Outline of the geology of the neighbourhood of Cheltenham / By Roderick Impey Murchison.

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OUTLINE

OF

THE GEOLOGY

OF THE

NEIGHBOURHOOD OF CHELTENHAM.

BY

RODERICK IMPEY MURCHISON, F.R.S.

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AND HON. MEM. OF THE LITERARY AND PHILOSOPHICAL INSTITUTION OF CHELTENHAM.

CHELTENHAM:

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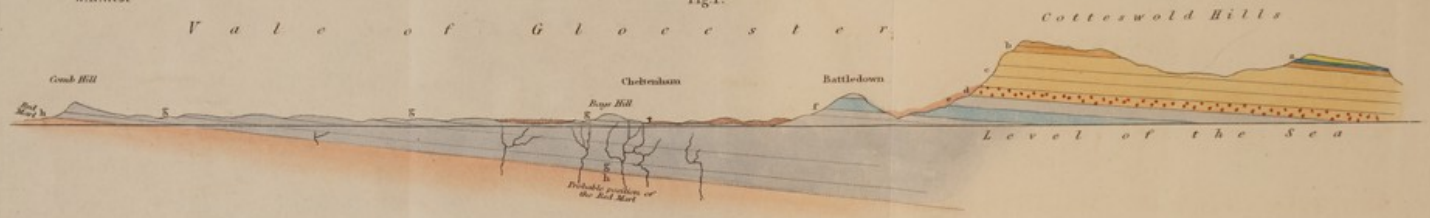
1834.

W.N.West

Fig.1.

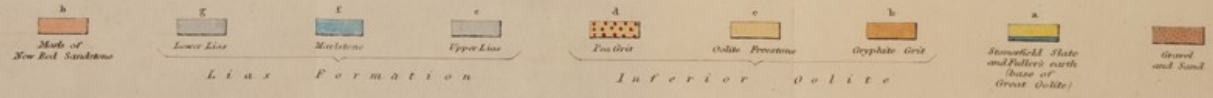
E.S.East



West

Fig.2.

East



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"Geology, in the magnitude and sublimity of the objects of which it treats, undoubtedly ranks in the scale of the sciences next to Astronomy."—*Herschel, Natural Philosophy*, 1831, p. 287.

J. B. NICHOLS & SON, 25, PARLIAMENT STREET.

OUTLINE

OF THE

GEOLOGY OF CHELTENHAM.

THE important uses of Geology, in explaining the true arrangement of the strata which constitute the mineral crust of the earth, are now generally acknowledged, and the subject is consequently becoming every day more popular. Rocks are to the Geologist what *Papyri* are to the Antiquary, imparting to every one who diligently lays them open, the history of the ages that have preceded us. But, although Herschel has declared Geology [a] to have "been brought effectually within the list of the inductive sciences," it has, at the same time, been doomed to undergo a persecution not unlike in spirit to that which was formerly inflicted upon Galileo and the early

[a] Prelim. Disc. on Natural Philosophy, p. 283. Lond. 1830.

astronomers; a reception, it would appear, which is usually given by a certain class of mankind to all great natural truths when first promulgated. Geology has been assailed by some uninformed, though perhaps well-meaning writers, as a study which undermines religious belief. This absurd assumption (for it is nothing else) is so far removed from truth, that the mind of every *practical* Geologist, it may be confidently stated, is stored with a multitude of facts, all demonstrative, not only of the power and wisdom of God in the works of his Creation, but also in the clearest manner indicating certain beneficent arrangements, whereby the ends of his providence have been *successively* accomplished, and the surface on which we are dwellers has been fashioned out to be our fitting abode.

This is not the occasion, even had I the power, to dilate upon those great and sublime laws, a knowledge of which can only tend to elevate the mind of man to the consideration of a great First Cause, and I desist from the topic; earnestly entreating all those who have been led away by false teachers, to consult the Rev. Professor Sedgwick's Discourse, recently preached before the University of Cambridge,[b] an eloquent effusion of

[b] Discourse on the Studies of the University, by the Rev. Adam Sedgwick, 1833.—*Parker*, London.

deep reasoning, in which the assertions of such sciolists are triumphantly refuted.

But to return to the immediate objects of this essay. The time is now fast approaching, when every populous district in the kingdom will possess some work explanatory of the structure of its subsoil and rocks. The following sketch is necessarily written in language more or less technical; and although I have endeavoured to make use of the plainest terms allowed by the subject, and have given several explanatory notes, I can scarcely hope it will be understood by those who have not previously sought to comprehend the first principles of the science, by the study of the works of Conybeare,[c] Lyell,[d] De la Beche,[e] and Bakewell[f].

I may be permitted further to state that, owing to almost ceaseless occupation during the last three years, in illustrating the geology of Wales and the border counties of England, it is only during occasional short visits, in passing through Gloucestershire, that I have been enabled to prepare this

[c] Geology of England and Wales.—*Conybeare and Phillips*, 1822.

[d] Principles of Geology.—*Lyell*, London, 1833, 2d and 3d edit.

[e] Manual of Geology.—*De la Beche*, London, 1833, 3d edit.

[f] Introduction to Geology.—*Bakewell*, London, 5th edit. 1833.

Outline; nor would it have ever seen the light, but for the suggestion of several members of the Literary and Philosophical Institution of Cheltenham, who anxiously desired to commence their acquaintance with the Geology of the place of their residence:—To these kind friends I dedicate this little Memoir.

A circle, having a radius of five or six miles, drawn around the town as a centre, will embrace the formations to be described. The rocks within this space are all sedimentary deposits, which have been successively accumulated under the ocean; their various layers or beds containing fossil remains of many extinct species of marine animals.

These deposits occupy a large portion of that class of rocks which Geologists term Secondary, a name signifying that they have been formed during an epoch between the Tertiary, or more recent accumulations, and the ancient rocks called Transition and Primary. The *Oolitic*[g] *Series*, a large and important division of this Secondary class, extends diagonally in a broad band across our island from south-west to north-east; and to

[g] For the meaning of the term Oolitic, see note, p. 9.

the lower part of this series belong the strata of which the Cotteswold Hills are composed.

The hard rocks of the *Oolitic Series* rest upon a very thick deposit of sandy marls and clays, with some bands of argillaceous limestone. This deposit is the *Lias;* it occupies the vale of Gloucester.

