus, we should expect, in accordance with the effects now produced by such agents, that they would become more or less filled up by drifted substances; and, if they were valleys above the level of the sea, as they now are, that the usual drift of transported matter would have partially covered their lower parts in the manner we now see. If the stream tin occurred in frequent layers and was irregularly dispersed in the mass of detritus now found in the valleys containing it, it might be supposed that rivers, running over ground traversed by strings or lodes of tin, brought down pebbles of tin ore when in flood, distributing them here and there according to circumstances, while at other times they merely carried forwards the ordinary and less ponderous detritus.

So far from the tin stone pebbles being thus dispersed through the mass of gravels and sands in the valleys containing them, we find these pebbles at the base of the whole, resting upon the subjacent rock, commonly termed *the shelf*, forcing their way, particularly when the tin stone grains are fine, into all the chinks and crevices on its surface. The only exception, if exception it can be called, to this general fact is that, occasionally, though rarely, at the meeting of two valleys, down each of which stream tin has been borne, the end of one stream tin mass, coming down one valley, overlaps the stream tin coming down the other, so that for a short distance a thin intermediate portion of non-stanniferous gravel may occur. The stream tin is always moreover found in greater abundance where we may suppose that eddies would be produced in a body of water pouring down the stanniferous valleys, these having the general forms they now possess. It appears as if any previous detrital contents of the stanniferous valleys, should such contents have existed, had been fairly washed out by a mass of water rushing over the land, rolling and driving various loose materials before it, and allowing the tin stone from its greater specific gravity to be strewed along the bottom, where circumstances permitted.

If we regard the surface of Cornwall, on which a crust of decomposed or disintegrated rock now exists, one arising from the action of atmospheric influences, and imagine a body of water to rush violently over it, carrying this disintegrated or decomposed surface before it down the present valleys, stream tin would be found distributed in them, much as it has been hitherto discovered, though not perhaps so abundantly, if we infer, from the present mode of occurrence of tin ores so comparatively near the surface in many lodes, that a previous surface, now removed, may have been still richer with respect to this metal than that which we now find. Those who have studied the decomposed granite near St. Austell, traversed as it is by a multitude of branches and strings of oxide of tin, would have little difficulty in perceiving that if a body of water were made to rush over it, the decomposed granite would be readily removed, and that the broken-up strings and branches of tin ore would be rolled into pebbles, and distributed just as the stream tin now occurs down the valleys in the neighbourhood. It so happens that the valleys and low grounds among, and proceeding from this granite, have been particularly

rich in stream tin; so that an hypothesis of this kind,—one merely requiring that, prior to the production of the stream tin of Cornwall, a mass of decomposed granite existed in the same place (in fact, a higher part of that which now remains), and that a body of water was driven violently against and over it,—would explain the phenomena observed.

When we consider that the specific gravity of stream tin varies, according to its purity and the admixture of other parts of the lodes whence it is derived, from about 5·6 to 6·9, while that of granite is from 2·62 to 2·74; of argillaceous slate and common grauwacke, from 2·64 to 2·81; of schorl rock, about 2·86; of quartz, 2·63; of felspar, from 2·53 to 2·60; and of mica, 2·94; it will be readily perceived that the tendency of the tin stones to come to rest, from diminished velocity in water capable of transporting all these substances, would be far greater than that of the other mineral bodies usually occurring as gravel with it, all other circumstances being equal. When, therefore, a transporting water could no longer carry tin stones onwards, it would be capable of pushing forwards or retaining in mechanical suspension the other gravel associated with it; so that a fundamental layer of tin-stone pebbles might be accumulated at the bottom of a valley, and remain settled, while lighter bodies were driven or carried over it, due allowance being made for the forms and volumes of the component parts of the whole transported detritus, tin-stone pebbles included.

Though Mr. Carne, some time since, called attention to the general facts connected with the stream tin of Cornwall as furnishing strong evidence in favour of a sweeping inundation having passed over the land, "the effects produced by which have never been repeated by any subsequent flood,"* less attention seems to have been paid to this evidence, while the distributing causes of various superficial gravels of England have been under consideration, than the relative importance of the subject appears to demand. The evidence of a considerable drift from the north, in many parts of England, is well known, and being conspicuous upon parts of the South Welsh coal-field, particularly in Glamorganshire, we should anticipate that it might be visible also in the district under consideration. In 1830, Mr. Carne pointed out the

* Trans. Geol. Society of Cornwall, vol. iv. p. 55.

evidence on this head connected with the stream-tin of Cornwall, and inferred that the tin had been swept from its original situations towards the south, more particularly insisting on the lines which cut off the gold drift near Ladock, the wood-tin at Tregurthy Moor, and other places.*

If there were any traces of accumulations, such as rivers would produce, in the tin-ground proper, or in the gravels of which the tin-stone usually constitutes the lower part, the simple fact of particular mineral substances stopping at given parts of valleys would not possess much weight as evidence of a drift from the north; but, when coupled with the general mode of occurrence of the stanniferous gravel, so indicative of a sudden rush of a great body of water, the prevalence of detritus, which can fairly be referred to such a violent passage of water, so much more down the southern than the northern valleys, is not without its importance, when we endeavour to trace the direction whence the water may have proceeded. On the opposite side of the Bristol Channel the drift from the north is readily seen, rounded portions of marked rocks, well known to occur on the north, being found not alone in valleys, but upon hills and on their flanks, where no rivers, such as would flow upon that land from the present inequalities of its surface, could produce the deposits of gravel and boulders there seen. A great mass of detritus seems to have been swept into the Bristol Channel from the northward, and this we could scarcely suppose would happen without a great body of water passing onwards to the southward, carrying before it, when it struck the opposite shores of the Bristol Channel, a large propor-

* "The peculiar situation," observes Mr. Carne, "in which nearly all the stream tin of Cornwall is found, compared with the localities of the most productive tin veins, is highly illustrative of the direction in which the current of the deluge swept over the surface. All the productive streams are in the valleys which open to the sea on the southern side of the Cornish peninsula; whilst most of the richest veins are situated near the northern coast, where all the valleys open towards the north. Most of these valleys have been explored; but, although small portions of tin have been found in many of them, no extensive beds have ever been discovered. The mines, for instance, of the parishes of Lelant, Gwinear, Camborne, Illogan, St. Agnes, and Peranzabuloe, are all near the northern coast; but there are no productive streams in any of those parishes. On the southern side, however, are the streams of Perran-arworthal, Ladock, St. Stephens, Roche, St. Austell, Luxillian, &c. Now, on looking at the direction which the streams bear from the mines, it will appear most probable that the course of the current, which swept the tin from its original situation, must have been from north to south, or rather from N.N.W. to S.S.E."—Trans. Geol. Society of Cornwall, vol. iv. p. 110.

tion of the disintegrated or decomposed surfaces of rock which existed in that direction, transporting them into the chief inequalities, and carrying them down the principal valleys, according to the directions of the minor currents produced by the inequalities of the land beneath.

From the search which has been, during so many centuries, made for stream tin in Cornwall and Devon, it is difficult to obtain sections of unmoved ground at present, except in situations where the tin-stone pebbles are not very abundant: hence we can form a very inadequate idea of the great accumulations which must have been first worked, and consequently of the tin-stone pebbles swept into the bottoms of valleys, or into basin-shaped depressions (such as occur at the Tregoss Moors, and on the north of Wendron), by the body of water which appears to have passed over this land. Traces of stream-works are to be seen from Dartmoor to the Land's End, often in depressions on the higher grounds; as, for example, on the former elevated region, whence tin pebbles have long ceased to be obtained, being the works of the *old men*, as the ancient miners are universally termed in Devon and Cornwall.

Though the richest deposits seem to have been well worked, and the ground turned over twice or thrice, the tin stones rejected at one time becoming valuable from their comparative scarcity at another, there is still enough of unmoved ground here and there working to enable us to judge of the accuracy of the general geological facts stated to be observable in connexion with the tin-grounds. This is more particularly the case when modern enterprise has directed works beneath the level of the sea, as at Pentuan, or abstracted the tin-stone pebbles from beneath the silt and sands of an estuary, permitting the latter gradually to fill up the space once occupied by the tin-ground, as is now done in Restronget Creek, near Falmouth.

The following is a section of the Happy-Union stream-work at Pentuan, as observed in 1829 by Mr. Colenso, the order ascending:—

a. Tin-ground of unequal thickness, according to the inequalities of the surface of grauwacke beneath (3 to 10 feet). With it are rounded pieces of granite and other rocks of the St. Austell hills traversed by the valley, as also fragments of grauwacke and greenstone, which, having been transported a short distance, are more angular. Most of the tin occurs at the bottom of this bed, though it is sometimes found in the higher parts. "The tin is from

the size of the finest sand to pebbles of 10 lbs. weight; and some rocks, richly impregnated with tin, weighing 200 lbs. and upwards, have occasionally been found here. The small tin, which is known by the name of grain-tin, is of the best quality: the larger stones contain more waste, and sometimes also copper and mundic." Roots of trees are seen in this ground, and on the top of it oyster-shells "still remain fastened to some of the large stones and the stumps of trees. The roots of the oak are in their natural position, and may be traced to their smallest fibres, even so deep as two feet: from the manner in which they spread, there can be no doubt but that the trees have grown and fallen on the spot where their roots are found."

b. "A stratum of dark silt, about 12 inches thick, apparently mixed with decomposed vegetable matter, and on the top of this a layer of leaves of trees, hazel-nuts, sticks, and moss, from six to twelve inches more. The moss appears in a perfect state, retaining almost its natural colour, and seems to have grown where it is now found. This layer of vegetable matter is about 30 feet below the level of the sea at low-water, and about 48 feet at high-water spring-tides. It is not found in particular spots only, but extends, with some interruptions across the valley."

c. A bed of sludge or silt, ten feet thick, changing from a brownish to lead colour in particular places. The whole is sprinkled with recent shells, together with wood, hazel-nuts, and sometimes the bones and horns of deer oxen, &c. The shells, particularly the flat ones, are frequently found in rows or layers; they are often double and closed, with their opening part upwards, so as to render it likely that the animals lived and died where their remains are now found."*

d. A bed of sand, about four inches thick, contains (marine) shells, and "the water which drains from it is nearly as salt as the sea, whilst all the water above and below it is fresh."

e. Silt or clay, two feet thick.

f. Sand, 20 feet thick. "In all parts of this sand there are timber-trees, chiefly oaks, lying in all directions; and also the remains of animals, such as parts of red-deer, &c."† Bones of whales are found in it: the bones of a large one were discovered in the upper part of this bed, as well as those of others in the lower portions of it.

g. A bed of rough river-sand and gravel, here and there mixed with sea-sand and silt, about 20 feet thick, and extending to the surface. Mr. Colenso states that, a short time before he described this section (1829), the remains of a row of wooden piles had been found in this sand, sharpened for the purpose of driving, and that they appeared to have been used in the construction of a wooden bridge for foot-passengers: they crossed the valley, and

* These shells are of the same species as those which now exist in the neighbouring sea; their appearance in the lead-coloured silty clay strongly reminds the geologist of that of the shells in the subappenine lead-coloured clays, such as those of Nice and other places.

Mr. Colenso states that, at about the time he wrote (1829), a piece of oak had been found in this silt, about two feet from the top, which appeared to have been brought into form by the hand of man. It was about six feet long, one inch and a half broad, and less than half an inch thick. It appeared to have floated in the sea, as at one end, which was much decayed, a small barnacle had fixed itself.

† Mr. Colenso notices human skulls as having been found in this sand.

were about six feet long, their tops being about 24 feet from the present surface,—just on a level with the present low-water at spring tides. He remarks that, if the sea-level had been then as now, such a bridge would have been useless.

These works are now abandoned; but, in 1837, others were carried on higher up the valley, on the south of the London Apprentice inn; from which it would appear that, from the general rise of its bottom, the sea had not entered this valley sufficiently high to permit marine deposits to be there accumulated. The tin-ground was covered by gravels, sand, and silt, among which trees, chiefly oak, were irregularly distributed, the whole probably being the accumulation of river-drift during a long period of time.

From information collected respecting the cutting of the Par canal, and from mining operations, it would appear that the tin-ground in the neighbouring valley of Par was covered by marine deposits to a level that would correspond with that observed in the St. Austell valley; and it is worthy of note, that, when the cutting of the Par canal was effected at Pons Mill, near St. Blazey, granite blocks were found arranged for a stone bridge nearly 20 feet beneath gravel which had accumulated upon it* in no small quantity, probably, from the washings of the tin stream-works higher up the valley, sections of which have been published by Mr. Henwood.†

The following is a section obtained by Mr. M'Lauchlan from Captain Barrett, of East Crinnis Mine, one seen in a shaft sunk in part of the lower ground near the Par estuary:—

	Feet.	in.
1. River deposits	1	6
2. Confused mass of mud, sand, clay, and stones, which has been much disturbed by the stream-tinners	7	0
3. Mud, clay, and vegetable matter, apparently an old surface	8	0
4. Fine sand, containing sea-shells like cockles, and on the top rolled pebbles	4	0
5. Mud, clay, sand, wood, nuts, and other vegetable productions, mixed together	3	0
6. Tin-ground, resting upon an uneven surface of slate	6 inches to 6 feet.	

In the Carnon stream-works, on the north of Falmouth, and up the continuation of the valley in which they occur inland in the

* Mr. Austen Trefry, at whose charge the canal was formed, has preserved these stones, and they were to be seen, in 1837, between Par Bridge and Par Harbour.

† Trans. Geol. Society of Cornwall, vol. iv. p. 60–64.

direction of St. Day, we have another example of tin-ground partly beneath marine accumulations and partly covered by common river detritus.

The following is a section of the Carnon stream-works by Mr. Henwood:*—

	Feet.	in.
1. Sand and mud; the river wash	3	0
2. Silt and shells—three successive beds	0	10
3. Sand and shells (a stream of fresh water percolates this bed)	2	0
4. Silt—three beds	12	0
5. Sand and shells	3 to 4	0
6. Silt, mixed with shells in large quantities	12	0
7. Silt, in some places containing stones	18 to 22	0
8. Wood, moss, leaves, nuts, &c. all of a dark colour, much resembling what has been charred; a few oyster-shells; animal remains, those of the deer being most abundant, and some human skulls	1	6
Towards the sea the bed 8 entirely disappears; giving place to 7, which reposes on		
9. The tin-ground, which consists of rounded masses of tin-ore, in some cases unmixed with any other substance, in others in a matrix of quartz, and quartz and schorl, with rounded pieces of slate, granite, and quartz, varying in thickness from a few inches to	12	0

The *shelf*, or surface of rock, on which the whole reposes, is composed of dirty white and pale-blue clay-slate.† The higher Carnon works are now abandoned, the search for stream tin in the same valley being confined to the bottom of Restronget Creek,

* Trans. Geol. Society of Cornwall, vol. iv. p. 58.

† In 1807 Mr. Edward Smith obtained the following section of the Carnon streams, and it should be here observed that this name has been given to a long line of works down the valley, so that the minor details would be expected to vary during the distance.

	Feet.
1. Mud and sand	7
2. Granite gravel, intermingled with small pieces of a substance resembling charcoal, and a few shells	4
3. Fine gravel, mud, and shells	12
About this depth are several irregular strata of oysters, about 4 or 5 feet in thickness, extending irregularly to within 4 or 5 feet of the tin-ground.	
4. Closer mud, intermingled with shells	19
In this stratum have been found several branches and trunks of trees, some of which had evident marks of being cut with an axe or other sharp instrument; horns and bones of stags, likewise human skulls.	
5. Tin-ground, varying from	1 to 6

Geol. Transactions, vol. iv. (1817), p. 404.

The shells noticed in these sections, at least those which we have seen, correspond with the species still found in the Falmouth estuary.

beneath the tidal waters of the estuary, as above noticed, on the south of Daniell's Point.

In the valley extending from Lower St. Columb Porth by Treloy towards Tregoss Moor, and in which stream tin has been obtained, we have evidence that on the north of Cornwall, as well as on the south, tin-ground was covered by marine deposits to a certain height up the valley, judging at least from information which we obtained from respectable sources on the spot, for no part of the valley was worked for tin when the Survey was engaged upon that part of the district. Here also, as on the south, a bed in which vegetable remains were abundant, chiefly oak-trees, the roots of which were described to us as standing in the position in which they appeared to have grown, rests upon the tin-ground towards the seaward termination of the valley.

We were informed by several respectable persons of a circumstance observed in this valley, during the time it was last streamed for tin, which seems to throw some light upon the condition of at least a part of it, relatively to the level of the sea, anterior to the drift of the tin-ground. It would appear that in the direction of Treloy some beds of hard grauwacke traversed the bottom of the valley in such a manner that, if the whole detrital contents were now swept out, water running down would form a cascade over them to a lower level. Upon the higher part, above this bar of rock, the tin-ground became scarce, but beneath it was abundant, and intermixed with shells of the common mussel of the present coast, many of which were in the position in which they were attached to the rock anterior to the accumulation of the tin-ground, this gravel appearing to have been readily brought to rest in a manner not to detach the mussels from their places at the bar of rock, but on the contrary to bury them firmly, in consequence of the eddy produced behind the fall. Supposing this information to be correct, the sea would have extended up the valley, as in a creek, to this bar of rock prior to the deposit of the tin-ground.

In the interior the tin-ground is usually covered by common river detritus, more open spaces frequently having a bed of peat, in which oaks are frequent, interposed between the tin-ground and the other detrital accumulations. This is readily observable in Tregoss and other moors near or among the Hensborough granite. In some *whole ground*, as the tin-streamers term the

stanniferous gravel and superincumbent beds which have not been previously disturbed by the *old men*, upon Bodmin Const Moor, the peat-beds, with oak, alder, &c., covering the tin-ground very irregularly, were in some places several feet thick, at others absent, though on the whole they seemed to keep a somewhat common level above the tin-ground. In some places thin peat-beds had been accumulated at still higher levels among the gravels, sands, and clays. The *shelf* composed of semi-decomposed granite was very irregular, holes 30 or 40 feet deep presenting themselves, in the bottoms of which there was usually good stanniferous gravel.

Upon the whole there appears evidence that, after the causes which produced the tin-ground or stanniferous gravel had ceased, the relative levels of land and sea were such in this district that a growth of plants and trees, not dissimilar from that of the present day, took place upon the gravel, and that subsequently these relative levels became altered so that the sea covered the lower parts of valleys previously above water. In the creeks thus formed silt and mud were accumulated, entombing the remains of marine and estuary shells, of the same species which now exist on the coast, and finally, from the continued drift of alluvial matter down the valleys, river detritus covered up these marine or estuary deposits when they had accumulated to the necessary height. While this was effecting on the coasts, the stanniferous gravel strewed down the higher parts of the valleys became simply covered by ordinary river alluvium, mingled with trees and vegetable matter; in flat places, such as may have constituted marshy ground or shallow lakes, peat accumulating intermingled with the wash of gravels, sands, and clays, from the adjoining higher lands, in the same manner as now takes place commonly in peat-countries.

From the occurrence of human skulls, and the works of man amid these detrital accumulations, supposing the fact well established, and it has been strongly asserted that it is so, and that no equivocal appearances may have been produced by the ground having been previously turned over in search of tin, man's remains are mixed with them in a manner to show that a very considerable amount of detrital matter has been accumulated in these situations since he inhabited Cornwall. At Carnon his remains are stated to have been discovered in a bed mingled with those

of deer and other animals, among wood, moss, leaves, and nuts, about 53 feet beneath the surface of mud and sand, described as river-wash; and at Pentuan human skulls are stated to have been found under about 40 feet of detrital accumulations, also mingled with the remains of deer, oxen, hogs, and whales. In both cases these remains were obtained beneath marine or estuary accumulations, supposing the sands at Pentuan, in which the skulls were found, to have been deposited in an estuary, into which the whale, whose bones were discovered towards their higher part, could have freely entered. Mr. Colenso indeed mentions a piece of shaped wood, which he considers had floated about, four feet lower down, in the upper part of silt that reposes on a kind of submarine forest, the trees in which appear to have grown upon the tin-ground, and may coincide in age with the bed with wood, nuts, &c., in which the human skulls were discovered at Carnon.

Assuming these facts to be correct, we seem to have evidence that Cornwall was inhabited by human beings when the earlier accumulations of detrital matter were effected over the tin-ground. That is, if we have been right in our inferences, not long, geologically speaking, after a body of water had passed over the land, the greater portion of which was previously above the sea and exposed to the surface-decomposing influences of the atmosphere, sweeping with it the stanniferous gravel that now occupies the lowest part of numerous valleys and depressed spaces in Cornwall.

If the bed in which the trees and other vegetable remains occur 52½ feet from the surface at Pentuan be equivalent to the similar bed with human skulls 53 feet beneath the surface at Carnon, and if there can be little doubt, and there seems to be none, that many oak-trees grew at the top of the tin-ground at the former place, sending their roots into it, then a considerable change took place in the relative levels of sea and land since man inhabited Cornwall, allowing estuary or marine deposits to be effected in creeks upon a surface that previously permitted the growth of terrestrial vegetation, the remains of the marine creatures entombed in the mud, silt, or sand, showing that these creatures were of the same species as those which now exist in the adjoining sea.

Unless the search for stream tin had been so economically important, and the detrital contents of so many Cornish valleys

turned over in this search, the facts above noticed never would have been known. In other parts of the district, therefore, where the detrital accumulations in the valleys have not been moved since their deposit, it can rarely happen that the existence of man could be traced to an epoch corresponding with that to which the Cornish stream tin-works, especially those near the sea, would assign it. We should still, however, expect to have a few facts brought to light corroborative of some general drift of detritus, and of a change in the general level of sea and land, by which a growing vegetation in valleys, and upon low ground bordering upon the sea, was submerged and covered by marine or estuary accumulations.

With regard to the drift, although we have evidence in numerous valleys of gravel accumulations, the pebbles of large size and the accumulations themselves often thick, particularly towards the sea, yet as we have no marked substances, such as the tin-stones, occupying the lower part of them, no good proof can be adduced that they have not been brought together in their present situations by the action of river floods during a very long lapse of time. In some places, however, as on the slopes of the hills and at variable heights above the present rivers, more particularly in the portions of country in which the comparatively soft rocks are exposed, we find the ground furrowed, and these furrows filled with transported gravel, which also irregularly overspreads the same slopes in patches. As the chalk of the district has been similarly furrowed prior to the deposit of the plastic clay series, and any other easily yielding rocks then exposed might have been similarly acted upon, and the furrows filled with the transported matter of that time, it becomes often difficult to assign these irregularities, with their gravels, to any particular date when uncovered by beds which would show them to be referrible to a particular period.

If we take the valleys of the Black Downs, of Lyme Regis, Sidmouth, and other similarly situated places, to have been formed after the deposit of the plastic clay series (as appears reasonable, inasmuch as they are cut out of rocks of that series once continuously stretching across the country in the same manner as the chalk and green sand by which they are supported), we find their flanks strewed with gravels, generally composed of flint and chert, and often furrowed, particularly where the valleys are cut into the

red sandstone series, the furrows being filled with gravel. Now, as the harder portions of the rocks, scooped by aqueous causes into these valleys, may readily have remained in part strewed over the flanks of the hills on their sides after they were so excavated, we do not feel quite assured that these gravels are more than such remains. If so, they would be of a date prior to the production of the stream tin, supposing that these valleys existed like those in which the stanniferous gravel occurs, before the production and transport of the latter, and were not formed or greatly modified about that time.

If we have reasoned correctly respecting the stanniferous gravels, very great modifications would be effected in such valleys as those above noticed, supposing them to have been formed before the production of these gravels, in consequence of the comparative softness of the rocks of which they are composed, so that gravels from the heights, originally formed at the period of the plastic clay, and others produced by the washing out of the flint and chert from the chalk and green sand, then again abraded, would be carried down these valleys and deposited according to circumstances, some detritus filling furrows which might then be formed. Large patches of flint and chert gravels are distributed unequally over the flanks of the hills among which these valleys occur, so that they often cover up the lias and rocks of the red sandstone series to the depth of several feet. Considerable quantities of this drift have proceeded down the valleys of the Axe, the Otter, and the Culm, and it is worthy of attention that, when the latter joins the valley of the Exe, the drift of chalk-flints and chert becomes intermingled with pebbles of grit of the carbonaceous series, not only in the lower grounds, but to some height, as may be seen on the new road out of Exeter to Tiverton, between the gaol and turnpike, where gravel (in 1838) was quarried for the roads.

On the north and north-east of the Black Downs there is much gravel composed of chalk-flint and green-sand-chert distributed over the red sandstone series and lias, becoming mingled on the north with gravel derived from the harder parts of the grauwacke of the Quantock hills. The greater part so occurs that we can scarcely explain its transport from the adjoining high lands by means of river drainages such as we now see. How much of it may be merely the remains of the chalk and green sand which

once covered a far larger portion of this district than we now observe it to occupy, it would be difficult to say. That there should be so few hard remains of these rocks, such as flint and chert, and that we should find them so little distributed over portions of the district where we may infer they once extended, is remarkable, more particularly if we suppose the green sand of Orleigh Court, near Bideford, with its superincumbent gravel of chalk-flints and chert,* apparently of the plastic clay series, to have once formed any continuous portion of the green sands of the Haldon Hills or the Black Downs. Some very powerful aqueous causes would appear to have swept off not only the harder parts of these deposits, but also those of the numerous other rocks hollowed into valleys, and which, we may suppose, once existed in great abundance.

By the opening of a quarry at a small hill close to Waddon Barton, near Chudleigh, where there is an isolated piece of limestone, we obtain evidence of the transport of a mass of detritus filling up considerable inequalities of rock beneath it in a manner indicative, probably, of a somewhat sudden accumulation, inasmuch as the materials are mixed pellmell with each other, and the locality rises above the drainage where such materials may have been gradually accumulated. The following is a sketch of the quarry as it appeared in 1837 : *a a* being the gravel, and *b b* the

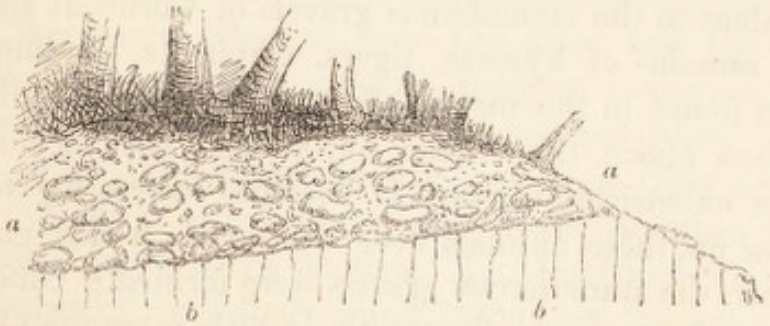
Fig. 73.

* The chert and chalk-flint gravel of this place is remarkable for being often cemented by hœmatite iron-ore. In some places it may be termed a flint breccia, with a rich iron-ore cement, minute cracks in the flints being even penetrated by this mineral.

limestone rising in an irregular manner into it, as if once an exposed tor of rock upon which this detritus had been drifted. The gravel is chiefly composed of chalk-flints and chert, bound together by earthy matter; but among it we find rounded pieces of porphyry resembling the elvans of Cornwall, and which may have had their origin in some elvan dykes not yet observed upon Dartmoor. By the admixture of porphyritic pebbles this gravel resembles that on the top of the Haldons at a higher level, and upon the Bovey clays at a lower, both of which contain porphyritic pebbles, as also others of granite, of the carbonaceous rocks, &c. How far a wash of waters over the Haldons may have distributed these gravels over lower levels, so that the detritus of these lower levels may contain pebbles of granite, porphyry, &c., it would be difficult to say. We cannot, indeed, however probable we may consider it, bring proof that these gravels at lower levels were distributed by a violent cause, such as has apparently been productive of the stanniferous gravels.

While studying the gravels of the district, it is necessary to pay due attention to the evidence which appears to exist of several rivers having flowed at higher levels than they now do. This evidence consists of lines of gravel and boulders, similar to those found in the river-beds beneath, occurring at the height of several feet above their present beds.

Fig. 74.



The annexed is a sketch of one of these gravel-banks rising about 80 feet above the present course of the Dart, near Holne Bridge, *a a* representing the gravel and boulders of the granite and of the altered carbonaceous rocks traversed by the river, resembling those now brought down by it, and *b b* schistose rocks on the edges of the laminæ of which the bank reposes. A continuation of the same line of gravel and boulders, preserving the same height, may be traced on the left and steep bank up the

river for some distance. Similar banks may be observed up the Teign above Chudleigh Bridge, and one is well seen on the road from Crowcombe Bridge to Farley. Banks of boulders and gravel, similar to those now found in the bed of the Tavy, are discovered near Tavistock, particularly on the old Plymouth road between the turnpike-gate and Tavistock, and on the northward of the latter town, near a modern villa. These banks above the Teign and Tavy are many feet higher than the present beds of those rivers. There are many localities in the district where small flats occur in the course of valleys, such flats being formed of gravel and boulders that have been drifted down until stopped by still or nearly still water, the level lands being now again cut through by rivers, the barrier of rock which formed the original lake or still water having in the course of time been lowered. If the localities above noticed be considered to have been the sides of similar, though larger lakes, filled gradually by gravel and boulders, to the height of the banks previously described, very great subsequent modifications of the valleys down which the Dart, Tavy, and Teign flow, must have taken place to admit of this explanation.

As ossiferous fissures and caverns occur in the district, and the remains of rhinoceroses and elephants have been detected at Lyme Regis and Charmouth in gravels which may be there considered as the oldest occupying the valleys, and, therefore, might be equivalent to the stanniferous gravels of Cornwall and Devon, while no remains of hyænas, tigers, elephants, or rhinoceroses, have been found in the marine, estuary, or common alluvial accumulations above the stream tin, though such accumulations have been extensively worked, it becomes interesting to inquire whether or not these animals were destroyed in this part of the world when the stanniferous gravels were formed. Unfortunately the Oreston fissures near Plymouth do little more than inform us that tigers, hyænas, elephants, rhinoceroses, &c., fell into them, as Dr. Buckland suggests, in the same manner that horses, oxen, sheep, &c., now fall into the clefts of limestone rocks in many places,* while Kent's Hole, near Torquay, so well investigated by the Rev. Mr. M'Enery, and the Yealm Bridge cave described by Lieutenant-Colonel Mudge, also show us little more than that they have been dens of hyænas, into which those animals dragged

* Reliquiæ Diluvianæ (1823), p. 78.

their prey, consisting of elephants, rhinoceroses, horses, deer, &c., which then inhabited the land, without being accompanied by such marked circumstances as would give the condition in which they were found a very definite geological date.

The Oreston ossiferous fissures have at different times been laid open during the excavations there made, chiefly to furnish blocks of rock for the breakwater at Plymouth. The first were observed by Mr. Whidbey in 1817, and again in 1820. In 1822 Dr. Buckland described a large ossiferous fissure then laid open during the progress of the quarry, and pointed out that the rock was subject to fissures, as frequently happens in limestone rocks of that character and age, and that some only of these fissures were ossiferous, while the greater part of them were more or less filled by loam, sand, or stalactite. The quantity of bones which have been taken from these fissures has been collectively very considerable. Many minor ossiferous fissures have not been publicly known, the workmen selling the bones as soon as they discovered that it became profitable to do so. Many even appear to have passed unnoticed, for in one of our visits to the Oreston quarries we obtained two teeth of a rhinoceros at the bottom of a narrow fissure, amid a dark clay, apparently impregnated with animal matter, in an old unnoticed part of the excavations. Considerable angular masses and smaller fragments of limestone often occur in the ossiferous and other fissures, and it can be readily understood that, before these cracks became filled by fragments detached from the sides and by the loam and sand, multitudes of animals ranging the ground above could have fallen into them, more particularly when chased by beasts of prey, often themselves the victims of their own eagerness and voracity, either during the chase or when the dead animals were visible in the fissures. Dr. Buckland suggests that the proportion of individuals found at Oreston, the graminivorous being very much in excess beyond the carnivorous, is consistent with an hypothesis of this kind.*

We are not aware that any very detailed account of Kent's Hole has yet appeared. Mr. M'Enery, who devoted much time and labour to the subject a few years since, proposed at one time to give one, but we believe his intentions were not carried into effect. Dr. Buckland also, we believe, possesses much information respecting

* Reliquiæ Diluvianæ, p. 79.

this cavern not yet before the public. The remains of bears, hyænas, elephants, rhinoceroses, deer, and other animals, have been detected in it, and it has been considered probable that the cavern was tenanted by bears before it became a den for hyænas. Among the proofs of its latter condition are gnawed bones and the fæcal remains of those animals. Dr. Buckland found rounded pebbles of greenstone mingled with the bones, under the coating of stalagmite, in this cavern, and Mr. M'Enery discovered rounded pebbles of granite in the same situation. Dr. Buckland has also informed me that the bone breccia in Kent's Hole, particularly the lowest, was full of fragments of grauwacke and slate, some of them rolled.

Lieutenant-Colonel Mudge, in describing the Yealm Bridge cavern, states that large quantities of the bones contained in it had been for some time burned in the lime-kiln, until Mr. Bellamy, of Yealmpton, discovered their importance. It appears that this cave contained the following five, distinct, sedimentary deposits, commencing with the highest:—

	Feet.
a. Loam, containing bones and stones	3½
b. Stiff whitish clay	2½
c. Sand	6
d. Red clay	3½
e. Argillaceous sand	6 to 18.

The upper bed only contained the animal remains, which consisted, according to Mr. Clift and Mr. Owen, of the bones or teeth of the elephant, rhinoceros, horse, ox, sheep, hyæna, dog, wolf, fox, bear, hare, water-rat, and a bird of considerable size. The remains of the elephant and rhinoceros, as far as could be estimated in the absence of the bones and teeth destroyed in the lime-kiln, were scarce, while those of the hyæna were abundant, as were also those of the horse and ox. Many of the bones were chipped, gnawed, and splintered, the fæcal remains of hyænas were detected in the same bed with the bones, and in one part, where the roof of the cavern was lower than usual, "the limestone is beautifully polished, as if by the friction of the animals which inhabited the cave," all evidences of the residence of hyænas in this place, such as have been adduced by Dr. Buckland for the celebrated cavern of Kirkdale. The pebbles found in the bed with the bones are stated to be apparently derived from the con-

fines of Dartmoor, and to differ from those in the bed of the Yealm, while in another and more spacious cavern, in which there were no animal remains, the pebbles corresponded with those now in that river; whence Lieutenant-Colonel Mudge infers that, when the elephant and hyæna inhabited the southern part of Devonshire, the Yealm Bridge cave and the latter cavern were exposed to very different conditions, the hyænas being probably prevented from entering into the more commodious den.*

Sedimentary deposits varying in total thickness from 18 to 30 feet, according to the inequalities of the lower part of the cave, were evidently accumulated in the Yealm Bridge cavern anterior to its occupation by the hyænas, and, as these deposits vary, so must also the causes which produced them, the mouth of the cavern being open during a length of time, of which we can form no estimate, to the entrance of waters charged with sand or mud, as the case might be. If we imagine it thus exposed to the entrance of water during floods, perhaps in the valley, we can readily understand that it would not be inhabited by hyænas, though they may have tenanted numerous other caves at that period, such, for instance, as that of Kent's Hole, where the conditions were more favourable to them. Let, however, the drainage of the country be lowered, as seems often to have happened since the present valleys of the district were first formed, so that the waters no longer entered the cave during floods, and it would become a fitting place for the hyænas, which might still, however, be prevented from entering the Kitley cavern, as noticed by Lieutenant-Colonel Mudge, because under water or not open to day, its fitness as a den for hyænas having been due to a still further lowering of the drainage (and it is not now much above high-water mark in the neighbouring estuary), after those creatures, and the elephants, rhinoceroses, &c., had ceased to exist in this part of Britain.†

The hyænas, bears, elephants, rhinoceroses, &c., may have inhabited Devonshire since the formation of the present system of valleys in it, one which may have been greatly advanced during

* Proceedings of the Geological Society of London, vol. ii. p. 399, 400. March 23. 1836.

† It may be here observed that the difference in the relative level of sea and land, shown to have taken place on this coast by the raised beaches on it, to be noticed in the sequel, would produce considerable difference in the height of the drainage of this and other similarly-situated valleys, so near the termination of estuaries.

the later parts of the supracretaceous or tertiary epoch, as it is more commonly termed, and subsequently to the destruction of a large part of the plastic clay beds of the Haldons and Black Downs. We know that in rocks of other parts of Europe, situated in as cold, and colder regions, elephants, rhinoceroses, &c., are found entombed in regular beds of the later supracretaceous period; hence there would be nothing in climate to prevent their living in Devonshire, and they may not be there found entombed in regular beds, merely because the condition for the production of such beds, either in great lakes or in estuaries, subsequently forming dry land, did not exist.

These animals may long have lived in this part of England; indeed the accumulation of their abundant remains in the caves and fissures proves that they did so, the only evidence we yet possess in this district, except in the gravels of Lyme Regis and Charmouth, of their having existed there at all. Now, if any body of water has passed over this land, such as we have supposed necessary to produce the stanniferous gravel, this would be a sufficient cause for their total destruction, and the reason why, except under some rare circumstances, their remains are not found in the gravels in the valleys, which we have considered were chiefly swept out at that period. The bones, however, accumulated in caves and fissures, would remain, mud, sand, and occasionally a few pebbles, being alone washed among them, the water draining off or evaporating, in the case of the caves, and leaving even surfaces on which, when conditions were favourable, stalagmitic incrustations were formed, the disturbance of the bones in the caves depending on the manner in which the water entered them, in some instances not breaking up the floor of any previous sedimentary accumulations, covered with bones, as at Yealm Bridge.

With regard to any evidence of a change in the general level of sea and land, previously alluded to (p. 406), by which a growing vegetation in valleys and upon low grounds, bordering the sea, was submerged and covered by estuary accumulations, we would appear to possess it in the

Submarine Forests,

as they are termed, beds of vegetable substances occurring in several places beneath the present level of the sea.

These submarine forests are so common that it is difficult not to find traces of them in the district at the mouths of all the numerous valleys which open upon the sea, and are in any manner silted up, so that we may consider they once formed creeks or the bottoms of estuaries. Commencing with the eastern part of the southern coast, we find the slight remains of one at the mouth of the Char, near Lyme Regis, resting upon lias, whether or not partly on gravel, in which the remains of the elephant (*E. primigenius*) have been found, is not clear from the great shingle-beach piled up between them. Although submarine forests have not been detected in front of the valleys of the Axe, the Otter, the Exe, and the Teign, vegetable accumulations would appear to have taken place beneath the silt or sand higher up in all of them, leading us to suppose that a bed of vegetable matter may be deep under them at the mouths of the rivers, though no more visible than that of Pentuan would be without the stream works.

At Tor Bay there are traces of a submarine forest, occasionally laid bare by the sea. In Millendreth Bay, near the Looes, there is a small portion of one. That at Mainporth, between Mawnan and Falmouth, has been described by the Rev. Canon Rogers, who there notices the stump of an oak in the situation in which it grew, the roots, as usual, running amid peat, bearing evidence of having been formed in marshy ground, and containing, he considers, the leaves and roots of *Iris pseudacorus* (the common yellow flag), now growing in the adjoining marsh.* The same author has also noticed the remains of a submarine forest with stumps of oaks and willows, in the situations in which they grew, a little above low-water mark at Porthleven, near Helston.†

The submarine forest in Mount's Bay has been described by Dr. Boase, who notices it as being covered by gravel and sand, upon which the sea is constantly encroaching, and by which the bed of vegetable remains is laid bare, sloping as it does, seaward beneath it, so that while part of the bed dips beneath the sea to a distance which is not known, other portions rise to its level. This author has given a minute detail of the section obtained between Penzance and Newlyn, from which it would appear that upon a base of the schistose and other rocks of the locality, the upper parts of which are decomposed, there is sand, and upon

* Trans. Geol. Society of Cornwall, vol. iv. p. 481.

† *Ibid.*, vol. i. p. 236, and vol. iv. p. 482.

this sand a bed composed of vegetable substances, which he says there can be little doubt are "the remains of a wood which once flourished on this spot," pointing out the resemblance of the accumulation to that which now takes place in the adjoining marsh. He states that the trees in this bed "do not appear to have been of large size, for, judging from their fragments, they were for the most part about six to nine inches, and very rarely a foot in diameter." The far greater part of this wood is noticed as hazel, with some pieces of alder, elm, and oak. Hazel-nuts are mentioned as abundant, and the fragments of insects, particularly the elytra and mandibles of the beetle-tribe, which still display the most beautiful shining colours when first dug up, but crumble into dust on exposure to the air, are mentioned as found amid the vegetable mass.*

It may be considered doubtful how far this submarine forest affords support to the old tradition that St. Michael's Mount was named "Carreg lug en Kug, or Le Hore rok in the Wodd," for it in a great measure seems to have been laid bare, as these beds generally have been, by the encroachments of the sea upon the beds of detritus that appear commonly to have once covered it, such beds having been placed by a change in the relative level of sea and land, so that the land was elevated within the reach of the destructive action of the breakers which previously rolled over them. Upon these beds, so raised above the sea, when, as we shall have occasion to show under the head of "raised beaches," the district generally was elevated many feet above that level, woods may, nevertheless, have abundantly grown, so that St. Michael's Mount may then have deserved the name of the "Hoar rock in the Wood," and this within historical times, the low ground and the woods upon them having been easily removed by the action of the heavy seas which now fall upon these coasts, and which may readily, before the low land was so raised, have washed the bases of the hills that back the remains of it. Of the great loss of this land within modern times, Dr. Boase adduces ample proof.

In the Hayle estuary we again have evidence of trees and vegetable accumulations beneath the present level of the sea, and under the Dunbar sands, at the mouth of the Camel, a similar bed has been seen. Traces of submarine forests occur also at

* Trans. Geol. Society of Cornwall, vol. iii. p. 173.

Perran Porth, Lower St. Columb Porth, and Mawgan Porth, between these two localities. A similar vegetable bed is stated to be found beneath Braunton Burrows, at the embouchure of the Taw and Torridge, near Barnstaple and Bideford.

At Porlock a small submarine forest is well exhibited at very low tides, the stumps of trees, which appear chiefly oaks, standing in the positions in which they grew. The present action of the sea has bared these trees by removing the silt and sand which once covered them, as can be seen by the continuation of the same bed of vegetable matter inland, beneath sands and silt, behind the present shingle beach that merely reposes, as can easily be seen, upon the inclined plane of the submarine forest. Another smaller vegetable accumulation is found near Minehead, and among the compressed plants and trees the bones and horns of the red deer have been discovered, a species still wild in the adjoining district of Exmoor.

The next submarine forest to be noticed, proceeding eastward on the southern shores of the British Channel, is that which appears to occur beneath a considerable portion of the Bridgewater levels, and which is well seen to pass beneath the present level of the sea towards Stert Flats. That portion which appears near Stolford has been described in detail by Mr. Leonard Horner,* who notices *Zostera oceanica* among its peat. Professor Buckland and the Rev. W. D. Conybeare consider that the trees at Stolford afford very clear evidence of having grown on the spot where they are now seen, and they have further noticed that trees of large dimensions, fir, oak, and willow, are found in the marshes of the levels at the depth of 15 or 20 feet from the surface, trunks lying prostrate, and stumps with their roots in the upright position in which they grew. Intermingled with them are furze-bushes and hazel-trees with their nuts; the whole being, as it were, bound together by a bed of reeds and other palustrine plants.†

Part of this vegetable accumulation may be comparatively modern, but undoubtedly a large portion of it occurs beneath estuary sand and silt, and at a level lower than that of the tide-waters in the adjoining Bristol Channel. We have been informed that, in making deep cuts for drainage purposes, it has been frequently

* Geol. Transactions, vol. iii. p. 380.

† *Ibid.*, 2nd series, vol i. p. 310.

found at the depth of from 15 to 20 feet. Professor Buckland and the Rev. W. D. Conybeare notice the occurrence of the peat beneath eight or ten feet of silt on the banks of the river near Bridgewater, and at 14 feet at about 2½ miles N.E. from that town. A similar layer, with stumps of trees in the position in which they grew, seems also frequently to have been detected beneath sand and silt in the low levels near the embouchure of the Axe, and thence under the low country extending by Worle and Wick St. Lawrence to the shores of the Bristol Channel in that direction.

Taking the general evidence afforded by the so-called submarine forests round the shores of Devon, Cornwall, and Western Somerset, we find that a vegetable accumulation, consisting of plants of the same species as those which now grow freely in the adjoining land, is frequently discovered occurring as a bed at the mouths of valleys, at the bottoms of sheltered bays, and in front and under low tracts of land, the seaward side of which dips beneath the present level of the sea, so that the terrestrial vegetation forming those parts of the bed could not have grown at their present levels. Now, as there appears to be the very best evidence that numbers of the roots of the trees occupy the situations where they did grow relatively to the subjacent ground, and as these roots are to be often traced as far as the tides recede, even at the equinoxes, we seem compelled to admit that a change in the relative level of the sea and land has taken place since these trees lived on the situations where we now find them.

When we regard such situations, and in imagination raise the present land merely 30 feet, it will readily be perceived, by reference to plate 1, where the ten-fathom or sixty-feet line is traced round the coast, that numerous small tracts of dry level country would be produced where creeks now enter the land at the bottoms of shallow bays, and in some situations, as in Bridgewater Bay, a large tract of land would appear. If the whole were raised 60 feet, it will be seen, by reference to the ten-fathom line (plate 1), that a very considerable alteration would take place in the coast-line. It is almost needless to remind geologists that the permanency of the new dry land thus produced would depend in a great measure on its amount of exposure to the action of the breakers. When well supported by rocky headlands, tracts of low country, their seaward slopes coinciding with the original fall

of bottom in that direction, would be established, and be protected as similar tracts now are under such physical conditions by sandy dunes, behind which, in many cases, particularly when the rivers were unable to keep their embouchures constantly open, marshy flats would be formed, among which a growth of wood would be finally established. From the want of the necessary physical conditions, the raised bottom of the sea would, in many localities, soon be removed by the violent action of the breakers, so that eventually a part only of this raised sea-bottom would remain, in spots irregularly separated from each other, though under certain conditions common, or nearly so, to all.

Let the land be depressed—(and we must here represent to those unaccustomed to investigations of this kind, that this supposition of alternate risings and depressions of land is perfectly in accordance with the necessary explanation of many geological phenomena)—so quietly that no heavy waves were produced upon the coast sufficient to carry off violently the vegetation established in the low tracts of ground, and to a depth sufficient to prevent plants being torn up by the breakers, and this vegetation would be entombed beneath silt, sand, and gravel, which would then accumulate upon it, where the levels were suited to such deposits. Should it be demanded if any evidence exists of the so-called submarine forests being so covered, it may be replied that the evidence on this head is very general, where the sea, at its present level, has not removed it. Estuary shells are sometimes found in the sands and silt that often cover them behind the beaches which, physical conditions being favourable, now bar the progress of the sea further inland.

We may select the Bridgewater levels (including under that term their continuation on the south and round the western part of the Mendip Hills), as affording a good example of this fact. Professor Buckland and the Rev. W. D. Conybeare have well pointed out the ancient sand and mud banks there observable, with the shells in them, identical with recent species; indeed they are so with those which now exist in the Bristol Channel adjoining. They have also shown that the lines of ancient beach may still be traced along the borders of Sedgmoor, at Sutton, Chedzoy, Weston Zoy, and Middle Zoy, and that Weston Zoyland and Chedzoy have been islands against which sands have been drifted and a shingle beach thrown up. They have re-

marked that these beaches contain rolled chalk-flints, mingled with fragments of the rocks prevailing in the neighbourhood, and that the sands and beaches often rise through the modern peat, isolated sand-banks occurring, as at Burtle in the marshes of the Brue, full of marine shells, while at other times, though more rarely, marine and fresh-water shells are found together, and that at one place, Chilton, one mile below Bridgewater, marine, fresh-water, and land-shells, are observed mixed.* Upon examining these facts on the spot and comparing them with the appearances which would be presented by the bottom of the adjoining Bristol Channel, if it were raised, we were forcibly struck with the general resemblance which they would offer; so much so, that we are induced to believe that, before the relative levels of the sea and land were here changed, so that the trees at Stolford and other places in front of the Bridgewater flat lands were washed by the sea in the manner we now find, the country up to and beyond Glastonbury, formed a branch from the Bristol Channel, in which mud and sand banks existed, as they now do in that channel.

From the remains of Roman potteries having been found at the depth of 12 feet below silt, 300 yards from Basin Bridge, and those of a Roman road near the same spot, the road constructed on silt, and now six feet beneath the level of high water, we might almost be led to infer that this difference of level was in a great measure effected since the occupation of Britain by the Romans, if we could be certain that they had not kept out the sea by embankments, which being neglected when they quitted the country, the tides entered freely over the land, depositing silt upon the old potteries and road. If the moulds for Roman coins, stated to have been found in the peat in some places in these levels, were so discovered in peat which could be referred to the date of the submarine forests, the evidence in favour of a change of level at that period would be very valuable, could we be certain, from their position, that they had not been buried in it.

If even we suppose the Romans to have employed embankments to keep out the sea when the road above noticed was used, the necessity of the embankments would show the relative level of the sea and land at that time, and the silt accumulated upon the potteries and upon the road would prove that a considerable deposit on these lands has been since effected, which may readily

* Geological Transactions, 2nd series, vol. i. p. 309.

have corresponded with part of the marine accumulations in the tin-stream works of Pentuan and Carnon, giving them a kind of historical date, while the human skulls found in both these works may have belonged to a people inhabiting that part of Britain at a still more remote epoch.

Raised Beaches and Estuaries.

We have now to consider the evidences of a change in the relative level of the sea and land, connected probably with the rise of the submarine forests with their covering of detritus to their present situations. In numerous places upon the coasts of the district under consideration, particularly in sheltered situations or in localities where the solidity and hardness of the rocks on which they repose has prevented them from being altogether removed by the breakers, though their lower portions may have been washed away, we find shingles and sands so arranged that little doubt can be entertained that they are the remains of beaches, similar to those which exist on the neighbouring shores, and which, from a change in the relative level of the sea and land, are now at heights varying from a few to 40 or 50 feet above high-water mark.

In 1758 Borlase figured and described the raised beach at Pornanvon Cove, south from Cape Cornwall.* Though he does not actually state that this may have been an ancient beach raised, he pointed out that it resembled that now at the base of the cliff. "It is a very remarkable structure," he observes, "which this cliffs presents us with, and highly deserving the attention of the curious in all its parts. First the large pebbles, from one foot and a half in diameter to six inches, which are now inserted in the cliff, are of the same size and texture as those strewed on the sand below, which, being tossed to and fro by the force of the tide, owe their roundness most probably to their circumvolutions."

In 1817 the Rev. R. Hennah noticed the raised beach at the Hoe, Plymouth.† In 1828 Mr. Carne pointed out the occurrence of boulders and smaller rounded stones, mingled sometimes, though rarely, with sand, in several localities along the cliffs of Western Cornwall, enumerating twenty-one places from Pen-

* Natural History of Cornwall, p. 76, and plate xix. fig. 4.

† Geological Transactions, 1st series, vol. iv. p. 410.

deen Cove to Mousehole, where beds of them are observable above high-water mark.* In 1832 we had occasion further to describe the raised beach at the Hoe, Plymouth, previously noticed by the Rev. R. Hennah, and to state that a raised beach was also observable near Redding Point, in Plymouth Sound, and that traces of a similar beach here and there occur between Plymouth Sound and Torbay.† In 1832 Mr. Fox pointed out the horizontal bed of rounded quartz-pebbles, gravel, and sand, resembling that of the present coast, extending about four miles between Falmouth and the Helford River, from nine to twelve feet above high-water mark, interrupted only in those places where solid rock-cliffs alone formed the coast.‡ In 1832 also Dr. Boase noticed the frequent occurrence of these beaches on the Cornish coast, referring them, however, to diluvium which had been raised. He considered that their maximum height did not exceed 50 feet above the level of the sea, sloping down gradually from that point beneath the sea, in the same manner as the present shore. "Thus also," he observes, "the beds of gravel and sand at Fistral and Gerrans Bay, and elsewhere, exhibit the same phenomena, the lower part of these sometimes touching the waves, and at others appearing on the cliffs resting on the rock far above the present sea-level." §

In 1835 Mr. Austen discovered and described the raised beach near Hope's Nose, and on the Thatcher Rock in Tor Bay; and in 1836 Professor Sedgwick and Mr. Murchison described the raised beach on the coast between Braunton Burrows and Baggy Point, in the north of Devon, respecting which the Rev. D. Williams furnished some additional information in 1837.

We should expect that, in a change of the relative levels of sea and land upon coasts such as those of Cornwall, Devon, and West Somerset, to the amount of 40 or 50 feet, we should not only have raised beaches, but that estuaries and sandy dunes would be found elevated also,—the whole coast, where not altered by the subsequent action of the atmosphere and sea, exhibiting evidence of the same general rise of land. Now this is precisely that which we do find, for between Tor Bay and Char-

* Trans. Geol. Society of Cornwall, vol. iii. p. 229—238.

† Geological Manual.

‡ Phil. Mag. and Journal of Science, December 1832.

§ Trans. Geol. Society of Cornwall, vol. iv. p. 468.

mouth, where, from the kind of rocks exposed on the cliffs, the coast is continually wearing away, and therefore no traces of beaches would be expected to remain, we observe beds up the valleys of the Otter and Exe, first noticed, we believe, by Mr. Austen, which could scarcely have been deposited by the sea at its present level, and which yet contain shells such as are commonly found in the estuaries at the lower parts of the same valleys, so that we may consider them to have been raised at the same time with the beaches on the coast. There are beds also in the lower part of the valley of the Axe, which would appear rather the raised bottom of an estuary than a mere accumulation of alluvial matter by the river at the present level of the sea. It is not improbable that, though the flat lands at the heads of most of the estuaries of the southern coast of Devon and Cornwall may in a great measure be due to the check the rivers flowing into them receive from the tide at its present level, much of the detritus accumulated in the valleys may have been so when the tide rose to a higher level. Unless, however, borings or cuts be made for some economic purposes through these flat lands, points such as these can scarcely be determined; and we should bear in mind that the amount of any accumulations to be raised would in a great measure have depended upon the time which may have elapsed between the sinking of the land in the valleys, with the woods, &c., now submarine, and the elevation of the country to the height of the present raised beaches above the sea.

The tin-stream works in the valleys of Cornwall, towards the sea, do not exhibit such a rise of estuary-formed beds, above the present level of the tides, as might have been expected if great accumulations had taken place in the valleys after the subsidence by which the low wooded tracts of land appear to have been submerged, even in cases when, as at Par, a raised beach is found inside the former estuary. In like manner, though the beaches on both sides of the united embouchures of the Taw and Torridge (including that noticed on the north side by Professor Sedgwick and Mr. Murchison, and the corresponding elevated range of beach on the south side, extending about a mile from Rock Nose Point to the southward), and the raised beaches in several places up the Barnstaple and Bideford estuaries, as near Westleigh, in Fremington Pill, at Penhill Point, &c., can leave little doubt that the sea once flowed up the valleys of the Taw and

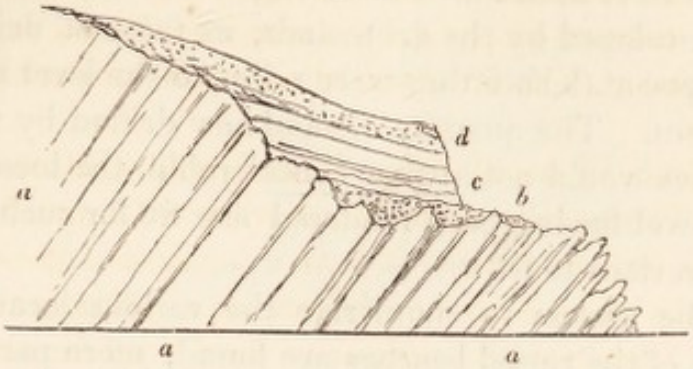
Torridge at an elevation of 30 or 40 feet higher than at present, the detrital matter which can be considered as a raised estuary bed does appear to be far elevated above the present level of high spring tides.

The evidence of raised sandy dunes is well exhibited in St. Ives Bay and in Perran Bay, on the north coast of Cornwall, more especially in the former, where we have a beach and dunes, 35 or 40 feet above the present level of the sea, on a cliff of grauwacke near Gwythian. Sands would appear to have been formerly accumulated from the same causes as those now in action at the bottom of this bay, only more extensively; and, when the change of level of the sea and land took place, part of the coast was so situated towards Gwythian that the rocks, on which the beach and dunes are based, were brought within the action of the breakers, so that a cliff of grauwacke was formed with the remains of a beach and dunes resting upon it. From this northern part of St. Ives Bay to the southern the slope was such that the cliff became gradually less, so that eventually, from the form of the land in front of Upton Towans, new sandy dunes were accumulated over the old, in a manner to prevent any distinctive line existing between them. The same also probably occurred at Lelant Towans, and in like manner, from the form of the coast and its levels, after the rise of land, modern accumulations of sands have covered the older dunes in front and on the sides of the valley between Gwythian and Godrevy Head, towards which, near Godrevy Farm, an excellent section is seen of a raised beach.

In like manner there would be little reason to doubt that Perran Sands have been partly accumulated before the change of level, and partly in more modern times, and we may readily infer the same with regard to the dunes on the south of Trevose Head, those in Padstow Harbour, at the mouth of which there is a raised beach, and on the north of Braunton Burrows, near Barnstaple, where indeed sandy accumulations are observed above the raised beach on the north of them.

In Fistral Bay, and near New Quay, there is no difficulty in perceiving that the sandy dunes have been raised. The following is a section (fig. 75), obtained on the east side of the Look-out Hill: *a a a* representing the grauwacke, upon which the ancient beach *b* rests, composed of rounded pebbles of the subjacent grauwacke, agglutinated by consolidated sand, and raised several

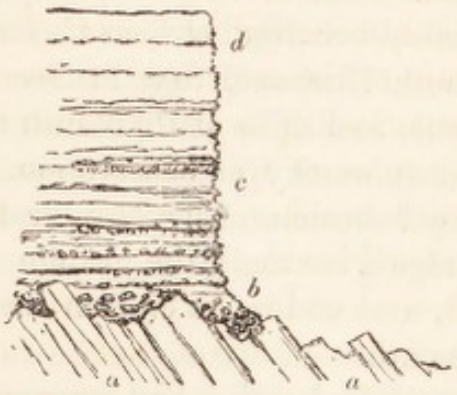
Fig. 75.



feet above the level of the sea; *c* being layers of sand, chiefly formed of comminuted sea-shells, such as are now found so abundantly on the north coast of Cornwall, where sandy dunes are accumulated, the lowest layers being consolidated; and *d* being a *head* of angular fragments derived from the grauwacke of the hill above.

In the adjoining Fistral Bay we may not only have a raised beach and sandy dunes, but probably also a shallow part of the bed of the sea which here existed anterior to the last elevation of this land. The following (fig. 76) is a section of the low cliffs

Fig. 76.



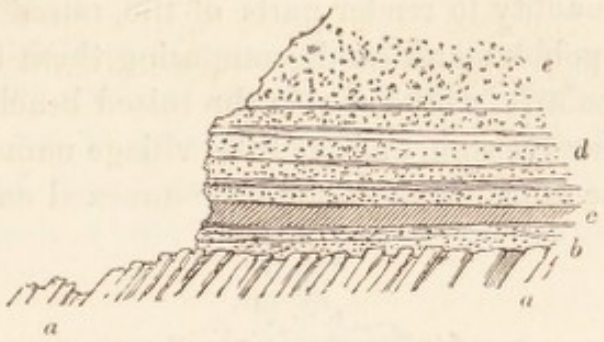
in this bay formed by the raised beach, and perhaps shallow bottom of the sea, which the breakers have thus partially removed; *a a* being grauwacke rocks, which from their hardness have prevented the wear of the coast to the extent it would otherwise suffer; *b*, rolled pebbles, frequently of large size, mixed with smaller gravel and sand; *c*, frequent alternations of fine gravel and sand, some layers of the latter being often more consolidated than the others; and *d*, less indurated sand, which, near the extremities of the dunes, on the north and south, become mingled with fragments of the grauwacke there rising into hills above it. Bones have been found amid the consolidated sands near New

Quay, which have been stated to belong to the ox, and which may have been enveloped by the drift-sands, as those of dead animals may be at present, before they were raised to the level at which we now find them. The quantity of sand now drifted by winds upon the old dunes would not appear considerable, the locality by the change of level having been rendered less fit for such accumulations than previous to it.

It would be useless to enumerate the various localities where the remains of the raised beaches are found, more particularly as their occurrence with respect to the form of the land and to the supporting rocks will be best understood by reference to the maps. It will readily be perceived that they are very numerous, so much so, that in Cornwall especially, where the supporting rocks from their hardness have not been easily removed, it is difficult to enter a sheltered cove without finding some traces of them. Perhaps the raised beaches on the north and south of the united embouchures of the Taw and Torridge, with those up the Barnstaple and Bideford estuaries, those near New Quay, the raised beaches and dunes in St. Ives Bay, including those near Godrevy and at St. Ives, those on both sides of Cape Cornwall, and in St. Loy Cove, the various raised beaches between Coverack Cove (Lizard district) and Falmouth Harbour, that in Gerrans Bay, which is a particularly fine one, and those of Plymouth and Tor Bay, may be enumerated as most worthy of observation. For worn rocks associated with raised beaches, the two best examples which came to our knowledge were amid the granite veins on the east of Trewarvas Head, and under the cliff on the east side of Pendennis Castle, Falmouth.

As a general fact, these beaches are composed of various accumulations, often in layers, of rolled boulders and pebbles, with finer gravels and sands, such as now form the beaches near them. They are composed of the harder parts of the adjacent rocks, or of such which we can readily see would, from the action of the prevalent breakers, be washed in that direction, or of sands such as are now blown on shore, and which in Cornwall are often composed of comminuted sea-shells mingled with a minor proportion of rock-sand. We only in one instance observed a diagonal lamination of a sandy bed in them. This occurs at the raised beach on the north of Braunton Burrows, where the following section (fig. 77) is afforded by the action of the

Fig. 77.



breakers, and we find consolidated layers of sand and pebbles, *b*, resting upon the edges of grauwacke, *a a*, and supporting a sandy bed *c*, diagonally divided by lamination. This is covered by layers of consolidated sand, mingled with a few pebbles, *d*, which are surmounted by similar sands and pebbles, *e*, unconsolidated.

The great exception to the ordinary composition of the raised beaches consists in the chalk-flints which are sometimes present both in the actual and raised beaches in a rounded state. With respect to those found in the actual beaches, it might often be supposed that vessels, partly in ballast, from the chalky coasts of England and France, had brought these flints, since they now occasionally do so, though this explanation would not be very satisfactory in some localities. The occurrence of these flints in some of the raised beaches (as at Coverack Cove, and other places in the Lizard district), while they are not to be found inland in the adjoining country, is not of easy explanation.*

* It is possible that these beaches have been raised since the country was inhabited by people who employed shaped flints in their weapons, and obtained chalk-flints for the purpose, and that many of the flints may have been thrown down in sheltered bays and creeks, where they were unloaded from the frail barks of the time, becoming subsequently rolled about and mingled with the common pebbles of the beach afterwards raised. This is certainly mere conjecture, but, as heaps of chalk-flints are stated to have been discovered with flint arrow and spear heads in some of the earthworks on the Cornish coast (near Lower St. Columb Porth, and other places on the north side), and we may thence infer that they were imported for the purpose of manufacture into weapons, similar importations may have taken place previously, even supposing that the earthworks in question were constructed after the alteration of the relative level of sea and land which produced the raised beaches we now see.

From the occurrence of chalk-flints near encampments, much caution is necessary when we reason on the occurrence of some which have been obtained in the Land's End district. It may indeed be said that the people, finding the flints on the land

In many places in the south of Cornwall black oxide of iron, in sufficient quantity to render parts of the raised beaches black, cements the pebbles and sands composing them firmly together. This is particularly well seen in the raised beaches between the Looe Pool, near Helston, and the little village named Cove, on the south. In one place we find, as in the annexed cut (fig. 78), not

Fig. 78.

only that a layer of the beach, *a a*, is composed to a great extent of this black oxide of iron, but that strings of the same substance, *b b*, descend from it downwards through other parts of the same beach, reminding us of similar strings of oxide of iron in the conglomerate and sandstone of the red sandstone series near Dawlish and Exeter. They were probably produced by the percolation of the water charged with the iron through chinks and easy passages downwards from the line through which it generally passed.

In Gerrans Bay also the occurrence of the oxide of iron as a cementing substance of part of a raised beach is well exhibited. The consolidation thus produced is so considerable, that the beach is enabled to resist the action of the breakers with considerable effect, and portions of it thus hardened jut outwards into the present beach. Portions also thus consolidated often remain adher-

or in the adjoining beaches, fashioned them into spear and arrow heads, and hence that we need not suppose they were brought by sea into the creeks and coves adjoining earthworks, from people more favoured with respect to flints on the eastward. Be this as it may, much error may arise if we do not pay sufficient attention to the importation of chalk-flints in modern times. For example, while examining the country near St. Austell we found a field on the hill westward from the turnpike-road near Bosinver, strewed over with unrolled chalk-flints. Upon inquiry into this unusual circumstance we were enabled to ascertain that the farmer had, some years previously, found chalk ballast, in which were flints, thrown out of a vessel in the neighbouring port of Charlestown, and, considering that the chalk would benefit his land, he brought it to his farm and strewed it over this, and we believe, one or two adjacent fields. The chalk had gradually disappeared and the flints had remained. If this had happened a century ago, and all knowledge of the carriage of the chalk to the top of the hill lost, the occurrence of the flints in such a position might have led to erroneous conclusions.

ing to the supporting rocks when all the rest of the raised beach has been removed.

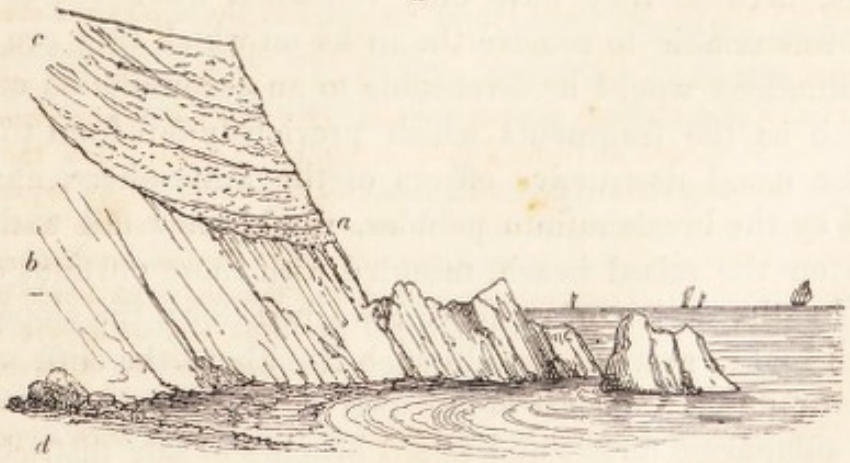
Consolidated portions of raised beaches, the sands and pebbles either cemented by oxide of iron or calcareous matter, and sometimes by both, are frequent, and have been long known in the neighbourhood of New Quay and other places. The following (fig. 79) is a sketch of part of the raised beach between Porthalla

Fig. 79.

and the Nare Point, on the north of Nelly's Cove, which has become so consolidated that the sea has worn out a cave, upon the top of a small fault under the beach, *a*, that supports a head of angular fragments, *c*, derived from the hill above, where the continuation of the grauwacke beds, *b b*, appear. Large fragments of the consolidated raised beach occur scattered in the present beach, *d*, equally with those of the grauwacke.

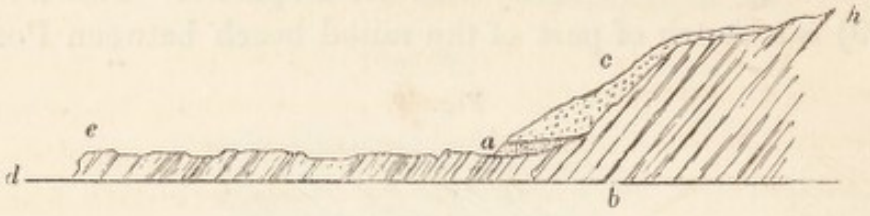
The following sketch (fig. 80) of a continuation of this beach, at Nelly's Cove, will exhibit the quantity of head, *c*, which has accumulated on the beach, *a*, since it was raised. It also shows

Fig. 80.



that the kind of cliff which rose behind the ancient and now raised beach did not differ from that at *b*, which now rises above the present beach *d*. Perhaps the same facts may be further illustrated by the following section (fig. 81), between Rosemullion

Fig. 81.



Head and Mainporth, near Falmouth, where the raised beach *a* is covered by angular fragments, evidently derived from the hill, *h*, a cliff of which, above *b*, backed the ancient beach *a*. This section also shows the elevation of a level, *e a*, formed of slate rocks, similar to that which is well seen between Swan Pool and Pendennis Castle, Falmouth, and which, if raised, and acted upon by the breakers where it would cut the altered level at high water, would be worn into a minor cliff, as in the section before us the slates, *e*, are worn by the sea, *d*.

A head of angular fragments is common to all the raised beaches of the coasts of the district, when hills of hard rocks rise behind them, showing not only that a considerable decomposition of such rocks has taken place since these beaches were elevated above the present level of the sea, but also that there has been a great movement of the decomposed surfaces of the hills downwards, covering up all inequalities that presented themselves, and rendering the surface more smooth than would otherwise happen. The raised beaches have been covered like other inequalities, because they have only remained where the action of the sea was unable to remove the rocks on which they are based. Such situations would be favourable to an accumulation of head, inasmuch as the fragments which previously fell from the cliff, from the usual destructive effects of the atmosphere, and were ground by the breakers into pebbles, would now fall and accumulate on the raised beach, mingled with those portions of rock which by the action of rains were washed down the slope of the adjacent higher grounds, should such rise above the cliffs, as they commonly do on the coast of our district.

The submarine forests and raised beaches of our district, how-

ever numerous, from accidental circumstances, the latter may happen to be, merely constitute a portion, and it will eventually, in all probability, be found a very limited portion, of those which are observable in Western Europe, and which show that much dry and low land has been depressed with a growing vegetation upon it, and that extensive lines of coasts have been elevated, since the vegetation upon the land and the shelly inhabitants of the sea were the same as we now find them in the adjoining lands and seas, and hence that no very material change in the general conditions of the one or of the other has been effected since these differences of level took place.

We must refer to the various geological works in which submarine forests and raised beaches are described for the evidence in favour of this statement, but as connected with the English Channel, and therefore with the raised beaches of the district, we may notice that Mr. Trevelyan has observed raised beaches and shore-worn rocks above the present action of the sea in the islands of Guernsey and Jersey, the raised beaches being elevated about eight feet above the present high-water mark,* so that the change in the relative level of sea and land which produced the raised beaches of Cornwall and Devon, has not been confined to the northern side of this Channel.

In most instances in which the submarine forests have been noticed there has been a covering of clay, silt, or sand, the removal of which by the action of the breakers on the coast has laid open the vegetable bed beneath, agreeing therefore generally with the phenomena observable on the coasts of Cornwall, Devon, and Somerset, where these forests are discovered. How far a large portion of Western Europe may have suffered a moderate change in the relative level of sea and land about the same period, so that extensive flats and low valleys bordering its shores were lowered, covered with a growing vegetation, sufficiently to be

* Proceedings of the Geol. Society of London, vol. ii. p. 577 (Nov. 15, 1837). In the beach on the east of Guernsey where the road descends to the islet of Lihou, the gravel, composed of pebbles of the neighbouring rocks, mixed with *chalk flints*, some not much rounded, covers a water-worn rock of granite, and is cemented firmly by a ferruginous sand. Above this is a bed of disintegrated granite, about three feet thick, mixed with angular fragments, thus reminding us of the head of angular fragments so commonly seen in Cornwall and Devon. In the north-west of Guernsey, near Fort Doyle, there is another raised beach, as also in Catherine's Bay, Jersey.

coated by mud or sand drifted upon them, may remain to be determined, and we may, perhaps, treat as a general movement a multitude of local movements effected at different times. There does, however, seem to exist fair evidence that at least the British Islands may have been exposed to this change about the same period, subsequently to which the land has been raised, so that numerous low grounds have been worn, and are now wearing away, disclosing a bed of entombed vegetation beneath, in which the roots of trees often remain in the places where they grew, some localities being defended by shingle or sandy beaches where conditions were favourable; an additional evidence of this rise of land being perhaps also found in the remains of beaches now seen above the present level of the sea.

CHAPTER XIV.

ACTION OF THE SEA ON THE COAST, AND EFFECTS OF ATMOSPHERIC INFLUENCES.

Action of the Sea on the Coasts.

As about four hundred and seventy-two miles of coast, exclusive of estuaries and minor irregularities, are in the district under consideration exposed to the action of the sea, considerable facilities are afforded for the study of this action, more especially as the rocks brought within its influence are very different, and the conditions under which they are exposed are also variable.

We soon perceive that the streams of tide, to the movement of which so much abrading power has been attributed, have very little effect upon this coast, and that it is chiefly in those places where the tides have little strength, but where the softer rocks prevail, and the exposure to the prevalent winds, and hence to breakers, is considerable, that the chief loss of land by the action of the sea is greatest. In fact, the tides rarely run beyond one or two miles per hour, except round the headlands, which are nearly all composed of hard rocks, the softer parts of the coast having been hollowed out by the breakers during the lapse of ages into creeks, coves, and bays, so as to be removed from the main streams of tide.

It would be difficult to form a correct idea of the geological time during which this coast has taken its present form. Parts of it may long have been exposed to the action of the sea while rocks may have been forming elsewhere, so that numerous geological ages may have passed away during the grinding of the coast into its present outline. When we perceive so many hard rocks worked into creeks and coves, and learn, as indeed from their aspect we should expect, that no appreciable change has been observed in them during the memory of man, we can readily believe that the present condition of this coast is due to no ordinary lapse of time as reckoned by him.

The tides round some of the main headlands run compara-

tively strong—four to five miles per hour—during high springs, but it may be very much doubted if the water with this velocity has any appreciable effect upon the rocks of the points round which it passes, such rocks being generally of the hardest kinds, and the actual rate at which it flows close to them being considerably less. Swallow Cliff or Sand Point, near Wick St. Lawrence, round which the strong tides of the Bristol Channel run with a velocity during high equinoctial springs of, perhaps, six miles per hour, is composed of hard mountain or carboniferous limestone, and bears no mark of being abraded by the tidal current; on the contrary, the sea-weeds and barnacles on the rocks most exposed to this velocity seem to prove that they are not worn away by it. Anchor Head, near Weston-super-Mare, and Brean Down Point, on the south of it, in like manner composed of carboniferous limestone and exposed to strong tides, also bear no marks of abrasion, and it should be recollected that the Bristol Channel waters are here much charged with detrital matter, and hence in a condition to wear rocks away by abrasion more than if they were clear.

