*with the author's kind regards*

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# ADDRESS

DELIVERED AT

## THE ANNIVERSARY MEETING

OF THE

# GEOLOGICAL SOCIETY OF LONDON,

*On the* 16*th of* February, 1872;

PREFACED BY

THE ANNOUNCEMENT OF THE AWARD

OF

## THE WOLLASTON MEDAL

AND PROCEEDS OF THE DONATION-FUND

FOR THE SAME YEAR.

By JOSEPH PRESTWICH, F.R.S., &c.,
PRESIDENT OF THE SOCIETY.

LONDON:
PRINTED BY TAYLOR AND FRANCIS,
RED LION COURT, FLEET STREET.
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# PROCEEDINGS

AT THE

## ANNUAL GENERAL MEETING,

## 16TH FEBRUARY, 1872.

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AWARD OF THE WOLLASTON MEDAL.

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THE Reports of the Council and of the Committees having been read, the President, JOSEPH PRESTWICH, Esq., F.R.S., handed the Wollaston Medal to DAVID FORBES, Esq., F.R.S., Sec. G.S., for transmission to Professor DANA, of Yale College, Connecticut, addressing him as follows :—

Mr. FORBES,—I have the pleasure to announce that the Wollaston Medal has been conferred by the Council of the Society on Professor Dana, of Yale College, Newhaven, U.S.; and in handing it to you, in the absence of our Foreign Secretary, Professor Ansted, for transmission to our Foreign Member, I beg to express the great gratification it affords me that the award of the Council has fallen on so distinguished and veteran a geologist. Professor Dana's works have a world-wide reputation. Few branches of geology but have received his attention. An able naturalist and a skilful mineralogist, he has studied our science with advantages of which few of us can boast. His contributions to our science embrace cosmical questions of primary importance—palæontological questions of special interest—recent phenomena in their bearings on geology, and mineralogical investigations so essential to the right study of rocks, and especially of volcanic phenomena. This wide range of knowledge he brought to bear in the production of his excellent Treatise on Geology, one of the best of our class books, embracing the elements as well as the principles of geology. His Treatise on Mineralogy exhibits a like skill in arrangement and knowledge in selection. In conveying this testimonial of the high estimation in which we hold his researches to Professor Dana, may I beg also that it may be accompanied by an expression of how strongly we feel that the bonds of friendship and brotherhood are cemented amongst all civilized nations of the world by the one common, the one universal, and the one kindred pursuit of truth in the various branches of science, before which special nationality is lost in that general nationality which groups all things and all men under one banner in the study of God's works.

Mr. David Forbes, in reply, said that it was to him a great pleasure to have, in the name of Prof. Dana, to return thanks to the Society for their highest honour, and for this mark of the appreciation in which his labours are held in England. It had rarely if ever occurred in the history of the Society that the Wollaston Medal had been awarded to any geologist who had made himself so well known in such widely different departments of the science; for not only was Prof. Dana preeminent as a mineralogist, but his numerous memoirs on the Crustaceans, Zoophytes, coral islands, volcanic formations, and other allied subjects, as well as his admirable treatise on general Geology, fully testify to the extensive range and great depth of his scientific researches.

At a moment when political troubles threaten the amicable relations so long existent between the two countries, it was a further source of gratification to see, in this award of the Council, not only a token of scientific amity, but also a proof that in science at least no other considerations than those of true merit are allowed to sway.

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### Award of the Wollaston Donation-fund.

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The President then presented the Balance of the Proceeds of the Wollaston Donation-fund to Professor Ramsay, F.R.S., F.G.S., for transmission to James Croll, Esq., and addressed him as follows:—

Professor Ramsay,—The Wollaston Fund has been awarded to Mr. James Croll, of Edinburgh, for his many valuable researches on the glacial phenomena of Scotland, and to aid in the prosecution of the same. Mr. Croll is also well known to all of us by his investigation of oceanic currents and their bearings on geological questions, and of many questions of great theoretical interest connected with some of the large problems in Geology. Will you, Prof. Ramsay, in handing to Mr. Croll this token of the interest with which we follow his researches, inform him of the additional value his labours have in our estimation, from the difficulties under which they have been pursued, and the limited time and opportunities he has had at his command.

Prof. Ramsay thanked the President and Council in the name of

Mr. Croll for the honour bestowed on him. He remarked that Mr. Croll's merits as an original thinker are of a very high kind, and that he is all the more deserving of this honour from the circumstance that he has risen to have a well-recognized place among men of science without any of the advantages of early scientific training, and the position he now occupies has been won by his own unassisted exertion.

## THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

JOSEPH PRESTWICH, Esq., F.R.S.

GENTLEMEN,—The satisfaction with which we can look back at the progress of our Society during the past year is, I regret to say, clouded by the recollection of our many and great losses. Our obituary list is unusually heavy, and contains in it the names of some of our oldest, most valued, and most distinguished members. Our losses have indeed been irreparable. Foremost amongst those the Society has to deplore stands the name of

SIR RODERICK IMPEY MURCHISON. Born in 1792 at Tarradale, in Ross-shire, he was educated for the army at the Royal Military College of Great Marlow, and obtained a commission in the 36th Foot in 1807. In the following year he accompanied his regiment to the battle of Vimiera, and shared in the hardships of the retreat on Corunna. At the siege of Cadiz he served on the staff of his uncle, Sir Alexander Mackenzie, and was afterwards promoted to a captaincy in the 6th Dragoons. After the war he quitted the army; and in 1815 he married the daughter of General Hugonin, whom he survived only two years.

Reared in the midst of the old Palæozoic rocks, his future great geological field—brought successively amongst the basaltic hills of the capital of Scotland, the Coal-measures of Durham, the Chalk downs of Marlow and Petersfield, and the peculiar scenery of the Peninsula, it may be presumed that one so observant as Roderick Murchison could hardly fail to have noticed the varying features produced by varying geological structures, and the integrity of each rock mass over large areas. The mine so laid would only want a spark, and this was supplied by the tastes of his wife, and by his attendance at the lectures of the Royal Institution. Old recollections, later teachings, the freedom of travel, and the many then unconquered fields of geology, fortunately led him to the study of our science. In 1825 he was elected a Fellow of this Society, and in the same year contributed his first paper—a paper followed up with indefatigable industry during the next forty-six years by a succession of some 120 separate or joint papers and works on geology. This early communication was on the Geology of the north-west of Sussex and parts of Hampshire and Surrey—a clear and useful paper, followed up some years afterwards by another relating to the "Drift" (a good general, although possibly temporary, term suggested by him) of the same and adjacent district of the Weald and the Downs. This latter paper is full of observations; but the hypothesis offered in explanation of them has been questioned. Mr. Murchison turned his attention, with Sedgwick, to the Oolitic and Coal strata of the north of Scotland—subjects eclipsed by his subsequent discoveries, but his papers on which are excellent specimens of geological work, and first drew attention to the fact that the Oolitic series occasionally contained beds of productive coal. He then travelled on the Continent, sometimes with Sir Charles Lyell, and at others with Professor Sedgwick; and their joint work appears in several important papers in our Transactions and elsewhere. It was on these occasions that he learned to attach so much value to the teachings of Von Buch. His interesting papers on the Fossil Fishes of the Bituminous Schists of Seefeld, and on the Fossil Fox of Œningen, were also part of the result of his foreign travels. All this time he was engaged, at the suggestion, I understand, of Dr. Buckland, upon the great investigation as to what was the order of succession of our older rocks—an investigation which resulted in the celebrated elaboration of the Silurian system in 1831 and 1834.