The Lias reposes upon the Red Marl, or New Red Sandstone, which occurs at Tewkesbury and the banks of the Severn. As the beds [h] of all these formations have a general dip or inclination to the east and south-east, at angles varying from 5° to 12°, it is evident that, in crossing the Cotteswold Hills, and the vale of Cheltenham, we shall see exposed the ends of the strata of each group, as they emerge from beneath those which have been deposited over them. In this way we make what Geologists call a *transverse section;* and the annexed diagram explains the meaning of the term. The following description applies, therefore, to such strata as are found in "*descending order*," [i]

[h] When a bed or stratum does not lie horizontally, but is inclined, the point of the compass to which it sinks is called the dip or inclination of the strata, and the angle which the line of dip makes with the horizon, is the angle of dip or inclination. See coloured Section.

[i] Strata are said to be described in "descending order," when examination commences with those beds which are the highest, and have consequently been the *last* accumulated. This successive arrangement of different strata above each other, is termed "the order of superposition." The youngest deposits in the neighbourhood of Cheltenham, are the gravel and sand; but those have been formed out of the debris of pre-existing rocks, which are necessarily first described.

upon any straight line drawn from the eastern slopes of the Cotteswolds to the banks of the Severn.

I. *Stonesfield Slate.*[k]

The slaty beds of Sevenhampton Common, which are quarried for roofing cottages and barns, are the youngest solid strata of the district under review. They occupy the same position in the order of strata established by geologists, as the slate of Stonesfield, near Blenheim.[l] At that place they have been long celebrated for the abundance and variety of their imbedded organic remains, including some very remarkable vertebrated animals, such as the Didelphis Bucklandi[m] an animal allied to the modern Opossum; the Pterodactylus[n] a flying reptile; together with crustaceans, and many shells.

In the hills of our district the slate has hitherto only been found to contain certain small unde-

[k] For an account of the Quarries at Stonesfield, see a sketch by Dr. Fitton, Zoological Journal, Vol. III. p. 416.

[l] The relative position of these beds has only recently been discovered by Mr. Lonsdale, who has further proved, that the true geological position of the Stonesfield Slate is at the base of the Great Oolite, or Bath Freestone. A full account of the formations which overlie the Lias of Gloucestershire, is about to appear in the Transactions of the Geological Society, from the pen of Mr. Lonsdale, who, from an elaborate study of these deposits near Bath, has been enabled to determine their equivalents near Cheltenham. With his permission, I have adopted his improved classification of the Oolite species.

[m] Broderip, Zoolog. Journ., Vol. III. p. 412. [n] Cuvier.

scribed bivalve shells, and impressions and casts of vegetables and wood. (See *a* of the coloured section.)

II. *Fuller's Earth.*

The clays which separate the Stonesfield Slate, or, in its absence, the Great from the Inferior Oolite, were named Fuller's Earth by the well known geologist[o] William Smith, because, in the neighbourhood of Bath, where they were first examined, they contain that substance.

These argillaceous beds are of inconsiderable thickness in this district, and in the coloured section they are therefore represented in the same division as the slaty beds above them.

III. *Inferior Oolite.*[p]

The calcareous rocks composing this formation rise to the west from beneath the above mentioned, and are well exposed in the escarpments of the Cotteswold Hills, which overhang the vale of Gloucester, particularly in Leckhampton Hill. The formation is in all about 150 feet thick, and is divisible into three parts.

[o] Mr. William Smith first taught us to identify strata by help of the imbedded organic remains; and the rocks of the Oolitic Series, or those which occupy the hills of Somerset, Gloucester, and Oxford, were proposed by him as offering clear types of subdivision of this great class of sedimentary deposits.

[p] The term *Oolite* (or egg-stone) is applied to calcareous rocks composed of fine spherical grains, in size generally less than a mustard seed. These sphericles were mistaken by many of the older naturalists, for the spawn of fishes, or eggs of insects, and hence the term *Oolite*, from the Greek ᾠόν, egg, and λίθος, stone.

1. The uppermost of these is a brown calcareous grit, of a very coarse aspect, owing to the number of shells it contains, among which the Gryphæa Cymbium, Lima proboscidea, and Pholadomya ambigua, are the most abundant. This grit seldom exceeds sixteen to twenty feet in thickness; it caps the hills of Leckhampton, Lineover, and Hewletts, and is extracted for the use of the roads. Beneath the Gryphite grit[q] are a few feet of flaggy, light-coloured Oolitic beds.

2. The central division is much the thickest, and contains the fine Oolitic building stone of Cheltenham, many of the varieties of which possess the Oolitic character, but in some this feature is wanting, and the mass is composed of grains of ndefinite forms. This part of the system is admirably exhibited in the double range of quarries of Leckhampton, extending thence to Birdlip Hill, and in the following descending order. The same order is to be observed in the hills between Hewletts and Cleeve Clouds.

a. Cream-coloured marlstone, in parts compact, in others concretionary; about thirteen feet thick

The Terebratulæ, Fimbria, globata, and perovalis, are the prevailing fossils.

Clypeus sinuatus characterizes this stratum on the summit of Birdlip Hill.

[q] I have so named this grit from the prevalence of the "Gryphæa," a bivalve shell, somewhat resembling an oyster. This name and that of Pea grit (p. 12) are local terms, which are only applicable to the structure of the Upper and Lower strata of the Inferior Oolite of Gloucestershire.

b. Upper Ragstone, and thin-bedded Oolite; about fifteen feet.

c. Freestone. A fine-grained, light-coloured Oolite. This is in the same position as the stone used for buildings at Cheltenham, which is extracted at Whittington, Syerford, Postlip, &c. At those places it varies from thirty to forty feet in thickness, and being quarried underground, is dressed with facility. Here it is not so thick, and the beds being exposed to the atmosphere, it is found less easy to work.[r] It is undistinguishable in lithological character from the freestone of Bath, although that rock is of more recent date, being what Geologists term the "Great Oolite."

d. Lower Ragstone. Very fine-grained, hard Oolite; some beds largely quarried as trough stones. The Oolitic structure becomes coarser downwards, and passes into a rough concretionary rock at the base of the formation.