The current of tide runs strong round Hurlstone Point, near Porlock, and the Foreland, near Linton, but the hard quartzose sandstones of which they are both composed bear no marks of being worn by it. Neither can any abrasion be observed at Morte and Baggy Points, round which there is a great rush of waters out of Bideford Bay on the flood tide, the former headland formed of curved beds of slate rendered hard by veins of quartz, and the latter composed of hard grauwacke sandstones. Hartland Point formed of shales and sandstones, variably indurated, of the carbonaceous series, is certainly wasting away; attention, however, to the ledges of rock running seaward from it, and exposed about half-tide, when the tidal stream is strongest, will show that this head is not worn by the current of tide-water, but that the heavy breakers would more speedily carry away this projecting point than they now do, were it not for such ledges which the stream of tide does not remove, but which throw a body of tidal waters to the north-westward upon the ebb.

The hard quartzose and trappean rocks of Trevose Head, the greenstone and trappean rocks of Pentire Point, near Padstow, the hard slates of St. Agnes Head, the compact sandstone and hard slates of Godrevy Head, the greenstone of St. Ives Point,

the greenstone and hardened schistose rocks of the Gurnards Head, and the granite of the Land's End, may be readily supposed incapable of being appreciably wasted by the action of the streams of tide which pass round them. In like manner the granites of many other points in the Land's End district, the serpentine, diallage, and hornblende rocks of the headlands in the Lizard district, the hard arenaceous grauwacke of the Dodman Head, the mica-slate and gneiss of the Bolt Head and Prawle Point, the slate crossed by quartz veins of the Start, and the hard limestones of Berry Head and Hope's Nose, on the extremities of Tor Bay, may well also be considered too hard to be abraded by any streams of tide which run across them.

So also, when we turn to the minor headlands across which minor streams of tide pass, we find them too hard, or too well defended by ledges or fallen blocks of hard rocks, to be worn away by the mere abrading power of such streams. When carefully examined they are all found capable of resisting the tidal currents which flow by them; and we must here observe that, properly to appreciate the abrading power of a tidal stream, it is essential that the coast should be observed during calms, although there may be some small difference between that condition of a tidal stream and when a current, produced by the propelling power of wind, in consequence of friction, is added to its usual velocity, otherwise, as has often been done, the powerful abrading force of the breakers is mistaken for the action of streams of tide. We have frequently watched on the shores of the district in calm weather, and during spring-tides, for the power of the tidal stream to move the small shingle and sand where the breakers pile them up; but, as such places are necessarily at the bottoms of bays or creeks, where the tidal current is so weak as to be scarcely appreciable, except by the direction of the long seaweeds or some floating body on its surface, we have rarely seen even the grains of sand moved by it.

A very short experience of the destructive effect of breakers will be sufficient to afford evidence of the form which a coast must take according to the variable manner in which it may be exposed to them, so that after the lapse of ages any given coast will readily show, from the wearing away of the softer rocks into creeks, coves, and bays, the harder being gradually left to protrude as points and headlands, that it has been scooped out ac-

cording to the unequal resistances of the rocks on the one hand, and the variable power of the breakers on the other, due allowance being made for the original form of the land and the indentations produced by the entrance of the sea, at its high-water level, into valleys, producing estuaries. If we regard the geological maps of the district we shall readily perceive that such has been the case with it, and that the form of its shores corresponds with the relative hardness of the rocks and their comparative exposure to the breakers, those parts now wasting away, proper allowance being made for land-slips caused by springs, where the rocks are comparatively soft, while those portions are not appreciably abraded where the rocks are hard.

It rarely happens that breakers do not fall on the western part of this coast, even in the calmest weather, undulations from the Atlantic, produced by gales of wind on some part of it, not too distant to allow the waves so caused entirely to subside before they meet the land, rolling in upon the shores, and often breaking with a heavy crash on them, causing probably as much abrasion as the waves at any other time. These are technically known as "ground-swells," as they tear up the beaches exposed to them, hold abundance of pebbles or sand, as the case may be, in mechanical suspension, and seem as it were to rise from the bottom of the sea, hurling the mechanically suspended substances upon the beach or against the cliffs with a heavy grinding noise, frequently heard far inland.* As these ground-swells very often roll in from the westward, the coast from Morte Point to the Land's End is much exposed to it, particularly towards the latter place. The Land's End and Tol-pedn-penwith protect Mount's Bay from its range, as does the Lizard-land the coast in the direction of Falmouth. When, as it often does, the Atlantic or ground-swell rolls from the south-westward, a large portion of the southern coast, otherwise protected, is exposed to it. It is sometimes observed on the Chesil Bank and Portland Island, but generally the formidable breakers caused by this swell, even in calm weather, do not extend beyond the Prawle and Start Points, so that a large amount of softer rocks, red marls and sandstones,

* The sudden rise of this "ground-swell" is sometimes attended with loss of life to the fishermen, and much caution is in consequence necessary while exploring the coast exposed to it. We have been three or four times unpleasantly situated in consequence of the breakers thus suddenly produced.

lias, oolites, green sand, and chalk, are protected from it in the Great Western Bay.

The ordinary breakers are well known to be the crash of the waves produced by winds blowing on the coast, and according to the exposure of the coast to open sea, other things being equal, are their magnitude and destructive powers. This may be readily seen by comparing any of the estuary cliffs, such as those up the Taw and Torridge, the Camel, the Exe, the Teign, and of the Kingsbridge and Falmouth waters, with the lias and red marl or sandstone cliffs of Watchet, in the Bristol Channel, these last with those of the Great Western Bay, and, finally, the cliffs of the latter with those exposed from Hartland Point to the Land's End, due regard being paid to the character of the rocks acted upon.

In many situations common atmospheric influences so combine with the action of the breakers to produce the destruction of the cliffs, that it may be difficult to say whether the loss of land may not be more due to the one than the other; in most places, however, the breakers nearly cause the whole loss, leaving isolated rocks to show, to a certain extent, the destruction they have caused. The cliffs from Trevose Head to New Quay may be selected as affording a good example of the destruction of a coast by the action of heavy breakers, the grauwacke slates and sandstones of which they are altogether composed, with the exception of the sands near Trevose Head and the greenstone at Park Head, being of a kind which, if placed in more sheltered places, such as the Great Western Bay, or in the higher parts of the Bristol Channel, might be expected to resist the breakers to which they would be there exposed far more efficiently than they now do. We can readily conceive that the Quies have once been united to Dinas Head, the less resisting rocks having been removed by the heavy action of the breakers from so many directions. The numerous deep coves between Trevarnon and Porthcothan Bays show the unequal destruction of the rocks according to their relative hardness. Park Head exhibits the amount of protection which a hard rock (greenstone) may afford to others, which, when fully exposed to the action of the breakers, as from thence to Trenance Point, are readily carried away, leaving islands or rocks separated by distances which there can be little doubt were once occupied by slate now removed, as will be seen by the accom-

panying sketch, representing the cliffs near Bedruthan, plate 12, fig. 1. It would appear that in the production of islands or rocks of this kind the breakers very often first form a cave, through a projecting point or headland, which becomes gradually enlarged, so that the roof, from want of support and sufficient cohesion, falls down, and the point remains an island, round which the breakers work their way, gradually increasing the distance between it and the main land. In the fifth headland in the sketch (pl. 12, fig. 1) a point is now seen to be separating from the main land and forming into an island by means of one of these arched caves.

The rocks between Teignmouth and Lyme Regis suffer much loss from the action of the breakers upon them, to an extent that, if the latter possessed the average force of those which wear away the coast last mentioned, very considerable inroads would be made upon them, and the bay would be much enlarged northward in the course of a few thousand years. No doubt much loss of land, in the vicinity of Lyme Regis especially, is occasioned by the slipping of chalk and green sand (as we have had elsewhere occasion to represent *) over the lias and red marl into the sea, producing picturesque undercliffs, the fragments of the fallen rocks protecting the coast from the loss of land it would otherwise sustain; but the movement thus caused, if the breakers did not carry away the fallen rocks, would be comparatively trifling, equal only to the landslips observed in the valleys near Lyme Regis and Axminster, where, from a similar cause, the green sand on the slopes of some parts of the hills slides upon the mud or clay to lower levels. Independently, however, of the loss by landslips, the lias cliffs near Lyme Regis are readily seen to be washed away by the breakers, as may easily be observed between Charmouth and that town, as also to the eastward of it. Considerable waste of this coast has thus been occasioned within the memory of persons now living, a waste first recorded, we believe, by De Luc, and one which is still proceeding at a considerable rate, the fall of the cliffs being frequent, particularly in bad weather.

Much loss of coast is sustained near Sidmouth, particularly in the direction of High Peake, the small green-sand cap on the top of which will disappear at no distant date, geologically speaking, and be only known to have existed from the geological maps

* Geological Manual, 3rd ed. p. 49, fig. 10.

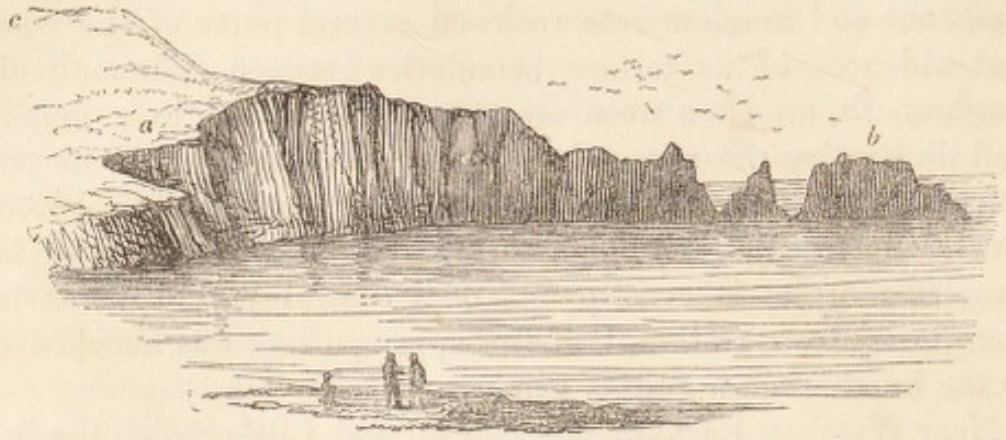
now constructed of that part of the country. The isolated red sandstone and conglomerate rocks on several parts of the coast, the evidences of its former boundaries between Sidmouth and Teignmouth, are often worn away by the breakers in a manner well illustrating the unequal resistance offered by different portions of them. One of these isolated masses, named the Chit Rock, which long rose above a ledge on the west of Sidmouth, was a few years since upset in consequence of a central part of it having been finally worn so thin, that the upper portion was knocked off by the breakers in a gale of wind.

Near Watchet, East Quantockshead, and Little Stoke, the lias, red marl, and sandstone of the coast suffer much annual loss—not so considerable a loss as they would sustain if exposed to the action of heavier breakers than now reach them, even to such as now batter and wear away similar rocks near Lyme Regis and Sidmouth, but sufficient to become well marked.

It will be readily supposed that, upon so considerable a line of coast as this district affords, numerous opportunities of observing its relative destruction by breakers according to the dip of the stratified rocks are afforded, some comparatively hard beds being worn away when their line of strike is cut by the coast, while softer strata are less abraded when their dip or lamination, in the case of schistose rocks, is seaward at right angles with the shore. The coast from Hartland Point to Boscastle may be adduced as a good example of the destruction of rocks when the edges of their beds are exposed, as may also that extending from Trevose Head to New Quay. No long line of coast can be brought forward as an instance of the comparative preservation of stratified beds in consequence of their dip, but it can be partially observed in several places, as at North Hill, near Minehead; at the Foreland, near Linton; in much of the coast between the Zoze Point, Falmouth, and the Dodman Head; from the Rame Head to Penlee Point, Plymouth Sound; in several parts of the coast from Plymouth Sound to the Avon Mouth; at the mouth of the Dart, &c.

The minor effects of the breakers are easily seen on every part of the coast, the harder rocks resisting their action, while the softer are worn into caves, creeks, and coves of every variety of form. Many of these coves afford shelter to the fisherman, and without them his occupation could not be carried on. The annexed

Fig. 82.



is a sketch of Polventon Bay, or Cove, on the east of Trevose Head, formerly well known as a smuggling place, and now often visited by vessels waiting for the tide into Padstow Harbour. From the action of the breakers the slate, *a*, has been so worn away from the line of greenstone, *b*, that the latter forms a natural pier named the Merope Rocks, affording shelter from the north-west winds*. This bay, or cove, may be taken as a good example of a natural harbour scooped out in a great measure by the breakers, for no trace of valley opens upon it, as frequently happens with the small harbours on this coast.

The sea, by its action upon rocks of unequal hardness, and the fall of some compact portions of them, or of large indurated nodules contained within them, often raises a barrier against itself, and the lower portions of cliffs become protected for a time, beyond that they would otherwise remain firm, even in some cases producing points of land composed of these blocks or more indurated masses of rock.† The force of the waves falling on the coast between Lyme Regis and Axmouth is in this manner con-

* It would appear that this natural harbour might be greatly improved at comparatively moderate cost, as the line of greenstone, part of which now forms the Merope Rocks, continues up to the higher ground (*c*, fig. 82) of Trevose Head, whence large blocks might be procured and sent down an inclined plane to the eastern extremity of the Merope Rocks, and the present breakwater be extended by these means to the amount which might be considered desirable. If a lighthouse were erected on Trevose Head, one much wanted by the trade up this much frequented and dangerous coast, a harbour at Polventon would be still more desirable, particularly as there is scarcely a place of refuge deserving the name between the Land's End and Ilfracombe during a heavy north-west gale.

† Indeed it may be said on this head, that beaches generally, more especially shingle-beaches, are only the harder part of abraded cliffs reduced to somewhat smaller dimensions.

siderably broken by masses of indurated green sand, known as "cow-stones," strewed over the shore, notwithstanding that so many of them have been broken to pieces or removed entire for economic purposes. Large portions of chert, derived from the green sand also, assist in protecting this coast.

Hard blocks of conglomerate in the same manner protect parts of the coast composed of the red sandstone series, as between Dawlish and Teignmouth, and between the latter place and Babbacombe. Where a mixture of hard sandstones and softer slates prevails on the coasts composed of the grauwacke and carbonaceous series, as is observable in many places, the same protection will be seen afforded by fallen blocks, as also where hard greenstones or elvans may be mingled with the slates.

Having thus briefly adverted to the destructive action of the breakers on this coast, we should notice the protection afforded by the common beaches thrown up in front of low lands. This, in the case of shingle, and partly also in that of sand, is accomplished by the breaker, after having been charged with the one or other when in full motion, losing the power to remove from the coast the detritus which it has thrown upon it; for it can then no longer keep a large portion mechanically suspended in consequence of the diminished velocity produced by its fall upon places where there is no rebound, but where its force is nearly destroyed. The retreat of each breaker, as is well known by the grating sound then produced, on shingle-beaches especially, undoubtedly again withdraws much shingle, but that it does not withdraw so much as it has driven or carried before it is proved by the fact that the greatest beaches are always piled up by the heaviest breakers, provided no hard cliff be reached by them at that time so as to cause a rebound. Shingles are also driven forward by blows from pebbles thrown against them by breakers. Though the same circumstances attend the breaking of waves on a sandy beach, the effect produced would be comparatively limited, inasmuch as such fine detritus is more readily again withdrawn by the retreat of a breaker, if the wind driving on shore did not assist the process of accumulation, so that eventually sand-hills on a coast rise higher than shingle-beaches. Sandy coasts are generally dry at low water for considerable distances seaward, hence, during gales of wind on shore, the surface often becomes dried, and the particles of sand are driven forcibly inland, where they accumulate into

low hills, taking forms resembling those seen in a great snow-drift. During more moderate weather also and neap-tides, much sand is blown on shore from the dried surface existing between the spring and neap-tide levels. If these sand-hills are not retained by vegetation, they continue to advance inland and desolate the adjoining land.

Commencing on the north we find sandy beaches accumulated before the low land between Middle Hope Hill and the River Parret, mixed here and there with some shingles. With the vicinity of the lias on the west of Stert Flats we obtain a shingle-beach composed chiefly of pebbles derived from it, and protecting the flat lands near Stolford from the ravages of the breakers they would otherwise suffer. In like manner we see the low lands near Minehead and Porlock defended by great shingle-beaches composed of rounded fragments, occasionally large, of the hard grauwacke and other rocks of the vicinity; two or three lines are accumulated in front of each other on the shore of part of the Warren, while part of the Minehead beach extends from the harbour to Greenaley Point, defending the cliff from the action of the breakers. In Morte Bay there is a good example of sand blown against high land in consequence of the drift during westerly winds from the Woolacombe sands. For about half a mile under Pickwell Down these sands appear to be accumulated against an old cliff, washed probably by the sea before the neighbouring beaches near Middleborough and Saunton Court were raised.

An excellent opportunity is afforded for the study of sand-hills and their manner of accumulation for about three miles in front of Braunton Burrows, and a fine shingle beach, often composed of large rounded stones, the rolled fragments of the hard sandstones of the adjacent carbonaceous series, extends on the seaward side of Northam Burrows, on the southern side of the united embouchures of the Taw and Torridge. Much sand is still blown upon the hills from the present coast in Padstow Harbour, in Constantine Bay, at the mouth of the Ganel, in Perran Bay, in St. Ives Bay, and at Whitesand Bay, near the Land's End, though the greater part of the accumulations of sand visible at these places appears to have been effected when the sea was at a higher level relatively to the land of this coast than it now is. The sands at present drifted into these localities, and into many minor bays

and coves on the line of coast extending from Hartland Point to the Land's End, are remarkable for being chiefly composed of comminuted sea-shells, and do not differ from the accumulations which had previously taken place, prior to the rise of the land to its present relative level with the sea, as previously noticed (p. 426). A large proportion of these shells would appear to have been those of mussels, multitudes of which are now attached to the rocks of the coast in numerous localities.* Vast quantities of land-shells are often scattered over the sandy dunes, and of necessity no inconsiderable number are embedded in them.

The drift of these sands inland has overwhelmed many buildings, some of which by their continued movement have again appeared; and it is worthy of note how soon a small spot, bared by accidental circumstances, may eventually, by the extension of the bared surface, cause a new drift. The old church at Perranzabuloe is among the more remarkable of the ancient buildings which have been found.

The manner in which running streams of water arrest the progress of the sand-drift is well shown in many places in Cornwall, and while watching the progress of a drift it is curious to observe how small a rivulet will produce this effect. By reference to the Ordnance Geological maps, it will be observed that the sands rising over the land behind Holy Well Bay, near Crantock, are suddenly cut off by the streamlet near Tregoe, while the Perran sands are bounded by a stream for nearly two miles between

* There has long existed a popular belief that the great sandy accumulations of Cornwall and Devon were produced by the *breaking up*, as it is termed, of some great sand-bank in the Atlantic, the component parts of which were driven upon these coasts. Independently of the extraordinary physical conditions necessary to produce this effect, we must observe that, under the general conditions of these coasts, sand could scarcely be otherwise than accumulated precisely in those places where we now see them accumulated and accumulating, both when the relative levels of sea and land existed as they must have done prior to the alteration which raised the beaches we so constantly find, and at present. An appeal has been sometimes made to a record of this supposed inundation of sand in the twelfth century. That a record may have existed of some great movement among them by a combination of extraordinary circumstances, is very probable; but that these sands were gradually accumulated as we now see, there appears no reasonable doubt, more particularly when we study their structure, in which traces of old vegetable surfaces may sometimes be traced, marking successive periods when the plants common to such soils could grow. Other traces of distinct deposits, as has been noticed by Mr. Carne (Trans. Geol. Soc. of Cornwall, vol. iii. p. 146), are sometimes seen in the mass of these sands.

Treamble and Holy Well Bay. We were informed that, from inattention to this circumstance, much land became covered by the drift from the Perran sands in consequence of a small stream near Gear having been covered by mining operations. Generally speaking, the chief sand-drift does not rise more than a few inches above the ground, the same grains rarely remaining suspended in the air beyond a short time; hence its progress is soon arrested by a streamlet sufficient to carry forward the sand blown upon its surface or against its margin.

At the bottom of every bay, creek, or cove on the coast, beaches are piled up by the breakers, sands being accumulated near the mouths of some rivers, such as near Barnstaple, Teignmouth, and Exmouth. These beaches travel in the direction of the prevalent breakers, or at least those which collectively strike the coast with the greatest average force. Although breakers appear to strike the coast in lines parallel to the shore, attentive observation will show that they rarely do so, except in deep bays or coves, unless the wind drives right upon it. It will be seen upon the more open shores that the pebbles or sand are struck somewhat diagonally when the wind at the time also blows diagonally upon it. Abundant evidence of this fact will be observed upon the shores of this district, the best cases to adduce being the lines or tongues of beach extending at the mouths of some rivers.

The mouths of all the valleys would be blocked up by beaches from the piling action of the breakers, if the streams or rivers descending down them were unable to keep a passage clear for the discharge of their waters into the sea. At the bottom of a large proportion of the creeks and coves the piling action of the breakers is sufficient to accumulate a permanent beach, and the drainage waters of the valleys, so blocked up at their mouths, escape by percolation, floods even being insufficient in some cases to break through the barrier of shingle. These cases are so numerous that it will be quite useless to notice the localities where they may be observed. Between them and those where, from the sea-level cutting the valleys, comparatively deep water prevails at the mouths of the rivers or estuaries, as at Falmouth Harbour, Fowey Harbour, Plymouth, and Dartmouth, every variety is observable. At the Looe Pool, near Helston, we find a considerable body of fresh water ponded back by a beach which the heavy breakers falling on this coast—and it is one well exposed to the

Atlantic—have piled up. Under ordinary circumstances the evaporation from this lake, and the percolation through the beach, are sufficient to carry off the drainage waters discharged into it; but during winter these means are incapable of removing the surplus waters which then accumulate, and a natural breach would be effected through the shingle barrier, if from old custom the lord of the manor did not cut an artificial channel for the discharge of the waters when they rose to a certain height, so as to reach the town of Helston. If this coast were not exposed to such powerful breakers, and the curve of the shore did not permit the collection of a beach, it is not improbable that the back-water of the ebb-tide, joined to the stream flowing down from the granite district inland, would be able to keep the mouth of the valley open, so as to form an estuary-harbour.

Another fresh-water lake produced by a beach piled up by the breakers, in a position where the shingles cannot travel so as to escape out of a bay, and where the coast is well exposed to a long range of sea, though inconsiderable when compared with that in front of the Looe Pool, occurs at Slapton in Start Bay. Here the power of the drainage waters down the three small valleys, in front of which the beach has been accumulated, is insignificant, compared with the piling power of the breakers, though the coast faces the eastward. A continuation of the beach even separates the cliffs behind Beeson and Hall Sands from the destructive action of the sea, a circumstance which may, however, partly arise from the elevation of this coast when the old beaches in Tor Bay and Plymouth were raised. Near Falmouth there is another instance, in the Swan Pool, of a body of fresh water ponded back by a beach piled up in front of a valley.

At Teignmouth and Exmouth we have examples of tongues of beach drifted in opposite directions in consequence of the different prevalence of the breakers to which they are exposed, the beaches in each case struggling to close the mouth of the valleys, as is done at the Looe Pool; but in both these cases, the rivers being comparatively large, their waters are enabled to overpower the piling action of the breakers and keep open shallow tidal estuaries.

At Teignmouth little or no beach is derived from the rocks to the southward, and the river-mouth is sheltered from the southerly and south-west winds. It is open, however, to the winds and consequent breakers from the eastward and north-

east; hence, the chief drift from prevalent breakers is from the northward, and a tongue of sand is the consequence, stretching to the southward, which would bar up the river if the latter did not escape by running against the solid land on the south and keep a channel open between the tongue of sand named the Den and the Ness Point. From the trend of the coast the mouth of the Exe is open to the south-west, and is sheltered from the north-east by Westdown Head; consequently it is open to the drift from the southward, the shelter afforded by the Tor Bay headlands not extending to it; hence, the beach accumulates from the southward, forming the Warren Sands, and the Exe escapes by flowing against the Exmouth or north-eastern shore.

At the mouth of the Axe, the prevalent breakers causing the beach to travel from west to east, the river escapes by flowing close to the eastern land. At Erme mouth the river runs to the sea by flowing against the south-eastern cliffs, the prevalent breakers piling up the beach in a tongue joining the north-west shore. At the united embouchures of the Taw and Torridge conflicting forces would appear to be brought into operation, the sands of Braunton Burrows trending to the southward, and the shingle beach of Northam Burrows stretching to the northward. Situated as this coast is, the beach may be regarded as piled up against the bottom of a bay upon which the prevalent breakers directly act, so that the effect produced would be similar to that seen at the bottom of Start Bay if the discharge of the waters of two considerable rivers did not keep a channel open. As, however, the united waters of the Taw and Torridge escape by keeping close to Appledore Point, though they are afterwards turned by the beach of Northam Burrows, the chief drifting force may be regarded as from the northward, to which indeed Barnstaple Bay is most open, the coast extending to Hartland Point sheltering it from the southward; thus the preponderating piling force of breakers would be from the former quarter, drifting the sands of Braunton Burrows against Appledore Point. The form of the embouchure of the Parret is no doubt much influenced by the strong tides in the Bristol Channel and the fine character of the sedimentary matter drifted. Where however anything like a beach has accumulated the drift has been in the direction of the prevalent breakers, from the westward, and the Stert Point has been the result. From the piling influence of the prevalent

breakers, the Ax cannot escape upon the Berrow Flats, but is compelled to do so between Brean Down and Uphill; the former, from its position, affording the mouth of the river sufficient shelter.

Effects of Atmospheric Influences.

With respect to decomposition there is scarcely a mass sufficiently extensive to deserve the name of rock which does not exhibit some traces of it. In some rocks it has extended to the depth of many feet, while in others slight portions only would appear to have been decayed through atmospheric influences. In numerous situations *tors* or *carns*, as hard bare projecting portions of them are respectively termed in Devon and Cornwall, afford a kind of rough measure of the decomposition of rocks surrounding them, not that many masses, as in the case of the trappean rocks, elvans and granites, may not have originally presented very uneven surfaces; on the contrary, many of these igneous products probably presented such surfaces at first, but when we carefully examine these tors or carns, we almost always find them composed of mineral matter, harder or less inclined to decompose than that by which they are surrounded.

These numerous *tors* or *carns*, so common in the granitic districts, more especially on Dartmoor, would appear to afford evidence of a considerable decomposition, from atmospheric influences, of the surfaces of the masses above which they rise, every allowance being made for the inequality of such surfaces, either original or produced by aqueous action on the large scale. The schorlaceous parts of the granitic districts very frequently show considerable power to resist decomposition. The schorlaceous outskirts of the Hensborough granitic mass will illustrate this circumstance. We there have Roche Rock, Calyquoiter Rock, Watch Beacon, St. Mewans, and some other carns standing out in relief. The sketch of the former, plate 12, fig. 2, taken from the southwest, will show the unequal decomposition to which this rock has been subjected, along the line in which it cuts through the adjoining grauwacke.

Much has been said respecting the concretionary arrangement in granite supposed to be shown by its decomposition in the tors and carns above noticed, as also in the loose blocks so frequently

dispersed over many parts of the granitic districts. After much attention to this subject, we are far from perceiving good evidence in favour of this opinion. The granites are separated by divisional planes, as previously stated (p. 164), into cuboidal or prismatic bodies, and the decomposition upon the faces of these bodies, when the blocks are detached, and the superior facility for disintegration afforded by the corners would appear to us sufficient to produce the rounded character we often observe them to possess. A close examination of the tors or carns themselves seems also to bear out this view, for the natural blocks composing them would appear no more to disintegrate into spheroidal bodies, than blocks of common sandstone taken from among ordinary stratified rocks and similarly exposed to atmospheric influences. We have nowhere been able to trace that arrangement of parts so easily seen in the decomposing concretions of the trappean rocks of Ashton, on the north of Chudleigh, of Hen Point, near Saltash (figs. 5 & 6, p. 63), and of some other places. The stain of oxide of iron which is sometimes pointed out as evidence of this concretionary arrangement of parts, and which frequently coincides in depth with the bounding surfaces, for the time being, of a granite block, is no more than the stain of a similar kind often seen in fragments, angular as well as rounded, of numerous other rocks, such as sandstones and limestones, in which, from the angular character of the stain, the latter is clearly seen to be the result of weathering according to the form of the surfaces exposed.

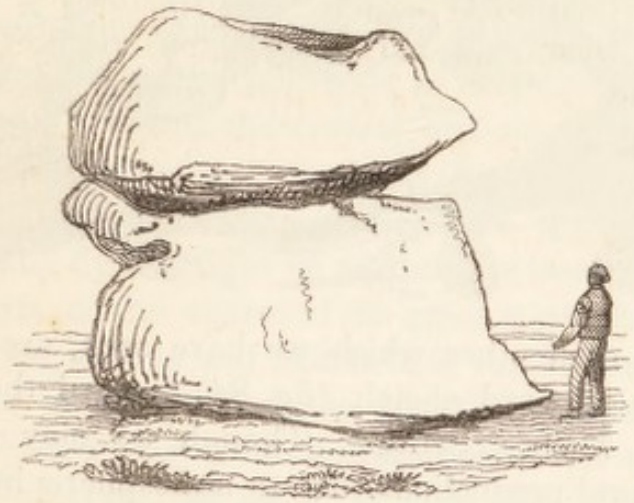
It is far from improbable that a tendency to a concretionary arrangement of parts may exist in the granite, and, as we have elsewhere stated,* sections between Okehampton and Moreton-Hampstead, by the road side, might lead us to suppose that hard rounded portions of that rock still remained, in consequence of this arrangement of parts, surrounded by decomposed portions of the same granite. A tendency to concretionary arrangement would sometimes also appear to exist in the elvans, as is more particularly shown in the granitic elvan which, with a north and south course, cuts through the grauwacke in Watergate Bay (fig. 22, p. 179). After much careful examination we are, nevertheless, inclined to refer the rounded character of a large proportion

* How to observe. Geology, *Art.* Degradation of Rocks.

of the blocks, either scattered over the surface, or still existing in the tors of the granitic districts, more to the decomposition of surfaces produced by divisional planes than to any other cause, for considerable quantities of these blocks are far from possessing a form which we could suppose the result of disintegration in concentric laminæ.

The following sketch (fig. 83) of the rock known as the Giant's Punch Bowl, in St. Agnes, one of the Scilly Islands, will pro-

Fig. 83.

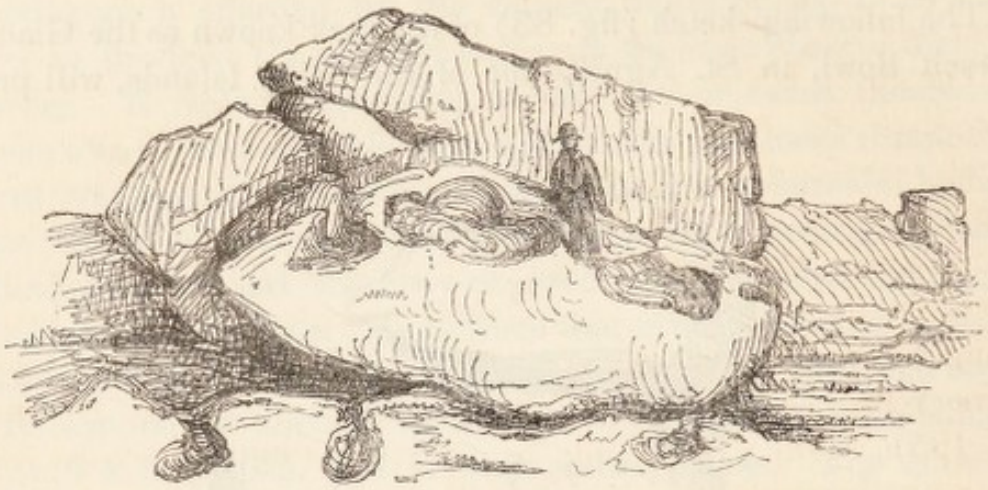


bably exhibit the irregular decomposition of two blocks of granite piled upon each other as well as any we could select. The upper block has externally a somewhat rounded character, such as has been supposed to arise from the decomposition of an original and concretional structure of the component parts, while the lower exhibits a form as irregular as can be well desired, being decomposed in a knotch on one side, and projecting out in an angular manner on the other. The highest block is decomposed on the upper surface, so that one of those cavities, commonly termed *rock basins*, and supposed formerly to have been the work of the Druids, is produced, extending even through the upper block to the division between it and the lower. There seems little reason to doubt, however isolated these blocks may now be, that they are the remaining portions of granite, similar to that on which they stand, that have resisted decomposition better than those which surrounded them, the latter having, by degrees, been disintegrated and removed.

Rock basins are so common in all the chief granitic districts,

that it is difficult to find any number of tors or carns on which some traces of the kind of decomposition thus termed may not be found. On Carnbrea, near Redruth, it may be readily traced in its various stages. The largest cavities thus formed in any

Fig. 84.



number near each other which we have seen, are those represented in the annexed sketch (fig. 84), named the Kettle and Pans, on St. Mary's, Scilly.* Though we may regard these basins as natural productions, due to atmospheric influences, and therefore not the work of the Druids, it does not follow that the latter may not have made use of a few which may have been properly situated for their purposes, even giving a more artificial form to some, should they have required similar basins at all.

With regard to the decomposition of granite, that from which china-clay is made in the vicinity of St. Austell, and that on the southern side of Tregoning Hill, near Breague, are the most complete in the district. Granitic gravel, if such it can be termed, resulting solely from the disintegration of granite in place, is so common in many localities that it would be useless to specify any. Often in road sections we perceive it thus disintegrated to the depth of many feet, in some places intermingled with hard granite that rises among the disintegrated parts, thus showing the unequal manner in which the whole has resisted decomposi-

* Dr. M'Culloch has suggested that the friction of the quartz and felspar fragments, not unfrequently found in rock basins, may have contributed to deepen them. As we have often observed these fragments in motion during high winds, both when the basins were dry or a small quantity of water in them, we are inclined to believe that this may be the case.

tion. This decomposition is, as may be readily supposed, almost entirely due to the disintegration of the felspar. In some cases when the granite is porphyritic, that is, when it contains disseminated crystals of felspar, such crystals remain undecomposed in their places among the disintegrated granite, and may be collected in great numbers. This may be well seen near Moreton Hampstead, especially on the descent from that town on the high road to Exeter. In many other places it also occurs.

The elvan dykes exhibit even more variation as to decomposition than the granites, while some are merely split into fragments, varying from large to small, others are reduced to a coarse sand, and even clay. These variations may be observed not only in the course of the same elvan dyke, as may be readily expected, but even in its breadth, the central and more crystalline parts being far more decomposed than the external portions, which have remained compact from the causes previously assigned (p. 185). Many dykes might be adduced as instances of this fact. In many parts of the course of the great north and south elvan, between Watergate Bay and Mitchell, it can be well seen. The decomposition of many elvans so that their upper surfaces resemble coarse sand or gravel is also common; several in Gwennap are thus disintegrated in parts, as also near Marazion and St. Austell. Good examples of clayey elvans are seen at Penlane * (S.E. from St. Columb Minor), between Lancorlar and St. Wenn, on the south of Castle an Dinas (near St. Columb Major), and on Killiganoon Downs on the south of Truro. As in granite, the disintegration of the elvans is chiefly due to the variable decomposition of the felspar.

As regards decomposition, the trappean rocks of the district are in very variable conditions. While some are reduced to a soft friable state, others rise in tors above the surrounding land, hard and solid, as if they had suffered little during ages of exposure to atmospheric influences. The trappean rocks which skirt the granitic districts, and which appear to have been altered (p. 268)

* Small quartz crystals, in hexagonal pyramids, base to base, may be obtained in multitudes from this elvan, by separating them from the clay. In like manner numerous crystals of pinite may be collected from the decomposed elvan which crosses the turnpike-road between St. Austell and Grampound, near Treloweth. In this also there are crystals of quartz of the kind above noticed; indeed such are not uncommonly found in the clayey elvans. Crystals of felspar are more rarely obtained, separated by decomposition, in the elvans; they are, however, here and there seen.

by exposure to long continued heat from the adjoining granite, are generally hard and little liable to decomposition, at least to decomposition appreciable in a few centuries. As examples of this fact, we may adduce Cock's Tor, Smear Ridge, and Whit Tor, near Tavistock, Sourton Tor, and other greenstone heights near Okehampton, Botter Rocks, near Hennock, and the trappean tors skirting the granite of Dartmoor, near Bridford and Cristow; Tolcarn Rocks, near North Hill, St. Clear Hill, and Michaelstow Beacon skirting the granite of the Brown Willy district; the greenstones around the Land's End granite near St. Ives, St. Just, Penzance, &c.

The trappean rocks are in many places partly solid and partly decomposed, the disintegration being as much produced by the decomposition of the hornblende as of the felspar in those chiefly formed of these two minerals, the protoxide of iron becoming a peroxide, so that the whole presents a rusty aspect. The trappean rocks which have been vesicular, and into the vesicles of which carbonate of lime and other substances have been infiltrated, rendering the whole a solid compact mass, are often decomposed, as far as regards the contents of the vesicles, for several inches, leaving the vesicles empty or filled with some friable substance, often ochreous. Examples of the first kind are by no means uncommon, particularly when the vesicular trappean rocks are associated with beds in which there is disseminated calcareous matter. Hence, the weathered surfaces of some of these vesicular trap-rocks often appear like varieties of recent lavas and cinders. The cinders in the trappean conglomerate of Brent Tor, near Tavistock, though found to contain infiltrated matter inside, usually appear on the exterior as if newly ejected and embedded.* Respecting the trappean ash associated with the grauwacke and carbonaceous series, it is not easy to estimate the amount of decomposition it may have suffered, inasmuch as we are not certain of the extent to which it may have been consolidated. It often, however, presents a very rotten and decomposed aspect, as may be well seen in the vicinity of Milton Abbot and other places between Tavistock and Tintagel.

* The hard greenstones sometimes exhibit an uneven surface upon exposed portions, showing unequal decomposing action on it. Where veins of actinolite traverse them, these sometimes stand out half an inch or more in relief, examples of which are no unfrequent in the greenstones skirting the granite of the Land's End.

The decomposition of the grauwacke series is as variable as the mineralogical character of the beds of which it is composed. The very hardest sandstones are, as at the Foreland, near Linton, intermingled with soft shales and slates, so that the disintegration of the softer parts exposes the harder, which thus often separate into small angular fragments, and are removed to lower levels by atmospheric influences. The northern side of the Foreland is covered with fragments thus produced, and its western side beautifully exhibits the unequal resistance of the component parts to decomposition from the combined action of the sea and the atmosphere. According to the variation of the beds from compact sandstone to very fine shaly slate, and the nature of their component parts, is the decomposition of their surfaces from mere fragments to clay, and the depth to which they are disintegrated, the slates occasionally showing decomposition for 20 feet.

The same will be observed with the carbonaceous series. In much of it, however, the sandstones having an argillaceous cement, the beds decompose into a yellowish clay, one not usually seen on the surface of the grauwacke sandstones. In the compact limestones of the district the exposed portions of the beds are generally much divided into fragments, and the gradual loss of surface in exposed cliffs, as well inland as on the coast, by quiet decomposition, is proved by the harder parts, such as many organic remains, projecting beyond the present surface. The vicinity of Torquay affords good examples of this kind of decomposition, in consequence of which delicate fossil bodies, too firmly embedded in the rocks to be otherwise well seen, are obtained in great perfection.

In the deep cuttings for roads near Exeter, and on the coast from Babbacombe to Axmouth, good examples are seen of the unequal decomposition of the red sandstone series; in the vicinity of Dawlish more especially, this is well exhibited. As to general surface, according as the subjacent beds are conglomerates, sandstones or marls, so is it for variable depths, gravelly, sandy, or clayey. From the argillaceous character of the lias, much clay is not uncommon on its surface, sprinkled with fragments of limestone in the lower portions where beds of it prevail. So friable is the green sand generally, that in deep cuttings for roads, such as between Lyme Regis and Charmouth, and in some other places, where inequalities in it are covered by gravel and clay, the latter are left projecting beyond the surface of green sand. The chalk

scales off wherever it is exposed to the weather, and the flints fall from it. In this district, however, neither chalk nor green sand are much exposed to the decomposing influences of the atmosphere, except in cliffs or in artificial sections, a covering of clay and gravel, which we have above referred to the plastic clay series, protecting both.

From this decomposition solutions of some of the substances acted upon must mingle with the drainage waters of the district, and pass unobserved into the adjoining seas, in the aggregate depriving the surface of the land of much solid matter. Some of this matter, chiefly carbonate of lime, is occasionally deposited before it reaches the coast; probably, however, the amount thus retained within the boundaries of the land, even under favourable circumstances, is very limited compared with that which escapes, and which may greatly assist in furnishing materials for the numerous creatures requiring carbonate of lime for their solid parts in the neighbouring seas, many rivers conveying it to situations where calcium is little abundant, except as a chloride. We know that such a thing as a spring of pure water can nowhere be obtained, all being more or less impregnated with foreign matter in solution. While some of these springs may rise through faults from unknown depths, and bring this foreign matter with them, others are certainly formed (such, for instance, as those which flow from beneath the green sand of the Blackdowns, and other places where similar conditions prevail) by the percolation of rain-water through rocks, until thrown out by beds sufficiently impervious.

The insoluble portion of this great surface decomposition is removed to lower levels by water descending to them. In a hilly country, such as Cornwall, Devon, and a large part of West Somerset, the descent of this detritus can be seen to be taking place in all directions, more particularly during heavy rains. According to the quantity of water, slope of ground, and other necessary conditions, will it be seen to travel. During every rain over the district there is a general movement of the particles composing a large portion of its surface from their previous places to lower levels. The amount moved may be comparatively insignificant during a year or a century, but the cubic contents of that which descends to lower ground, during the lapse of a great geological period, must be very considerable. True it is that when we collect the foul waters of a flooded river and examine them, we are

frequently surprised at the small quantity of sediment thus obtained in a cubic foot of water, even when they appear much coloured by it. Few persons, however, can have watched the various rivers of the district discharging themselves into the sea, without perceiving that, collectively, a large body of detritus in mechanical suspension is annually transferred from the dry land into it. If we even suppose that every square mile in the district merely furnishes upon an average one cubic foot of fine detritus daily to the drainage waters, we should have 1,719,880 cubic feet, or taking 15 cubic feet to the ton, 114,660 tons of fine sedimentary matter annually thrown into them, independently of gravels of various size.*

The grass lands protect the subjacent soil from removal, but in the arable fields there is much movement of surface when they are situated on the slopes of hills. In woods the surface of the ground is generally liable to be carried away by the water running through them, the growth of grass and small plants being usually scanty in such places, except, indeed, in the cases where much moss prevails. The ditches and other drainage arrangements throw a greater amount of water into the valleys than would probably take place during a given time under a given fall of rain without them, and that they are the means of conveying much detritus downwards to the rivers, the necessity of frequently cleaning them proves; but as a large portion of sedimentary matter is frequently thus caught in its progress and again thrown over the land, it may be a question how far the superior aid they afford to the descent of detritus may not be compensated by the quantity arrested through their means, and again conveyed to the high grounds.

Those streams only which have short and comparatively highly-inclined beds, carry or drive forward gravel into the sea adjoining this district, and among them the Lyne, which descends rapidly with a course of about eleven miles from Exmoor to the Bristol Channel at Lynmouth, may probably be cited as the largest.

* We may here observe, that the common process of estimating the matter mechanically held in suspension in rivers, by evaporating the water to dryness and weighing the result, is defective, inasmuch as by this mode of operating many substances in solution, such for instance as carbonate of lime, may be thrown down. Very clear waters, if there be sufficient free carbonic acid, may contain a large proportion of carbonate of lime, which by such a process may be made to appear as matter which had been mechanically suspended in them.

As, however, the number of those streams which vary in length from one to ten miles, amounts to about 118, the collective quantity of gravel transported by their agency to the coast, during floods, may be more considerable than at first sight might be suspected.

In the larger rivers the transport of gravel is usually arrested in the higher part of their tidal portions: thus the Ax and Parret do not carry or propel gravel in those parts of their courses which come within our district; the Taw ceases to do so for some distance above Barnstaple bridge, and the like may be said of the Torridge, above Bideford. The Camel does not carry or propel gravel for some distance higher than Egloshayle, and the Ganel only transports mud and silt beyond Trevemper Bridge. At Hayle, sand and mud are alone discharged by the river into the sea, and in the Helford estuary the transport of gravel ends high up. In the Falmouth estuary, gravels are alone moved at the higher parts of the various branches from it; even in the line of the Fal, gravels do not appear to be borne or propelled by floods beyond Lamorran, if so far. The Fowey ceases to be a gravel-bearing river for several miles from its mouth, as does also the Tamar for a much greater distance; neither the Yealm, the Erme, nor the Avon, transport gravel as far as the sea. In the Kingsbridge estuary, the gravels are deposited where the little streams at the heads of its branches meet the tide, and the gravels of the Dart, the Teign, and the Exe, are arrested far up these rivers.

Although accumulations necessarily take place in various parts of rivers where diminished velocity in the transporting waters causes any portion of the detritus they held in mechanical suspension to be thrown down, and there are numerous examples in the valleys of the district where little lakes or pieces of still water have been apparently filled up, the chief check is afforded by the meeting of the tidal and river waters. As most of these rivers flow onwards over the higher portions of their tidal beds, with the full force of their streams, when the tides are out, gravels are borne seawards beyond the exact meeting of the tidal and river waters for variable distances, according to the fall of the beds and volume of water discharged. Hence, during floods gravel banks are often accumulated in the course of the tidal portions of their channels. In the Dart below Totnes there are two or three of these bars, as

they are termed. The finer sedimentary matter is, however, carried onwards, and while the muddy condition of the banks of the higher parts of tidal rivers and estuaries shows that some of it is deposited on their shores, the usual foul state of their waters affords proof that a large proportion of it is kept mechanically suspended, a part escaping during every ebb-tide into the adjoining seas. During floods the escape of the muddy river waters over the heavier waters of the sea, the former being still under ordinary circumstances specifically lighter than the latter, can readily be seen on the coasts of Devon and Cornwall, the coloured superficial streams bending in the direction of the ebb-tide along shore.*

Though much detritus is carried into the sea, a considerable check is necessarily sustained by the tidal waters of rivers where they meet the latter, particularly where the breakers strive to drive a beach across their embouchures, and pile up much of the sand brought down by them. *Bars*, as they are termed, are the result both of the check to the waters and the piling action of the breakers, good examples of which may be observed at the mouth of the Taw and Torridge, and at the embouchures of the Teign and the Exe. This action is necessarily observed in a less degree where the breakers do not force a beach along shore, but where the depth will still permit the on-shore movement of the waves to be felt, and to cause a rise of bottom to variable heights, sufficient to be termed a bar when elevated so as to have breakers upon it at low water. Thus, the bottom is less deep at the mouth of the Dart than opposite Dartmouth, and a bar upon which the sea breaks occurs at the entrance of the Kingsbridge estuary.

From the deposit of detrital matter, the tidal portions of the various rivers in the district would appear to have been much

* The flowing of river waters in floods over sea water is occasionally well shown at Hamoaze, Plymouth, where, during freshets, the heavy men-of-war, drawing several feet of water, swing round with their heads to the south upon the making of the flood-tide, while the boats alongside, drawing comparatively little water, ride with their heads to the northward, the fresh waters flowing to the south over the sea waters, which then run up the Tamar to the northward. In this, as in all estuaries and tidal rivers where there is sufficient depth of water, the flood-tide wedges up the fresh waters of the rivers until they finally check their progress altogether, the facility with which they do so varying according to circumstances, so that in the Parret the resistance is suddenly overcome, and the flood-tide rushes in with a considerable wave, termed the *Bore*, which may be well observed at Bridgewater.

silted up even within historical times, more especially where the tidal and river waters meet, and in the tributary creeks down which small streams flow. The Dart, at Totnes, is considered to be now much less accessible to vessels than formerly, and the Fowey, near Polruan, has become perceptibly shallower, even within a few years.

The detritus thus worn from the land by breakers, and carried from it by the drainage waters, is either strewed along shore by the former, or distributed over the bottom of the adjoining seas by the streams of tide. The heavier portions being incapable of transport by tidal streams, even when aided by the movement of the waves, they are piled upon shore by the breakers, and gradually ground smaller by attrition; fresh fragments from the cliffs, and pebbles from the rapid streams, supplying the loss thus occasioned. The lighter portions are carried outwards by the tides, assisted by the movement of the waves.* The finest sedimentary matter can be, and generally is, conveyed to the greatest distances from the land, while the less comminuted is deposited nearer the coast.† Hence, allowing for exceptions from local causes, while the shingles or pebbles formed in the present condition of this part of the earth's surface occur only along shore, sands constitute the bottom of the sea nearest the coast, and mud that most remote from it; all destined probably in some future condition of this portion of our planet, with the remains of the creatures that exist in and upon them, to be raised above the level of the Atlantic and to be covered with terrestrial life, as has happened with the far greater part of the well-peopled and cultivated lands of Cornwall, Devon, and West Somerset, which is merely formed of the superficially decomposed bottoms of ancient seas that have been elevated above water into the atmosphere.

* From observations which we have made, more especially on the shores of this district, we have been led to estimate the depth beneath large waves, at which fine detritus can be agitated, as it were, to the surface, at about 90 feet.

† The mud deposited near the shores of the Bristol Channel, in many places between Middle Hope and Minehead, merely comes under the head of estuary mud, drifted about in the eastern part of the Bristol Channel and in the Severn, as in any other estuary, and being deposited under similar circumstances.

CHAPTER XV.

ECONOMIC GEOLOGY.

That the inhabitants of a civilized country are much governed in their occupations, all other things being equal, by the geological structure of that country, has of late been often remarked, and the coal districts of England have been adduced in proof of the correctness of this view, their manufacturing character contrasting strikingly with the agricultural condition of others in which coal is either not found, or from which the distance or kind of communication renders its transport expensive. Coal and iron so frequently occur together in our carboniferous districts, and the price at which both can be consequently obtained close to each other is so low, that the power of such districts to produce manufactures requiring much machinery and fuel, all other circumstances being the same, far exceeds that possessed by those in which these geological conditions are not found. When the facilities of transport to and from such districts are favourable, it could scarcely happen, supposing the necessary demand to exist, that manufacturing establishments would not be formed in them preferably to those countries where both iron and coal were at high prices. In many cases manufacturing establishments could scarcely be rendered sufficiently profitable to be formed at all, but for the geological structure of the country near them.

Perhaps there are few localities in which the advantages of geographical situation, combined with cheap fuel, arising from geological position, are better exemplified than at Swansea, where not only the copper ores of Cornwall and Ireland, but those also of Cuba and Chili, are brought to be smelted; these advantages even rendering it profitable to transport ores from the western shores of South America round Cape Horn to the fossil vegetation entombed in South Wales. It is not improbable that at some future period the South American copper ores may be reduced to metal more profitably in other and nearer countries in which sufficient coal may be discovered; but should this change take place, it would still be due to geological conditions. Merthyr

Tydfil, in Glamorganshire, may be cited as an excellent example of the economic value of geological conditions, the proximity of the carboniferous limestone, the coal, and ironstone to each other, in that part of the country producing a cheap combination of flux, fuel, and ore, scarcely to be surpassed.

It will readily be understood that, where a considerable portion of any given population, all other things being equal, lives by labour requiring constant skill, ingenuity, and judgment, that habits of reasoning and thought will be produced which would render it mentally superior to another given population in which the greater number of persons merely followed some routine occupation during their whole lives, in doing which they were not called upon to exercise any of the mental powers they might happen to possess. To those whose pursuits take them among the labouring part of the population, the variation in the mental condition of the people in the district under consideration, is remarkably striking. This variation is no doubt due to many local causes, but among them the geological structure of the country would appear to hold a more important place than might, perhaps, at first sight be anticipated. The chief contrast would probably be found between the labourers on the poor lands of the carbonaceous series of North-western Devon and the miners of Cornwall, both considered in the mass. While the former are thinly distributed over the country, full of prejudices against improvement, and still often firm believers in witchcraft, ghosts, &c., the miners are thickly congregated together in the neighbourhood of the working lodes, abound with intelligence, and from the constant exercise of their judgment, upon which indeed the living of a large proportion entirely depends, able to take correct and enlarged views of many other subjects than those immediately connected with their ordinary occupations. The miners, nevertheless, in Cornwall and Devon, labour under considerable disadvantages as regards education when compared with those of many other countries, where mining colleges, or schools, are founded. There is not a single place in the whole district where they can learn the results of the mining experience of other countries, and by combining it with their own, advance both their knowledge and its practical application. Neither is there any school to teach them those sciences that bear upon their labours, and which would be so useful to them. The

necessity of studying the varying condition of their lodes has, nevertheless, so accustomed their minds to the habit of reasoning, that they certainly, as a mass, greatly exceed in intelligence the other labouring population of the district, which, with the exception of the fishermen and sailors, is chiefly agricultural; the manufactures carried on in the towns, omitting Tiverton and Chard, not being sufficiently important to impress a manufacturing character upon them.

This contrast will readily be seen to be due to the geological structure of the respective portions of our district above noticed, for if the granite, elvan, slate, and metalliferous veins of the one were transferred to the area now occupied by the sandstones and shales of the other, there would appear no reason why the population at present occupying that part of North Devon should not be mentally as far advanced as the generality of Cornish miners now are, possessing, as they would, similar opportunities. When the physical features of our district are combined with the mineral structure of its rocks, very considerable variations in the condition of the population will be observed, less striking, it is true, than that above noticed, yet still sufficiently marked, and of which, if it entered into the plan of this report, we might readily adduce proof.

Agriculture.

It can scarcely escape the most casual observer that the fertility of the district varies most materially, and that very striking contrasts in the productive character of the soil present themselves to his attention in different parts of it. If he will take a geological map in his hand and compare this variation in fertility with the colours marked upon it, he will scarcely fail to find that there is an evident connexion between the greater or less productiveness he may have noticed, and the areas differently tinted in the map. Those who examine more minutely into the subject will soon perceive that this coincidence extends very generally to the boundary lines of the various colours, so that if the scale of the map be sufficiently large, the relative fertility may, in some cases, be traced even across fields, portions of them being far more productive than others.

In endeavouring to estimate the relative amount of fertility that

may be due to the decomposition of the sub-soil rocks, it is essential that due attention be paid to local conditions as regards aspect, height above the sea, and other necessary circumstances, otherwise many erroneous conclusions may be drawn, especially in a country like that we are now noticing, in which so many places are exposed to the influence of the sea-winds, and where heights vary considerably. We should necessarily expect that sheltered situations with a good southern aspect would be those in which, all other things being equal, we should find the capability of any given soil best exhibited; and that hence, by comparing localities as nearly alike in this respect as we can find them, we may be the better able to observe any differences which may arise in soils from the mineral structure of the subjacent rocks.

Fortunately there are many short valleys on the southern coasts of Devon and Cornwall, the component parts of which do not so materially vary in latitude as to render their temperature on that account to any very important extent different, where the general atmospheric conditions are so nearly similar,* that the

* It would appear from an account of the climate of Penzance by Mr. Edward Collins Giddy (Phil. Mag., and Annals of Philosophy, January to June, 1828, p. 173, vol. iii., new series), that the mean temperature for the year, from twenty-one years' observations, was 54·5° Fahr. The mean, however, as deduced from seven years' observations of a register thermometer, gave only 52°; probably the latter mean may more nearly approach the truth than the former. He gives the following as the mean temperature of the various months at Penzance:—

Jan.	Feb.	March.	April.	May.	June.
43°	45·5°	47°	51.5°	58·5°	62·5°
July.	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
65·5°	64·5°	60°	55·5°	49°	46°

As regards rain, he gives the following as the mean fall in inches for the several months during seven years:—

Jan.	Feb.	March.	April.	May.	June.
26·825	22·800	27·135	12·735	21·450	15.020
July.	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
20·740	24·475	24·060	39·295	36·035	42·075

	Inches.
The average quantity of rain for seven years is estimated at . .	44·702
Ditto, of wet days for seven years	177·5
Ditto, of dry days for seven years	187·5

Through the kindness of Mr. Holland, who completed a series of twenty years' meteorological observations at Lyme Regis in September, 1836, with the exception of those on temperature, which were uninterruptedly carried on for only thirteen years,

relative fertility of the soils in them may be fairly appreciated, due allowance being made for the greater prevalence of cloud as we proceed westward, viewing the district as a whole. At Lyme Regis we have a lias valley, and at Sidmouth one formed of red marl and sandstone, both bounded by hills of green sand, and both much strewed over in places by flint and chert-gravel. The superior fertility of the Sidmouth valley is readily seen, though of the two it is most exposed to the northerly winds. Independently

we are enabled to state that the mean temperature for the year at that place, at an elevation of ninety-five feet above high water mark, was 50·65° Fahr. He gives the following as the mean temperatures of the various months:—

Jan.	Feb.	March.	April.	May.	June.
40·17°	41·77°	44·76°	47·71°	53·29°	57·20°
July.	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
60·34°	60·40°	57·28°	53·22°	47·86°	43·76°

Mr. Holland, commencing his winter with October, as a more natural division for meteorological purposes than that which is usually adopted, and ending it with March, estimates the mean temperature for the winter at Lyme Regis = 45·26°, the mean for the remaining, or summer months, being = 56·04.

With regard to the local variations in mean temperature of this or any place upon the sea coast, with the same aspect, Mr. Holland had occasion to observe during a hard frost that while near the sea side the temperature was 27°, at his own house (ninety-five feet above the sea), it was at 21°, and at another house, about 200 feet above the sea, at 15°; so that there was then a difference of 12° in 200 feet, produced partly by difference of height, and partly by distance from the mass of sea-water at a much higher temperature.

The average number of rainy days at Lyme Regis is estimated at 178 (a number closely agreeing with that given by Mr. Giddy for Penzance), divided for the various months as follows, the number of hours of rain being also stated:—

Jan.	Feb.	March.	April.	May.	June.
16	14	16	14	13	13 *Days.*
75	75	71	67	59	50 *Hours.*
July.	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
14	13	14	17	17	17 *Days.*
63	60	60	80	86	85 *Hours.*

We are enabled to state, through the kindness of Mr. Snow Harris, that from eleven years' observations at Devonport and Plymouth, he finds the mean annual temperature of that part of the coast to be = 52·5°, the mean temperature of the various months being as follows:—

Jan.	Feb.	March.	April.	May.	June.
42·7°	44·3°	45·9°	48·8°	56·0°	59·7°
July.	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
61·8°	61·1°	57·5°	53·6°	48·2°	46·4°

of the decomposed lias being less favourable to general cultivation, though it is commonly valuable for grass land, the geological conditions of the two valleys are such that, while the rain-water, which percolates through the green sand on the tops of the bounding hills, is allowed to pass through the red sandstones in the valley of Sidmouth, being thrown out only by the marls, the lias in the valley of Lyme throws it out altogether, producing land-slips and much wet ground.

If we compare the short valleys, with a southern exposure, of Lamorna Cove (on the west of Penzance), in granite, of Chyandower (near the same town), in greenstone and slate, of Kennack Cove (Lizard), in serpentine, of Pendowa (near Veryan), in ordinary schistose grauwacke, of Polperro, chiefly in variegated clay slate, and several others in different varieties of grauwacke, with each other and with those of Sidmouth and Lyme Regis, we can scarcely doubt that their relative fertility, and their power of growing particular kinds of plants to advantage, greatly depends upon their sub-soil rocks.

That shelter from the prevalent sea-winds, which strike so many parts of the coasts of Cornwall and Devon with great force, is important to the vegetation of the district, will be amply testified by the bent and stunted character of such trees as can be made to grow exposed to their influence, and by the fine appearance of those which flourish freely when defended from them, even when they closely approach the sea, as at Newlyn, near Penzance, at Mount Edgecumbe, near Plymouth, and at Dartmouth. It will be observed, in the continuation of the same range of rocks, that, while the portions which are exposed to these

Six years' observations for rain, the fall of which Mr. Snow Harris obtains in cubic inches upon a square foot, give him a mean annual quantity of 5313·58 cubic inches, or, according to the usual mode, 36·24 inches in depth, the mean monthly quantity being as follows :—

Jan.	Feb.	March.	April.	May.	June.
350·7	439·9	354·1	448·8	290·4	352·9
July.	Aug.	Sept.	Oct.	Nov.	Dec.
427·4	464·3	617·3	487·5	435·96	644·26

With respect to winds, he finds from observations made for 2,191 days, or during six years, three times in each day, and occasionally at night, that they can be divided as beneath :—

Winds.	North.	N.E.	East.	S.E.	South.	S.W.	West.	N.W.	Variable.
Days.	280	90	298	119	219	288	522	178	197

prevalent sea-winds will scarcely support the growth of more than a few bent and stunted shrubs, the sheltered parts are covered by vegetation in proportion to the fertility of the rocks of the locality.* Let, for instance, the vegetation on the mica slate and chlorite rocks of the Molt, at the entrance of the Kingsbridge estuary, be compared with that on the continuation of the same rocks in the Sewer valley, opposite the Ham Stone, and we shall find flourishing gardens overhanging the sea in the former situation, orange and lemon trees growing in the open air, with little shelter during the winter, though the Molt is exposed to the south-east; while in the latter, trees and shrubs are completely cut up where exposed to the south and south-west winds. For similar reasons, fine woods clothe the coast near Clovelly, in North Devon, though its aspect is northern; while the continuation of the same beds of the carbonaceous series, near Hartland Pier, will scarcely support the growth of a tree when exposed to the western winds. So also the Culbone woods, near Porlock, which rise gradually from the shore, and flourish, with a northern aspect, would be speedily swept away, or be contorted and stunted in their growth, if exposed to the full force of the same winds.

Though from the want of friction, beyond that which they receive from the surface of the sea, the prevalent sea-winds act most severely on the coast vegetation exposed to them, preventing that growth which adjacent sheltered spots show the decomposition of the same rocks to be capable of supporting, their influence is not confined to the coasts, but extends inland in proportion to distance from the sea and height above it. Many a valley, therefore, in a given range of rocks, is comparatively fertile; while the high grounds, in the same range, make a poor return for the labours of the agriculturist.

The chalk of the district is seldom exposed on the surface, and

* Mr. Worgan, in his General View of the Agriculture of Cornwall (1811), p. 47, calls the attention of farmers to the value of the tamarisk for fences in situations exposed to the brunt of the sea winds, where scarcely another shrub will grow in the hedges. We have observed good fences of this plant on the south, near Landewednack (in the Lizard district), and around Harlyn House, near Trevose Head, on the north. Hence it is probable that it might, notwithstanding this plant suffers from frost, be successfully cultivated along a large portion of the coasts of Cornwall. As it is, this useful tree is sparingly found. It is probable, also, that it would thrive along the southern shores of Devon, as it grows fairly in some gardens close to the sea at Lyme Regis.

therefore contributes little, by decomposition, to the superjacent soil; hence we find no area of importance presenting the marked agricultural character of the chalk portions of the adjacent counties on the eastward. The chalk and green sand are, indeed, generally so completely covered by the gravels which we have previously noticed (p. 395), that those parts, represented in the maps as composed of these rocks, afford a very common agricultural character, and cannot on the whole be considered fertile. Downs of heath and furze are very common upon these gravels; and those portions cultivated as arable land abound in flints and fragments of chert. The gravels also frequently contain much clayey matter intermingled with them, so that water does not readily percolate through them, and black peaty soils are often observed. In places where marls, probably the remains of the plastic clay beds, are found near the surface, the agricultural character of the land above the chalk and green sand is much improved, and the country more fertile. In those situations in the Black Downs, where the gravels have not descended thickly spread over the sides of the hills upon the red marls, or lias, beneath the green sand, the contrast offered between the agricultural condition of the country, upon the one and the other, is remarkably striking; indeed a well-marked line of heath and common nearly coincides with the division between the two rocks. Haldon Hills also afford good examples of the contrast between the vegetation upon the green sands, with their gravel covering, and upon the rocks beneath them.

When the agricultural character of the lias is compared with that of the red marl and sandstone adjoining it, a very striking general superiority is observed in the latter. Good opportunities for observing this circumstance are afforded by the Vale of Taunton, where both rocks occur under similar general conditions as to climate. It will be seen also in the neighbourhood of Bridgewater, in that of Watchet, and near Uphill and Worle, in the vicinity of Weston-super-Mare, on the north, and in the valley of the Axe on the south. Excellent grass-land is often seen on the lias, as also many good orchards; but in general the arable land upon it seems not very remarkable for abundant produce. Oaks, as might be expected, often grow well, particularly upon the marly or clayey parts.

Taken as a whole the area occupied by the red sandstone

series is one of considerable fertility, especially when uncovered by transported gravels. The red marls, with their higher variegated parts adjoining the lias, would appear very favourable for the growth of apples; and the cider obtained from their range is commonly found to be very excellent, when sufficient attention is paid to the mode of making—an attention not so common as could be desired. The cider obtained from the red and variegated marls of the Vale of Taunton, and that made in the valleys of the Otter, the Coly, the Yart, and the Axe, where they cut into the same beds, and the surface is fairly clear of gravel, may be taken as examples of this circumstance. In many places, also, where beds of red marl are intermingled with the sandstones and conglomerates of the other parts of the series, or the latter contain much marly matter, the same fact will be observed. Some of the best lands in Somerset and Devon are upon the red sandstone series; and the general rich appearance of the vegetation it bears, more particularly where the soil is directly based upon it, so that its component parts have been superficially decomposed to form the chief part of such soil, is one of the marked features of the country. No doubt as these component parts vary, so does the fertility; but there are few soils of any great extent, composed really of decomposed portions of the red sandstone series, which are not rich in general products. Their different porosity certainly causes minor variations, some of the marly grounds being inclined to be wet, while some of the sandstone grounds are too dry. The upper beds are most disposed to be wet and clayey, while of the too great porosity of sub-soil rock, the localities are more scattered.

Taken as a whole, the contrast between the fertility of the soil on the beds of the red sandstone series, and that on the rocks upon which it rests, is marked and striking, and much in favour of the former. As the country formed of this series generally occupies a lower position than that composed of these subjacent rocks, it may be said that it is more sheltered, and that often this contrast is deceptive, the lower and less exposed portions of ground deriving the usual advantages from position. If, however, we take the country between Tiverton and Bradninch, where beds of the red sandstone are mingled on the surface with those of the carbonaceous series, at equal heights and under similar general conditions as to climate, or that near Cadbury and Stokeleigh Pomeroy, where the former occupy the highest ground, their

superior fertility is not the less marked. If it be said that this is not a fair comparison, inasmuch as the beds of the carbonaceous series are generally far from affording a good soil, we may take the country between Totnes, Torbay, Babbacombe Bay, and Newton Bushell, where the red sandstone series is intermingled, under similar conditions as to height and climate, with grauwacke slates and limestone; and except trappean rocks occur among the latter, the same circumstance will be observable.

The soil on the carbonaceous series generally is far from good, though here and there more fertile spots may be found, as in some places near Bideford, Tiverton, and a few other localities, particularly where the beds are red. In those situations, also, where trappean rocks are mingled with them, as near Launceston, Milton Abbot, and Tavistock, on the west, and near Bridford, Cristow, Ashton, and Trusham, on the east of Dartmoor, their condition seems often much improved, the wash of the decomposed parts of these trappean rocks often passing over them. The country between Launceston, Hartland, and Okehampton, is among the most dreary and barren in the district, a poor yellow clay being a very common product of the decomposed shales and sandstones there found, for the grains of the sandstone are frequently cemented by matter which thus decomposes. The land, moreover, is generally high, and down succeeds down in monotonous succession. The country improves in appearance in the range of these rocks to the eastward; still, however, as a whole, its general character is not fertile, as a journey from Barnstaple to Tiverton will readily show. Oaks flourish well upon these rocks in several situations, and might probably be successfully raised in many valleys now almost uncultivated.

From the very variable mineralogical character of the grauwacke we might anticipate the very great difference observable in the country occupied by that rock, every due allowance being made for the varied meteorological conditions to which it is exposed according to locality. On the north, the hard sandstones of the Foreland, and those extending from the Hangman Hills to Croydon Hill, on the south of Dunster, form such high land, that, for that reason alone, we should not expect much successful cultivation; but in the lower and more sheltered situations little fertility is observable; indeed, there are few among these sandstone beds which would be readily decomposed at their exposed surfaces.

The agricultural character of the calciferous band of schistose rocks extending from Ilfracombe and Combe Martin, by Exford, to Nettlecombe, near Monksilver, is much superior to the last, and very fair land may be seen in the less elevated and sheltered situations. The next band of grauwacke, ranging from the coast between Ilfracombe and Bull Point, on the south of the last, is again less fertile; while that which succeeds it in the ascending series, and which is chiefly composed of fine argillaceous slate, is generally not much inferior, being, however, liable to form a clayey soil where the natural drainage is not good. The next band, principally formed of sandstones, and ranging from the coast, at Morte Bay and Baggy Point, to Heydon and Main Downs, near Wiveliscombe, presents generally a poor soil; while the band above it, extending from the vicinity of Barnstaple, by Dulverton and Raddington, to Bathealton, and which is often calciferous, is frequently fairly fertile.

On the south, the differences of soil, from variations in the mineral structure of the grauwacke and its associated trappean rocks, is still more remarkable; and we may here observe that the latter rocks, which are chiefly compounds of hornblende and felspar, afford the most fertile soils of any in the district, when their decomposition has taken place to any sufficient depth; so much so, that when much disintegrated, they are sometimes worked as marl-pits for manure, and the land thus treated is always found to be greatly benefited. The trappean ash, particularly when mingled with calcareous matter, which is sometimes the case, affords a remarkably fine soil.* Limestone occurs in sufficient abundance in the vicinity of Torbay, Newton Bushell, and Plymouth, to afford an agricultural character. The land upon it is generally considered good, but it is frequently light, and, from the hardness of the subjacent rock (though its surface is often broken into fragments from atmospheric causes), liable to be washed away in exposed situations. In this respect it agrees with the carbonife-

* The trappean rocks in Devon and Cornwall are very commonly known by the name of *dunstone*, the harder being not unfrequently termed *iron* or *ire stone*, particularly in the latter county. Much of the vesicular trap and trappean ash is known as *honeycomb dun*, especially in Devon, and land upon it is always highly esteemed by the farmer. Mr. Worgan (View of the Agriculture of Cornwall, p. 10) observes that wherever the dun, or ironstone, is met with in Cornwall, "it is deemed a fortunate circumstance, being a certain indication of the fertility of the incumbent soil."

rous limestone on the north of the district, near Weston-super-Mare and Uphill, as might be expected from the similarity of their mineral composition. The range of the red and variegated slaty beds of the grauwacke may, upon the whole, be considered as among the most productive of that series in Cornwall and Devon, and very frequently much barley is successfully grown upon it. Thus, much barley, often malted, is exported from Kingsbridge and Padstow, grown upon the red and variegated slates of the country adjoining those places. The red slates, particularly when they contain some calcareous matter, are favourable also to the growth of apples, as upon the banks of the Dart and Fowey.

As in the north, in those localities where the sandstones prevail, there is less fertility than where slates occur. According to the general mineral composition of the latter is also their character of heavy or light; those most approaching to clay slates being liable, where the drainage is imperfect, to become clayey. They generally support a fine growth of oak, as is well seen in the numerous sheltered valleys of southern Cornwall and Devon. The band of grauwacke, including the associated limestones and trappean rocks, which ranges from Ashburton, Newton Bushell, and Torbay, between the granite of Dartmoor and the mica slates of Marlborough and Chivelstone, to Plymouth, and thence along the southern shores of Cornwall by the Looes, Fowey, Veryan, and Falmouth, to the northern part of the Lizard district, may be considered, upon the whole, the most fertile part of the Cornish and South Devon grauwacke, especially the more eastern part between the Tamar, Torbay, and Newton Bushell. Other minor areas, no doubt, afford equally good land; as, for instance, the vicinity of Penzance, a tract the superior fertility of which has been pointed out by Dr. Paris, and correctly referred by him to the decomposition of the greenstone rocks which there abound. He states that, when he wrote (1818), a belt of land around that town, of 1000 acres, produced an annual rent of 10,000*l.**

The mining districts have often a very barren aspect, independently of the destruction of vegetation produced by mining operations on the surface. We have frequently found the ground

* Observations on the Geological Structure of Cornwall, with a view to trace its connection with and influence upon its Agricultural Economy, and to establish a rational System of Improvement by the scientific application of Mineral Manure.—Trans. Geol. Soc. of Cornwall, vol. i. p. 188.

covered, in such situations, by a thin bed of quartz fragments, composed apparently of the parts of those minor veins which often abundantly traverse such countries in different places. It would appear as if, during the decomposition of the general surface by meteoric influences, and the removal of the finer particles of the slates by rains, these fragments had gradually accumulated on the surface, rendering it even less fertile than it would otherwise be.*

Judging from the Lizard, the soil on the serpentine is far from fertile, frequently retaining the water on its surface, so that swamps and marshy places are common. Even on the slopes of the hills, where the natural drainage is good, little can be said for its agricultural qualities, though we have here and there seen some fair grass land, and better corn crops than might, at first sight, be anticipated. As is well known, the serpentine of the Lizard offers a marked example of a particular plant, the *Erica vagans*, a very beautiful heath, keeping to the soil upon it, so that the boundary of the serpentine against the other rocks may be fairly traced by its aid; indeed this plant is rarely found beyond it. The general barren character of the serpentine of the Lizard contrasts very forcibly with the soil on the adjoining diallage rock and sienite, among the most fertile, if not the most fertile, of the lands in the district. As Dr. Paris observes, "the lands between the church (of St. Keverne) and Coverack Cove constitute one of the most extraordinary districts in the kingdom, presenting a rare combination of rudeness and fertility; gigantic boulders of sienite (and diallage rock), lying scattered in all directions, and yet, in point of luxuriant fruitfulness, this country may be denominated the garden of Cornwall."† It affords, indeed, a good example of the unequal decomposition of a rock, so that while it is sufficiently disintegrated in places that pits may be

* Quartz is commonly known by the name of *spar* in western Cornwall, and as *white-acre* in eastern Cornwall and part of Devon. Mr. Worgan, noticing the loose quartz fragments of various sizes dispersed over the surface in many parts of Cornwall, and that it may be sometimes profitable to remove them, states, that "Mr. James, of St. Agnes, cleared a large field of spar, by screening the whole mass of spar and earth, as deep as the yellow substratum, in the same manner as masons screen the earth for their mortar; and the experiment answered well, although it cost 40*l.* per acre: the land was afterwards let for 3*l.* per acre, and the stones were purchased to make a road." (View of the Agriculture of Cornwall, p. 11.)

† Trans. Geol. Soc. of Cornwall, vol. i. p. 189.

formed, and the decomposed rock taken away for manure, in others, hard blocks are scattered over the ground or rise in tors through it; and it also exhibits an instance of the fertility of a soil chiefly derived from the decomposition of hornblende, or diallage, and felspar, the crystallization being large grained.