William Smith had before established, with remarkable skill and sagacity, the order of succession of the Tertiary and Secondary rocks—a very great work, especially when we consider that it was all done single handed; but of the rocks below the Mountain Limestone little was known. Here, and on the Continent, they were designated "*en bloc*" as "Transition rocks;" and the general term "Greywacke" was employed to denote their common lithological character. As these rocks are almost always greatly disturbed, faulted, and altered by metamorphic action, the work of unravelling their hitherto unknown order of succession was attended with very great difficulty, and afforded a fitting problem for the best geologists of the day. The obscurity which prevailed in this section of the geological series was finally dispelled by the researches of Mr. Murchison and Professor Sedgwick, the results of which were detailed in a series of remarkable papers communicated to this Society. The labours of the former were chiefly directed to the border counties of England and Wales, where he found a more regular sequence of strata and much excellent local knowledge available for the master mind; while those of the latter were carried on among the more complicated rocks of the Lake-district of England, and in the more central and westerly districts of North Wales. Working from these different base-lines, the one established the Silurian system, the other the Cambrian system—two great divisions of the older Palæozoic rocks, the exact boundaries of which have probably yet to be settled. The importance of the Silurian system was at once recognized. From its home in Shropshire, Herefordshire, and Monmouthshire, it has been traced not only over Europe but over the whole world. Everywhere the terms and often the divisions of Murchison have been accepted; and but little has been added to the structure originally designed by him. The summary of the results of his successful investigations appeared in 1836, in a separate work entitled 'Silurian System,' in the palæontological sections of which he was ably assisted by Robert Brown and James de Carle Sowerby.

Almost concurrent with the establishment of the Silurian system was that of the Devonian system by Murchison and Sedgwick. They were the first to show that the Old Red Sandstone of Herefordshire was of the same age as the Limestones of Devonshire; and extended observations on the Continent enabled them to confirm the independence of the Devonian system. It shows, it is true, relations both to the Carboniferous and to the Silurian systems: but that does not destroy its independence as a stratigraphical division; for it must be borne in mind that such divisions, as marking measures of consecutive periods of time, must always be in some degree arbitrary.

Mr. Murchison's numerous observations on the Red Sandstone series of Worcester and adjacent counties, next led him not only to suppose that the lower divisions, including the Magnesian Limestone, already well characterized by Phillips as containing Palæozoic fossils, should be associated with Palæozoic rather than with Mesozoic rocks, but to conclude, both from organic remains and from physical features, that they should be formed into a separate *system*. A journey to Russia enabled him to investigate the same series of rocks in the district of Perm, where they are very largely developed; and in 1841 he proposed for them the designation of Permian system—a division now generally accepted equally with the Silurian system.

In 1840 he visited Russia, in company with the distinguished French geologist, M. de Verneuil; and on the invitation of the Emperor of Russia they undertook, accompanied by Count Keyserling, a more extended survey in 1841. They traversed the country from the borders of Germany to the Ural Mountains, and from Archangel to the Black Sea. The result of these researches appeared in 1854, in the great work entitled the 'Geology of Russia and the Ural Mountains,' by Murchison and his colleagues. In the first volume he gives the history and survey of the great empire which he had explored, while the second volume, which is in French, contains a description, with illustrations, of the Palæozoic fossils by M. de Verneuil, and of the Jurassic and other fossils, by M. Alcide D'Orbigny. It was from observations made during this journey in the goldfields of the Ural Mountains, that Murchison was led to infer, with great sagacity, the probable existence of gold in Australia. The conclusion was based upon the analogy which he recognized between the mountain-system and rocks of the Ural and those of Australia. Unknown to Sir Roderick, the actual discovery of gold had, however, been known to Count Strzelecki, Sir Thomas Mitchell, Mr. Hargreaves, and probably to others a few years previously; but it had up to that time led to no results.

To determine the extent and structure of the Silurian and Devonian rocks elsewhere than in England, Murchison, now Sir Roderick, made several journeys over large portions of Europe, on some of which occasions he was accompanied by Prof. Morris and Prof. Rupert Jones. The result of these researches appeared in 1854, in his other great work, 'Siluria,' which gives an admirable account of the history of our globe during these early palæozoic periods. This work has gone through three editions, has been translated into various languages, and will long remain a monument of the power so eminently possessed by its author of deciphering complicated rock-masses, and assigning to each its true stratigraphical position and palæontological value.

Among Sir Roderick's later achievements were his bold and able generalizations on the very disturbed and perplexing series of older rocks of the north-west of Scotland. From amidst the confusion he eliminated a base, and showed that at the bottom of all the Scottish rocks there was a series of gneissose schists, distinct in character from the overlying unconformable strata, and which he identified with the Laurentian series of Northern America.

In 1855 Murchison succeeded Sir Henry de la Beche as Director-

General of the Geological Survey and of the Museum of Practical Geology; and under his superintendence, by the energy and skill of the efficient staff connected therewith, the work of the Survey has been carried on with all its pristine vigour and success. He was consulted by the Government in many cases, especially in connexion with the Coal Commission, of which he was one of the most influential members. He presided over Committee D, and assisted greatly in furthering to the fullest extent every branch of the inquiry; and he adhered to the last to the opinions he originally expressed at Nottingham, respecting the non-existence of Coal under the newer formations of the South of England.

The British Association also owes much of its present prosperity to the zeal and perseverance of Sir Roderick during its earlier years. He was one of the first to volunteer his support, and for years he was rarely absent from its meetings. He long acted as general Secretary, and he presided over the meeting held in Southampton in 1846.

Conjointly with his position amongst the leaders of geological science, he took a most prominent part in the cause of geographical exploration and in the action of the Royal Geographical Society. For more than a quarter of a century Murchison was untiring in his efforts to promote geographical science, and distinguished himself by his energy, faith, and zeal in the cause of Franklin and Livingstone. From 1844 to the time of his death he was almost perpetual President. The numerous addresses delivered by him during that period show how extensive his reading and inquiry were, and how thoroughly, aided by the friendly cooperation of others, he made himself master of the subject. Even his last illness did not prevent his writing the address of 1871.

Sir Roderick acted as Secretary to our Society from 1826 to 1830, and was Foreign Secretary during 1828 and 1829. He was twice President—in 1831–32, and again in 1842–3. On his temporary retirement from the Council in 1864, that body took the opportunity to award him the Wollaston Medal, "in recognition of his contributions to Geology as an inductive science." His last act in connexion with our Society was his legacy of £1000, the particulars of which you have heard announced this morning, and which will in future years serve, I trust, to excite the emulation and zeal of many generations of young geologists. Another act in furtherance of our science was his liberal donation of £6000 to found a chair of Geology in the University of Edinburgh, which he lived to see so successfully inaugurated.

Sir Roderick Murchison entered upon the study of geology at a time when its great structural framework had to be completed, and he was truly the right man in the right place. His large fortune, which enabled him to give time to make, and travel to extend, his observations, his quick and intuitive perception of the leading features of a country, his broad and clear views and powers of generalization, his command and judicious use of the best palæontological evidence, his untiring energy and indefatigable zeal, his social position, his conscientiousness and amiable character constituted a great power, which, notwithstanding a tendency to geological conservatism, has had a large share in the wonderful advance made in geology during the last half century, and has served to establish its very foundations on a sure and sound basis. Who among us also can forget the charm of manner, peculiarly his own, his kindly and encouraging expressions to younger geologists especially, and his admirable temper, or not feel how much by his example and otherwise than by his works he has advanced the cause of geology, and helped to promote the interest, wellbeing, and good fellowship of this Society. At the commencement of Sir Roderick's geological career, opinions prevailed with respect to the former energy of physical forces, and the rapidity of geological changes, which are now not generally held in this country; but it may be a question, while admitting the necessity of modification, whether geological opinion has not in some cases run to an opposite extreme. Sir Roderick was always a consistent and able supporter of the more moderate views of the older school.

Murchison received many foreign honours and distinctions, was knighted in 1846, created a Companion of the Order of the Bath in 1863, and had a Baronetcy conferred on him in 1866. He was a Trustee of the British Museum, and had the honour of being elected an Associate of the French Institute. He was also a member of the greater number of the scientific Societies of Europe and America, and held honorary degrees of the Universities of Oxford, Cambridge, and Edinburgh.

Full of honours, full of years, Sir Roderick has passed away from us. It will probably be long before his place will be filled; but his memory will still remain among us endeared by many pleasant recollections of the man, in pleasant work in the new fields he opened to us, and in the completion of the edifice, in laying the foundations of which our late colleague had so large a share. He died on the 22nd of October, 1871, and lies buried with his wife in Brompton Cemetery.