The lowest member of the Inferior Oolite has a

[r] In general, the Oolitic freestones, from whatever part of the series they are derived, on being exposed to the atmosphere, part with much of that moisture which they naturally possess under ground, and become extremely indurated. The quarries of Ketton, in Northamptonshire, which are in the *Great Oolite*, yield blocks like those of Cheltenham, of very large dimensions. These blocks are easily cut with the saw on being first extracted, but become rapidly indurated on exposure to the atmosphere, so as to clink like a piece of metal under the hammer.

remarkable mineral aspect. It is of a rusty brown colour, and is in great part made up of small flat concretions, from a quarter to half an inch in diameter, which give to the rock, on first inspection, the appearance of a Nummulite rock.[s] It is called "Pea Grit" by the country people, and is a useful stone, when employed for gate-posts and other rough work. Coralline bodies and Pentacrinites are spread over the sandy iron-shot faces of the beds below Cleeve Clouds. Veins of crystallized carbonate of lime (the spar of the workmen) are of frequent occurrence throughout the strata.

The organic remains of the formation in these hills are very numerous. Those which follow I have collected, and they are probably but a portion of the fossils which will hereafter be found.

[s] The Nummulite is an extinct genus of small round flat chambered shells, which, although of exceeding rare occurrence in England, are so abundant in parts of Europe, Africa, and Asia, that considerable hills are entirely made up of them. The Pyramids of Egypt are built of Nummulite Rock, and the name was first given by the workmen, from the supposed resemblance of the shell to a coin: "Nummus," Lat. Money, and "lithos," Gr. stone. In those parts of France (Beauvais, &c.) where Nummulites abound in the rocks, they are in like manner termed "liards," or farthings. The fossil is, however, characteristic of strata of much younger age than those of our district; and it is only through a false appearance that the flattened concretions of the Inferior Oolite have been mentioned in conjunction with those organic remains.

Fossils of the Inferior Oolite of the Cotteswold Hills.[t]

1 Ammonites[u] corrugatus M. C. t. 451. f. 3.
2 Ammonites elegans? - M. C. t. 94.
and portions of other species of Ammonites.
Belemnites[v] (portion of)
1 Berenicea diluviana Lammourroux. Expos. Method. t. 86. f. 12 & 14. M. C. t. 424.
1 Cirrus carinatus M. C. t. 429.
1 Clypeus sinuatus[w] Parkinson, Organ. Rem. vol. III. t. 2, f. 1.
Corals (of several species.)
1 Gryphæa Cymbium Lamarck, see Deshayes Coquilles Characterist. des Terrains, pl. 12. f. 1 & 2.

[t] The greater number of the organic remains in this list, have been figured and named by Mr. J. Sowerby, in a work entitled "Mineral Conchology." The letters M. C. refer the student to this valuable book, which forms an essential part of every Geological Library. Some of the fossils are to be found in Phillips's "Geology of Yorkshire," a modern treatise of high geological merit.

[u] Ammonite. The chambered shell of an extinct marine animal, allied to the modern Nautilus; so named from its resemblance to the horns represented on the head of Jupiter Ammon. (Cornu Ammonis of old authors.)

[v] Belemnite, a long, straight, and chambered shell, belonging to an extinct marine animal, so called from the Greek word Βέλεμνον, a dart.

[w] Clypeus, a genus of the Echinidæ of Lamarck, familiarly known as Sea Urchins or Eggs.

1	Isocardia concentrica -	M. C. t. 491. f. 1.
2	——— costata -	M. C. t. 295. f. 3.
1	Mya calciformis -	Phill. t. 11. f. 3.
1	Modiola plicata -	M. C. t. 248.
2	——— gibbosa -	M. C. t. 211. f. 3.
1	Natica adducta -	Phill. t. 11. f. 35.
1	Ostrea Marshii -	M. C. t. 48.
2	—— solitaria - -	M. C. t. 468. f. 1.
	Pentacrinites.[x]	
1	Pholadomya Fidicula -	M. C. t. 225.
2	——— ambigua -	M. C. t. 227.
3	——— obtusa - -	M. C. t. 197. f. 2.
1	Pecten	Species undetermined.
2	——	
1	Plicatula	Species undetermined.
1	Plagiostoma punctata	M. C. t. 113. f. 1 & 2.
2	——— cardiformis -	M. C. t. 113. f. 3.
3	——— gigantea - -	M. C. t. 67.
4	——— Parkinsoni -	
1	Terebratula perovalis -	M. C. t. 429.
2	——— fimbria -	M. C. t. 436, f. 3.
3	——— obsoleta -	M. C. t. 326.
4	——— media -	M. C. t. 83. f. 7.
5	——— emarginata -	M. C. t. 83. f. 5.
6	——— globata -	M. C. t. 435. f. 6.
1	Unio abductus[y] -	Phill. pl. 11. fig. 42.

[x] Pentacrinite. A division of the family Crinoidea or lily-shaped animals which live at the bottom of the sea, attached to rocks. Called Pentacrinite from the five angled form.

[y] All the organic remains in this list consist of lost or extinct

Should the observer extend his range to the south-west, he may track similar strata, containing many of the same species of fossils, from Gloucestershire through Somersetshire, to the coast cliffs at Bridport, Dorsetshire, where he will see the beds laid bare, dipping under younger formations, and resting upon the *Lias*, as in the Cotteswold Hills. In like manner, if he follow these beds north-eastward, he will perceive them occupying the same position in the high and rugged cliffs between Scarborough and Whitby, in Yorkshire.[z]

IV. *The Lias.*

The Lias forms the sub-soil of the whole of the vale of Gloucester, extending from the Cotteswold Hills to the Severn. Like the Inferior Oolite, this formation may be followed to Dorsetshire on the south west, where it terminates at Lyme Regis,[a] and, to the north-east, at Whitby, Yorkshire.

species. In some of these the shelly matter is preserved, but in most it has perished, the greater number presenting only the internal mould or cast of the shell.

[z] See the Geological Map of England and Wales, by Mr. Greenough. Those who desire to obtain a full knowledge of the different localities in which the same species of fossils have been found, must consult the instructive tables in the "Geological Manual" of De la Beche (3rd edit. 1833). And to arrive at a clear view of the general connection of the deposits near Cheltenham, with the overlying and underlying rocks throughout the kingdom, the student must have recourse to the Geology of England and Wales, by Conybeare and Phillips, 1822.

[a] Every fossilist should visit the collection of Miss Mary

Near the latter place it is perhaps more fully developed than in any other part of the kingdom, and has there been divided into three parts.