The hornblende slate and rock of the Lizard is also extremely fertile, contrasting strikingly with the serpentine, which it bounds in many places, and through which it, indeed, rises in small patches in one or two localities, so that it is necessary not to confound the more abundant vegetation upon it with a growth upon the serpentine. Some land near Lizard town, upon hornblende slate was, after being enclosed, not manured for several years, though frequently cropped with barley and wheat; so fertile is the soil upon that rock. No doubt, from the mild temperature of the Lizard district, where snow is rarely seen to rest upon the ground, vegetation may possess advantages upon a given rock, which it would not have in colder parts of Cornwall or Devon; but as at the same time it is much exposed to sea winds, which often sweep over it with great fury, and as the slates, greenstones, hornblende rocks, diallage rock and sienite, serpentine and talco-micaceous rocks, are all exposed to the same conditions, the contrast afforded by the varied fertility upon these mineral compounds is highly instructive, and illustrative of the fact, that soils do, all other things being equal, mainly depend on their subjacent rocks for their agricultural character.*

Dr. Paris has pointed out that the relative fertility of the granitic soil of Cornwall would appear greatly to depend upon the abundance and easily-decomposible character of the felspar in the subjacent rock; and he has also remarked that the relative proportion of mica would seem to have an appreciable effect upon such soils, tending to render them poor, while the iron in some may become an useful element in them.† Our own observations would tend to confirm this view, due allowances being made for

* Speaking of the fertility of some lands in Mullion and other places near the Lizard, Dr. Borlase notices that in his time barley had been sown, and that "in nine weeks commonly, oftentimes sooner, they have had it again in the sack, fit for market. This quick return," he continues, "is not owing to any particular sort of barley, but to the soil and situation, and a kindly warm season, the nights in the summer time on the sea-coasts being seldom or ever cold."—Natural History of Cornwall, (1758), p. 87.

† Trans. Geol. Soc. of Cornwall, vol. i. pp. 173, 174.

exposure to atmospheric influences. These would, however, seem very considerably to influence the agricultural character of the granitic, or *growan** soils, as they are generally termed. For instance, we have been unable to detect any appreciable difference between much of the granite on the high land of Dartmoor and that in the Scilly Islands, in places where both were well decomposed. In the Scilly Islands, particularly in St. Mary's, there is much *growan* land which is fairly fertile, producing good crops of potatoes, wheat, barley, and grass, while Dartmoor is merely covered by heath and coarse grass, and peat is abundant. In one case we have islands in the Atlantic of small relative height, and upon which it is rare to see snow; while in the other there is an extensive area in the interior, varying from 1,400 to 2,000 feet above the sea, on which fogs are frequent, and snow often falls and rests before it is seen on the lower grounds. The country around Moreton Hampstead, several hundred feet lower than the mass of Dartmoor, of which it is the geological continuation, being composed of a portion of the same mass of granite, forms a striking contrast as to fertility with the high land on the west of it. The grass land is generally good, tolerable crops of barley are obtained from it, and the potatoes grown are very highly esteemed and readily purchased at the Exeter market, one to which the products of many fertile lands are brought; yet the general character of the granite round Moreton Hampstead, and of that upon much of the adjoining high land of Dartmoor, is mineralogically the same.

Judging from Devon and Cornwall, there are few soils which are more affected by relative elevation above the level of the sea, in the climate there found, than the *growan*, or granitic soils. No doubt there may be some variation in the mineralogical character of the subjacent granites, and, consequently, of their relative productiveness; but, nevertheless, there is a very constant and prevailing kind of granite which readily decomposes, forming a large part, with the exception, probably, of that in the Hensborough boss, to be found in the whole of them, between the relative fertility of the soil above which, according to locality, very useful comparisons may be instituted. Dr. Boase has indeed already remarked that the fertility of the granitic groups of

* *Growan* is the Cornish name for gravel.

Cornwall gradually increases as they diminish in elevation,* an observation which may very properly be extended to Devonshire. The granitic, or growan soil, is one which frequently requires rain, of which, however, there is no want generally in the district, and the grass grown upon it is considered good for feeding cattle. Under fair conditions as to height and exposure, it is very commonly celebrated for producing good potatoes.† Barley and oats are chiefly cultivated upon it where employed for arable land, wheat being rarely a successful crop except in a few situations, among which St. Mary's, Scilly, and land in the parishes of Burian, Sennen, and St. Leven, in the Land's End district, are the most remarkable.‡ Oaks, ash, and sycamores, grow well upon the growan soils in sheltered situations, and where sufficient attention is paid; of which the grounds of Trebartha Hall, near North Hill, afford as good an example as any we can select.

Peat is very common upon the granitic soils, more especially where the land rises high. Dartmoor produces a large quantity of this substance, which is much employed as common fuel in the country adjoining it.

It has been considered that, at the junction of the granite and slates in Cornwall, the soil is considerably improved by the mixture of the decomposed portions of each rock; and Dr. Paris states that this fact is very observable in many places, more particularly pointing out the superior fertility of this kind of junction at Trengwainton, near Penzance, from Chyoon to Mousehole (famous for producing two crops of potatoes in the year), in the vicinity of Penryn, at St. Michael's Mount, and at Pendarves. This may

* Trans. Geol. Society of Cornwall, vol. iv. p. 365.

† Mr. Worgan observes that "if Cornwall does not grow wheat enough for its inhabitants, it certainly has the merit of supplying other counties with large quantities of potatoes."—(View, &c., p. 75.) He further remarks that, not only are many thousand bushels annually sent to Plymouth and Portsmouth, but that (in 1808) some ship-loads were exported to London. Much of this produce is grown upon the growan soils, and the export would appear as considerable as ever. Indeed large quantities are now forwarded to London by the Dublin steamers which touch at Falmouth, and early potatoes are thus introduced abundantly into the London market. The vicinity of Penzance contributes largely to this early produce, chiefly there grown, however, upon the greenstone soils.

‡ Mr. Worgan states (View of the Agriculture of Cornwall, p. 9), that from 40 to 45 Winchester bushels of red wheat, per Cornish acre, have been raised upon the lands of these three last-mentioned parishes, the Cornish being larger than the common statute acre, in the proportion of about 6 to 5.

no doubt be true in many cases, but it is far from being a general fact. Indeed we can readily perceive that the benefit of such a mixture must depend upon the mineralogical character of both rocks at their junction; now as these vary materially, so we should consider would be the agricultural value of the effect produced. Those parts of the Hensborough or St. Austell granite which contain much schorl, as a large portion of the western side does, are far from fertile, and the altered slate rocks in contact with them are often steril, as may be seen on Fatwork Hill. The like may be seen on Castle-an-Dinas and Belovely Beacon. A large proportion of the skirts of Dartmoor is poor land, especially those parts which come into contact with the carbonaceous series. In those situations where the decomposed drift from the trappean rocks has mingled with the soil, as near Tavistock, Okehampton, Bridford, Cristow, and Hennock, the soil is much improved, and being close to the granite, so that the disintegrated portions of the latter are occasionally washed down and mingled with it at the same time, the opinion above noticed might appear to be more borne out in those situations than it really is. As the granite is more constant in its mineralogical character than the rocks which come into contact with it, and generally become more or less altered, often a sufficient reason in itself for their decomposed portions to be more fertile than they might otherwise be, probably the benefit that may be derived from any mixture of the growan and schistose soils mainly depends upon the mineral composition of the slates near their junction with the granite.

The alluvial lands, though generally fertile, vary, as might be expected, according to the mineralogical composition of the rocks from which they have been chiefly derived, as may be seen by comparing the flat lands bordering the rivers in numerous places. Let, for example, the alluvial land on the banks of the Culm, traversing red marl and sandstone, be compared with that between Sheepwash and Monks Okehampton on the banks of the Torridge, flowing among the carbonaceous series, or with many among the granitic districts, and there will be little difficulty in perceiving the superior fertility of the former. Numerous compounds would appear to be effected, in some places producing better soils than each rock separately affords; of this, probably, the alluvial lands among the limestones and slates of the grau-

wacke may often be taken as examples. Wherever the rivers have held their courses amid easily decomposed trappean rocks, the usual grauwacke compounds appear much improved. Indeed by carefully considering the rocks traversed by the rivers, and the kind of finer sedimentary matter likely to be borne down during floods, adding the relative amount of soil, in which there is already much animal and vegetable matter, that may be transported at the same time, and a fair average estimate may be formed of the relative agricultural value of alluvial lands. At the heads of estuaries much alluvial matter is necessarily accumulated, offering a more uniform character than it would otherwise do from the deposit of estuary mud in such situations, nevertheless presenting differences in the drier places according to the kind of sedimentary matter borne down by the rivers which respectively flow into them. The Bridgewater and Worle levels can scarcely be considered alluvial in the ordinary acceptation of the term, since a large part of them would appear regular detrital deposits upon the bottom of an estuary in which creatures usually inhabiting such situations lived and died, as they have done in many rocks. These levels support considerable numbers of fine cattle, and portions of them supply large quantities of cheese, generally known as Cheddar cheese, to Cornwall, Devon, and South Wales.

As connected with the economic geology of the district, we must not omit to notice the sea and blown sand which is extensively employed as manure in different parts of it. It is, as we have seen (p. 426), partly now thrown up and partly an accumulation at various points when the relative levels of sea and land were different from those we now find, the land having been apparently raised. It was employed, as now, for agricultural purposes, 236 years since, as appears by Carew's Survey of Cornwall (1602). Mr. Worgan, in 1811, estimated the expense incurred for the whole county in land-carriage for this sand at upwards of £30,000 per annum.* Dr. Paris states it to have been ascertained, that 4000 horse-loads have been taken from Bude in one day.† Not only is

* View of the Agriculture of Cornwall, p. 128. Borlase cites a letter in the Philosophical Transactions of April, 1675, in which the carriage of sand is estimated at £32,000 per annum (Nat. Hist. of Cornwall, p. 48). Taking this sum and that given by Mr. Worgan as fairly accurate, and as Borlase did not object to a similar charge for the carriage of sand in his time, it would appear that it had remained nearly the same for about 140 years.

† Trans. Geol. Society of Cornwall, vol. i. p. 193.

it carried from that place by the Bude and Launceston canal, with its branch extending to Holsworthy, the chief commerce on which is the conveyance of this sand, but it is conveyed over land abundantly in carts, so that a considerable portion of the adjoining portions of Cornwall and Devon are supplied with it from Bude. A good road has been constructed to Trebarwith Sands, on the coast near Camelford, purposely for conveying the sand there found into the interior.

Large quantities of sand are obtained upon the Dunbar in Padstow harbour, employing constantly about eighty men in several barges. The amount of sand taken from this harbour was estimated in 1836 at about 100,000 tons per annum,* a large proportion of which was transported into the interior from Wade Bridge by the Bodmin railway, and its branch, up the Camel, to Wineford. Notwithstanding the constant addition of sand thrown by the sea upon the Dunbar, this large demand appears to cause its decrease; and we were assured by competent persons that it had lost from six to eight feet in height within the last half century. Independently of the sand conveyed inland by means of the river, large quantities of sand are also taken away by means of carts, horses, and donkeys, from the sand hills opposite Padstow.

Sand for agricultural purposes is also obtained in numerous bays and creeks on the north coast of Cornwall from Trevose Head to the Land's End, and is esteemed in proportion to the shelly matter it contains. Of the few places whence sand is carried on the south of Cornwall, that from Falmouth harbour, composed of little else than corals, shells, and their fragments, is most esteemed. If we consider that Padstow harbour furnishes one-fourth of the sand employed for agricultural purposes in Cornwall and Devon, and estimate the ton as containing about fourteen cubic feet, we should have 5,600,000 cubic feet of sand, chiefly composed of comminuted sea-shells, annually conveyed from the coast, and spread over the land in the interior as mineral manure.

* According to Mr. Worgan, the quantity of sand taken from Padstow harbour, in 1811, was 54,000 cart loads. Probably the facility afforded by the Wade Bridge and Bodmin railway may have considerably increased the consumption of this mineral manure, independently of the general improvement in the agriculture of the country, within twenty-five years.

If we take the produce of Padstow harbour as only a fifth, then we should have 7,000,000 cubic feet thus distributed.

As may be readily conceived, numerous local causes tend to diminish or increase the value of the sands along the coast; generally speaking, the harder the coast and the less the detritus that can be worn from it, the greater the proportion of the comminuted shells in a given portion of sand. The easier also the streams or rivers flowing towards the shelly sands can deposit the sandy detritus they may bring down in floods before they reach the shelly banks, the finer the sand. We have found the sands, considered worth removal for agricultural purposes, to vary from 40 to 70 per cent. in their calcareous contents. Dr. Paris states that the samples of sand usually employed, and which he examined, contained from 60 to 64 per cent. of carbonate of lime. Probably this may be taken as a fair average proportion. The same author suggests that, though unquestionably the beneficial effects of this mineral manure depend on the presence of the calcareous matter, the sea salt with which it is impregnated contributes materially to its fertilizing powers; citing as a fact, bearing strongly in favour of this opinion, that the farmers send several miles to the harbour of Padstow for the sand which is drifted close to them.* The farmers certainly seem to prefer the sand which the tide has just left, and which must consequently contain much saline matter. It often also then contains fragments of sea-weed, and occasionally fresh animal matter derived from dead marine creatures, among which are the tenants of microscopic shells still little decomposed in them.

Road Materials.

As the ability of maintaining good roads, however skilfully they may have been planned, greatly depends upon the facility of providing proper materials for them, the geological structure of a district is necessarily important as to the power of forming efficient means of communications through its various parts. That under consideration is, as a whole, extremely well supplied with fair

* Trans. Geol. Society of Cornwall, p. 194. Borlase has observed that the salter the sand the better it was for agricultural purposes.—(Nat. Hist. Cornwall, p. 82.) "Blown sand," he says, "which has been long exposed to the air, is good for little, its salts are so wasted by wind and rain."—(*Ib.* 83.)

material for this purpose, and occasionally with some which cannot be exceeded in its quality.

In general, road surveyors and commissioners of turnpikes are too apt to consider that a very hard material must necessarily be the best for the roads, not perhaps always reflecting that toughness is also a very essential quality. Road-stones have to resist both friction and pressure—friction chiefly caused by the blows from horse-shoes, the aggregate amount of which is very considerable over a mile of a well-frequented road; and pressure, principally produced by the weights, often great and upon narrow wheels, drawn over them. Hence a road-stone should be both hard and tough, qualities which are not always attainable in the same rock.

Upon the chalk and green sand of the district, covered as they are by flint and chert gravel, there is no deficiency in good material, though certainly, on some of the bye roads upon these rocks, it cannot at present be said that it is always laid upon them in the most effective manner. We also sometimes see, on the part of the surveyors, a choice of the flint instead of the chert gravel, where both are to be had equally cheap and plentiful, because it is the hardest. Being, however, comparatively brittle, the flint is greatly inferior to the chert, which is both tough and hard, making a far better road, as may be observed in some of the lines of turnpike traversing the Black Down Hills and their geological equivalents nearer the southern coast, where both are employed, according to the different views of the commissioners or their surveyors.

As much of the flint and chert gravel is scattered over the lias and red marl and sandstone adjoining the green sand and chalk hills, facilities are afforded for making good roads over them which they would not otherwise possess, for even the lias limestone is an indifferent road material, as may be observed in the vicinity of Langport and Somerton, being neither hard nor tough, and therefore easily pulverised, becoming muddy in rain, and dusty in dry weather. Independently of the chert and flint strewed over much of the red marl and sandstone, conglomerate beds in the lower part of that series, and gravel, such as that of Straightway Hill (p. 396, fig. 72), also scattered over it towards Exeter, afford fair road materials. The neighbourhood of the Haldons is supplied either with the flint and chert gravel, brought

from them, or scattered over the adjoining lower ground, or from some conglomerates of the red sandstone series. When sufficiently hard, the trappean rocks, associated with the latter series, are employed for road-stones; as near Thorverton, Silverton, Kellerton, Posbury, and Exeter. If well selected, for hardness and toughness combined, they make excellent roads; that from parts of Posbury Hill is particularly good. The siliceous pebbles rejected by the lime-burners from the conglomerate with a magnesian cement, between Thorn St. Margaret, and Fitzhead, and extending thence towards Williton, supply materials for the country adjoining, when there is insufficient transported gravel for the purpose.

The beds of the carbonaceous series afford materials of very variable quality. Those beds which approach chert, as is often the case in some localities, are the best. Fair roads composed of this material may frequently be seen, somewhat marked in appearance when rendered black by the admixture of carbonaceous matter; as between Barnstaple and South Molton. The ordinary sandstones, unless somewhat cherty, do not form good roads, being readily crushed; and when the cementing matter of the grains is argillaceous, as often happens, easily reduced to mud. The roads, therefore, in the area occupied by the carbonaceous series are very variable, independently of the differences caused by the unequal amount of skill in the surveyors, both parish and turnpike. While some of the cross-roads are in wretched condition, from the want of good materials within a reasonable distance, others are hard, however indifferently they may be placed on them, from their proximity. There is, nevertheless, generally, throughout the area occupied by the carbonaceous series, a sufficient mixture of sandstones with the shales to ensure good main parish roads, with ordinary traffic upon them. The limestones, where they occur, are commonly too precious to be employed for roads; though, near those places where they occur, the roads are sometimes advantageously repaired with them. Towards the south, where trappean rocks (many of which are hard and tough) are intermingled with this series, the roads formed with them are necessarily good, and quarries among them are common for that purpose.

With respect to the area occupied by the ordinary grauwacke, there is also much variety of road materials. In North Devon

and Western Somerset, where bands of very different mineral structure range across the country, we find the power to procure good materials for roads to correspond with them. Thus, while upon the range of the hard sandstones of the Foreland and the Hangman Hills, a fair material is to be obtained by opening quarries close to the road; upon the argillaceous slates, it must be procured from variable distances, and when the expense of so doing becomes heavy, the main communications are alone well kept, and the minor lanes become almost impassable in wet weather from their clayey character. According, therefore, to the mineralogical character of the respective parts of the grauwacke of North Devon and Western Somerset, may we expect to find the power of procuring good road materials, the actual state of the roads depending greatly in the relative facility with which that power is brought into action.

On the South, from the mixture of hard beds with the more common argillaceous slates in many places, the frequent occurrence of limestones, trappean rocks, and elvans among the grauwacke, the indurated character of many of the altered beds near the granite, and the multitude of quartz veins traversing the rocks in many localities, there are few portions of the area there occupied by the grauwacke series without the power of readily procuring good materials for roads. Where the hard and tough limestones are sufficiently abundant to be broken up for roadstones, as is the case near Newton Bushell, Torquay, Brixham, Yealmpton, and Plymouth, good roads are the consequence; due allowance being made for the necessary care in construction. Some of these limestones are carried by water to less favoured localities; as, for instance, from Plymouth to the argillaceous slate country near Kingsbridge.

The hard and tough trappean rocks, associated with the grauwacke of South Devon and Cornwall, form the best road material of the whole district, and some of them can scarcely be exceeded for their value in this respect. Greenstone has already been advantageously shipped, as a road material, from the Dart to London, and employed in some parts of the suburbs of the metropolis. It would be difficult to find a substance better calculated to resist the great wear of the streets in London than the hard and tough greenstone of Treluswell, near Penryn, which might be exported at comparatively small cost from the latter

place. So tough and hard is this greenstone, that though the material was acknowledged to be excellent, the commissioners of the adjoining turnpike trusts were compelled to relinquish the use of it, from the mere cost of breaking it; an objection that would be scarcely urged against its use in the streets of a great metropolis.

The elvans are often used as road-stones, and when well selected for combined toughness and hardness, constitute an excellent material for that purpose. Among the toughest and hardest we have observed, may be noticed that which traverses the greenstone at Burnt House, on the road from Penryn to Redruth. Its extensive use, however, would necessarily be limited from its mode of occurrence and the comparatively small breadth of the dyke. The use of compact elvans, when well chosen, renders many of the Cornish roads excellent.

Generally speaking, the roads constructed with quartz are very uneven. This substance is commonly obtained from veins in which the hard quartz is found irregularly mingled with more earthy portions; and while it sometimes occurs in large lumps, it at others runs in thin veins or strings in softer matter; hence, when the whole contents of a vein, for they are seldom separated, are thrown upon a road, the harder parts best resist the pressure and friction, and the road becomes uneven. From a similar cause, those roads which are formed with the varied materials rejected from the mines are commonly irregular on their surface.

The common Cornish and Devonian granites are far from affording good road materials, the felspar readily crushing under pressure. In all those roads traversing the granitic districts, and upon which there is a fair allowance of travelling, this fact will be readily observed. In such situations, those in charge of the high-roads are commonly compelled to use the harder varieties of schorl rock, or the compact elvans, when either can be procured within reasonable distances. Where quartzo-schorlaceous veins traverse the granite, as is frequently the case in some localities, they are broken and employed for the same purpose. In the dock-yards at Plymouth, where very great weights are often moved, it is found that pavements of Cornish or Devon granites do not resist pressure so effectually as the sienite from Guernsey and Jersey, and hence the latter is employed for that purpose.

The diallage rock of the Lizard would probably be found a

good road material, a large portion of it being both hard and exceedingly tough. It would also be excellent for pavements where great weights are moved or much traffic exists, and therefore good for wharfs, dock-yards, and the streets of towns. This diallage rock might readily be exported, at comparatively small cost, from the little pier-harbour of Coverack Cove, near which place millions of tons, in blocks of large size, are scattered neglected over the surface, particularly in the direction of Crousa Downs; whence the name of *Crousa stone* for diallage rock in the vicinity of St. Keverne and Coverack.

Building Stones.

The relative facility with which good materials may be obtained in a district is, to a certain extent, marked by the appearance of the towns and villages in it, the comparative cost of obtaining them being in general better shown by the character of the ordinary houses than by that of the public buildings and larger mansions, the stone for which may sometimes have been carried comparatively considerable distances. From the frequent practice, however, of selecting those stones which yield readily to the tool, and are hence commonly termed *freestones*, whatever may be their other mineralogical characters, the most desirable, and therefore, eventually, the cheapest, are far from being always employed. Indeed it sometimes happens that we find the common cottages built of durable materials, while the larger mansions and public buildings are not; the materials for the latter having been selected because they were readily worked up for the ornamental parts, while those for the former may have been thrown aside in the same quarry because they yielded less freely to the tool.

In passing through the chief towns of Great Britain, it will be easily seen that if more attention were paid to the mineralogical character of the stone employed in the construction of the buildings, that frequent decay, or decomposition, even in those erected within a few years, which we so often observe, would be avoided, at comparatively small cost; and we should find fewer of our public edifices losing all traces of the finer work of their original structure. The number of cathedrals and other public buildings mouldering away externally, from inattention to the

quality of the stone employed in them, is far greater than might be anticipated by those who have not directed their attention to the subject. Building materials for cathedrals, churches, abbeys, castles, and the public edifices of towns, can scarcely, in general, be said to have been selected, except probably by the Normans; stone having been usually taken from the nearest quarry, provided it had a tolerable appearance and was readily worked, it being left to accident whether the material so obtained were durable or not.

There was much excuse for this accidental durability of the stones employed in public or large private edifices in former days, when the mineralogical structure of building materials was so little understood; and the architects of those times could not always have churches or castles before them, from which they might judge of the relative durability of any stone they were about to employ; the quarries opened by them being also then often first worked to any considerable extent. The architects and engineers of the present day cannot, however, avail themselves of these excuses, for the necessary chemical and mineralogical knowledge is readily acquired; and the number of public and private edifices, of various dates, scattered over the country, is so great, that the relative durability of the materials employed in their construction can easily be seen. It is, nevertheless, well known that, with some few exceptions, the mineralogical character of the stone employed in public works and buildings has hitherto received little attention from either architects or civil engineers in this country, more especially from the former, whose value of a material seems commonly to have been guided by the opinion of the mason. Now the mason seems almost always guided in his opinion by the freedom with which a stone works—no doubt an important element in the cost of a building, but certainly one which should not be permitted to weigh heavier in the scale than durability—and hence many a fine public or large private building is doomed to decay even, in some cases, within a few years.

In estimating the relative durability of any given stone, which may appear to resist decomposition from atmospheric influences in the country, no doubt due allowance should be made for the power of lichens to protect the external parts of buildings in the latter. These are not usually found in large towns, particularly those

in which there is much coal smoke, such as Birmingham, Manchester, Bristol, and London, which appears unfavourable to their growth. Still, however, the value of relative mineral structure remains the same, and we should not expect a sandstone, formed of quartz grains loosely cemented by calcareous or argillaceous matter, to last so long, exposed to the weather, as one in which quartz grains were firmly bound together by a compact argillaceous or siliceous substance. According to the texture and variable composition of the different calcareous and calciferous rocks, might a judgment be formed of their relative durability; and granites, in which decomposition has already commenced in the felspar, cannot be expected to remain firm under atmospheric influences. In the inspection of quarries, and for large works it is very necessary to inspect them, these and the various other mineralogical circumstances, to be considered in building stones, should be taken into account; and indeed a knowledge of them ought to be required on the part of those engaged in public works.

At Beer, in Devonshire, we find the lower part of the chalk or the upper part of the green sand, for the beds may be said to occur at the passage of the one into the other, worked for building stone. It is nearly white, and chiefly composed of carbonate of lime, with the addition of some argillaceous and siliceous matter, and a few scattered particles of green silicate of iron. When first quarried this stone is, as is generally the case with similar materials, somewhat soft and easily worked, from the presence of the water disseminated through the stone, becoming hard when this water has been evaporated by exposure. The chief quarry is subterraneous, and extends into the hill about 180 yards, the roof being supported by large square pillars formed by portions of the workable beds left standing. The following eight beds are worked beneath about eighteen feet of indurated chalk without flints, termed *skull*:—

	Ft.	in.		Ft.	in.
1. Upper bed—rather hard	1	6	5. Hard	1	4
2. Soft	1	6	6. Mixture of hard and soft	1	4
3. Rather soft	2	0	7. Very hard	0	8
4. Rather soft	2	0	8. Very hard	2	0

A shaft was formerly sunk, and a level driven into the hill, between Beer Head and Branscombe, in order to obtain a continu-

ation of the same beds, but the work does not appear to have been profitable, as it is now abandoned.

The Beer stone has been quarried for ages, and some of it is stated to have been employed in the old work in the interior of Exeter cathedral. Though not generally considered to stand exposure well, we have seen portions of the harder beds looking little decomposed in some old walls. It could be exported from Beer.

Chalk flints and green sand chert are often employed in the construction of common houses and walls; and, in one instance, the Wellington monument on the Black Down Hills, they have been used in works of more architectural appearance. Though by no means sightly, they are necessarily very durable materials. The indurated nodules of the lower part of the green sand, when separated from the latter by the action of the sea, and strewed over the coast, are used in building, and have been extensively employed in the interior of the pier, or Cobb, at Lyme Regis. It is a material that may be considered to resist the action of the atmosphere fairly.

The inferior oolite does not produce good building stone within our district; the nearest place to it, where durable material is obtained from this rock, occurs at Ham Hill, between Ilminster and Yeovil. A brownish shelly limestone is there worked, above the inferior oolite sands, of excellent quality, readily tooled, and very durable, if properly selected; as is proved by the fine condition of numerous churches and mansions in the neighbourhood.

With respect to the lias, though some of the limestone beds are employed for buildings, and the houses in some small towns and many villages are constructed with them, it is rarely a good material for resisting the decomposing effects of weather. When taken from the sea-side, as near Lyme Regis, where it has become impregnated with saline water, it is notoriously bad. As the beds vary materially in mineralogical structure, chiefly as respects the quantity of the argillaceous mingled with the calcareous matter, much depends upon their selection in the construction of buildings, and hence the very variable condition in which we find them. Some thin and compact beds, to the eastward of our district, are placed on their edges and employed for fences, where they appear fairly to resist the action of the weather. To show the condition of lias after long exposure, we may

cite the external parts of the chapel of Joseph of Arimathea, a beautiful Norman structure, among the ruins of Glastonbury Abbey, also out of our district, though only a few miles from it in the eastward. We there find that, while the Doulting stone, probably an equivalent of the Ham Hill rocks, has scarcely suffered from decomposition after so many centuries of exposure to atmospheric influences, the lias columns and capitals, wherever employed, have nearly mouldered away, though from those parts which remain the material employed seems to have been of the compact kinds.

In the red sandstone series, the beds, with the exception of the conglomerates, are seldom sufficiently indurated to serve even for the commonest building purposes. The conglomerates, however, are often much used for house walls, but the material being far from sightly, and liable to decomposition from exposure to the weather, the better buildings constructed with them are covered by cement or rough-cast. The conglomerates from the Heavitree quarries, near Exeter, have long furnished common building stone for the neighbourhood, and various other conglomerates on the eastern part of the red sandstone series have likewise been quarried for the same purpose. When sufficiently indurated, it is employed for bridges. A fairly indurated conglomerate is worked by the side of the Taunton and Tiverton canal, between Halberton and Sampford Peverell, and is used for this and similar rough purposes. The magnesian limestone or conglomerate is occasionally used for building near Western-super-Mare, but the facility with which the adjoining carboniferous limestone may be obtained for the buildings there required, renders it less employed than it would probably otherwise be. The conglomerate with the magnesian cement, between Williton and Thorn St. Margaret, is in places used for common building purposes. Cobb cottages prevail throughout a large part of the area occupied by the red marls and sandstones, when the locality is not sufficiently near the lias, or to the flints and chert still upon the green sand, or transported over the red marls or sandstones. The brick town of Taunton shows that good stones for architectural purposes are not readily obtained in its vicinity; and the like may be said for several other places.

On the south, the trappean rocks of the red sandstone series are often employed for buildings, and though not suited for

fine architectural work, they are durable if well selected, as is shown by the remaining walls of Rougemont Castle, at Exeter, where the porphyritic, and even vesicular trap, probably obtained from the hill on which the castle stands, is generally in as good condition as the day it was worked. Thorverton stone has also been much used, and is, if well chosen, a very good material where its brownish colour is not objectionable. The porphyritic blocks from the red conglomerate of Teignmouth are employed as building materials in that town, and for common walls are found very serviceable. In selecting these trappean rocks care should be taken to avoid those which show the commencement of decomposition, though they are then most easily worked, for the felspathic portions in them will readily disintegrate before the weather.

The carboniferous limestone on the north-east of the district, which is now merely employed for common walling, usually covered with cement in the better houses, might readily be tooled and rendered available for finer architectural purposes, if its usual gray tint were not objectionable. It is both a hard and durable material, and for engineering purposes large blocks might be readily obtained.

As to the carbonaceous series, though it abounds in sandstones, many of which are employed for the buildings in that part of the district, there are scarcely any which deserve to be used for fine work, or far from the localities where they may be quarried. There are few also which can be considered durable, with the exception of those in which the siliceous matter so abounds as to render them almost cherty, in which case they rarely have a good appearance.

With respect to the grauwacke of North Devon, though the sandstones in it are employed for the ordinary building purposes of the country, there are none which we have seen that deserve notice or use beyond those places near which they are raised. Many of them are very hard and durable, but their usual colours are against them, as for example those of the Hangman Hills, the Foreland, and North Hill, between Porlock and Minehead.

Throughout South Devon and Cornwall, the grauwacke here and there only furnishes material calculated for finer architectural purposes, though it often affords common building-stone in abundance. The better beds are chiefly found near Newnham Park, on

the north of Plympton, in Devon, and in the vicinity of Liskeard, and of Bodmin, in Cornwall, the arenaceous strata being there readily worked as freestones. Some of the trappean ash beds are also known as *freestones*, and are employed for buildings, and would appear to be more durable than might be expected, as will be seen by the ancient door-way now forming the entrance into the White Hart Inn, at Launceston, which is, considering its antiquity, in tolerably fair condition. The limestones of South Devon are, of course, employed as building materials in the vicinity of those places where they occur, in the same manner as the harder trappean rocks, but they are rarely tooled highly for architectural purposes, though they would form a durable material where their gray tint would not be considered heavy. The new church at Bridge Town, near Totnes, is chiefly built of tooled limestone from the neighbourhood. At Plymouth, the limestone there so common has been extensively employed for the breakwater in the Sound. While on the subject of the limestone in the grauwacke, we should notice the dolomitic rocks near Yealmpton, so well fitted both on account of durability and specific gravity for sea-walls and piers for harbours.* It might readily be obtained in great abundance and be easily shipped upon the Yealm, which is tidal to distances varying from half a mile to one mile from localities where it might be so procured.

Generally speaking, granites or elvans are so distributed in Cornwall, that they constitute the larger proportion of the building materials of that county, more especially the elvans which are much employed; hence the number of quarries opened upon them, and the facility with which these granitic dykes may be commonly traced. Around Dartmoor also, and between that mass of granite and the Brown Willy boss, they are also much used. There is much good granite on Dartmoor, though it is not always sufficiently accessible to be carried long distances; the chief places where it is worked in large quantities and afterwards exported,

* For sea-walls and pier-harbours exposed both to heavy breakers and to the grinding action of shingles mechanically suspended in them during on-shore gales of wind in many situations, it is obviously very desirable to combine hardness with great specific gravity when both can be obtained in the same material. The greater the weight of a given sized sea-wall or pier, all other things being equal, the better will it stand the force of the breakers; hence, this dolomite would stand the battering forces of the breakers better than the Plymouth or Torbay limestones, in the proportion of about 285 to 275.

are Hey or High Tor on the east, and near King Tor on the west. The granite from the former place is conveyed by a tram-road to the Stover canal, down which it is carried in boats and afterwards down the Teigh to Teignmouth, to be shipped for its destination. That from the west side of the moor is conveyed by the Prince's Town and Plymouth tram-road to the latter place and shipped.

The continuation of the Hingston Down granite is worked up the Tamar near New Bridge, and exported from Morwellham. A very hard variety is obtained upon the higher part of the Down, and has been employed advantageously for pavements.

The granite of the Brown Willy boss has not hitherto been much used except in its immediate neighbourhood, though it contains material of excellent quality, as may be seen in front of the great hotel at Bodmin, built of that from St. Breward,* where large quantities of equally good material may be obtained, as also from Pendrief, near Blisland. We believe, however, that within the last year or two it has been exported from Wade Bridge, after being brought down the railway in the valley of the Camel, which runs at the foot of some of the best rocks. It is evidently a material that might be advantageously exported for works at or near ports in the Bristol Channel.

The chief quarries in the eastern or hard part of the Hensborough mass of granite, are those of Mr. Austen Treffry, up the Par valley, commonly known as Lostwithiel granite. Extensive quarries are there worked, and the stone is brought to the head of the canal, near Pons Mill, upon which it is conveyed to Par Harbour, and there shipped. Large quantities of this granite have lately been exported. The greater part of the western portion of the Hensborough granite is too decomposed to allow of its use in those works for which granite is usually employed. Nevertheless, that obtained near St. Stephen's, and thence named St. Stephen's granite, is not of unfrequent use in some of the adjacent parts of Cornwall, though it is a material which can scarcely be considered durable. A much better stone than that usually known as St. Stephen's granite, is obtained at Burthy Quarry, about a mile and a quarter south of Caliquoiter Rock.

The Carn Menelez mass has chiefly furnished the granite most commonly known as *Cornish*. It is nearly altogether shipped at

* Commonly pronounced in that vicinity, *Simonward*.

Penryn, where it is brought variable distances from different quarries in the vicinity, many situated in the parish of Mabe. Being obtained from different localities, it will readily be supposed that the quality of the stone is very variable. It is commonly divided into first and second grits, and it is to be feared that, in many works executed in Penryn granite, less of the fine or first grit has been employed than ought to have been used.* As might be expected from irregularity in demand, the export from Penryn has fluctuated materially.

In 1824	it amounted	to	10,178 tons.
1825	,,	,,	10,781 ,,
1826	,,	,,	18,179† ,,
1835	,,	,,	8,310 ,,
1836	,,	,,	11,538 ,,
1837	,,	,,	5,295‡ ,,

* Though the prices of Cornish granite vary materially from time to time according to circumstances, the following list of those which we have obtained for the Penryn granites may be useful, as showing what they may be now (1838) rendered for in the river Thames below London bridge, and under a crane if required, as also nearly showing the cost of granites generally shipped from the south coasts of Devon and Cornwall, due allowance being made for differences in quality.

Ashler for building sea-walls, from three-fourths of a ton to two tons, standing around all fair :—

Best blue fine granite or grit, at . .	2*s.*	2*d.*	per cubic foot, scabled.
Second blue grit	2	0	Ditto.

Coping for sea-walls, of or about 4 feet wide, from 4 to 6 feet long, and 1 foot 3 inches to 1 foot 6 inches thick :—

Best blue fine grit	2*s.*	4½*d.*	per cubic foot, scabled.
Second blue grit	2	2½	Ditto.

Blocks of granite from 2 to 4 tons, regular sided :—

Best blue fine grit	2*s.*	7½*d.*	per cubic foot, scabled.
Second blue grit	2	4½	Ditto.

Blocks of granite from 4 to 6 tons, regular sided :—

Best fine blue grit	3*s.*	0*d.*	per cubic foot, scabled.
Second blue grit	2	9	Ditto.

Paving from 3 to 10 feet superficial, 6 inches thick, good blue grit, pick-worked, at 1*s.* 2*d.* per foot superficial.

† The quantity for this year is taken from the Transactions of the Geological Society of Cornwall, vol. iii. p. 360. That for the other years is from the information of Mr. Paul Williams of Penryn.

The total quantity of granite exported from Cornwall in 1826, as stated in the above work, excepting that from the Tamar, which could not be ascertained, was 21,710 tons, 2189 tons having been shipped at Gweek, 998 from Charles Town, and 344 from Fowey.

‡ The quantity of granite estimated to have been shipped at Penryn for Plymouth, from 1835 to 1838, inclusive, is 3000 tons.

*

A granite is obtained from Breague, forming part of Tregonning Hill, resembling that from St. Stephen's above noticed, being like it in an incipient state of decomposition. As, therefore, it is easily tooled, it is employed in its vicinity.

Though there is good granite in the Land's End mass, we have not heard of its being exported, though it readily might be shipped from Penzance. A fine-grained variety, considered very durable, and one much used near the latter town, is obtained from Castle-an-Dinas. The granites from Paul and Madron usually contain large crystals of felspar, and that from Ludgvan is very micaceous. They are all esteemed durable materials, though not so sightly as when the constituent minerals are more equally mixed. The granite of the Scilly Islands is generally of a coarse appearance, and therefore not ex orted. Judging from old buildings, much of it is fairly durable. The granite of Lundy Island contains some of good quality for the more common purposes for which that material has been employed, and seems hitherto to have been much neglected, though from the position of the island it might be easily conveyed to the various ports in the Bristol Channel and up the Severn.

It would be extremely difficult to obtain an approximation to the value of the granite annually raised in the district, and employed for bridges, pavements, rolling-stones, columns, and gate-posts, in it, independently of that used in common buildings. Collectively, it is probably considerable; but, if we estimate the average quantity exported in Devon and Cornwall at 20,000 tons annually, and value it on the average, before export, at 1*s.* 9*d.* per cubic foot, taking fourteen cubic feet to the ton (the usual allowance), the value of granite exported would amount to 24,500*l.* annually.

For durable stone, the harder elvans of the district, particularly when of good cream and other light colours, may be considered

It is stated by Dr. Paris, in the Transactions of the Geological Society of Cornwall, vol. i. (published in 1818), p. 232, that the quantity of this granite shipped in the previous ten years amounted to 40,000 tons, the quantity actually raised having been much larger in consequence of the number of blocks which had been condemned, from being damaged, and sold at low prices for common building purposes in the country. The number of men employed in quarrying the granite near Penryn was then (1818) estimated at about 400, their wages varying from 12*s.* to 15*s.* per week each, the lords of the soil receiving ½*d.* per cubic foot, or 7*d.* per ton, for all the granite quarried. The average number of men employed in these quarries for the last four years (up to 1838) may have been about that above noticed.

as the best building materials in it; their durability and appearance may be seen in many churches and old mansions, where the finer carvings of the ornamental parts are as sharp as the day they were put up. Occasionally the felspar crystals may have been decomposed and have been washed out, but the siliceo-felspathic base has remained firm, thus preserving the sharp character of the work. The Roborough stone, an elvan which crosses the Down of that name between Plymouth and Tavistock, has long been celebrated in that neighbourhood for its appearance and durability. The Pentuan stone has hitherto been that most celebrated in Cornwall; it certainly is a fine material, but probably owes its relative celebrity very much to position, being readily exported from the port adjoining it. It has been much employed in Cornwall, and found durable. It is also more readily sculptured than might be expected, as will be seen in the work executed in Pentuan stone for Mr. Austen Treffry's mansion at Place, Fowey.*

The elvans may be considered as among the chief building-stones of Cornwall, and are commonly employed in the houses and works at numerous mines, dykes of them being frequently found in and near them. When, however, in an incipient state of decomposition, and then too frequently prized by the mason for his work, they cannot be trusted for durability, though they often have a good appearance. They would sometimes be mistaken for fine light-coloured sandstones, as, for example, those which occur at Newham, near Truro, and at Porkellis, near Wendron. Some fine and apparently durable elvans, occur near Penryn, as at Trewarles and Roscrow, which might readily be exported with the granite from that place.

We cannot close this sketch of the building materials of the district without noticing the consolidated sand, now probably in part forming, which has been employed in the construction of houses, and even in churches, as for example that of Crantock, where it has been much used. The chief locality whence it has hitherto been obtained is New Quay, where no doubt the quantity that can be supplied is somewhat limited. It is found also at the bottom of the blown sand hills in other places, but probably in small quantities compared with the unconsolidated

* Carew notices the use of Pentuan stone for "windows, dornes (door-posts), and chimnies," in his History of Cornwall, 1602 (reprint of 1769, p. 6).

head of sand above it, and, therefore, of difficult access at small cost. When first raised from its bed it is easily cut, but by exposure to the atmosphere it becomes hard, in consequence of the evaporation of the water previously contained in it.* Judging from Crantock church, it is a substance which suffers little from atmospheric influences. Ancient stone coffins constructed with this material, have been found in Crantock churchyard, and one or two may now be seen there.

Finer materials for polished columns, vases, &c.

With respect to the finer materials for buildings, such as will advantageously admit of being worked and polished, as also for smaller ornamental purposes, such as interior columns, chimney-pieces, slabs for tables, vases, and even stones employed in jewellery, the southern part of the district may be considered rich. Commencing with the chalk, we find numerous flints in it, and indeed in the gravels above it, which, when cut and polished, have a good appearance if worked into snuff-boxes and articles of the like kind, particularly when the spongiform bodies included in them are marked by many varieties of colour. In the green sand the chalcedony is often extremely beautiful, and pieces sufficiently large to form small cups or vases might be sometimes obtained. Portions of this mineral when worked into seals cannot be distinguished from the finest white cornelian, which in fact they then are. Both such flints and chalcedony are found on the coast between Lyme Regis and Sidmouth, where also are discovered some varieties of jasper (from the green sand), many specimens of which closely approach to those known as Egyptian pebbles, and indeed are quite as beautiful. Some of the silicified fossil wood is extremely handsome when worked into ornaments.

Rock-crystals are, as might be expected, somewhat frequent among the quartziferous veins in the granite, elvan, grauwacke,

* The cement of a coarse conglomerate at New Quay, formed of this consolidated sand, is so hard, that the pebbles of quartz and grauwacke are generally broken across by a blow upon the rock, and do not separate from the cement. Borlase describes the consolidated sands of New Quay as the only good freestone in Cornwall, and remarks, that less perfectly consolidated substances of the same kind are here and there discovered among the Gwythian and Perran sands. He observes that it becomes hard by exposure, and points out Crantock church as an example of this fact.—Nat. Hist. of Cornwall, p. 95.

and beds of the carbonaceous series in Devon and Cornwall. Many found in the latter county, and commonly known as *Cornish diamonds*, are sufficiently transparent to be cut and set in brooches, seals, and other personal ornaments, though far more rarely now than formerly, when, judging from old jewellery preserved in some Cornish families, they would appear to have been very often employed for these purposes. The greatest number of clear and large specimens have been obtained from veins in the slate quarries of Delabole and the vicinity of Tintagel. We have seen very clear crystals from thence of the usual form (an hexagonal prism terminated by an hexagonal pyramid), about three inches high and one inch and a half thick. Cornish diamonds would appear to have been esteemed and used for personal ornaments in the time of Queen Elizabeth, for Carew notices them and observes that, though "in blacknesse and in hardnesse they come behind the right ones, yet I have knowne some of them set on so good a foile, as at first sight they might appose a not unskilfull lapidarie."* The violet rock crystal, or amethyst, seems scarce; we have, however, seen a few Cornish specimens, and among them some which might have been advantageously employed for personal ornaments if they had not been more precious as mineralogical specimens.

The lias rather furnishes an interesting than a beautiful material when portions of it containing ammonites or other organic remains are cut and polished. Some of the larger ammonites, however, when thus cut, afford very elegant ornaments for chimney-pieces. With the exception of the porphyritic rocks associated with the red sandstone series, some of which, when the crystals of felspar are firm, would furnish a good material for moderately-sized vases, that series affords nothing for ornamental purposes, the gypsum, chiefly obtained near Watchet, being seldom of sufficient size, or possessing forms to permit vases being turned in it. The best porphyritic blocks are to be obtained near Teignmouth.

The carbonaceous series contains little ornamental material. The black limestones, indeed, might probably be usefully worked, and many would certainly appear as if they would furnish good marbles, if those parts were selected which would receive a fair polish. The Chudleigh marble has a good appearance, varying from grey to black; with white stripes, and seems to be included in the southern part of this series. Some of the Holcomb Rogus and

* Survey of Cornwall (1602), reprint of 1769, p. 7.

Westleigh beds might furnish a fair common marble with gray tints. The hard greenstones and other trappean rocks associated with this series, and with the beds for which we have collectively employed the term grauwacke, and separated from it for the purposes of description, might advantageously be employed in works for which they were often used by the ancients, more particularly those kinds which are large-grained, approaching sienite and hypersthene rock, as, for example, the greater part of those which run near the granite in various places. Cock's Tor and other localities near Tavistock, in the vicinity of Okehampton, Bridford, Cristow, Hennock, Alternan, Davidstow, Tintagel, Michaelstow, Port Isaac, Padstow, St. Cleer, and several other places, would furnish good materials of this order. Among the products of the carbonaceous series, we should notice the red jasper on the north of Brent Tor, near Tavistock, where it occurs in blocks, sometimes large and of good colour.

The limestones in the grauwacke frequently make good marbles, and have of late been much employed, more particularly those of Babbacombe and Plymouth. The marbles known by the former name are worked at Petit Tor, near St. Mary Church, and large blocks are readily obtained, as they either occur in the lower part of the red conglomerate at that place, or form broken portions of subjacent and fractured limestone (p. 205). The colours are generally varied tints of grey, sometimes mingled with veins of white. Many blocks are composed almost entirely of fossil-corals variously mingled in the mass, and are then commonly known as *madrepore marbles*. Red and yellowish marbles are also found, but in smaller quantities, and these are usually worked into vases and other smaller ornaments. Marble work is extensively carried on at St. Mary Church, and a variety of columns, vases, &c., can easily be obtained from thence.

The marbles at Plymouth are not very dissimilar from those obtained at Petit Tor, with the exception of the black, a good variety of which is found at Cat Down. At Ipplepen there is a reddish variety that is extremely handsome ; and near Totnes there are some of good appearance, Indeed, throughout the limestones between Newton Bushell, Babbacombe, and Plymouth, marbles of very great varieties of colour may be obtained, though tints of grey chiefly prevail, and they deserve to be far more extensively employed than they have hitherto been : a

greater demand would cause many more varieties to be worked.* A beautiful green marble is found in Kitley Park, and the rose-coloured dolomite in the vicinity of the same place affords a very handsome though hitherto neglected material.

Much of the serpentine of the Lizard, though hitherto most strangely neglected, is extremely beautiful, particularly where veins of red traverse the olive-green ground, mixed with lighter tints. This variety chiefly occurs in the lowest parts of the rock, adjoining the hornblende slate and rock; both of which may be also cut and polished to advantage. The best places for obtaining the red-striped varieties which we have seen occur at the Balk, near Landewednack; at the Signal Staff Hill, near Cadgwith; at Kennack Cove; and on Goonhilly Downs, on the N.W. of Roscrowgie. A variety, with an olive-green base, striped with greenish-blue steatite veins, is found at the commencement of the serpentine near Trelowarren, close to the high-road from Helston to Goonhilly Downs. As to the variety of tint, it is almost endless. We must not, however, neglect to notice a very hard and beautiful variety, having a reddish base studded with crystals of diallage, which, when cut through and polished, shine beautifully, of a metallic green tint, in the reddish base.

It has been supposed that blocks of fair size could not be obtained from the Lizard serpentine. This we are inclined to consider a somewhat hasty opinion, inasmuch as quarries to ascertain the fact have not been opened in those places where the hard weathered fragments, chiefly now employed in the few ornamental works executed in this material, would lead us to suppose that the rock might be sufficiently solid beneath to afford serpentine in large solid blocks. It is to be regretted that such situations as the Cadgwith Signal Hill have not been fairly worked. Blocks of fair dimensions, from which chimney-pieces have been cut, have already been obtained of the reddish-brown serpentine, containing crystals of disseminated diallage—a rock which occurs in large quantities both near the Black Head on the east, and north-west from Lizard Town on the west.†

* Marble-masons are established in many of the towns of the district, by whom the Devon marbles are worked, but the demand is in general limited to their immediate vicinities.

† While noticing the economic uses of the Lizard serpentine, we should not omit to mention that two or three cargoes of it are shipped annually to Bristol, for the purpose of furnishing magnesia for the carbonate of magnesia there manufactured.

Some of the steatite veins in the serpentine, when sufficiently large and intermingled with fragments of the containing rock, afford a handsome material for small vases. Veins of this kind, though far from common, are found in different places, but more particularly between Pedn Boar and the Black Head.

The diallage rock, or Crousa Down stone, which Mr. Majendie long since pointed out as, "from its great beauty and hardness, eminently adapted for purposes of architectural ornament;" further observing, that columns and blocks of any required size might be obtained near the coast, and be easily shipped from thence,* still remains neglected. When cut and polished, some varieties have a fine purple tint, and others verge more on green. It is an excellent material, and might be exported in any quantity at Coverack Cove, as previously mentioned, when its qualities as a pavement-stone were noticed. Near the latter place there are some varieties, in which saussurite prevails, from which small ornaments might advantageously be worked.

The granites of the district, though many look extremely well when cut and polished, have hitherto also been much neglected. The columns in the hall at Pendarves are the chief exceptions of which we are aware. These were obtained from the neighbouring granite, and have a good appearance. In the grotto at Menabilly, there is a central polished table, constructed of a variety of Cornish granites and elvans. Among those which have been cut and polished for the Museum of Economic Geology,† the fine-grained granite from Castle an Dinas, near Penzance, may be noticed as possessing an agreeable rich light-brown tint. The

* Trans. Geol. Society of Cornwall (1818), vol. i. p. 36. The bad polish stated to be taken by the serpentine of the Lizard, by Mr. Majendie, must chiefly have arisen from the inability of the workmen employed to produce it. The vases worked at Penzance, in this material, have a good appearance; and the chimney-pieces, at Truro, are well polished. We had many slabs worked, and found the polish always fair, and, in general, good, much depending on the relative hardness of the rock.

† In this Museum, established under the Department of Woods and Public Works, the various British mineral substances used for roads, for constructing public works, or buildings, employed for ornamental purposes, from which the useful metals are extracted, and which illustrate the application of geology to agriculture, with models of mines, and the machinery employed in them, are now collecting. Already considerable progress has been made, and there is a large collection illustrative of Cornish copper and tin lodes, and building and ornamental stones; due, almost exclusively, to the liberality of the Cornish gentry and mining agents who have presented numerous specimens.

fine granite of Mabe is of a good grey tint, and would be very ornamental if polished for columns or tables.

Much granite, with a purplish felspar, raised in the old workings at Wheal Damsel, in Gwennap, would be handsome if worked and polished; as also that of Cligga Point, which contains crystals of rose-coloured felspar. For appearance few granites can exceed the white variety found up the valley of the West Okement, near Okehampton. It occurs as an isolated patch amid altered carbonaceous rocks, greenstones, and limestones, on the skirts of Dartmoor. It is a beautiful material, and may be obtained in large quantities; but we believe it has not hitherto been employed, except by the Honourable Newton Fellowes, for a chimney-piece, at his seat at Eggesford, near Chumleigh, in North Devon. At a short distance this granite has the appearance of statuary-marble.

As part of the granitic masses we should notice the schorl rocks, many of which, when sufficiently hard, would be handsome, if properly worked and polished. An elegant variety of this rock, from St. Mewan's Beacon, near St. Austell, is worked for Mr. Austen Treffry's house, at Place, Fowey: it presents a white base of quartz, through which are disseminated black spots of schorl.

Many of the hard elvans are very beautiful, when worked and polished, particularly those which are most porphyritic, and in which there is much contrast between the base and the contained crystals. The most remarkable are, probably, those which are obtained from the dyke extending from Tremore, near Bodmin, towards the east, on the south of Withiel and St. Wenn. They vary much in colour, but that with a reddish or flesh-coloured base, in which there are white crystals of felspar, and occasionally some of schorl and quartz, is the most beautiful, and occurs in large quantities at Tremore village, and in the ravine through which a brook flows down to Ruthan Bridge. Mr. Austen Treffry has caused this reddish porphyry to be cut and polished by means of water-power, at Fowey Consols Mine, for his house at Fowey, where it is employed, mixed with the schorl rock above noticed, for pavement and for steps. It has a very handsome appearance, and may be obtained of large size, blocks being found up to five or six tons weight; and it may be shipped, at small comparative cost, at Wade Bridge, a branch from the rail-road between that place and Bodmin, extending to within a short dis-

tance of the main mass of porphyry. There is one variety which may be obtained in fair quantities at Tremore, in which light-pink crystals of felspar, with others of quartz and schorl, are embedded in a brownish flesh-coloured felspathic base. Another, of which however we only found small portions, contains greenish felspar crystals in a light flesh-coloured base.

A very beautiful reddish elvan is found at Barton and Ennis, near the Indian Queen Inn, between Bodmin and Truro. Good varieties may be obtained from some of the Gwennap elvans; that at Seveock Water, near Chasewater, with a grey granitic base, containing a somewhat roseate felspar and radiated nests of schorl, looks well. An elvany rock at Mayon, near the Land's End, composed of felspar and schorl, with some quartz, and which is sometimes red and at others light-coloured, with patches of black, has a handsome appearance when worked and polished. Mr. Carne points out also a kind of granitic elvan at Bosava, in the same district, "possessing many shades, from greyish and brownish white to deep red," rarely containing mica, but a great quantity of schorl.* Among the innumerable varieties of elvans which might be selected for ornamental purposes, we may notice that which is roseate-tinted, between Tyecombe and Dowgas, near St. Austell, and the very light-coloured elvan near Camelford, as deserving of attention.†

Roofing Slates.

With respect to roofing slates, there are many quarries in the district, generally supplying their immediate neighbourhoods, and which are rarely exported, with the exception of the Delabole and other slates near Tintagel. In the northern grauwacke there are scarcely any of importance; some slates are, indeed, raised near Treborough, but the quantity is not considerable. Slates are worked in the carbonaceous series at Ashbrittle, on the north, and in the same series near Coryton and Launceston, on the south; the chief quarries, in the vicinity of Launceston, being

* Trans. Geol. Society of Cornwall, vol. iii. p. 242.

† Though not a granitic porphyry, but belonging to the trappean family, we may here notice that, having a greenish-black base, with white crystals of felspar, found among the serpentine of the Lizard, between Penhale and Bochin, as also the porphyritic greenstone of Boswednon Cliff, near Zennor.

near Newchurch farm, Tresmarrow, and on the south of Bad Ash. Slates are also raised in the range of the latter beds on the western coast.

There is much roofing slate in the grauwacke ranging round the southern part of Dartmoor. There are quarries at Ingsdon, near Bickington; at East Down, between Ogwell and Ashburton; at Bulland, on the south of the latter place; near Wash, on the east of Buckfastleigh; at Bow, on the north of Staverton; at Tigley and Moor, near Rattery; at Roster Bridge, near Harberton Ford; at Brixham; at Wood and Ludbrooke, near Ugborough; at Cann Quarry, near Boringdon Park (to which a canal has been made up the Plym, and extensive works have been carried on); at Leigham, on the east of Egg Buckland; and at Mill Hill, near Tavistock. There are slate-quarries in Cornwall, at Hay, near Callington; at Kerney Bridge, on the south of Linkinghorne; at St. Neott's; at Newporth, near Morgan; at Penquean, near Wade Bridge; and at a few other minor places. The great Cornish quarries are at present those of Delabole, and the vicinity of Tintagel; including a large one on the sanding road between Penpethey and Pentafridle.

The Delabole quarries have been long celebrated for producing a beautiful and durable material, combining considerable lightness with strength.* Borlase, in 1758, states, "that for its lightness and enduring of weather, it is generally preferred to any slate in Great Britain." He describes the great quarry, as in his time, 300 yards long, 100 wide, and 80 deep; observing, that "all the slate is carried, with no small danger, on men's backs, which are guarded from the weight by a kind of leather-apron or cushion." These carriers then, it appears, disposed of their loads of slate in rows, side by side, until the area allotted to their partners was full (for it seems they worked in different parties, probably something like the tribute-men of the mines);

* Speaking of the slates of Cornwall as *healing-stones*, that is, roofing-stones, Carew, in 1602, describes the blue as "in substance thinne, in colour faire, in waight light, in lasting strong, and generally carrieth so good regard, as (besides the supply for home provision) great store is yeerely conveyed by shipping both to other parts of the realme, and also beyond the seas, into Britaine and Netherland." Survey of Cornwall, reprint of 1769, p. 6. As this description would scarcely apply to any other Cornish slate, anciently worked, than that of Delabole, and its neighbourhood, we may conclude that about two centuries and a half since it was in great repute, both in England and in parts of the Continent.

after which horses were ready to take them off, and carry them, by tale, to the person that bought them.* The mode of working this quarry is, as may be readily supposed, much improved at present; and the slates, in the rough, are raised by a whim to the top, whence, after being more finally split and shaped, they are carried away by carts and waggons (means of conveyance probably not much known in that part of the country in Borlase's time). There is probably little difference in the slates raised in the old quarry, and that also now extensively worked near the sanding road above mentioned; but the slates worked on the coast, in some places between Trebarwith Sands and Growar Rock, near Boscastle, are not generally considered of equal quality. The Delabole slates are shipped at Tintagel and Boscastle, and are much used and generally esteemed in Cornwall.

Flagstones.

Flagstones are raised in many places, both in the carbonaceous series, and in the grauwacke of the district, where the more schistose or laminated sandstones furnish a material fitted for the purpose. In the slate quarries, also, flagstones are often obtained; some portions not splitting up sufficiently thin for roofing purposes, while other varieties would not repay the cost of dividing them to that extent. The flagstones, or thick slates, of this kind, are highly esteemed from the Delabole quarries. They are exceedingly durable, not only when exposed to atmospheric influence with inscriptions (such as those on tombstones) upon them, but for pavements in passages, court-yards, &c. If slightly roughed, they might be advantageously employed for the sides of streets, being not readily worn away by such friction as they would there receive, and not liable to be damaged by frost.

Gypsum.

The gypsum in the vicinity of Watchet is occasionally collected on the coast and exported to Bristol, Swansea, and some other places in the Bristol Channel; the quantity, however, thus removed, seems inconsiderable, and by no means equal to that

* Natural History of Cornwall, Oxford, 1758, p. 94.

which might be obtained if there were an extensive demand for it, as shafts could easily be sunk inland, and galleries driven among the gypsiferous portions of the red marl in that part of the district. The gypsum obtained from the red marl, near Branscombe, between Beer Head and Sidmouth, is so inconsiderable as scarcely to deserve notice.

Lime.

As regards the article of lime, the larger portion of the district may be considered as fairly supplied, many places near the northern coast, within a reasonable distance from which it is not found, being furnished with it from the carboniferous limestone of Wales; and on the south the limestones of Torbay and Plymouth being sent up the numerous creeks and estuaries on that side.

The country near Weston-super-Mare and Bleadon, including the adjoining Worle, Lympsham, Burnham, and Huntspill levels, are readily and well supplied with lime for agricultural and building purposes from the carboniferous limestone of Bleadon, Worle, and Middle Hopes hills. The lias of Cossington, Puriton, Stokecourcy, East Quantockshead, St. Decuman, and Watchet, furnishes that which is excellent for the foundations of buildings, and works under water, many beds being good, as generally happens with the lias limestones, for what are commonly termed *water-setting* purposes. It it also a fair material for land and buildings generally, though not considered so valuable as the lime from the carboniferous limestone, or as that of the grauwacke limestone of Cannington Park, near Bridgewater, whence large quantities are supplied; or as that from the patches of similar limestone at Cothestone Park, Asholt, Over Stowey, Doddington, and some other places on the north-east and south-east of the higher part of the Quantocks.

Much lime is supplied, chiefly, however, for agricultural purposes, by the conglomerate, with a calcareo-magnesian cement, of the red sandstone series, extending from Williton, by Stogumber, Lydeard St. Lawrence, Fitzhead, Milverton, and Langford Budville, to Thorn St. Margaret. This material varies much in quality, as might be expected, but is best where rolled pieces of grauwacke limestone form part of the conglomerate. In break-

ing up the stone the siliceous pebbles are separated, so that as much of the cementing matter may be burnt pure, except in the case of the limestone pebbles above noticed, as can be managed. Extensive works are carried on near Wiveliscombe and Milverton to supply the country on the east and west.

The grauwacke limestones near Withycombe, Nettlecombe, Treborough, Luxborough, and Cutcombe, furnish lime, generally of good quality, to the country adjacent to them. The conglomerate with calcareo-magnesian cement affords this material at Alcombe, near Minehead; but the supply being very limited, Welsh lime is imported at the latter place. The valley of Holnicote and Luckham contains both calcareo-magnesian conglomerate and lias, which are worked.

The mass of the Exmoor country is ill supplied with lime. Small patches occur at Exford, Newland, Simonsbath, and Challicombe; but the amount furnished by them is relatively so small as scarcely to deserve notice. At Combe Martin it again becomes comparatively abundant, and is extensively worked at various places between Ilfracombe and Kentisbury. There is a considerable space, as will be seen by reference to the map, between Morte Ray and Dulverton, which can be only furnished with lime from the patches which hold their course, either in the grauwacke or in the carbonaceous series, from Fremington and the neighbourhood of Barnstaple, to Bampton and Holcombe Rogus. These limestones furnish materials of very variable quality; that from the carbonaceous series being marked by the carbonaceous matter it contains, with the exception of a few beds at Bampton, and the grey limestones of Holcombe Rogus and Westleigh, which afford as fine lime as the best grauwacke limestones of Devonshire. The value of this material in that line of country is shown by the expense incurred in procuring it, frequently in situations (as at Swimbridge, and some quarries at Bampton), where a mass of other and non-calcareous beds has to be removed. The quarries of Holcombe Rogus and Westleigh supply large quantities of lime to the non-calcareous country around them.

On the south of Taunton the lias country in the direction of Staple Fitz Paine, Hatch Beauchamp, Curry Mallet, Fivehead, Ashill, and Broadway, is of course well furnished with this necessary material, and supplies it to a part of the district formed by the red sandstone series on the north, and to a portion of the

green sand country of the Black Down Hills which rise above it. Quarries of lias are worked in the valley of the Yart (among these hills), near Marsh; and the chalk supplies lime upon them, at the head of the Otter Valley, at Brue Moor, and on the east at Northay; also at White Staunton, and in the vicinities of Combe St. Nicholas, Chard, Chardstock, Brinscombe, and Membury. Lias limestone is worked near Wambrook, and the lias portion of the valley of the Axe supplies lime for that part of the district, as is the case also with the valley of Lyme Regis. From the latter place much lias has, from time to time, been exported for the purpose of making cement in London, for which it is an excellent material. While noticing this lias, it is worthy of remark, as illustrating the economic value of geological information, that when Smeaton built the Eddystone Lighthouse, he sent round the Land's End to Aberthaw, in South Wales, for the very same material which he could have procured equally good from Lyme Regis, and at a cost less by the difference of freight from the two places. Not only lias, but chalk also, is burnt for lime on the west of Lyme Regis; and the latter rock is also employed for the same purpose at Beer and Branscombe, in the direction of Sidmouth.

A glance at Plate I. will show that there must be, from the absence of limestone in a large tract of country comprised between Bideford Bay and Boscastle on the west, and the greater portion of the Black Down Hills, with their southern continuation, on the east—a considerable area, in which lime must be expensive, in consequence of the heavy land-carriage that must be borne, more especially by those inhabiting the central portions of it. The estuary of the Exe, by breaking into this area on the south-east, offers the facility of water-carriage, and, consequently, a cheaper and more abundant supply of this article than would otherwise be obtained. Limestones from Babbacombe or Torbay are carried up it, and burnt in various kilns along its shores, supplying Exeter, and its neighbourhood, at comparatively small cost.

In the calciferous country around Chudleigh, Ashburton, Newton Bushell, Totnes, and Torbay, there is of course no want of lime, and the stone being good the product is much used. Large quantities of limestone are quarried in Tor and Babbacombe Bays, and exported to the Teign, the Exe, and the Otter. Though limestone patches occur here and there in the country between the

Dart and the Erme, lime becomes scarce in some parts of it. Plymouth limestone being imported into the Kingsbridge estuary, a large portion of the land near it is supplied at moderate cost. The like happens up the tidal portions of the Avon and Erme, at the heads of the creeks in which lime-kilns will be generally found. The limestones of Sequers Bridge and Yealmpton plentifully supply the country near them.

The extent to which the Plymouth limestones are worked is very considerable ; not only are they sent to the eastward as above noticed, but they are also plentifully exported to the westward, where there are no limestones to compete with them, except those from South Wales. A great quantity of the former limestone is also carried up the navigable parts of the Tamar, Tavy, and Lynher ; so that we are less surprised at the vast excavations near Plymouth than we might otherwise be, more particularly when we recollect the great number of tons which have been used at the Breakwater in the Sound. From the great distance to which the Tamar is navigable (p. 23), a large portion of country in which lime would otherwise be an expensive article, is supplied at moderate cost.

The patches of limestones in the carbonaceous series from the vicinity of Lifton to Bridestow (and found also in continuation at Elmdon, near Okehampton, at South Tawton, and Drewsteignton) furnish lime of variable quality and in fair quantity to the country near them, being, however, dark-coloured, from the carbon in them.

With the exception of the patches of limestone at South Petherwin, Trenalt,* Rock (near Padstow), and some other places, the supplies from which are comparatively inconsiderable, Cornwall is furnished with lime either from Devon or South Wales ; on the northern coast, entirely from the latter. According, therefore, to the proximity to places where it may readily be landed, depends the cost of this material. As, however, the situations where limestone cargoes may be discharged, including those creeks and coves where the shore may be approached in fine summer weather, are numerous, Cornwall is by no means so deficient in this material as might be imagined, though of course

* A large cavern has been formed at this place by working out the limestone found amidst the slate.

there must be many parts of it where it is comparatively expensive.*

China Clay and Stone.

This substance is prepared artificially in Cornwall and Devon, chiefly from the Hensborough, or St. Austell granite, and from the south side of Tregonning Hill in the former, and from the southern granite of Dartmoor, near Cornwood, in the latter. The process is exceedingly simple, and consists in washing the decomposed rock in such a manner that, by the aid of a succession of tanks, the heavier and useless particles of quartz, schorl, or mica, may fall from the water in which they were held mechanically suspended, or forced forward by its velocity; while the finer particles, those composed of the remains of the decomposed felspar, are carried onwards and allowed quietly to settle in other tanks, where, the water being removed and the sediment partially dried, the latter is conveyed to proper houses, where the drying is completed.

In a district of decomposed granite, such as much of the eastern part of the Austell mass, those places are selected in which the rock contains as little matter, except that formed from the decomposition of the felspar, as possible, and where water can be turned on conveniently. The decomposed rock, usually containing much quartz, is exposed on an inclined plane to a fall of a few feet of water, which washes it down to a trench, whence it is

* Carew, without mentioning the localities where limestone was obtained in his time, states that lime was then made in Cornwall, "either by burning a great quantity thereof (the stone) together, with a fervent fire of furze, or by maintaining a continual though lesser heat, with stone cole, in smaller kils. This," he continues, "is accompted the better cheape, but that yeeldeth the whiter lime." (Survey of Cornwall, p. 6.) As he mentions in another place (p. 21), that stone coal was at that time imported for fuel into Cornwall, it would thus appear that Welsh coal or culm was used, as now, in the Cornish limekilns, nearly two centuries and a half since.

We learn from Borlase, that lime was chiefly employed for manure in the middle of the last century, in the eastern parts of Cornwall. He mentions limestone as raised at Wolvedon, in the parish of Probus, and near Pencarrow. The limestone of Padstow was then considered as not paying the expense of burning, while that near New Quay was found to be easily vitrified. He praises the lime of South Petherwin, which he notices as being much employed in that vicinity; stating, however, that the lime employed on the east of Cornwall was then chiefly derived from Plymouth and Lifton. Nat. Hist. Cornwall, p. 85.

conducted to the catch-pits. The quartz and other impure particles are in a great measure retained in the first catch-pit; but there is generally a second, or even third pit, in which the grosser portions are collected before the water, charged with the finer particles of the clay, is allowed to come to rest in the larger tanks or *ponds*. Here the china-clay sediment is allowed to settle, the supernatant water being withdrawn as it becomes clear, by means of plug-holes in the sides of the tank. By repeating this process the tanks become sufficiently full of clay to be drained of all water, and the clay is allowed to dry so much as to be cut into cubical or prismatic masses of about nine inches or one foot sides, which are carried to a roofed building, through which the air can freely pass, and where the cubical or prismatic lumps are so arranged as to be dried completely for the market. When considered properly dry, the outsides of the lumps are carefully scraped, and exported to the potteries either in bulk or in casks, as may be agreed upon.*

The clay necessarily varies much in quality: the best has generally been obtained from the neighbourhood of St. Stephens. It appears that 1757 tons of this clay were exported from Charles Town to the potteries in 1809, 1888 tons in 1810, 2086½ tons in 1811, and 1252 tons in 1812.† Between 25th March, 1816, and the same day in 1817, 1775 tons were shipped at the same port for the china manufactories in Worcestershire.‡ It also appears that this export had greatly increased in 1826, for we find that 7090 tons were shipped from Charles Town in that year for various places; making, with 400 tons at Pentuan, 30 at Porthleven, and 18 from St. Michael's Mount, 7538 tons shipped from Cornwall in 1826.§ If in round numbers the artificial china-clay at present exported from Cornwall and Devon were estimated at about 7600 tons per annum, it would probably be not far wrong.

Independently of this artificial china-clay, the district fur-

* By preparing a clay, naturally coloured by iron, from a decomposed elvan on the west of Killiow, near Truro, a very excellent yellow ochre is obtained, and considerable quantities of it are sent from thence. Other decomposed elvans, as, for example, that on the downs on the east of Carnon, and at Penlane, near Colan, are made into excellent crucibles, commonly known as Cornish.

† Lysons' Magna Britannia, Cornwall, p. ccxi.

‡ Trans. Geol. Society of Cornwall, vol. i. p. 233.

§ *Ibid.*, vol. iii. p. 360.

nishes about 25,000 tons of a natural china-clay of inferior quality from the supracretaceous deposit of Bovey Tracey.* This clay, which is stated to have been first worked about the year 1730,† is shipped at Teignmouth for the potteries, and would appear to have been formed naturally, much in the same manner as is now done artificially in Cornwall and Devon, though on a larger scale, decomposed granite having been washed down from Dartmoor into a lake or estuary; so that while the grosser particles were first lodged at its higher end, nearest the granite, the fine sediment was accumulated at the lower part. Large quantities of this material have been and still continue to be raised from the neighbourhood of Teigngrace and Whiteway, and other places at that side of Bovey Heathfield, The mode of raising it is extremely simple, generally consisting in removing the gravel head and sinking a large rectangular pit, the sides of which are supported by wood. As the pit is sunk, the workmen who cut out the clay in cubical or prismatic lumps, weighing from about 30 to 35lb. each (of much the same size as those used for the artificial clay), fling the pieces by means of a pointed staff from stage to stage, according to the depth; after which it is carried to the clay cellars, and thence forwarded when properly dried.

A large vein of steatite, in the serpentine, was formerly worked for china-making at Gue Grease, near Kynance, in the Lizard district. This is now exhausted as regards its profitable extraction; but it would appear that, about twenty years since, 12 tons of it were annually exported to the china-works at Swansea.‡

Independently of the china-clays, about 350 tons of a fine clay are annually shipped from Hayle to the copper-works in South Wales. The clay of St. Agnes Beacon (p. 259) is extensively used by the miners to hold their candles; an employment of it, however, which must be somewhat of modern date, inasmuch as

* The Rev. John Templer estimated the annual export of this clay, in 1822, at about 20,000 tons. *Lysons' Magna Britannia, Devonshire,* p. ccxci. The demand was then stated to have greatly increased within forty years. Supposing our estimate of the present export to be correct,—and it appears that of late years (Austen MS.) it has varied from 23,000 to 28,000 tons in different years,—the quantity of this clay worked in the potteries has increased within the last fifteen years.

† Lysons' Magna Britannia, Devonshire, p. ccxci.

‡ The actual quantity raised was far greater, the finer parts alone having been selected with care and exported.

both Borlase and Pryce, when noticing this clay, merely state that it had been used for making tobacco pipes, but that the Pool clays had superseded it.

In addition to the china-clay, a semi-decomposed granite of nearly the same composition as the china-clay before it is prepared, when the gains of quartz are still disseminated through it, is exported to the potteries. Indeed, the china-clay can be considered as little more than this granite in a more advanced state of decomposition. It is, as Dr. Boase has remarked, composed of quartz, semi-decomposed felspar, and scales of a greenish-yellow talcose substance, requiring nothing more than to be broken into convenient pieces for carriage to be fit for exportation, those parts of a quarry being avoided in which schorl becomes intermixed with the rock. This china-stone is chiefly quarried from the granite on the north of St. Stephens, and about 5000 tons of it are annually exported from Charles Town.*

If in round numbers we take the artificial china-clay exported from Cornwall and Devon at 7500 tons, the natural china-clay at 25,000 tons, and the china-stone at 5000 tons, we have 37,500 tons of mineral matter annually shipped from the district to the potteries. It appears that the china-clay has been lately (1838) selling, for ready money, at 1*l.* 12*s.* per ton, and the china-stone at 16*s.* per ton; the former in bulk at that price, and without being packed in casks, for which 4*s.* per ton additional are charged. The annual export of the china-stone and artificial china-clay may therefore be estimated at 16,000*l.*, and if the average cost of the natural clays from Devon be taken at only 1*l.* 2*s.* per ton, the value of these various materials would amount to 43,500*l.* annually. This export, considerable as it has become, is of comparatively recent date. Borlase, in his list of clays, in 1758, makes no mention of any employed in pottery. He

* It is stated in Lysons' Magna Britannia (Cornwall, p. cexi.) that the china-stone exported from Charles Town amounted—

In 1809 to 1162 tons	In 1811 to 1535 tons.
„ 1810 „ 1563 „	„ 1812 „ 1530 „

The following is a return of the china-stone exported from Cornwall in 1826 (Trans. Geol. Soc. Cornwall, vol. iii. p. 360.) :—

Shipped at Charles Town	5000 tons
„ Porthleven	150 „
„ St. Michael's Mount	102 „

The china-stone shipped at the two last places was probably from Tregonning Hill.

merely notices that of Amalebria, in Towednack, as likely, from some experiments he made, to be useful in making porcelain;* and states that there were other white clays, such as at Tregonning Hill, near Breague, in the parish of St. Enoder, &c. He must, therefore, have seen those which have been subsequently worked for china-clay, though it does not appear that any were then used as such. He states, however, that Mr. Cookworthy, of Plymouth, had made experiments on the Breague china-stone, and that it had been found useful in the making of porcelain.† Mr. Cookworthy was the first to manufacture porcelain in England;‡ and Mr. Dillwyn informs us that some of his china, made in experimental works, is still the most beautiful which has been produced in this country. Pryce, in 1778, states that the public were indebted to Mr. Cookworthy for his late improvements in the porcelain manufactory established at Bristol, which he describes as then likely to rival the best Asiatic china; § and he further informs us that china-clay was then made in the parishes of Breague and St. Stephen's, by repeated washings with clear water, and afterwards packed in casks and sent off. ‖ The artificial making of china-clay in Cornwall would thus appear to have commenced between the years 1758 and 1778; and as Mr. Cookworthy, who is mentioned as a person of much talent, was busily engaged during that time in bringing his porcelain manufacture to perfection, we may infer that the first preparation of this clay was due to his exertions.¶

Anthracite and Lignite.