William Lonsdale was born in 1794. At the age of sixteen he obtained a commission in the 4th Regiment, and served with it at the battles of Salamanca and Waterloo, for both of which he received medals. At Waterloo he was the only officer in his regiment who was not wounded. After the war he retired from the army and devoted himself to scientific pursuits, first in connexion with the Literary and Scientific Institution of Bath, and afterwards in London as Assistant-Secretary and Curator of the Geological Society from 1829 to 1842, when he resigned in consequence of the enfeebled state of his health.

Lonsdale's early contributions to geology related to the Oolitic districts of the west of England. He afterwards took up the investigation of fossil Corals, and was the first to detect the peculiarities of the fossils of the Limestone of South Devon, which led to the establishment of the Devonian system. He was also amongst the first to direct attention to the use of the microscope in geological work; and by its means he detected to how great an extent microscopic life had helped to build up the Chalk. The Polyparia of some of the American Miocene and Eocene formations were described by him in our Journal, as were also some of the Corals of the Lower Greensand.

It was not only, however, by his original papers that Lonsdale contributed to the progress of geology, but it was as much also by his unwearied and devoted cooperation with other geologists in their own special work. Those who remember the Society in the days of his Assistant-Secretaryship will never forget the unceasing and manifold labours to which he devoted himself for its interests, nor the patient and valuable assistance he was ever ready to render to such as sought his counsel and advice. Too many nights, indeed, were, I know, given up by him to these disinterested and friendly offices. The unseen hand and the thoughtful head may be felt and recognized in many of the important papers which then appeared in our 'Transactions.'

Added to a great knowledge of geology and palæontology, Wm. Lonsdale was endowed with extreme caution, and had a keen sense of the importance of using, in scientific papers especially, as few words as possible, whence a free use of the scissors was generally granted to him, by many of the then great leaders in geology, in consequence of their high opinion of the sound judgment and discrimination of their able Assistant-Secretary. To this he added much taste and accuracy in literary composition. The system then adopted of publishing the more important papers in the 'Transactions,' and abstracts of others in the 'Proceedings,' had probably the advantage of leading to greater brevity in text, clearer illustration in sections, and the winnowing of a not inconsiderable amount of irrelevant matter, redundant description, and loose speculation. The condensed and readily available statement of facts recorded in the 'Proceedings,' and the excellently illustrated selection of longer papers in the 'Transactions,' may well serve as examples of the publications of a great learned society.

Lonsdale was elected a Fellow of the Society in 1829. On three occasions, in 1832, 1844, and 1849, the proceeds of the Wollaston Fund were awarded to him, in aid of his geological investigations of the Oolites, and to assist in promoting his researches on fossil Corals; and in 1846 he was awarded both the Wollaston Medal and Fund "for his many valuable contributions to geological science, and more especially for his description of the Corals in the Silurian and Devonian rocks, for his later Report in the first volume of the 'Quarterly Journal' on the Corals from the Tertiary formation of North America, and for his description of the Corals from the Palæozoic formations of Russia." His great abilities were accompanied by great modesty. His friends alone knew how many were his unrecorded labours. He was of a most retiring disposition, and after leaving London he so withdrew from the Society that even his address often remained unknown to his friends. He has, however, not been forgotten, nor has his influence ceased to be felt; whilst the memory of William Lonsdale will be treasured by those who had the privilege of ranking among the friends of that able and thoroughly disinterested man. He died in November last, at the age of 77.

The Rev. James Yates was born in 1789, and was educated at the Universities of Glasgow and Edinburgh. In 1817 he was appointed minister of the Unitarian Chapel at Birmingham, built on the site of the one formerly belonging to Dr. Priestley, but retired in 1825. He afterwards travelled much on the Continent, and for a short time had charge of a congregation in Little Carter Lane. In 1819 he was elected a Fellow of this Society; and his name appears in connexion with several papers in our early publications, the most important being one on the rocks of the border counties of England and Wales. He also published an elaborate paper "On the Formation of Alluvial Deposits," in which he showed, on theoretical grounds, that, from the structure of some valley-gravels, they must be regarded as old alluvial deposits; and more lately he wrote an interesting memoir "On the excess of water in the region of the earth about New Zealand." But the natural-history inquiry of most interest in which he was engaged, was connected with the study of the Cycads, both fossil and living. His valuable collection of living species was the largest private collection existing, and was always opened in the most courteous and obliging manner for study to the geologist and botanist.

Mr. Yates took an active part in the foundation of the British Association, but of late years he was best known in connexion with the question of a uniform international decimal system of coins, weights, and measures. He devoted himself to it regardless of time and expense, and published a large series of pamphlets on the subject, for one of which he was in 1851 awarded the Telford Medal of the Institution of Civil Engineers. He was also a good classical scholar, and contributed many papers on ancient art and other subjects. His pleasant garden gatherings of scientific men at Lauderdale House, Highgate, will long be remembered. His death took place on the 7th May, 1871.

Sir Thomas Dyke Acland, Bart., was one of our oldest members, having been elected in 1818. He brought before the British Association in 1847 a notice of some of the phenomena connected with the Suldan glacier. He was born in 1781, and died in July last.

Sir John Herschel. This great philosopher—one of a race of philosophers—was born at Slough in 1792. In 1809 he entered St. John's College, Cambridge, where he was contemporary with Babbage, Peacock, and other illustrious men. He took the highest honours, and graduated as Senior Wrangler. This is not the place to notice the invaluable services rendered to mathematical and astronomical science by Herschel. These have been enumerated in the last obituary notices of the Royal Society. I will confine myself to his geological work, to which, in early life especially, he gave a good deal of attention.

In 1826 he was elected a Fellow of our Society; and several contributions from his pen have at intervals appeared in our publications. That "On the Astronomical causes which may influence Geological Phenomena" entered into the consideration of the possibility of any changes of climate arising from the varying eccentricity of the earth's orbit. The reasoning of the author upon the effects which result from the excess of eight days in the duration of the sun's presence in the northern hemisphere over the southern hemisphere has been too much overlooked in the discussion of the problem during the last few years. Sir John concluded that that difference alone was not productive of an excess of annual heat and light. In other papers he has discussed the questions of the temperatures of the surface as well as of the interior of the earth, and shown what were the causes which might influence the secular variations of the isothermal surface of the earth's crust. He wrote also on metamorphic action, on slaty cleavage, on some of the phenomena of glaciers, and on the internal temperatures of large masses of ice and snow. In his 'Physical Geography' various subjects bearing on geology are treated of and merit great attention; but the passages respecting ocean-currents and temperatures have been shown by recent researches to require modification. His review of the position, objects, and rank of geology, in his admirable 'Discourse on the Study of Natural Philosophy,' is a chapter which all geologists ought to make themselves acquainted with. Of late years some admirable notices of geology have appeared from the hand of Herschel in some of the popular periodicals of the day. He was created a baronet in 1838, and appointed Master of the Mint in 1850. In 1855 he was nominated one of the eight foreign Associates of the French Academy of Sciences, and was a member of almost every scientific society of Europe. He died on the 11th of last May, at the advanced age of 79.

George Grote, the distinguished and philosophical historian, was elected a Fellow of this Society in 1843. His historical labours have been recorded in the obituary notice published by the Royal Society. It was in the countenance and aid he gave to the advancement of the natural sciences generally that his influence in this Society has been felt.

Mr. Grote took an active part in the foundation of the London University, afterwards called "University College." At that time there were in London no courses in the natural sciences adapted to the general student. Even at the College there was at its first starting no chair of geology, and the only information to be obtained on the subject was from a few supplementary lectures attached to the courses of chemistry and zoology. Many of the men who of late years have been contributors to some of the various branches of the natural sciences, myself among the number, received the elements of their scientific education at that institution, of which Mr. Grote was of late years the indefatigable President. He was also from the first on the Senate of the University of London, and acted as Vice-Chancellor since 1862. He was likewise a Trustee of the British Museum and a member of the French Institute. Mr. Grote was born at Beckenham in 1794, died in June 1871, and rests, with Herschel, in Westminster Abbey.