1. *Upper Lias*, or *Alum Shale.*
2. *Marlstone.*
3. *Lower Lias Shale.*

This threefold division is applicable to the formation in Gloucestershire. The Upper Lias, or Alum Shale of Yorkshire, here consists of a blueish clay, containing occasionally nodules, or spherical concretions of dark argillaceous limestone, precisely similar to the "cement stones" of the Yorkshire coast. This sub-group ranges along the sides of the escarpment of the Cotteswold Hills, and may be most conveniently seen between the Dowdeswell turnpike-gate and Sandywell Park, where it has been cut through in making the new road to London. At this spot, about 450 feet above the sea, I collected in the year 1831 the following organic remains (*e* of the coloured section).

Anning, at Lyme Regis, who, by her talent and perseverance, has so materially contributed to our acquaintance with the organic remains of the *Lias*, especially in the class of those gigantic reptiles which characterize the formation. In Yorkshire, the Museums of York, Scarborough, and Whitby, are full of interesting fossils of the north-east of England, scientifically arranged. In Somersetshire the Museums of Bristol and of Bath are too well known to require any commendation; they are particularly rich in fossils of Oolite and Lias.

1 Arca, or Cucullæa? fragments.
1 Ammonites Walcottii M. C. t. 106.
2 ——— undulatus - Smith Strat. System. p. 114. M. C. t. 254. f. 1 & 3.
3 ——— annulatus - M. C. t. 222.
1 Belemnites acutus - M. C. t. 596. f. 7, 8, & 10.
2 ——— tubularis - Phill. t. 11. f. 27.
3 ——— penicillatus - M. C. t. 590. f. 5 & 6.
1 Gervillia. New species.
1 Inoceramus dubius - M. C. t. 584.
1 Lucina?
1 Modiola. New species?
1 Nucula. Do.
1 Nautilus.
1 Plicatula spinosa - M. C. t. 245.
1 Pholadomya
1 Trochus bisectus - Phill. t. 11. f. 27.

Where not exposed by any similar cut, the presence of this zone of clay, which in some places must have a thickness of sixty or seventy feet, is marked by the outburst of water, either in the form of springs, or as indicated by rushes and wet ground. It forms, in fact, the retentive support of all the rain water which percolates the overlying and porous strata of the Inferior Oolite, and thus gives rise to the river Chelt; to the seven springs, or chief feeders of the Thames; to the springs

which supply the Cheltenham reservoir; to those which in ancient times filled the Roman baths near Whitcomb; and to many other streamlets.[b]

The *Marlstone* (*f* of section) is made up of alternating layers of yellow and blue marly clays and sands, foxy-coloured sandstone, sometimes calcareous, and beds of impure limestone.

The most prevailing fossils are—

1	Avicula inequivalvis -	M. C. t. 224. f. 2.
1	Belemnites penicillatus	M. C. t. 590. f. 5 & 6.
1	Cardium truncatum -	M. C. t. 553. f. 3.
1	Gryphæa gigantea -	M. C. t. 391.
1	Pecten equivalvis -	M. C. t. 136. f. 1.
1	Terebratula tetraedra	M. C. t. 83. f. 4.
2	——— concinna -	M. C. t. 83. f. 6.

Numerous ravines, by which the western sides of the Cotteswold Hills are furrowed, open out a view of this sub-division; and near the town of Cheltenham it is clearly exposed in the deep and watery lane, which leads up from the farm of Southfield to the quarries on the north face of Leckhampton-hill. Here it would appear to be about 100 feet in thickness. The marlstone is also found near the summit of Battledown, that round and verdant

[b] I hope soon to present to the Cheltenham Institution the Ordnance Map of the environs, geologically coloured, by consulting which, this memoir will be rendered much more intelligible.

hill, which, rising to the east of Cheltenham, is separated by a depression from the main ridge of the Cotteswolds. A portion of the marlstone will afterwards be described in detail, when we come to the "outlier" Church Down Hill.

The *Lower Lias Shale*, (*g* of section) or great mass of the formation, occupies nearly all the Vale of Gloucester.

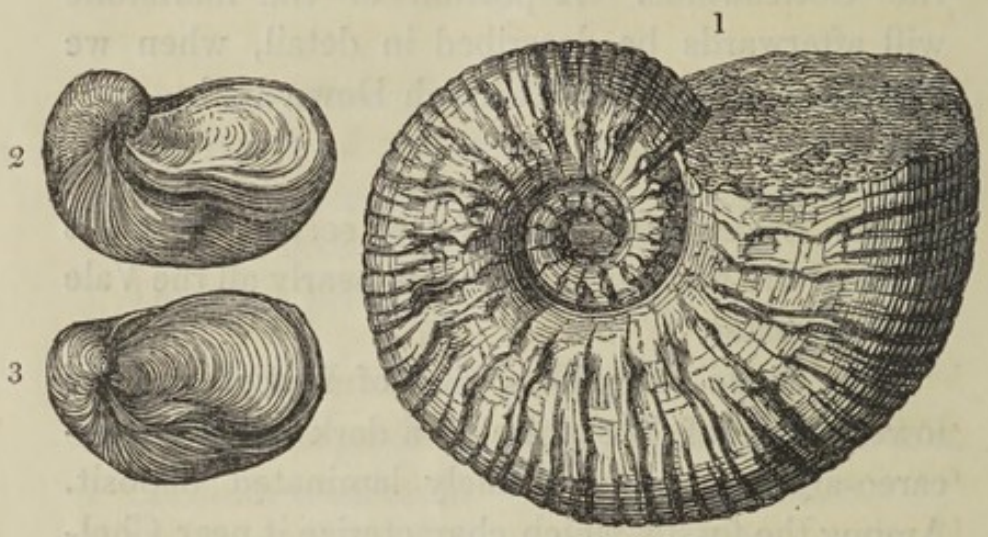
This Shale resembling that of Dorset and the lower Shale of Yorkshire, is a dark coloured calcareo-argillaceous and finely laminated deposit. Among the fossils which characterize it near Cheltenham, are found

Ammonites Cheltiensis. New species, and various other Ammonites, some very small.
1 Gryphæa obliquata - M. C. t. 112.
2 ——— incurva - Parkinson, Org. Rem. vol. III. t. 15. f. 3.
1 Hippopodium ponderosum [c] M. C. t. 250.
&c. &c. &c.