The beds of anthracite which stretch across the country from Barnstaple Bay by Bideford and Alverdiscot towards Chittlehamp-

* Nat. Hist. Cornwall, p. 64. He elsewhere observes (*ib.*, p. 320), that, for making porcelain, many clays may be found in Cornwall.

† Nat. Hist. Cornwall, p. 99.

‡ Dillwyn MS. According to Lysons (Mag. Brit. Devon., p. cccv.), Mr. Cookworthy first established his porcelain manufactory at Plymouth, in 1733; whence it was removed to Bristol, and afterwards to Worcester, where it has been since carried on. It is not clear whence he obtained his first clays.

§ Mineralogia Cornubiensis, p. 116. ‖ *Ib.*, p. 32.

¶ It is possible that Cookworthy may have used artificial Cornish china-clay before 1758, and that he kept it secret.

ton would appear to have been long known; indeed it is probable, as the crop of the beds is very readily seen, that these portions were long since worked. Vancouver, in his Agricultural Survey of Devonshire, notices a bed varying from four to twelve inches in thickness, near Chittlehampton, probably the bed in Hawkridge Wood, near the Taw. According to Lysons, the culm or anthracite in the parish of Tawstock, perhaps meaning the beds near Eastacot, was extensively worked in the middle of the last century, the pit re-opened about 1790, and again abandoned, on account of the water, in 1800, when the depth of the pit is stated to have been 25 fathoms, and the quantity of anthracite thrown up equal to 900 bushels per week.*

Old pits on the out-crop of the anthracite beds are very common, so that these beds may be easily traced across the country. Making a very considerable angle with the horizon, they have been worked in the manner of lodes or mineral veins. They are very irregular in thickness, and are therefore comparatively expensive to work (see fig. 14, p. 125), except where a fair average thickness can be obtained for some distance. Culm or anthracite mines are now (1838) at work about a mile on the east of Bideford; Mr. John Rundle, M.P., who is interested in them, informs us that for the last year they had not done much there, but that about twelve to eighteen months since they drove a little under the adit, and in a short time obtained from 600 to 700 tons of anthracite. It appears that these mines were partially opened by two parties, about twelve or fifteen years since, for 200 fathoms in length, above an adit 15 fathoms deep. The eastern mine, in full work, employed three men and five boys, and produced about 700 bushels, or 58 tons of anthracite per week. From the western mine about 1500 tons were raised in one year. The middle or great anthracite bed, upon which all the chief workings have been carried on, is described as varying from 6 inches to 14 feet in thickness, the average being about 7 feet. As far as had been seen or heard of this bed, it had everywhere been removed by old workings to the depth of 8 or 10 fathoms, as far probably as could then be conveniently accomplished before the water became too abundant for the common machinery employed.† Sufficient

* Magna Britannia, Devonshire, p. ccxcii.

† Rundle MS.

anthracite was at one time raised near Greenacliff, in Barnstaple Bay, to burn with the limestone brought there from South Wales.*

Here and there thin anthracite seams have been detected in other parts of Devon, as in the grauwacke with the plants on the north of Barnstaple (p. 50), between the limestones near Ashburton, amid the limestones of Bunker's Hill, near Totnes,† as well as in a few other parts of the carbonaceous series; indeed a bed of six inches is stated to have been lately cut during the progress of the Bristol and Exeter railroad near Collumpton.

Generally speaking, sufficient carbonaceous matter has been found in the carbonaceous series of Devon to produce a profitless expenditure in the search of coal. So long as there was enough carbon to render the shales tolerably black, every success was anticipated. In consequence, much money has been thrown away in such fruitless trials, which it is to be feared may still be repeated, though, from the numerous sections afforded in the country, it must be clear that the only chance of working anthracite at all profitably (and it is the only substance likely to be obtained) must be in the line of beds above noticed, as extending from Barnstaple bay to Chittlehampton. Among the numerous and useless trials for coal which have been made we may especially notice those in the vicinities of Exeter, Bradninch, and Tiverton, as even to this day it is still supposed probable that coal may be found there. We may, however, hope that geological knowledge is too far advanced to allow of further trials for coal in the lias, such as were made a few years since near Chard, when about 3000*l.* was thus thrown away.‡

The lignite on Bovey Heathfield, commonly known as Bovey coal, was first raised for use early in the last century.§ Dr. Maton described these beds of lignite, in 1797, as being from four

* A variety of the anthracite, probably formed from decomposed portions of it, is raised near Bideford, and employed as a pigment, and, as such, has been employed in our dock-yards. Lysons (Mag. Brit. Devon., p. ccxcii.) states that it was thus used at Plymouth in 1822, and a few years since it was sent to Chatham for the same purpose.

† Austen MS.

‡ Some lignite, such as is often found dispersed among the marls of the lias in the vicinity, assisted, we believe, in confirming the speculators in their opinion that this was a proper place for the trial.

§ Lysons' Magna Britannia, Devonshire, p. ccxcii.

to sixteen feet in thickness, alternating with clay, and stated that the pits were about 80 feet deep, and worked for the supply of a neighbouring pottery. It appears that two potteries have been established near Bovey Tracey, one at Ideo, and another close to the pits, the former in 1772, and the latter about 1812.* The latter still exists, but the former is, we believe, abandoned: it must have been that mentioned by Dr. Maton. The state of the pits, though necessarily much lignite has been raised from them in forty years, would appear not to differ much from that noticed by Dr. Maton. The offensive smell emitted by this lignite when burnt has always prevented its use for domestic purposes, except among the poorer cottagers of the neighbourhood.

Sithe-stones, or Whetstones.

These are manufactured from indurated concretions of the lower portion of the green sand on the Western part of the Black Down Hills, on the sides of which the rubbish thrown out of the numerous galleries driven into them, in search of the concretions, forms a marked line when the hills are viewed from the west. This manufacture is probably far from modern. De Luc notices it in his travels. It affords occupation to many persons in the parishes of Kentisbeere, Broad Hembury, and Payhembury. Dr. Fitton has published a detailed account of the mode in which the sithe-stones are prepared, with figures of the tools employed, and has pointed out that the irregular concretions used for this purpose vary from about six to eighteen inches in diameter, and that the beds which afford them would form a total thickness of about seven feet, of which four are fit for sithe-stones. The same author has also mentioned that the galleries or levels (pits, they are termed in the country) are driven almost horizontally about 300 yards into the hill, and at 40 yards apart, a greater distance inwards not repaying the cost of carrying out the sand in which the indurated concretions are found. Dr. Fitton informs us that the sithe-stones were, in 1825, chiefly bought from the makers by a person at Honiton, who supplied the retail dealers.†

* Lysons' Mag. Brit. Devon., p. cccv.

† Geol. Trans., 2nd Series, vol. iv. p. 238. It appears that the prices then varied from 2*s.* per dozen for the finest stones down to 8*d.* per dozen for the coarsest.

It is stated by Lysons that, about 1822, sithe-stones were also prepared on the east side of Haldon, in the parish of Kenn, where, indeed, we have observed similar indurated concretions in the green sand, but we believe that the preparation of them in that locality is now discontinued.* According to the same authority, a large part of these sithe-stones, or *Devonshire batts*, was shipped at Bridgewater, and forwarded thence to Bristol, Gloucester, Worcester, &c. A large portion of the southern part of England is supplied with these *Devonshire batts*, the sithe-stones of the north being chiefly obtained from Derbyshire and Yorkshire, where considerable numbers are manufactured.†

Mineral Springs.

Employing the name of mineral spring in its usual acceptation, these would appear to be rare in the district, with the exception of chalybeate springs; at least they have hitherto been seldom detected and used. Chalybeate springs are very common, and several of them have at different times been highly extolled. Several wells in Cornwall have formerly had miraculous virtues attributed to them, though simply springs of common good water. Borlase notices Madron well,‡ Euny well, in Sancreed,§ and Holy well, on the coast near Crantock, as in repute by the country people in 1758. We found, in 1836, that the last-mentioned well was still frequented at the proper times by some of the surrounding peasantry.‖

The mineral spring at Plymouth, known as the Victoria Spa, is, we believe, the only one in the district at present used for its medicinal properties. The water is obtained from a boring 360 feet deep, and the following is an analysis by Professor Daniel of the dry salts contained in a wine pint of it:—

* Magna Britannia, Devonshire (1822), p. ccxciv.

† We had a recent opportunity of ascertaining on the spot that the average price of these sithe-stones was about 18*d.* per dozen.

‡ By dropping pins into this well and shaking the ground near the spring, at a proper time of the year, moon, and day, bubbles arose which were interpreted as responses to the questions proposed by the visitors.

§ This was considered a healing well.

‖ Four trees still stand at the celebrated St. Kaine's well, as in Carew's time, but we have forgotten whether they are of "withy, oke, elme, and ash," as noticed by him.

	Grains.
Chloride of Sodium	96·64
Muriate of magnesia	18·68
Muriate of lime	15·10
Sulphate of soda	9·55
Sulphate of lime	8·94
Carbonate of lime	2·06
Carbonate of iron	0·69
	151·66

Its specific gravity at 62° is 1013·3, and it contains 8·1 cubic inches of carbonic acid gas in an imperial wine pint.*

Harbours.

After enumerating the harbours in Cornwall, Carew says, "Divers of these are dayly much endammaged by the earth which the tynners cast up in their working, and the rayne floods wash downe into the rivers, from whence it is discharged in the havens, and shouldreth the sea out of his ancient possession, or at least encrocheth upon his depth. To remedy this, an act of parliament was made, 23 H. 8, that none should labour in tynneworks neere the Devon and Cornish havens: but whether it aymeth not at the right cause, or hath not taken his due execution, little amendement appeareth thereby for the present, and lesse hope may be conceyved for the future."† According to Lysons, this bill of 1531 states in the preamble "that so great a quantity of sand, gravel, stone, rubble, earth, and filth, descending and coming down the rivers near which the said works were carried on, had so filled and choked the said havens, that, whereas ships of 800 tons might heretofore have easily entered at low water, then ships of 100 tons could scarcely enter at half-flood."‡ The penalty was 10*l.*, four years afterwards increased to 20*l.*, for any person searching for tin near the rivers connected with the havens, unless they made "hatches or tyes," for preventing the sand, gravel, &c., from being carried down into them.§

There can be little doubt that streaming for tin during so many

* From the information of the proprietor.

† Survey of Cornwall, p. 26.

‡ Great as the damage thus caused may have been to the havens noticed, we can scarcely avoid supposing that the amount of it here specified may have been somewhat exaggerated.

§ Mag. Brit. Devon., p. cclxxxii.

centuries, must have materially tended to silt up the river harbours in many localities far beyond that which would otherwise have taken place from the natural drift during the same lapse of time. Even now it has frequently appeared to us that much turbid water from the mines is permitted to flow into situations where the deposit is injurious, the ill effects of which might be considerably diminished by catches or mounds, so that still water, and a consequent deposit of sediment, might be procured higher up the valleys.* In situations where weirs or mounds are formed across the heads of tidal rivers for various purposes, very frequently to furnish a supply of water for mills, or for salmon fisheries, it will be observed that much detritus borne down the rivers, especially that forced forwards on the bottoms, is there stopped; and it has appeared to us that, if these catches were more frequent and cleared out from time to time, the natural amount of silt and gravel carried into the estuaries, used as harbours, would be considerably diminished. If ancient accounts may be trusted, many of the estuary harbours in the district have been much silted up within the lapse of a few centuries, an event which must be expected from a long continuance of natural causes, but which seems one that might be much retarded by judicious management.

In several of these tidal rivers we have observed encroachments on the water-way, which would scarcely have been permitted, if it were recollected that the greater the body of tide that enters these estuary harbours on the flood, the greater the amount of water which is employed on the ebb to keep their embouchures open, so that by cutting off the entrance of several thousand or million tons of sea-water, as the case may be, the scouring effect of the ebb upon the bars and entrance of the rivers generally is diminished by the amount of friction on the sides and bottom which would have been due to this body of water on its out-flow. The condition of the mouths of estuary rivers is but the result of a variable contest of antagonist forces, among which the sea-water which has entered on the flood is one possessing much power to

* Catches are prepared near the mouth of the Par by Mr. Austen Treffry, so that finally a marshy spot may be converted into dry fields. Where the bridge over the Par now crosses a shallow stream there was formerly a ferry over the branch of an estuary, one which would appear to have belonged to the duchy of Cornwall, and from which toll was taken. Even within the recollection of old persons this place has been much silted up.

drive off bars and keep the embouchures clear, no small effect being also produced by the ponding back of the river-waters by it during a certain part of the tide, to be let loose, in addition to the ordinary discharge of the river, upon the ebb. Hence, all other things being equal, the greater the quantity of sea-water which can flow up an estuary, the clearer will be the mouths of such harbours.

At Padstow the waters on the ebb are sufficient to cut down the Dunbar sands, so that they do not rise above high water. Being still, however, then impassable for vessels, and the more dangerous because hid, it has been proposed so to manage the out-flow of the tide, by building a pier on these sands, that the whole force of the waters on the ebb shall be directed upon the channel, and thus increase its present width, which is inconveniently narrow. There can be little doubt that, if twice the quantity of sea-water could enter the Hayle estuary than now does, the entrance-channel would be much better than at present, because twice the quantity would in a given time be employed in scouring it out. At present part of the tide which enters on the flood is cut off by gates in the eastern branch of this estuary, and the water thus collected being let out at about half-ebb, it rushes out with much force in consequence of the difference of level then existing between the ponded water and that in the sea, and hence a scouring effect is produced beyond that which would otherwise have happened with the same quantity of water.

At Teignmouth and Exmouth we see harbours in which the drift from either one bank or the other would block up the channel but for the force of the sea and river waters on the ebb. It will be clear that any diminution of the out-scouring forces in these estuaries must damage their entrances to the amount of the effect produced by it, and that hence, if, by naturally silting up or by artificial encroachments, the basin for the reception of the tidal waters inside their embouchures be diminished, the condition of the latter will be deteriorated.

At the mouth of the Axe (South Devon) we find the conjoined effect of the ebb-tide and the ordinary river-water unequal to keep a navigable channel open against the opposing forces, and hence it is alone by artificial means that a harbour can be formed at the entrance. At the Looe Pool, near Helston, we find the piling force of the sea so great that a natural depression, which would

otherwise be an estuary harbour, is barred up, so that, if artificial means be not employed, a situation which would be very desirable as a port, both as a place of refuge and a harbour for commerce, is rendered useless.*

As pier-harbours are but artificial coves and creeks so arranged that free entrances into them are secured and the vessels in them well defended from the breakers, it is always desirable that they should be so placed as to be as little silted up by detritus driven along-shore, or forced into them directly from seaward, as can be arranged. In situations where natural or artificial backwaters may be brought to bear, much detritus may be driven outwards at the proper time of tide, but, being coves, they must to a certain extent have their bottoms raised, as all sheltered coves have, and, therefore, in such harbours provision is usually made for carrying the silt and sand away either in ballast or at the cost of the port. The various pier-harbours in the district are so variably situated, that much instruction may be derived by comparing them with each other and with various natural coves. Not, however, to dwell longer on this subject, we shall merely notice the pier or *cobb* at Lyme Regis, the original form of which is very ancient,† though the old pier battered down by the breakers has been replaced by modern work. We there have an instance of a dry pier-harbour kept in fair condition (and not so well known as it ought to be as a place of refuge for smaller vessels caught in that part of the great western bay in a gale of wind), without a backwater, though exposed to the drift of a considerable shingle-beach. Whether by design or accident it is now difficult to say, but it so happens that the shingle-beach on the west, stopped by the main

* In the time of Henry VIII. it was remarked by Leland that, "if this bar might be always kept open, it would be a goodly haven up to Helston." We believe that, by means of piers projecting sufficiently far seaward to prevent the passage of the pebbles round their heads, a passage might be kept open with the Looe Pool, which would thus become an estuary harbour. By running a mound or wall, with locks, across the lake at any convenient distance up it, a powerful backwater might be obtained (to let loose as occasion might require), for scouring out the entrance between the piers, and at the same time the waters usually kept back might, with the assistance of a canal near Helston, afford a passage for small craft up to that town, and would still form a handsome lake in front of the grounds of Penrose.

† We suspect that a fault runs close under the outer pier, and that the harder portion of the lias on one side of this fault, rising seaward, first suggested the idea of a port where it is now situated, instead of nearer the town. Natural projections of rock seem often to have suggested the position of piers, as behind them the boats of the time probably sheltered themselves.

pier, and which would otherwise accumulate behind it so as eventually to pass round its head, thus tending to bar the harbour, is allowed to pass, after having accumulated to a considerable mass, over a low part of the pier adjoining the shore, so that the surplus pebbles, forced forward by the breakers, travel onwards before the town of Lyme Regis, and by means of jetty-walls,* which from time to time arrest a sufficient quantity of them, protect that town from the ravages of the sea, by which it must otherwise, by this time, have been swept away, unless very expensive and heavy sea-walls had been erected. This contrivance, if it were one, is extremely simple, and merely places the pier or *cobb* in the condition of outstanding rocks behind which vessels can safely ride, without barring the progress of the beach in its natural course onwards.

Mines.

The period at which Cornish tin was first worked and exported would appear to be lost in the obscurity of past ages. That it was known and employed in very remote times would appear evident; and perhaps it may not be assuming too much to suppose that the tin-stones first raised were from the stanniferous gravels, which, after having been searched for centuries, still furnish enough to repay the labours of the stream-tinner in favourable situations. The superior weight of the tin-stone pebbles above all others which the rude inhabitants of the country could find might call attention to them, if they, as most savage nations have been found to do, employed stones as missives against their enemies. The weight of such pebbles may have induced more cultivated people to try them with fire when these tin-stones became known to them, even supposing that they may not have been previously acquainted with the ore, and that accident may not have led the natives themselves to the discovery of the metal contained in them. Stanniferous gravels, according to Sir Stamford Raffles, now furnish the tin from Banka, and numerous other parts of the Ma-

* Probably there are few places where the protection to a coast, obtained by partially stopping the progress of a beach, is better illustrated than at this place. As soon as the jetty-walls cease, and consequently the protecting beaches, so soon do we find the lias rock worn away by the breakers, so that the cliffs immediately beyond the most eastern wall are continually battered by the sea and broken down.

layan peninsula and islands;* and we may readily imagine that, in countries where both tin-veins and these gravels are found, the latter would, from the greater chance of being first discovered, and the comparative facility with which they may be raised when discovered, be the earliest ores smelted. We can still further suppose that, while these stanniferous gravels continued to afford an abundant supply, the more costly and difficult operation of actual mining would be scarcely attempted, except under very favourable circumstances; and hence, as the supply of stream-tin necessary for any given demand began to fail, the mines gradually came into work, at first only in a limited manner, and afterwards more extensively, as the power of machinery to extract the water and ore from the lodes became increased.

It has been considered that the Phœnicians, supposed to have been the earliest traders for tin with Cornwall, regarded the commerce in that metal as so important, that they concealed the situation whence it was obtained. Mr. Hawkins, who has bestowed great attention upon the ancient tin-trade of Cornwall, considers that the Phœnician colony of Gades, on the western coast of Spain, was the medium or entrepôt of the commercial intercourse between Phœnicia and Cornwall.†

From a passage in the writings of Diodorus Siculus, who flourished in the time of Augustus, we obtain, as Dr. Barham has observed, a very interesting and authentic piece of early Cornish history, inasmuch as the locality where the trade was

* Sir Stamford Raffles informs us that the Banka tin has been discovered about a century, and that the highest produce has been estimated at 3500 tons per annum, though of later years it had not exceeded 1750 tons. This supply would necessarily fluctuate according to demand, and the ability to work the stream-tin with the least waste. Sir Stamford Raffles considered that the latter number of tons might be raised for centuries, and he estimated the average produce from Banka and the Malayan peninsula, and other islands, at 50,000 peculs, or about 2920 tons, per annum: of which about 20,000 peculs were exported to China (where this tin was more esteemed than the English tin, and sold for a dollar per pecul more), Bengal took from 6000 to 10,000 peculs, and the remainder was sent to America and Europe.

It would appear that the Indian tin might be far more extensively and profitably worked than it is now; and the Chinese, who almost exclusively raise the Banka tin, are represented as far more industrious and cheaper miners than the Malays. The Banka ore is stated to yield from 50 to 70 per cent. of pure metal. When it does not produce 30 per cent., the ore is not considered worth smelting.—Letter from Sir Stamford Raffles to Mr. Davies Gilbert, Trans. Geol. Soc. of Cornwall, vol. iii. p. 247.

† Trans. Geol. Society of Cornwall, vol. iii. p. 116.

carried on, and the mode in which it was conducted, are both noticed.

"We will now," says Diodorus, "give an account of the tin which is produced in Britain. The inhabitants of that extremity of Britain which is called Belerion both excel in hospitality, and also, by reason of their intercourse with foreign merchants, are civilised in their mode of life. These prepare the tin, working very skilfully the earth which produces it. The ground is rocky, but it has in it earthy veins, the produce of which is brought down and melted and purified. Then, when they have cast it into the form of cubes, they carry it to a certain island adjoining to Britain, and called Iktis. During the recess of the tide, the intervening space is left dry, and they carry over abundance of tin to this place in their carts. And it is something peculiar that happens to the islands in these parts lying between Europe and Britain; for at full tide, the intervening passage being overflowed, they appear islands, but when the sea retires a large space is left dry, and they are seen as peninsulas. From hence, then, the traders purchase the tin of the natives, and transport it into Gaul, and finally, travelling through Gaul on foot, in about thirty days they bring their burdens on horses to the mouth of the river Rhone."—Diodorus, lib. v.*

That the Iktis here noticed is likely to be St. Michael's Mount, as is considered to be the case by Sir Christopher Hawkins, Dr. Barham, and Mr. Hawkins, seems extremely probable; indeed, as far as the geographical description above given extends, there is no other place on the Cornish coast which will answer to it, as seems generally admitted. Although we are not to expect much exactitude in the expressions employed respecting the mode in which the ore occurred, still the reference to the rocky ground and earthy veins would seem to show that it might have been partly obtained by mining at that time.

The bronze instruments usually termed *celts*, the use of which, whether for warlike or peaceful purposes, has been disputed; and rings of the same metal formed to go round the wrists (and similar rings, we were informed, were actually found round the wrists of a skeleton dug up a few years since at the earth-work near Lower St. Columb Porth), have been discovered in old tin-stream works, probably lost by the persons employed in them, when they used such instruments and wore such ornaments. Such remains may readily have been far more abundantly found than has been

* Barham, Some Arguments in support of the Opinion that the Iktis of Diodorus Siculus is St. Michael's Mount. Trans. Geol. Soc. of Cornwall, vol. iii. p. 88.

Mr. Hawkins remarks that, in another passage, Diodorus informs us that this tin was carried to Massilia (Marseilles), and more particularly to Narbo, then the greatest commercial mart of that part of Europe. Trans. Geol. Soc. Cornwall, vol. iii. p. 120.

recorded. Carew notices the discovery of these celts in the stream-works in his time, as also of Roman coins.* A circle of brass, inlaid with gems, and six inches in diameter, was found in Trenoweth stream-work in 1802.† Mr. Henwood mentions a more recent discovery of celts and Roman coins in the stream-works of Treloy, near Lower St. Columb Porth, as also of ancient rings and brooches‡. These latter remains are now in the Museum of Economic Geology. One ring is made to fit the wrist, as above noticed, and one of the brooches would appear to be Roman. An instrument of bronze, constructed apparently for piercing wood, or substances of that hardness, is curious, inasmuch as it would seem to show that iron was then scarce. Coins of the early English kings have been also found near Treloy, but our informant stated that they did not occur with the celts, &c.

Mr. Hawkins considers that the general use of bells in churches, introduced into Western Europe in the sixth and seventh centuries, caused a considerable demand for Cornish tin, more particularly as those of large size were cast for the principal cathedrals; and that, subsequently, its sale was greatly increased by the demand produced by the use of bronze cannon.§ The same author points out that, in the thirteenth century, the chief emporium of the tin-trade was Bruges; and that, in the fourteenth century, the merchants of Italy obtained the tin of Cornwall and distributed it among the countries of the Levant, though Bruges still continued to be the great market for Cornish tin.‖

According to Borlase the produce of tin in Cornwall was very

* Survey of Cornwall, p. 8. He mentions a brass coin of Domitian as so found.

† Lysons, Mag. Brit. Cornwall, p. ccxxi.

‡ Trans. Geol. Soc. Cornwall, vol. iv. p. 65. § *Ib.*, vol. iii. pp. 122—124.

‖ Mr. Hawkins informs us that he acquired a knowledge of the Italian trade from a record of the commercial industry of Florence, entitled La Pratica della Mercatura, composed by Francisco Balducci Pegolotti between the years 1332 and 1345, and printed in 1766 from the original MS. in the Riccardian library. Balducci states that "the tin is imported from Cornwall, in England, in large slabs, of a long square form, each slab weighing about one cantaro and a third, Barbaresque weight of Majorca, where, and at Venice, they make bundles of tin-rods, bound together with rods of the same metal; each bundle made up at Majorca weighing about one cantaro and a quarter, Barbaresque weight of Majorca. The loss in smelting down the slabs, and in casting the rods, at Majorca, was from 1 to 2 per cent., and the expense of making the rods was one soldo of the small Majolichin money per cantaro; and because every one of the rods which was made at Venice had on it the stamp of St. Mark, those of Venice fetched a better price in the Levant, by 2 to 3 per cent., than those of Majorca or Provence, though they were both qually good."—Trans. Geol. Soc. Cornwall, vol. iii. pp. 129-135.

inconsiderable in the time of King John,* the property of the mines precarious and unsettled, and the tin raised engrossed by the Jews, to the great regret of the barons and their vassals, the right of working the tin being wholly in the King, as Earl of Cornwall. The tin-farm of Cornwall then only amounted to 100 marks (66*l.* 13*s.* 4*d.*) per annum, while the tin of Devon was at the same time farmed for 100*l.*†

During the time of Richard, Earl of Cornwall and King of the Romans, the produce of the tin-mines is described to have been very considerable, so that he derived great revenue from them; but after the banishment of the Jews, in the 18th of Edward I., the mines were again neglected.‡

"After this it hapned," says Carew, "that certain gentlemen, being lords of seven tithings in Blackmore, whose grounds were best stored with this minerall (tin), grewe desirous to renew this benefit; and so upon suit made to Edmond Earle of Cornwall, sonne to Richard King of the Romans, they obtayned from him a charter, with sundrie privileges; amongst which it was granted them to keepe a court, and hold plea of all actions (life, lymme, and land excepted); in consideration whereof, the sayd lords accorded to pay the earle a halfpeny for every pound of tynne which should be wrought; and that, for better answering this tax, the said tynne should bee brought to certayne places purposely appointed, and there peized, coyned, and kept, untill the earle's due were satisfied. Againe, the lords of these tithings were, for their parts, authorised to manage all stannerie causes, and for that intent to hold parliaments at their discretion; and in regard of their labour, there were allotted unto them the toll-tynne within those tithings, which their successors do yet enjoy. This charter was to be kept in one of the church-steeples, within those tithings; and the seale had a pickaxe and shovell in saultier graven therein."§

This and the charter of King John were confirmed in the thirty-

It appears, from another passage in Balducci's work, that the price of 1000 lbs. of tin, in Cornwall, was then 10 marks sterling. The value of the mark at that time, Mr. Hawkins informs us, was equal to 4 florins, as fixed by a convention between the Papal See and England, "the pound of gold being coined into 96 florins, each of which (in 1337) was equal to 62 soldi of 12 denarii; so that the relative value of gold and silver was as 1 to 12." The cantaro of tin, it appears from Balducci, weighed 140 lbs. of Pisa and 145 lbs. of Genoa, and "the cwt. of tin, which is 112 lbs. in London, is equivalent at Bruges to 120 lbs. and 122 lbs."—*Ib.* vol. iii. pp. 134, 135.

* For a character of King John to the Tinners of Devon and Cornwall, see Appendix.

† Nat. Hist. of Cornwall, p. 190. It appears that the Bishop of Exeter then received, and in Borlase's time still received, 6*l.* 13*s.* 4*d.* in lieu of his tenth part.

‡ *Ib.*, p. 190.

§ Survey of Cornwall, p. 17. Carew obtained this information from "Master William Carnsew," who had seen the charter, though it was then no longer extant.

third year of Edward I., and the tinners of Cornwall and Devon, who previously formed one body, meeting on Hingston Hill, near Callington, every seventh or eighth year, to concert their common interest, became divided, and formed distinct bodies of men. Five coinage-towns for Cornwall and three for Devon were then appointed, and each tinner was permitted to sell his own tin, unless the king insisted on buying it himself.*

Other ancient charters followed, and the warden of the Stannaries † was appointed with the power to nominate a vice-warden. In Elizabeth's time the tinners of Cornwall were divided into four portions, named from the chief works at that period, Foymoore, Blackmoore, Tiwarnaill, and Penwith. Each of these divisions had its steward (appointed by the lord warden), who kept his court once in every three weeks. In them were tried the cases of debt or trespass, in which any one dealing in black tin (the ore), or white tin, was either plaintiff or defendant. The verdict was given by a jury of six tinners, according to which the steward pronounced judgment. By Carew's account, these courts were not over-remarkable for fair verdicts in his time. In matters of importance, concerning the whole stannary, the lord warden, or the vice-warden, impaneled a jury of twenty-four principal tinners, six from every division, returnable by the mayors of the four stannary towns (Helston, Truro, Lostwithiel, and Liskeard), and whose acts bound the remainder.‡ The consent of sixteen of these twenty-four stannators, as they were called, was sufficient to enact any new law.§

Carew has furnished us with a most valuable record of the state of the Cornish mines about two centuries and a half since. He first notices stream-works and lodes, and the opinion of the tinners that the tin-stones in the stanniferous gravels were derived from the lodes by the deluge; "for," say they, "the foremencioned floud carried, together with the moved rockes and earth, so much of the load as was inclosed therein, and, at the asswaging, left the same scattered here and there in the vallies and ryvers where it

* For copies of these Charters to Cornwall and Devon, see Appendix.

† Carew notices this officer as one "who supplieth the place both of judge of the law and of a chancellor for conscience, and so taketh hearing of causes, either *in forma juris*, or *de jure et æquo*."—Survey of Cornwall, p. 17.

‡ Survey of Cornwall, p. 18.

§ Borlase, Nat. Hist. of Cornwall, p. 192.

passed."* He next describes the process of *shoding*, or *shoading*, which seems to have been then conducted much in the same manner as is now practised, that is, by tracing fragments detached from the lode, following the slopes of hills, until, by the increase in the abundance of such fragments, they find the upper part of the lode itself whence they have been derived:† he notices that the shode for the lodes "either lieth open upon the grasse or but shallowly covered." Having found this shode, they next, he says, sunk pits "of five or six foote in length, two or three foote in breadth, and seven or eight in depth, to prove where they may so meet with the load. * * * If they misse the load in one place, they sincke a like shaft (pit) in another beyond that, commonly farther up towards the hill, and so a third and a fourth until they light at last upon it."

If the lode found offered a fair prospect of success in the working, the discoverer commonly associated others with him in the enterprise; hence it would appear that the system of adventurers was then in operation. When the works were sufficiently important, a captain was appointed, whose duty it was to see that the men did the work properly, to attend to the timbering of the lode and to the pumps. "In most places," says our author, "their toyle is so extreame, as they cannot endure it above four hours in a day, but are succeeded by spels; the residue of the time they weare out at coytes, kayles, or like idle exercises. Their kalender also alloweth them more holy-dayes than are warranted by the church, our lawes, or their own profit."‡

The tools described were extremely simple, and such as suited the mining of the time. They consisted of an iron pick-axe, sixteen inches long, sharp at one end and made flat-headed at the other for the purpose of driving small iron wedges, and of a broad shovel, "the utter part of yron, the middle of timber, into which the staffe is slopewise fastned."

As to the mode of working the lode, it appears that they sometimes followed it to the depth of 40 or 50 fathoms, and that the miners were let down and taken up in a stirrup by two men, who

* Survey of Cornwall, p. 8.

† The upper part of a lode is usually now termed the *broil*, or *bryle*, apparently an ancient name for it.

‡ Survey of Cornwall, p. 10. Although this passage occurs under the head of "Captaine," it would rather seem to apply to working tinners of that time generally.

wound the rope, probably over a winze, whence we may conclude that they did not employ ladders at that time. When the lode sloped, the miners are described as working to a convenient depth, when they sunk a shaft from the top "to admit a renewing vent, which, notwithstanding, their work is most by candle-light." The loose work was kept up by timber, and their way through the hard ground was sometimes so slow that "a good workman shall hardly be able to hew three foote in the space of so many weekes." *

The miners of that time, as might be expected, were much harassed by water. Their drainage machinery is described as composed of "pumps and wheeles driven by a streame, and interchangeably filling and emptying two buckets, with many such like." Adits were also driven to cut the lode from the nearest convenient valley, and are noticed as "costly in charge, and long in effecting." Even in cases, however, where the latter were driven, they would have to raise the water to it from any workings under its level; and, therefore, we may readily conceive that with all the inventions of the time they could not keep it out, and that the mines were in consequence abandoned after a limited depth.

In dressing the ore they first broke it with hammers, after which it was carried to the stamping-mills, formed much like those of the present day which are seen near the smaller mines, and composed of three or six beams shod at the bottom with iron, raised up by means of cogs and a water-wheel, and falling by their own weight upon the ore beneath, which is thus crushed. It would appear that in Carew's time the ore was stamped dry, and afterwards ground into a fine sand by a machine called a *crazing-mill*, worked by a water-wheel, and in which the ore was passed between two grinding-stones. The present practice of stamping the ore wet was then, however, coming in, and the crazing-mills were not employed for the best ores.

The account of the washing process is curious, particularly in the employment of the turf and peat; it is as follows:—

"The streame, after it hath forsaken the mill, is made to fall by certayne degrees,† one somewhat distant from another; upon each of which, at every descent lyeth a green turfe, three or four foote square, and one foote thick. On this the tinner layeth a certayne portion of the sandie tinne, and with his shovell softly tosseth the same to and fro, that through this stirring, the water, which runneth over it, may wash away the light earth from the

* Survey, p. 11.

† Steps, probably.

tinne, which, of a heavier substance, lyeth fast on the turfe. Having so cleansed one portion he setteth the same aside, and beginneth with another, until his labour take end with his taske. The best of those turfes (for all sorts serve not), are fetched about two miles to the eastwards of St. Michael's Mount, where at low water they cast aside the sand, and dig them up: they are full of roots of trees, and in some of them nuts have been found, which confirmeth my former assertion of the sea's intrusion.* After it is thus washed, they put the remnant into a wooden dish, broad, flat, and round, being about two foot over, and having two handles fastened at the sides, by which they softly shogge the same to and fro in the water between their legges, as they sit over it, untill whatsoever of the earthy substance that was left, be flitted away. Some of later time, with a sleighter invention, and lighter labour, doe cause certaine boys to stir it up and downe with their feete, which worketh the same effect: the residue after this often cleansing, they call black tynne, which is proportionably divided to everie of the adventurers, when the lord's part hath beene first deducted upon the whole.'" †

It could scarcely fail that by this rough process much tin would be lost, and accordingly we find that even in our author's time, Sir Francis Godolphin,‡ with the aid of "a Dutch mynerall-man," as Carew calls him, was enabled to make tin with great profit from the refuse which the tinners rejected. After the black tin was divided, each man, it appears, carried his portion to the blowing-house, where it was melted with charcoal, the fire being blown by a great pair of bellows (whence the name of blowing-house), worked by a water-wheel. This process was so roughly conducted, that "divers light sparkles" of tin are described as being driven up on the thatched roof, in such quantities that it was usual for the owners of these blowing-houses to burn them once in seven or eight years, and they then found as much tin in the ashes as paid for a new building, "with a gainefull overplus." Carew values the tin thus obtained at 10*l.* per annum, if the blowing-house were well frequented.§ A better

* There would here appear to be some mistake as to the side of St. Michael's Mount on which his peat was obtained, as the description would accord with the submarine forest, noticed p. 417, on the west of it.

† Survey, p. 12. Black tin was measured by the *gill* (a pint), by the *topliffe* (a pottel), the *dish* (a gallon), and the *foot* (towards two gallons). A foot of black moor or stream tin was considered good if it weighed about 80lbs; the same measure of mine tin about 52lbs. Two pounds of good black tin or ore would yield one pound of white tin or metal.—*Ib.* p. 15.

‡ It would appear that Sir Francis Godolphin very greatly improved the produce of the tin mines of Cornwall at this time. He is described as not only having derived considerable profit from these improvements himself, but also as having taught others to obtain great gain out of the ores they previously disregarded.

§ Survey of Cornwall, p. 13.

practice would appear to be then, however, coming in, as it is mentioned that other blowing-houses were constructed with large sloping chimneys, so that the light particles of tin driven off by the blast were collected in them, and the burning of the houses saved.

It would appear by the Charters of King John and Edward I. that power was granted to the tinners to take both turf and wood for smelting their tin, as had been their ancient custom, so that both then and previously both these kinds of fuel were employed.* Carew, speaking of the woods in Cornwall, when he compiled his Survey, says, that in the west of the county they were scarce, and the few that were preserved were principally employed in making charcoal for the blowing-houses. "This lacke," he adds, "they supply either with stone-coal from Wales, or dried turfes, some of which are also converted into coal to serve the tinners turne;"† so that both charcoal and turf were then also employed in the smelting of tin.

From a speech of Sir Walter Rawleigh in parliament, in 1601, when Lord Warden of the Stannaries, it would appear that the pay of a working tinner was then four shillings per week, finding himself. Of this he boasts as a great change for the better, inasmuch as previous to the patent granted him by Queen Elizabeth of the pre-emption of Cornish tin, which was then claimed on the part of the duchy, the tinner only received two shillings per week, finding himself.‡ By all accounts the tinners were in a bad condition at this period; and Carew observes that the parishes in which tin was worked were in a "meaner plight of wealth" than in those which were simply agricultural.§ He also gives a curious account of the manner in which the London merchants of that time took advantage of any want of money Cornish gentry in London might experience in order to defray their expenses there, by binding them to furnish tin for money advanced at great ultimate loss to the Cornishmen. They also, it appears, had their agents in Cornwall, who advanced money to the needy tinners, partly in wares and partly in money, upon agreement that they

* See copies of these Charters in the Appendix.

† Survey, p. 21.

‡ Hawkins, who quotes from Townsend's Account of the four last Parliaments of Queen Elizabeth. Trans. Geol. Soc. Cornwall, p. 80.

§ Survey, p. 16.

should furnish certain quantities of tin at the next coinage, by which the tinners experienced great loss.* Much of the tin raised at this period must, therefore, have been in the hands of the London merchants.

Though there may be much uncertainty as to the exact time when the working of tin-mines, either in *Several* or *Wastrel*, was established, with the practice of *Bounding*, it seems to be generally considered by the writers on this subject that the latter followed the charter of 1305. The meaning of these terms, and the mode of undertaking a tin-mine in consequence, during the latter part of the sixteenth century, will be best understood by the following passage from the Survey of Cornwall :—

"Their workes, both in *Streame* and *Load*," says Carew, "lie either in Severall or in Wastrell, that is, in enclosed grounds, or in commons. In *Severall*, no man can search for tynne, without leave first obtained from the lord of the soile; who, when any myne is found, may work it wholly himselfe, or associate partners, or set it out at a farme certaine, or leave it unwrought at his pleasure. In *Wastrell*, it is lawful for any man to make triall of his fortune that way, provided that hee acknowledge the lordes right, by sharing out unto him a certain part, which they call toll; a custome savouring more of indifferencie, than the tynners constitutions in *Devon*, which inable them to digge for tynne in any man's ground, inclosed or unclosed, without license, tribute, or satisfaction. Wherethrough it appeareth, that the law-makers rather respected their owne benefit, than equitie, the true touch of all lawes. The *Wastrel* workes are reckoned among chattels, and may pass by word or will. When a myne is found in any such place, the first discoverer aymeth how farre it is likely to extend, and then, in the foure corners of his limited proportion, diggeth up three turfes, and the like (if he list) on the sides, which they terme *Bounding*, and within that compass every other man is restrained from searching. These bounds he is bound to renew once everie yeare, as also in most places to bestow some time in working the myne, otherwise hee loseth this priviledge. The work thus found and bounded, looke how many men doe labour therein, so many *doales* or shares they make thereof, and proportionably divide the gaine and charges. The lord of the soyle is most-where allowed libertie to place one workman in every fifteene for himself, at like hand with the adventurer, if hee be so disposed."†

Respecting the working of the copper-mines of Cornwall at this time, the following passage has often been quoted as establishing the fact:—"Copper," says Carew, "is found in sundrie places, but with what gaine to the searchers, I have not been curious to enquire, or they hastie to reveal. For at one mine (of

* Survey, p. 15. † *Ib.*, p. 13.

which I took view) the owre was shipped to be refined in Wales, either to save cost in the fewell, or to conceale the profit."* Let the motive have been as it might, the fact itself is interesting, inasmuch as it shows that, two centuries and a half since, Cornish copper was, as now, smelted in Wales. Seeing that fuel was scarce in West Cornwall, and known to be abundant in Wales, we may readily suppose that saving in the expense of smelting the ores was also then, as now, one great cause of its shipment to the latter place. In another part of his survey, Carew notices copper-mines as worked near St. Ives.†

There is much obscurity respecting the date at which copper was first raised in Cornwall. As has often been observed, the miners could scarcely have failed in finding it while working in the tin lodes, many of which have been subsequently worked, in depth, for copper. We may readily suppose that when malleable, or native copper, was discovered, that it would be extracted, and the search for more would have been instituted and trial made of the oxides, and gray sulphurets of copper, often found with it. In the early grants to search for copper, that metal seems merely to be enumerated with gold and silver, and there is no proof that mines of copper were then worked. Mr. Carne has shown that the information of Camden and Norden was incorrect as respects their accounts of the copper in Cornwall. The statement of Carew, however, that from the copper mines he visited the ores were sent to be smelted in Wales, shows that copper ores were considered worthy of notice in his time.

A writer in the Philosophical Transactions in 1671, who describes himself as acquainted with the Cornish and Devon mines, details the mode of mining at that time, which probably did not much differ from that practised when Carew wrote, and is therefore useful in supplying a description of those things which he has neglected to mention. It would appear that levels were then driven at about five fathoms under each other, and the water was raised to the adit, or to the surface, if no adit was formed, by means of "a winder and keeble, or leathern bags, pumps or buckets." The following is interesting, as showing the mode in which works were commenced upon lodes at that time, many

* Survey, p. 6.

† *Ib.*, p. 154. The copper lodes of Wheal Trenwith and Wheal Providence, near that place, may then have been known.

remains of which may be now seen in different parts of Cornwall, the pits being commonly known as *coffins*.

"When we have found our load," says this writer, "the last *essay hatch* exchanges its name for that of a *tin shaft*, or tin hatch, which we sink down about a fathom, and then leave a little, long, square place, termed a shamble, and so continue sinking from east to west* till we find the load to grow too small, or degenerate into some kind of weed, as mundick or maxy, &c. Then we begin to drive east and west, as the goodness of the load or convenience of the hill invite, which we term a drift, three foot over and seven foot high; but in case the load be not broad enough of itself, then we usually break down the *deads*,† first on the north side of the load, and then we begin to rip the load itself.

"The *beele-men* rip the *deads* and ore; the shovel-men convey it off, and land it by casting it up with shovels from one shamble to another; unless we have a winder with two keebles, which as one comes up the other goes down."‡

As Carew's work is valuable for the insight it affords of the state of the mines during the latter part of the sixteenth century, though he was evidently no miner; indeed he acknowledges the great assistance he derived from Sir Francis Godolphin on mining subjects, an important statement, as it renders his account more useful than it would otherwise be; so also is the Natural History of Borlase valuable for the condition of the Cornish mines in the middle of the last century, and therefore their state after the lapse of a century and a half.

Borlase mentions stream works as carried on at St. Stephen's Branel, St. Ewe, St. Blazey, and other places (the most important being those in the valley between St. Austell and the sea), in which tin is still streamed, though the Pentuan works (p. 401) are now abandoned. He states that when the stream tin, then obtained in this valley, and without any other dressing than being washed on the spot, was sent to the smelting-house, 13 lbs. of metallic tin were delivered to the owner's order by the melter for every 20 lbs. of ore so sent in.§ Borlase also notices that tin ore

* That is, as high as a man can conveniently throw up the ore with his shovel.

† Portions of the adjoining rock, or unprofitable parts of the lode.

‡ Philosophical Transactions, No. 69, p. 2096 (1671), Phil. Trans. abridged, vol. ii. p. 565, and Carne, Trans. Geol. Society of Cornwall, vol. iii. p. 47.

§ Nat. Hist. Cornwall, p. 163. It is still a very common practice among the tinners of Cornwall to reckon the produce of metal from tin ore at so much in 20, meaning that so much, whatever the weight may be, of metallic tin is obtained from every 20 lbs. of tin ore.

had then been lately obtained, with advantage to the lords of the soil, in the creeks of Falmouth Harbour, probably alluding to Restronget creek, which has since been so extensively worked. He also says that he had seen tin ore in a pulverised state in the sands of Mount's Bay.*

It is mentioned that, in searching for tin lodes, some persons drove adits through their grounds to cut them; but the most common mode was by shoding, which seems to have been conducted much in the same manner as it had been a century and a half previously, and probably long anterior to that date.

"To afford a view of the manner in which a mine was worked in his time, Borlase selected the Pool mine, in the parish of Illogan, a mining section of which he has figured. In this figure we perceive that there were seven shafts upon the lode, upon one of which there was a fire-engine working the pumps,† and raising the water of the mine, which it unwatered, to the adit level, 20 fathoms from the surface. Another shaft has a whim upon it, probably a water-whim, from its name; and the remaining six are represented as having common winzes at their heads; though, judging from the section, two of them must have been 45 fathoms, and one, 55 fathoms deep. This plate also shows that the lode was worked by stoping, or in steps, so that many men could readily be employed at the same time upon it—a practice probably ancient, and derived from working the open lodes by stages, the miners throwing the ore and rubbish from one stage to another until they reached the surface, as has been supposed by Pryce.‡ The walls of the lode were supported by timber, and planks were laid upon them in proper places, on which the *deads*, or unprofitable parts of the workings, were thrown. Captains superintended the work, and saw that it was properly conducted; and it appears that they employed the magnetic compass, or dial, in ascertaining the bearings of work to be executed, such as sinking shafts, &c.

"With respect to the machinery employed to unwater the mines, Borlase enumerates the *water-whim*, the *rag and chain pump*, the *water-wheels and bobs*, and the *fire-engine*, independently of the hand and forcing pumps for small depths. The whim seems to have been the same with the common horse-whim of the present day, employed to draw ores from moderate depths, the only difference being that water was raised in the kibbles, or buckets, instead of ore. The rag and chain pump consisted of an iron chain, furnished at intervals of two or three feet with knobs of cloth, stiffened with leather, which, being turned round by a wheel two or three feet in diameter, furnished with iron spikes that fitted in to the links of the chain, and made to pass through a wooden pump-cylinder (about six or eight inches diameter,

* Nat. Hist. Cornwall, p. 164.

† The pump cylinders are described as partly of iron and partly of brass.

‡ Mineralogia Cornubiensis, p. 141. He supposes that driving and stoping in tin-mines was not more than three centuries old in 1778.

and twelve or fifteen feet long), brought up the water which rose into the bottom of this wooden cylinder between the knobs of rag. The surface of the water to be pumped out was necessarily some height above the bottom of the cylinder, and beneath it the chain, with its rag-knobs, dipped in its passage round the wheel and through the pump-cylinder. These pumps were worked by hand in the mines, and afforded a stream of water in proportion to the circumvolution of the wheel turned. Rag and chain pumps were then also, it appears, worked by small water-wheels in the tin-stream works near St. Austell. The water-wheels with bobs sometimes worked pumps with brass cylinders, and seem to have been much used, as Borlase complains that, from the great want of water in summer, many of these engines could not work from May or June to October—a great hindrance, it is observed, to the mines at that season of the year."*

Our author gives a figure and description of the steam or fire-engine of his day, and notices the great advantages it possessed over other machinery for drawing water. The number of engines of this kind then in Cornwall is not stated, though he mentions those at North Downs, Pitt-louarn, Polgooth, Godolphin Hill, Herland, Bullengarden, Dolcoath, the Pool, Bosprual, Huelros, and Ludgvan-lez. It appears that one, with a cylinder 70 inches in diameter, was erected at Herland Mine, near Gwinear. An engine, with a cylinder 47 inches in diameter, at Ludgvan-lez, making about 15 strokes in a minute, is represented as raising 15 hogsheads of water per minute from 30 fathoms and through pumps 15 inches in diameter. The consumption of coals in these engines was, as is well known, enormous. It appears that the duty on coals, at 5*s.* per chaldron, and remitted by government upon five fire-engines upon three mines (two upon North Downs, Redruth, two upon Pitt-louarn, Resnorth, and one upon Polgooth Mine), amounted, in one month, to 139*l.* 18*s.* 3*d.*† The coals, therefore, consumed by them were equal to about 560 chaldrons per month, or 6720 chaldrons per annum.

According to Carew, the black tin was divided among the adventurers, and the lord's portion taken after it was dressed; but we now find that the ore was divided into shares, or *doles*, upon being raised from the mine, the lord taking a sixth part, clear of all costs, or an eighth or tenth when he allowed for draining, or

* Nat. Hist. Cornwall, p. 171.

† This curious statement was derived by Borlase from Mr. Lemon, who, in his letter, dated May 8, 1756, states that this and some other calculations on the duties, of ropes, iron, candles, powder, &c., consumed in these three mines, were faithfully extracted from the account-books belonging to them.

wished otherwise to encourage the adventure. In cases where the land was bounded, the bounder had the right of granting the sett, or right of working, taking for his share a sixth, clear of cost, or otherwise as he might agree, the lord then only obtaining a fifteenth part. Great care was taken to divide the tin raised from any mine fairly, and having put aside the portions due to the lord, or bounder and lord, as the case might be, they threw the remaining parcels into one heap, and then readily divided it among the adventurers according to their shares, lots being cast for the smaller parcels thus made.*

"We now find the mode of dressing the tin-ores greatly improved. Each owner of the black tin, as he thought proper, carried it to the stamping-mills, a figure of one of which Borlase gives, representing a common overshot water-wheel between four stamps (though probably, from the description, six were intended to be represented).† This stamping-mill did not apparently differ much from the wet-stamps employed 150 years previously, or from those still seen in some minor works. The iron stamp-heads, at the bottom of the stamps, are mentioned as weighing 140 lbs. each. The stamped ore could only escape through small holes punched in a plate of iron, by means of the water which kept constantly flowing through them, after having passed under the stamps where the black tin was pounded. The pulverised ore was carried hence by water into two pits, one corresponding to each set of (or three) stamp-heads, where it was deposited according to its relative specific gravity.

"The ore was then *budded*, *trunked*, and *framed*, processes which we shall shall have to describe hereafter, and which seem to have been conducted at that time nearly as at present, the whole depending upon separating the heavy tin ore from the lighter and other particles by means of moving water.

"The tin being dressed was carried in sacks upon horses‡ to the melting-house, and an assay taken of it. The melter, for the coals, labour, and utensils employed in the fusion, was usually paid $\frac{3}{20}$ of the product, $\frac{17}{20}$ being given to the owners, who, if the tin ore was very rich, received twelve and a half, and even thirteen parts out of twenty; while, on the other hand, for very poor ores they did not obtain more than eight parts in twenty.

"'The melter,' says Borlase, 'having bargained for the parcel brought, gives his note to deliver the quantity of white tin agreed upon at the ensuing coinage, and at his own conveniency (taking care to mix, correct, and qualify the different sorts of tin which he takes in), melts the tin in a reverberatory furnace, with a fire of pit-coal, all which comes from Wales. The great consumption of wood used in charcoal by the former, and more ancient method of melting tin by a blowing-house, suggested at last the necessity of introducing the pit-coal for this purpose, and among the rest, to the noble

* Nat. Hist. Cornwall. p. 175. † *Ib.*, p. 177, and pl. xix. fig. 3.

‡ About 300lbs. weight on each horse.

Sir Bevel Granville, of Stow, in this county,* who, as I have been informed, made several experiments of melting tin therewith (though without success), in order to save wood, and keep the tin from wasting in the blast. The invention of the reverberatory furnace about fifty years since, has rendered this fire effectual, but the pit-coal leaves a sulphureous brittleness in the metal which the wood fire does not, * * * * and this is the reason that tin melted in the blowing-house by charcoal sells for more at the market (usually a twelfth part more), than that of the furnace, as being the purer metal. When the ore is sufficiently melted, it is poured into quadrangular troughs or moulds of stone, containing about 320lbs. weight of metal, which, when hardened, is called a block of tin, and carried to the coinage town."†

We now see that coal was employed for smelting the tin ore, and that this change took place probably towards the end of the seventeenth or the commencement of the eighteenth century. It seems to have greatly superseded the use of blowing-houses, as Borlase states, that blowing tin, as it was termed, though practised in his time in some parts of Cornwall, was only employed for small parcels of ore.

After mentioning that Polgooth had produced the most gain among tin mines (and it is generally considered to have been one worked at a very remote period), at the rate of 20,000*l.* per annum for several years to the adventurers in his time, Borlase notices Polberou mine, in St. Agnes, as the richest tin-mine for ore that he had ever heard of. The ore, consisting principally of large-grained crystals was, in 1750, so abundant in several parallel and contiguous veins, that they could not find horses enough in the neighbourhood to carry it to the smelting-house, and were compelled to take it away in carts, described as "a very unusual sight, though doubtless a more effectual and easy draught where the ways will admit of wheels." A considerable part of this ore was so rich that it did not require to be stamped, and large blocks of tin-stone were obtained. In March, 1750, one was taken to Killenick smelting-house, weighing 664lbs., and was so rich that it yielded eleven and a half for twenty, without stamping or dressing. Another block brought to the smelting-house from the same mine is stated to have weighed 1200lbs.‡

Copper mines were now in full work in Cornwall, but it is stated

* In the time of Charles I.

† Nat. Hist. Cornwall, p. 182. The coinage towns were then five, among them, Penzance, added in the time of Charles II.—*Note. Ib.*

‡ Nat. Hist. of Cornwall, p. 188.

that they had not turned out any considerable profit to the owners until towards the close of the seventeenth century, or about 100 years after Carew compiled his Survey. Borlase enumerates the following as having turned out the greatest profit between 1718 and 1758:—Chacewater, in Kenwyn; North Downs, in Redruth; Huel-rös, in St. Agnes; Roskear and Huel * Kitty, in Camborn; Huel Fortune, in Ludgvan; the Pool, in Illogan; Dolcoath, Bullengarden, Entral, and Longclose, in Camborne; Metal Works, Huel Virgin, and Trejeuvyan, in Gwennap; Binner Downs and Clowance Downs, in Crowan; Huel Cock and Rosmoran, in St. Just; and Herland Mine, in Gwinear. At the commencement of the working of Huel Virgin (now part of the Consolidated or Consols Mines), in July and August, 1757, the first fortnight produced copper ore which sold for 5700*l.*, and the next three weeks and two days, as much as sold for 9600*l.* the cost of raising the former quantity being only 100*l.*, and that of the latter a trifle more in proportion to the quantity.† The lord's dues on the copper mines, which it must be observed were not subject to the practice of bounding, as was the case with the tin mines, then amounted to one-fifth part of the whole produce, clear of all expense, and was never less than one-eighth, also clear. Mr. Lemon computed that for fourteen years previous to January, 1758, the copper of Cornwall produced cash one year with another, to the amount of 160,000*l.*‡ In mines which threw up a good quantity of the ore, it was broken in the lode, raised to the surface, dressed and sorted at one-tenth part of the whole produce when sold, and sometimes for less.§

* It is much to be regretted that the modern Cornish have altered the old spelling of this word, which means a mine, into Wheal, more particularly as it is retained with the old spelling in some parts of Brittany, and has there the same meaning.

† Nat. Hist. Cornwall, p. 206. ‡ *Ib.* p. 207.

§ *Ib.* p. 204. Respecting the other metals worked at this period, antimony is stated to have been raised in St. Minver, and is noticed as occurring in the parishes of Endellyon, St. Austell, St. Stephens, and St. Kew.—*Ib.* p. 129. Manganese was worked near Tregoss Moor, (not improbably the lode from which some was obtained two or three years since, near the Indian Queen), and the ore was so near the surface that it only cost 18*d.* per ton in raising. Many tons of this ore were obtained, though there was little demand for it; a circumstance which Borlase considered due to the want of intercourse and correspondence between Cornwall and the proper mineral markets, as in 1754 a ton of this manganese was sent to Liverpool and afterwards carried forty miles, and sold for 5*l.* 8*s.* 6*d.*—*Ib.* p. 130. Lead appears to have been little worked. The old lead mines of Penrose, near Helston, are stated to have yielded a tolerable profit within the thirty previous years, and a mine in St. Issy, near Padstow, was the only one of note then working for its lead alone.—*Ib.* p. 212.

We are presented with the following account of the manner in which copper ores were then sold, one which Borlase states had existed for about thirty years previously:—

"A quantity being sorted, cleaned, and divided into heaps," he says, according to the quality of the ores, the agents for the copper companies of Wales and Bristol (who reside at Truro and Redruth), upon notice given, attend to sample the ore, and each sampler having taken from each pile as much as is sufficient for assaying and ascertaining the value of that pile, a day is appointed by joint consent of the seller and buyer, at such distance as may give the sampler time to repeat and verify his assays for the sale of the copper: on the fixed day each of the samplers attends, and produces a ticket, or written paper, sealed up, in which is expressed the price which each sampler will give for the ore; he, who in his ticket bids most, has the ore."*

This mode of selling copper ores in Cornwall, which has continued upon the same principle to the present day, and has therefore lasted about 110 years, is described more in detail by Jars, who visited the Cornish mines in 1765. After mentioning that there were then nine copper smelting companies in England, the greater number being in Wales and Bristol, and that there was only one copper smelting-house in the county, each copper company having an agent resident in Cornwall, in order to receive instructions and make purchases, he proceeds to state that,

"When there is ore to be sold in a mine, the agents are informed that, on such a day, samples will be taken. Each agent then goes to the mine on the day appointed, and from each of the heaps of ore one is made the quarter of the quantity to be sold. From this quarter the samples are taken after the ore has been well mixed. Each of the agents then puts some of the ore into a small bag, about the measure of a quarter of a bottle, in order to make the assay on which the price is fixed, the result of which is kept a profound secret until the sale takes place. This generally follows about a fortnight after the samples have been taken, when the adventurers in the mines, or their agents, and the agents of the smelting companies assemble and dine together at the charge of the lord, whose portion of ore is sold with the others, since he takes his share in money. Each of the agents seated with the adventurers round a table, gives in a paper containing his offer for each kind of ore, specifying the weight of each heap, always expressed in tons, writing, for example, 18 tons of ore at 3*l.* or 6*l.* All the papers are then read aloud, and each person takes a note of the offers which have been made, upon which the purchaser makes his engagement to pay in a given time.†

* Nat. Hist. Cornwall, p. 204.

† Voyages Métallurgiques, tom. iii. (Paris, 1781), pp. 210, 211. The Cornish copper works are noticed as existing at Hayle (p. 217), and two large copper works at Bristol are stated to be those to which the largest quantity of copper ore raised in Cornwall was then sent (p. 222). Some ore is represented to have been sufficiently rich to have been sold at 60*l.* per ton, while none were sold below 1*l.* 10*s.* per ton, as they would not pay for smelting (p. 212).

Thirteen years after the visit of Jars to the Cornish mines, we find Pryce describing the dinners given on the days of the copper-ore sales, or ticketing-days, as they are termed, as resembling a city feast, and being provided at the expense of the mines, in proportion to the ores each had to sell; so that, for the convenience of sale, it would appear that the various mines had then agreed to assemble on fixed days, whereas the description of Borlase and Jars would lead us to suppose that the sales were previously made at each mine. He observes that, about the year 1751, when he first became acquainted with Cornish mining affairs, there were only six copper-companies established for buying ores, while then (in 1778) there were thirteen companies.* By a ticketing notice, given by Pryce, of the copper-ores sold at Redruth on July 10, 1777, it would appear that the same publicity was afforded to the offers of the thirteen parties there noticed, as is now done in the present sales, at which about eight companies bid.

These sales now happen weekly at Truro, Redruth, or Pool; and it is usual, after the results of the last sale are published, to announce those that will take place at the two next ticketing-days, distinguishing the mines and the number of tons of ore (of 21 cwt.) which each intends to sell. The following will afford an idea of the results of one of these weekly sales, the purchasers named being those whose tickets, at the meeting, were found to contain the highest offers for each respective lot or parcel of ore:†—

* It would appear that in Pryce's time there were two copper-companies in Cornwall—that at Hayle, mentioned in a previous note (which it seems was first established by Mr. Sampson Swaine, with others, at Entral, in the parish of Camborne), and another at Tregew, on the Falmouth estuary, which had been first established at North Downs, near Redruth, the former being removed to the sea-side for the greater facility of procuring coals, as probably was also the case with the latter. Both these copper-works are now abandoned—that at Hayle, now converted into iron-works, having lasted to within a few years. Among the various attempts to smelt copper ores in Cornwall, Pryce notices that of Mr. Scobell, Sir Talbot Clark, and Mr. Vincent, at Polruddon, near St. Austell, about 1708, when the first piece of copper was smelted, refined, and brought to perfection in that county.

† This account is selected only because it is the last we have seen before going to press. We should observe that when the tickets of two or more companies offer the same sum for a parcel of ore, that parcel is equally divided between the companies so offering the same price.

Copper Ores sold at Truro, November 29, 1838.

Mines.	21 Cwt.	Purchasers.	Price.
Consol. Mines	115	P. Grenfell and Sons	£7 10 0
,,	102	Freeman and Co.	8 1 0
,,	101	P. Grenfell and Sons	7 19 6
,,	98	Freeman and Co.	7 5 6
,,	96	,,	4 10 0
,,	87	Vivian and Sons, and Freeman and Co.	5 1 0
,,	86	P. Grenfell and Sons	5 14 6
,,	75	Freeman and Co.	8 3 0
,,	74	Williams, Foster, and Co.	7 13 6
,,	73	Sims, Willyams, Nevill, Druce, and Co.	5 2 6
,,	72	Mines Royal Co.	6 12 0
,,	70	,,	11 10 6
,,	68	Williams, Foster, and Co.	2 3 0
,,	66	Vigurs, Batten, James, and Co.	9 9 0
,,	57	Mines Royal Co.	8 18 6
,,	56	Sims, Willyams, Nevill, Druce, and Co.	5 17 6
,,	55	,,	6 1 6
,,	54	,,	5 19 6
,,	53	Vivian and Sons	3 1 6
,,	52	Mines Royal Co., and Williams, Foster, and Co.	7 13 6
Gt. St. George	81	Sims, Willyams, Nevill, Druce, and Co.	3 18 6
,,	70	Vivian and Sons	3 4 0
,,	67	,,	2 8 6
,,	60	,,	6 2 6
,,	58	,,	2 8 6
,,	55	,,	2 13 6
,,	46	,,	6 9 6
,,	43	,,	3 1 6
,,	42	,,	3 12 6
Wh. Ellen	68	Williams, Foster, and Co.	3 5 6
,,	63	Mines Royal Co., and Williams, Foster, and Co.	4 1 0
,,	61	Mines Royal Co.	5 17 0
,,	60	Vivian and Sons	3 5 6
,,	48	Mines Royal Co.	5 4 0
Fowey Consols	107	Freeman and Co., and P. Grenfell and Sons	6 3 0
,,	95	Vivian and Sons, and Freeman and Co.	5 10 0
,,	93	Vivian and Sons	5 6 0
Levant	85	,,	10 2 0
,,	65	Williams, Foster, and Co.	16 9 6
Wh. Perran	50	P. Grenfell and Sons	8 19 0
,,	37	Ditto and Sims, Willyams, Nevill, Druce, and Co.	3 13 0
,,	32	P. Grenfell and Sons	3 17 0
Carried forward	2896		

Mines.	21 Cwt.	Purchasers.	Price.
Brought forward .	2896		
Wh. Perran . .	30	Vivian & Sons, P. Grenfell & Sons, and Sims, Willyams, Nevill, Druce, & Co. .	£3 0 0
Wh. Leisure . .	55	Sims, Willyams, Nevill, Druce, and Co,..	2 10 0
,, . . .	44	,, ...	3 12 0
,, . . .	43	,, ...	1 17 6
Trewavas . . .	59	Mines Royal Co.	8 5 6
,, . . .	49	,, ...	6 6 6
Wh. Providence . .	44	Freeman and Co.	3 14 6
,, . . .	38	P. Grenfell and Sons	5 0 0
Tretoil . . .	65	Williams, Foster, and Co. . . .	11 9 6
Total .	3323		

Average Produce, 8—Quantity of fine Copper, 266 tons 15 cwt.—Amount of Sale, 20,124*l.* 5*s.*—Average Standard, 109*l.* 14*s.*

At the conclusion of this sale it was announced that the following would be sold at the two next ticketing-days, so that a fortnight's notice is always given, the same being done after each sale.

Copper Ores for sale at Redruth, December 6.

East Wh. Crofty, Longclose, and Dudnance, 1006; United Hills, 318; Fowey Consols, 307; Dolcoath, 233; Wh. Lydia, and South Towan, 233; East Pool, 192; Tin Croft, 191; Stray Park, 178; South Wh. Bassett, 135; St. Enoder Consols, 26. Total, 2849 twenty-one cwts.

Copper Ores for sale at Redruth, December 13.

Carn Brea, 706; Wh. Virgin, 496; Wh. Treasury, and Drewollas, 473; Fowey Consols, 245; Great Wh. Fortune, Owen Vean, and Rospeath, 228; Relistian, 216; Tresavean, 198; Wh. Unitywood, and Union, 187; Levant, 143; Wh. Vor, 116; Wh. Leeds, 85; Wh. Osborne, 40; North Godolphin, 29; South Polgooth, 20; Wh. Elizabeth, 9. Total, 3191 twenty-one cwts.

It will be observed, that while some parcels of ore brought prices varying from 10*l.* to 16*l.* per ton (of 21 cwt.), others were sold much lower, even from the same mine: thus, while one parcel of 70 tons from Consols' Mines sold for 11*l.* 10*s.* 6*d.* per ton, another parcel from the same mine, of 68 tons, only brought 2*l.* 3*s.* per ton. This arises from the practice of dividing the ores out into lots according to their respective qualities: thus, the 1510 tons of ore sold by Consols' Mine were divided into 20 lots or parcels, all of which brought different prices, according to their value. The average produce per cent. necessarily varies considerably according to the ores brought to the sale; in that preceding the one above noticed we find it equal to $7\frac{7}{8}$ per cent. Sir Charles Lemon gives the following tabular view of the produce, per cent., of Cornish copper ores, in decennial periods, from 1771 to 1837, observing that the quality of the ores found cannot

have varied in the degree marked in the average produce, but rather that the decline has depended on the produce of the ores brought to market being always lower as the improvements in smelting advanced.*

Years.	Tons of Ore.	Tons of Copper.	Produce per Cent.	Years.	Tons of Ore.	Tons of Copper.	Produce per Cent.
1771	27,896	3,347	12	1801 to 1810	67,532	6,059	9
1781	28,749	3,450	12	1811 to 1820	78,560	6,602	8½
1791	Records lost.			1821 to 1830	114,040	9,143	8
1800	55,981	5,187	9⅜	1831 to 1837	142,785	11,637	8⅛

The standard noticed is the estimated value of the fine copper, per ton, considered from the various assays to be in the ores sold, less a fixed sum (2*l.* 15*s.*) per ton, allowed for the cost of smelting. From the improvements in obtaining the metal from the ores, and probably also from the return of fine copper from the ores on the large scale being greater than the assays would show, copper is now usually sold under the price considered as the standard. The standard, of necessity, fluctuates considerably, and its state is in consequence anxiously looked for by the miner. The standard of the sale above noticed was 109*l.* 14*s.*, while we find that of the previous ticketing to have been 110*l.* 8*s.*, so that it had fallen 14*s.* within the week; but at a fortnight preceding it was 107*l.* 18*s.*, so that there was a rise within that time of 1*l.* 16*s.*, and it was consequently advantageous to the miner to that amount.

Pryce notices the rapid increase in the produce of the Cornish tin mines in his time, observing that, for the last twenty years (1758 to 1778), the annual average of block tin had amounted to about 3000 tons, which was double the quantity annually coined sixty years previously (about 1718), and one-third increase within the last thirty years.† It would appear that charcoal was still employed in smelting stream tin,‡ and that culm, and not bituminous coal, was considered the proper flux for assaying tin,§ a fact to which attention seems not to have been paid while working tin

* The Statistics of the Copper-mines of Cornwall, Journal of the Statistical Society, June, 1838, v. i. p. 68.

† Mineralogia Cornubiensis, Introduction, p. xi.

‡ *Ib.*, p. 65. § *Ib.*, p. 40.

ores on the large scale at the smelting-houses until of late years, during which culm has been employed in preference to common coal.

The same author laments that the practice of shoding had greatly declined in his day, and states that out of all the miners there were then not fifty who scientifically or experimentally understoood anything about the matter. It seems still less practised now; though, if a stone of tin-ore should turn up in working the ground, endeavours will still be made to see whence it may have been derived, by working in various directions until it shall be found that the fragments of tin-ore multiply, and thus the ore be traced to the broil, or bryle, of the lode whence they have been derived, the miners generally trying up the hill from which these and other decomposed portions of the rocks composing it have descended.

Tin-streaming seems to have been conducted in Pryce's time much as it is at present, though now probably there are fewer profitable works of this kind, from the general decrease of stream-tin. A sett or lease of the ground having been obtained, and terms made with the lord,* an excavation is made down to the fundamental rock or shelf upon which the stanniferous gravels rest. The over-burden, or superincumbent beds of gravels, clay, sand, or peat, as the case may be, are removed, and streams of water so conducted that they may be made to fall upon proper washing-places, where the tin-stones are separated from the non-stanniferous portions of the gravel or sand, the water that drains into the excavation being removed either by hand-pumps of a very ingenious description, by which even small pebbles may be raised with the water, or by those of a more common construction. In places where there is much water, and adits cannot be well contrived to carry it off, small water-wheel pumps with balance bobs are erected. In the more important works, such as those of Pentuan were, and those in Rostronget Creek (p. 401) now are, steam-engines are employed. We have nowhere seen the rag and chain-pumps noticed by Pryce as being employed in the stream-works of his time, and believe this kind of pump to be now disused. The fall of water is usually conducted upon an inclined plane of wood, upon which the stanniferous gravel to be washed is thrown. The gravel being worked about, the tin-stones, if of sufficient volume, and the force of the water not too great, remain in great part upon this inclined plane, from their greater relative specific gravity, while the non-stanniferous gravel is washed away. Some-

* It would appear that in 1778 the lord either took a share varying from a sixth to a ninth of the black tin raised, ready for smelting, or the streamer contracted "to employ so many men and boys annually in his stream-work, and to pay him, for liberty, from twenty to thirty shillings a-year for each man, and so in proportion for every boy; that is, for twelve shillings monthly wages, he contracted to pay the lord half as much as for a man."—Min. Cornubiensis, p. 132.

times the finer grains, if reduced to sand, escape to the end of this inclined plane or tye, but in such cases the supply of water is usually regulated accordingly.

In the more important works the stream-tin obtained is dressed with more apparent care, but in numerous situations throughout Cornwall little stream-works will be observed upon which four or six miners may be employed, sometimes only one solitary streamer, which collectively must still produce much tin-ore. It is very common for stream-tin, the produce of these small works, to be brought into the towns on market-days and sold to the smelting-houses; and a solitary man may often be here and there seen on the moors or in the valleys, turning over his little heap of half-dressed stanniferous gravel, giving it the final preparation for the market. As these poor fellows very frequently wash gravel that has been turned over once or twice before, their gains cannot be great, and, judging from all those with whom we have spoken on the subject—and they have been many—it must be with great labour that they can earn a scanty livelihood. The produce of these little adventures is usually stamped and further dressed at the smelting-houses. In Pryce's time the stream-tin seems generally to have been smelted at the blowing-houses, which were farmed, and, instead of being sold as formerly, were disposed of by sample, as the mine-tin was at the smelting-houses. It would also appear that the refuse and leavings of the old stamping-mills, which had been some years lying and collecting in the lower grounds, would then yield a profit to the dressers.* We believe there is at present but one blowing-house, or blast-furnace, in Cornwall, the one usually known as the Higher Blowing House, near St. Austell. Here stream-tin, chiefly obtained from the neighbourhood, is smelted. Stream-tin, however, from many other places, appears to be smelted in the reverbatory furnaces of the usual smelting-houses.

On the subject of bounding, it would appear that in 1778 new bounds were seldom cut, as the lords availed themselves of the three months' notice which, by the Stannary laws, it was necessary to give them and the Stannary court, of the intention of others to cut bounds. Upon this notice being given, they presented an instrument praying for liberty for themselves and the enrolment of such bounds within that Stannary. Then, as now, these tin-

* Mineralogia Cornubiensis, p. 135.

bounds seem to have been fertile in disputes, more particularly as the bounders may have no title to any part of an estate above ground on which they grant sets for working tin.