Robert Chambers was born at Peebles in 1802, and from his boyhood to his death distinguished himself by his active and unwearying efforts in the interests of education, literature, and science for the people, in which he was eminently successful, and by which he and his brother, Mr. William Chambers, have conferred on the many a boon which almost assumes national proportions. Their 'Edinburgh Journal,' started in 1832, had an immense success, and yet survives in active vigour and utility. Their Educational Course, of from fifty to sixty volumes, contains some of the cheapest and best popular rudimentary works on science.

In 1852 Mr. Robert Chambers published a paper "On Glacial Phenomena in Scotland and parts of England," in which he was, if not the first, one of the first, to maintain that while our lake-district had been the seat of local glaciers, each of which moved down its respective valley, the glaciation of Scotland had been far more general, more like that of Greenland at present. He showed the prevalence, over all the north of Scotland, of striæ having a general direction N.W. and S.E., passing over high hills and traversing the valleys independently of the configuration of the country; and he considers that this points to a wide extension of the circumpolar ice, with a southward movement of it over the greater part of Scotland. To the abrasion caused by this enormous mass of ice he was disposed to attribute, not only the rounded form of many of the lower hills, but the excavation of many of the valleys; while he assigned to a later period the more local radiating valley-system of glaciers. He instanced, in support of these views, similar phenomena in Scandinavia, where the glaciation has also been general and passed over tracts 4000 feet in height.

In 1858 his well-known work on "Ancient Sea-margins" appeared. In it he expressed an opinion that "the superficial formations bear the marks of former levels of the sea at various intervals up to at least 1200 feet" in Great Britain and Ireland and parts of France. Much as we may differ from the author on the extent of his generalization and number of sea-levels, the work is full of interesting facts and descriptions, collected with great care and labour, which cannot fail to be of value to future observers. I believe that in this work river-terraces are frequently classed with the supposed marine phenomena. Of such, many interesting notices are given; one in particular gives the terraces of the old Seine. These are true as to the levels, although the presence of fluviatile shells shows their fresh-water origin.

Mr. Robert Chambers's 'Traditions of Edinburgh' and 'Walks in Edinburgh,' written at a very early age, abound in curious interesting old lore; and his later descriptive works, 'Tracings in the North of Europe,' 'Tracings in Iceland,' and others, are full of excellent observations relating to the various geological questions connected with the glacial and other phenomena of the Quaternary period. The scientific periodicals of the day also contain many papers on these subjects from his pen. Robert Chambers was elected a Fellow of this Society in 1844. In 1868 the honorary degree of LL.D. was conferred on him by the University of St. Andrews. Late in life he resided for a few years in London, and afterwards removed to St. Andrews, where he died in March, 1871.

In the Rev. William Venables Vernon Harcourt we have lost another early and distinguished Fellow of our Society, which he entered in 1823. Born in 1789, he was at first destined for the navy; but abandoning that intention he entered Christ Church, Oxford, where he was the contemporary of Conybeare and Buckland. The discoveries of the latter at Kirkdale Cave led to the establishment of that successful institution the 'Yorkshire Philosophical Society,' in which Mr. Harcourt took an active part. In the halls of that institution the original founders of the British Association met in 1831; and Mr. Vernon Harcourt, in an able address, set forth an exposition of the objects and plan of the Association, which was followed by resolutions regulating so successfully the general plan of proceedings that in all essential particulars the organization remains the same. For several years he was General Secretary, and in 1839 he was President at the Birmingham Meeting. He early applied himself to the study of geology, and worked with Phillips in the district round the Caves, and at the bone-bed of Northcliff. He also described the strata on the coast north of the Humber. His experiments on the effect of heat on mineral and organic substances, were carried on in some of the Yorkshire iron furnaces for periods respectively of five and fifteen years; but they unfortunately led to few results, from the circumstance of the crucibles getting so disturbed and mixed that they could not afterwards be identified with any certainty. These, and his many other researches on the effects of long-continued heat illustrative of geological phenomena, were preliminary essays of much interest, and were carried on with extreme assiduity during a great part of his life. Mr. Harcourt died at Nuneham, in April last.

George Tate was born at Alnwick, in 1805. Possessed of a strong love of natural history and of antiquities, he noted every object of interest in his own county, and, notwithstanding the active and honourable part he took in the affairs of his native town, and the claims of business, the local scientific societies lose in him one of their most able and indefatigable members. The publications of the Berwickshire Naturalists' Club contain numerous contributions to geology, and several able addresses from his pen. He successively described some of the glacial phenomena of Northumberland, the flora of the Mountain-Limestone district of the Eastern Borders, the geology of Northumberland and Durham, and the natural history of the Farne Islands. His paper on the "Sculptured Rocks of Northumberland and the Eastern Borders" attracted much attention. He also contributed an excellent chapter and map on the geology of the line to the last edition of Dr. Bruce's 'History of the Roman Wall.'

His great work, on the History of Alnwick, the occupation of many years, was completed only two years before his death, and is one of the best and most complete of our county histories. It contains a chapter on the Botany and Zoology of Northumberland, and another on the Geology, with map and sections. In this an excellent brief account is given of the strata and organic remains of this district; but the novel point in Mr. Tate's observations is the subdivisions he introduced in the Carboniferous formation. This he divided in this district into five groups, consisting, in descending order, of:—1st, the Coal-Measures; 2nd, the Millstone Grit; 3rd, the

Mountain Limestone; 4th, the Tuedian group; and 5th, the Upper Old Red Sandstone. The Tuedian group, which he established in 1856, consists of a series of shales, limestones, and sandstones, 1000 feet thick. It contains no beds of coal; but many Coal-measure plants and fishes are common, together with a very few of the marine Vertebrata of the Mountain Limestone; whereas the latter, which has an aggregate thickness of 2600 feet, contains some twenty-three seams of productive coal, and has the usual assemblage of marine organic forms. He was also of opinion that the Tuedian group passes up conformably from the Upper Old Red Sandstone, which he removes thereby from the Devonian. Mr. Tate was elected a Fellow of this Society in 1843, and died in June 1871.

A. Keith Johnston was distinguished as an enlightened and scientific geographer. He published, in 1862, some observations on the Gulf Stream; but he is best known by his large work in two folio volumes, 'The Physical Atlas of the World,' published conjointly with Berghaus. This work contains valuable charts "of the Geological Structure of the Globe, by Ami Boué," and a Palæontological Map of the British Islands by Edward Forbes, together with others relating to volcanic phenomena, botany, zoology, glacier systems, &c., of very great use to the geologist. Mr. Keith Johnston was elected a Fellow of our Society in 1845, and died in the summer of last year.

Robert Mushet was elected a Fellow of our Society in 1863, and was a frequent attendant at our evening meetings, although not a contributor to our Journal. For many years he held an important position at the Royal Mint during the masterships of Brande, Herschel, and Graham, and was distinguished for his knowledge of the metallurgy of the precious metals. He died in last September.

Richard Meeson, of Grays, Essex, was elected a Fellow of this Society in 1859, and was well known to all geologists whose studies led them to investigate the Quaternary deposits of the Thames valley. He was the proprietor of the celebrated "Grays Pit;" and it is to the encouragement which he gave the workmen to save every thing they met with, that we are indebted for the preservation of a large portion of the important Mammalian remains which that pit has yielded. This was done by Mr. Meeson, not to increase his own collection, but in the general interest of geologists and of science.

Mr. Meeson was also a good and acute observer; and it is only to be regretted that he put none of his observations on record, although most free and liberal in communicating them to others. In driving a tunnel between two chalk-pits, the under surface of a bed of chalk was found to be covered with impressions of magnificent entire *Inocerami*. He had the surface cleared, and a number of casts taken of this interesting feature. His great practical work was his discovery and utilization for the water-supply of Brentwood and some of the surrounding districts—but not, as he had hoped, of part of east London—of some fine and large springs in the Chalk, brought to light by the excavations in the pits. Mr. Meeson was born in 1814, and died in October 1871.