The Ammonite which I have named in honour of the town, is also found in the Lias of Lyme Regis in Dorset. It is represented in the following wood cut (fig. 1), together with the two

[c] This singular bivalve is called a "horse's or ass's foot" by the country people.

most characteristic bivalve shells, Gryphæa incurva (fig. 2), and G. obliquata (fig. 3).



I cannot offer a complete list of the organic remains of the lower shale of the Lias of this neighbourhood, the study of Geology not having yet become sufficiently popular in Cheltenham, to have induced individuals to make systematic collections. We may, however, now indulge a hope that in a district so very fertile in fossils, some assiduous collectors will soon supply this defect.[d] Their labours may bring to light specimens of those marvellous and large aquatic rep-

[d] The museum of the Philosophical Institution of Cheltenham, we may presume, will ere long exhibit a complete suite of the fossils of the neighbourhood. In the meantime, I may observe that S. Bendall, the intelligent chemical assistant in Mr. Thompson's manufactory of salts, has begun to collect in so zealous a manner, that I have little doubt he will soon add many undescribed species to our previous lists. His collection is open to the public.

tiles, so common in the Lias of other parts of the island the Icthyosauri and Plesiosauri, animals of extinct forms, partaking both of the characters of fishes and lizards; and as fine specimens of fish palates have been collected near the town, we may reasonably expect that some of the fishes of the formation, the Dapedium politum for instance, will soon be added to our list. It ought, however, to be borne in mind, that the opportunities of collecting fossils in the lower strata of the Lias have been rare; no deeper sections, with the exception of the wells at Cheltenham, having been made, than are required for the foundation of houses,[e] or the excavation of ponds and trenches. In recent sinkings to deepen the mineral spring near Tewkesbury, the Gryphæa incurva appeared to be by far the most abundant fossil, the Shale having been penetrated to the depth of 90 feet.

Specimens of the Ammonites Cheltiensis, which I found in pits near Charlton in great profusion, were covered with an iridescent nacre, and some of the associated cement stones, or concretions of argillaceous limestone, had been formed around a nucleus of Belemnites. Many of the layers of this shale near Cheltenham, are highly charged with

[e] The new and beautiful quarter of the town called Lansdown is built upon the Lower Lias Shale. In the excavations preparatory to the new buildings, I have frequently collected the Gryphæa obliquata in great abundance, and several species of Ammonites, &c. &c.

iron pyrites[f] (sulphuret of iron), and when the fossil remains are coated with this mineral, it generally gives to their surface that bright metallic lustre seen upon many of the ammonites. The lowest beds of the formation are laid bare at Comb Hill, five miles to the west of Cheltenham, where dark-coloured bands of flaggy limestone are underlaid by thick beds of white Lias, enclosed in layers of thinly foliated black shale. The hard dark-coloured bands are known in the country under the name of "Claystone," signifying that they are the only solid beds in this argillaceous deposit. These claystone bands are also cut into and quarried near the Plough Inn, on the road to Gloucester.[g]

On the right bank of the Severn, I observed (1831) several detached and outlying masses of Lias, resting upon the Marls of the New Red Sandstone, which, although they lie beyond the geographical limits of this memoir, are worthy of notice,

[f] A compound of iron and sulphur. The name is derived from the Greek word πῦρ, fire, because the mineral sometimes produces spontaneous inflammation.

[g] This "claystone" of the Lias was formerly employed as the only good road-stone; but the facilities afforded by water carriage and the tram roads, are now so great, that nearly all the high roads of the Vale are repaired with that limestone, which, by geologists, is termed the mountain or carboniferous limestone. It is brought from the neighbourhood of Bristol. Being much more free from earthy matter, and much more compact and crystalline than the claystone, it forms a more even and durable road.

because their existence had not previously been remarked, while they exhibit clear sections of the lowest beds of the formation, and some peculiarities in their structure. Corsewood Hill, two miles west of the Haw Bridge, is the most prominent example. Three distinct beds of compact lias-stone are there raised, for the purposes of paving, burning for lime, and road mending. These beds are subordinate to much stiff clay, and they are overlaid by several thin slaty layers of stone. The most abundant fossils are an undescribed species of Ostrea, and Modiola minima (M. C. T. 110. f. 5, 6, and 7). The marls of the New Red Sandstone surround the base of this hill, but their absolute junction with the Lias, or the passage of the one formation into the other, is better seen about two miles and a half west of Tewkesbury, on the road to Ledbury.

One of the new cuts, which has traversed a low hill, exposes the following beds in descending order, dipping 8 or 10 degrees to the East.

1. Grey coloured stone bands, 1 ft.
2. Thinly laminated shivery blue shale, 12 ft.
3. Slaty and stony blue layers, half-inch thick, charged with a profusion of small bivalves, probably Gryphææ or Ostreæ, and a Plagiostama, 6 in.
4. Dark blue shivery shale, as above, in parts pyritous, 10 ft.
5. Fine laminated micaceous white sandstone, with casts of shells, 8 in.

6. Dark blue shivery shale, with ochreous veins of decomposing pyrites, 4 ft.
7. Thin band of green marlstone.
8. Slaty green and red marls.

V. *New Red Sandstone (Red Marl*[h]*).*

This is the lowest formation which comes up to the surface in this vicinity. The place nearest to Cheltenham where it is best seen, is at Comb Hill, beyond the Gloucester and Tewkesbury road, in the descent to the canal. Red and green Marls, the upper members of the formation, are there overlaid by shivery Shales, and thin courses of stone, the lowest bands of the Lias formation; the whole dipping E. S. E., at angles of 12 to 15°. No organic remains have been discovered in the New Red Sandstone.

Such are the deposits which may be observed by any one passing across this district from East to West. They are all rocks of mechanical origin, and are made up of a prodigious number of beds or layers. Each formation possesses an individuality of mineral character; and, as we de-

[h] The term Red Marl is, in a geological sense, synonymous with New Red Sandstone. In this district the marly beds prevail.

scend in the series, we find the remains of animals differing from those which had been deposited in the beds of earlier age.