From a section of Bullen Garden Mine, Camborne,* it would appear that it was then ninety fathoms deep, unwatered by means of an engine-shaft extending down the whole depth of the mine, in which shaft were two pumping fire-engines raising the water from the sump up two separate pumps to the lower or deep adit, about sixty-seven fathoms, and by two water wheels with bobs, one working immediately under the surface, and the other at the depth of about six fathoms, these pumps assisting to raise the water through separate shafts after it had been lifted forty-seven fathoms by the fire-engine shaft, as also to carry off water coming in by a level from Dolcoath Mine. There were two whims, apparently horse-whims, drawing ores through shafts extending to the deepest level in the mine, which was worked by stoping. The engine-shaft was well supplied with ladders, as also one of the water-wheel pump-shafts, and other parts of the mine, so that the communication by ladders seems to have been good. Judging from this plan, and that given by Borlase of the Pool Mine (p. 535), the mode of working mines in the depth would appear to have been much improved within the intervening twenty years.

Pryce gives a very detailed account of the state of mining in his time, which it is interesting to compare with the present system, after the lapse of sixty years. The manner of raising water was by hand and force-pumps, and small water-barrels for small depths, and by horse-whims with water-barrels for greater, when the shaft was perpendicular.† The rag and chain-pumps were now nearly laid aside from their expense, estimated at 50*l.* or 60*l.* each, per month, and the destruction caused among the men who worked them, from the great fatigue they were compelled to undergo at them. It required twenty-four men to keep one of these engines constantly at work, in spells of six at six hours each spell, and they worked naked at them, with the exception of loose trousers.

The water-wheel with bobs was employed where a supply of water could be obtained, and one at Cook's Kitchen Mine was forty-eight feet in diameter, and worked tiers of pumps of nine inches bore, divided into four lifts, and raised water eighty

* Mineralogia Cornubiensis, plate 4, p. 172.

† The smaller barrels used with these horse-whims contained sixty gallons each, the larger would hold 120 gallons, and two additional horses were then added to the whim, which was thus worked by four. It was considered that the water must be lifted within twenty fathoms, and at the rate of not less than two barrels per minute, to make these larger barrels worth their charge.—*Ibid.*, p. 151.

fathoms to the adit. The power of a water-wheel of this diameter was estimated to be equal to a fire-engine of that time (improved Newcomen's), of forty-seven inch cylinder.* Very powerful water-wheel pumps are now to be seen in several parts of Cornwall where a proper supply of water can be obtained. From the latter circumstance they are commonly employed in the Devonshire mines, the largest and finest in the whole district having been recently erected at Wheal Friendship near Tavistock. Where the supply of water is so precious, not only for water-wheel pumps, but also for dressing ores, large sums of money are often paid in Cornwall and Devon for the use of it, and no small contrivance is frequently exhibited in turning a stream to the greatest account.†

The atmospheric, or steam-engine of Newcomen, which had been gradually much improved since it was first introduced (about sixty-five or seventy years previously‡), though still very costly, from the quantity of coal consumed by it,§ was in 1778 giving place to Watt's engines, one of which of thirty-inch cylinder is noticed by Pryce as at work at Huel Bussy (Chacewater), while three others were erecting at Ting Tang, Owanvean, and Tregurtha Down Mines. He describes the former as working "a pump of six inches and a half in diameter in two shafts by flat rods with great friction, 300 feet distant from each other, forty-five fathoms high on each shaft, equal in all to ninety fathoms, and as making fourteen strokes of eight feet long per minute, with a consumption of coals less than twenty bushels in twenty-four hours."‖ The remuneration required by Watt for the use of his engines

* Mineralogia Cornubiensis, p. 152.

† Mr. Carne cites Wheal Reeth, a mine in granite between Penzance and St. Ives, as a singular instance of one so dry in the workings, that, though 160 fathoms deep, the quantity of water raised by a steam-engine to the surface was so small (in 1824) that it was not sufficient for stamping and dressing the tin-ore obtained.—Trans. Geol. Soc. Cornwall, vol. iii. p. 63.

‡ Newcomen's patent was granted in 1705. Mr. Carne states that the first steam-engine in Cornwall was erected at Wheal Vor, a mine at work from 1710 to 1714, but considers it doubtful whether it was on the plan of Savary or Newcomen, as engines of the latter do not appear to have been much known before 1712.—*Ibid.*, vol. iii. p. 50.

§ *Ib.* p. 154, and plate 3, p. 160. Notwithstanding numerous contrivances to diminish the cost of the coals consumed in these engines, among which there was one of a granite boiler heated by means of three tubes passing through it, the consumption of fuel was still great, and estimated at 3000*l.* per annum for engines of large size.—*Ib.* p. 308.

‖ *Ibid.*, p. 313.

was, as is well known, one-third the saving of coals effected by them compared with the amount consumed by the old engines, and to acertain this a *counter* was invented, which, being attached to the main beam, marked the number of vibrations of this beam, from which the work done by the engine was calculated, and, the amount of coal consumed being ascertained, the saving was found. Though the patent right no longer exists, this mode of calculating the work executed by the Cornish steam-engines still remains, and their *duty*, as it is termed, is estimated by ascertaining the number of pounds' weight which are lifted one foot high by them by the consumption of one bushel of coals. The saving effected by the use of Watt's engines was too obvious to be neglected among the Cornish mines, and we find that for three engines erected at Chacewater Mine the adventurers compounded for the one-third of the saving of fuel they thereby gained at 2400*l.* per annum, which would show that the whole saving exceeded 7200*l.* per annum.*

Great as were the advantages to the mines which followed the introduction of Watt's first engines, they have been exceeded by the improvements which have been since adopted; so that, for effectually performing their work at great depths, and for the small relative amount of fuel consumed by them, the Cornish pumping-engines of the present day stand pre-eminent, and mines are worked which must long since have been abandoned but for their existence. Though it may appear strange, the value of these engines seems not to have been fully appreciated out of the mining districts of Cornwall and Devon until lately. It is now a very common practice to have the duty of the engines on mines ascertained and published; and for this purpose Captain Lean † is appointed, by those mining adventurers who desire it, to fix a counter upon the various engines which are, as it is termed, to be

* The Steam Engine familiarly explained and illustrated. By Dr. Lardner. 5th edit. p. 94.

† When Watt's patent expired, and there was no *necessity* for keeping the counters on the engines, they were abandoned, except in a few mines, where they were retained for the satisfaction of the agents. In 1812 Captain Joel Lean suggested the plan of placing a counter on every engine, and of publishing the estimated duty performed by them. This plan having been adopted very generally, by degrees, the stimulus to improvement and attention has been so considerable, that, from an average duty, supposed to have been below 17,000,000 lbs., it has increased to the present average (in 1837) of 47,087,374 lbs.

reported—that is, have their duty published once per month. As this plan is found valuable, and excites much emulation among the engineers, there are few engines the duty of which is not reported. The counter is furnished with a Bramah's lock, the key of which Captain Lean keeps, and it is inspected by him once per month. If considered desirable another counter is attached to the engine, which is open to the inspection of the engineer, the agents of the mine, and the engine-men. A separate party supplies the coals, which are delivered to the order of the engine-men as they may require them. These orders are examined and countersigned by Captain Lean, and then passed. At the end of each month the coals not consumed are measured, and thus the real amount consumed is ascertained. This being done, and the counter examined, the *duty-papers*, as they are termed, are published, and include an account not only of pumping-engines, but also of steam-engines employed in drawing ores up the shafts, and in stamping ores.* The following Tables of the average

* This paper contains, for the pumping-engines—1, the name of the mine; 2, the name of the engine and the diameter of its cylinder; 3, the average quantity of water drawn per minute; 4, the load per square inch on the piston; 5, length of stroke in the cylinder; 6, number of lifts; 7, depth of the lifts; 8, the time between the observations; 9, the consumption of coal in bushels; 10, number of strokes; 11, length of the stroke in the pump; 12, load in pounds; 13, pounds lifted one foot high by consuming a bushel of coal; 14, number of strokes of the beam per minute; and, 15, the engineers' names, with remarks as to the position of the main-beams, whether the draught be perpendicular or diagonally, &c.

For the engines employed in stamping, the paper contains—1, the name of the mine; 2, that of the engine and the diameter of its cylinder; 3, the length of the crank; 4, length of stroke in the cylinder; 5, diameter of the fly-wheel; 6, number of stamp-heads; 7, time through which the observations extend; 8, consumption of coal in bushels; 9, average height which every head lifts in inches; 10, number of times which every head lifts at a stroke of the engine; 11, number of strokes; 12, weight of heads and lifters in pounds; 13, pounds lifted one foot high by consuming a bushel of coal; 14, number of strokes per minute; and, 15, the engineers' names, and remarks.

For the engines employed in drawing ores we have—1, the names of the mines; 2, that of the engine and the diameter of its cylinder; 3, consumption of coal in bushels; 4, average number of kibbles (iron buckets in which the ore is raised) drawn from 100 fathoms; 5, average weight of a kibble (with ore) in pounds; 6, pounds drawn one foot high by consuming a bushel of coal; 7, horse-whim kibbles drawn from 100 fathoms by consuming a bushel of coal; and, 8, engineers' names and remarks.

With respect to the duty of the pumping-engines reported, Mr. Wicksteed has observed (on the effective power of the high-pressure expansive condensing steam-engines commonly in use in the Cornish mines, Transactions of the Institution of Civil Engineers, vol. i.) that the friction is not taken into account; and that, as this

duty of the pumping-engines in Cornwall for 1836, and for the half-year ending June, 1837, will show the estimated work performed by these engines for that time:—

Average Duty of Steam-Engines employed in pumping in the Mines of Cornwall in the Year 1836.*

MINES.	Engine, and the diameter of the cylinder.	Load per sq. inch on pist.	Length of stroke in cylind.	Length of stroke in pump.	Pounds lifted 1 foot high by consuming a bushel of coal.
		Lbs.	*Feet.*	*Feet.*	
W. U. Wood ..	Williams's 80 in.	7.8	10.0	7.5	47,540,000
Poldice	Sims's 90 in.	5.84	10.0	7.0	40,990,000
Wh. Damsel...	Stephens' 50 in.	12.6	9.33	7.25	41,870,000
Wheal Jewel ..	39 in.	13.2	8.5	6.0	33,500,000
Cardrew Dwns .	66 in.	5.2	8.75	7.0	32,990,000
Wheal Tolgus .	Davey's 70 in.	7.56	10.0	7.5	47,880,000
„	Horton's 70 in.	15.0	10.0	7.5	62,420,000
„	Pryce's 25½ in.	14.97	6.0	6.0	27,260,000
Dolcoath	76 in.	12.8	9.0	7.5	43,720,000
E. Wh. Crofty .	80 in.	7.6	10.33	7.75	42,570,000
North Roskear .	New eng. 70 in.	10.8	10.0	8.0	72,140,000
South Roskear .	W Chance 60 in.	7.05	9.0	7.0	43,740,000
Tincroft	56 in.	13.7	9.33	7.25	38,050,000
Binner Downs .	W. Treas. 50 in.	14.77	9.66	8.0	43,620,000
„	Gregor's 42 in.	15.8	9.0	7.5	41,620,000
„	Burn's 64 in.	12.1	9.33	7.75	53,790,000
„	W. Penny, 24 in.	18.2	5.25	5.25	28,090,000
Wheal Julia . .	80 in.	5.03	11.0	9.0	
W. Darlington .	80 in.	14.6	10.0	8.0	77,040,000
Marazion.....	Powlet's 60 in.	15.1	9.0	8.0	61,790,000
„	E. Rodney, 40 in.	6.36	9.0	7.0	36,100,000
Consolidated ..	Taylor's 85 in.	11.46	10.33	7.75	73,160,000
„	Davey's 80 in.	12.0	11.33	8.75	68,220,000
„	Pearce's 65 in.	16.8	9.0	7.5	48,620,000
„	Woolf's 90 in.	11.6	10.0	7.5	53,100,000
„	Bawden's 90 in.	8.3	10.0	7.5	44,300,000
„	Shears's 65 in.	12.9	9.0	7.5	58,340,000
United Mines ..	Cardozo's 90 in.	10.98	9.0	8.0	48,070,000
„	Little en. 30 in.	17.96	9.0	7.5	66,480,000
„	Loam's 85 in.	10.5	10.0	7.5	72,330,000
„	Hocking's 85 in.	12.9	10.0	8.5	68,260,000
W. Beauchamp.	Western 36 in.	14.8	7.75	6.0	25,980,000
„	Powning's 36 in.	12.0	8.0	6.0	33,770,000

varies in every engine, and the machinery worked by it, the reported duty is not the whole performance of the engine; and that, therefore, "an engine which is reported as performing a certain duty may, in fact, be doing as much work as another engine whose reported duty is greater." From this it would follow, that the whole reported work of these engines falls short of that which they actually perform. It will also be evident that the coals employed may vary much in their heating powers, though probably this will not much affect the relative duty of the engines, as we have found, though the quality of the coals used in the mines does vary, that they are generally of a fair average common quality.

* From Mr. English's Mining Review, Feb., 1837.

(*Table continued.*)

MINES.	Engine, and the diameter of the cylinder.	Load per sq. inch on pist.	Length of stroke in cylind.	Length of stroke in pump.	Pounds lifted 1 foot high by consuming a bushel of coal.
		Lbs.	*Feet.*	*Feet.*	
Polgooth	66 in.	9.2	9.8	7.4	73,200,000
Charlestown U .	50 in.	9.08	9.3	8.2	52,730,000
Pembroke	Pearce's 50 in.	8.0	9.0	7.0	41,340,000
,, ...	Edgecum 40 in.	17.5	9.0	6.5	47,830,000
East Crinnis...	Husdon's 76 in.	12.9	10.33	7.25	52,990,000
,, ...	Rundle's 41 in.	16.0	9.3	7.25	47,180,000
Fowey Consols .	Austen's 80 in.	10.5	10.3	9.25	85,650,000
,, ...	Sawle's 24 in.	15.24	8.5	5.5	41,440,000
Roche Rock ...	36 in.	14.2	8.5	6.8	39,230,000
Brin Tye	36 in.	7.0	5.75	5.75	
E. Wheal Rose.	36 in.	4.8	7.5	6.0	19,390,000
Wheal Vor	Borlase's 80 in.	13.8	10.0	8.0	74,480,000
,, ...	Trelawny's 80 in.	13.53	10.0	7.5	62,830,000
,, ...	Woolf's 53 in.	16.0	9.0	7.5	45,860,000
,, ...	Carleen en. 45 in.	18.3	6.8	5.6	43,690,000
Great Work ...	W. Breage 60 in.	11.45	9.0	7.0	43,660,000
,, ...	Leed's en. 60 in.	13.5	8.0	7.0	59,400,000
Wheal Leisure'.	Eastrn. en. 70 in.	12.14	10.0	8.0	
,, ...	Westrn. en. 66 in.	10.36	9.83	7.75	34,820,000
Gt. St. George .	North 60 in.	10.84	10.0	6.5	52,420,000
,, ...	South en. 40 in.	15.74	9.0	7.5	30,490,000
,, ...	Devonsh. 70 in.	6.2	10.0	7.5	27,030,000
Wh. Prudence .	33 in.	14.45	8.75	6.75	54,760,000
S. Wh. Towan .	40 in.	11.58	9.0	7.0	61,310,000
Wheal Liberty .	58 in.	13.2	9.3	8.0	44,440,000
Wh. Relistian..	60 in.	10.37	9.6	8.0	43,020,000
Wh. Prospect ..	50 in.	5.8	9.0	7.5	31,440,000
Wheal Virgin..	40 in.	11.88	9.0	7.0	35,360,000
Wheal Leeds ..	36 in.	15.8	8.0	8.0	33,100,000
Ballaswidden ..	24 in.	9.7	7.0	6.0	56,580,000
Levant	New en. 40 in.	8.36	9.0	7.0	24,490,000
Ding-dong	30 in.	10.0	6.0	6.0	25,820,000
Providence, St. Ives	30 in.	12.2	6.0	6.0	25,820,000

Average Duty of Steam-Engines employed in pumping in the Mines of Cornwall, for the Half-year ending June, 1837.*

MINES.	Engine and the diameter of the cylinder.	Load per sq. inch on pist.	Length of stroke in cylind.	Length of stroke in pump.	Pounds lifted one foot high by consuming a bushel of coal.
		Lbs.	*Feet.*	*Feet.*	
W. U. Wood .	Williams's 80 in.	8.38	10.0	7.5	56,685,000
Poldice . . .	Sims's 90 in.	5.84	10.0	7.0	42,964,000
Wh. Damsel .	Stephens' 50 in.	13.0	9.33	7.25	45,329,000
Wheal Jewel .	39 in.	13.6	8.5	6.0	34,795,000
Wheal Tolgus .	Davey's 70 in.	7.56	10.0	7.5	47,536,000
,, . .	Horton's 70 in.	15.0	10.0	7.5	60,537,000
,, . .	Pryce's 25½ in.	14.97	6.0	6.0	25,206,000
Dolcoath . .	76 in.	9.83	9.0	7.5	46,398,000
E. Wh. Crofty .	80 in.	8.32	10.33	7.75	44,392,000

* From Mr. English's Mining Review, December, 1837.

(*Table continued.*)

MINES.	Engine and the diameter of the cylinder.	Load per sq. inch on pist.	Length of stroke in cylind.	Length of stroke in pump.	Pounds lifted one foot high by consuming a bushel of coal.
		Lbs.	*Feet.*	*Feet.*	
North Roskear .	New eng. 70 in.	13.2	10.0	8.0	79,535,000
South Roskear .	W. Chance 60 in.	7.05	9.0	7.0	43,534,000
Tincroft . .	56 in.	13.88	9.33	7.25	40,952,000
Binner Downs .	W. Treas. 50 in.	14.01	9.66	8.0	48,559,000
,, . .	Gregor's 42 in.	15.8	9.0	7.5	41,204,000
,, . .	Burn's 64 in.	12.37	9.33	7.75	48,443,000
,, . .	W. Penny 24 in.	13.1	5.25	5.25	32,438,000
Wheal Julia .	80 in.	7.74	11.0	9.0	
W. Darlington .	80 in.	14.6	10.0	8.0	71,259,000
Marazion . .	Powlet's 60 in.	15.32	9.0	8.0	55,043,000
,, . .	E. Rodney 40 in.	7.2	9.0	7.0	40,611,000
Consolidated .	Taylor's 85 in.	11.46	10.33	7.75	63,020,000
,, . .	Davey's 80 in.	13.09	11.33	8.75	71,454,000
,, . .	Pearce's 65 in.	16.8	9.0	7.5	51,535,000
,, . .	Woolf's 90 in.	11.56	10.0	7.5	51,132,000
,, . .	Bawden's 90 in.	8.3	10.0	7.5	44,736,000
,, . .	Shears's 65 in.	12.9	9.0	7.5	54,418,000
United Mines .	Cardozo's 90 in.	11.9	9.0	8.0	50,776,000
,, . .	Little en. 30 in.	17.96	9.0	7.5	59,461,000
,, . .	Loam's 85 in.	11.6	10.0	7.5	63,866,000
,, . .	Hocking's 85 in.	12.7	10.0	8.5	68,635,000
W. Beauchamp	Western 36 in.	16.3	7.75	6.0	32,714,000
,, . .	Powning's 36 in.	12.0	8.0	6.0	31,440,000
Polgooth . .	66 in.	9.2	9.8	7.4	74,615,000
Charlestown U.	50 in.	12.41	9.3	8.2	46,501,000
Pembroke . .	Pearce's 50 in.	8.0	9.0	7.0	43,553,000
,, . .	Edgecum. 40 in.	17.5	9.0	6.5	44,008,000
East Crinnis .	Hudson's 76 in.	12.9	10.33	7.25	57,403,000
,, . .	Rundle's 41 in.	16.0	9.3	7.25	55,402,000
Fowey Consols .	Austen's 80 in.	10.97	10.3	9.25	87,065,000
,, . .	Sawle's 24 in.	16.93	8.5	5.5	42,832,000
Roche Rock .	36 in.	14.2	8.5	6.8	40,269,000
Brin Tye . .	36 in.	7.0	5.75	5.75	29,605,000
E. Wheal Rose.	36 in.	4.8	7.5	6.0	21,247,000
Wheal Vor . .	Borlase's 80 in.	13.94	10.0	8.0	74,073,000
,, . .	Trelawney's 80 in.	13.89	10.0	7.5	61,335,000
,, . .	Woolf's 53 in.	16.0	9.0	7.5	41,390,000
,, . .	Carleen en. 45 in.	17.13	6.8	5.6	37,459,000
Great Work .	W. Breague 60 in.	10.89	9.0	7.0	45,292,000
,, . .	Leed's en. 60 in.	15.9	8.0	7.0	63,236,000
Wheal Leisure	Eastrn. en. 70 in.	13.34	10.0	8.0	47,969,000
,, . .	Westrn. en. 66 in.	11.3	9.83	7.75	48,677,000
Gt. St. George .	North 60 in.	10.84	10.0	6.5	35,120,000
,, . .	South en. 40 in.	17.76	9.0	7.5	54,500,000
,, . .	Devonsh. 70 in.	7.9	10.0	7.5	
Wh. Prudence .	33 in.	16.7	8.75	6,75	27,236,000
S. Wh. Towan .	40 in.	14.43	9.0	7.0	43,995,000
Wheal Liberty .	58 in.	13.2	9.3	8.0	67,365,000
Wh. Relistian .	60 in.	11.34	9.6	8.0	44.572,000
Wheal Virgin .	40 in.	15.24	9.0	7.0	31,119,000
Wheal Leeds .	36 in.	19.18	8.0	8.0	39,859,000
Ballaswidden .	24 in.	9.8	7.0	6.0	35,294,000
Levant . . .	New en. 40 in.	10.0	9.0	7.0	67,810,000
Ding-dong . .	30 in.	12.58	6.0	6.0	26,156,000
Providence, St. Ives . . .	30 in.	16.2	6.0	6.0	32,889,000

From the following Table, by Sir Charles Lemon,* it would appear that since the establishment of the duty-papers the work performed by the Cornish engines has been far more than doubled in twenty-four years, and the duty performed by the best engines during that time has been more than trebled.

A Table of the Duty performed by Steam-Engines in Cornwall, showing the Average Duty of the whole for each Year, and also the Average Duty of the best Engine.

Years.	Approximate No. of Engines reported.	Average Duty of the whole.	Average Duty of the best Engine.	Years.	Approximate No. of Engines reported.	Average Duty of the whole.	Average Duty of the best Engine.
1813	24	19,456,000	26,400,000	1826	48	30,486,630	45,200,000
1814	29	20,534,232	32,000,000	1827	47	32,100,000	59,700,000
1815	35	20,526,160	28,700,000	1828	54	37,100,000	76,763,000
1816	32	22,907,110	32,400,000	1829	54	40,910,000	76,100,000
1817	31	26,502,259	41,600,000	1830	55	43,108,747	76,885,516
1818	32	25,433,783	39,300,000	1831	58	43,350,555	71,087,000
1819	37	26,252,620	40,000,000	1832	59	45,040,221	85,045,000
1820	37	28,736,398	41,300,000	1833	56	46,626,558	73,335,000
1821	39	28,223,382	42,800,000	1834	52	47,837,064	90,920,000
1822	45	28,887,216	42,500,000	1835	51	48,210,293	91,672,211
1823	45	28,156,162	42,122,000	1836	61	46,646,250	85,399,000
1824	45	28,326,140	43,500,000	1837	58	47,087,374	87,212,000
1825	50	32,000,741	45,400,000				

It will be readily supposed that the water pumped up by these engines must be very considerable; and, admitting that a large proportion of it thus removed from the lodes and the workings generally in mines would not naturally rise to the surface, that the mining districts must be deprived of numerous springs which would otherwise flow in them. The following Table, extracted from the duty-paper for December, 1837, is not only useful as showing the greatest and least quantities of water, in imperial gallons, discharged *per minute* from the mines mentioned in 1837, but also as pointing out the months when the greatest quantity of water necessary to be pumped up prevails in them. Though there are local variations in the latter respect, as will be seen, yet the greatest quantity of water in the mines, as we might expect, is found after the winter-months, produced by the percolation of water during that season into them, and showing that it is to the top, or surface water that this variation of the quantity in mines

* Statistics of the Copper Mines of Cornwall, Journal of the Statistical Society, June, 1838 (vol. i. p. 67).

is chiefly due, the bottom waters, or those rising from beneath, being more constant as to their general supply.

Table of the greatest and least quantities of Water, in Imperial Gallons, discharged per Minute from the Mines in 1837.

Mines.	Maximum.		Minimum.	
Wheal Unity Wood .	March . .	460·59	November .	226·98
Poldice	,,	695·87	,,	328·05
Wheal Damsel. . .	,,	80·46	December .	58·05
Wheal Jewel . . .	February .	96·13	Nov. and Dec.	51·13
Wheal Tolgus . . .	March . .	869·99		
Dolcoath	,,	294·25	October . .	180·35
East Wheal Crofty .	,,	213·98	,,	120·66
North Roskear . . .	,,	243·51	December .	133·22
South Roskear . . .	,,	156·06	October . .	108·80
Tincroft	,,	229.73	,,	113·19
Wheal Seton . . .	May . .	175·53	,,	123·50
Wheal Treasury . .	March . .	1001·91	,,	593·73
Wheal Darlington . .	January .	1216·57	November .	717·18
Marazion Mines				
Powlet's E.	March . .	600·44	December .	223·53
Rodney E.	June . .	199.52	October . .	64·50
Consols	February .	1657·18	November .	1284·82
United Mines . . .	March . .	1634·49	,,	1036·90
Wheal Beauchamp .	February .	359·78	October . .	215·55
Wheal Julia . . .	July . .	429·16	May . . .	323·06
Carzise	June . .	191·90	October . .	235·62
Polgooth	February .	1084·67	,,	643·74
Pembroke	March . .	748·37		
East Crinnis . . .	,,	1097·97	October . .	621·50
Charlestown . . .	July . .	280·14	April . . .	167·84
Fowey Consols				
Austen's E.	February .	430·60	October . .	290·85
Sawle's E.	,,	108·00	,,	66·36
Roche Rock . . .	,,	293·38		
Bryn Tye	,,	34·47		
East Wheal Rose . .	March . .	248·00		
Wheal Union . . .	August .	430·39		
Wheal Vor	March . .	1019·68	October . .	883·00
Great Work . . .	February .	377·33	,,	219·30
Wheal Leisure . . .	March . .	752·00	December .	558·17
Great St. George . .	,,	823·00	November .	528·22
Wheal Prudence . .	,,	145·26	Nov. and Dec.	123·33
Wheal Liberty . . .	,,	649·14	September .	506·05
South Towan . . .	December .	302·48	July . . .	262·14
Relistian	March . .	225·68	October . .	152·17
Wheal Virgin . . .	January .	233·30	December .	151·87
Wheal Leeds . . .	June . .	228·60	October . .	199·56
Ballaswidden . . .	February .	22·36	September .	10·16
Levant	June . .	31·24	January . .	22·90
Ding Dong	November .	87·60	September .	22·60
Providence	March . .	139·08	November .	96·13
Morvah and Zennor .	December .	139·70	September .	68·31

Sir Charles Lemon has formed the following Table of the water discharged by the engines reported in the duty-paper for the year 1837. It has been considered that the estimated quantity of water raised by the Cornish engines is too great: even admitting this in a degree, still, when we consider the quantity that must be raised by them, by the engines which are not reported in the duty-paper, both in Devon and Cornwall, and by the various pumping water-wheels, adding that which drains into the adit levels without machinery, the collective amount of water removed by mining operations must be very considerable in the district under consideration.

Water discharged in 1837 *by the Engines reported in the Duty Paper.*

Months.	No. of Engines.	Galls. per Min.	Months.	No. of Engines.	Galls. per Min.
January .	62	17,143	August .	59	13,866
February	63	18,915	September.	59	13,221
March .	64	17,588	October .	57	12,188
April . .	58	15,605	November.	57	12,299
May . .	62	15,422	December .	56	12,891
June . .	60	15,152			
July . .	60	14,634	Total . .	178,924	=31,141,800 tons for the year 1837.

By Second Duty-Paper, 11 Engines . 5,758,912 tons.

Total . . . . . 36,900,712 tons.

To show the present general mode of working the mines we must refer to plates 7, 8, 9, 10, and 11. Plate 7 represents the plan of the old and long-celebrated mine of Dolcoath. As respects the levels on the lodes, the ground is supposed to be transparent, though the houses, fields, roads, &c., are shown on the surface, as in any common plan or map. By thus supposing the ground transparent the course of the under-ground levels, adits, &c., are exhibited in the relative positions they occupy beneath, as respects the surface above, so that a perpendicular line let fall from it through the ground would exactly cut the levels, adits, &c., represented beneath at their various depths. If we look at the main lode, we find that several lines, with different numbers near them, run across the plan. These lines represent the levels driven upon the lode, and the numbers correspond with their respective depths, beneath a given level; and, if perpendicular lines were let fall from this level upon such lines, they would cut them at the various depths marked, such as 60, 70, 80, 100, or any other number of fathoms, as the case may be. In this, as in most Cornish and Devon mines, the depths of the levels are reckoned from that of the adit, and not from the actual surface of the country, which often undulates considerably, so that a given level may be 100 fathoms beneath such surface at one place, and only 50 fathoms at another; hence the practice of reckoning beneath a constant well-known level, that to which the water is pumped up, and at which

occurs the gallery or channel through which it is conducted into some lower ground or valley.

It will be observed, by the increase of the numbers marked on the levels to the southward, that the dip or *underlie* of the lode must be in that direction; and, further, that lines, representing equal depths, are much closer to each other in some places than in others, showing that the lode approaches more towards the perpendicular in those places than in others. In reality, these lines are far more irregular than can be represented on the scale of this map. It will be seen that, while the engine-shaft is inclined with the dip or underlie of the main lode, that the Gossan-shaft is sunk perpendicularly; so that, cutting the plane of the lode somewhere near the 125 fathom level, cross-cuts are made to communicate with it, at less depths from the north and at greater depths from the south, in order that the ores raised at those levels may be brought to it and lifted to the surface. Several other cross-cuts will be observed on the plan, some of which are merely for the purpose of uniting the various parts of the mine conveniently together, while others act as channels for draining the waters so that they may be brought to the most convenient place for pumping. Cross-cuts of this kind will be seen between North Entral lode and the main lode, at the various depths of 40, 70, 80, 100, and 120 fathoms; and the levels upon a southern lode, known as the Caunter, will be seen to cut across or abut upon those of the main lode, where the two lodes meet. As the levels upon this caunter, or contra lode, cut an elvan dyke in such a manner that the deeper they are the more the elvan occurs to the northward in the plan, it will be clear that this elvan must have a dip, or underlie, more or less in that direction, the caunter dipping, or underlying, towards the true south, varying in this respect from the main lode which underlies towards the present magnetic south.

This plan shows, therefore, the mode in which the levels on the lodes, the shafts, the adits, and cross-cuts, occur, as regards the surface of the country, upon which the area representing the sett, or space allowed by the lords to be worked, is laid off. In the larger mines, the whole sett may be composed of grants from several lords or proprietors of the land; and, perhaps, different arrangements may have been made with each as to dues, according to the prospects of success upon each lot of ground, or the condition of the mine at the time. As each lord or proprietor takes perpendicularly downwards, from the surface-boundary of his land, and a branch of ore may be cut partly in his rights and partly in those of another, the perpendiculars of such surface-boundaries are carefully ascertained in the under-ground workings, and so well is this accomplished, that disputes on this point are rare. Unfortunately good plans of these workings are by no means so common among the mines of Cornwall and Devon, as we might expect, and as the interests of the adventurers would seem to require. On some mines, which it would be invidious to notice, the plans are exceedingly well executed, and mining draughtsmen are appointed, so that the workings are perfectly understood, and great facilities afforded for conducting new operations; advantages which it might be supposed were so obvious that no mine of fair importance would be without its draughtsman, combining his

labours, when the plans would not afford him sufficient occupation, with some other duty on the mine.*

If we suppose the south side of the main lode at Dolcoath, and, consequently, as it underlies south, the upper, or *hanging*, wall, to be removed, we should have the section of the workings represented in plate 8, the lines of levels in which correspond with those in the plan (plate 7). It will readily be observed that, by this section, we see many things which could not be so well shown on the plan, and others, which could not be represented at all in it. In this section of the workings those portions which have been cut for galleries in the levels, the shafts, andwhere bunches or accumulations of ores have been found, are shaded; and those parts in which the rubbish of the workings† has been thrown back, and so arranged that the galleries or levels, and the shafts, should pass freely through them, are represented as composed of broken fragments. The killas, or slate, remains white, while the granite is dotted. We now see that this main lode cuts into granite in its eastern prolongation (a circumstance not shown in the plan, where the surface-boundary of this rock, and of the slate, or killas, is alone represented), and a tabular piece of granite, forming a projecting mass, or vein, from that rock, at a higher level, being cut by the lode, at a short distance from the main mass of granite, appears as if separated entirely from it amid the slate. The bunches of ore will be observed to have occurred very irregularly, and the places which they occupied, in a great measure, will be seen filled up by the rubbish or *attle* taken from the non-productive workings of the mine. Levels, on the east, have been driven into the granite, and, on the west, into the killas, for the purpose of *discovery*, as it is termed, —that is, in search of bunches of ore—and, in both directions, the search was abandoned, as it was not considered advisable to incur further cost for that purpose.

The lowest part of the engine-shaft is termed the *sump*, and it will be perceived that it forms the lowest part of the mine, and, consequently, if the drainage is properly contrived, that all the water can find its way to it. A mine which has been abandoned, and again set to work, is said to be *in fork*, when all the water that accumulated in it, and which it was necessary to remove, has been pumped out. The proper drainage of a mine requires constant attention and good management; so that the new workings may be as clear as possible from water as they are advanced.‡ The various breaks or *lifts* in the arrangement of

* Speaking of the mines in the great mining district of Gwennap, Redruth, and Camborne, Mr. Thomas remarked, in 1819, that there were but two or three of them, "where regular plans and sections are to be seen, as the registers of the workings appear in general to be merely the rough accounts of the measurements, or at best detached sketches." (Report on a Survey of the Mining District of Cornwall, from Chacewater to Camborne, p. 7.) In this matter there is certainly improvement within the last twenty years, but it is far from considerable.

† Commonly known as the *deads* or *attle*.

‡ Mr. Carne observes that, of late years, very great improvements have taken place in unwatering the mines. He remarks that, not long previous to 1824, from the bad condition of the adits and the pit-work connected with the pumps, and the

the pumps down the engine-shaft are represented, and it will be observed that they terminate upwards in the deep adit through which the water so raised is conducted away from the mine. A system of ladders will be seen in this shaft, up and down which the miners ascend and descend to the various levels; and, by other ladders, dispersed through the mine in convenient situations, so that a complete communication is kept up through its various parts. The ores were drawn to the surface up four shafts by the three steam-whims (one drawing at two shafts), when this plan was made; and it should be borne in mind that, as the state of a mine varies according to circumstances, so will the position and number of the shafts employed for drawing ores at given times, the facility of work, combined with cost, being always studied. Many shafts exist, therefore, in an old mine, which are not used for drawing ores or pumping, as appears to have been the case with several shafts on the main lode at Dolcoath, including an old pumping-shaft. As every shaft has its name and every level is known by its depth, the position of work in any part of a mine is at once comprehended by all.

The various cross-courses traversing the lode are marked and named; and though these, when they heave the lode considerably, bar the progress of the miner, or cause a great increase in the influx of water into the mine, are injurious, at other times they are highly useful by keeping out the water of a neighbouring mine. In the latter case they are, in consequence, preserved uncut, as in the mine before us, where the great cross-course on the east of the lode is untouched, except at the adit-levels, which traverse it. This cross-course has cut through the lode, the continuation of which is worked in the adjoining mine of Cook's Kitchen, and heaved it, so that a line prolonged from one would not strike the other; and it lately kept out a body of water which had accumulated in the old workings at Cook's Kitchen. Such main cross-courses, which frequently bound setts, and thus often separate great mines, are carefully preserved, so that the failure of one mine does not cause its waters to pour in and deluge the other beyond the power of its engines to clear it. In different parts of the same mine the cross-courses are occasionally in part preserved, in order to keep out the water from the deeper levels, when this can be conveniently accomplished. On the west of the section before us the workings on the west do not reach a cross-course beneath the 40-fathom-level, though, from a shaft having been sunk upon it, the workings which reach it on the east side are deeper. Cross-courses are found extremely useful for driving adits upon, and, as they generally cut the lode at considerable angles, the work thus carried on exposes a good sec-

want of good surface-draining, much water, pumped up, again found its way back among the workings, or escaped from the surface into them, so that the quantity of water then drawn up many of the deep mines, in consequence of proper attention to these points, was less than it was at the commencement of this century, though the mines had become deeper. Mr. Carne, writing in 1824, remarks that the water drawn to the adit in Huel Unity and in the Consolidated Mines was estimated at about three-fifths of the quantity drawn under the old system, and the water from Treskirby, Huel Chance, and North Downs, was not so much as was pumped formerly from the latter mine alone.—Trans. Geol. Soc. Cornwall, vol. iii. p. 67.

tion of the *country*, as it is termed, or rocks, on both sides, and, consequently, of any lodes which may there occur.

It will be observed that the distances at which the levels have been driven from each other are very irregular upon this lode, excepting in the lower workings, beneath those of 150 fathoms, which have been made more in accordance with the frequent modern practice of forming them ten fathoms from each other, as will be seen in plate 9, representing the workings on the caunter or contra lode, in the same mine, where we find complete regularity in this respect, from the adit to the 90-fathom level. The workings beneath that level have been driven for discovery, and, probably, at greater distances to save expenses. It will be observed that, upon this caunter or contra lode, which is worked through Harriett's lode up to the main lode, considerable expense must have been incurred in driving levels, both in the depth and towards the eastward, in search of ore, which was unattended with success. These heavy expenses, on account of discovery, can only be profitably borne by mines of a certain magnitude, which, throwing up a fair general amount of ores, can afford to put aside a certain proportion of the profits for discovery. Perhaps Fowey Consols may be cited as the best existing example in the district of the value of a constant system of working for discovery; so that, from having a large amount of ground open, from which a great quantity of copper-ores are on the whole raised, expenses are incurred for discovery which would be ruinous if this mine were split up into three or four smaller adventures; for, from time to time, the search being attended with success in various parts of the mine, as a whole, a constant profit is kept up.

An idea may be obtained of the different kinds of workings carried on upon a level, when driven for discovery, and when success attends the labour, by reference to the sketch, of part of Fowey Consols, plate 6, in which the gallery, in the distance, through which a miner is proceeding with his light, was driven for discovery upon an unprofitable part of the lode; indeed, on one, where it was *wrung up*, or *nipped in*, from the meeting of the walls (p. 317), so that the level or gallery was driven onwards by working out a sufficient quantity of the *country*, or rock, on both sides. The open space, where the walls are supported by junks of timber, is where, in the progress of driving the level onwards, the lode again spread out and a bunch of ore was cut, which being cleared out, this cavity was left. The white line on the left hand is a quartzose branch, which quitted the lode in that direction. Towards the eye, a few fathoms from the miner represented as seated, the lode again became small, but, the work of discovery having been continued, another bunch of ore was cut. It must be confessed that the sketch (plate 6) should not be taken as a general representation either of the height of the galleries or of the width of lodes where ore is broken.* The former necessarily depends upon the mode in which a mine is worked, and the expense which it may be thought advisable to incur; so that, in mines which are not very prosperous, some of these passages are very low confined

* In the sketch itself, also, the miners are represented too small as respects the gallery and open cavity, which therefore appear too large.

places. Generally, however, in the Cornish and Devon mines, there is ample space for all useful purposes. The open spaces whence ore has been taken vary considerably, as must happen, according to the breadth of the lodes in those situations and the amount of ore in them; for the lode may be broad or *big* enough, and yet not contain ore in sufficient quantities to be worked. There can be scarcely any rule in a variable thing like a mineral vein, or lode, as to the breadth of the parts which may be worth working, for, though small, with little ore in some places, it may be several feet across in others, and be there rich; or it may be thin and rich in one place and broad and comparatively poor in another; so that it may even be questionable how far it may be advisable to take that portion out at all. These are matters upon which the chief agents decide according to their skill and judgment. It is usual in mines, particularly those worked on the large scale, and for a continuance, not to take out all the ore which could be immediately got at, if thought necessary, but to leave it, here and there, to be worked as the general prospects of the mine may require, and to which the miners return if less ore is raised generally in the adventure than could be wished. The ores thus left in various places are often termed the *eyes* of the mine; and when it may be necessary, in abandoning the mine, or from any pressing circumstances, to remove them, it is termed, *picking out the eyes of the mine*. In some mines these "eyes" are very valuable, and much skill and judgment is employed by the captains in so arranging the workings that a general good supply of ores may be obtained.

The transverse section across the lodes in Fowey Consols Mine, plate 11, will show the mode in which the workings on different lodes are connected with each other by means of cross-cuts, so that the ores may be brought to the shafts, not only in the course of the lodes, as represented in plates 8 and 9, but at right angles to their courses, as in the section before us. The Union shaft (G) cuts perpendicularly through five lodes, reckoning that near the surface and the branch from the Crosspark lode beneath the 60-fathom level, and by means of the cross-cut at that level it communicates with all the lodes which are found at it in the mines, namely, thirteen. Another cross-cut at the 22-fathom level unites a smaller number of lodes with this shaft. As the Union shaft cuts perpendicularly through lodes dipping north, it will happen that cross-cuts must be made both on the north and south to meet it, as will be readily seen, by the section, has been done. Sampson's shaft affords an example of one partly perpendicular, so as to cut a lode, and partly sunk upon its dip or underlie, the perpendicular portion being sunk about 38 fathoms from the surface, or to the 10-fathom level (beneath the adit), to meet the Crosspark lode, upon the underlie of which it descends to the 80-fathom level. These inclined shafts, upon the underlie of lodes, are usually employed to save the charge of sinking perpendicular shafts in particular parts of mines, and when the angle with the vertical is not great, the amount of wear and tear upon the kibbles carrying up the ores, and upon the chains by which they are commonly suspended in such shafts, is not so considerable as might be supposed.

In this cross-section (pl. 11) we have an example of the more modern prac-

tice of sinking a whim-shaft, for raising the ores, close to the engine-shaft, both being united at convenient distances by short cross-cuts. The engine-shaft in this case is beneath Austen's engine, one much celebrated for the duty performed by it.* The advantages of these double shafts are consi-

* As there has been much discussion respecting the real merits of this engine among mining engineers, we shall quote the description given of it by Mr. Wicksteed, an engineer unconnected with the mines, who was sent by the directors of the East London Water-works into Cornwall to make inquiries respecting the engines there used in the mines.

"The next engine that I saw," says Mr. Wicksteed, "was one at the Fowey Consolidated Mines, near St. Blazey. The cylinder was 80 inches, the pump-stroke 9¼ feet; the duty was, in August, equal to 83,296,000 lbs., raised one foot high with an imperial bushel or 84 lbs. of coals; it consumed about a bushel or 84 lbs. of coals per hour. This is a most splendid engine, and does greater 'duty' than any other engine in Cornwall. The construction of the valves and other parts of the engine is so perfect, that, although its load was equal to about 51,000 lbs., the hand-gear might be worked by a boy of ten years of age, as far as strength was required. I worked it myself with perfect ease; whereas, although the load upon one of our engines of 36 inches cylinder is only about 12,000 lbs., it requires not only a strong, but also a weighty man to work it.

"The hand-gear is all bright work, and finished in first-rate style. The quantity of bright work in an engine of course depends upon the taste of the person ordering it, and I certainly saw many Cornish engines, of longer standing than the one in question, that displayed very little bright work; but that it can be executed as well in Cornwall as in any other county in England must appear evident to those who have seen this engine, and the founderies or engine-manufactories at Hayle. At the latter place I saw an 80-inch cylinder, 12 feet feet long, in the boring-machine, and could not perceive a flaw in it.

"I was very much struck with the ease with which the engine in question appeared to work; there was scarcely any noise, the greatest was that of the steam in its passage through the expansion-valve. To one who had been used to the noise of the pumping-engines in London it appeared remarkable.

"The reason that this engine does more work than any other in Cornwall is, in my opinion, owing chiefly to the construction of the boilers, which are different to the generality; inasmuch as they have an internal tube, of about 21 inches diameter, passing through the main flue of the boiler, extending from the back part of the boiler as far as the bridge of the fire-place, dividing the flame as it passes from the fire-place, and thus where the heat is more intense the surface exposed to its action is greatest. There is also a tube of about the same diameter, and 36 feet long, around which the flue from the boilers passes before entering the chimney: into this tube the feed is sent before it passes into the boilers, and is previously heated to a temperature of 180° by means of the heat that might otherwise pass into the chimney unused."—*Transactions of the Institution of Civil Engineers*, vol. i., 1836.

It will be seen (p. 552) that the average duty of this engine for 1836 was equal to 85,650,000 lbs.; the next best engine for duty being one of 80-inch cylinder, at Wheal Darlington, near Marazion, which was equal to 77,040,000 lbs. The average duty of the same engines (p. 553) for the half-year ending June, 1837, was respectively 87,065,000 lbs. and 71,259,000 lbs. The average duty of Borlase's engine at Wheal Vor (80-inch cylinder) was = 74,480,000 lbs. in 1836, and = 74,073,000 lbs. for the last-mentioned time. The average duty of Taylor's engine

dered to be considerable, and hence they are coming into use in some of the best-worked mines. The water raised is delivered into the adit-level, running across the various lodes, and opening out into an adjoining valley. It cuts through no less than thirteen lodes, from which the water is delivered into it by the various pumping-machinery of the mine, among which we must not neglect to notice the water-engines, in which water supplies the place of steam, worked above this adit-level.

To sink shafts in deep mines, so as to cut a lode at the lower levels, is a work of no little skill and labour: it is one, however, which is in general extremely well executed by the Cornish miners. To sink a perpendicular shaft downwards to a depth where it is calculated the lode should be cut may seem to require little skill further than that necessary for correctly finding the spot on the surface whence the work is to commence. When, however, they are sunk in several pieces, beneath each other, at the same time, each piece of work, in order to save time, being commenced at different levels, it will readily be admitted that those engaged in this work must employ no small skill, so that the different pieces of the shaft thus formed may exactly fit when connected with each other—a very small error of measurement amid the various subterranean passages or levels beneath being sufficient to throw a piece of work out of its proper place. There are several instances recorded of work thus performed with very great precision; and it will be readily understood that the power thus possessed of sinking a shaft in the fourth, sixth, eighth, or any other proportion, as the case may be, of the time which would be required to sink it from the actual surface downwards, must be of great importance to mines to which a somewhat speedy communication of this kind, between the surface and the greater depths, may have become necessary.

To drive an adit up a cross-course, or to meet a lode which offers a broad surface, may also be no difficulty; but to drive from one point to another, through many fathoms of country, does require skill, more particularly when the work, in order to save time, commences at both ends, and is intended to meet, and form one gallery, in the intermediate distance.

(85-inch cylinder), and of Davey's engine (80-inch cylinder), at the Consols Mines (Gwennap), was respectively 73,160,000 lbs. and 68,220,000 lbs., in 1836, and 63,020,000 lbs. and 71,454,000 lbs. for the first six months in 1837. The average duty of the 66-inch cylinder engine at Polgooth was, in 1836 = 73,200,000 lbs.; and for the latter period = 74,615,000 lbs.

The system of adits is one requiring much attention. The *great adit*, as it is termed, through which the waters of numerous mines in Gwennap and near Redruth are discharged, measures, according to Mr. Thomas (who has laid it down in his map of the mining district from Chacewater to Camborne), about 26,000 fathoms, or nearly 30 miles in length, the various branches being included. "The greatest length to which any branch appears to have been extended from the adit-mouth is at Cardrew Mine, measuring about 4800 fathoms, nearly 5½ miles. The highest ground it has penetrated is at Wheal Hope, where the adit is 70 fathoms deep, at Chilcot's shaft, and is deeper in the branches extending from thence."* This adit is 39 feet above the level of the sea at high-water in Restronget creek, into which the waters discharged from it flow, its mouth being near Nangiles, in a valley communicating with the creek.†

As the greater number of mines in Cornwall have from time to time been enlarged, or the works carried on in different parts of the lodes, as circumstances arose, there are few regularly-planned surface-works. Those on Fowey Consols Mines, represented in plate 10, are the most concentrated of any with which we are acquainted. The lodes which run across this part of the mine are there shown occurring beneath the surface-works, the relative positions of which will be best understood by reference to the plan itself. It will be observed that there is a very complete system of rail or tram roads, by which the ores are conveyed from the

* Report on a Survey of the Mining District of Cornwall, from Chacewater to Camborne (1819), p. 29. This Report, accompanying two sections and a map, contains very valuable information respecting the condition of ninety-three mines at that time, some unworked, many in full work. It is not a little curious to observe the different state of many of them after the lapse of only eighteen or nineteen years, some being abandoned which were then considered good mines, while others have increased in value, and some have remained much in the same state.

† The variable heights of other adits in the same district will be seen by the following table, by Mr. Thomas, of those of other adit-mouths above the same level:—

Carn Marth Cove Water-shoot . .	413 feet
Adit at Laity Mill	52 „
New Wheal Virgin Adit . . .	374 „
Pedden Andrea	287 „
Tresavean	208 „
Wheal Harmony	171 „
Wheal Mary	81 „
Wheal Sparnon	315 „

shafts, where they are raised, to the dressing-floors. Independently of the steam-engines and water-wheels for pumping water and raising ores which occur in this part of the mine, we find a variety of buildings and arrangements, the use of which will be better understood when the mode of treating the ores, after they have been brought to the surface, is noticed. We may however observe that the water-power possessed by this mine, situated as it is upon a hill, is a very unusual circumstance in Cornish mines of magnitude, and is due to the foresight and perseverance of Mr. Austen Treffry,* who obtained it at much labour and cost.

With respect to the persons employed in the mines, much depends on the relative magnitude of the latter. While on the smaller adventures one, or, at most, two captains or agents, with a few miners and surface-people, will suffice, in the larger mines there is an establishment of clerks, several captains or agents, and a large amount of miners and labourers. When the sett of a mine is taken, and the necessary arrangements made with the lord or lords of the land, as the case may be, certain shares are created, which are very variable in number in different mines, and the persons taking these shares are termed the adventurers. In the older adventures the shares were commonly either 64 or 128 in number in each mine, but of late years the shares have materially varied in this respect. In the great Consols Mines the shares amount to 100, and the old number seems seldom employed in the more modern adventures. Within the last three or four years the scrip system has been introduced among the mines of the district, and the number of shares has amounted to 10,000 or more in the scrip mines. The shares are of course bought and sold, and necessarily vary much in value, according to the mines, the number of shares in them, and their prosperity at the time. Thus, while a share in the Great Consols may be worth from 1200*l.* to 1500*l.*, one in the minor and scrip mines may not be above 1*l.*, and may be even less.

The adventurers in the one case, or the directors of the scrip companies in the other, having arranged with the lords, and obtained the sett or grant of a lease for working under stipulated conditions, they adopt such a mode of management as they may consider most proper; and hence, as Mr. John Taylor observes, there is rather a general coincidence than an absolute uniformity of practice.† The practical direction of the works is confided to agents, named captains, who are generally selected from the most intelligent workmen. In the larger mines their duties are divided. A "captain of the greatest experience usually governs the rest, and in conjunction with, and under the advice of, one of the partners, or some person appointed as the principal manager, attends to all the business of the concern; while the departments of account, of the construction and care of engines, of the pur-

* The chief and great adventurer in these mines.

† English's Mining Review, December, 1837, p. 265.

chases of the various articles used, of the ore-dressing, &c., are superintended by persons appointed by the manager and principal captain. Upon them, indeed, is thrown generally the great weight of responsibility, and, therefore, the appointment of their subordinate agents."* The captains, under the chief, have different duties assigned them—those employed underground see that the work is there conducted properly; while the *grass-captains*, as they are usually termed, superintend the work on the surface, such as the dressing of ore, &c., which is done in the *bal*, or upper part of the mine. Engineers are also appointed, and to them is confided the care of the various engines and machinery.

In the generality of mines the *purser* is the chief officer, keeping all the accounts, and receiving and paying all money. As in Pryce's time, he is usually one of the adventurers, and chosen by the rest, presenting an account of the general state of the affairs at the mine at their meetings, at intervals of one or two months, as the case may be, when the accounts are examined. Having been frequently present at these meetings of adventurers, we must say that nothing can be more fair and open than the statements there made: whether the affairs of the mine be prosperous or not, we never found any concealment of the circumstances from the strangers present; and it rarely happens that such are not present, for Cornishmen still keep up fully their old renown for hospitality. At these meetings the best modes of working the mine are considered, each adventurer voting according to the number of shares he may possess—the greater number of shares carrying the decision, whatever it may happen to be. This mode of conducting mines refers to those in which the shares are few, and the large proportion of the adventurers could readily assemble if occasion should require. With respect to the mode in which the scrip companies conduct their business we are less acquainted: the shareholders being numerous, they must necessarily appoint directors, under whom the management is arranged. These directors, being for the most part non-resident in the mining districts, appoint some person as purser, or chief manager, who reports to the directors. The affairs, therefore, of such companies are made known only through the directors to the holders of scrip shares generally, at any meetings which may be appointed in London, or elsewhere, according to the place where the scrip company may have been formed.

The captains are, as a whole, a very valuable body of men, possessed of a large amount of practical knowledge, and one on whom the adventurers, as the captains deserve, place great reliance. To them the Survey has been under great obligations, and we are anxious to take this opportunity of acknowledging the very able and kind assistance they have at all times, without one single exception, afforded us in tracing out the lodes on the surface, for the purpose of entering them correctly on the Ordnance geological maps. We have to thank them, also, for the prompt manner in

* Taylor, English's Mining Review, December, 1837, p. 265.

which they have answered all questions which bore upon facts connected with the geological phenomena exhibited in the mines under their superintendence.

The persons performing the work under the captains in the various parts of mines may, as a whole, be divided into *tributers*, *tutworkmen*, and *labourers*, though it by no means follows that these divisions are applicable to all mines, for where these are small, or the prospects not good, it is often difficult to obtain tributers. In a mine, however, with fair prospects, they commonly exist, and consist of men who agree to work a portion of a lode for a given time in the best manner they can, receiving as remuneration a certain portion of the value of the ores raised, as may be agreed upon. This portion necessarily varies according to the value of the part of the lode which it is considered will be worked in the given time, usually one or two months. Thus, if the lode be rich, and there be a fair prospect of its continuing so, a smaller portion of the value of the total quantity of the ores raised by the miners, taking the *pitch* or lode to be worked in the given time, is agreed upon, than when the lode is somewhat poor, and may, from all appearances, continue so. The mode in which the agreement is made is very fair. Upon the setting-days, as these agreement-days are termed, the miners assemble before the counting-houses, where the captains are also collected together. The captains, having previously examined the various parts of the mine, have, to the best of their judgment, determined the value of the different pitches to be set, that is, having carefully examined the appearances at the time they have determined what they consider fair terms upon which the various pitches should be granted. The men, on the other hand, have also come to an estimate of the terms upon which they shall offer to execute the work, taking all the usual chances. The chief captain now puts up the various pitches to auction, the biddings being downwards. The captain, therefore, generally names a price above that which should be given, and the miners bid downwards against each other, if they please, until the fair price is agreed upon, which is generally nearly understood beforehand, as all parties are fairly aware of what it ought to be. It may happen, indeed, that the miners at work on the spot, immediately previous to the setting-day, have discovered appearances which lead them to think that they may take the pitch on apparently low terms, so that they may gain largely by breaking an amount of ores which the captains may not consider probable; but this appears to occur very rarely. The pitches are commonly taken by a number of men proportioned to the work to be executed, but, though they often vary from two to twelve, it is usually contrived that there should at least be two for each spell, or core, of eight hours, the usual division of the spells.* This

* Mr. Carne, writing in 1824, observed that it was then only within a few years that the spells, or cores, had been extended from six to eight hours—a change due, he considered, to the improved ventilation and size of the levels which had been effected, so that the miners could work the eight hours instead of six with equal ease and care for their health.—Trans. Geol. Soc. Cornwall, vol. iii. p. 64.

partnership is generally termed a *pair* of men, whatever the number may be, and one commonly acts as bidder, at the setting-days, for the rest.

By obtaining a certain sum in the pound for the ores when sold, the tributers are necessarily interested in sending up as much ore to the surface as they can accomplish during their occupations of the various pitches in a mine, and hence their interests become those of the mine generally. If a pitch should turn out better than was expected, they may make large sums of money, as has often been done; but, should it become poorer, they suffer loss in proportion. From the arrangements usually made in a mine, the produce of each pitch is well separated; and, as disputes are seldom heard between the tributers and the adventurers respecting the proper shares of money to be apportioned to each, it may be fairly concluded that, from good management on one side, and the intelligence of the tributers on the other, even this part of the system works well. The tributers pay for their coals, candles, and gunpowder, at certain rates; for the use of the machinery by which the ore is raised to the surface; and the wages of those who wash and prepare the ores for sale.*

It is difficult to ascertain the exact time at which this system of working on tribute was introduced. It was in force when Jars travelled in Cornwall, in 1765; the period, however, for which the pitches were then taken was four months instead of one or two, as at present. He describes the extent of a pitch as being commonly from 15 to 24 fathoms, the tributers finding the necessary tools, candles, and powder, and paying the charges of preparing the ore for sale; the adventurers only taking upon themselves the charge of the machinery, ropes, &c., for bringing it to the surface. The modes of setting the pitches was then, as now, by bidding downwards.†

Pryce mentions that it was sometimes the practice in his time to let out whole mines on tribute; one, we believe, which has been altogether discontinued, except occasionally in the smaller adventures. Some able miner took the mine on tribute for half a year, a whole year, or even for seven

* Mr. John Taylor has well observed, on the working of this system, that "the mine-owners, having, by their capital and the skill of their agents, discovered the ore, formed approaches to it, drained off the water, and ventilated the places for working, admit co-adventurers for a time, whose interest it is, not only to search out every piece of ore that can be profitably worked, but so to detach it from the matter with which it is mixed, as to incur the least possible expense in after-processes. The payments they make," he continues, "cause them to look with a jealous eye on all cost incurred by others through whose hands the ores may pass, and thus to tend to a general economy, and perhaps, above all, discoveries are much extended by speculation among the men, who risk their labour only while they bring into play the judgment which the habit of constant observation enables them to form."—English's Mining Review, for Dec., 1837, p. 268.

† Voyages Métallurgiques, tom. iii. p. 202.

years, as he mentions was the case at Bullen Garden, and the means of that mine's discovery. In a tin-mine he first paid the lord's and bounder's dues (if it were bounded), in ore, free of all cost, ready for the stamping-mill; of the remainder he paid the adventurers one-half, or one-quarter, as may have been agreed upon according to the supposed prospects of the mine at the time of setting.* In a copper-mine the tributer was at the charge of breaking, raising, and rendering the ore merchantable, and the proceeds of the sales were paid over to the adventurers, who, after settling the lord's dues, divided the remainder between themselves and the tributer, according to the agreement between them. The tributer was bound to keep the mine in good order and properly timbered, to work it fairly, and not so as to encumber the adventurers, upon their re-entrance into possession, by leaving the barren parts, or *deads*, which they would have to remove. To ensure this fair working, the adventurers reserved the right for themselves or their agents to go down into the mine at will, to see that the terms of the agreement were fulfilled.†

Tutworkmen are those who execute work by the piece, generally calculated by the fathom. In this manner shafts are sunk, adits driven, and the labour usually performed in those parts of the mines which do not produce ores, executed. Tutwork is also employed upon the lode itself, though, from the advantages generally considered to arise from the tribute system, the latter is commonly employed as much as possible in mines at full work. The day-labourers are generally employed on the surface in dressing ores and occupations of the like kind, though in some mines day-labour is also used under ground. A large proportion of the surface-labourers consists of women and girls. The gains of the tributers of necessity, as we have seen, vary considerably. Mr. John Taylor stated, in 1837, that the lowest average among the tributers of the Consolidated Mines per month, for one year, was 3*l.* 7*s.*, and the highest 4*l.* 12*s.*‡ Sir Charles Lemon has published the following table, as showing the rate of wages per month, in 1837, near Penzance, Redruth, and St. Austell, remarking that, in places distant from each other only a few miles, this rate sometimes differs largely and for long periods.§

Rate of Wages per Month in 1837.

	West of Penzance.		Midland District, &c.		St. Austell District, &c.		Average.		
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	
Tributers	47	6	68	0	59	0	58	2	*s.* *d.*
Tutworkmen.....	45	0	57	2	59	0	53	8	51 6
Day-labourers	42	0	41	0	45	0	42	8	

The numbers of each class are nearly equal.

* Mineralogia Cornubiensis, p. 187. † *Ib.* p. 188.

‡ Mining Review, December 1837, p. 267.

§ Journal of the Statistical Society, June 1838, vol. i. p. 73.

The comforts of those employed in the mines has of late received far more attention than formerly, and it is rare now to find those places where the women and girls pound or pick the ores on the surface undefended from the weather. Not only are there barracks in which the miners change the clothes in which they have laboured under ground, but, in the better managed mines, there are also others where they may dry those which have become wet during their work. (See plan of Fowey Consols Mines, plate 10.) The miners, are liable, from their occupations, to many accidents and diseases, and it is therefore usual for medical attendance to be provided for them and their families out of a fund raised by small monthly contributions among the miners, under the superintendence of the chief agents. In the deep mines they suffer much from climbing the ladders* to the surface, after they have completed their labour beneath, as also from the great changes of temperature they experience in the winter, when, after working several hours under ground, in a temperature from 70° to 90°,† they walk various distances to their homes in the cold.

Treating of the diseases to which the Cornish miners are subject, Mr. Lanyon shows the mischievous effects of climbing the ladders upon the heart and lungs, and those of "beating the borer," more particularly when this is done, as it frequently is, in *bad* or *poor air*. Though the mines of the district may now generally be considered as well ventilated,‡ many parts of them must necessarily be filled with noxious gases, particularly when the men are driving in places where the general ventilation is still imperfect, as often happens in those places where the ore or rock is broken by blasting with gunpowder. Mr. Lanyon gives the following table of the average ages

* It is the duty of persons appointed for the purpose to attend to the condition of the ladders, and see that they are safe. The attention paid to the ladders in different mines varies materially, but it is considered that they are generally far better kept than formerly.

† Mr. Lanyon states (Essay on the Diseases of (Cornish) Miners, Report of the Royal Polytechnic Society of Cornwall for 1837, p. 56) that he has understood that, from perspiration in the bottom parts of mines, the loss of weight of a man frequently amounts to 3lbs. or 4lbs., and often, he was informed, to as much as 5lbs., 6lbs. or 7lbs., in a single "core" or spell.

‡ Formerly, it appears, the ventilation was so ill-contrived, that shafts were obliged to be sunk about thirty fathoms from each other; now, however, the miners can work 100 fathoms from the shaft without inconvenience. Mr. Carne attributes this change chiefly to a contrivance by which a stream of water is passed into one of the shafts, and, by placing an air-pipe close to the discharge of the water, the air which accompanies the current is carried to the extreme point of the level.—Trans. Geol. Soc. Cornwall, vol. iii. p. 64.

of 1101 miners, working under ground, as *men*, and paid as such, in seven Cornish mines, in 1837.

Mines.	No. of Men in each.	Average Age.	Average No. of Years of Working under Ground.
1	118	30 yrs. 5 mos.	14 yrs. 10 mos.
2	200	30 3	14 10
3	240	31 7	16 10
4	112	31 3	16 3
5	253	30 6	15 4
6	50	30 1	15 11
7	128	32 6	19 6
	1101		

"The aggregate of the years of all these miners," observes Mr. Lanyon, "amounts to 34,152, which gives 31 years for each individual; and the number of years in which they have been engaged under ground is 17,812, furnishing an average of 16 years 2 months for each." Of the total number he found—

532	of 30 and less than	40 years.	34	of 55 and less than	60 years.
263	40	45	14	60	70
157	45	50	1	70, and above.	
78	50	55			

Mr. Lanyon found great difficulty in obtaining any number of labourers, in the same mining district, who could be termed true agricultural labourers, and who had not, in some way or other, been connected with the mines. Of 174 persons whom he did so find, the average age was 47 years, 32 of which they had spent in their respective occupations.* Although the number of agricultural labourers may be too few for the purpose of exact comparison with the mines above noticed, still it is sufficient to show a very great difference in the average longevity of the miner and agricultural labourer, in favour of the latter.†

The importance of constructing machinery, by means of which

* Report of the Royal Polytechnic Society of Cornwall for 1837, p. 58.

† Mr. Lanyon is careful (*ib.* p. 59) that it should be understood that his average estimate of the longevity of Cornish miners is of those in the daily habit of working under ground, and not that which a register of deaths would furnish. "In the latter," he observes, "the longevity would be found greater in consequence of the diseases of the miners being of a character which generally incapacitates them from going under ground, and yet protracts their lives frequently for many years after, which are not unfrequently spent in great suffering, and in a state of inability to perform any labour." With regard to the kind and proportional amount of diseases to which the Cornish miners are subject, Mr. Lanyon found that, out of 270 persons, whom he personally examined, without selection, further than that they had all at least worked ten years under ground, 85 persons had cough, dyspnœa, or palpitation, or all (72 of these being 30 years of age or above, and only 13 below); 70 were subject to dyspepsia, 28 to chronic rheumatism, and 31 to other affections. Only 32 of the 270 had ever had hœmoptysis.

the labour of climbing the ladders may be avoided, has lately engaged much attention in Cornwall, chiefly through the exertions of the Polytechnic Society * established in that county, by which premiums have been offered during the last four or five years for the best available method of facilitating the descent and ascent of miners. A sum, amounting to 480*l.*, was this year (1838) subscribed among the members of the society for promoting the application of machinery to this purpose; and a description has been published by them of the mode adopted, and which has been found successful, in the deep mines of the Harz.†

From the facility of placing steam-engines wherever a proper supply of water can be obtained for them, which is seldom difficult in mines generally, the ores are very commonly raised to the surface in adventures of the larger class by steam-whims, as they are termed, and these are often so contrived as to draw from two shafts, and occasionally from three (pl. 10). The duty of many of the engines in the steam-whims is reported monthly, with that of the pumping-engines; and we find that the average weight of the kibbles raised by them varies considerably. Thus, in the beginning of 1837, the average weight of the kibble raised by a steam-whim at the Charlestown United Mines was estimated at 1120 lbs., of that raised by Edgcumbe's engine at Pembroke Mine at 960 lbs., and of that lifted by Woolf's engine at the Consolidated Mines at 571 lbs. These steam-whims necessarily afford great advantages in working a mine where water is scarce, and horse-whims would be insufficient.‡ Water-whims, therefore, are seldom employed in western Cornwall. On the east of

* A very valuable institution, which has already tended considerably to promote Cornish science and art by its exhibitions, premiums, medals, and prizes, though it has not been established more than six or seven years. It holds its annual exhibition and meetings at Falmouth, in a large hall built expressly for the purpose.

† Documents to illustrate this mode were furnished by the Minister of Finance in Hanover to Mr. Alfred Fox, Hanoverian Consul at Falmouth, from which Mr. Tregelles, civil engineer, has prepared drawings and estimates. By these it would appear that the cost of machinery for descending and ascending mines 200 fathoms in depth, would be 2365*l.*, and that the general charges, at the rate of 20*s.* per day, wear and tear of machinery for 240 men, and the cost of coal for the steam-engines for descending and ascending once, would only amount to 1½*d.* each man, so that we may hope that this or some other equally effective plan may soon form as much a part of necessary mining expenses as the machinery that pumps the water.

‡ Mr. Carne estimates the difference in the expense of steam and horse-whims for drawing ores at 50 per cent. in favour of the former.—Trans. Geol. Soc. Cornwall, vol. iii. p. 61.

the district, however, where water may be more conveniently obtained, they are frequently used. There are three water-whims at Fowey Consols, collectively estimated at 86-horse power; and one of very large size at Wheal Friendship, near Tavistock.

Inclined planes for raising ores are very rare, circumstances being seldom such that they can be employed with advantage. There was one some years since at Wheal Crebor, near Tavistock; and there is another now at work at Wheal Friendship, near the same place. Horse-whims are still very commonly used in small adventures, or upon the shallow extended workings of the larger mines.

A great improvement has been effected of late years in the facility of transporting the ores under ground by the introduction of small tram-roads and carts, instead of the old practice of wheelbarrows and planks. Mr. Carne estimates the expense of work performed by means of the tram-roads and carts as less than one-half that executed by the old system. Considerable improvements also have taken place in the timbering of mines and the disposal of the rubbish, or *attle;* so that not only are the walls of the lodes, where inclined to press together, better kept apart than formerly, but the communications through the old workings are more freely established. The quantity of timber used annually in the Cornish and Devon mines is very considerable, and consists almost entirely of Norwegian pine. Sir Charles Lemon, having counted the rings of annual growth upon average trees, considers that the average age of the timber employed in the Cornish mines is about 120 years, and that it would require 140 square miles of Norwegian forest to afford a supply for these mines.* A drawback is allowed upon the importation of this timber, the money paid for which, to the 10th October, 1837, will be seen by the following return to an order of the House of Commons, dated November 28th, 1837, for an account showing the several amounts paid as drawbacks on timber imported for and used in the mines of tin, lead, and copper, in the counties of Devon and Cornwall, in each year since that drawback has been allowed:—

* Journal of the Statistical Society, June, 1838 (vol. i. p. 81).

Years.	Amount of Drawbacks paid.
1811, from the 1st of July . .	Records destroyed by fire.
1812	
1813	
	£. s. d.
1814	3,622 13 8
1815	8,707 10 9
1816	12,859 16 3
1817	12,466 18 6
1818	16,093 3 4
1819	25,903 11 1
1820	30,075 4 6
1821	25,267 9 8
1822	20,312 12 5
1823	31,537 18 5
1824	38,251 8 10
1825	50,749 5 10
1826	27,799 2 11
1827	26,441 18 9
1828	36,585 16 2
1829	39,190 9 3
1830	32,818 10 2
1831	36,711 8 6
1832	39,235 7 6
1833	41,363 11 4
1834	44,385 13 11
1835	56,183 18 11
1836	81,919 13 5
1837, to the 10th of October . .	31,802 14 0

The effect produced on the importation of Norwegian timber by the mining speculations of 1836 will be readily perceived by this table, so many old mines which were then cleaned out either wholly or in part having required a large amount of it.* The following is a table, by Sir Charles Lemon, showing the number of loads, price, and value of debenture timber used in the Cornish mines from 1818 to 1837 inclusive:—†

Years.	Loads.	Price. Shillings.	Value, Carriage Included.	Years.	Loads.	Price. Shillings.	Value, Carriage Included.
1818	5,726	107	£30,634	1825	21,732	70	£76,062
1819	9,240	78	36,036	1826	12,305	66	40,606
1820	10,700	74	39,590	1827	11,687	61	35,643
1821	9,723	66	32,085	1828	16,170	61	49,318
1822	8,419	62	26,098	1829	17,321	57	49,364
1823	13,072	70	45,752	1830	14,506	57	41,339
1824	15,855	70	55,492	1831	16,266	52	42,291

* In like manner the year 1825 is marked by a greater importation of mine-timber than several years which precede or follow it.

† Journal of the Statistical Society of London, vol. i. p. 81.

(*Table continued.*)

Years.	Loads.	Price. Shillings.	Value, Carriage Included.	Years.	Loads.	Price. Shillings.	Value, Carriage Included.
1832	17,341	47	£40,751	1835	24,832	52	£64,563
1833	18,282	47	42,962	1836	36,207	52	94,138
1834	19,595	52	50,947	1837	14,056	52	36,545

50 cubic feet = a load—on the average contained in four trees. Thus the consumption of 1836 was 36,200 loads, × 4 = 144,800 trees.

It is difficult to ascertain the time when blasting by gunpowder came into use among the miners of our district. Mr. Hawkins considers it cannot be traced higher than the beginning of the last century, or a century later than its invention in Germany. He quotes letters from Mr. Davies Gilbert, dated in 1792, by which it would appear that this practice was introduced by the Germans in the eastern mining districts of Cornwall, and afterwards passed into the west. One old man informed Mr. Davies Gilbert that it was first used in the district of Lelant, Zennor, and St. Ives, about ninety years previously, by two men who came from the east, named Bell and Case, and that they affected to keep their operations a secret, suffering no one to see them charge the holes.* The Cornish miners are now extremely skilful in blasting with gunpowder, working with much effect and precision. Accidents, however, are frequent from it, notwithstanding the invention of the safety-fuse and Mr. Robert Were Fox's wedge, by means of which the dangerous work of tamping is avoided,† neither having yet sufficiently spread among the mines. The annual value of gunpowder used in the Cornish mines has been estimated at 13,200*l.*, the quantity being about 300 tons of 2000 lbs. each.‡

If we compare the detailed accounts furnished by Pryce, in 1778, of the manner of dressing tin-ores in his time, with that given by Mr. Henwood in 1828,§ we shall be able to see the

* Trans. Geol. Soc. Cornwall, vol. iv. p. 84—86.

† This invention is described, with a figure, in the Report of the Polytechnic Society of Cornwall for 1835, p. 114, pl. vii. fig. 2. A premium of 10 guineas was offered by this Society, in 1838, for the best report of a series of experiments made with this wedge.

‡ Sir Charles Lemon, Journal of the Statistical Society, vol. i. p. 81.

§ Trans. Geol. Soc. Cornwall, vol. iv. p. 145. Mr. Henwood's descriptions refer especially to the manipulations to which tin-ores were subjected in the central mining district of Cornwall. Pryce's account also, as his residence was at Redruth, probably also referred principally to the same area. As, however, his descriptions accord with those given by Borlase, who was rector of Ludgvan, near Penzance,

changes which may have taken place within the half century included between those dates, and at the same time learn the mode employed at the present day, as Mr. Henwood's descriptions will nearly suffice for the processes now in use.

With respect to the dressing of tin-ores, Pryce's descriptions do not differ much from those by Borlase twenty years previously. Indeed to illustrate them he has merely enlarged the figure of the stamps, buddles, &c., given by the latter. After noticing the stamping-mill, he describes the stamped ore as carried by the water, which kept the ore wet and the stamp-heads cool, into the first or rectangular pit, where, arranging itself according to its specific gravity and volume, the heaviest part (or *crop*, as it is now termed) accumulated at the head, while the more slimy ore passed to the lower end, some settling in a round pit at the end of the first, all the matter afterwards held in mechanical suspension being allowed to be carried away by the water as worthless. In 1828, in addition to the common water-wheel stamps, steam-stamps had been introduced, and the number of stamp-heads in them is noticed as amounting in some instances to 36 and 48. The pits in principle seem much the same as in 1778, the *crop* being collected in the rectangular, and the *slime* in the round pits.