Major R. J. Garden became a Fellow of this Society in 1860, and died last year. In 1855 he communicated a paper to us on the Geology of some parts of Natal, a district on which so much interesting information has been brought before us during the last two years. He also brought with him from Africa an interesting collection of new Cretaceous Ammonites, collected by himself, with great energy and at some personal risk, on a wild and uninhabited part of the coast.

Samuel Hughes died in 1870, at the age of 55; but the Society was not aware of his death until recently. This gentleman was a civil engineer, who, to great knowledge of his profession, as regards the supply of water and gas to towns, added a considerable acquaintance with geology. He was the author of a very useful little work, in Weale's series, on Water-Works for the Supply of Cities and Towns, in which the dependence of water-supply on the geological condition of the strata is well put, and shows the importance of an acquaintance with this branch of geology to engineers connected with the works of town water-supplies.

The death of another old and valued Fellow of the Society has just been announced to us, in the person of Mr. C. B. Rose, of Yarmouth. Born in 1790, he spent the greater part of his life in the active duties of his profession as a medical man at Swaffham, in Norfolk. His leisure hours, however, were devoted from an early period to the study of geology. While Mr. S. Woodward described the Crag, Boulder-clay, and Chalk districts of the eastern division, Mr. Rose wrote on the Chalk and Lower Cretaceous series of the western division of Norfolk, the two memoirs forming together probably the best account of any county geology we then possessed. In this paper Mr. Rose showed the true position of the Red Chalk of Hunstanton, and that the so-called Carstone should be referred to the Cretaceous and not to the Oolitic series. The curious deposit known as the Nar-Valley Clay, at that time largely worked for its oyster-shells for use as manure, attracted the attention of Mr. Rose, who collected a large series of the shells found in it, all of them proving to be recent, though some no longer live on the coast of Norfolk. From these it was apparent that the deposit is of comparatively recent age —subsequent not only to the Crag, but to the Boulder-clay.

After retiring from practice Mr. Rose resided at Yarmouth, where he drew our attention to the remarkable section given by Sir E. Lacon's well. He also discovered the interesting fossiliferous bed of Aldeby, which has yielded so large a collection of fine Crag shells. He was active in promoting the successful reception of the British Association at Norwich in 1869, and, it is to be feared, never recovered from the exertions he made at that time. He was elected a Fellow of our Society in 1839, and died on the 29th January, 1872; and he has, I understand, left his large collection to the Norwich Museum.

Although not Fellows of this Society, there are two names which cannot be passed in silence.

Charles Babbage, the eminent mathematician and ingenious inventor of the calculating machine, was a very frequent attendant at our evening meetings, and occasionally took part in the discussions. In 1834 Mr. Babbage communicated to our Society a paper on the celebrated "Temple of Jupiter Serapis," in which he dwelt on the slow periodical alternations of elevation and depression of portions of the earth's surface, which he considered might, in many cases, be due to the variable expansion caused by heat in strata of different lithological composition. He also contributed to our Journal a paper "On the Action of Ocean Currents in the Formation of the Strata of the Earth," which is marked by much originality. That portion of his views which maintains the great distance which sediment is carried out to sea and the extreme slowness with which it is deposited, has received marked confirmation from the recent observations of the 'Porcupine' expedition in the Mediterranean. In 1862 Mr. Babbage read a paper before the Royal Society to explain the way in which human remains might become mixed with the bones of extinct Mammalia in cave-deposits; for, as he justly observes, "whilst we ought to be quite prepared to examine any evidence which tends to prove the great antiquity of our race, yet, if the facts adduced can be explained and accounted for by the operation of a few simple causes, it is unphilosophical to infer the coexistence of man with those races of extinct animals." Mr. Babbage was also the author of the 'Ninth Bridgewater Treatise.' He was born in December 1792, and died in October 1871.

James de Carle Sowerby was born in 1787. His name and that of his father have been, as naturalists and artists, connected with our science since its infancy. In their well-known work, the 'Mineral Conchology,' they described and illustrated all the early-discovered specimens of fossil shells found in the several formations of this country; and if the species were too multiplied, it was because the connecting links were wanting rather than from any want of discrimination and information on the part of the authors. As artists, their work is characterized by accuracy and truth of drawing, and by the expression of all the essential natural-history points. The volumes of our 'Transactions' bear witness to the ability of Mr. De Carle Sowerby, while his original contributions to science appear in our own and in the 'Transactions' of the Linnean, Zoological, and other Societies. The fossil shells in most of the important papers of Buckland, Sedgwick, Murchison, Fitton, Grant, and others in our 'Transactions,' as well as in other works, were described and figured by Sowerby; and his conscientious co-operation in these works rendered great service to our science.

In 1840 the Council of the Society awarded him the proceeds of the "Wollaston Fund" as a testimony of the estimation in which they held the 'Mineral Conchology,' and to aid in its continuation. In 1846 he held, for a short time, the post of Curator of our Museum. He terminated a long and active life, during the latter portion of which he held the post of Secretary of the Royal Botanic Society, in August of last year.

Among our Foreign Members, science has also suffered several heavy losses.

Edouard Lartet, the distinguished palæontologist, was born in 1801, at En Poucouron, near Castelnau-Barbarens, in the South of France, a small property which has been in the possession of the family at least 500 years. He was educated at Auch, and afterwards at Toulouse, for the law; but, having some independent means, this profession was shortly abandoned, and Lartet devoted himself to the pursuits of science. Cuvier had recently brought to light a wholly new mammalian world of the Eocene period, and many parts of a Quaternary fauna; but comparatively little was then known of the mammalian fauna of Miocene age. A discovery made by Lartet in 1834 helped to fill up this break. At a distance of four leagues from Auch is the hill of Sansan, which consists of freshwater marls of Upper Miocene age, containing land and freshwater shells. In these beds and in beds of like age at Simorre, M. Lartet found a vast number of animal remains—representatives, in fact, of almost all the fossil quadrupeds scattered over the rest of France. He worked out ninety-eight genera, subgenera, and species of mammalia and reptiles, besides birds. The remains of fishes were scarce. This interesting deposit contains, according to M. Lartet, five species of Mastodon, two of Dinotherium, six of Rhinoceros, one of Palæotherium, one of Anoplotherium, six large species of Deer, a new species of large Carnivore (*Amphicyon*), besides an antelope, a dog, a cat, several small rodents, remains of tortoises, ornitholites, &c. The bones were so numerous that Lartet was able to restore nearly the entire skeleton of three Rhinoceroses. But the most important discovery made by him here was that of the *Pliopithecus antiquus*, an anthropomorphous Ape, and the first Ape found in a fossil state. Another species, the *Dryopithecus Fontani*, was afterwards described by Lartet from Saint-Gaudens, where it was found in beds of about the same age as those of Sansan. In concluding his palæontological considerations on these deposits, M. Lartet observed that "the new species here discovered seem destined to form the passage between other existing genera too distant among themselves. The same may be said of those animals in the great chain which in ancient times connected the creatures of this magnificent primitive creation, of which now only scattered fragments remain on the surface of the globe." This work was followed by a review of the fossil ruminants of the sub-Pyrenean Tertiary strata, and by considerations on the Diluvial beds of that area.

The remarkable collection of Pliocene mammalia brought home by M. Gaudry from Greece, next engaged the attention of M. Lartet, and led to a preliminary notice conjointly with M. Gaudry. He afterwards described the species of fossil Elephants found in the neighbourhood of Rome, and other Quaternary animals. These studies resulted in an interesting paper on the ancient migrations of the Mammalia of the Recent Period, in which Lartet showed that Europe was formerly peopled by two groups of Mammalia, one or both of which may have been of Tertiary age or origin in Asia, and Quaternary in Europe, and that, while a certain proportion of each died out, the remaining species of one group migrated northwards to Arctic regions, and those of the other southward to Africa.