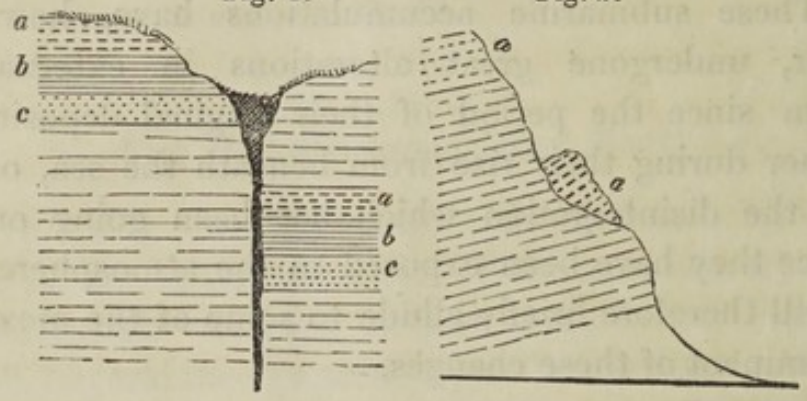
These submarine accumulations have, however, undergone great alterations in external form since the period of their original deposit, either during their rise from beneath the sea, or by the disintegration which has been going on since they have been exposed to the atmosphere. I will therefore briefly allude to some of the most prominent of these changes.

Dislocations.

Remarkable instances of disruption occur in many upland situations in the Cotteswold Hills; as, for example, in the depression between Cleeve Clouds and Nottingham Hill, on the side of the Hill above the Church of Dowdeswell, &c.; where the strata of Inferior Oolite dip in opposite directions, and at high angles of inclination. Many of these derangements are due to subsidences, occasioned by the undermining and consequent sinking of the soft and decomposing beds of the Lias; but a few are referrible to what geologists term "faults," dislocations which are invariably to be detected in all hilly regions. A correct knowledge of all their details in the Cotteswold Hills can only be obtained by long and patient research. I annex this wood-

cut to exemplify the nature of a fault[h] (fig. 1), and also of a slip or subsidence (fig. 2.)

Fig. 1. Fig. 2.



Outliers.

The hill of Church Down,[i] which from its insulated position presents so striking an object when viewed from Cheltenham, affords one of those examples of denudation[k] with which the Vale of Gloucester is replete. The quarries upon the tabular summit of Church Down Hill, are covered

[h] Fault is a geological and mining term, used to express a sudden break and displacement of the strata, the separated portions being found at different levels of the crack or fissure. Sometimes the faces of the displaced beds are parallel to each other, as in fig. 1, but frequently they are inclined in opposite directions.

[i] Pronounced Chosen by the inhabitants.

[k] This term denudation, in the language of geology, describes an action of water, which carrying away from the surface a certain portion of the solid materials of a deposit, lays bare the inferior parts : and when one mass of it is thereby left insulated from the rest, it is said to be an " outlier." (See the coloured section, fig. 2) [k]. Robin Hood's Hill, near Gloucester, is an " out-lier," similar to that of Church Down. Oxenton and Bredon Hills, north of Cheltenham, are outliers of the Inferior Oolite. Corsewood Hill is an outlier of the Lias.

with a few feet of yellowish sandy loam, containing some spheroidal concretions of hard calcareous grit, called by the workmen men's heads. These nodules resemble those which mark the lines of stratification in the Inferior Oolite in the coast cliffs near Bridport, Dorsetshire; and which I have described as occupying the same geological horizon in the Hebrides.[1] In this place they mark the former existence of a cover of the Inferior Oolite, which has been worn away. Beneath this sandy loam, the quarries in work, 1831, exhibited the following beds of the Marlstone of the Lias.

1. Lightish yellow micaceous sandstone full of Belemnites, 4 ft.
2. Pot-ears. Bluish gray calcareous grit, quarried for troughs, 1 ft. 6 in.
3. Pendle. Brownish hard calc grit, full of joints and fissures, 10 in. Wayboard of clay, with some fossils, 3 in.
4. Leathering-bed. Thick bedded very hard micaceous marlstone, of greenish brown colour, charged with fossils, of which Pecten equivalvis and Belemnites abbreviatus are the most abundant, 5 ft.
5. Best double Blue. Hardest and best roadstone, weathers to a brown colour, 1 ft. 3 in.
6. Lowest Blue. A blue limestone, or highly calcareous grit, partially discoloured by the decomposition of pyrites, 1 ft. 5 in.

[1] Transactions of the Geolog. Soc. New Series, Vol. II. p. 353.

Beneath this bed, the water stands upon the clay of the lower Lias, which occupies the sloping sides of the hills. A line drawn to the East, in the prolongation of the plane of the dip of these beds, would precisely fall upon that part of the escarpment of the Cotteswolds, where the strata of the Marlstone of the Lias, containing similar organic remains, occupy their regular place in the series. (See fig. 2 of coloured section.) It is therefore evident, that the intervening valley has been hollowed out subsequently to the formation of the Lias and the Oolite; or, in other words, that there was a period when the strata of the Cotteswolds extended in solid masses as far as Church Down Hill.

Gravel and Sand. (See the dotted rusty brown colour of section.)

The sand and gravel in the environs of Cheltenham have been derived from the breaking up and degradation of the adjacent rocks which have been described, and chiefly of the Inferior Oolite. In all the gravel pits near the town, we find many fossil shells, generally water-worn, which have been washed out of the neighbouring formations by the same aqueous action which produced the gravel. In certain depressions on the surface of the Lias, as for example in that between the High Street of Cheltenham and the Pittville Spa, all this detritus has been ground down into a finely comminuted yellow sand, upon which this new quarter of the town is building. A large quan-

tity of the same is also spread out to the West of the town, and also to the East towards Charlton. These accumulations are however all superficial, and belong to the class of Alluvial phenomena.[m] They are invariably based upon a substratum of blue Lias, various knolls of which rise up from beneath these small basins of sand and gravel. Besides the water-worn gravel and sand which has been deposited in the Vale of Gloucester, there is another and more recently formed variety of Alluvium, consisting entirely of angular fragments of the Inferior Oolite. Heaps of this rubbish, which have been washed down by storms and rain from the escarpments, often hide from view the real position of the uppermost members of the Lias on the sloping escarpments of the Cotteswold Hills. (See the section, fig. 1.)

Deposits from Springs.