In 1778, after the first or rectangular pit was full, the contents were separated into two parts, known as the *head and tail*, or good and bad portions, the higher being necessarily richest in ore. It was then taken to a pit termed a *buddle*, described as 7 feet long, 2½ wide, and 2 feet deep. The dresser, standing in the buddle, arranged the pulverised ore upon an inclined wooden frame at its head, named the *jagging-board*, in small ridges parallel to the run of some water which was allowed to enter the frame with a regulated velocity. By this process the lighter parts were carried to the most distant part of the pit or buddle, into which the pulverised ore was gradually washed, while the heavier and purer portions remained near the head, the dresser lightly scraping his foot occasionally upon the sediment in the buddle, so that the lighter parts should, by the motion of the water, be carried still further towards the lower part of the pit. When the buddle became full they divided the contents into three parts, that next the jagging-board being termed the *head* or *crop*, which was saved by itself; the central portion the *crease* or *middle head* and the third, most distant from the jagging-head, and therefore least pure, being called the *hind-crease* or *tails*. If thought proper the head was buddled over again, and the crease was brought to an equal condition with it, and the buddlings were repeated until the desired quality of the ore was attained; the waste from these buddlings and the tail of the original buddle being put aside for *leavings*. In 1828 the operation was conducted in the same manner, with the exception

and therefore likely to have been well acquainted with the mode of dressing tin-ores then adopted in that part of Cornwall, we may take Pryce's account as fairly representing the practice generally, with due allowance for local variations. An account of dressing the tin-ores of St. Just, which are frequently mixed with copper-ores, is given by Dr. Boase, in the Trans. of the Geol. Soc. of Cornwall, vol. ii. p. 386, &c.

that the middle head was divided into two portions, named *first* and *second middle heads.*

In 1778, the ore after being buddled was placed in a large vat, named a *keeve*, about one-third full of water, in which one workman kept stirring the water with a shovel, while another let the tin ore fall into it by degrees at the side of the *keeve*, where it was *tozed, (tossed)* or stirred by the other until the vat was almost full. By this process the lighter portions, or waste, were kept in mechanical suspension in the water, while the heavier settled. The keeve being thus nearly filled, it was struck on the sides by two boys with mallets (or *packed*) for a quarter of an hour, until it had settled hard. The water was then poured off from the surface of the tin ore, and the lighter part, or waste, was skimmed off, and laid by itself to be buddled over again by the name of *skimpings.* In the above process the comparative volume of mineral substances which were not tin ores having made up for their want of equal specific gravity with such ores, the whole was then sifted through a copper or brass-bottomed sieve, by which the mineral substances above noticed were kept back, while the finer tin ores passed through. If the tin ore which passed through the sieve did not require to be buddled over again, it was made clean by repeatedly tossing and packing. In some cases it was necessary to buddle it over again, when the operations of tossing were repeated until the whole was brought to the required condition.

In 1828, after the tin ores (of the *crop*) had been buddled, and divided as above noticed, the *heads* were *tossed* or *tozed*, the *first middle heads* were *chimmed*, the *second middle heads* were *dillued*, and the *tails*, if poor, were thrown among the *leavings.* The operation of tossing, or tozing, was performed in much the same manner as in 1778. This part of the process having been completed, the mineral matter in the keeve was divided into two or more parts. If divided into three, the two upper portions were termed *top* and *bottom skimpings:* these were again buddled and tossed, and, after buddling, the *tails* were thrown among the *leavings*, and the *middle heads* were mixed with the skimpings of the *first middle heads;* after tossing, the skimpings were put to the *leavings* and dressed on a frame. The ore in the lowest part of the keeve was either fit for the smelting house, or the roasting or burning house, according to its composition. *Chimming* is a process of modern times, and consists in inclining the keeve at an angle of about 45°. About 2 cwt. of ore, with the same weight of water, is put into it, and violently agitated by stirring until the whole of the ore is mechanically suspended. After stopping the stirring, the contents of the keeve are *packed* as in common tossing, and similar divisions made of them. This is considered an improvement on ordinary tossing, as the lower part of the collected mineral matter is narrower, while there is more space above for the deposit of the impurer portions.

The process of *dilluing* or *dilleughing* was carried on much in the same way in 1778 as it is at present. It consists in one workman holding a *dilleugher*, or large fine hair sieve, in a keeve one-third full of water, while another throws a shovel or two full of ore into the sieve, which the former shakes to and fro, and up and down, with much dexterity, for the purpose of ar-

ranging the contents according to their relative specific gravities. When these are well suspended in the water, he adroitly dips one side of the *dilleugher* under the surface of the water in the keeve, by which the lighter particles, kept mechanically suspended in the former, are allowed to escape into the keeve. By continuing the operation, the richer parts of the ore alone remain in the *dilleugher*, and are removed as occasion may require, to make room for more ore, after the operator has satisfied himself that the proper quality is attained.

As most of the Cornish and Devon tin ores contain arsenic, sulphuret of copper, common iron pyrites, or other substances which it is desirable to remove, as much as possible, before the tin ores are sent to the smelting-house, the process of roasting or burning the ores, next employed in 1778, as at present, has, probably, been long considered necessary. By this operation many impurities are driven off in vapour, and the ores rendered more free from them. Beneath will be found a description of the present roasting furnaces, by Mr. Henwood, which are those more commonly employed.* In Wheal Vor there is a very ingenious roaster moved by water power, so arranged that the pulverised tin ores, upon a circular support, are stirred by the teeth projecting from a wheel above it, so that all the different particles are properly exposed to heat, which is not so well accomplished in the ordinary roasting houses.†

After being roasted, the crop tin ores were, in 1778, as at present, again buddled, tossed and packed as before, until considered fit for smelting. Some kinds of ore in 1828 required other operations after roasting, generally either *tying* by itself, or *tying* and *jigging*. "The *tye* is a long, narrow, inclined furrow, through which passes a stream of water, three or four times larger than that used in *buddling;* the ore being placed at the head and agitated with a broom, the rough and lighter particles are carried to the lower part

* The furnace in which this (the roasting) is done, is about nine feet long; its width is irregular, being about three feet where it adjoins the fire-place, five feet in the widest part of the middle, and one and a half at the mouth; the height is about sixteen inches in the middle, and ten at the sides; the fire-place is about twelve inches in breadth, and is separated from the body of the furnace by a wall just high enough to keep the fuel separate from the ore. On looking in at the mouth, the flame of the fire is seen proceeding from the fire-place through all the length of the furnace, and going up the chimney, which is situated close to the mouth. The furnace being raised to a dull, red heat, about 7 cwt. of the ore is put into it, through a hole in the top; if it were roughly stirred at once, the rapid evaporation of the moisture contained in it would, probably, dissipate a portion of the ore: it is therefore allowed to remain unmoved for about an hour, in order to the gentle evaporation of the water; it is then spread over the furnace for about four feet in length, nearest the fire; and, by means of an iron rake, is turned every half hour or oftener, that the whole may be equally exposed to the action of the fire. This continues until it ceases to give out whitish fumes, or, when turned, to exhibit bright sparkles; it is then withdrawn through a hole now uncovered in the bottom of the furnace, and allowed to cool.—Trans. Geol. Sur. Cornwall, vol. iv. p. 153.

† The arsenic fumes from the burning house at Wheal Vor, are collected in a long chamber through which the vapours pass.

of the tye." The ores at the head of the tye, unless requiring again to be *dillued*, are fit for the smelting-house, and the remainder, if considered poor, is thrown among the leavings, but otherwise it is jigged, an operation in which the dresser places the mineral substances in a copper-bottomed sieve, and by giving the latter a compound motion both round and vertically in a vessel of water, above which the sieve is never lifted, he arranges the substances according to their relative specific gravities, and therefore the richer portions accumulate at the bottom, and the lighter are thrown among the leavings.

It will have been evident from this sketch of the different processes noticed, that while, from time to time, portions of the ores, after roasting, if that operation were necessary, are put aside as fit for the smelting-house; other portions are added under various names to the original *slime* or stanniferous mud in the pits. All these come under the head of *leavings*. In 1778 we find that the slime and tails, after having been allowed to dry, were *trunked* and *framed*. The trunk was a pit ten feet long, three wide, and nine inches deep. At the higher part of it was another and circular pit named the *strèk*, or *step*, large enough to contain four hand-barrows of slime, which there became mixed with water that ran into the strèk, and conveyed it into the upper part of the trunk, which was semicircular, and named the *head* or *pednan*. In this *pednan* a boy stirred the muddy water with a small shovel in such a manner that the wash was carried over a cross board about ten inches deep, somewhat lower in the middle, separating the pednan from the body of the trunk. As in the buddle, the leavings thus washed into the trunk arranged themselves according to relative specific gravities, so that the portion nearest the head was richest in tin ores. This portion was taken to be framed, while the lower part was removed to the pednan to be trunked over again, and the coarser portions formed at the bottom of the strèk, which would not, from their size, be so mixed with the water as to be carried to the pednan, were sent again to the stamping mill.

The three divisions of the trunk are still found where trunking by machinery is not practised; but, as stated by Mr. Henwood, they are generally known by the names of the *strèke*, the *còver*, and the *hutch*. The *strèke* is now no longer circular, but a pit about five feet long, and two feet and a half deep, at the higher end two and a half wide, and at the lower only six inches. The còver is found next to the strèke, and is a box containing about three cubic feet. The hutch is a wooden case, about eight feet long, two and a half to three feet wide, and about one foot deep, its bottom and that of the strèke being slightly inclined. The hutch is separated by a board from the còver, over which, as in Pryce's time, the muddy water passes when agitated by a boy with a shovel, so that the ripples slop over the dividing board into the hutch, in which the richer parts of the slime accumulate nearest the còver.

The trunking by machinery, which has now become somewhat common, was introduced at St. Ives, according to Mr. Henwood, about the year 1825. It is a very simple arrangement, consisting of an horizontal axle stretching across as many còvers as there may be trunks, from which flat blades of iron or wood descend into the contents of the còvers, performing the office of

the shovels above noticed, by means of a to-and-fro motion produced on the axle to which they are fixed: this to-and-fro motion, which slops over the necessary quantity of stanniferous muddy water into the hutch, being communicated either by hand or, what is now becoming more common, by being attached to some other machinery, as, for instance, to the nearest water-wheel.

The *frame* of 1778, and that of 1828, would appear to have differed so slightly, that we shall annex Mr. Henwood's description of it, more particularly as it is now very commonly in use. "The frame," he states, "is a flat piece of wood, about eight feet long and five feet wide, with a rim five inches high around it. This is suspended in an inclined position on pivots;* but is fastened by a kind of latch; at the upper end is a *jagging-board* (similar to that of the buddle) which is connected with the frame by a moveable sloping piece of wood, to prevent the ore from falling between the board and the frame; underneath the frame are two boxes which, being placed end to end, extend its whole length;† at the lower end of the floor a vacancy of two or three inches leaves an aperture for the escape of the water. The mode of conducting the operation is as follows:—the operator (usually a woman or stout boy or girl) spreads on the jagging-board from two to three quarts of the *trunked slime*, on which runs a stream of water, equal to five-eighths of an inch in diameter; and with a small toothless rake, makes it into small furrows, in the direction in which the water runs. In this way the ore is carried from the board to the *frame:* the richest part rests at and near the head, and the poorer parts further down: the impurities are carried off by the water and escape at the bottom. The operator runs the rake across the frame, to agitate the ore, as often as appears requisite. When the richer part of the ore has sufficiently accumulated, the jagging-board being swept clean, the latch is lifted, and the frame turned on the pivots from a horizontal to a vertical position, and the ore is swept or washed into the boxes beneath; the best into the upper, and the inferior into the lower box. It is of the greatest importance that the water should pass of equal depth and velocity over every part of the frame, or the different parts of the mass will be mixed with each other, and some of the ore carried off with the waste.‡

In 1778, the contents of the upper box, or fore-kôfer, were sifted through a fine hair sieve, or with a copper bottom, into a keeve with water in it; it was then buddled and saved in different portions, like crop tin, and it also underwent the various operations of tossing, packing, skimping, dilluing, &c. The burning or roasting is not noticed, but we may readily suppose that it was employed with the greater part of the ores, as in 1828 and at present. The contents of the second box or kôfer, as also of the first, should occasion require, are then brought to as pure a state as the ore will admit. The modes of dressing *leavings* were so various in Pryce's time that he could not detail them, "without danger of prolixity." They are not less so now,

* Named *melliers* by Pryce.

† The boxes beneath the frame are termed *fore* and *hind kôfers* by Pryce.

‡ Trans. Geol. Soc. of Cornwall, vol. iv. p. 157. It will be readily seen that this frame is but a modification of the buddle, in which the manipulation is conducted with additional care.

but it may be stated that, with the means above noticed, they are worked until it is supposed that any tin ore which may still remain in them, will not further repay the cost of washing.*

In selling tin ores to the smelter the system of ticketing, as used for those of copper, has of late years been introduced, so that black tin is now sold partly in that manner and partly by private contract.† The ticketing sales take place at Redruth and Tre-

* It should be observed, while on the subject of the Cornish mode of washing ores, that it is generally considered inferior to the methods adopted in Germany and in France. On his return from Freiberg in 1804, Mr. J. H. Vivian pointed out the various modes of dressing ores employed in Germany, and some of the suggestions he then offered have been subsequently adopted with great benefit.‡ The shock-frame, though superior to anything of the kind used in Cornwall, still remains neglected, though Mr. Vivian presented a model of it many years since to the Geological Society of Cornwall, as also of another useful German frame, termed the sweep-frame.

† The Cornish mode of assaying tin ores consists generally in taking two ounces of black tin, or tin ore, and adding to them a flux composed of culm, about one-third the weight of the ore, and borax 4 dwts. If the ore contains much iron more culm is added. This being exposed to strong heat a button of tin is obtained, the value of which is estimated by its properties under the hammer. The scrapings from the crucible are usually washed, to search for any tin which may be in them. It seems probable, that this method has been long employed: Pryce describes it in 1778.

Berthier has pointed out (Traité des Essais par la Voie Sèche, tom ii. p, 552) that though the oxide of tin is completely reducible by charcoal at a white heat, that it possesses such an affinity for silica that, when that substance is present, it cannot be reduced altogether, except at the highest temperature of a wind-furnace; whence the necessity of making all assays of tin at a high temperature.

This excellent analyst and metallurgist recommends that the powdered stanniferous ores should be boiled for a very short time in aqua regia (a compound of one measure of nitric acid with two measures of hydrochloric acid), in order to deprive the ore of any pyritous or arsenical matters which it may contain, then to add water to it, throw the ore which remains upon a filtre, and wash it carefully. The filtre is then dried, the ore is taken from it, the paper is burnt, and the whole is calcined, in order to drive off a small quantity of sulphur with which it may become mixed from the action of aqua regia. By these means the ore is completely purified without the loss of the smallest trace of tin. He recommends, when great precision is required, that the fluxes should be the same as those used for iron assays. These fluxes may be either earthy and very calcareous glasses, carbonate of lime, or a mixture of carbonate of lime and dolomite (carbonate of lime, and carbonate of magnesia). Borax and carbonate of soda may be employed as fluxes where this precision is not required, in the proportion of three-tenths or four-tenths at furthest.

Independently of the button of metal obtained in the assay, there are always some granules at the surface of the slag or scoria. To obtain these, it is recommended that the slag should be pulverised and the powder passed through a fine sieve. If the metal be malleable it will remain in little plates on the sieve; if it be breakable it passes through with the powder of the slag or scoria; but should it be magnetic, as frequently happens in such cases, it may be taken up with a magnet

loweth, commonly twice a-month, and alternately at these two places. The following table will show the mines from which tin ores were sold by ticket in 1837, and the relative amount produced by each. It will not afford a view of the relative value of these mines, inasmuch as several are large copper mines, such as Consols, Wheal Jewel, Carn Brea, &c., producing only a small amount of tin.

Mines from which Black Tin has been sold by Ticket in 1837.

MINES.	Tons.	Average Price per Ton.			Amount.		
		£.	s.	d.	£.	s.	d.
Charlestown United Mines .	582¾	45	1	2	26,258	12	5
St. Ives Consols . .	397	45	9	3	18,049	17	6
Polgooth	252	47	7	3	11,935	19	3
Boscaswell Downs . .	239	50	0	7	11,957	10	0
Great Work . . .	225	52	4	9	11,753	10	0
Wheal Reeth . . .	192¼	45	10	9	8,754	11	10
Wheal Budnick . . .	169	48	6	0	8,162	18	9
Wheal Kitty . . .	162⅓	46	10	7	7,514	13	9
Wheal Mary . . .	160½	45	2	6	7,242	17	6
Royal Polberou Consols .	148½	44	5	7	6,575	18	1
Wheal Darlington . .	134¼	47	1	6	6,320	5	1
Carnon	122	51	11	3	6,291	7	11
Tin Croft	105	41	18	0	4,399	1	9
Carried forward . .	2889¾				135,217	3	10

and when this method cannot be employed it is washed with care, or, as would be said in Cornwall, vanned.

To show the influence of silica upon the peroxide of tin, Berthier made the following mixtures with this ore, and pulverised quartz :—

	a	*b*	*c*	*d*	*e*
Tin ore	10	10	10	10	10
Quartz	2·5	6·6	10	15	30

These heated with four times their weight of black flux, produced *a*, 52 per cent. of tin; *b*, 43 per cent.; *c*, 28 per cent.; *d*, 10 per cent.; and *e*, no return of tin at all, so completely had the quantity of silica prevented its fusion. The slags, therefore, retained different quantities of oxide of tin, in proportion as they were siliceous.

After observing that the black flux should not be employed in the assays, except when it is only intended to obtain a very large proportion of the pure metal from the ores, Berthier proceeds to observe that, when this only is desired, the ore should be reduced to a fine powder and mixed with about a tenth of its weight of charcoal, then exposed in a crucible lined with charcoal to a strong white heat for an hour or two, when it becomes a granular metallic and sandy mass. This mass is ground down in a mortar and melted in an open crucible with half its weight of carbonate of soda, or potash. A button of pure tin is then obtained, and the foreign metals, such as iron, tungsten, &c., remain in the slag with a certain quantity of oxide of tin. An ore, containing 70 per cent. of tin, easily gave 55 per cent., of pure tin when treated in this manner.

(*Table continued.*)

MINES.	Tons.	Average Price per Ton.			Amount.		
		£.	s.	d.	£.	s.	d.
Brought forward . .	2889¾				135,217	3	10
Marazion Mines . . .	102¾	44	10	7	4,575	8	9
Bottle Hill . . .	100½	43	11	7	4,378	5	7
Carn Brea . . .	80	47	8	9	3,794	11	3
Wheal Olds . . .	79	54	3	9	4,281	5	0
Balleswidden . . .	74	44	14	10	3,310	16	3
St. Austell Hills . .	69½	42	13	1	2,964	11	3
Poldice	59¾	38	16	8	2,320	8	0
Balnoon	59½	50	4	1	2,987	13	9
Boscean	57½	54	7	0	3,125	3	9
Levant	56½	36	17	6	2,083	6	3
St. Enoder Consols . .	45¾	46	1	0	2,106	16	2
Roche Rock . . .	38¼	46	9	0	1,786	12	5
Wheal Unity Wood . .	28	44	0	10	1,233	4	4
Wheal Jewel . . .	26½	45	11	3	1,207	15	0
Morvah and Zennor Mines .	26½	48	0	9	1,272	19	11
East Levant . . .	25	48	2	5	1,203	2	6
Consolidated Mines . .	24¼	37	4	8	902	18	9
South Polgooth . . .	20½	42	1	5	862	10	7
Cornwall Great United .	20½	43	18	9	900	15	0
Cook's Kitchen . . .	17	43	17	7	746	6	3
Wheal Gilbert . . .	12	47	17	6	574	10	0
Carzise	12	49	12	6	595	10	0
Wheal Providence . .	10¾	43	17	2	471	11	10
St. Neot Mines . . .	10½	28	2	4	295	10	0
Wheal Pye . . .	10¼	39	2	3	400	17	7
West Poldice . . .	10	41	8	0	414	0	0
Great Wheal Venture .	9¾	47	13	8	464	18	0
Teague's Bargain . .	9½	47	2	6	447	13	9
East Wheal Strawberry .	9½	45	18	6	436	6	3
Wheal Maitland . .	9	50	13	7	456	12	6
Gavaragan . . .	8	50	5	4	402	2	6
Wheal Castle . . .	7¼	47	13	5	345	15	0
Wheal Grey . . .	6½	53	7	6	346	18	9
Gwallan	6	41	17	1	251	2	6
Wheal Gorland . .	5½	45	6	4	249	5	0
Wheal Ann Dues . .	5½	51	18	6	285	12	6
West Tresavean . . .	5	54	8	6	272	2	6
Boscaswell Dues . .	4¼	44	12	6	189	13	1
Friendly Mines . . .	4¼	46	17	3	199	3	8
Trelubbas Bargains . .	4	47	6	3	189	5	0
South Wheal Rose . .	3½	54	5	0	189	17	6
Royal Duchy Mines . .	3½	48	7	6	169	6	3
East Wheal Fortune . .	3½	44	2	6	154	8	9
Beam	3¼	53	17	4	177	11	3
Cuddra	3¼	44	7	4	144	3	1
Bosorn	3	53	5	0	159	15	0
Bollowall	3	57	0	0	171	0	0
Perran Downs . . .	3	42	17	6	128	12	6
West Wheal Jewel . .	2¾	40	12	6	111	14	4
Spearn Moor . . .	2½	51	2	6	127	16	3
New Crinnis . . .	2	43	7	6	86	15	0
Good Providence . .	2	51	8	9	102	17	6
Wheal Edward . . .	2	40	8	9	80	17	6
Tregavara . . .	1½	58	0	0	87	0	0
Spry's Dues . . .	1½	53	15	0	80	12	6
North Downs . . .	1½	37	15	0	56	12	6
Parknoweth . . .	1	46	2	6	46	2	6
East Beam . . .	1	52	2	6	52	2	6
United Mines . . .	1	43	15	0	43	15	0
Total . .	4105¼				190,721	4	11

To obtain the total quantity of tin-ore sold in 1837, that sold by private contract must be added, as also the quantity raised by the Wheal Vor adventurers who smelted for themselves. This, according to the number of blocks coined, and taking the average price of that sold by ticket for that which is disposed of privately, would make the total value of the tin-ores sold in 1837 amount to 363,322*l.* 16*s.* 4*d.*,* giving 172,601*l.* 11*s.* 5*d.* for the value of the ores disposed of by private contract and coined by the Wheal Vor adventurers. The number of blocks of tin coined by the latter amounted to 2,638 in 1837, which, taking these blocks to average those of the 27,383 coined in that year, would give, in round numbers, ore of the value of 35,014*l.*, leaving about 137,587*l.* for the value of the ores sold by private contract in the year 1837.

Although the cupreous sulphuret of tin, or tin pyrites, has been found at Wheal Rock, in St. Agnes; at Stenna-gwyn, in St. Stephen's; at Wheal Scorrier, in Gwennap; and at Botallack, in St. Just, it has only occurred in small quantities.† The ore from which all the tin is procured is the peroxide, of variable degrees of purity, sometimes crystalline and at others mixed with much earthy matter, so that by an inexperienced eye it would scarcely be detected. Dr. Thomson gives the following as the constituent parts of a crystalline reddish brown specimen from Cornwall, the specific gravity of which was 6·945 :—

Peroxide of tin . .	96·265	Peroxide of iron	3·395
Silica	0·750	Sesquioxide of manganese .	

The processes by which the peroxide of tin is mechanically separated from the earthy substances, or other ores, with which it may be found combined in the lodes or stream works, depending upon its greater specific gravity, it may be sufficiently purified from these by the manipulations above detailed, except when mixed with wolfram, or the tungstate of iron and manganese, as sometimes happens, the specific gravity of which, being about 7·155, is somewhat greater than that of the peroxide of tin, as it usually occurs, and even of that ore in its purest state, from which circumstance, its presence is highly injurious in a tin-lode.

* English's Mining Journal, 1838.

† It has been generally considered that this mineral is more of a mechanical mixture than a chemical compound; in fact, a more minute mixture of the peroxide of tin and sulphuret of copper than those frequently found in mines.

Great dexterity is exhibited by the tinners in the operation termed *vanning*, which consists of separating the pulverised tin-ore from the other ores or earthy matter with which it may be mixed on a pointed shovel. This is done by placing a small portion of the pulverised matter to be examined towards the end of the shovel, and then by dexterously dipping it in water, and agitating it by means of a peculiar motion of the arms and wrists, the pulverised matter arranges itself according to the relative specific gravity of its component parts, and hence, the tin-ore being the heaviest, except when wolfram is present, it is collected on one side, and its relative proportion to the whole pulverised matter placed in the shovel, can be fairly estimated. We have seen a miner dexterously *van* pulverised iron pyrites, copper pyrites, and the peroxide of tin into three parts on his shovel, so that the copper ore was on one side, the tin ore on the other, and the iron pyrites in the middle; the specific of these ores being about 4·16, 6·8, and 4·9. For a summary mode of roughly estimating the relative quantity of tin in mixed ores, vanning is extremely useful.

Independently of the grain-tin, as it is termed, the produce of the best stream-tin ores, the block-tin is now divided into common block-tin and refined, the latter by an ingenious process being far more free from impurities, such as iron, copper, arsenic, or earthy matters, than the former, and, consequently, bearing a higher price in the market.

After being smelted, the tin has for more than six centuries paid a tax to the earls and dukes of Cornwall. Having been cast into blocks that appear, judging from ancient blocks which have found, to have varied in size and form, but which of late have been of a rectangular shape with a bevel, corresponding with the mould, between the upper and lower surfaces, and weighing about 3·34 cwts. each, the tin, each block being marked with the smelter's stamp, was carried to certain towns for the purpose of being coined, that is, after having a corner of each of the blocks struck off and examined by duchy officers, appointed for the purpose, in order to see that the tin was of a proper quality, the blocks were stamped with the duchy seal, the dues paid, and the blocks permitted to be sold. It appears by the charter of the 10th April, of the 33rd of Edward I. (1305), to the Cornish tinners that the coinage towns then appointed were Lostwithiel, Bodmynyan (Bod-

min), Liskiriet (Liskeard), Treueru (Truro), and Helleston.* In 1778 the coinage towns in Cornwall were Liskeard, Lostwithiel, Truro, Helston, and Penzance, the latter having been added in the time of Charles II. The ancient stannary towns of Devon were Tavistock, Ashburton, Chagford, and Plympton, the latter town made such in 1328,† and the three former are noticed as such in a charter of 1305, by Edward I. to tinners of Devon. In 1837 the coinages of the Duchy of Cornwall were effected at Morwellham, in Devon, and at Calstock, St. Austell, Truro, Helston, Hayle, and Penzance, in Cornwall, and there would then appear to have been about fourteen tin smelting-houses, exclusive of one or two blowing-houses.

In the sixteenth century the coinages took place only twice a-year, about Midsummer and Michaelmas; but it appears from Carew that in his time post coinages were allowed.‡ The coinages afterwards became quarterly. According to the charter of Edmund, Earl of Cornwall, as quoted by Carew, the tin paid a duty of a halfpenny for every pound weight when coined.§ In the reign of Edward I. the duty was fixed at 4*s.* for every hundred weight of coined tin, at which amount it has since continued. The duchy dues upon the tin coined in Devon have been long less than those imposed upon that of Cornwall, having been only at the rate of 1*s.* 6½*d.* per cwt. By an act of the 16th of August, 1838, the duties payable on the coinage of tin in Devon and Cornwall were abolished, and a compensation in lieu of them was given to the duchy, founded on the amount of the clear annual revenue derived from them for the last ten years, and at the same time the duties on the import of foreign tin were reduced, and fixed at 15*s.* per cwt. for tin, and at 10*s.* per cwt. for tin-ore.‖

In 1213 the duty on tin, payable to the Earl of Cornwall, was farmed for 200 marks for Cornwall, and 200*l.* for Devon, by which it would appear that the Devon mines were then the most valuable.¶

* A copy of this charter, as also of one, bearing the same date, to the tinners of Devon, will be found in the Appendix, and fac-similes of their enrolment in the Record Office at the Tower of London, in plate 13. Regulations respecting the coinage in the time of King John will be seen by a document of that date also given in the Appendix.

† Lysons' Magna Britannia, Devon, p. 12, 96, and 408; and Pat. 2 Edward III.

‡ Survey of Cornwall, p. 14. § *Ibid.* p. 16.

‖ This Act came into operation on the 10th October, 1838.

¶ Lysons' Mag. Britannia, Devon, p. cclxxx., who cites Madox's Hist. of the Exchequer.

By a record of 1337, the year in which Edward the Black Prince was created Duke of Cornwall, it appears that the average profit of the coinage was 3000 marks per annum, but that in consequence of the tin raised, it was that year equal to 4000 marks.* In the same year the profits for the coinage of Devon were 273*l.* 19*s.* 5¾*d.*† The coinage dues of the Stannaries in 1374 produced 1,016*l.* 1*s.* 4*d.* per annum.‡ In 1471 the quantity of tin raised in Cornwall was 851,116lbs., and in Devon 242,624lbs., the profits to the duchy being 1705*l.* 0*s.* 5*d.* for the former county, at 4*s.* per cwt., and for the latter, 190*l.* 17*s.* 11*d*½., at the rate of 1*s.* 6¾*d.* per cwt. In 1479 the amount of the coinage dues was 166*l.* 9*s.* 5½*d.* for Devon, and 1620*l.* 17*s.* 11*d.* for Cornwall. The profits of both counties in 1524 were 2771*l.* 3*s.* 9¼*d*; 424 tinners of Devon in that year paying, in addition to the coinage dues, 8*d.* per annum for *white-rent* to the duchy.§ In 1602 (44 Queen Elizabeth), the tin coinage amounted to 2623*l.* 9*s.* 8*d.* in Cornwall, and 102*l.* 17*s.* 9¾*d.* in Devon. According to Pryce, the annual amount of tin raised in the reigns of James I. and Charles I., was from 1400 to 1600 tons,‖ which, supposing that a proportion of this produce may have been from Devon, would give from 5000*l.* to 6000*l.* in dues to the duchy. In the time of Charles II. the tin revenues became small, but during the latter part of the reign of Queen Anne, and in the beginning of George I., they had again risen to about 1600 tons.¶ From the statement of a committee formed of Cornish gentlemen in 1742, to report on the proposals of the Mines Royal Company for farming the tin for seven years, it appears that the average produce for several years past had been about 2100 tons.** The tin revenues of the duchy are stated to have been about 9620*l.* per annum, for the years 1799, 1800, and 1801, and in 1814, about 8500*l.* per annum.††

* Lysons' Mag. Britannia, Cornwall, p. cciv. citing an extent of the Duchy of Cornwall in the King's Remembrancer's Office in the Exchequer.

† *Ibid.*, Devon, p. cclxxx.

‡ *Ibid.*, Cornwall, p. ccv., and Roll of the Revenues of the Black Prince in the Tower.

§ *Ibid.*, Devon, p. cclxxx., from Records of the Duchy.

‖ Mineralogia Cornubiensis, Introduction, p. 10. ¶ *Ibid.* p. 10.

** *Ibid.* p. xi. This committee also reported that 3*l.* 9*s.* per cwt. for grain-tin, and 3*l.* 5*s.* per cwt. for block-tin, were the lowest prices at which such tin could be sold to the contractors, exclusive of all coinage dues and fees.

†† Lysons' Mag. Brit. Cornwall, p. ccv.

In 1820, Cornwall produced 2775 tons of tin,* which would afford dues to the amount of 11,080*l.*; and according to Lysons, the average dues for Devon for six years ending Michaelmas in that year, yielded 45*l.* 17*s.* 9*d.*, so that the coinages of 1820 afforded about 11,125*l.* 17*s.* 9*d.* to the duchy. The average tin revenue from 1820 to the abolition of the coinage in October, 1838, has been commonly estimated at between 11,000*l.* and 12,000*l.*, for Cornwall and Devon.

It is not easy correctly to ascertain the number of tons of tin raised in the duchy of Cornwall from the number of blocks coined, unless access be obtained to accounts of the dues collected. The weight in each block has been usually estimated at from $3\frac{1}{4}$ cwts to $3\frac{1}{2}$ cwts. Judging from documents in which the number of blocks and their total weight is given, the weight of each block may be taken at from 3·34 to 3·35 cwts. By multiplying the number of blocks coined for the years mentioned in the following tables (the first taken from the Transactions of the Geological Society of Cornwall,† and the second from the information of Mr. John Taylor), a fair approximation will be obtained for the number of tons raised in those years.

An account of the Annual Produce of the Tin Mines of the Duchy of Cornwall from 1750 *to* 1779 *inclusive.*

Years.	Blocks.	Years.	Blocks.	Years.	Blocks.
1750	18,698	1760	17,662	1770	19,355
1751	14,776	1761	15,571	1771	18,349
1752	16,574	1762	16,801	1772	20,531
1753	16,358	1763	17,786	1773	18,540
1754	17,708	1764	16,997	1774	15,975
1755	17,924	1765	17,923	1775	17,024
1756	18,033	1766	19,861	1776	17,240
1757	17,887	1767	18,529	1777	18,010
1758	17,681	1768	17,334	1778	16,302
1759	17,140	1769	18,838	1779	17,411

* Trans. Geol. Soc. Cornwall, vol. ii. p. 425.

† Vol. ii. p. 426. A table which continues the annual produce to 1821 inclusive, without, however, the average price of tin for those years.

An account of the Annual Produce of the Tin Mines of the Duchy of Cornwall from 1780 *to* 1838, *inclusive, with the average price of common Tin per Cwt. for each year.*

Years.	Blocks.	Average Price per Cwt.			Years.	Blocks.	Average Price per Cwt.		
		£	*s.*	*d.*			£	*s.*	*d.*
1780	19,022	3	8	0	1810	12,528	7	17	0
1781	16,969	3	11	0	1811	14,675	7	1	6
1782	16,548	3	12	6	1812	14,606	6	8	0
1783	16,705	3	17	6	1813	14,306	6	14	0
1784	17,456	3	17	6	1814	16,069	7	16	6
1785	18,753	3	19	6	1815	18,101	7	0	6
1786	22,096	3	19	6	1816	20,608	5	14	6
1787	20,824	3	19	6	1817	25,379	4	13	6
1788	21,790	3	13	6	1818	23,248	4	4	9
1789	22,132	3	8	0	1819	18,881	3	15	3
1790	20,753	3	12	6	1820	17,084	3	13	3
1791	22,561	3	19	0	1821	19,273	3	15	8
1792	24,763	4	12	6	1822	18,731	4	15	6
1793	20,805	4	18	0	1823	24,077	4	14	9
1794	21,793	4	15	6	1824	28,602	4	8	0
1795	22,353	4	13	0	1825	24,902	4	11	4
1796	19,902	4	16	6	1826	26,299	3	17	0
1797	21,063	4	17	0	1827	31,744	3	16	0
1798	18,332	4	14	0	1828	28,178	3	13	3
1799	18,603	4	17	0	1829	25,337	3	14	0
1800	16,397	5	1	0	1830	25,392	3	13	9
1801	14,552	5	5	0	1831	24,568	3	13	6
1802	16,420	5	8	6	1832	24,702	3	12	9
1803	18,212	5	9	0	1833	23,236	3	12	9
1804	18,716	5	9	0	1834	22,792	3	18	0
1805	17,139	5	12	6	1835	24,160	4	11	6
1806	17,846	6	0	6	1836	23,169	5	9	6
1807	15,168	5	17	6	1837	27,373	4	8	0
1808	14,589	5	14	0	1838	29,321	4	2	0
1809	15,680	6	2	0	..	..		..	

The following account of the tin coined in Cornwall and Devon from Midsummer 1837, to Midsummer 1838, will not only show the tin produced in the district, and the relative quantity in each county, but nearly also the relative proportion of mine to stream-tin, the grain-tin being of the latter kind. To a certain extent also it exhibits the relative amount of tin raised within the range of each coinage town, it being desirable to save the expense of carriage as much as possible.

Cornwall.

Coinage Towns.	Grain Tin.	Common Tin.	Total.
Calstock.....	....	393	393 Blocks
Truro.....	1,345	8,952	10,297
Hayle...,.....	118	5,334	5,452
Penzance	....	12,423	12,423

Devon.

Coinage Town	Grain Tin.	Common Tin.	Total.
Morwelham.....	82	674	756 Blocks.

Making a total of 29,321 blocks, or 5,130 tons, of which 1,545, or about a nineteenth of the whole produce, are grain-tin, and the remainder, or 27,776 blocks, common tin.*

Copper pyrites, or the bisulphuret of copper, is the chief ore of that metal which occurs in Cornwall and Devon, other copper ores being found in comparatively small quantities. According to Phillips' analysis, a Cornish yellow copper ore consisted of sulphur, 34·46, copper, 31·20, iron, 30·80, and earthy matter, 1·10; and a fine crystal from the United Mines, of the specific gravity 4·16, gave Dr. Thomson, sulphur, 34·655, copper, 33·640, iron, 31·535, and earthy matter, 0·555. This ore, therefore, contains nearly as much iron as copper, when pure. In the lodes it is often mixed up with other substances, such as sulphuret of zinc, iron and arsenical pyrites, quartz, chlorite, and other minerals, so that though considerable masses of the pure ore may occasionally be seen, the bisulphuret of copper is commonly so intermingled with other mineral substances on the large scale, as to require careful separation by dressing previous to sale. Borlase states that this ore (which in 1758 sold from 10*l.* to 20*l.* per ton), was, about the end of the seventeenth century, termed *poder*, and thrown away by the miners.†

The next important Cornish copper ore is the sulphuret, commonly known as grey ore by the miners. A fine crystal (specific gravity, 5·702) from the United Mines, afforded to Dr. Thomson, upon analysis, copper, 77·16, sulphur, 20·62, iron, 1·45. Grey copper ore was valued about the middle of the last century, at from 50*l.* to 60*l.* per ton.‡ Many variable compounds would appear to pass in Cornwall under the name of grey ores, and require analysis. From among them tennantite has been separated by Phillips, who found this mineral to be composed of sulphur, 28·74, arsenic, 11·84, copper, 45·32, iron, 9·26, and silica, 5. The proportions of these substances in a mineral bearing this name from Gwennap, analysed by Mr. Hemming, were some-

* The quantity of tin imported into the United Kingdom for the year ending January 5, 1838, was 1,451 tons; and the quantity exported in the same year, 1,465 tons; so that the import and export were nearly the same, leaving the English produce of that year for British consumption.

† Natural Hist. Cornwall, p. 205. ‡ *Ibid.* p. 198.

what different, being, sulphur, 21·8, arsenic, 11·5, copper, 48·4, iron, 14·2, and silica, 5.

The black ore (considered to consist of copper, 79·83, and oxygen, 20·17,) is sometimes found in sufficient quantities to be of importance in a mine. Pryce states that this ore also was, in the beginning of the last century, thrown away by the tinners by the name of *poder** (dust), mundic, or waste, and that several thousand pounds worth of it was formerly washed down into the sea from the old Pool mine.† The carbonates of copper have been rarely found in Cornwall and Devon in sufficient quantities to form a mineral of much mining importance; and the same may be said of the red oxide of copper, and native copper. The latter has been found from time to time, in pieces of large size; a mass weighing 122 lbs. was obtained from Condorrow mine, in Camborne.‡

It would appear that the Cornish copper ores were so little understood towards the close of the seventeenth century, that persons who then came from Bristol purchased them at the rate of 2*l.* 10*s.* to 4*l.* per ton. About 1718 other persons at Bristol became adventurers in the Cornish copper mines, and Mr. John Costar, who is described as being well skilled in metals, mechanics, and hydraulics, drained some considerable mines with success,§ and taught the Cornish a better way of assaying and dressing their copper ores,‖ so that copper mining efficiently commenced in Cornwall about that time, though, as Mr. Carne suggests, mines may have been worked for copper about 1700, previous to which this metal was obtained from mines worked more especially for tin.¶

* As *poder* means *dust*, which would agree with the appearance of this friable ore, it may be questionable how far Borlase may have been correct in stating that the yellow copper was thus named. As *poder* has this meaning, may not the name be merely a provincial manner of pronouncing the English word *powder?*

† Mineralogia Cornubiensis, p. 62. Mr. Carne, writing in 1824, observes, that some 50 years previously these rich black ores were thrown away by the miners, from ignorance, at Wheal Jewel.—Trans. Geol. Soc. Cornwall, vol. iii. p. 44.

‡ Trans. Geol. Soc. Cornwall, vol. iii, p. 333. Though native copper is generally found in Cornwall at shallow depths, Pryce mentions several tons having been raised and sold to the Cornish Copper Company from a deep situation in Cook's Kitchen.—Min. Corn. p. 61.

§ Costar, it appears, introduced the use of water-wheels, of 30 or 40 feet in diameter, instead of the small wheels previously employed.—Pryce, Min. Corn. p. 307.

‖ Borlase Nat. Hist. Cornwall, p. 205. He further states that "Mr. Beauchamp, of Gwennap, at this time covenanted to sell all the copper which should rise out of a mine well stocked, for 20 years, at 5*l.* per ton; and the ore at Relistian, in Gwinear, was covenanted for at 2*l.* 10*s.* per ton."—*Ib. note.*

¶ Trans. Geol. Soc. Cornwall, vol. iii. p. 44.

Borlase, after noticing that the richer sorts of ore were kept together under ground in the copper mines, has presented us with the following account of the manner of dressing the ores from them in his time, which it is interesting to compare with that now adopted, after the lapse of 80 years :—

"What comes from the people below," he says, "is re-examined as soon as it arrives at the mouth of the shaft; the best is broken small with hammers, which they call *spalling*, or brought away to the adjacent bucking mills, where there are men ready to bruise it upon a rock with a short bar of iron, and thence carried to the heap of best ore, and what is not worthy of the first place, is laid by to make another sortment; the best small ore (which consists of the smaller fragments of what has been broken and sorted before,) is then washed and sifted into a tub or keeve, as near to the shaft as possible (to prevent waste); first through an iron sieve or searce, called in Cornwall the *griddle*, the meases about an inch square; here the waste, or barren stone, by washing is discovered and thrown away, while the copper in it, sorted into *best* and *dredged*, (that is, streaked, spotted, powdered ore, which requires a second washing,) and the larger pieces of ore of each sortment are thus divided: what passes through the griddle is taken up out of the keeve, and put through another searce of smaller meash, called the *jigging* searce, which has eight holes in every square inch: here, when it has been lifted up and down, and turned round in the searce a few times, (which they call jigging,) the waste will all rise to the top, and settle in the middle like small sand, and what remains underneath will be clean ore. The poorer sort, which is the streaked or dredged ore, is carried from the mine to the next adjoining stream of water, where in several pits made for the purpose, called the *strakes*, it is washed clean. All the richest bits of ore are then culled from the rest by girls or boys, at the hire of 4*d*. per day, and the poorest or most stony parts, which are not fit to be put with the picked ore, are carried to a stamping-mill, there pounded and passed through a rough grate. What ore remains in the fore-part of the pit, (into which the pounded ore was washed from the stamps,) is carried back to the *jigging* searce and worked as before mentioned; but what runs off the hindmost part of the pit and remains there in the second pit, (similar to that in the tin pits,) is slimy, and must be *trunked*, *buddled*, and *tozed*, as the slimy tin."*

Twenty years subsequently, in Pryce's time, some slight modifications, supposing the foregoing description to have been exact, would seem to have been effected in dressing copper ores. When brought to the surface, or grass, as the miners term it, the larger were separated from the smaller stones, and spalled or broken to less size, and the poorer ores were put aside to be straked. When the ores were raised and moderately dry, they were griddled near the shaft, and the parts which passed through the griddle, if not then clean enough for sale, were washed, and it appears that the griddled ores generaliy required it. The strakes are described as consisting of two boards laid for a bottom, 14 inches in the ground, so as to form an in-

* Nat. Hist. Cornwall, p. 203.

clined plane, with two sides, formed of one deal board each, the whole resembling a shallow and narrow chest, without a cover. Through this ran a somewhat quick stream of water, into which the ore was thrown by one person while another moved it about in the water, so that the fine earthy particles were washed into a pit prepared to receive them, while the stony part, from its great volume, accumulated at the lower end or *tail* of the strake-boards, and the better ores, by their superior gravity, and from a peculiar motion employed in stirring it with a shovel, were retained towards the head of the strake. With the latter the mundic, or iron pyrites, if such were mixed with the copper-ores, would be retained, from its gravity and according to its relative volume. The larger stones also, whether of the waste or ore, were retained, and were usually thrown out by the dresser on one side of the strake to the pickers, who separated the better from the rest. The stony matter which accumulated at the tail of the strake was put aside to be stamped, as it generally contained ore.

The picked ores which were solid and rich, more especially those which were first separated at the mouth of the shaft, were broken with hammers into the size of a chestnut or less by girls, called *cobbers*, and the ore so treated was termed *cobbed ore*, and fit for sale. The stony ores left by the pickers, sometimes termed *dredge-ore* (from being streaked or powdered through its matrix), and the refuse from the cobbers, were taken to the bucking-mill, a contrivance like a wooden coalscuttle, placed on a low hedge, with a hard-stone upon its lower and narrow end, upon which a strong girl broke the ores with a flat hammer, or *bucking-iron*, into the size of peas or beans. From the buckers the ores were conveyed to be *jigged*. Preparatory to jigging a kieve was half filled with water, on the surface of which one person held a coarse iron sieve, of two holes to the inch, while another threw the ore into the sieve, which the former dipped into the water and shook twice or thrice, so that the smaller part fell through it into the water in the kieve. The portion that remained in the sieve the workman reserved by itself until he considered he had a sufficient quantity, when it was either jigged clean, if the ore contained in it were sufficient, or else it was picked and the refuse bucked over again, according to the judgment of the dresser. When the kieve, under the sieve noticed above, was almost full of the ore which had passed through the meshes, the water was poured off and the ore taken out, and might be again sorted, if thought proper, by passing it through other sieves with smaller holes.

The jigging-sieve was made of brass wire, with holes varying in different sieves from four to eight in the square inch, as might be considered best for the ores to be jigged. This was held by the dresser in a kieve with water in it, and by a kind of combined rotatory and vertical motion the ores and other matters in the sieve were made to arrange themselves according to their relative specific gravities and volumes, so that the part composed of iron pyrites or copper-ores attained the lower part of the jigging-sieve. The upper portions were removed by means of a piece of wood, named a *limp*, in shape and size resembling half the head of a small barrel; and if considered rich enough in ore they were jigged over again. The dresser also

took off the good ore and reserved the remaining iron pyrites, which, from its greater specific gravity, got to the bottom, until it became of sufficient quantity to jig over again, in order to separate any copper-ores which, from their greater volume or otherwise, might be entangled among it. The gravel refuse was sometimes straked, a very quick stream of water being employed, and the muddy portion, composed of the finer particles which fell through the wires of the sieve, were cleaned in a tye, a contrivance much like the strake, but through which a very slow stream of water was permitted to pass, on account of the fine particles on which it had to act, or else by buddling and framing as with the tin-ores. The best ore being separated and dressed by itself, the refuse went, at that time as at present, by the name of *halvans*, and was dressed over several times by means of the strakes, stamps, &c.

At present the copper-ores, after having been brought to the surface and thrown into the proper places appointed to receive the various portions raised from different parts of a mine, are broken or spalled as before, and divided into pieces of good ore, commonly termed *prills*, *dredge-ore* (of the same kind as that above noticed), and *halvans*, or leavings. In most of the principal mines the process of breaking the best ores by bucking is discontinued, and the same work is accomplished better and at much less cost by means of crushing-machines, in which the ore is crushed to the size required between iron or steel rollers, generally set in motion by water-power. As the crushed ore falls from the rollers it is received in a sieve, commonly inclined and made cylindrical, so that by turning round on its axis the larger pieces of ore slide down to the bottom, while the smaller pass through the wires of the sieve. By these means the pieces of ore which have not been sufficiently crushed are again passed through the rollers. Crushing-machines were introduced among the Tavistock mines about 25 or 26 years since.

Jigging is now also performed by machinery in the better mines, and is accomplished by converting the kieve into a rectangular chest, in which, immersed to the proper height in water, a rectangular sieve is suspended; to this sieve a vibratory motion is communicated, usually by means of a water-wheel acting on a lever so adjusted as to produce it. The old operation may still, however, be seen in the smaller mines.

The ores are still cobbed and picked by women and children, the cobbing being usually executed by strong girls, for the work is anything but light. When the ores are mixed with much foreign matter they require to be picked with care, and to a stranger the little picturesque groups of children thus employed, and the practical judgment they have usually attained, are generally subjects of interest.

When the ores are not sufficiently pure to be separable by the eye and hand, the remaining operations are all founded upon the relative specific gravities of the parts subjected to dressing, and they are crushed or pounded to various degrees of fineness, so as to render the ore sought separable with the aid of water from the other parts. Stamping, therefore, is employed when the ores are finely disseminated through the quartz or other hard matters of the lode, or when the non-metalliferous portions of them are so hard that it becomes profitable to pound them under stamp-heads. When

we were in the district, the steam-stamps of Carn Brea were the largest employed for pounding copper-ores.

By the union of picking, crushing in various manners, jigging, and washing in buddles, &c., the ore is rendered saleable.* Tin-ores, which some-

* The mode of assaying copper-ores in Cornwall is usually conducted in a somewhat rough manner, and accurate results can scarcely be expected from it. Indeed chemistry has as yet made little progress among the assayers of Cornwall. The process which appears to be considered among the best, for they vary (some being precisely the same with that given by Pryce 60 years since), is to take 400 grains of the sample of ore, pound it fine, sift it, and place it in a crucible to roast in an air-furnace, keeping the ore stirred frequently with an iron rod. When the sulphur is considered to have been sufficiently driven off (for the ores are usually either bisulphurets or sulphurets), the ore is taken from the fire and allowed to cool gradually in the crucible: if then the upper part appears red or brown, and the under part black, the proper roasting is supposed to have been given. A standard flux —composed of borax 5 dwts., lime 1½ ladleful (diameter of the ladle about ¾ of an inch, and depth ½ an inch), and powdered fluor spar 1 ladle—is then mixed with the roasted ore and put in a crucible, the mixture being covered with salt. It is then melted, and what is termed a *regal* or *regule* produced. This regule is thought good if it will produce from 8 to 12 in 20. The grey sulphurets, the black oxides, and the carbonates, have sulphur added to them, to "throw back the ores," as it is termed, as they are considered not to have enough of it for the purposes of the assay. To fine this regule it is pounded and roasted in a crucible until the sulphur is considered to be driven off. A flux—of nitre 3 dwts., red tartar 10 dwts., borax 5 dwts., and salt 2 ladles—is then added, and salt sprinkled over the top of the mixture. Coarse copper is now obtained. If this comes out clean, as it is termed, the assay is put into a crucible without flux, and when melted the crucible is taken out of the furnace and shaken until the surface appears blue. A refining flux is now prepared by mixing 2 parts of nitre and 1 part of white tartar in an iron mortar, and stirring the mixture with a red-hot iron until deflagration has ceased. The flux thus made is powdered and sifted when cold, and 5 dwts. of it are added to a ladle of salt, put with the assay into a crucible. When all is melted the copper is poured into one mould and the slag into another. The latter is again melted with two ladles of red tartar, and the small button or *prill* of copper, now found, is added to that previously obtained, and the assay is completed. Such is the kind of process supposed to give fair accurate assays of copper-ores.

For an exact assay the humid way would be the best; but, as it requires both skill and time, it can scarcely be expected to come into use at present in Cornwall and Devon. Good simple dry assays are described by Dr. Ure (Dictionary of Arts, Manufactures, and Mines, p. 331) and others.

Berthier (Traité des Essais par la Voie Sèche, tom. ii. p. 474), describing assays of the sulphurets of copper mixed with iron (such as the Cornish and Devon ores usually are), and after noticing the roasting, in which it is necessary to stir the particles of ore continually, so that all should come into contact with the air, says, "When the roasting is somewhat advanced the heat should, from time to time, be increased to a bright red, in order to make the sulphurets and sulphates act upon each other, and produce reciprocal decomposition. When sulphurous acid ceases to be disengaged a white heat should for some minutes be produced, in order

times are mixed with those of copper, are commonly accumulated at the heads of the tyes or buddles, in consequence of their greater specific gravity: and, when thought of sufficient quantity or value, they are roasted and dressed as tin-ores usually are; any copper which may occur in them (and the mixed ores are usually sulphurets or bisulphurets of copper, and peroxides of tin) being extracted after having been formed into a sulphate in the roasting-house, or when afterwards exposed, by precipitating it from a solution by means of iron.*

After being dressed, sampled, and sold at the ticketings, as above noticed, the copper-ores of Cornwall and Devon (for none are now raised in Somerset) are wholly exported to South Wales, and are there smelted in addition to copper-ores from other parts of the United Kingdom, and imported from foreign countries, nearly the whole of which is taken to the same places.†

The following is an account of the copper-ores sold at the Cornish ticketings during the year ending the 30th June, 1838:—‡

to decompose the last trace of sulphate. When the roasting has been conducted with care, the assay, melted with three or four times its weight of black flux, will give nearly all the copper which it contains, and all the iron will remain disseminated through the slag, partly in a metallic state and partly in a state of oxide. If the roasting has been imperfectly executed the slag or scoria will be sulphurous, and will retain copper in combination. When the copper-ore is poor, and contains much iron, the scoria or slag is always pasty (pâteuse), whatever care may be taken, and small granules of copper will remain in it, the weight of which sometimes amounts to two or three per cent. This loss may, indeed, be decreased by adding about one part of borax to the black flux, in order to render the scoria or slag more liquid; but it is preferable, in such cases, to assay by the humid way." Berthier, indeed, strongly recommends the humid assay for ores of this class.

* In some mines these mixed ores are extremely troublesome, and it becomes difficult to determine whether portions of them should be dressed for tin or copper. Mr. Carne states that one ton of copper per annum was obtained in this way from the mixed ores of Botallack, about 1821, and that this mode was then practised for the mixed tin and copper ores at Dolcoath, Cook's Kitchen, Chasewater, and in some parts of St. Agnes.—Trans. Geol. Soc. Cornwall, vol. ii. p. 335.

† The improved process of copper-smelting, as practised at the Haford works, Swansea, was published by Mr. I. H. Vivian, M.P., in the Annals of Philosophy for 1823. A detailed account of the process at present employed is given, with figures, in Dr. Ure's Dictionary of Arts, Manufactures, and Mines, p. 18, &c.

‡ From Gryll's Annual Mining Sheet, No. 7. Redruth.

MINES.	Ore from Each Mine.	Money in each Mine.	Average Price per 21 cwt.
	21 *cwts.*	£. s.	£. s. d.
Buller and Beauchamp, Wheal	1,983	11,876 18	5 19 8
Botallack	10	185 15	18 11 6
Busy, Wheal	669	1,802 17	2 13 10
Burrow, Wheal	390	868 0	2 4 6
Consolidated Mines	19,459	126,211 12	6 9 8
Carn Brea Mines	6,918	41,362 19	5 19 4
Carharrack and Wheal Maiden	1,152	5,003 6	4 6 10
Copper Bottom	552	3,635 1	6 11 8
Cardrew Consols	306	1,643 9	5 7 5
Cook's Kitchen	2,030	9,909 5	4 17 7
Clifton, Wheal	86	270 12	3 3 0
Curtis, Wheal	127	662 5	5 4 3
Dolcoath	2,962	13,787 8	4 13 1
Darlington, Wheal	540	3,119 12	5 15 0
Damsel, Wheal	253	1,449 19	5 14 9
Duffield Mines	739	5,638 0	7 12 6
Dast Wheal Crofty	8,134	40,185 12	4 18 9
East Pool	1,957	15,311 2	7 16 5
East Crinnis	1,033	7,504 10	7 5 3
Ellen, Wheal	1,762	8,695 0	4 18 8
Elizabeth, Wheal	116	601 10	5 3 8
Fowey Consols	15,254	85,434 19	5 12 0
Great St. George	5,774	27,097 17	4 13 10
Great Wheal Fortune, &c.	3,143	19,079 2	6 1 4
Gorland, Wheal	498	3,574 13	7 3 6
Great Wheal Charlotte	659	2,340 9	3 11 0
Godolphin	1,602	11,963 19	7 9 4
Great Work	207	2,033 1	9 16 5
Hallenbeagle	1,104	5,010 7	4 10 9
Harriet, Wheal	221	402 16	1 16 5
Harmony, Wheal	490	3,693 14	7 10 9
Jewel, Wheal	3,317	20,701 1	6 4 10
Julia, Wheal	1,061	6,166 19	5 16 3
Kitty, Wheal	50	466 19	9 6 9
Levant	2,910	37,070 1	12 14 9
Leisure, Wheal	1,073	3,322 7	3 2 0
Leeds, Wheal	474	2,796 19	5 18 0
Marazion Mines	1,659	9,729 9	5 17 3
North Roskear	4,310	24,554 15	5 13 11
Osborne, Wheal	110	813 1	7 7 10
Pembroke	196	1,204 10	6 2 11
Providence Mines	777	6,576 17	8 9 3
Providence, Wheal	741	6,055 19	8 3 5
Poldice	815	4,989 19	6 2 5
Prudence, Wheal	916	3,730 19	4 1 5
Plenty, Wheal	155	841 4	5 8 6
Polbreen	18	198 0	11 0 0
Relistian	2,435	16,405 19	6 14 9
South Wheal Basset	2,039	10,994 8	5 7 9
South Roskear	2,517	11,659 13	4 12 7
Stray Park	1,132	6,554 1	5 15 9
South Towan	1,771	9,260 19	5 4 7
South Caradon	140	1,198 6	8 11 2
Speed, Wheal	301	2,640 1	8 15 4
Seton, Wheal	112	821 7	7 6 8

(*Table continued.*)

MINES.	Ore from each Mine.	Money in each Mine.	Average Price per 21 cwt.
	21 *cwts.*	£. *s.*	£. *s.* *d.*
Sydney Cove	88	635 16	7 4 6
Sparrow, Wheal . . .	134	570 0	4 5 0
Spearn Moor	14	317 12	22 13 8
Sundry small Mines, &c. . .	1,067	3,906 1	3 13 2
Tresavean	12,303	76,272 9	6 4 0
Trewavas	1,073	6,866 0	6 8 0
Tincroft	1,987	8,327 5	4 3 9
Treasury, Wheal . . .	2,704	13,605 3	5 0 7
Trenwith, Wheal . . .	476	4,457 18	9 7 3
Trethellan	591	2,324 17	3 18 8
Treleigh Consols . . .	546	2,579 2	4 14 5
Trevaskus	274	1,928 15	7 0 9
Tolgus, Wheal . . .	177	955 13	5 8 0
United Mines . . .	4,359	28,544 1	6 11 0
United Hills	4,010	20,691 4	5 3 2
Unity Wood, Wheal . . .	3,204	17,420 6	5 8 8
Union, Wheal	101	423 13	4 3 10
Virgin, Wheal	2,936	16,768 13	5 14 2
Vyvyan, Wheal . . .	225	982 4	4 7 3
Ver, Wheal	62	391 5	6 6 2
West Wheal Jewel . . .	198	701 16	3 11 0

Average Standard—109*l.* 3*s.* Average Produce—7$\frac{7}{8}$.
Average Price per 21 cwt.—5*l.* 17*s.* 6*d.* Fine Copper—11,527 tons, 4 cwts., 1 qr., 17 lbs.
Amount of Money—857,779*l.* 11*s.* Copper-Ore—145,688 21 cwts.

It will be seen, by the foregoing table, that the value of the copper-ores raised during the year varied very materially; while a small quantity from Botallack brought 18*l.* 11*s.* 6*d.* per ton (of 21 cwt.), and another from Spearn Moor 22*l.* 13*s.* 8*d.* per ton, the ores from Wheal Burrow only averaged 2*l.* 4*s.* 6*d.* per ton. Levant Mine produced the greatest quantity of rich ores, their average price being 12*l.* 14*s.* 9*d.* per ton, and their total value for the year 37,670*l.* 1*s.* 6*d.*; thus bringing for about the same weight of ores more than double the money produced by the Wheal Virgin ores, though the latter sold at nearly the average price for the year. The three mines producing the greatest quantity of ores and money were the Consolidated Mines (19,459 tons of ore, worth 126,211*l.*), Fowey Consols (15,254 tons, 85,435*l.*), and Tresavean (12,303 tons, 76,272*l.*).

The following table of the foreign and British ores sold at Swansea by ticket, in the manner practised in Cornwall, may be useful in showing the amount of foreign copper-ore imported into

South Wales during the same year* (also ending 30th June, 1838), as also the produce of some of the copper-mines in Ireland and Wales for the same time:—

	21 Cwt.	£. s. d.	£. s. d.
Allihies	4,575	43,436 0 6	9 9 10
Ballymurtagh	6,711	21,840 16 0	3 5 1
Ballygahan	634	2,322 10 6	3 13 3
Chili Ores	5,619	115,915 1 6	20 12 7
Cobre Mines	5,644	114,406 15 6	20 5 4
Copiapo	1,047	19,475 9 0	18 13 4
Cuba	1,133	20,604 11 0	18 3 8
Cronbane	2,056	7,499 19 0	3 12 11
Connoree	350	1,552 9 6	4 8 8
Cwm	23	194 7 0	8 9 0
Drwsycoed	400	2,332 17 0	5 16 7
Knockmahon	6,345	53,561 10 0	8 8 9
Llandidno	811	6,909 17 6	8 10 4
Llanberris	494	2,083 6 6	4 4 4
Llandegai	66	469 2 0	7 2 1
Laxey	137	513 9 0	3 15 0
Mexican	90	797 13 0	8 17 3
Norway Ores	1,591	18,303 7 6	11 10 0
Penralt	74	494 18 6	6 13 9
Symnia Dylluan	186	1,425 0 6	7 13 2
Sygun	183	728 19 6	3 19 8
Sundries	362	1,780 1 0	4 18 4
Tigrony	2,034	9,354 18 6	4 12 0
Union	446	1,460 9 0	3 5 5
Valparaiso	1,920	33,859 14 0	17 12 8

Average Standard—97*l.* 17*s.* Average Produce—13¾.
Average Price per 21 cwt.—11*l.* 4*s.* 6*d.* Fine Copper—5,906 tons, 9 cwt., 2 qrs., 25 lbs.
Amount of Money—481,323*l.* 3*s.* Copper Ore—42,931 21 cwts.

The amount of copper-ores thus sold in Cornwall and Swansea, for the year ending as above, would amount to 188,619 tons (of

* The following is a comparative account (given in the Third Annual Report of the Swansea Philosophical Institution, June, 1838, p. 48) of the copper-ores imported into the United Kingdom, for five years, ending 1837:—

	1833. Tons.	1834. Tons.	1835. Tons.	1836. Tons.	1837. Tons.
Liverpool	3,235	2,786	6,696	7,479	5,928
Swansea	2,562	4,276	7,008	9,074	12,665
Llanelly	134	220	236	693	299
London and Bristol	1	19	5	1,173	604
	5,932	7,301	13,945	18,419	19,496

A large portion of the ore received at Liverpool, and the whole of that received at London and Bristol, was transhipped in smaller vessels to Swansea, and there smelted.

21 cwts. each), estimated to contain 17,433 tons of fine copper, and sold for 1,339,102*l.* 14*s.* The foreign copper-ores are merely introduced for the purpose of smelting, and the purchasers of such ores are bound to export as much copper as is estimated, from assays made previous to sale, to be contained in them; hence the quantity necessary to be exported depends upon the accuracy of such assays.*

The following account of the receipts and expenditure of the Consolidated and United Mines, in Gwennap, adjoining each other and under the same management, for 1836, and for which we are indebted to Mr. John Taylor, will afford an insight into the money-transactions of one of the largest copper-adventures in Cornwall:—

		Tons.	Value. £.	s.	d.	Lords' Dues. £.	s.	d.
Quantity of ores raised in the Consolidated Mines.	Copper...	18,498½	143,039	12	5	5,959	19	5
	Tin.....	..	2,533	0	10	105	10	9
	Arsenic...	..	144	7	10	6	0	4
			145,717	1	1	6,071	10	6
Quantity of ores raised in the United Mines.	Copper ...	2,874	26,272	6	10	1,094	13	4
	Tin	..	106	11	0	4	8	8
			26,378	17	10	1,099	2	0
Amount of Ore-money, deducting Dues.		Consolidated Mines ...				£139,645	10	7
,, ,,		United Mines				25,279	16	10
						£164,925	7	5
Total Expense for the Year.	Consols	£102,007	12	1				
	United Mines...	35,960	16	0		137,968	8	1
		Amount of Profit				£ 26,956	19	†4

* The following is a statement of the copper, British and Foreign, exported for ten years ending 1837, obtained from one of Sir Charles Lemon's tables. Journal of the Statistical Society of London, vol. i. p. 83:—

Years.	British Copper. Tons.	Foreign Copper. Tons.	Total. Tons.
1827 . . .	7,171	..	7,171
1828 . . .	6,206	7	6,213
1829 . . .	7,976	33·6	8,009·6
1830 . . .	9,157·7	164·1	9,321·8
1831 . . .	8,530·6	354·4	8,885·0
1832 . . .	9,730·6	694·7	10,425·3
1833 . . .	7,811·6	1,624·6	9,436·2
1834 . . .	8,886·5	1,185·7	10,072·2
1835 . . .	9,111·2	2,772·8	11,884·0
1836 . . .	8,076·2	1,939·0	10,015·2
1837 . . .	7,129·3	5,155·2	12,284·5

† The profit upon the Consolidated Mines being 37,637*l.* 18*s.* 6*d.*, and the loss upon the United Mines 10,680*l.* 19*s.* 2*d.*

Expenses in 1836.	Consolidated.	United.
Agents' Salaries	£ 3,343 19 0	£ 1,373 17 6
Tutwork Bargains	26,177 5 8	10,974 11 4
Bargain on Surface, Wages, Stems, &c.	2,539 8 11	865 17 7
Carpenters, Masons, Smiths, Engineers, &c.	3,099 0 2	1,696 11 9
Carriage and Horse-work	922 6 6	208 12 8
Materials	15,008 6 4	5,222 9 0
Engine or Water-cost (including rent of Water, 405*l.* 13*s.*)	15,415 7 4	4,967 19 8
Expenses on Ores	7,803 8 7	767 17 5
Tribute Subsist, and Balances	25,030 17 0	9,219 12 3
Sundry Payments	1,872 3 1	339 19 4
Doctor and Club (half to each)	795 9 6	323 7 6
	£102,007 12 1	£35,960 16 0

The undermentioned articles are included under the head of Materials and Water-cost, amounting to 40,614*l.* 2*s.* 4*d.*:—

	Consolidated.	United.	Total.
Coals	11,817 *tons.*	3,453 *tons.*	15,270 *tons.*
Iron of various sizes	108 „	63 „	171 „
Candles	113,916 *lbs.*	48,228 *lbs.*	162,144 *lbs.*
Gunpowder	64,000 „	18,000 „	82,000 „
Debenture-timber	49,091 *feet.*	13,500 *feet.*	62,591 *feet.*
Yellow Pine	2,129 „	372 „	2,501 „
American Oak	..	31 „	31 „
Steel of various descriptions	135 *cwt.*	28 *cwt.*	163 *cwt.*
Tallow	375 „	148 „	523 „
Flat and round Ropes	977 „	162 „	1,139 „
192 Hides of leather	8,996 *lbs.*	4,497 *lbs.*	13,493 *lbs.*
Patent ½-inch Chain	3,474 *fms.*	606 *fms.*	3,080 *fms.*
Pick and Shovel Hilts	13,098 *doz.*	3,600 *doz.*	16,698 *doz.*
Nails of various descriptions	91 *bags.*	57 *bags.*	148 *bags*
Engine-shag and Poldavey	3,438 *yds.*	1,140 *yds.*	4,578 *yds.*
Cod-oil	269 *gals.*	..	269 *gals.*
Rape-oil	727 „	207 *gals.*	934 „
Foundry-bill for Pumps and Castings	£1,735 0 1	£586 18 1	£2,321 18 2
Safety-rods used in blasting, 9*d.* per 24ft.	262 10 0	131 5 0	393 15 0
Books and Stationery	50 6 7	16 6 0	66 12 7

The following is a list of the numbers and descriptions of persons employed in these mines in 1836:—

	Consolidated.	United.	Total.
Agents	28	9	37
Tutwork-men . . .	441	198	639
Tributers	392	217	609
Surface-men . . .	335	110	445
Boys underground . .	109	138	247
„ surface . . .	327	23	350
Females	755	114	869
	2387	809	3196

The following was the rate of wages paid in this year:—*

	Per Month. £. s. d.
Tutwork-men . . .	3 11 6
Tributers	4 5 0
Surface-labourers . .	2 6 0
Women and Girls above 17 .	0 18 0
Girls from 14 to 17 . .	0 15 0
Girls from 12 to 14 . .	0 12 0
Girls from 9 to 12 . .	0 8 0
Boys above 12 . . .	0 13 0
Boys below 12 . . .	0 9 0

For a detailed description of these mines we must refer to Mr. Burr's descriptions of them in the Mining Review.† The same author has given a very elegant small mining section of the Consolidated Mines, in his Elements of Practical Geology, which will afford an excellent general view of the chief lode, with its levels, adit, and shafts, as also of the great extent of these mines; which are nearly two miles long, and in their greatest depth nearly 1800 feet. During about twenty years, underground operations in the Consolidated Mines, in sinking and driving, mostly in the solid rock, for the sole purpose of discovery, have been executed to the extent of more than 55,000 fathoms, or about 63 miles, at an expense which cannot have fallen short of £300,000.‡

* As the wages in this year were higher than usual in consequence of the great demand for miners, so that it was difficult to procure agricultural labourers in the mining districts during 1836, the usual rate should be estimated somewhat lower.

† Descriptive notice of the Consolidated and United Mines, English's Mining Review, No. VII., July 1835, p. 17. The machinery then employed in them consisted of eight large steam-engines, used in pumping, varying from 90 to 65-inch cylinders, with a small engine of 30-inch cylinder, employed for the same purpose, and of eight steam-engines of about 20-inch cylinder used in drawing ore and other mineral matter out of the mines. There was also a water-wheel, 48 feet in diameter, for pumping, one of about 40 feet diameter, for driving machinery, and five smaller water-wheels for stamping and grinding ores, besides horse-whims, chiefly used in the United Mines.

‡ Burr, Elements of Practical Geology, p. 288.

The following is a table of the transactions of the Consolidated Mines for eighteen years, ending 1836:—*

Years.	Capital and compound Interest.	Cost.	Lords' Dues.	Value of Ores.	Tons of Ore.	Wages.
	£	£	£	£		£
1819	15,267	..	..	..	..	..
1820	36,644	..	..	..	..	..
1821	18,223	..	..	..	..	..
1822	3,506	..	..	..	..	..
1823	3,479	69,836	3,478	83,488	11,532	43,716
1824	13,001	84,081	4,584	110,036	14,980	47,885
1825	2,768	95,451	4,971	119,312	13,379	53,275
1826	1,985	82,865	3,848	92,355	13,872	43,200
1827	1,726	81,322	4,108	98,601	13,637	41,439
1828	1,199	69,825	4,013	96,313	13,262	37,568
1829	340	68,177	3,673	88,171	12,578	38,183
1830	Capital repaid.	69,897	3,795	91,092	13,512	39,304
1831	. .	75,290	4,310	103,451	15,292	43,410
1832	. .	83,472	4,791	115,000	15,670	47,051
1833	. .	89,696	5,967	143,227	18,191	51,844
1834	. .	88,956	5,652	135,670	20,022	42,690
1835	. .	90,216	5,607	134,574	19,619	53,787
1836	. .	102,007	6,071	145,717	18,499	61,257
					214,045	644,699

It may be useful to compare the transactions of another large mine, the Fowey Consols, with the statement above made, more particularly as it is situated in another mining district of Cornwall. Mr. Austen Treffry had kindly furnished us with a statement of these transactions for 1836, but as one for 1837 has appeared, we have preferred giving the latter, as that year was one of much less mining excitement than 1836, though this excitement would be little felt in such mines as the Consolidated, in Gwennap, or in the Fowey Consols, except perhaps in the cost of wages.

	Tons.	cwt.	qr.
Quantity of ores raised in 1837 in Fowey Consols Mines†	15,710	12	0
Amount of proceeds for the ores sold, including carriage-money paid for the same	£89,083	15	2
Total amount of expenses for the year	73,262	16	3
Amount of profit, 1837	£15,820	18	11

* From Sir Charles Lemon's Statistics of the Copper Mines of Cornwall, Journal of the Statistical Society, Vol. I. p. 77.

† The quantity raised in 1836 was 14,006 tons, producing from the difference in the price of copper, £97,996 11s. 5d.

The expenses may be divided under the following heads, viz.:—	£	s.	d.
Amount of agency, including purser and clerks	1,361	3	6
,, Lords' dish or dues	4,886	2	11
,, Smithery, carpentry, and sawing	1,701	19	0
,, Tutwork	16,347	10	10
,, Tribute	18,821	7	11
,, Sundry surface labour and sundries	3,392	6	5
,, Charges on ores, including carriage, and sampling and weighing fees	5,956	2	0
,, Drawing, filling, and landing	2,229	19	1
,, Parochial rates	292	16	6
,, Paid to sick labourers, of both sexes, from the sick club,* when unable to work	607	2	0
,, Paid for medical attendance	324	10	5
,, Rent of water and engine charge (exclusive of coals)	2,247	12	3
,, Stores	15,094	3	5
Total expenses as above†	£73,262	16	3

Under the head of stores, the following articles may be considered as constituting the principal items, making the above sum of 15,094*l.* 3*s.* 5*d*:—

	Weight. Tons.	cwt.	qrs.	Amount. £	s.	d.
Coals	1888	14	0	1,770	13	4
Iron, of various sizes and descriptions	106	14	2	1,029	18	4
Steel, of various sizes and descriptions	6	18	3	266	0	5
Patent flat and round ropes	30	7	2	1,074	5	1
Candles (6890 dozen lbs.)	36	18	1	1,777	5	6
Best Russia Tallow (83 cwts.)	4	3	0	189	1	7
Gunpowder (90,100 lbs.)	45	1	0	1,929	12	0
43 hides of leather (2393 lbs.)	1	1	2	224	0	4
590 fathoms of patent iron chain	3	18	3	111	6	1
89 bags of nails of various descriptions	6	13	2	155	15	11
Foundry bills of castings, &c.	114	18	2	1,967	11	1
	Number.					
Debenture timber (Dram and Longsound)	59,843 feet			2,766	14	7
Yellow pine	997 ,,			71	16	6
American oak	835 ,,			125	9	3
13,802 coils of safety fuze	331,248 ,,			568	6	8
811 dozen of pick and shovel hilts	———			87	3	3
Engine shag and poldavey	1,119 yds.			46	16	1
Cod oil	763 gals.			148	7	9
Rape oil	136 ,,			49	2	10
Copper powder-cans				51	10	0
Sieves, riddles, and stamp-grates				124	7	3
Account-books and stationery				75	4	8
Sundries of various descriptions				483	14	11
				£15,094	3	5

* Each miner in these mines receives 30s. per month during illness, and has medical attendance, with medicine provided for himself and family, for the support of which a deduction of 1s. 9d. is made upon his monthly earnings.

† The expenses, in 1836, were £74,960 5s. 10d.