France is exceedingly rich in ossiferous caves. The picturesque ravines, the rocky gorges, and the scarped valleys of the beautiful southern provinces abound in fissures and caverns, in which the remains of recent and extinct animals had been long known to exist. In the determination of these fossils, Lartet was for years assiduously engaged. While in some of the caves the assemblage was very similar to that of the bone-caves of Germany and of Wales, there were others which, besides being rich in the remains of the extinct Mammalia, abounded also in the remains of man. Tournal and other French geologists had long ago called attention to these facts, but without avail. Boucher de Perthes had also long insisted in vain on the antiquity of the flint implements of the Somme valley; but it was not until 1858 that his case was accepted—a result in which we were in some degree instrumental. In the same way the Cave evidence had been carefully and cautiously investigated by Lartet, and fresh and more conclusive proofs obtained; and in 1860 he published a paper on the "Antiquity of Man in Western Europe," followed in 1861 by his other celebrated paper entitled "New Researches on the Coexistence of Man and of the great fossil Mammifers characteristic of the last geological period." In this paper he made public the results of his discoveries in the Cave of Aurignac, and he showed that in a cave frequented by man, first as a place of habitation, and afterwards of sepulture, there were found abundant contemporary remains of elephant, rhinoceros, and other animals, some extinct and some living.

But another group of caves, containing objects of an equally or possibly still more remarkable character, were now being explored in the Périgord and adjacent districts of the south. In this work our lamented countryman, the late Henry Christy, took a prominent part. He devoted himself to the zealous and laborious exploration of these caves; and while he collected the archæological evidence, his friend Lartet gave his valuable cooperation in the investigation of the mammalian and human remains. The first result of these inquiries appeared in a joint paper by these gentlemen, descriptive of the Dordogne Caves and their contents, published in the 'Revue Archéologique' in 1864. Up to this date the industrial remains of man in the north of France and in England were confined to a few rude implements in flint and stone, and traces only of his fossil remains had been discovered; but in these caves of Southern France a new and novel phase in his former existence was brought to light. Flint-flakes were found in thousands—more perfect instruments in hundreds; and with these were also found pieces of the mammoth ivory and fragments of deer's horn, with rude but unmistakable contemporary drawings of the animals of the period etched upon them; while of works for domestic use there were found arrow-heads, fish-hooks, harpoon-heads, and needles of bone and ivory, and a rude whistle fashioned out of a metapodal bone. These remarkable discoveries, and especially the drawing of a mammoth on a plate of ivory, greatly excited the attention of palæontologists both in France and England, and led to a very active and productive investigation of a large number of the French caves.

The importance of continuing these researches in a systematic manner was so strongly felt, that Mr. Henry Christy, already known for his collections of stone implements and simple textile fabrics of mankind, not only secured by leases and otherwise the grounds of the caves for work, but proposed, with the cooperation of M. Lartet and others, to publish at his own cost, on an extensive scale, the result of the explorations. This publication, under the name of '*Reliquiæ Aquitanicæ*,' as suggested by the late Hugh Falconer, commenced in 1865, under the editorship of Professor Rupert Jones. Successive parts of this work contain essays by Edouard Lartet, his son M. Louis Lartet, Professor Rupert Jones and others, together with descriptions and full illustrations in lithograph of the bone implements by M. Lartet, and of the stone implements by Professor Rupert Jones. Mr. Henry Christy unfortunately died soon after the commencement of the book; but his executors, with M. Lartet, Mr. Franks, and other friends, liberally and actively aided in carrying out his intentions in such a way that this valuable work should be placed, at a moderate price, within the reach of scientific men. The '*Reliquiæ Aquitanicæ*' has now lost both of its original authors; but we look forward to its continuation with undiminished interest at the hands of executors and editor, with the material help of M. Louis Lartet and other scientific men in France —aided by the abundant manuscripts and collections which the deceased have left.

But, as in the case of our own Lonsdale, it was not alone by his original work, but equally by his work-in-aid, that the influence and knowledge of Edouard Lartet were felt. Considerate in the extreme for the opinions of others, without personal ambition, careful and cautious in his conclusions, ever hesitating for truth but never hesitating with her, always ready to impart information, and most liberal with his specimens, there was probably no man in Europe whose scientific opinion was more looked up to and more valued than that of Edouard Lartet. His little room in the Rue Guy-de-Labrosse will long be remembered by those, I was going to say who had the privilege of entrance; but there was no privilege, and on every Wednesday it was open to all who wished for his opinion and advice. One not only met there the scientific men of France, but the geologists of all countries came with specimens in hand to seek the opinion of the great master in palæontological zoology. His time, his knowledge, his counsels, and his specimens, were all placed at the disposal, not only of his friends, but also of interested strangers—of whom his gentle cordiality, his affability and amiable manners, soon made staunch friends. Lartet was an officer of the Legion of Honour, but, fortunately for science, declined to accept a political post offered him in 1848. In 1857 he was elected a Foreign Member of our Society. Only a few weeks before his last illness he had been elected Professor of Palæontology at the Museum of the Jardin des Plantes. The fatal issue of that illness disappointed the hopes of his friends, and deprived the public of that store of knowledge too late placed at their service. Suffering in health, and deeply affected by the disasters of his country, he retired to his country home at Seissan, where he was suddenly struck by death in January of last year.

Paolo Savi, of Pisa, was one of the remarkable men of his day. Born in 1798, his early tastes all showed his natural-history bent, and at the early age of 22 he was appointed assistant-lecturer on Zoology at the University of his native city. Here he made himself so noticed that on the death of Prof. Santi in 1823 he was selected to fill the chair. The same professor then lectured on Zoology and Geology; and young Savi had already distinguished himself in both these branches of science, and had also studied chemistry with considerable success. He now devoted himself to the active cultivation of the two first-named sciences, and to the improvement of the collections by which they were illustrated. At that time they were meagre in the extreme, and utterly unworthy of a great University. By indomitable perseverance, and aided by the liberal assistance of the Dukes of Tuscany, Savi not only enlarged the galleries, but created one of the finest collections in Europe—one especially noticeable for the physiological collection attached to the zoological department. Savi was also eminent as an ornithologist, and his great work on the Birds of Italy is of high repute.

Nor is Savi less known among geologists. His first paper was in 1825, "On the Bone-Cave of Cassano;" and his early studies on Monte Pisano and the Alpi Apuane are classical works. He unravelled the structure and classified the ancient rocks of the first range (of which he published a map in 1832), and explained the metamorphic origin of the Marmo di Carrara in the second. He was the first to show the true age and extent of the Miocene lignites of Monte Bambolo, and to describe their organic remains. He paid particular attention to the volcanic, igneous, and dolomitic rocks of Tuscany, to the action of metamorphism, and to the iron-ores of Elba. In 1850 he published an important work on the Geology of Tuscany, and the following year made his report on the minerals and rocks of the Duchy. He also wrote many papers on geology in conjunction with Signor Meneghini, who succeeds him in the professorship of Geology. His geological works altogether number about forty; and his other works on natural history are still more numerous. He was one of the few men who have been equally eminent as geologists and naturalists. He contributed largely to the revival of science in Italy, and was regarded as the father of Italian geology. He was elected a Foreign Member of this Society in 1864, and died in the month of May last, at the age of 73.

Wilhelm von Haidinger, the distinguished mineralogist, was born in Vienna in 1795. In 1822 he came over to this country, where he remained for a few years engaged with the late Mr. Allan, of Edinburgh, in the translation of Moh's Mineralogy. He afterwards travelled through Europe, and made the famous collection of minerals, known afterwards as the Greg Collection, now in the possession of the British Museum. He then undertook the superintendence of a china-manufactory in Bohemia. In 1840, after Moh's decease, he settled in Vienna as Councillor of Mines, and in 1843 commenced his courses of lectures on mineralogy. In 1845 his valuable treatise on that science was brought out, and has since passed through several editions. In 1847 he organized the society of "Friends of Natural Science;" and in the same year the great Geological Map of Austria was commenced under his superintendence.

In 1849 Haidinger was appointed Director of the Imperial Geological Institute of Vienna, then newly established, and which he continued to direct with great ability until two or three years since, when he retired with rank and pension. A large number of papers were contributed by him to various scientific societies, devoting especial attention, amongst other subjects, to the study of meteorites. His Viennese friends remark that to Haidinger especially is due the development of scientific life which has taken place in Austria within the last quarter of a century. He endeavoured incessantly to assemble around him, and to instruct and encourage, young and active men. Haidinger was elected a Foreign Member of this Society in 1851. His death occurred in March 1871.