This neighbourhood offers an example of a small deposit actually forming from a spring. The Chelt, which gushes out upon the upper clay of the Lias formation, after having percolated the calcareous strata of the Inferior Oolite in the manner before described (p. 17), is charged with a certain quantity of carbonate of lime held in solution, which it deposits in the early part of its course upon any substances over which it happens to flow. This process of incrustation may be observed in actual

[m] From the Latin "Alluvio," an overflowing, or inundation of water.

operation, on a small scale, below Sandywell Park, at the source of this river. The quantity of carbonate of lime held in solution is small, and upon the escape of the carbonic acid gas, the earthy residuum is only for a short space left adhering to and covering the contiguous moss or branches.[n] To these, which have been called petrifying springs, the term encrusting is more correctly applicable.

Origin of the Mineral Waters of Cheltenham.

It is singular that the true nature and geological position of the strata through which these celebrated waters rise, should not have been previously pointed out to the public. In one of the published analyses, the Cotteswold Hills are described as being made up of magnesian limestone, and the blue clay, through which the waters

[n] Springs holding in solution various proportions of carbonate of lime, which they deposit upon issuing to the atmosphere, are common in many parts of England. It was only, however, during a geological tour of last summer, that I became acquainted with a deposit of so large a size, resulting from one of those springs, as to merit the name of a rock of English Travertin. It is situated in Worcestershire, about eight miles E. of Tenbury, and is called the "Southstone Roch." It is 50 feet high, and of such dimensions as to afford space for a cottage and garden upon its surface. From its cavernous structure, it is called *puffstone* by the natives; and although solid enough for purposes of masonry, it contains imbedded snail shells of existing species (see proceedings Geol. Society, 1834). For full information on the subject of such modern deposits, consult Lyell's Principles of Geology. The word Travertin (Travertino of the Italians), is a corruption of the term lapis "Tiburtinus," the stone being formed in great quantities by the river Anio, at Tibur, near Rome.

ascend, is said to cover the limestone. That this clay, the lower Lias, passes beneath the calcareous rocks, is a fact now known to every geologist; and instead of the magnesian limestone (which, if it exists in the district, could only be found by penetrating to vast depths beneath the surface), the stone of the adjoining hills has been shewn to be the *Inferior Oolite*. Again, in a very recent work, the production of an able chemist, the waters are said to rise through the sand[o] of the Lias. It is therefore desirable to state distinctly, that the lowest marly and argillaceous beds of the blue Lias formation are really the strata through which these waters find their way to the surface. For a long time after their first discovery, it was the general belief that they had only one source, but the enterprise of Mr. Thompson proved this notion to be erroneous. By numerous sinkings, at depths from 80 to 130 feet, adjacent to and at considerable distances from the old springs, he established the fact, that many strata were saturated with water, holding in solution the chloride of sodium and the sulphates of soda and magnesia, and other mineral substances.

These sinkings were followed by others, at a distance of nearly two miles from the most distant wells of Montpellier, and the discovery of waters

[o] Thermal and Mineral Springs, by Dr. Gairdner, 1832, pp. 419. An excellent and useful work. The mistake in this case is that of confounding the superficial sandy detritus of the district, with the formation on which it rests. The Lias shale contains no beds of sand. (See p. 28. Gravel and Sand.)

of nearly the same composition, has led to the establishment of the New Spa of Pittville.

It is thus demonstrable, that the mineralization of this broad expanse of water must be due to causes co-extensive with the impregnated strata.

From the analyses of these waters, by several distinguished chemists, it appears that their principle constituents are the chloride of sodium (muriate of soda), or sea salt, and the sulphates of soda and magnesia. Sulphate of lime, oxide of iron, and chloride of magnesium, are present in some wells only, and in much smaller quantities.[p] It is remarkable that the proportions in which these substances occur is stated very differently by different chemists, a circumstance which most probably arises from the waters themselves varying in composition. Besides the ingredients just mentioned, Iodine and Bromine have been detected in several of the sources by Dr. Daubeny.[q] That gentleman was desirous of ascertaining whether these two active principles, which the French chemists had recently discovered in modern marine productions, did not also exist in mineral salt waters, issuing from strata which were formed be-

[p] The waters were formerly analysed by Brande and Parkes, subsequently by Drs. Scudamore and Daubeny. Professor Daniell has examined those of Pittville, and Mr. Cooper has recently made a very elaborate analysis of those of Montpellier, with the details of which I am not acquainted. His observations, I believe, coincide with those of Dr. Daubeny, in the detection of Iodine and Bromine.

[q] Philosophical Transactions, May 1830.

neath the sea. This examination has established their existence not only in the waters of Cheltenham, but also in the greater number of the salt-springs of Great Britain.

The great subterranean storehouse of the rock salt and brine springs of England, is the New Red Sandstone (or Red Marl),[r] a formation which is fully developed in Cheshire and the east of Shropshire. It extends from thence to the S. W. through Worcestershire and Gloucestershire, where its position, with respect to the overlying Lias of Cheltenham, has been explained. (See fig. 1, coloured diagram).

Now, if sea salt be the most abundant saline ingredient in all the mineral waters of Cheltenham, it is present in still larger quantities in those wells which occur near the western edge of the formation, where the Lias forms only a thin covering above the marls of the New Red Sandstone. At the new spa near Tewkesbury, where formerly the mineral water at shallow depths below the surface was very slightly saline, it was recently found to be much more impregnated with salt when the sinking was carried to the depth of 90 feet; and I have no doubt that a similar result would follow, by deepening any of the mineral sources which are so numerous in the Vale of Gloucester, at Walton, the bottom of Church

[r] See the memoir of Dr. Holland, Geol. Trans. vol. i. p. 38, and that of Mr. L. Horner, vol. vi. p. 95, Old Series.

Down Hill, for instance, &c. &c. Again, at Cheltenham, when experimental borings were made by Mr. Thompson, to the depth of 260 feet below the surface, the water of the lowest stratum of marl or clay was found to be more highly charged with the chloride of sodium, or common sea salt, and to contain less of the sulphates, than the existing wells, none of which have been sunk to a greater depth than 130 feet.

These facts may be accounted for under the supposition, that the source of the saline ingredients of those waters, is the New Red Sandstone, the uppermost strata of which must, from their known inclination, lie at depths of several hundred feet below the town of Cheltenham. The lower part of the coloured section, fig. 1, explains this rise of the waters. If this be the case, and that saline waters are continually flowing upon the inclined surfaces of these beds, we can readily explain why they occasionally rise to the surface; for waters collected in the New Red Sandstone at higher levels than the surface of the Vale of Gloucester, would naturally ascend to their original level by any cracks or open veins which might present themselves in the overlying Lias.