The following is an account of the agents, labourers, and others employed in and on these mines :—

Designation.	No.	Average monthly wages.	Remarks.
Agents, &c.....	14	£8 2 0	.... Agents 8, clerks 5, and store-
Engineer	1	8 8 0	[keeper 1.
Napper and dialler ...	1	8 8 0	
Tributers	340	3 7 1	.... Minus deduction of 1s. 9d. for club and doctor.
Tutworkmen.....	358	2 19 2	
Sumpmen	52	3 15 10	
Boys underground ...	15 .. .	0 17 6	.. Employed blowing air-machines.
Day labourers ditto ..	112	2 12 0	.. Maximum 3*l.* 5*s.* Minimum 1*l.* 19*s.*
Day & monthly labourers at the surface.....	192	2 0 1	.. Maximum 2*l.* 3*s.* 4*d.* Minimum 1*l.* 16*s.* 10*d.*
Boys employed at surface	312	1 0 7	.. Maximum 1*l.* 12*s.* 6*d.* Minimum 0*l.* 8*s.* 8*d.*
Women and girls ditto	309	0 16 3	.. Maximum 1*l.* 3*s.* 10*d.* Minimum 0*l.* 8*s.* 8*d.*
	1706*		

The extent of these mines is considerable, numerous lodes running through the sett for nearly two miles. Including the late Lanescot mine, which has merged into them, they have realized and divided a profit among the shareholders of 132,949*l.* 14*s.* 3*d.*, after repaying the original outlay expended in bringing them into a profitable state of working, together with the machinery and other materials now on the mines, which, with the balance in hand in June, 1838, exceeded in value 50,000*l.*†

In Pryce's time, the largest copper mines are described as supporting an annual expense of 30,000*l.* for coals, candles, timber, leather, ropes, gunpowder, and various other materials, with the labour of men, women, children and horses, and also including the lords' dues, which he mentions as generally a sixth, seventh, or eighth part of the whole proceeds in money.‡ Mr. William Phillips, who visited Cornwall in 1800, states that the annual expenses of Wheal Alfred (a copper mine), for labour and materials, were then about 63,600*l.*; and that the number of men, women, and children, amounted to 1500.§ Tresavean mine is among the

* The number of persons employed in 1836 amounted to 1680.

† English's Mining Review, July, 1838, vol. iv. p. iii.

‡ Mineralogia Cornubiensis, Introduction, p. ix.

§ On the veins of Cornwall, Trans. Geol. Society of London, vol. ii. This mine ceased working in 1816. Carne, Trans. Geol. Soc. Cornwall, vol. iii. p. 69. Phillips notices Wheal Crenver, Cook's Kitchen, and Dolcoath, as the deepest mines in Cornwall at that time, the first being 200 fathoms deep, the second 200 fathoms, and the third 228 fathoms.

most valuable in Cornwall; the average of its profits for the last five or six years has been estimated at from 40,000*l.* to 50,000*l.* per annum.*

The following is an account, by Pryce, of the copper ores sold in Cornwall from 1726 to 1775, inclusive:—†

	Ten Years' Tonnage.	Average Price per Ton. £. s. d.	Amount. £.	Average Annual Tonnage.	Average Annual Amount. £.
1726 } 1735 }	64,800	7 15 10	473,500	6,480	47,350
1736 } 1745 }	75,520	7 8 6	560,106	7,552	56,010
1746 } 1755 }	98,790	7 8 0	731,457	9,879	73,145
1756 } 1765 }	169,699	7 6 6	1,243,045	16,970	124,304
1766 } 1775 }	264,273	6 14 6	1,778,337	26,427	177,833

The subjoined Table shows the copper ores raised in Cornwall, with their value, from 1771 to 1838, inclusive:‡—

Years.	Tons of Ore.	Tons of Copper.	£.	Standard. £. s.	Years.	Tons of Ore.	Tons of Copper.	£.	Standard. £. s.
1771	27,896	3,347	189,609	81 0	1805	78,452	6,234	862,410	169 16
1772	27,965	3,356	189,505	81 0	1806	79,269	6,863	730,845	138 5
1773	27,663	3,320	148,431	70 0	1807	71,694	6,716	609,002	120 0
1774	30,254	3,630	162,000	68 0	1808	67,867	6,795	495,303	100 7
1775	29,966	3,596	192,000	78 0	1809	76,245	6,821	770,028	143 12
1776	29,433	3,532	191,590	79 0	1810	66,048	5,682	569,981	132 5
1777	28,216	3,386	177,000	77 0	1811	66,499	5,948	563,742	126 0
1778	24,706	2,965	140,536	72 0	1812	75,510	7,248	608,065	113 0
1779	31,115	3,734	180,906	73 0	1813	86,713	8,166	685,572	113 0
1780	24,433	2,932	171,231	83 0	1814	87,482	7,936	766,825	128 0
1781	28,749	3,450	178,789	77 0	1815	79,984	6,607	582,108	121 0
1782	28,122	3,375	152,434	70 0	1816	83,058	7,045	541,737	109 0
1783	35,799	4,296	219,937	76 0	1817	75,816	6,608	422,426	96 0
1784	36,601	4,392	209,132	72 0	1818	80,525	6,714	587,977	121 0
1785	36,959	4,434	205,451	71 0	1819	93,234	7,214	728,032	136 0
1786	39,895	4,787	237,237	75 0	1820	92,672	7,364	620,347	119 0
1787	38,047	..	190,738	..	1821	98,803	8,163	628,832	111 0
1788	31,541	..	150,303	..	1822	106,723	9,331	676,285	104 0
1789	33,281	..	184,382	..	1823	97,470	8,070	618,933	110 0
1790	..	..	..	..	1824	102,200	8,022	603,878	110 0
1791	..	..	..	..	1825	110,000	8,417	743,253	124 0
1792	..	..	..	..	1826	118,768	9,140	798,790	123 0
1793	..	..	..	..	1827	128,459	10,450	755,358	106 0
1794	42,816	..	320,875	..	1828	130,866	9,961	759,175	112 7
1795	43,589	..	336,189	..	1829	125,902	9,763	725,834	109 14
1796	43,313	4,950	356,564	..	1830	135,665	10,890	784,000	106 15
1797	47,909	5,210	377,838	..	1831	146,502	12,218	817,740	99 18
1798	51,358	5,600	422,633	..	1832	139,057	12,099	835,812	104 14
1799	51,273	4,923	469,664	121 0	1833	138,300	11,185	858,708	110 0
1800	55,981	5,187	550,925	133 3	1834	143,296	11,224	887,902	114 4
1801	56,611	5,267	476,313	117 5	1835	153,607	12,271	896,401	106 11
1802	53,937	5,228	445,094	110 18	1836	140,981	11,639	957,752	115 12
1803	60,566	5,616	533,910	122 0	1837	140,753	10,823	908,613	119 5
1804	64,637	5,374	570,840	136 5	1838	145,688	11,527	857,779	109 3

* This is a very dry mine, requiring comparatively little machinery to raise the water from it; and it is also well situated on the slope of a hill.

† Mineralogia Cornubiensis, Introduction, p. xv.

‡ It is compiled up to 1832, from the Account of the Annual Produce of the

In 1815 Dolcoath was the mine from which the copper ores produced the greatest amount of money (66,839*l.*); in 1817, the United Mines were those which afforded the largest sum (63,116*l.*)* for their ores; and in 1822, the Consolidated Mines became those whence the copper ores raised afforded the greatest amount of money (in that year, 80,311*l.*); and they have continued to occupy the chief position in this respect to the present time.

There is a difficulty in comparing the amount of copper estimated to be contained in the ores raised formerly and at present, inasmuch as these estimates have been formed upon assays which, though they may be better now than formerly, have never possessed that very exact scientific character that could be desired. That the metal obtained formerly from given copper ores was not equal to that which is now yielded, is readily seen by the composition of old slags, many of which have been worth working for the copper in them.† Pryce states that 9000 tons of ore were, in 1737, raised in Cornwall. This number is, probably, only an approximation, as his account of the tonnage of each year appears to be merely such, anterior to 1760; taking, however, this number as a somewhat fair approximation, and the average price per ton, as stated by the same author, at 7*l.* 8*s.* 6*d.*, we should have 66,825*l.* as the approximative value of the copper obtained

Copper Mines of Cornwall, from the year 1771 to 1822, inclusive, given in the Trans. Geol. Soc. of Cornwall, vol. ii. p. 438, and from the Tables of the produce of the same mines in ore, copper, and money, appended to different volumes of the same Transactions. The remainder to 1838, inclusive, is from Gryll's Annual Mining Sheet. The produce in copper in 1787 and some succeeding years cannot be ascertained, as also the amount of ores raised, and of money obtained from 1790 to 1793, inclusive. The accounts of 1801 and the following years are made up to the 30th June in each year. Some few corrections for the standard are obtained from Sir Charles Lemon's Tables in vol. i. p. 69 of the Journal of the Statistical Society of London.

* In 1818, the value of the ores raised from these mines was £88,541.

† According to M. Strom, State Officer of Mines in Norway, the slags now wholly thrown away at the copper works at Swansea, and taken indiscriminately for examination, contain 30 per cent. more copper than the average slag at Roros, in Norway. He considers that copper to the amount of 3 lbs. per ton of ore is gained by the process adopted in the latter place; but states that he does not know how the loss could be avoided by the English method, except at an increased expense. (English's Mining Review, vol. iii. p. 67.) Judging from the old slags at Chasewater mine, the loss sustained by the mode of conducting the smelting there about 60 years since must have been very considerable, even grains of metallic copper were then left in the slag.

in that year. By the comparing this with the value of the ores raised in 1837, we find that the value of the copper produce of Cornwall has increased more than thirteen times and a half during the century ending in that year. If we compare the produce of 1787 with that of 1837, we obtain for the half-century an increase in the same value of four times and two-fifths nearly.

Though it would appear that copper was raised in Devon early in the last century, it was not until the commencement of the present century that the copper-mines in that county became important. The following table will show the ore and metal raised, chiefly from the mines near Tavistock, between 1801 and 1837, inclusive, with the exception of one year:—*

Years.	Ore. Tons. Cwts.	Metal. Tons. Cwts.	Years.	Ore. Tons.	Metal. Tons. Cwts.
1801	1078 18	.... 136 6	1820	4037	.... 463 11
1802	2204 6	.... 252 12	1821	....	.... 483 0
1803	2486 0	.... 288 4	1822	5064	.... 562 9
1804	2578 17	.... 283 16	1823	5250	.... 557 5
1805	3832 16	.... 332 0	1824	5483	.... 531 11
1806	4542 13	.... 412 0	1825	5732	.... 578 2
1807	3916 5	.... 394 15	1826	5126	.... 496 17
1808	3308 3	.... 346 6	1827	4450	.... 472 16
1809	3206 7	.... 364 19	1828	3911	.... 431 12
1810	3747 2	.... 358 1	1829	3160	.... 318 0
1811	3540 0	.... 323 13	1830	4034	.... 365 15
1812	5321 1	.... 506 15	1831	3721	.... 311 0
1813	5020 3	.... 475 10	1832	2940	.... 248 0
1814	5743 3	.... 473 5	1833	3403	.... 307 0
1815	4691 5	.... 371 10	1834	4763	.... 395 0
1816	3650 14	.... 319 5	1835	5114	.... 455 0
1817	3390 8	.... 287 2	1836	5759	.... 531 0
1818	4053 15	.... 407 16	1837	6328	.... 527 0
1819	3776 20	.... 374 16			

The produce of the ores will be observed to have varied from about 8·2 to 11·2 per cent., and to have been frequently 9 and 10 per cent. Their value was 12,878*l.* in 1801; 50,714*l.* in 1806; 31,517*l.* in 1811; 26,270*l.* in 1816; and, judging from the sales of the Cornish ores, 40,793*l.* in 1822; 34,111*l.* in 1827; 17,132*l.* in 1832; and 44,242*l.* in 1837.

In 1811 there would appear to have been only seven copper mines yielding ores—viz., Wheal Friendship, 110 tons; Wheal Crebor, (near Tavistock,) 1308 tons; Crowndale, 863 tons; East Crowndale, 913 tons; Ding Dong, 250 tons; Wheal Hope, 6

* This table is compiled from that communicated by Mr. John Taylor to the Lysons, Mag. Brit. Devon., p. cclxxxii., containing the years from 1801 to 1820, inclusive; and from information kindly sent to us by Mr. John Taylor, respecting the produce from 1822 to 1837, inclusive. The produce for 1821 is taken from the Trans. Geol. Soc. Cornwall, vol. ii. p. 443.

tons; and Wheal Hockworthy, 10 tons.* Wheal Friendship has been working since the end of the last century, and is still an important mine. This and Wheal Franco, also near Tavistock, are, at present, the most considerable copper mines in Devon; Bottle Hill mine, near Plympton, being chiefly worked for tin. One of the oldest copper mines in Devon would appear to be that formerly worked near North Molton, the ore from which is described as having been plentiful in 1729, and to have brought 6*l.* 10*s.* per ton. It was abandoned before 1778, and again re-opened, without success, in 1813.†

The copper adventures of West Somerset appear never to have become of much value. The chief workings seem to have been at Doddington, on the N. E. of the Quantocks. The ores raised here were principally carbonates; and Mr. Leonard Horner has pointed out, that green and blue carbonates of copper were first worked in the red sandstone conglomerate down upon the lode in the grauwacke beneath.‡ Shafts have been sunk at other places, such as Grabbist Hill, near Minehead, but without any profitable return. Copper is not raised in Somerset at present.§

The metal next in importance, and raised in the district, is, at present, manganese. The mines which produce it are mostly shallow, and we are not aware of any in which more than a common horse-whim is required for raising the ore. Common hand winzes are often sufficient, and are most frequently employed. The chief manganese mines now in work are found in the vicinity of Tavistock and Launceston. According to Lysons, manganese was first raised in Devon about the year 1770, at Upton Pyne, near Exeter, the ore from which, with two other mines of less consequence, upon the same lode, at Newton St. Cyres, for many years supplied the United Kingdom with this article. After its use in bleaching became established, the consumption of manganese became considerable. As the mines at Upton Pyne and Newton St. Cyres became exhausted, (the latter failed in 1810, and the former some little time afterwards,) many ores were found and raised at Doddescombleigh, Ashton, Cristow, and other places in

* Lysons, Mag. Britannia, Devon, p. cclxxxiii, where a long list, by Mr. John Taylor, of Devon copper mines abandoned before 1815, will be found.

† *Ib.* p. cclxxxv.

‡ Trans. Geol. Soc. London, vol. iii. p. 352 & 363.

§ It appears that 28 tons of copper were obtained from Somersetshire in the year ending 30th June, 1821. Trans. Geol. Soc. Cornwall, vol. ii. p. 443.

that neighbourhood. About 1815, the manganese mines in the neighbourhood of Launceston and Tavistock were discovered and worked.* Those in the north of Devon have hitherto produced comparatively little manganese. Borlase notices manganese as raised on the Tregoss Moors in 1754; and mentions its use in glass-making,† for which, and in the manufacture of Egyptian ware in Staffordshire, it was wholly employed, until it came into use for bleaching. Manganese was recently raised near Tresweeta, in the vicinity of St. Stephen's.‡

Although several ores of manganese occur in the district,§ pyrolusite, or grey and black ore, containing from 70 to 99 per cent. of peroxide of manganese, combined with variable quantities of siliceous and aluminous earths, oxide of iron, &c., is that which forms nearly the whole of the manganese ores raised in Devon and Cornwall.

The quantity of manganese shipped from Exeter from 1804 to 1810 amounted to about 3000 tons per annum. According to Mr. E. Williams, twelve mines in Devon, which he enumerates, produced 1911 tons of manganese ore in 1821. In the same year, 2212 tons of this ore were shipped from Plymouth, and the export was then increasing, 1336 tons only having been exported in 1819.‖ It is difficult to obtain a fair approximation to the quantity now raised in the district, but it is usually estimated at about 5000 tons per annum. This annual produce, taking the value of the ton to be, on the average, 8*l*., would give 40,000*l*. for the value of it.

Lead has often been profitably raised in the district, but at present little is produced. Mr. John Taylor states that only about 140 tons were obtained in 1835 from the Devon and Cornish mines; Wheal Betsy, near Tavistock, having produced 40 tons.¶

* Mag. Britannia, Devon, p. cclxxxix.

† Nat. Hist. Cornwall, p. 130.

‡ In fact, this mine is on a cross course chiefly filled with hematite iron ore, the manganese generally occurring as small branches running in from the sides. Out of this district, in the vicinity of Wrington, Somerset, we have lately seen a lode (east and west) in the carboniferous limestones, about 3 feet broad, in which good oxide of manganese occupied the south side, and rich hematite iron ore the north side.

§ Braunite is found near Launceston, Psilomelanite at Upton Pyne and near Launceston, Bisilicate of manganese near Tavistock and Callington, &c.

‖ Lysons, Mag. Britannia, Devon, p. ccxc.

¶ English's Mining Review, February, 1837, p. 36. The lead produced in Great Britain and Ireland in 1835, Mr. Taylor estimated at 46,112 tons.

This latter mine, North Wheal Tamar, between Launceston and Tavistock, a mine near Lamerton, (on the west of the latter place,) and the Combe Martin Mines in Devon, Treburget Mine near St. Teath, a little Mine near St. Merryn, East Wheal Rose in Newlyn Downs, Wheal Hope and the Goonhavern Mines near Perranzabuloe, and Wheal Rose, Wheal Penrose, Wheal Unity, and Wheal Saturn, near Porthleven, in Cornwall, were all which we found working in the district. The produce of the whole of them would scarcely amount to 180 tons.

Borlase mentions, in 1758, that lead mines had anciently and lately been worked in Cornwall, and that those most noted formerly were Penrose, Penwerty, Trevascus, Relistian, and Guarnek (Garras). He states that the Penrose Mines (near Helston), had been wrought for about 200 years, that is, from about the middle of the sixteenth century, and that they had yielded tolerable profit within 30 years.* The only lead mine worthy of note at work in his time was at St. Issy, near Padstow.† Pryce describes the lead ore of Garras, near Truro, to have been so argentiferous, that, when wrought about 1720, it produced 100 oz. of silver in the ton of lead.‡ Wheal Pool, near Helston, about 1790, yielded from 40 to 50 oz. of silver per ton of lead; and works were erected for extracting the silver. The lead ore of Wheal Rose contained 60 oz. of silver per ton.§

In Devonshire, the Combe Martin and Beer Alston Mines have long been celebrated for their argentiferous lead ores. It is stated that the produce of these mines was unusually great in the reigns of Edward I. and Edward II. In 1293 William de Wymundham accounted at the Treasury for 270 lbs. of silver raised in Devon. In 1294 it amounted to 521*l.* 10*s.* weight; and in 1295, to 704*l.* 3*s.* 1*d.* weight. In 1296 great profit is stated to have been derived from the Devon mines; and 360 miners were impressed out of Derbyshire and Wales to work in them.‖ In 1360, a writ was issued, authorising certain persons

* Nat. Hist. Cornwall, p. 210.

† Nat. Hist. Cornwall, p. 212.

‡ Mineralogia Cornubiensis, p. 58. This mine was re-opened in 1814, and continued two years in work. During that time it produced 800 tons of argentiferous lead ore, containing 13 parts in 20 of lead, the lead yielding 70 oz. of silver per ton.—Carne, Geol. Trans. Cornwall, vol. 1. p. 120.

§ Carne, on the discovery of silver in the mines of Cornwall.—Trans. Geol. Soc. Cornwall, vol. i. p. 119.

‖ Lysons, Magna Britannia, Devon, p. cclxxxv.

to take up as many miners and workmen as should be necessary to work in the King's mines in Devon, allowing them reasonable wages, according to the custom of the country; to arrest and imprison such as should resist, till they should give security to serve the King in the said mines, and to buy and provide timber at a competent price.*

Henry, Bishop of Winchester and Cardinal of England, as one of the executors of John, Duke of Bedford, who had a grant from the King of the gold and silver mines of Devon and Cornwall, rendered 26lbs. and 2 oz. weight of pure silver, as the 15th part of the pure silver raised in those counties from 15th December, 21st, to 16th August, 23d of the same King's reign.†

The Combe Martin Mines were re-opened in the reign of Elizabeth. The working of these mines was strongly recommended to the Long Parliament in 1659; but Lysons observes that they do not appear to have been again worked until the close of that century, and then without success. In 1813, they were again opened and worked for 4 years, producing only 208 tons of ore in that time.‡ In 1837 they were again worked, and we had an opportunity of observing that the previous mining operations presented every appearance of having formerly been very unskilfully managed. The two lodes near Bear Alston have produced large quantities of argentiferous galena, often containing from 80 to 120 oz. of silver per ton of lead. According to Mr. Hitchings, the greatest quantity which occurred in that part of them named the South Hooe Mine, was 140 oz. of silver per ton of lead.§ In 1784 and 1785 the silver produce of these mines amounted to 6500 oz.‖ From Wheal Betsy, near Tavistock, which was re-opened in 1806, from 300 to 400 tons of lead, and from 4000 to 5000 oz. of silver, were annually obtained about 15 years since. The produce of this mine, as we have seen above, is now greatly reduced.

Independently of the silver contained in argentiferous galena, other silver ores and native silver have been obtained in marketable quantities in Cornwall. The silver raised at Herland Mine, Gwinear, in the beginning of the present century, produced about

* *Ib.* p. cclxxxvi. and Pat. Rot. Edward III. A great number of grants to various persons for working the Devon mines, is quoted by Lysons, from old records. By one of 1384, tithe was to be paid to the Church, and one-ninth to the King.

† Plowden's Reports. Great Mining Case, 9 & 10 Elizabeth.

‡ *Ib.* p. cclxxxvii. § *Ib.* p. cclxxxviii. ‖ *Ib.*

8000*l.*; and the ores consisted of native silver, arseniet of silver, and sulphuret of silver, (vitreous silver, and black or *goose dung* ore of the Cornish miners).* About 1810, silver ores, to the value of 2000*l.*, were raised in Dolcoath. At Wheal Duchy, or Wheal Brothers, near Callington, native silver, ruby and grey silver ores, and the black sulphuret, have been raised. About 1812, the value of 3000*l.* of silver was obtained from this mine;† and, lately also, silver ores have been raised, but of what value we have not heard. Silver ores have been obtained in other mines, usually in sufficient quantities only to supply the demands of mineralogical cabinets.

Gold has, at different times, been discovered in the tin stream works. "Tynners," says Carew, "doe also often find little hoppes of gold amongst their owre, which they keep in quils, and sell to the goldsmithes, often with little better gaine then *Glaucus* exchange."‡ The practice of putting the grains of gold found by the stream tinners into quills, still continues. We have seen them thus brought to Truro, where the gold is made into wedding rings, and small articles of jewellery. The gold thus obtained, chiefly, however, finds its way into mineralogical cabinets. It is stated by Beare, that in Queen Elizabeth's time, "two blocks of tin, carried by one Mr. Robert Davy, to Bordeaux, were, by two Florentine merchants, valued to be worth all the rest of the tin there, by reason of the gold contained in them."§ Rings and seals have, at various times, been made of this gold; some of old date are still preserved in Cornish families. Borlase mentions, that in 1753, some persons streaming for tin, in St. Stephen's, Branel, found gold so plentifully mingled with the tin, that the smelter, Mr. Walter Roswarne, taking the gold at first for mundic, or copper, blamed the tinners for not having roasted or burnt the ore before it was brought for sale. The tinners who found this gold were considered to have derived much profit from it, and search was made for the same metal by others. Borlase describes it as having been found in the parishes of St. Ewe, Creed, St. Stephen's, St. Mewan, Probus, Kenwyn, and other places; and

* Carne, Trans. Geol. Soc. Cornwall, vol. i. p. 122.

† *Ib.* p. 123.

‡ Survey of Cornwall, p. 7.

§ MS. by Beare, of that date, in the possession of Pryce, entitled "The Bailiff of Blackmoor."—Mineralogia Cornubiensis, p. 52.

mentions that the largest piece he had seen, weighing 15 dwts. 3 grs., was found in 1756, and was then in the possession of Mr. Lemon, of Carclew. It was found in the parish of Creed, near Grampound.* Sir Christopher Hawkins notices the mixture of gold and tin in the Ladock stream works, in the latter part of the last century.† Among the various stream works in Cornwall where gold has been discovered, and it has been found in many in various parts of the county, those at Ladock and Carnon (at the head of Restronget Creek, in the Falmouth estuary,) seem to have produced the largest pieces. Several fine specimens of Cornish gold are in the celebrated mineral collection at Scorrier House, near Redruth. Gold is stated to have been found among the tin stream works of Dartmoor; and it has been discovered in grains and small plates among hematite iron ore, in a lode at the copper mine in North Molton.‡

Respecting cobalt, it appears that, in 1754, the Society for the Encouragement of Arts and Useful Discoveries, awarded a premium of 30*l.* for the best cobalt found in England, to Mr. Beauchamp, who obtained some in Gwennap. The same lode contained bismuth, which was thrown away, until Dr. Albert Schlosser, who visited the mine in 1775, separated the cobalt from the bismuth, and preserved both.§ The cobalt was discovered in a branch of of a lode, while driving an adit upon Pengreep estate, but did not hold in depth.‖ Pryce mentions that cobalt had been then found at Wheal Trugo (near St. Columb Major), at Dudman's Mine (in Illogan), at a mine near Ponsnooth (in Perran Arworthall), and in Dolcoath. That discovered at Wheal Trugo was found in a vein, from 4 to 6 inches thick, where it crossed a copper lode, but continued only for a short distance. It was considered to be worth about 60*l.* per ton.¶ Cobalt has been since discovered in a cross course, and adjoining a copper lode, at Wheal Sparnon, near Redruth. We have seen very good cobalt both from the

* Nat. Hist. Cornwall, p. 214.

† Trans. Geol. Society Cornwall, vol. i. p. 235.

‡ Robert Were Fox, MS., and the Lysons, Mag. Britannia, Devon (1822), p. cclxvii., who mention that Mr. Flaxman, of South Molton, had there found it of late.

§ Borlase, Nat. Hist. Cornwall, p. 130.

‖ Pryce, Mineralogia Cornubiensis, p. 50.

¶ Mineralogia Cornubiensis, p. 50.

latter mine and Dolcoath. Hitherto this valuable metal has not been discovered in sufficient quantities to produce much profit. It is also stated to have been found near Botallack (St. Just); at Herland Mine (Gwinear); at Polgooth (near St. Austell); and in Wheal Unity (Gwennap).* Cobalt has been discovered at Wheal Huckworthy (Sampford Spiney),† and in two or three other localities in Devon.

Nickel has been obtained at Pengelly mine in St. Ewe, and at Wheal Chance, St. Austell; but whether it was profitably raised or not we have not been able to ascertain. The ores which we have seen from thence consisted of the sulphuret of nickel and the arseniet of nickel.

Bismuth has been found in several places, among which may be enumerated one or two mines in St. Just, Herland Mine, Wheal Sparnon, and Dolcoath. The native ore has been found in St. Just, Wheal Sparnon, Dolcoath, and some other places; and the carbonate (examined by Mr. Gregor) at St. Agnes. Mr. Warrington found a sulphuret of bismuth, from Western Cornwall, to consist of bismuth 68·53, sulphur 19·33, iron 2·9, copper 2·98, and silica 5.01. Although bismuth ores have sometimes been obtained in fair quantities in one or two localities, the bismuth of Cornwall seems hitherto to have been little used.

Antimony has been chiefly raised in profitable quantities in the north of Cornwall, and principally in the neighbourhood of Endellyon. Borlase mentions its occurrence in that parish, and also in those of St. Stephen's and St. Austell, stating that this metal was then (1758) obtained from some lands in St. Minver.‡ Pryce observes that, in the three years, from 1774 to 1776, inclusive, 120 tons of antimony were raised in Cornwall, of which 95 tons were furnished by Wheal Boys, in Endellyon, at from 13*l.* to 14*l.* 14*s.* per ton, the remaining 25 tons being chiefly obtained from a mine near Saltash,§ (perhaps meaning the lode at Tredinnick, near St. Urney, on the west of that place,) which was worked for antimony some years since. Antimony has, from

* The ores of cobalt found in Cornwall consist chiefly of white cobalt (binarseniet of cobalt), and cobalt bloom. Black oxide of cobalt was noticed by the Rev. J. J. Conybeare, in the (new) red sandstone near Dawlish.

†1700lbs. of ore of an inferior quality were sold from this mine in 1820. Lysons, Mag. Brit. Devon, p. ccxc.

‡ Nat. Hist. Cornwall, p. 129. § Mineralogia Cornubiensis, p. 47.

time to time, been raised, during late years, near Endellyon, at Trevathan, near St. Teath, and at St. Merryn; but the mines seem to have been abandoned after short workings in them. This metal was discovered in Pillaton about the year 1819, and 20 tons were raised in that year, 33 tons in 1820, and 79 in 1821.* Antimony is stated to have been obtained near Hennock and Bovey Tracey, in Devon. It appears, that in 1778, there were antimony works on Restrongett Creek, Falmouth Estuary. The ore found is the grey or sulphuret of antimony, consisting, according to Dr. Thompson, of antimony 73.77, and sulphur 26.23.†

Sulphuret of zinc, blende, or *black jack*, occurs abundantly in the district, and is very common in many copper and lead lodes. An analysis of this ore, from Wheal Ann, gave the Rev. W. Gregor, zinc 43, iron 22.5, sulphur 31.5, copper ·8, and loss 2.2. The iron, therefore, in this specimen, was in considerable quantity, as would appear to be the case with the greater proportion of the sulphuret of zinc found in Devon and Cornwall. Some of the purest sulphuret of zinc which we have seen, was raised at North Wheal Tamar, a little mine near Graystone Bridge, between Tavistock and Launceston. The ore, which is found mixed with galena and bisulphuret of copper, is yellowish and abundant, though entirely cast aside and neglected at present. It probably contains little else than zinc and sulphur. Cadmiferous blende, in fibrous botryoidal concretions, has been found in Fowey Consols. Carbonate of zinc or calamine has been worked on the north-east of our district, in veins in the carboniferous limestone, a continuation of that of the Mendip Hills, where it was formerly extensively wrought, and where one or two mines of it are still in work. An analysis of some calamine of Somerset gave Mr. Smithson, oxide of zinc 64·8, carbonic acid 35.2. Plowden, in 1578, mentions that calamine was then considered to be plentiful in England, and that this mineral was fused with copper, to

* Lysons, Mag. Brit. Devon, p. ccxc.

† Outlines of Mineralogy, &c., vol. i. p. 86. Jamesonite, a mineral composed, according to Rose, of antimony 34·40, lead 40·75, iron 2·30, sulphur 22·5, with a little zinc and copper, is obtained from Cornwall; and, we believe, from the vicinity of Endellyon. Another mineral, named Endellione by Count Bournon, from being found at Wheal Boys, in that parish, but commonly now known as Bournonite, is, according to Dr. Thompson, composed of sulphur 17·00, antimony 24·35, lead 41·12, copper 12·80, iron 1·20.—Outlines of Mineralogy, vol. i. p. 625.

make *lattin* (brass); but he does not state that any works of that kind were carried on at that time in this country.*

Pryce observed that *black jack*, or blende, was the most plentiful mineral, next to iron pyrites, in Cornwall. Several ladings of it had then been shipped off for making brass, at 40*s*. down to a moidore per ton.† A few years since this ore was raised for sale at three or four mines in Cornwall, but at present it is cast aside among the rubbish-heaps, as it will not repay the cost of bringing it into the market.

Several fine lodes of rich hematite iron-ore are found in the district which have been worked at various times. It would appear that in 1758, though iron-ore was known to occur in many parts of Cornwall, it was not worked.‡ In 1778, also, these iron-lodes still remained unwrought.§ Between 1796 and 1802 iron-ore, to the amount of 9293 tons, was shipped from the lode near Combe Martin to the iron-works at Llanelly in South Wales.‖ Micaceous iron-ore is found at various places upon Dartmoor;¶ and, under the name of *Devonshire sand*, was some years since sent to London and used as writing sand, selling at from 3*l*. 3*s*. to 8*l*. 8*s*. per ton. It is probable that the great Lostwithiel iron-lode was wrought many years since, judging at least from the old workings. It is now that from which the greatest quantity of Cornish iron is raised, the ore being easily shipped upon the Fowey for export.** The red hematite of the red sandstone series of Luckham and Wotton Courtney forms part of the rock, as we have before stated, and is quarried as such in considerable quantities, which are exported to the iron-works of South Wales from Minehead and Porlock. The regular lodes at work, during the progress of the survey through the district, consisted of one near Brixham, another near Shaugh Prior in Devon, and one near Lostwithiel, two on Nantallan Downs, near Bodmin, one near Lanivet, one near St. Stephen's, and one near Ladock, in Cornwall.

* Plowden's Report's, Great Case of Mines, 9 and 10 Elizabeth.

† Mineralogia Cornubiensis, p. 46. ‡ Borlase, Nat. Hist. Cornwall, p. 195.

§ Pryce, Mineralogia Cornubiensis, p. 65.

‖ Lysons, Mag. Britannia, Devon, p. cclxxxix.

¶ A vein, said to be two feet thick, containing this ore, was found in granite near Hennock.

** The average price of the ore from this lode, and probably also from most of the iron-lodes in the district, is about 12*s*. per ton at the mines.

The amount of ore raised we were unable to ascertain, but it must have amounted to several thousand tons within the last four or five years. The iron-ore near Ilsington (on the east of Dartmoor) was at one time raised in considerable quantities. Magnetic iron-ore, of good quality, has been worked near South Brent,* Devon, and at Treluswell, near Penryn, Cornwall. There can be little doubt that a large supply of good hematite iron-ore could be readily obtained from the district under consideration, if the necessary demand existed.

Independently of the arsenic sublimed from roasting the ores mixed with arsenical pyrites at the mines and roasting-houses, works are established near Perran Arworthall, for the purpose of obtaining the arsenic of commerce directly from arsenical pyrites (42.88 arsenic, 36.04 iron, and 21.08 sulphur, according to Stromeyer), and many tons are annually exported. Plumbago, of good quality, has been found in small nodules in an elvan near Deveron (Restronget Creek), but hitherto not in any quantity to be profitably employed.†

We have seen (p. 527) that, by ancient charters, the tinners in the duchy of Cornwall were exempt from all other jurisdiction than that of the stannary courts, except in cases affecting land, life, and limb; and that no new laws affecting the tinners could be enacted by the Duke and his council, without the consent of twenty-four stannators, such stannators for Cornwall being returned from its four divisions. The meeting of these stannators was termed a parliament, and when they assembled they chose a speaker. These parliaments have, from time to time, been assembled by the Lord Warden, in order to revise old or to enact new laws, as occasion may have arisen. It appears that the last Cornish stannary parliament was held at Truro in 1752, and was continued by adjournments to the 11th of September, 1753.‡ Crokern Tor, on Dartmoor, was, from ancient times, the place where the stannary parliaments of Devon were held; and it is stated by Lysons, in 1822, that, within the memory of man, the commission was opened and the jurors sworn at this wild spot;

* Dr. Edward Cotton sent a piece of this ore, weighing 60lbs., to the Royal Society in 1667, which moved a needle placed at the distance of nine feet.

† The only specimen we have seen was in the cabinet of Mr. Robert Were Fox, of Falmouth, who obtained it from the locality mentioned above.

‡ Lysons, Magna Britannia, Cornwall, p. ix.

after which the court was adjourned to one of the stannary towns.*

Lostwithiel was either continued or appointed, by the charter of Edward I. in 1305, as the prison for the Cornish tinners, and Lidford Castle was appointed that for the Devon tinners, by a charter, bearing the same date, and granted to them.† In 1512 an act of parliament describes Lidford Castle (the ruins of which still remain) as "one of the most hanious, contagious, and detestable places in the realm."‡ Stannary courts were held in Lidford Castle till nearly the end of the last century. That the stannary courts considered they possessed great powers is proved by the imprisonment in this castle of Mr. Richard Strode (of the ancient family of Newenham Park), then member of Parliament for Plympton, for refusing to pay fines levied upon him in 1512 by the tinners' court at Crokern Tor.§

The jurisdiction of the stannary courts being limited to cases in which tinners (a term never very accurately defined) were concerned, and their practice having remained unaltered for a long series of years, and doubts having arisen whether the Vice-Warden had or had not original equitable jurisdiction, the offices of Vice-Warden and Steward of the Stannaries became almost sinecures; little or no business being transacted in their respective courts.

* Lysons, Magna Britannia, Devon, p. 314. Crokern Tor probably became the place at which the Devon tinners assembled after the charter of Edward I., in 1305, as the combined tinners of Cornwall and Devon previously met on Hingston Down, as above noticed.

† See copies of these charters in the Appendix.

‡ The Lysons observe that this prison had not much improved in repute a century afterwards, as appears from Browne's mention of it in one of his poems, in the reign of King James, who says—

"To lie therein one night'tis guest,
'Twere better to be stoned and prest,
Or hang'd:—now choose you whether."

Magna Britannia, Devon, p. 313.

§ Mr. Strode, who had "rendered himself obnoxious," say the Lysons, "to his brother-tinners (for it appears that he himself was concerned in the tin-works), by his patriotic exertions in Parliament towards the procuring the act for protecting the western harbours from the injuries caused by the stream-works, was prosecuted for imputed crimes against the stannary laws, in the Tinners' Court, at Crokern Tor, and fined in heavy penalties, which refusing to pay, he was thrown into the dungeon of the stannary prison at Lidford.....Here he was kept for more than three weeks in irons, and fed on bread and water."—Mag. Brit. Devon, p. 414. These authors proceed to observe that this case of daring outrage gave occasion to the establishment and maintenance of some of the most important privileges of Parliament.

The necessity of a court of peculiar jurisdiction, embracing mines and mining transactions of every description within the county of Cornwall, and sitting from time to time in some central part of the mining district, having become daily more apparent of late years, several county meetings were convened, and a committee, consisting of some of the most intelligent and practical men in the county, was appointed to investigate and report on the subject. The result of the labours of this committee was an able report, which led to the passing of the Act 6 & 7 William IV., c. 106 (in August, 1836).

By this Act the original equitable jurisdiction of the Vice-Warden is recognised and confirmed. The courts of equity and common law are united (there being an equity and a common-law side), and both are to be presided over by one judge, the Vice-Warden, who should be a barrister of not less than five years' standing. From his orders and judgments an appeal lies to the Lord Warden, assisted by not less than three members of the judicial committee of the Privy Council, and from thence to the House of Lords.

In cases unprovided for by its own rules, this court is guided in its practice by that of the courts of law and equity at Westminster, but the Vice-Warden is empowered from time to time to make rules, orders, and regulations touching practice and pleading, such rules, &c., as apply to the equity side of the court being approved of by the Lord Chancellor, and such as apply to the common-law side by a judge of one of the superior common-law courts; and, when approved, being transmitted to one of the Secretaries of State, to be laid before Parliament, one month after they have been made, if it be sitting; but, if Parliament be not sitting, then within one month after the commencement of its next session.

We have been informed by competent persons that great benefit has already been derived from this new court by persons interested in mining transactions in the county of Cornwall. The remedies afforded to merchants and others supplying mines with materials, and to labouring miners and other creditors of mining companies, are stated to have been found expeditious and comparatively inexpensive; and the facility with which accounts are settled between mining adventurers, and the assistance rendered to pursers and managers of mines, are described as having been most valuable.

As every little shaft, a dozen fathoms in depth, may bear a name as imposing as that of the largest mine, it is extremely difficult to form any just estimate of the number of mines which may at any given time be at work in the district under consideration. By giving a list of names we merely show that so many mining adventures may exist at some given time, or rather may be supposed to exist, for some of the mines may be of such a character that they may not have lasted during the necessary time employed in collecting the information.

Sir Charles Lemon has formed the first tables which we have seen that contain an account of the persons employed in the different mines of Cornwall, distinguishing the number of men, women, and children at work in each about a given time (1836 and 1837). From two tables which he has given the following has been compiled:—

Number of Persons employed in the Cornish Mines in 1836 *and* 1837.

Mines.	Men.	Women.	Children.	Total.	Mines.	Men.	Women.	Children.	Total.
Wheal Ann	..	..	..	121	Brought forward	..	..	..	7,334
Wheal Andrew	7	..	2	9	Camborn Consols	4	..	..	4
Wheal Agar	..	..	..	55	Copper Valley	4	..	1	5
Wheal Amelia	4	..	..	4	Copper Bottom	43	21	8	72
Balnoon	62	6	12	80	Cook's Kitchen	..	..	..	247
Bell	..	..	..	6	Wheal Clinton	4	..	1	5
Binner Downs	250	100	40	390	Wheal Curtis	..	..	..	60
Boscaswell Downs	182	5	59	246	Wheal Change (Lanevit)	..	..	..	40
Boscean	65	..	24	89	Wheal Charles	..	..	..	10
Bosorn	16	..	4	20	Wheal Clarence	..	..	..	10
Baldue	5	..	1	6	East Wheal Crofty	456	404	144	1004
Ballowall	27	..	9	36	Wheal Coit	8	4	4	16
Wheal Budnick	99	41	32	172	Dolcoath	300	220	70	590
Wheal Brothers	2	..	..	2	West Dolcoath	4	..	1	5
Wheal Bolton	64	6	..	70	East Downs	6	..	2	8
Wheal Barnes	..	..	..	22	North Downs	16	3	5	24
South Wheal Bassett	..	..	..	230	Wheal Damsel	28	1	11	40
East Wheal Bassett	..	..	..	100	Wheal Darlington	215	50	52	317
Wheal Buller	83	42	30	155	Wheal Ellen	..	..	..	220
Wheal Busy	34	50	28	112	Fowey Consols and Lanescot	1057	308	315	1680
Consols and United Mines	1730	869	597	3196	Friendly	8	2	2	12
East Crinnis	124	46	62	232	Wheal Fire	6	..	..	6
Carharrack	42	34	20	96	Wheal Friendship	4	..	..	4
Cardrew	24	6	10	40	Wheal Fancy	..	..	..	8
Carrygian Roche	30	1	4	35	Wheal Friendship	85	19	11	115
Charlestown	431	120	263	814	Great Wheal Fortune	165	15	27	207
North Claze	7	1	1	9	Gunnis Lake	62	7	19	88
West Cliff Down	..	..	..	6	Godolphin	370	70	40	480
East Cornwall	6	..	..	6	Glebe	2	..	2	4
Creigbraws	26	5	10	41	Gurnett's Head	24	..	..	24
Cornwall Great United	155	20	22	197	Great Work	298	46	74	418
Carclaze	8	..	6	14	Geallon	100	16	20	136
Carn Brea	517	137	69	723	Wheal Gorland	53	12	21	86
Carried forward	..	..	..	7,334	Carried forward	..	..	..	13,279

(*Table continued.*)

Mines.	Men.	Women.	Children.	Total.
Brought forward .	..	..	..	13,279
Wheal Gray . . .	..	..	..	130
Hallamaning and Retallack . .	..	..	..	10
Hallenbeagle . .	122	20	50	192
North Hallenbeagle	30	6	4	40
Holmbush . . .	145	8	38	191
Wheal Harriette .	21	8	4	33
Wheal Julia . . .	100	26	22	148
Wheal Jewel. . .	212	53	94	359
West Wheal Jewel.	79	10	35	124
Wheal Kitty. . .	118	52	88	258
Levant	320	44	186	550
Levant Consols . .	..	..	..	20
Wheal Leisure . .	68	6	21	95
Marazion Mines. .	222	83	96	401
Morvah and Zennor	86	2	28	116
Wheal Maiden . .	15	11	11	37
Wheal Martha . .	26	10	4	40
Wheal Mary. . .	118	14	31	163
Wheal Mary and Parent . .	..	..	..	30
Wheal Maitland. .	20	..	6	26
Wheal Millpool . .	..	..	..	20
South Wheal Mary .	11	..	3	14
Wheal Neptune . .	4	..	..	4
Owen Vean . . .	62	4	6	72
Wheal Owles . .	110	..	21	131
Wheal Osborne . .	40	6	6	52
Penberthy Crofts .	21	3	3	27
Providence . . .	83	19	30	132
Polgooth	141	10	51	202
Polberrou. . . .	362	34	82	478
Pembroke . . .	75	12	52	139
Perran Consols . .	80	14	6	100
South Polgooth . .	92	14	20	126
Perran Downs . .	41	..	..	41
Pentuan Stream. .	18	..	5	23
Phœnix (Padstow) .	13	..	1	14
Polbreen	80	..	..	80
West Poldice . .	..	..	..	30
Wheal Prosper . .	10	..	4	14
Wheal Bye . . .	3	2	1	6
Wheal Prudence .	40	20	13	73
Wheal Providence .	61	8	24	93
Wheal Prosper . .	68	6	6	80
East Pool . . .	111	82	18	211
North Roskear . .	300	190	150	640
South Roskear . .	148	172	60	380
Rospeath. . . .	42	4	6	52
Rocks.	74	9	12	95
Carried forward .	..	..	..	19,571

Mines.	Men.	Women.	Children.	Total.
Brought forward .	..	..	..	19,571
Relistian	138	67	45	250
Redmoor Consols .	110	16	25	151
Wheal Rome . .	..	..	..	8
Wheal Rose . . .	4	..	..	4
Wheal Reeth . .	147	18	66	231
South Rose . . .	29	..	12	41
Spearne	..	..	..	70
Streamers (Camon).	144	2	66	212
Stray Park . . .	137	30	22	189
Great St. George .	255	35	50	340
St. Austell Hills .	72	13	24	109
St. Ives Consols . .	237	16	60	313
East Wheal Strawberry . . .	71	19	30	120
Wheal Speed . .	10	..	..	10
Wheal St. Just . .	2	..	..	2
Wheal Sarah. . .	12	..	..	12
Wheal Sparrow . .	..	..	..	31
Wheal Seaton . .	..	..	..	50
Wheal Sisters . .	..	..	..	4
Tresavean . . .	..	..	..	1354
North Tresavean .	..	..	..	..
Trevenen	..	..	..	30
Trethellen . . .	..	..	..	77
Tresavara . . .	25	8	..	33
Turnavoore . . .	4	..	1	5
Trebelzue. . . .	19	..	..	19
Tincroft Consols .	..	..	..	309
East Tincroft . .	..	..	..	4
West Tincroft Consols	33	..	4	37
North Towan . .	..	..	..	20
Trewavas . . .	102	42	17	161
Trevaskus . . .	103	30	11	144
Trevarthen Downs .	6	7	3	16
Tredarva	8	3	5	16
Wheal Triumph . .	10	..	2	12
Wheal Treasure. .	5	..	3	8
Wheal Trumpet . .	..	..	..	60
Wheal Trenwith .	83	6	20	109
Wheal Trevannance	12	..	..	12
Wheal Tamar and South Hooe . .	83	6	20	109
West Wheal Tamar.	..	..	..	45
Unity Wood . . .	206	80	138	424
United Hills. . .	269	90	..	359
Wheal Uny . . .	..	..	..	146
Wheal Virgin . .	167	134	91	392
Wheal Vor . . .	592	327	255	1174
Wheal Vyvyan . .	54	25	24	103
Total . 160 Mines.	..	..	..	26,896

Having omitted some mines, Sir Charles Lemon considers that 28,000 persons might be taken as the number then employed in the mines. If we add 2000 persons as about the number working in the Devon mines, we should have 30,000 persons directly employed in the mining operations of the district in both counties for the years 1836 and 1837.

With respect to the total annual value of the exported mineral produce of the district, it will have been seen that it has been considerable for a long period, though subject to frequent fluctuations from variations in price. The quantity of tin raised has not very considerably increased during the last half-century; the number of blocks coined in 1788 was 21,790, and in 1838 they amounted to 29,321, and there was much fluctuation during the interval. The average price per cwt. was 3*l.* 13*s.* 6*d.* in 1788, and 4*l.* 2*s.* in 1838. In 1788 the tons of copper-ores raised amounted to 31,541, for which 150,303*l.* were obtained; in 1838 the quantity of copper-ores raised amounted to 145,688 tons, producing 857,779*l.*; the value of the standard of copper for 1778 has unfortunately been lost, but appears to have been about 73*l.*, while that of 1838 was 109*l.* 3*s.* The annual tin produce and its value have only increased to a moderate extent, while that of the copper has been greatly augmented. The produce of silver and lead has decreased of late years, but that of manangese has much increased since 1788, while the exports of granite, and china-clay and stone, have only become considerable within the present century. If we examine into the value of the mineral exported produce of 1837, we shall have, exclusive of slates, arsenic, and iron, with some minor substances, for

Cornish and Devon	Copper	£952,855
,, ,,	Tin	415,518*
,, ,,	Manganese	40,000
,, ,,	Lead	3,600
,, ,,	China Stone and Clay	43,000
,, ,,	Granite	24,500
		£1,478,973

With the addition of the slates, iron, arsenic, antimony, and minor substances, we should have about 1,500,000*l.* for the value of the mineral produce of the district for that year. The standard for copper was then certainly somewhat high (119*l.* 5*s.*), but the price of tin was less than it had been in the two previous years, so that probably, if we consider the value of the annual and exported mineral produce of the district to be at present between 1,400,000*l.*

* The small quantity of tin retained in the district for consumption in it may be disregarded in this calculation, inasmuch as the copper, manganese, &c., are probably under-estimated in value, the amount of private bargains, for copper-ores more especially, not being well known.

and 1,500,000*l.*, we shall probably make a fair approximation to the truth.

If we estimate the value of the metals annually raised in Great Britain and Ireland at about 10,597,000*l.*,* and consider that of this sum the iron amounts to 8,000,000*l.*, the value of the remaining metals would be 2,597,000*l.*, of which Cornwall and Devon would furnish about 1,340,000*l.*, or more than one-half, leaving 1,257,000*l.* for the value of all the metals, with the exception of iron, raised in other parts of the United Kingdom. The two great metallic products of the district are copper and tin: of the former it yields one-third, and of the latter nine-tenths of the whole supply of copper and tin furnished by the British Islands and all the countries of the continent of Europe.

HENRY T. DE LA BECHE.

* To obtain this amount, and neglecting arsenic, antimony, and chrome, we estimate the annual value of the

Iron at	£8,000,000
Copper	1,200,000
Lead	920,000*
Tin	390,000
Manganese	50,000
Silver	30,000*
Zinc	7,000
	£10,597,000

The sums marked with an * are taken from the information of Mr. John Taylor. If to the sum of 10,597,000*l.* for metallic produce, we add 9,000,000*l.* as the value of the coal raised, at the pit mouth, and about 400,000*l.* for that of salt and other minor substances, we should have 20,000,000*l.* as the annual value of the mining produce of Great Britain and Ireland.

With respect to the general produce of the mines of the various countries of Europe, M. Verlet has formed the following comparative table (General and Statistical Review of Metallurgy, 1837), taking those of Great Britain for unity:—

Great Britain	1	Hartz	$\frac{1}{12}$
Russia and Poland	$\frac{2}{7}$	Tuscany	$\frac{1}{31}$
France	$\frac{1}{4}$	Bavaria	$\frac{1}{33}$
Austria	$\frac{2}{13}$	Saxony	$\frac{1}{34}$
Spain	$\frac{1}{8}$	Piedmont and Savoy	$\frac{1}{38}$
Prussia	$\frac{1}{9}$	Denmark	$\frac{1}{39}$
Sweden	$\frac{2}{19}$	Norway	$\frac{1}{35}$

Fac Simile of Charter granted by KING JOHN, in the 3d year of his Reign, to the Tinners of Cornwall & Devonshire, taken from the Cart. Antiq. K. N.° 5.

Fac Simile of the Enrolment of the Charters granted to the Tinners of Cornwall & Devonshire by KING EDWARD. I, taken from the Charter Roll 33. Edw. I, Memb. 8.

APPENDIX.

APPENDIX A.

The following are copies of the charters of the 29th October of the 3d of King John (1201), and of the 10th April of the 33d of Edward I. (1305), granted to the Tinners of Cornwall and Devon, as they appear by the Rolls in the Record Office, in the Tower of London. For these copies, and permission to make the fac-simile of the charters as enrolled, and which are given in plate 13, we are indebted to the kindness of Mr. Petrie, Keeper of Her Majesty's Records in the Tower.

Rot: Chart: Antiq: K. No. 5.

Johannes Dei gratia Rex Angliæ, &c. Sciatis nos concessisse quod omnes stammatores nostri in Cornubia et Devonia sint liberi et quieti de placitis nativorum, dum operantur ad commodum firmæ nostræ vel commodum marcarum novi redditus nostri quia stammariæ sunt nostra dominica. Et quod possint omni tempore libere et quiete absque alicujus hominis vexatione fodere stammum et turbas ad stammum fundendum ubique in moris et in feodis Episcoporum et Abbatum comitatuum sicut solebant et consueverunt et emere buscam ad funturam stammi sine vasto in regardis forestarum et divertere aquas ad operationem eorum in stammariis sicut de antiqua consuetudine consueverunt. Et quod non recedant ab operationibus suis pro alicujus summonitione nisi per summonitionem capitalis custodis stammariarum vel baillirorum ejus. Concessimus etiam quod capitalis custos stammariarum et baillivi ejus per eum habeant super prædictos stammatores plenariam potestatem ad eos justificandos et ad rectum producendos et quod ab eis in carceribus nostris recipiantur si contigerit quod aliquis prædictorum stammatorum debeat capi vel incarcerari pro aliquo retto. Et si contigerit quod aliquis eorum fuerit fugitivus vel udlagatus quod catalla eorum nobis reddantur per manum custodis stammariarum nostrarum, quia stammatores firmarii nostri sunt et semper in *debito** nostro. Præterea concessimus thesaurariis et ponderatoribus nostris ut sint fideliores et intentiores ad utilitatem nostram in receptione et custodia thesauri nostri per villas marcandas quod sint quieti in villis ubi manent de auxiliis et taillagiis dum fuerint in servitio nostro thesaurarii et ponderatores nostri quia nihil habent aliud vel habere possunt per annum pro prædicto servitio nostro. Testibus Willielmo Comite Sarresburiæ, Petro de Stokes, Warino filio Geroldi. Data per manum S. Wellensis Archidiaconi apud Bonam Villam super Tokam vicesimo nono die Octobris anno regni nostri tertio.

* *Sic.* From another document it appears that this word should be *dominico*.

Rot: Chart: 33 *Edw: I. No.* 41.

Pro Stannatoribus in comitatu Cornubiæ. } Rex Archiepiscopis, &c. salutem. Sciatis nos ad emendationem stannariarum nostrarum in comitatu Cornubiæ et ad tranquilletatem et utilitatem stannatorum nostrorum earundem concessisse pro nobis et hæredibus nostris quod omnes stannatores prædicti operantes in stannariis illis quæ sunt dominica nostra dum operantur in eisdem stannariis sint liberi et queti de placitis nativorum et de omnibus placitis et querelis curiam nostram et hæredum nostrorum quoquo modo tangentibus. Ita quod non respondeant coram aliquibus justitiariis vel ministris nostris seu hæredum nostrorum de aliquo placito seu querela infra prædictas stannarias emergente nisi coram custode nostro stannariarum nostrarum prædictarum qui pro tempore fuerit exceptis placitis terræ et vitæ et membrorum nec recedant ab operationibus suis per summonitionem alicujus ministrorum nostrorum seu hæredum nostrorum nisi per summonitionem dicti custodis nostri. Et quod quieti sint de omnibus tallagiis therloniis stallagiis auxiliis et aliis costumis quibuscunque in villis portubus feriis et mercatis infra comitatum prædictum de bonis suis propriis. Concessimus etiam eisdem stannatoribus quod fodere possint stannum et turbas ad stannum fundendum ubique in terris moris et vastis nostris et aliorum quorumcunque in comitatu prædicto; et aquas et cursus aquarum ad operationes stannariarum prædictarum divertere ubi et quotiens opus fuerit; et emere buscam ad funturam stanni, sicut antiquitus fieri consuevit, sine impedimento nostri vel hæredum nostrorum Episcoporum Abbatum Priorum Comitum Baronum seu aliorum quorumcunque. Et quod custos noster prædictus vel ejus locum tenens teneat omnia placita inter stannatores prædictos emergentia et etiam inter ipsos et alios forinsecos de omnibus transgressionibus querelis et contractibus factis in locis in quibus operantur infra stannarias prædictas similiter emergentia, et quod idem Custos habeat plenam potestatem ad stannarios prædictos et alios forensecos in hujusmodi placitis justitiandos et partibus justitiam faciendam prout justum et hactenus in stannariis illis fuerit usitatum. Et si qui stannariorum prædictorum in aliquo deliquerint per quod incarcerari debeant per Custodem prædictum arestentur et in prisona nostra de Lostwythiel et non alibi custodiantur et detineantur quousque secundum legem et consuetudinem regni nostri deliberentur. Et si aliqui stannatorum prædictorum super aliquo facto infra comitatum prædictum non tangente stannarias prædictas se posuerint in inquisitione patriæ una medietas juratorum inquisitionis hujusmodi sit de stannatoribus prædictis et alia medietas de forensecis, et de facto totaliter tangente stannarias prædictas fiant inquisitiones sicut hactenus fieri consueverunt. Et si quis eorundem stannatorum fugitivus fuerit vel utlagatus vel aliquod delictum fecerit, pro quo catalla sua amitterre debeat, catalla illa per custodem prædictum et coronatorem nostrum comitatus prædicti appretientur et per ipsos proximis villatis liberentur ad respondendum inde nobis et hæredibus nostris coram justitiariis itinerantibus in comitatu prædicto. Volumus insuper et firmiter præcipimus quod totum stannum tam album quam nigrum ubicunque inventum et operatum fuerit in comitatu prædicto ponderetur apud Lostwithiel, Bodmynyan, Liskiriet, Treueru vel Helleston per

pondera nostra ad hoc ordinata et signata sub forisfactura totius stanni prædicti et quod totum illum stannum coignietur in eisdem villis singulis coram custode prædicto ante diem Sancti Michaelis in Septembre sub forisfactura prædicta. Et concessimus pro nobis et hæredibus nostris quod omnes stannatores nostri prædicti totum stannum suum sic ponderatum licite vendere possint cuicunque voluerint in villis prædictis faciendo inde nobis et hæredibus nostris coignagium et alias consuetudines debitas et usitatas nisi nos vel hæredes nostri stannum illud emere voluerimus. Quare volumus et fermiter præcipimus pro nobis et hæredibus nostris quod stannatores nostri prædicti habeant omnes libertates liberas consuetudines et quietantias suprascriptas, et quod eis sine occasione vel impedimento nostri vel hæredum nostrorum justitiariorum Escaetorum Vicecomitum aut aliorum ballivorum seu ministrorum nostrorum quorumcunque rationabiliter gaudeant et utantur in forma prædicta. Hiis testibus venerabilibus patribus W. Coventrensi et Lychfeldensi, S. Sarum, J. Karliolensi Episcopis, Henrico de Lacy comite Lincolniæ, Radulpho de Monte Hermerii comite Gloucestriæ et Hertfordiæ, Humfrido de Bohun comite Herefordiæ et Essexiæ, Adomaro de Valencia, Hugone Le Despenser, Johanne de Hastinges, et aliis. Data per manum nostram apud Westmonasterium decimo die Aprilis.*

Rot: Chart: 33 Edw. I. No. 40.

Pro Stannatoribus in comitatu Devoniæ. } Rex Archiepiscopis, &c. salutem. Sciatis nos ad emendationem stannariarum nostrarum in comitatu Devoniæ et ad tranquillitatem et utilitatem stannatorum nostrorum earundem concessisse, &c. ut supra. Et si qui stannatorum prædictorum in aliquo deliquerint per quod incarcerari debeant per custodem prædictum arestentur et in prisona nostra de Lydeford et non alibi custodiantur et detineantur quousque secundum legem &c. ut supra. Volumus insuper et firmiter præcipimus quod totum stannum tam album quam nigrum ubicunque inventum et operatum fuerit in comitatu prædicto ponderetur apud Tavystok, Asperton, vel Chaggeford per pondera nostra ad hoc ordinata et signata sub forisfactura &c. ut supra. Quare volumus &c. ut supra. Hiis testibus &c. ut supra. Data ut supra.

It would appear, from the following petition to Parliament, in the first year of Edward III., preserved among the records of the Tower of London, and for the knowledge and copy of which we are indebted to Mr. Hardy, of Her Majesty's Record Office, that the tinners of Devon had taken advantage of the clause in the charter above cited, which permitted them to search for tin in other lands than those of the king, and had destroyed private property in this search, as will best be seen by the petition, which, being interesting, we have inserted at length beneath.

* According to a MS. of the time of Queen Elizabeth, entitled "The Bailiff of Blackmore," the original of this charter was kept in Luxullion church, whence, for greater security during the civil war, it was removed to Lostwithiel, and there destroyed, with other stannary records, by the Earl of Essex's army in 1644.—Lysons, Mag. Brit. Cornwall, p. viii.

" *Devonshire.*

" To our Lord the King and his Council sheweth the Commonalty of the county of Devon that whereas the Tinners of the said county have a Charter from the Progenitors of our said Lord the King, that all those who are willing to be Tinners to dig Tin, may dig in every place of waste and moor where they believe Tin can be found within the said county which belonged to your said Progenitors at the time the Charter was granted; the which waste and moor were only the Forest of Dartmoor, which, at the time when the said Charter was granted, was in the hands of your said Progenitors. And also your said Progenitors did grant to the said Tinners that they should be quit of all manner of tallages, tolls, and charges; and also that they should have the cognizance of all manner of pleas arising within their said Stannary; by color of which grant, and by color of the several other Charters of confirmation granted subsequently by several other of the progenitors of our said Lord the King, the said Tinners do daily dig and claim to dig in every species of land, as well in tilled as in other lands, and destroy houses, meadows, and woods, and divert and turn the course of waters running as well to mills as elsewhere throughout the whole County, to the great destruction and disherison of the said Commonalty, since the said lands, meadows, and woods which are digged by the said Tinners never bear herbage nor any other sort of fruit, wherefore several of the said Commonalty are wholly ruined and disinherited, and their ruin and disherison, by the cause aforesaid, is daily increasing. And also the said Tinners and the Officers of the said Stannary take cognizance of all manner of pleas at the suit of the said Tinners, and of all others who claim to be Tinners, as well without as within the Stannary, and make attachments and excessive distress, as well without as within the Stannary, for they wrongfully claim all the County of Devon to be their Stannary; and the said distresses, be they never so wrongfully taken, they detain without allowing any deliverance of them to be made, and they do those things by color of their franchise aforesaid, to the great ruin and disherison of all the Commonalty aforesaid. Wherefore the whole Commonalty of the said County prays our Lord the King that it will please him (for the salvation from ruin and disherison of his said Commonalty) to cause the said Tinners to come with their Charters, by which they claim the franchises aforesaid, before the Justices of the King's Bench, or of the Common Bench, in order to show by what warrant they claim the said franchises; and also that a Writ be sent to the Sheriff of Devonshire (as well for the advantage of our Lord the King as the Commonalty aforesaid) to warn the said Commonalty to send for themselves, four, five, or six, to be there on the day that the said Tinners shall have to them appointed, to show, for our Lord the King and the said Commonalty, how the said Tinners have, contrary to the form of their Charter, badly used their franchise."

This petition is endorsed, " Let the Tinners, and some of the Commonalty who shall be empowered for the rest, come before the Chancellor in Chancery, and show the Charters and Confirmations of which the Petition makes mention: and they being summoned who are to be summoned, and the reasons for the King and the parties being heard, let right be further done."

Though the subject of this petition may then have been made matter of inquiry, half a century appears to have elapsed before somewhat efficient steps were taken to lessen the grievances of which the inhabitants of Devon complained; for we find that, in the 50th of Edward III. (1377), a petition of the commonalty of Devon was presented to the King in Parliament, praying redress for the same grievances, and reciting parts of the charters of the 33rd Edward I., when it was directed that the customs and usages of the tinners should be diligently inquired into, and that the Warden of the Stannaries should not suffer any of them to dig in the meadows, fell the woods, and knock down the houses of others, nor turn the waters out of malice; further stating, that if the tinners should disobey the Warden, the King in council would thereupon find a due and speedy remedy.*

By Carew's statement it would appear that, though about the year 1600 the Cornish tinners only claimed to work without permission of the lord or owner of the land upon wastes or in wastrall, those of Devon still claimed the right "to digge for tynne in any man's ground, inclosed or unclosed, without licence, tribute, or satisfaction."†

APPENDIX B.

The following is the translation of a letter contained in the Red Book in the Exchequer, from William de Wrotham and others, to Hubert Archbishop of Canterbury, Chancellor of England; Geoffrey Fitz Peter, Justiciary of England; and the Barons of the Exchequer; which exhibits the regulations in force respecting the tin coinage in Devon and Cornwall, at the end of the 12th or commencement of the 13th century. Mr. Hardy, of Her Majesty's Record Office in the Tower, to whom we are indebted for this interesting document, states to us that it contains internal evidence of having been written before the year 1205.

"The Sheriff of Devonshire and Cornwall, William de Wrotham, Richard Fleming, Robert Champeaus, Richard Peverell of Honiton, Richard Fitz Walter, Richard Fitz Gilbert, Luke Fitz Bernard, Henry d'Aunay, and Otho Fitz Frewin, to Hubert, by the grace of God Archbishop of Canterbury, the Lord Geoffrey Fitz Peter, and to all the Barons of the Exchequer of the Lord the King, send greeting. Know ye that I, the Sheriff of Devonshire and Cornwall, have received by the hand of William de Wrotham the precept of the Lord Archbishop of Canterbury, in these words:—

Hubert, by the grace of God Archbishop of Canterbury, Primate of England, and Legate of the Apostolic See, to the Sheriff of Devonshire and Cornwall, greeting. We command, on behalf of the Lord the King, that, in the stead of Geoffrey Fitz Peter, you commit to William de Wrotham all the stannaries of the Lord the King in your bailiwick, and all things per-

* Parliament Roll of the 50th of Edward III., No. 130, preserved among the records of the Tower of London.

† Survey of Cornwall, p. 13.

taining to those stannaries; and cause him to hold the tinners in that freedom which they ought and have been accustomed to have. Cause him also to have all those lawful men whom the said William shall name to you, and whom for this he shall think fit to assist him in aid and counsel in taking charge of the King's coinage, and all the issues of the same stannaries, and in disposing of their profits. Also prohibit all men, in common, in your bailiwick, from conveying any tin, either by sea or by land, without the licence of the said William; and do you assist him to your utmost in expediting the present matter for the King, so that he may proceed in the business, and the Lord the King incur no damage by your default. Witness, Stephen de Turnham, at Westminster, on the 20th day of November. And know ye that I, the Sheriff of Devonshire and Cornwall, have received another precept of the Lord Archbishop of Canterbury in these words:—

Hubert, by the grace of God Archbishop of Canterbury, Primate of all England, and Legate of the Apostolic See, to the Sheriff of Devonshire and Cornwall, greeting. We command you that, by the oath of twelve free and lawful men of your bailiwick, by whom the truth of the matter may be better known, you cause diligently to be inquired what were the weights of the first smelting, and what were the weights of the second smelting; and cause those weights hereafter to be observed, as William de Wrotham, bearer of these presents, shall tell you. Witness, G. de Bocland, at Shrewsbury, on the 7th day of January.

Also, know ye that we have received the letters of the Lord Geoffrey Fitz Peter that we should be, with William de Wrotham, as justices in the stead of Geoffrey Fitz Peter, to carry into effect the precept of the Lord of Canterbury concerning the admeasurement of the weights of the first and second smeltings, and the disposition of the available profit of the King's tin. Whence it arises that the Sheriff of Devon, and we, William de Wrotham, Richard Fleming, Robert de Champeaus, Richard Peverell of Honiton, and Richard Fitz Walter, do greet the Lord Hubert Archbishop of Canterbury, the Lord Geoffrey Fitz Peter, and all the Barons of the King's Exchequer. And we inform you that, on the 19th day of January, in the ninth year of the reign of King Richard, in full county court at Exeter, we inquired, upon the oath of Roger Rabi, Gervase Merc, Adam de Movinton, Martin Prudhome, Hugh de Movinton, Walter Fitz Turbern, William Hastiment, Sampson nephew of Ralph, Geoffrey Faierchild, William Dennis, John Fitz Ralph, John Caperun, Philip de Sede, Alfred de Brente, Walter le Bon de Tottneys, Walter Bolt, Humphrey Smith, Ailward Burgeis, Osbert Prigge de Ashburton, Ailward Fairmund, John Prigge, Robert de Prato, William Esse of Plimpton, Robert de la Cnole, Alfred de Lega, and Ely Mewi, wise and discreet jurors, concerning the just weights of the tin in Devonshire, and that the just and ancient weight of the city of Exeter, by which anciently and now and at all times the second smelting of tin was wont to be made, is, and always ought to be of such quantity that the just and ancient weight of the first smelting of tin, anciently, now, and at all times, was, and is, as eight to nine, and which it ought to be by the weight of the city of Exeter, of the second smelting, and for this reason, viz., because for every thousand weight weighed by the greater weight there

are given to the Lord the King, by ancient custom, thirty pence for the farm of the stannaries in Devonshire, and for the cost of the carriage to the market-towns, because the tin wastes in the second smelting; and according to their oath in such quantity they are measured before us, and settled in the stannaries and the towns in Devonshire.

And we also inform you that, on the above-written 19th day of January, in the 9th year of the reign of King Richard, William de Wrotham first took the stannaries of Devonshire, and then first commenced to work by the weights of the just and ancient quantity admeasured and settled by the oath of the said jurors. Also the Sheriff of Cornwall, and we, William de Wrotham, Richard Fitz Gilbert, Luke Fitz Bernard, Henry d'Aunay, and Otho Fitz Frewin, have inquired in Cornwall, in full county, at Launceston, on the 25th day of January, in the 9th year of the reign of King Richard, by the oath of Herbert the Reve of Bodmine, Nicholas Fitz Margaret, Saul de Bodmine, John Fitz Alfred, Adam Dai, Osbert the Merchant, Stephen Fitz Bele, Robert Reustek of Truro, Roger the Merchant, Ailmar the brother of Bernard, William de Polstad of Liskeard, William de Lanteisin, Robert Preinos, Fulk de Liskeard, Robert Tropinel, William Cole, Aulf the Reve of Lansaveton, and Dudman de Lansaveton, wise and discreet jurors, concerning the just weights of the tin in Cornwall, and that the just and ancient weight of the second smelting of the tin in market-towns in Cornwall, anciently, and now, and at all times, was wont and ought to be of such quantity that the just and ancient weight of the first smelting be as seven to eight; and that the just and ancient weight of the first smelting of tin in Cornwall, anciently, and now, and at all times, was wont and ought to be greater by thirty pence of tin than the weight of the first smelting in Devonshire; and for this reason, that for every thousand weight weighed by the greater weight there are given to the King, by ancient custom, five shillings for the farm of the stannaries in Cornwall, and for the cost of carriage to the market-towns, because the tin wastes in the second smelting. And, upon the oath of the same jurors, in like quantity are measured and established before us in the stannaries of Cornwall and in the market-towns. And we also inform you that, on the above-written 25th day of January, in the 9th year of the reign of King Richard, William de Wrotham first took the stannaries of Cornwall, and then first commenced to work by the weights of the just and ancient quantity, admeasured and established by the oath of the aforesaid jurors. We also inform you that the Lord the King, from the time after William de Wrotham took the stannary, shall have of new annual rent from every thousand weight, weighed by the weight of the second smelting, one mark of silver, which weights of the second smelting in Devonshire and Cornwall are admeasured by equal weight and established by equal quantity. Also we inform you that neither the King's mark of new rent of tin, nor the ancient customs of the farm of tin, nor the weighings of tin, can (as it appears to us) in any manner, be better, more legally, exactly, or conveniently collected, for the advantage of the King and the people, than it is now provided by the chapters which are made, concerning tin and the tinners in Devonshire and Corn-

wall, by our Council and by the providence of William de Wrotham, in the 9th year of the reign of King Richard: these to wit—

All the diggers and buyers of black tin, and the first smelters of tin, and the traders in tin of the first smelting, shall have the just and ancient customs and liberties, established in Devonshire and Cornwall; and also all the just and ancient weights of the first and second smeltings of tin, ordained by the oath of the above-written jurors, and stamped with the stamp of the Lord the King, shall be kept.

Also all men shall have common emption of tin, by just ancient and free customs, as they ought and are wont to have, upon paying a mark for each thousand weight of the second smelting.

Also in boroughs and market-towns in which the Chief-Warden of the Stannaries shall direct a second smelting, the Lord the King shall have thereof, *de novo*, one mark for each thousand weight; the second smelting of the tin shall be by weight of the city of Exeter, and the same weight shall be stamped, with the stamp of the Lord the King, for one mark.

Also the established weight of the city of Exeter is always to be committed to the custody of two lawful men in market-towns, and of a clerk appointed on behalf of the King.

Also the one-mark stamp, by which the weight ought to be stamped, and all the tin of the second smelting, shall be always kept under the seal of the keeper of the weight of the second smelting, and of the clerk appointed on behalf of the King, unless whilst it is being used by them.

Also the keepers of the second smelting and the clerk shall (as they value their persons) diligently and perfectly cause to be recorded all the thousand weights, hundred weights, and pound weights which, by the weight and stamp in their custody, shall be weighed and stamped, during the whole year.

Also in each town where there shall be a second smelting, two lawful and wealthy men shall be appointed, who shall receive from the traders the mark for the Lord the King (in the presence of the keepers and clerk of the second smelting and stamp) for the weighing and stamping. And the clerk and keepers of the stamp shall not permit the tin to be removed until the treasurer of the Lord the King shall have received the mark for the Lord the King and the tin custom.

Also the treasurers appointed to receive the mark for the Lord the King shall make tallies and chirographs respecting such marks, against the keepers and clerk of the weights and stamp. And in the chirographs shall be contained the day of receipt, the money received, the number of thousand weight, hundred weight, and pounds weight received, and the names of the traders who shall have acquired tin.

Also the treasurers of the Lord the King shall, in like manner, deliver the treasure of the Lord the King to the Chief-Warden of the Stannaries, by the like tallies and chirographs.

Also the Chief-Warden, or any of his officers, shall not presume, in any manner, to disturb the King's treasurers during their lives, or their heirs after the death of their fathers, so long as they can reasonably acquit themselves of the receipt of the King's treasure, according to the tallies and chiro-

graphs made against the keepers of the second smelting and the clerk of the Lord the King.

Also the keepers of the stamp and weight, and the clerk of the Lord the King, shall always in their common custody keep safely under their seals the tallies and chirographs made against the treasurers, and under such a lock, that each of them shall have a separate key.

Also the notary-clerk of the King's mark, and the clerk of the chirographs of the mark, shall be retained in the King's wages and livery.

Also in each town where there shall be a second smelting (not within the walls of the city of Exeter and the town of Bodmin) one house at the hiring of the King shall be appointed where all the second smelting, weighing, and stamping shall be done; and no one, as he valueth his person and his goods, shall presume elsewhere to make a second smelting, weighing, or stamping.

Also in the city of Exeter and in the town of Bodmin tin shall be smelted in the second smelting, in places as hitherto accustomed, with this proviso, that no one, as he valueth himself and his goods, shall presume to make a second smelting, unless in the presence of the keepers of the weight and smelting and of the clerk appointed on behalf of the King.

Also no one in market-towns shall presume to have any weights by which he shall weigh tin, unless before the keepers of the weight, until it has been weighed by the weight of the Lord the King, and stamped with the stamp of one mark for the Lord the King.