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GENTLEMEN,—In looking at the labours of the Society during the past year, it is satisfactory to notice the same activity, the same wide range of subjects as ever, and the same independence of research for truth's sake which there ever should be. But, though good work has been done in special branches and the technical details of Geology, not so much progress has been made in its higher problems. I would, however, direct your attention to the steps made in grouping our volcanic rocks, and in the determination of the fauna of our Cambrian strata, which proves to be so much larger and richer than was anticipated a few years back. Both these subjects are in able hands, and cannot fail to yield important results—the latter especially in aiding to settle that interesting question, the true line of division between the Silurian and the Cambrian Formations. On the subject of denudation and river-action we have also had several excellent papers, and look forward with interest to the further development of the many original views which they have put before us.

The great question of the history of our globe during the Quaternary period seems also to be advancing towards more completeness. Many able observers, both in and out of our own Society, are engaged upon this interesting subject; and various scientific periodicals and the publications of our local Societies are rich in contributions bearing upon it. There is no more wonderful chapter in the earth's history than that which embraces the phenomena connected with the prevalence of great and exceptional cold immediately preceding our time,—the first dim appearance of man—his association with a race of great extinct Mammalia belonging to a cold climate—the persistent zoological characters of the one, so far as we have yet gone, in opposition to the variable types presented in geological time by the others—the search for connecting links, and the measure of man's antiquity,—all of which constitute theoretical problems of the highest interest, and are now occupying the attention of geologists in all countries. Allied also to this subject are the great questions relating to the form of our present continents, the elevation of the land, the origin of valleys and plains, and all that which prepared this globe for the advent of man.

But while treating of these abstract and philosophical questions, geology deals also with the requirements of civilized man, showing him the best mode of providing for many of his wants, and guiding him in the search of much that is necessary for his welfare. The questions of water-supply, of building-materials, of metalliferous veins*, of iron and coal-supply, and of surface-soils, all come under this head, and constitute a scarcely less important, although a more special branch of our science than the palæontological questions connected with the life of past periods, or than the great theoretical problems relating to physical and cosmical phenomena. Looking at this triple division of geology, and seeing that the first, or applied geology, is, as it were, only incidental to our general studies, and therefore not often the topic of our discussions, notwithstanding its practical importance, I propose on this occasion to say a few words in connexion with the two momentous subjects which, during the last few years, have been made the subjects of investigation by two Royal Commissions †, on both of which the geological questions have received much and careful consideration. I shall here restrict myself to the more special geological bearings of the subject, extending them, however, in some directions beyond the scope of the original inquiries, and refer you to the Reports and Minutes of Evidence themselves for the many valuable economical questions and practical details which are there discussed.

* On this subject we have witnessed with much interest the publication, during the past year, of a work by Mr. Henwood, of Penzance, on Metalliferous Deposits and Subterranean Temperature,—a work of great research and to which the writer has devoted many years, during which he has carried on his observations with scrupulous care. As a record of the variations of underground temperature in deep mines, and of the directions and bearings of lodes, this work offers a mine of facts to the geologist.

† Royal Commission on Water Supply, appointed April 1867. Report of the Commissioners and Minutes of Evidence and Appendix: June 1869.

Royal Commission on Coal Supply, appointed June 1866. Reports of the Commissioners, Minutes of Evidence, and Appendix: July 1871.

### *Our Springs and Water-supply.*

The site of a spring, or the presence of a stream, determined probably the first settlements of savage man; and his civilized descendants have continued, until the last few years, equally dependent upon like conditions—conditions connected, first, with the rainfall, and, secondly, with the distribution of the permeable and impermeable strata forming the surface of the country. Under ordinary circumstances, few large towns have arisen except where there has been an easily accessible localized water-supply, and where the catchment-basin, on which depends the volume of the rivers, has been large, and permeable strata prevail. Take, for example, London. Few sites could be more favourable in every respect. Beneath it are strata rich in springs, while at a distance there is that large development of those massive permeable strata so necessary to maintain a sufficient and permanent flow in our rivers. As the conditions exhibited in the London basin afford all the illustrations we need for our subject, I will confine myself in this address to that area alone.

London stands on a bed of gravel varying in thickness from 10 to 20 feet in round numbers, and overlying strata of tenacious clay of from 100 to 200 feet. The former being easily permeable, the rain falling on its surface filters through it, until stopped by the impermeable London Clay, where it accumulates and forms a never-failing source of supply to the innumerable shallow wells that have been sunk all over London from time immemorial, and which for centuries constituted its sole water-supply. Not only does it form an easily accessible underground reservoir, although of limited dimensions, but as, north of the Thames, various small valleys cut down through the bed of gravel into the London Clay, a portion of the water in this reservoir escapes at the junction of the two, and gives rise to several springs formerly in much repute, such as those of Bagnigge Well, Holywell, Clerkenwell, St. Chad's Well, and others.

The early growth of London followed unerringly the direction of this bed of gravel:—eastward towards Whitechapel, Bow, and Stepney; north-eastward towards Hackney, Clapton, and Newington; and westward towards Kensington and Chelsea; while northward it came for many years to a sudden termination at Clerkenwell, Bloomsbury, Marylebone, Paddington, and Bayswater; for north of a line drawn from Bayswater, by the Great Western station, Clarence Gate, Park Square, and along the north side of the New Road to Euston Square, Burton Crescent, and Mecklenburg Square, this bed of gravel terminates abruptly, and the London Clay comes to the surface, and occupies all the ground to the north. A map of London so recent as 1817, shows how well-defined was the extension of houses arising from this cause. Here and there only beyond the main body of the gravel there were a few outliers, such as those at Islington and Highbury; and there habitations followed. In the same way, south of the Thames, villages and buildings were gradually extended over the valley-gravels to Peckham, Camberwell, Brixton and Clapham; while, beyond, houses and villages rose on the gravel-capped hills of Streatham, Denmark Hill, and Norwood. It was not until facilities were afforded for an independent water-supply by the rapid extension of the works of the great Water Companies, that it became practicable to establish a town population on the clay districts of Holloway, Camden Town, Regent's Park, St. John's Wood, Westbourne, and Notting Hill.

On the outskirts of London a succession of villages grew up for miles on the great beds of gravel ranging on the east to Barking, Ilford, and Romford—on the north, following the valley of the Lea, to Edmonton and Hoddesdon—and on the west, up the Thames-valley, to Hammersmith, Ealing, Hounslow, Slough, and beyond; whereas, with the exception of Kilburn, hardly a house was to be met with a few years since between Paddington and Edgeware, or between Marylebone and Hendon, and not many even between the New Road and Highgate and Hampstead. As a marked case of the excluding effects of a large tract of impermeable strata close to a great city, I may mention the denuded London-Clay district extending from a mile north of Acton, Ealing, and Hanwell, to Stanmore, Pinner, and Ickenham near Uxbridge. With the exception of Harrow (which stands on an outlier of the Bagshot Sands), Perivale, and Greenford (on outliers of gravel), there are only the small villages of Northall and Greenford Green. In the earlier edition of the Ordnance Maps there was a tract of ten square miles north and westward of Harrow within which there were only four houses. Yet the ground is all cultivated and productive. But immediately eastward of this area, and ranging thence to the valley of the Lea, the ground rises higher, and most of the London-Clay hills are capped by gravel of an older date than that of the London valley, and belonging to the Boulder-clay series. On these we have the old settlements of Hendon, Stanmore, Finchley, Barnet, Totteridge, Whetstone, Southgate, and others.