The salt water having to pass through various strata of marl and clay, loaded with iron pyrites, or sulphuret of iron, it is to be presumed that during this passage certain chemical changes take place, which give to the waters their most valuable medicinal qualities. The most important process

in this moist subterranean laboratory, would be the decomposition of the sulphuret of iron, which supplies a large quantity of sulphate of the oxide of iron, a process which must be highly accelerated by the structure of these incoherent and finely laminated beds, through which the pyrites is so very widely disseminated. The sulphuric acid, thus generated, will necessarily react on the different bases, such as magnesia and lime, which it may meet with in the strata, and form those sulphates so prevalent in the higher or pyritous beds of the Lias, the oxide of iron being at the same time more or less completely separated. By such means, it is presumed that these mineral waters, which are principally brine springs at the greatest depths, acquire additional and valuable properties in their rise. In suggesting this explanation, we must not, however, overlook the fact, that fresh water is perpetually falling from the atmosphere upon the surface of the Lias clay, more or less percolating its uppermost strata. Many of the saline springs must therefore be somewhat affected by this cause, and the existing condition of the various wells of Cheltenham may ultimately depend upon three causes :—

1. The supply of salt water from the inferior New Red Sandstone, in the manner above described.

2. The chemical action produced during the filtration of water through the variously constituted strata.

3. The supply of fresh water from the atmosphere.

The chemical relations, and medicinal virtues of these celebrated waters, have been well described in other treatises, and they have only been mentioned in this place to convey a clear notion of their origin, and their connection with the geological structure of the district.

Heights above the Sea at Low Water.

Cleeve, or highest point of the Cotteswold Hills, as determined by the Trigonometrical Survey, 1,134 feet.

Leckhampton Hill, about 900 feet.

Dowdeswell (at cross roads), about 500 feet.

Church Down Hill, about 500 feet.

High Street, Cheltenham, about 100 feet.

THE END.

J. B. NICHOLS AND SON, 25, PARLIAMENT STREET.

POSTSCRIPT.

THROUGH inadvertence, three species of fossil shells, of the uppermost strata of the Inferior Oolite, or Gryphite grit, have not been enumerated, viz.—

	Ostrea Marshii	- M. C. t. 48.
1	Trigonia costata	- M. C. t. 85.
2	——— striata	- M. C. t. 237. f. 1, 2, 3.

Since the Memoir was printed, a box, containing fossils found in the environs of Cheltenham, has been forwarded to me. The greater number of these specimens belong to the Literary and Philosophical Institution, and were collected by Mr. Thompson and Mr. Holdsworth. A few are from the museum of John Bendall.

Some of these organic remains are identical with those which characterize the same formations in distant parts of Great Britain; others, as might have been anticipated in exploring this hitherto neglected neighbourhood, are undescribed. The new species will be drawn, named, and published, by Mr. J. Sowerby, in the supplement to his work, "Mineral Conchology."

List of additional Fossils.

Inferior Oolite.

Ostrea and Trigoniæ, as above named.

1 Ammonites Brownii - M. C. t. 263.

2 ——— N. S.

Clypeus, an unpublished species.

Gervillia. Not published in any English work, but the species occurs in rock of the same age in Normandy.

Ostrea acuminata - M. C. t. 135.

Plagiostoma, N. S.

Besides these, there are casts of other shells, apparently undescribed.

Lias.

1 Ammonites
2 ———
3 ———
4 ——— *

All of undescribed species, as well as the A. Cheltiensis, which I have named, p. 19. The small species, so abundant in the clay of Lansdown, most resembles A. arcigerens, Phillips, pl. 13. f. 9.

Astacus. New species.

Avicula * inequivalvis M. C. t. 244.

1 Belemnites * elongatus Miller.

2 ——— * abbreviatus M. C. t. 590. f. 2, 3, & 9.

Crenatula † ventricosa M. C. t. 443.

1 Cucullæa † elongata - t. 447.

2 ——— N. S.

Pentacrinites * scalaris. Goldfuss.

1 Pecten * N. S.

2 Pecten * N. S.
3 ——— * N. S.
Plagiostoma antiquata * M. C. t. 214.
Serpula, N. S.
Spirifer.
Turritella muricata ? * - M. C. t. 499.
Unio.

Dorsal vertebræ of the Icthyosaurus have also been found.

The specimens marked (†), were found in the clay of the Leckhampton brook, near the base of the hill, and therefore most probably belong to the upper division of the Lias. The same may be said of the Serpula, which, together with a very beautiful species of Ammonite, still retaining its shelly matter, was found in blue Marl, alternating with clay, in the brick yards at the foot of Leckhampton hill.

The specimens marked (*), are from the Lower Lias, a few having been found in the Lansdown clay; others, particularly the undescribed Pectens, flattened bivalves too imperfect to name, Belemnites elongatus, and Spirifer, &c., are from well-sinkings at depths of thirty-five to fifty-six feet below the surface, on the property of Mr. Jones.

The vertebræ of the Icthyosaurus were collected by John Bendall, who has also procured a new species of Astacus, one of Unio, and two new species of Ammonites, all of which are from the Lias formation.

The Astacus (a genus including the common lobster,) will be drawn and figured by Mr. Phillips, under the name of A. glaber.

Small portions of lignite, in the state of jet, precisely resembling that of Whitby, were brought up from the lower Lias, in sinking a well near the Laboratory.

ERRATA.

Page 8, Note *l*, *for* "classification of the *oolite species*," *read* "classification of the *oolitic series*."

—— 10, *for* "ndefinite" *read* "indefinite."

—— 14, *for* Isocardia costata, *read* Isocardia *rostrata*.

——— *for reference to* Plagiostoma gigantea, *read* t. 77.

——————— Terebratula perovalis, *read* t. 436. f. 2 & 3.

——————— Terebratula fimbria, *read* t. 326.

——————— Terebratula obsoleta, *read* t. 83.

——————— Terebratula emarginata, *read* t. 435, f. 6.

——————— Terebratula globata, *read* t. 436, f. 1.

Page 16, ——————— Belemnites acutus, *read* t. 590.

—— 18, ——————— Avicula inequivalvis, *read* t. 244.

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