Also for the custody of the weight of the first smelting, and the stamp of the farm of which the Lord the King shall have his ancient customs pertaining to the farm of the Stannaries, there shall be appointed two lawful men and a clerk on behalf of the King, before whom all the tin of the first smelting shall be weighed and stamped.

Also the keepers and clerk of the first smelting of tin, as they value themselves and their goods, shall diligently and perfectly record all the thousand weights, hundred weights, and pound weights which shall in the whole year be weighed and stamped by the weight and stamp in their custody.

Also neither man nor woman, Christian nor Jew, shall presume to buy or sell any tin of the first smelting, nor to give or remove any of the first smelting from the Stannary, or out of the place appointed for weighing and stamping, until it shall he weighed and stamped in the presence of the keepers and clerks of the weight and stamp of the farm.

Also neither man nor woman, Christian nor Jew, shall presume, in the Stannaries nor out of the Stannaries, to have in his or her possession any tin of the first smelting beyond a fortnight, unless it be weighed and stamped by the keepers and clerk of the weight and farm stamp.

Also neither man nor woman, Christian nor Jew, in market-towns and boroughs, on sea or on land, shall presume to keep beyond thirteen weeks tin of the first smelting weighed and stamped, unless it be put into the second smelting and the mark discharged.

Also neither man nor woman, Christian nor Jew, shall presume in any manner to remove tin, either by sea or by land, out of the counties of Devon and Cornwall, unless he or she first have the licence of the Chief-Warden of the Stannaries.

Also good and lawful men are established in the ports around Devonshire and Cornwall, to take the oaths of all the steersmen and mariners there landing, that they will not remove, nor allow to be removed, in their ships, any tin, unless it be weighed and stamped by the royal customs, and unless they have a writ from the Chief-Warden of the Stannaries.

Also the stamp of the farm shall be always kept under the seal of the keepers and clerk, unless whilst being used in the appointed places.

Also, in all weighings of tin, the tongue of the balance shall be even between the weight and the tin, so that at the will of the buyer the tongue of the balance be not brought towards the tin beyond the true equipoise. And that the Lord the King, and the Lord Hubert Archbishop of Canterbury, and the Lord Geoffrey Fitz Peter, and all the Barons of the Exchequer may know that we have diligently and readily applied all our care, zeal, and solicitude, with William de Wrotham, to provide for the advantage of the King in respect of his tin; and that the Lord the King may not henceforth be easily cheated or deceived by any person in the world, we have made four chirographs hereof, and we have sent one to the Lord Archbishop of Canterbury and the Barons of the Exchequer; another to the Lord Geoffrey Fitz Peter. We have delivered a third into the common custody of the treasurers of the mark of the Lord the King, and the keepers of the stamps and weights of Devonshire and Cornwall; and we have given the fourth to William de Wrotham, in testimony. To each of the chirographs we have set our seals."

APPENDIX C.

For the following observations respecting Cornish steam pumping-engines, more particularly relating to their progressive improvements as measured by duty, we are indebted to I. S. Enys, Esq., of Enys, who is well known to have devoted much time and attention to the subject. We greatly regret that, from the space to which we are necessarily limited, we are unable to furnish more than an abstract of a portion of the observations which he was kind enough to prepare at our request for the use of the survey; but it is hoped that, though comparatively short, this abstract may be found useful.

We cannot refer, Mr. Enys says, to the increase of depth in the Cornish mines without considering the progressive improvements in the steam-engines by means of which their drainage has been effected. As a rough approximation, each successive depth of 100 fathoms may be attributed respectively to Newcomen's engine, Watt's low-pressure engine, and to Watt's engine using high-pressure steam expansively. The latter appears of sufficient importance to constitute an epoch in the drainage of mines. The following table contains several particulars connected with each kind of engine:—

Engines.	Newcomen's.	Watt's low pressure often expansive.	Watt's high pressure expansive.
Largest Cylinder in inches	72 single	63 double	90 single
Load in lbs. per square inch	6 to 7½	6 to 9	3 to 18
Period of use	1720 to 1778	1778 to 1812	1812 to 1838
Highest Duty in Million lbs.	3 to 7	12 to 9	20 to 93
Average Duty in Million lbs.		19½ in 1793 17½ in 1798	About 50
Depth of mines worked in fathoms	90	200	290

The knowledge of the duty performed by the Cornish steam-engines in the last century, has been chiefly preserved in the Philosophical Transactions of 1827 and 1830, by Mr. Davies Gilbert, who formed one of a committee in 1798, appointed to inquire into the alleged decrease of the duty performed by Watt's patent engines, as deduced from the calculated weight of water in the pumps, multiplied by the space, in feet, of motion given to it by the consumption of each bushel of coal. This method of estimating the work performed by steam-engines originated in the agreement made between Watt and the mining adventurers, that he should receive one-third of the saving of coal effected by the use of his engines, in the performance of an equal amount of work, when compared with the coal used in Newcomen's engines of the original construction. The nature of this agreement shows that a decrease of the enormous coal-expenditure, to which they were then subject, was more the object of the miners than an increase of power; indeed, not one of the engines reported in 1798 appears to have possessed so much power as the 72-inch atmospheric engine erected by Smeaton, in 1775, at Wheal Busy, near Chasewater. The best atmospheric engine erected in Cornwall, is said to have been made on similar principles by Bridge, an engineer of Camborne. In both these engines, the cylinder had been removed from its old position over the dome-headed boiler.

In 1778 a committee, consisting of gentlemen and agents connected with the mines, together with Messrs. Boulton and Watt, superintended a trial of the two steam-engines at Poldice Mine, in Gwennap, and reported that the engines together worked 4 lifts of 17-inch pumps, 58 fathoms in depth, with a stroke of 5½ feet, at the rate of 6 strokes per minute, consuming 14,080 Winchester bushels of coals in 61 days. Hence, the load was $17 \times 2{,}0454$ lbs. (the weight of a circular inch of water one fathom in length) $\times$ 58 fathoms = 34,285 lbs. The space of motion per bushel of coal was 5½ feet $\times$ 6 strokes = 33 feet, per minute; $\times$ 6.2385 minutes (the average time of the consumption of each bushel of coal) = 205.87 feet, and consequently, 34,285 lbs. $\times$ 205.87 feet = 7,058,252 duty. A performance which, from that time, was considered the standard of Newcomen's engines.

At present, the consumption of an imperial bushel of coals will readily produce about 100 strokes, 8¾ feet in the pumps, with a load of 85,530 lbs.; hence, 85,530 lbs. $\times$ 875 feet = 74,838,750 duty, and deducting 5 per cent. for the difference between the Winchester and imperial bushel, the duty for comparison with the standard becomes 71,096,813.

The piston of steam-engines is most commonly calculated to move at the rate of 220 feet per minute, or 2½ miles per hour, a velocity considered most advantageous for a horse. The latter is supposed capable of lifting 150 lbs. over a pulley for 8 hours at this rate: hence, a steam pressure of 150 lbs., exclusive of engine resistances, on a piston moving at 220 feet per minute, was considered equivalent to a horse-power, though it is more usually expressed as 33,000 lbs., raised one foot high for convenience in the estimate of a greater or less neat steam pressure at other velocities per minute.

In Davey's engine, in the Consolidated Mines, Gwennap (80-inch cylinder and 11⅓ feet stroke), steam of 20 lbs. pressure above the atmospheric, or 34.75 lbs. pressure, is admitted into ⅛ of the cylinder, after which the communication with the boiler is closed, and the steam is worked, expansively, in the remaining ⅞ of the cylinder, aided by the nozzle steam, which amounts to about ⅛ of the quantity of steam used in each stroke.* By an indicator the mean pressure in the cylinder has been shown to be about 19½ lbs. per square inch, so that by taking ⅞ as effective, we should have 4,784,748 lbs., raised one foot high, or 145 horse power. When the engine rises above its usual rate of 6 strokes per minute, to 10 strokes, at which it has worked, its power would be then increased to 240 horse power. The calculated load in the shaft amounts to 13.12lbs. per square inch on the piston, and when deficient water delivery is deducted, and the pitwork friction is added, the estimate coincides as nearly as could be expected.

As, fortunately, the water delivery is increased in most cases as the pitwork friction is reduced, the above method of calculating the duty performed is found to afford a tolerably fair estimate, even at different periods, of the performances of steam-engines, which, as is usually the case, form one machine, compounded of boiler and engine. Watt received payment for the whole machine, whether depending upon boiler or engine; thus he obtained his proportion of the savings in coal produced by the substitution of rectangular instead of the old dome-headed boilers, and which were not due to his patent engine. In like manner, part of the present increased duty of Cornish engines is due to the greater evaporation effected in Trevithick's boilers, in consequence of the great extent of their flue-surface.

The causes of the increase of duty in Cornish pumping steam-engines may be classed under the heads of—1st, A reduction of pit-work resistances, if not balanced by an increase of water delivery; 2nd, A reduction of engine resistances, jointly with an increase of power, from a given quantity of steam; and 3rd, An increase of water evaporated, in cubic feet, in the boilers per bushel of coal consumed.

At all periods the friction in the pumps, on a given load, has varied in different shafts, from several causes, among which may be enumerated, the original quality of the workmanship of the pit-work, the state of order in which it is kept, the length and number of the lifts, the diameter of the pumps, the underlie of the shaft, and the use of flat rods to work a second

* In April, 1838, this engine was making 7½ strokes per minute, and the communication between the boiler and the cylinder was only open for a ½ second at each stroke.

column of pumps in another shaft. The delivery of the actual water raised, as compared with that calculated, has also always varied from the impracticability of at all times supplying the exact quantity of water to the cisterns, when pumps of different diameters are employed at different lifts, especially when part of the water is taken from the upper levels which are liable to be affected by rain in winter, or where two columns of pumps are worked in separate shafts of unequal depth, independently of leakages of all kinds. All these various causes of error have been neglected for the sake of a convenient method of comparing the work performed by the steam-engines with the different velocities and loads, within certain limits, a course rendered necessary by the nature of the agreement between Messrs. Boulton and Watt and the mining adventurers; and since 1812, when the patent for these engines terminated, by the spirited competition which has been established among the mining engineers, by the monthly report on the duty of the Cornish engines.

Since 1775, the most important changes in the pit-work, exclusive of the general attention to avoid leakage in the pumps and valves, and the better packing, accompanied by an increased water delivery, have been the substitution of one connected main-rod, with offsets to work each separate lift of pumps, instead of a separate rod to each lift, and also the introduction of plunger-pole instead of bucket-pumps.

The original introduction of plunger-poles is unquestionably due to Boulton and Watt, under the direction of Murdock. The plunger-pole pump, however, came into general use long after the expiration of Watt's patent. Its effect on the increase of duty is in some degree counterbalanced by the improvement in the actual water delivery due to the great facility with which the packing is tightened without stopping the engine, or replaced without drawing the pump-rods, operations which, from their attendant difficulty, were often too long delayed in bucket-pumps.

Having alluded to the nature of the work to be done, we may consider the requisites of a good mining engine, which consists in the facility with which the number of strokes per minute can be increased, and also the load in the shaft; the first augments the quantity of water delivered, the second enables the mine to be deepened without the expense of a new engine. Both Newcomen's and Watt's engines were deficient in the latter point, from the limited increase of load allowable upon the pistons: hence, as the mine deepened, it was customary to load the engine to its fullest extent, and, in Watt's engines, often to some degree of risk with boilers formed of flat plates. When, therefore, the mine was poor, it was abandoned; and, if rich, another engine was erected to work the deeper levels, and relieve the older engine from the excess of its load. Under these circumstances, the engines so worked, that one brought the water from the sump, until it was lifted by the other to the adit: the consequence of which was, that if, from accident, one engine stopped, the lower levels of the mine became full of water. At present, most of the engines using high-pressure steam lift their loads of water from their respective sumps, or bottoms of the shafts; and in the larger mines, in case of accident to one engine, the water is drawn by the other engines, which are then made to work faster in con-

sequence; this being, however, only practicable where there is a reserve of power in the engines, on the mine generally, so that they are worked at a less number of strokes than they are capable of making.

Newcomen first afforded the Cornish miner an expensive but efficient machine to drain their mines. The average daily consumption of two of these engines, with 72 and 66-inch cylinders, at Wheal Busy, amounted to 320 bushels of coal, exceeding that consumed in any two of the largest pumping steam-engines at present in the county. Watt's engines soon enabled the mines to be worked to a depth before considered unattainable, and laid the foundation for further improvement. The present limit to the depth of the mines will probably be found in other causes than in any want of power to effect the drainage at reasonable cost. Soon after Watt's patent expired in 1800, it was thought that the cost of working the engines had not decreased to the amount anticipated from the cessation of the allowance for coal-savings previously paid to Boulton and Watt; but this was not ascertained to be well founded until 1811, when the average duty of several engines was found to be only equal to 13,500,000. Watt's counters were then again employed in Cornwall under the care of Captain Lean, and the effect of this measure was, in the first year, to raise the average duty to 20,000,000, showing that inattention, and not inferiority in the engines, had produced the previous deterioration in duty. It was rather before this period that Woolf introduced into Cornwall the use of high-pressure steam, worked expansively in a double-cylinder engine, similar to that of Hornblower. His engines performed a duty of 50,000,000 as early as 1816; and he kept the lead in the monthly reports for nearly fifteen years, though closely followed by other engineers, Jeffree, Gribble and Sims, and others, using high-pressure steam, generated in Trevethick's boilers, expansively in Watt's engine. The double-cylinder engines were never favourites with the mining agents, and their use appears to have been abandoned about 1827, when Grose re-introduced clothing, so necessary when high-pressure steam is used, in a very efficient manner, and first reached a duty of 80,000,000 in engines of Watt's construction at Wheal Towan. Hornblower, in 1781, took out a patent to work steam expansively in a double-cylinder engine; and Watt, in the ensuing year, obtained a similar patent for his engines, and is said to have been well acquainted with its advantages at an earlier period. Hornblower was an engineer employed in the erection of atmospheric engines in Cornwall, and, from the nature of his profession, had ample opportunities of becoming well acquainted with the expansion of steam before he ventured to take out a patent, and was, at all events, the first who brought this subject before the notice of the public. Both parties appear to have been unable to attain the practical advantages equivalent to theory, possibly from their fear of high-pressure steam, which seems to have been justified by the boilers of that period.

The reduction of engine-resistances has been mentioned as having produced an increase of duty in recent engines: this is partly due to better workmanship, the increased size of the engines themselves, the less burden on the air-pump from steam, at only one-half or two-thirds of the pressure usual in Watt's engines, when admitted into the condenser after expansion,

and perhaps in a slight degree to the adoption of Hornblower's double beat-valves, by means of which the largest engines, using high-pressure steam, are managed with the greatest facility; for with a 12-inch steam-valve the pressure of 30 lbs. steam is reduced from above 3000 lbs. to about 800 lbs., since the steam-pressure acts only on the seating of the circumference, and not on the whole valve.

The difficult question of the relative friction and resistances of a given load in the different shafts, has always been avoided by the mining adventurers in their estimate of work performed. Were it possible to obtain the whole performance in lbs. lifted one foot high per bushel of coals consumed, perhaps several engines, whose pitwork is disadvantageous, would be found in a higher relative position than they now occupy at present, or have formerly occupied.

The subjoined account of the weight and cost of the pitwork in the shaft of Davey's engine, in the Consolidated Mines, will afford a better idea of the subject than the number of lbs. lifted one foot by the consumption of one bushel of coals:—

Weight.

		Tons.	Cwts.
Fixed Work	Pumps, Windbores, &c. . .	161	8
,,	Wood-work, about . . .	50	0
Moving Work...	Main Beam	26	0
,,	Pump-rod	40	5
,,	Main-rod	94	15
,,	4 Balances and 1 Water-lift .	96	10
,,	Load in the Shaft . . .	38	3
		507	1

Cost, according to Prices of 1837.

	Tons.	Cwts.	£.
Wood-work . .	117	0 . .	716
Wrought Iron . .	83	17 . .	1575
Cast Iron . . .	203	14 . .	1969
Brass . . .	6	10 . .	976
			5236

In order to illustrate the value of Cornish engines, and their connexion with the pumping apparatus in the shafts, the following particulars respecting Davey's engine and the pitwork in the shaft, are subjoined:—

It appears, from the report of February, 1838, that in 30 days, this engine made 269,200 strokes of 8·75 feet each in the shaft, by the consumption of 2859 bushels of coal, or 120 tons of coal per month; hence, each bushel worked the engine, on the average, 15·11 minutes, making about 94 strokes per bushel, the load of 85,530 lbs. being lifted 823½ high, or 70,434,155 lbs. one foot high per bushel.

At each stroke, a quantity of water, equal to 8¾ feet of a 12-inch pipe, was delivered at the adit from a depth exceeding 1600 feet, being 33½ gallons, or more than half a hogshead; while, in addition, 45 gallons were delivered at

the surface for injection-water, and for turning water-wheels at a level above the adit. To effect this delivery, a weight of more than 300 tons is put into motion at each stroke, which is balanced, with the exception of the load in the shaft, equivalent to the weight of the column of water, and amounting to 38 tons 3 cwt.

The main rod, which is 290 fathoms long, is formed for about the first 120 fathoms, of two 12-inch square Riga baulk, each from 50 to 70 feet in length, and afterwards of 15-inch square baulk, decreasing to 14 and 12-inch in descending. The whole is connected together by iron straps for a distance of one-third of a mile perpendicular, and during action is kept in a proper position by 40 guides in the shaft. In consequence of the bad or corrosive water pumped up, the interior of the pumps is lined with wood, which increases the friction of the water rising through them.

In consequence of the reciprocating action of the pit-work, as a greater power is required to commence than to continue motion, an engine working with full pressure in pumping without air-boxes, as is usual in mines, is accelerated towards the end of the stroke. Watt employed expansion sufficient to guard against danger from this cause; but the fear of high-pressure steam at that period prevented both him and Hornblower from employing steam high enough to be capable of moving a load equal to, and often greatly exceeding, the full load of a low-pressure engine, and thereby, with a small relative amount of resistances, obtaining a variable power to coincide with a variable load.

In engines where the steam is used more than five times expansively, the velocity of the piston is sometimes visibly diminished towards the end of the stroke. In other cases, the low duty of an engine may be traced to a small amount of expansion, when the steam is not cut off until the half stroke, the weak flat rods under ground not being able to bear high steam.*

In Davey's engine, steam of about 34¾ lbs. pressure, as shown by an indicator, is admitted on the piston; the steam valve is shut at one-fifth part of the whole stroke, and the opening closed between the cylinder and boiler; the remaining four-fifths of the stroke is completed by the expansive action of the diminishing steam pressure, aided by the momentum acquired by the pit-work. The actual steam pressure on the piston is just 80 tons, becoming scarcely 18 tons at the termination of the stroke. The leverage of the main beam about balances the resistances of the engine, and, therefore, these weights may be considered as the neat moving power acting directly on the pit-work resistances and the load of 38 tons.

The worst engines now reported almost reach the average of the four best of Watt's engines working in 1798, and their average size is rather less. The average duty of 23 engines, in one month, in 1798, was 17½ millions, and consequently, 19¼ millions per imperial bushel of Swansea coal. At that

* Strong pit-work is necessary for the system of working steam expansively. In several instances a low duty can be traced to a weak part of the rods, which can only bear the admission of steam of lower pressure on the piston at the commencement of the stroke, and thus the necessary mean pressure must be obtained with the valve open through a larger portion of the cylinder.

period the strength of the boilers was the limit of the load in the shaft, which seldom exceeded 10 lbs. per square inch on the piston. At present the strength of the pit-work is the limit to the load, which sometimes exceeds 17 lbs. to the square inch. Trelawney's engine at Wheal Vor, with an 80-inch cylinder, worked for some time with this load, during which the mean steam-pressure must have been about 25 lbs., and the expansion under such a load could not have been more than that of one volume into three.

The load on the safety-valves of the boilers seldom exceeds 30 lbs. per square inch, producing steam of 45 lbs. pressure, which is often much above that required in the cylinder.

The temptation to increase the load, as the mine deepened, more than one of Watt's rectangular boilers for low-pressure engines could bear, rendered engines with such boilers, except in careful hands, far more dangerous than the same engines worked expansively with high-pressure steam generated in Trevethick's cylindrical boilers. The danger in the latter case is a deficient supply of water, to which almost every explosion which has taken place with them can be traced. To guard against this, a plug of lead is usually so placed, near the fire-place, that when the water becomes too low it is melted, and the water in the boiler rushes out and extinguishes the fire. Probably, however, the certain discovery of the slightest neglect in this point more ensures safety than the advantage this plug might otherwise possess.

The rectangular boiler, unfit for high-pressure steam, is now entirely superseded in the Cornish mines by one formed of two cylindrical tubes, respectively about 4 and 6 feet in diameter, the smaller placed inside the larger, and not exactly in the middle. The fire is placed at one end of the interior tube, through which the flue passes, and is returned several times in different modes along the exterior cylinder.* The following are the dimensions of the boilers in Davey's engine, above noticed :—

No of Boilers . .	3	Area of fire surface .	120	}	square feet.
Length of do . .	37 feet	flue surface .	2750		
Diameter, Outer, B.	6½	Water space . . .	1700	}	cubic feet.
Inner, B.	4½	Steam space . . .	370		

The consumption of steam in this engine is from 500 to 800 cubic feet per minute. Each fire-place has about 17 feet area, and contains 6 or 7 bushels of coal (about 20 altogether), while in 1780 a boiler under one of Newcomen's engines, of half the size, required 64 bushels of coal to fill the fire-place. Watt reduced the depth of the fire-place to 2 or 3 feet ; but after 1800 it was again increased by Hornblower to 5 feet, at the United Mines ; and it is well authenticated that a man standing on the fire-bars could just reach the bottom of the boiler. Woolf first introduced shallow fires under his cast-iron tubular boilers, and equalled, if he did not exceed, the previous amount of evaporation, but was unable to compete with the modification of Trevethick's rail-road boilers, afterwards introduced among the mines. The

* Rectangular mining boilers, with the fire beneath, were subject to the destruction of the plates from the stony deposit which took place in them *over* the fires. This deposit is now only affected over the lowest flue *below* the fire, where the temperature seldom exceeds that of melting lead.

chimneys are made about 60 feet high, as a sharp draught is of value in getting up steam rapidly, but the boilers are, in most instances, sufficiently large to be worked with a slow draught from closed dampers. This practice, and the use of Welsh coal, account for the absence of smoke in the mines.

From the system of clothing, as it is termed, or covering with bodies which are non-conductors of heat those parts of the engines which may require it, the temperature in a Cornish engine-house seldom exceeds 70° Fahr.* The boilers are covered with cinders, and occasionally saw-dust is placed above them if they are very tight. The steam jacket outside the cylinder is imbedded in 4½-inch brick-work, around which are 10 inches of saw-dust, confined in a wooden case. The steam-pipes and nozzles are also covered with saw-dust, the latter often in neat cast-iron cases. The following temperatures were obtained, in May 1838, at three engines in the United Mines :—

	Cylinder in inches.	Temperature. Open Air.	Engine Ho.	Mid. of Cyl.	Top of Cyl.	Ashes over Boiler.
Hocking's...	85	51°	63°	67°	90°	79°
Loam's	85	55°	66°	68°	90°	82°
Eldon's.....	30	55°	55°	68°	98°	99°

It may be observed that the duty usually obtained in the pumping-engines of Cornwall is far within the limits of steam-power, as the evaporation of each cubic foot of water at a pressure of two atmospheres produces a gross power of 3,800,000 lbs. lifted one foot high by the consumption of one bushel of coals; hence 53,000,000, at 14 cubic feet of water per bushel of coal, and, allowing for the theoretic advantage of five times expansion, a gross power of 136,000,000.

APPENDIX D.

ADDITIONAL NOTES.

Page 25.—According to ancient custom, when the town mills at St. John's Bridge, Helston, have their wheels stopped by the swelling of the Looe Pool, the mayor of the town applies to the Lord of Penrose, and, by presenting him with a few halfpence in a leathern purse, has a right to cut through the bar between that lake and the sea, so that the water may pass out, and the mills be no longer impeded.

Page 47.—In tracing the relative position of the grauwacke beds near Linton, care must be taken not to confound a great bend in the direction of the strike, visible on the high-road to Porlock, immediately on the ascent of the

* Clothing the proper parts of steam-engines with substances commonly termed non-conductors of heat formed part of Watt's patent, and was used, it is said, to a great extent in the Briggan engine, the first double-acting 45-inch erected in Cornwall. As this system of clothing requires exceedingly tight joints, its subsequent disuse, until 1827, has been accounted for by the condition of the Cornish engines and boilers after 1800, which was not remarkable for those requisites.

hill out of Lynemouth, with a curve in the direction of the dip. Without attention to the direction of the coast compared with the run of the rocks, and to the faults which let down that side of the valley of the Lyne, it might be easily otherwise supposed that the gray calciferous grauwacke of Linton arched over beneath the red sandstone rocks, which are, however, well seen to occur beneath the former by a careful examination of the cliffs at low water, beneath Linton, as also in other places up the valley of the Lyne.

Page 65.—The black slate of Kitley Park contains small specks of anthracitic matter in some places.

Page 70.—Respecting the appearance of a fault at Connator quarry, near Newton Bushell, it is possible that it may be deceptive, and that the limestone of the hill may be included in the carbonaceous series.

Pages 74 *and* 110.—From a visit to that part of the country since the notice of the Chudleigh limestone in p. 74 went to press, we are much inclined to consider that these limestones are included in the carbonaceous series. A well sunk through very characteristic beds of that series to the limestone, after passing through intermediate variegated slate, was open in the early part of 1838, near Lower Herkley, on the west of Chudleigh, corresponding with the section obtained near Woddon Barton, on the descent from which into the valley on the north, where the limestone has every appearance of being supported by characteristic rocks of the carbonaceous series, with an intermediate portion of fine gray argillaceous slate; the whole much reminding us, as to the mode in which beds with a certain mineralogical character are associated with them, of the Holcombe Rogus limestones on the north. Perhaps some of the limestones of Orchard Well, Rock Hill, and Lyndridge, are but the continuation of the same limestones brought to the surface by contortions and faults, both of which are abundant.

Page 75.—The remarkable fossil shells of Newton Bushell, and of the district generally, are now under examination by Professor Phillips, in consequence of an order of the Lords Commissioners of Her Majesty's Treasury to that effect.

Page 109.—Some appearances up the Dart, near Holne Bridge, might lead us to suppose that the rocks, which we have termed the carbonaceous series, dip beneath the argillaceous slates near the bridge, the beds of which, though indistinct, from the multitude of lamination planes cutting through them, seem contorted.

Page 161.—Dr. Maculloch estimated the weight of the Logan stone at 65·8 tons.—Trans. Geol. Soc. London, vol. ii. (1814.)

Page 267. The fine particles of copper carried up through the flues of the refineries at the copper-works at Swansea may be thus lifted mechanically by the current of air up them. When some volatile bodies are melted with others not commonly termed volatile, the loss sustained by the latter has been by some considered to arise from the fine particles of the volatile body carrying off mechanically a certain portion of the non-volatile particles adhering to them.

Page 275.—While lately engaged in an extensive examination of the chief building-stone quarries of Great Britain, preparatory to the selection of a proper material for the new houses of parliament, we have been much

struck with the great proportion of instances in which the divisional planes of a great variety of rocks, ranged in directions from N. to N.W., and S. to S.E., being cut by cross planes meeting them at angles approaching a right angle.

Page 350.—Phillips states, on the authority of Captain Teague, that, in some parts of Dunkin's vein, in Tin Croft Mine, granite was found on one side of it, and slate on the other; and that detached masses of each substance occurred both in it and in the south vein.—Trans. Geol. Soc. London, vol. ii. (1814) p. 155. The same author mentions Captain William Davey, of Redruth, as stating that, at Wheal Gorland, "for some fathoms both in length and depth, one wall of its vein was of granite and the other of schist." (*Ib.* p. 132.) Both, apparently, instances of faults, between the sides of which the lode had been accumulated.

Page 353.—By reference to Borlase's Natural History of Cornwall (1758) it would appear that Pryce was preceded in his opinion respecting the evidence of more than one disturbance of the rocks by the heaves and dislocations of the Cornish lodes. Borlase observes that, from fractured lodes and heaves, "and several other apparent alterations in the bowels of the earth, it is highly probable that the strata were not only unfooted, shaken, and brought to fall once or twice, but several times."—Nat. Hist. p. 106. The same author cites Hutchinson, in his tracts on the Cornish lodes, as considering that the north and south lodes (cross-courses), which run in a full body through the main lodes (east and west lodes), were formed after the main lodes, which, by cracking, gave way for the cross-lodes to pass through them (Nat. Hist. p. 156); so that Hutchinson appears to have been the first to observe that the fractures having different directions in a district may be of different ages. In proof of subsidences at different times, Borlase notices the North Down Mine, near Redruth, illustrating the heaves by a figure (pl. xvii. fig. 5), headed "starting of lodes."

Page 381.—The mixed crystalline composition of some lodes is extremely interesting, often depending on the character of the adjoining rocks. We have occasionally seen separate crystalline grains of tin thus intermingled with quartz, felspar, and schorl, in lodes in granite; so that, in a hand specimen, the compound would pass for a stanniferous granite. In a lode through granite, at the St. Austell Hills, topaz, in numerous small crystals, was added to the above-mentioned minerals. The crystalline mixture of felspar, quartz, and carbonate of lime, found in some fissures near Delabole and Tintagel, is also illustrative of the same circumstance.

Page 391.—Respecting the disappearance of one mineral substance and the substitution of another, Mr. Robert Were Fox informs us that fossil shells were found replaced by vitreous copper-ore at the Buckingham copper-mine, at Doddington, near the Quantock Hills. From a sketch of a specimen which we have seen, they were probably productæ or shells of that family.

Page 401.—It must necessarily happen that, in following lodes near the coast, works are carried on beneath the sea, which, if the lode be solid, and sufficient be left to support the pressure of the superincumbent water, is no

more dangerous than working beneath dry land. The principal inconvenience felt is the want of power to sink shafts except on the dry land, and therefore the workings in the direction of the sea are limited, from the difficulty of sending good air into them. When under the beach, and the levels not deep, the roar of the breakers, mingled with pebbles, is described as producing a fine effect beneath. One of the most curious submarine mines in the district was that named the Wherry, established upon a part of an elvan-course running in front of Penzance, parts of which are dry at low-water. Small stanniferous veins having been observed to traverse this elvan, attempts, according to Mr. Hawkins (Trans. Geol. Soc. Cornwall, vol. i. p. 136), were made to work them towards the beginning of the last century. A poor miner, by great industry and perseverance, established a shaft upon it about the year 1778. Notwithstanding the spot was under water during the greater part of the tide, and the coast exposed to heavy breakers, he succeeded in forming a water-tight case, as an upper part of the shaft, against which the sea broke, while a communication with the shore was established by means of a wooden frame-work bridge, above the reach of the sea, for about 120 fathoms. In 1791 the depth of the pump, shaft, and workings was four fathoms two feet; and ten men, in six months, working about one-tenth of the time, broke ore worth about 600*l.* (*Ib.* p. 140.) Altogether tin-ore, to the amount of 70,000lbs., was raised from this adventure, which was closed by an American vessel driving from her anchorage in the roadstead near the mine, and destroying the case for the upper shaft, thus letting in the sea. In 1837 this mine was again put to work, but with what success we have not heard.

Page 419.—Borlase says that, when he wrote (1758), red deer were seldom seen in Cornwall, but that some occasionally appeared on the hilly downs near Bodmin, and that they haunted the woods about the neighbouring moors. He mentions that they were then found plentifully between Launceston and Stratton, where they have now (1838) become rare, though two or three are occasionally seen. Leland mentions that they were found in his time about Dosmere Pool, to the northward of St. Neot's.

Page 421.—Borlase, after describing the sub-marine forest in Mount's Bay, draws the following among other conclusions:—"That the body of these trees must have stood at least twelve feet higher than at present; consequently there has been a subsidence on these shores, and the ground has sunk more than twelve feet." . . . . "That the ground which sunk appears to have been a swarthy, marshy plain of land, not much unlike the lower lands of Gulval and Ludgvan, parishes adjoining, covered thick with trees of the oak, hazel, and willow, at least, if not a greater variety."—Nat. Hist. Cornwall, p. 223.

Page 427.—A deer's horn was found in the consolidated sand of New Quay in the year 1752. Borlase figures this horn (Nat. Hist. Cornwall, pl. xxvii. fig. 5), and mentions that, having put fragments into vinegar, they dissolved, which a recent horn would not do, and that it had lost its toughness, breaking short. (*Ib.* p. 281.) Hence we may conclude that this horn

was undergoing the changes which bones imbedded in rocks have usually experienced.

Page 429.—Respecting chalk-flints in the present beach in Mount's Bay, Borlase states that, in the low lands of the parish of Ludgvan, in a place called Vorlas, there is a bed of clay about three feet under the grass, in which numbers of chalk-flints are found, with pebbles of quartz, and some shingle, with pieces of angular slate.—Nat. Hist., p. 106.

Page 478.—The Cornish sea-sand, for manure, is known to have been in use as early as the reign of Henry III. The liberty of taking sand for manure was granted by Richard King of the Romans, and confirmed by Henry III.—Lysons, Mag. Brit. Cornwall, p. cciii., who cites Rot. Chart. 45 Henry III.

Page 510. *Note.*—It appears that a large quantity of ochre was formerly found and manufactured in the parish of East Down, in North Devon, and that, in the parish of Combe Martin, umber was formerly worked.—Vancouver's Agricultural View of Devon, p. 59.

Page 526.—The charter of King John was recited and confirmed in a charter of the 2d of April, in the 36th year of Henry III.—Records of the Court of Chancery, in the Record Office in the Tower, M. 18.

Page 526.—"The tithe of the farm of tin in the counties of Devon and Cornwall" was granted to the church of St. Peter, Exeter, and bishops of Exeter, by a charter of the 13th of June, in the 18th of John (1216).—Charter Roll of the 18th John, No. 9. Records of the Court of Chancery, preserved in the Tower.

Page 527.—It appears by the record, preserved in the Tower, of the Parliament roll of the 8th of Edward II. (1315), M. 15, No. 115, that the tinners of Devon were then without a warden, as they petitioned the King that he would appoint one, for want of the control of whom the petitioners state that the tinners "do maliciously subvert, dig, destroy, and waste the arable lands, meadows, groves, houses, and gardens, of the same men (the petitioners) in the said county; sometimes even to the number of 300 acres and upwards annually; so that these destructions and damages are wholly, as it were, borne by the poor, and little profit accrues therefrom to the King." The petitioners further assured the King, if he would take that stannary into his own hands, and appoint a warden, who should dwell among them, that "it will be to his great advantage, and that, of the issues of the stannary, there shall be annually answered as great a sum of money as any one of his progenitors, formerly kings of England, had been accustomed to receive and have in the year, in any times past, and 40*l.* more."

Page 527.—It would appear from memoranda of the Parliament of King Edward I., held at Westminster on the Sunday next after the feast of St. Matthias the Apostle, in the 33rd of his reign, that the tinners of Cornwall petitioned to have a charter of liberties to themselves, not joined with the tinners of Devon, according to the form of the confirmation of King Henry; and it was answered, "Let them go to the Exchequer and exhibit their charter, &c., and make their fine, &c.; and let them have what they seek, &c."—Book containing the proceedings of the Parliaments of King Edward,

preserved in the Record Office, Tower (fol. 102). Disputes, it appears by a patent roll of the same king (Pat. Rol. 35 Edward I., M. 43), had about two years afterwards arisen between the tinners of Devon and Cornwall; and Thomas de la Hyde and Thomas de Swaneseye were appointed justices, to inquire into this matter, and the reason of a large sum of money collected to pay the King being detained by those who took possession of it "by reason of their seignories;" as also to inquire into the false weights stated to have been employed in weighing tin, to the King's prejudice.

Page 545.—Though streaming for tin has formerly been carried on extensively upon Dartmoor and in the valleys rising from it, stream-works are not now found in Devon. The last stream-work of which we can obtain information seems to have been that noticed by Vancouver as carried on near Plympton St. Mary's about the year 1808. View of the Agriculture of Devon, p. 67.

Page 611.—By the appointment of John Botright to be governor of all mines in Devon and Cornwall from which gold or silver could be obtained or refined, bearing date the 20th June in the 31st of Henry VI. (1453), as shown by the Patent Roll of that time, p. 2, n. 6, preserved in the Record Office, Tower, it is stated that he should pay to the King "the tenth part of the pure gold and pure silver, and also the tenth part of the copper, tin, and lead, from which any gold or silver shall happen to come." Six pits or shafts at Beer Ferrers were reserved for the King's use, and described as worked by him at his own costs and charges, for the superintendence of which Botright was allowed 40*l.* per annum. Botright and his deputies were empowered to dig where they pleased in search of the ores so containing gold and silver, to take wood necessary for their assays and smelting, making a reasonable payment to the owners, and "to take so many workmen and labourers as shall be necessary for working the mines aforesaid, within liberties or without (church property alone excepted), whenever from time to time it shall be required, and to put them in those works, there to stay, upon the reasonable payment of the same John, his deputies or servants and farmers aforesaid." To Botright, his deputies, and the miners, were granted the same privileges and franchises as the miners of Byer "by the reason of the like mines" have been accustomed to enjoy.

Page 612.—In an ordinance of the 26th of Edward I., concerning the King's mines in Devon (1298), preserved among the communia of the term of St. Hilary in that year, in the Remembrancer's Office in the Exchequer (Roll 51), we find the following curious directions respecting smelting the ores, argentiferous galena, more especially intended, it would appear, for the mines at Beer Alston.

"That the carriage be made as soon as the produce (ore) is measured, as far as the boles or elsewhere, and that the * * and other smelters be there in their own persons, and forthwith receive it by tale as thereunto belongs. And that all the produce of the mine be smelted under good survey, and, so soon as the ore shall be smelted and marked, it be weighed and delivered to the wardens into their common guardship by the smelters, and by tally made between the wardens and the smelters, as to the work belongs, as heretofore it has been there used, or commanded and ordained to

be there used. And when this metal is delivered to the refiners for fining by the quantity and number of pieces to be weighed, and becomes changed in the manner which follows, that is to say, as soon as the metal shall be fallen and sunk in the moulds on the coals, before the cinders have imbibed any of the metal, that the metal be caused to be stirred and mixed in order that it be equally good throughout, and that thereupon there be taken a quantity of the metal weighing to the amount of six shillings or thereabouts, and that such quantity be pierced into two halves, and the one half be delivered to the finer under the seals of the wardens, labelled with the date and the name of the refiner, and with the other half be made an assay by the King's assayer in presence of the wardens and in presence of the refiner, or in presence of one of the wardens if both at any time be unable to attend on account of other business. And that by this assay the refiner be charged to answer for all such refinery as nearly as he reasonably can, having regard to decrease and abatement in the grand refinery more than takes place in the small way. And when the silver shall be properly and purely refined it be delivered by the refiners to the wardens by tally of weight, so that suspicion or fraud cannot lie with one side or the other." * * * * * "And that there be five good refiners who know how to chase as well as refine, for this is meet, especially for the responsibility and the charge aforesaid; and that they be at the King's wages by the week, or for certain by the year, or according to the portion of a year that they may continue or be required."

From this document it would appear that the Beer Alston mines were then worked at the King's own cost, and that the argentiferous character of the lead-ore there found was well understood in the year 1298. The ordinance directs that the miners and others employed in the King's mines in Devon should be paid on the Saturday, and "that no miner shall dwell in market-towns on pretence of purchasing meat, nor in another manner, without leave, beyond the next day at noon." Reference is made to the Combe Martin mines and others in Cornwall, as if they were then at work. A tin-mine named Dindods appears also to have been in the King's hands, and 100 tinners are directed to be there.

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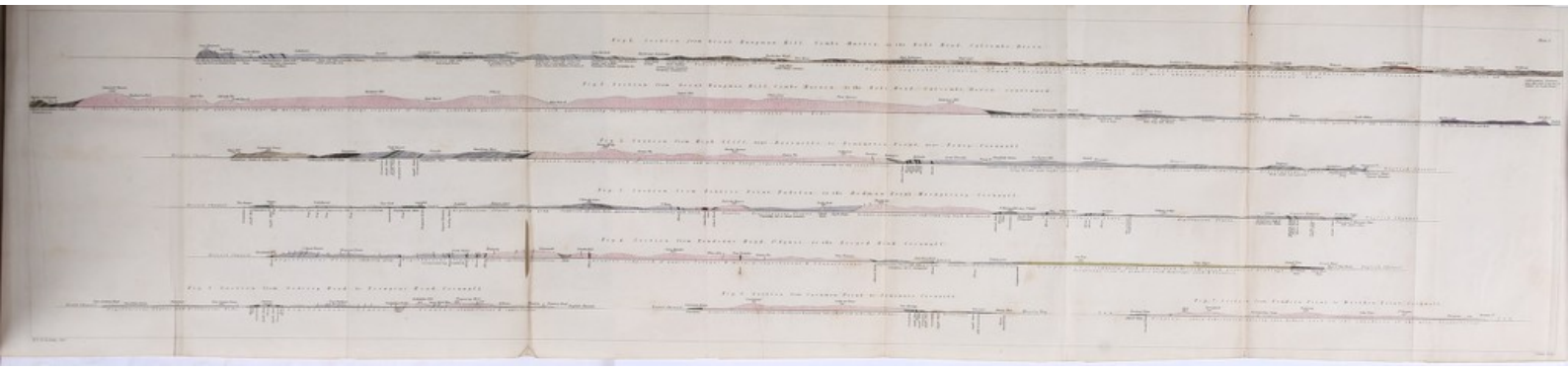
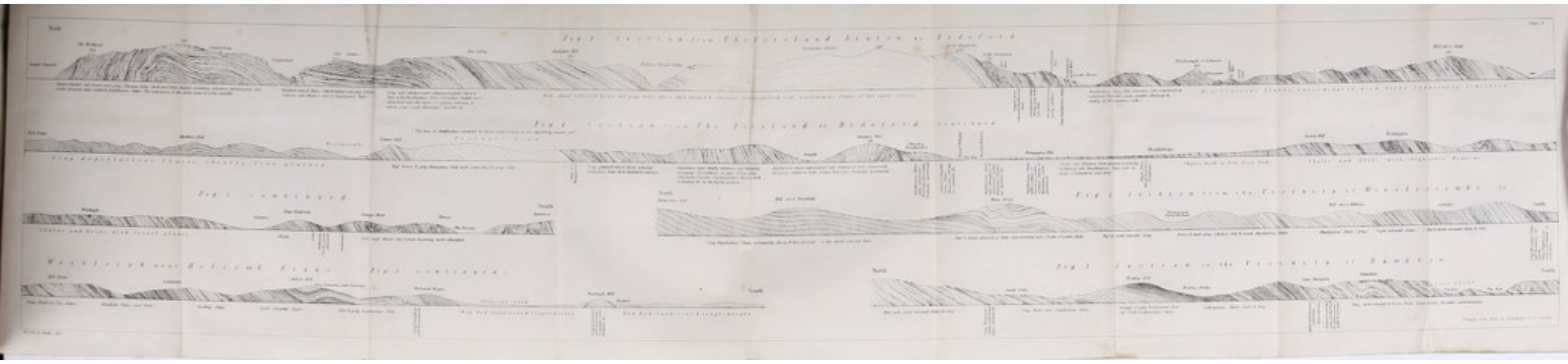
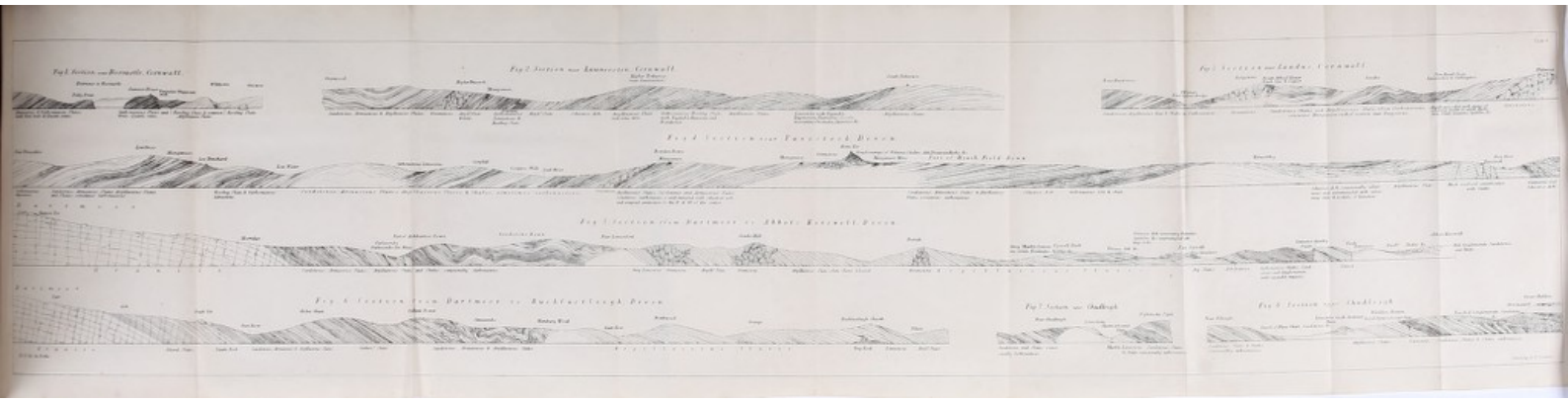
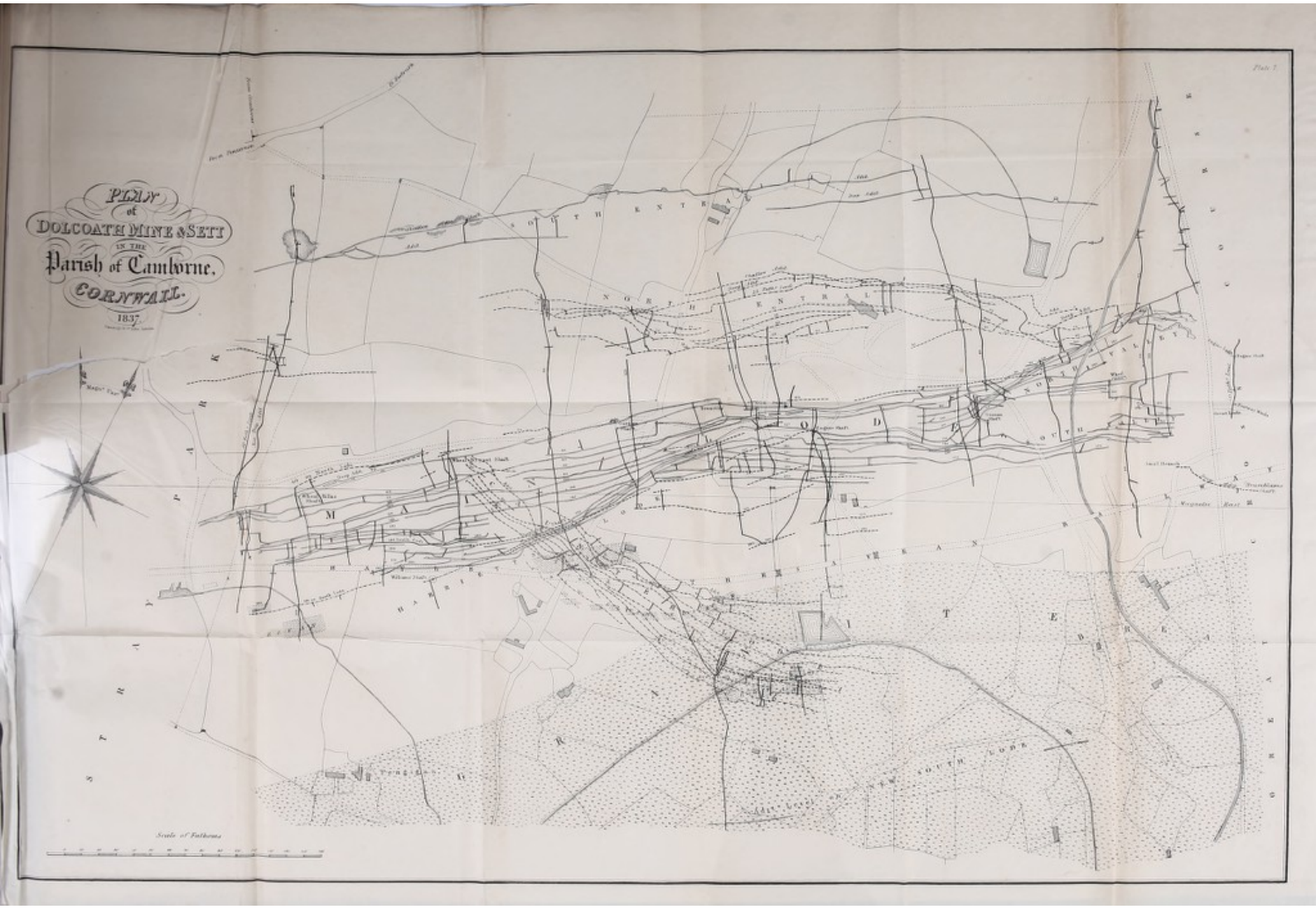


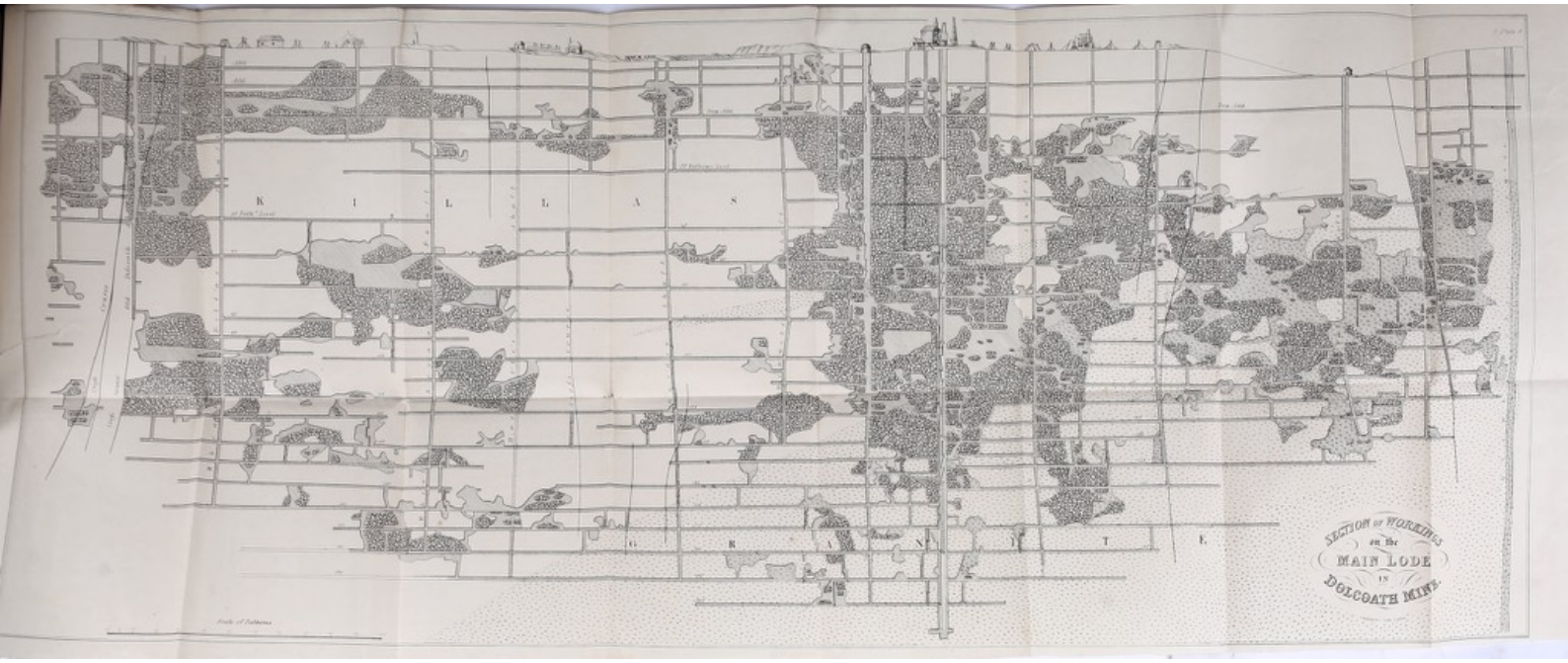


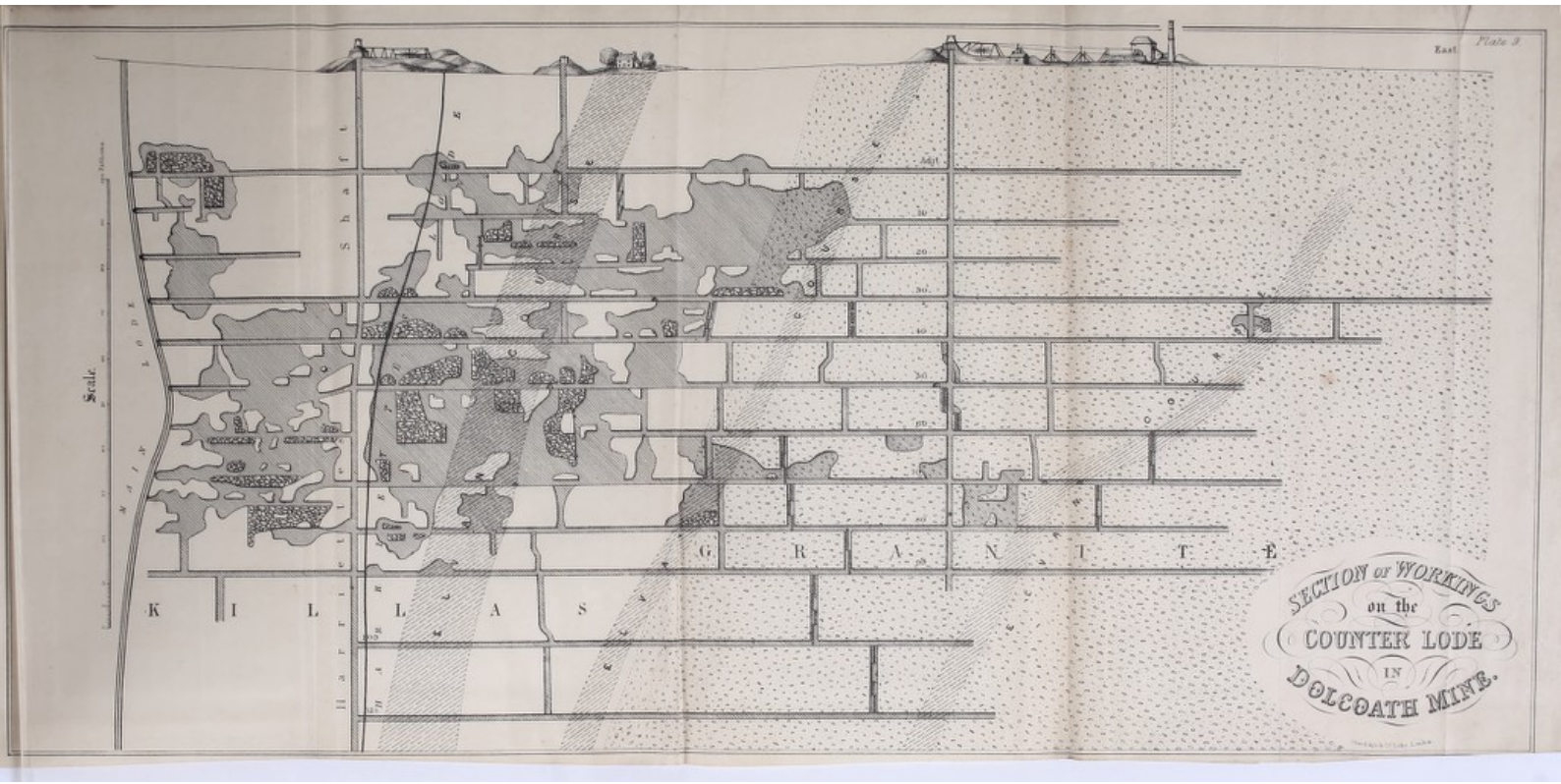


Granite Veins in Slate, Wicca Pool, Zennor.

Plate 5.


PLAN
of
DOLCOATH MINE & SETT
IN THE
Parish of Camborne.
CORNWALL.
1837.
Plate I.
SOUTH ENTRAL
NORTH ENTRAL
CROSS COURSE
Scale of Fathoms


K I L L A S
G R A N D T E
SECTION OF WORKINGS
on the
MAIN LODE
IN
DOLCOATH MINE


East
Plate 3
Scale
Main Lode
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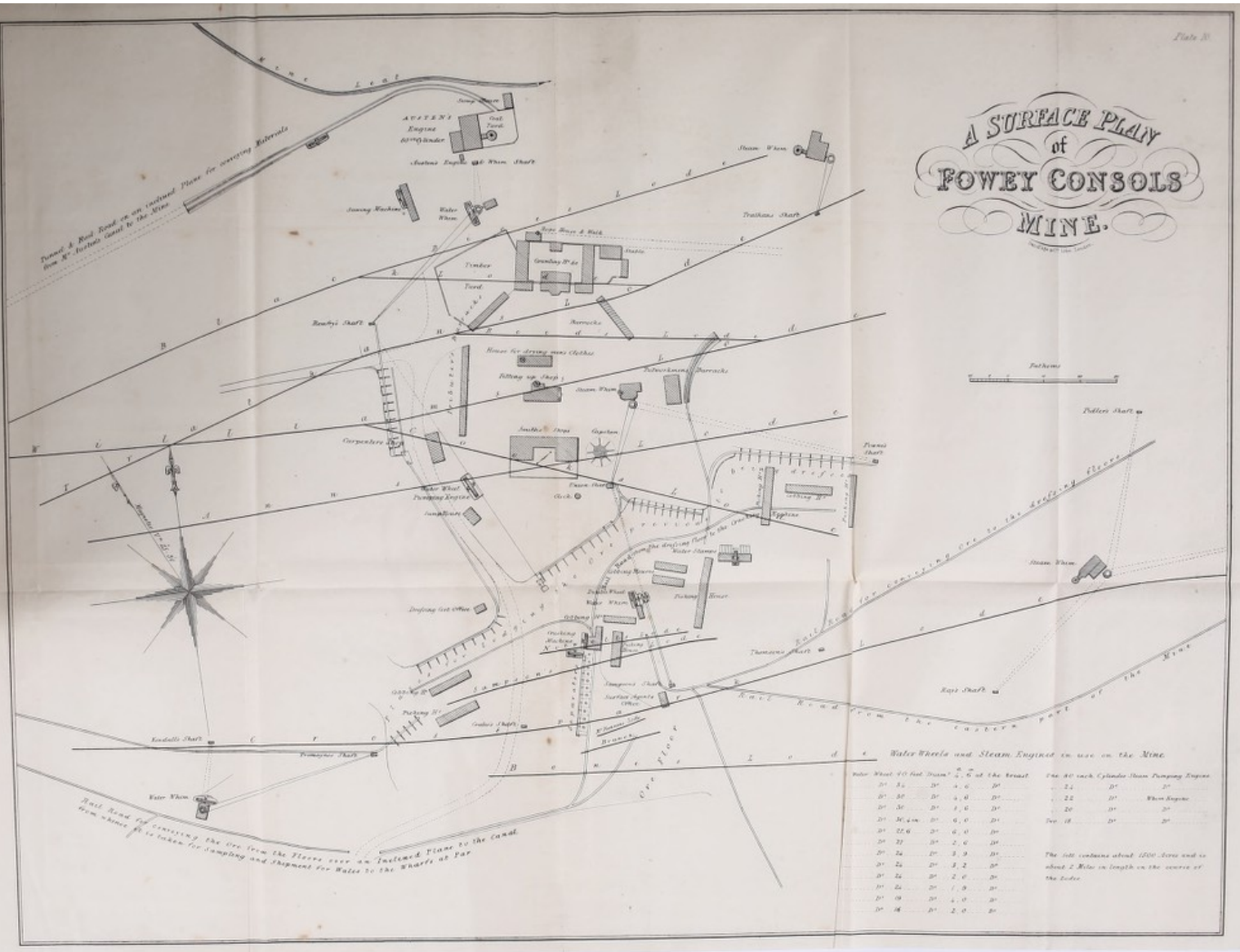
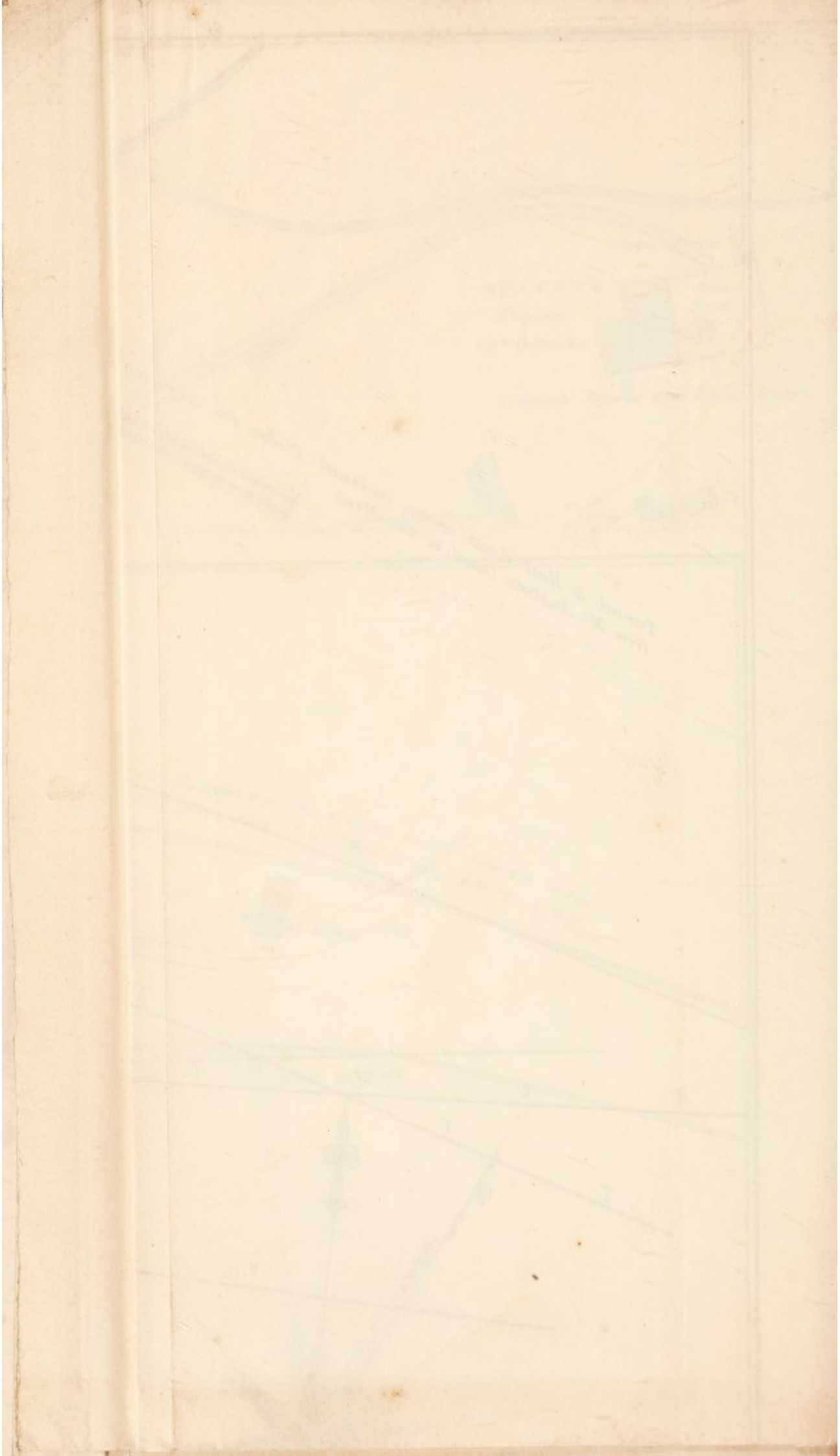
G R A N I T E
K I L L A S
Harriet
SECTION of WORKINGS
on the
COUNTER LODE
IN
DOLCOATH MINE.

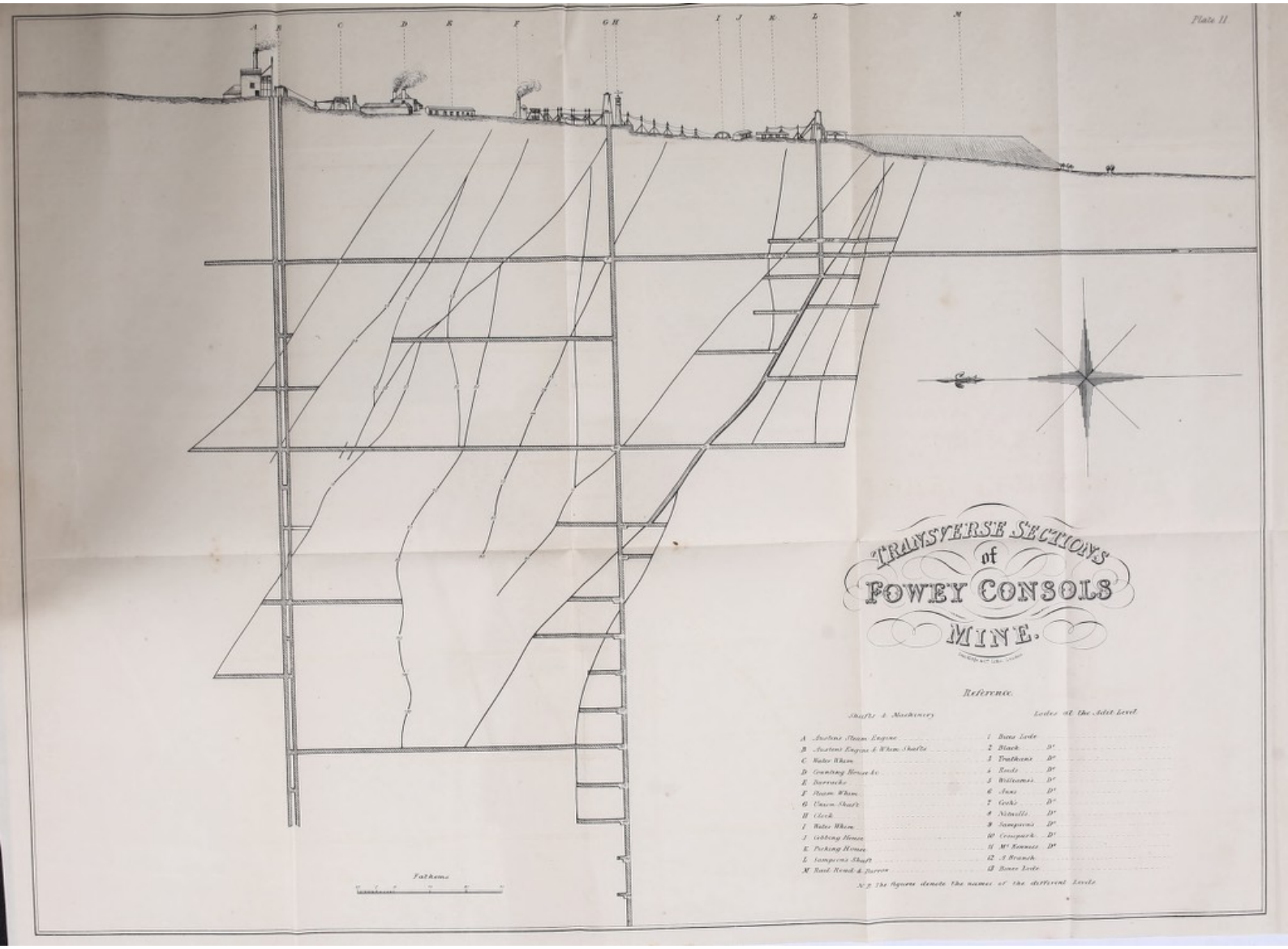
A SURFACE PLAN of FOWEY CONSOLS MINE.



Water Wheels and Steam Engines in use on the Mine.

Water Wheel	Fall	Diam.r	Stroke	Diam.r of the breast		One 80 inch Cylinder Steam Pumping Engine
1	31	31	4 . 6	31		21
1	32	31	4 . 6	31	One 22 inch Cylinder Steam Pumping Engine	
1	36	31	4 . 6	31		20
1	36 & 6 in.	31	6 . 0	31	One 18	31
1	22 6	21	6 . 0	31		
1	33	31	2 . 6	31		
1	24	31	3 . 9	31	The Sett contains about 1500 Acres and is about 2 Miles in length on the course of the Lode	
1	24	31	3 . 2	31		
1	24	31	2 . 6	31		
1	24	31	1 . 9	31		
1	19	31	4 . 0	31		
1	16	31	2 . 0	31		





TRANSVERSE SECTIONS of FOWEY CONSOLS MINE.

Reference.

Shafts & Machinery		Lodes at the 3d st Level	
A	Austins Steam Engine	1	Bists Lode
B	Austins Engine & Wheel Shafts	2	Black Dº
C	Water Wheel	3	Trathems Dº
D	Counting House &c	4	Reads Dº
E	Barracks	5	Williamses Dº
F	Steam Wheel	6	Sims Dº
G	Cheese Shaft	7	Grubs Dº
H	Check	8	Nicholls Dº
I	Bates Wheel	9	Sampsons Dº
J	Cobbing House	10	Crowpark Dº
K	Picking House	11	Mrs Reeves Dº
L	Sampsons Shaft	12	A Branch
M	Back Roads & Barrow	13	Bones Lode

N.B. The figures denote the names of the different Levels

Plate 12.

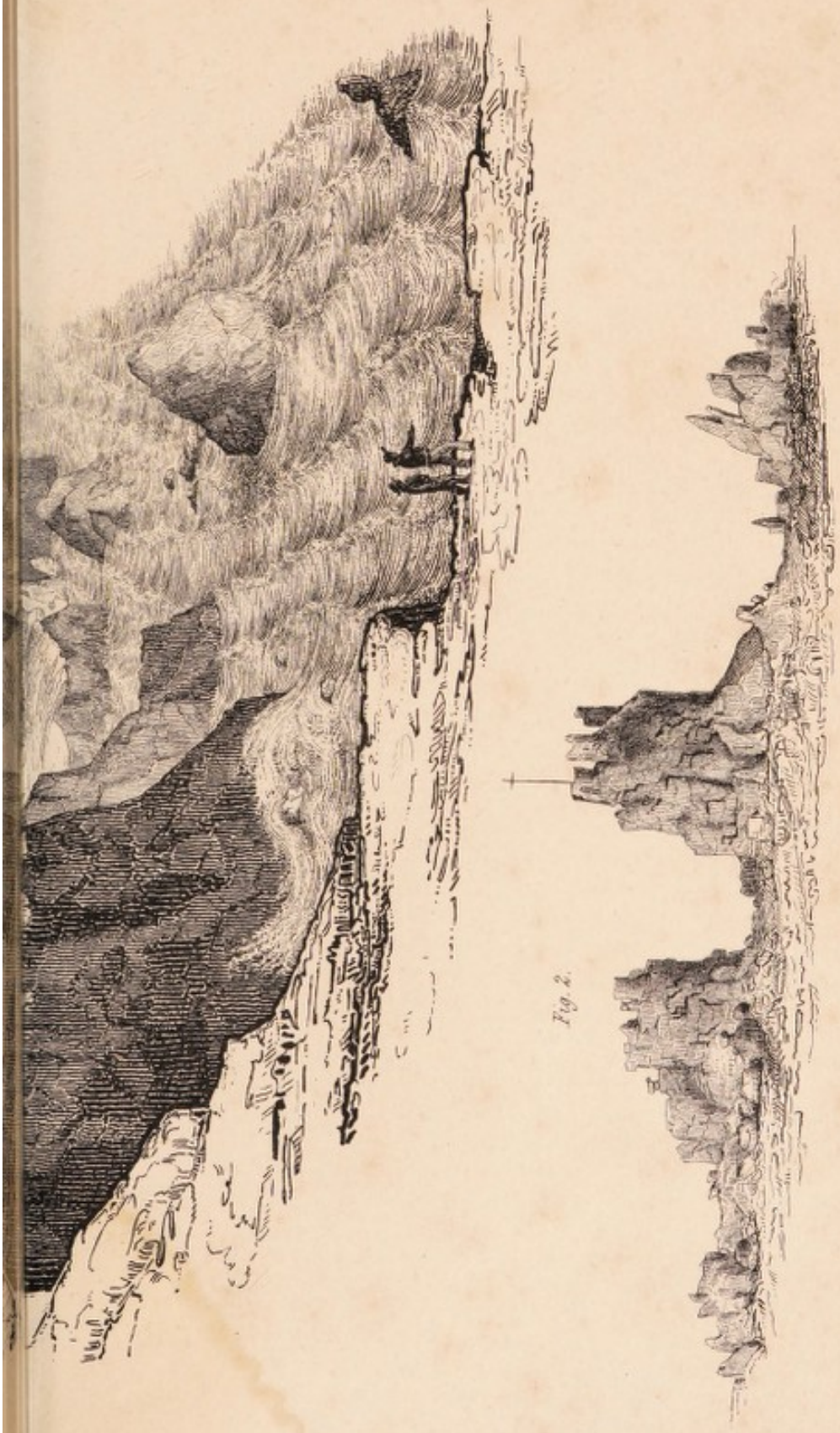


Fig 2.

H. T. Dela Beche, Del.

Standidge & Co. lithr. London.

237. Chalc. w L. Regis. in sandstone under chalk
227 Belemnites at foot of Golden Cap
197 rich blk haematite w Luckham
202 igneous rocks w Credilon
202 ditto w west Clist
204. porphyry & conglom. on shore } N of Teignm°
with glassy felspar coast)
205,6. Petit Tor
111 Lydian Stone &c Ugbrooke Park, Ogwell, Heston Down
112. Ashton. Concretionary masses Kings Kerswell. & Kingsteignton to Bishopst.
120. Brent Tor } volcanic.
123 } Trappean } Jasper on E of hill
141 } rocks at Christow, Bridford, Trusham.
Doddiscombsleigh, Ashton.
264. chalcedony in Wheatstone pits. Blackdown
262 ditto. W. escarpment of Blackdown Hills
from Punchbowl Down to Upcott Barn
165. granite veins in slate. Roche Quarry

158. School crystals | 159 St Austell
above Broadley w Ashburton
Holne Lee
Ilsley, Ugborough Beacon
Blatchford, Cornwood
(Burrator reservoir N end / S. res^r
? Wildcott granite quarries
162 schorl crystal
177. Granitic porphyry
507 albitic } granite of West Okement
494. good serpentine w Tolcarne &c
496. Economic use of semi-precious stone
453 crystals in slimes, clay, spoil &c.
290. iron plate changed to silver
283 Six metalliferous districts
288. Silver. Horrabridge mine w Buckland
289. Roborough stone. Oreston

w moreton H.
w Columb. Minor
(doubtless)