There is yet another very common source of well-water supply from beds of gravel, directing population to low sites in valleys, which is this. Everywhere on the banks of the Thames and its tributaries there is a lower-lying bed of valley-gravel or of rubble on, and often passing beneath, the river-level. This bed is fed by the rain falling on it, by springs thrown out from the adjacent hills, or by the drainage from those hills, and in places by infiltration from the river, when, from any cause, the line of water in the gravel falls below that of the adjacent river; while, on the other hand, the surplus land-supplies find their way, direct and unseen, from the bed of gravel to the river. A great part of London South of the Thames, also Westminster, Battersea, and a number of towns up the Thames, as Hammersmith, Brentford, Eton, Maidenhead, and others, together with Newbury and several villages on the Kennet, and the towns of Ware and Hertford on the Lea, have this shallow-well supply. A great many towns and numberless villages along most of our river-valleys all through England, and on whatever formation situated, are dependent on this superficial source of supply—a supply much more permanent than the other shallow-well supplies, in consequence of the outside aid from springs and rivers. It is, however, only in case of exceedingly dry seasons or of excessive pumping, that the supply requires to be supplemented by the river-waters. As, in ground of this description, the land-water is generally dammed back by the stream, the level of the water in the wells, which are always shallow, varies with the level of the water in the streams, rising and falling more or less with them.

A few of the higher London-Clay hills in the neighbourhood of London are capped also by outliers of the Bagshot Sands, as, for example, Harrow, Hampstead, and Highgate, all of which are sites of old habitations. The sands at these places attain a thickness of from 30 to 80 feet, are very permeable, and afford a sufficient water-supply by means of wells to a limited population. A number of well-known small springs also are thrown out at the contact of the sands and the clay on the slopes just below and around the summit both of Highgate and Hampstead Hills. In some instances, owing to the presence of iron in the sands, they are slightly chalybeate. When the Bagshot Sands, further westward of London, attain their fuller development of from 300 to 400 feet, the depth to the water-level at their base becomes so great that the upper porous beds are left high and dry and form uncultivated wastes, such as Bagshot Heath, Frimley Heath, and others; but on the outside of this area, where the sands become thinner, and the water-level more within reach, we find a number of villages, such as Englefield Green, Sunninghill, Bracknell, Wokingham, Alderstone, Esher, Weybridge, Woking, &c. There are also some thin subordinate beds of clay in the middle of the series which hold up a sufficient quantity of water for small local supplies, and give rise to small streams in the valleys of the Blackwater and of Chobham. The running nature of portions of these sands, and the presence of beds of ferruginous and green sands, often interfere much with the construction of deep wells, and the quality of the well-water ; and, externally, the mixed clay-and-sand character of the upper beds of the London Clay fails to give any good retaining-line for the water, which therefore rarely issues as springs, but oozes out from the general surface of the intermediate spongy mass.

The 70 to 100 feet of sands and pebble-beds belonging to the Lower Tertiary strata under the London Clay, and overlying the Chalk, are also very permeable ; and being intercalated with some beds of retentive clay, they give rise to one or two levels of water, affording, wherever these strata form the surface, as at Blackheath, Bexley, Chiselhurst, and Bromley, a moderate water-supply to shallow wells. Where these sands dip under the London Clay, and only present a narrow belt on the surface, a small valley is commonly formed, into which the London-Clay hills drain on the one side ; and on the other the Chalk, dammed back by the Tertiary strata, throws out its springs, and the sands are thus kept charged with water up to a short depth from the surface. As instances of the many places whose sites have no doubt been determined by these favourable circumstances, I may name Croydon, Beddington, Carshalton, Sutton, Cheam, Ewell, Epsom, Ashstead, and the villages between Leatherhead and Guildford, and again between Old Basing and Kingsclere.

But besides furnishing a supply by ordinary wells to a number of villages on their line of outcrop, the Lower Tertiary sands have of late years contributed to the Metropolitan supply, as well as to the supply of those adjacent districts where the surface is formed of tenacious clay, and water is scarce, by means of Artesian wells. For along the line of country just named, and along a more irregular belt on the north of London, these Sands pass beneath the London Clay ; so that the water they receive from rain and springs on the surface, passes underground, where it is prevented from rising by the impermeable superincumbent clay ; consequently, as there is no outlet for the water below ground, these sand-beds are filled with water along their whole underground range, between their outcrop in Surrey and that in Hertfordshire.

I need not dwell here upon the construction of Artesian wells, which has been explained by Héricart de Thury *, Arago †, Degousée and Laurent ‡, Burnell §, Hughes ‖, myself ¶, and others, beyond offering a few explanatory remarks on this particular case, which we shall have to bring to bear upon the origin of springs.

The surface of the ground at the outcrop, just referred to, of the Lower Tertiary Sands is about 100 feet above the level of the Thames, whilst under London the sands are at a depth of from 100 to 220 feet below that level, thus forming the shell of a trough from 200 to 300 feet deep, the centre of which is filled with a depressed mass of impermeable clay. There is, however, a notch in the lip of the basin, where it is traversed by the Thames at Deptford and Greenwich, which is at a level 100 feet lower than the rest of the rim. Below this level, as there is no escape for the water, the strata are naturally perpetually water-logged; and if any water is withdrawn from one part, it is, owing to the permeability of the strata, at once replaced from adjacent parts of the same strata. Early in the present century, bore-holes were made through the overlying London Clay to the sands at depths of from 80 to 140 feet; and the water from these deep-seated springs at once rose to a height of several feet above the level of the Thames, where it tended to maintain itself, and thus form, in the lower-lying districts, permanent natural fountains. But the ease and facility with which this abundant supply was obtained, led to the construction of so great a number of such wells that a time soon came when the annual rainfall no longer sufficed to meet the demand, or, rather, it could not be transmitted fast enough to the central area of abstraction to replace the outdraught. The consequence was, that after some years the water ceased to overflow, and the line of water-level has gradually sunk at London, until it now stands some 60 to 70 feet below Trinity high-water mark. This, however, is not the case at a distance from London; and in many parts of Middlesex, and more especially in Essex, where Artesian wells are common, they have been found of very great service.

In order to supply the deficiency thus caused in the Lower Tertiary

* Considérations Géologiques et Physiques sur la Théorie des Puits forés, ou Fontaines Artésiennes. Paris, 1826.

† Annuaire du Bureau des Longitudes for 1835.

‡ Guide du Sondeur. Paris, 1847.

§ Sinking and Boring, by J. Swindell, edited by G. Burnell. Weale's Series, 1849.

‖ On Waterworks for the Supply of Cities and Towns. Weale's Series, 1859.

¶ The Water-bearing Strata of the Country around London. London, 1851.

Sands, most of the Artesian wells in London have of late years been carried down into the underlying Chalk, which also extends beneath London at depths of from 150 to 280 feet. Both formations are permeable, but in different ways. On both the rainfall is at once absorbed; but the transmission of it is effected differently. Through the sands it filters at once; not so with the Chalk. A cubic foot of the latter will hold two gallons of water by mere capillary attraction; and it parts with water with difficulty. Still in time the water finds its way through the body of the Chalk, aided by the innumerable joints, fissures, and lines of flints by which this formation is traversed; and when once below the line of saturation, the water in these fissures circulates freely. This line of saturation is governed in this as well as in all other permeable formations, by the level of the lowest natural point of escape, which is either the coast-line, if near, or the nearest river-valleys. Below these levels permeable strata are always charged with water; consequently under London the Chalk is everywhere water-bearing; but as the Lower Chalk is more compact than the Upper, and is less fissured, especially when covered by other strata, and as the more compact water-logged Chalk delivers its charge with extreme slowness, it is not until a fissure is met with that a free supply of water is obtained. Further, as there is no law regulating the position of the fissures, the depth to which the Chalk has to be traversed before meeting with a free supply of water is quite uncertain. It is a question of probability, depending upon meeting with a fissure sooner or later: from 10 to 15 feet have sufficed in some of the deep London wells, whereas in others it has been necessary to sink to a depth of from 100 to 200 feet or more before hitting on the necessary fissures. Large as this source of supply is, the same causes which have operated in the case of the sands have told also on the chalk-supplies (and, no doubt, there is some community between the two), and the great demands on it have occasioned a similar lowering of the water-line. At the same time this line also remains unaltered at a distance from London; and, as with the Tertiary Sands, the mass of the Chalk beneath the level of the intersecting river-valleys remains constantly charged with water. Ordinary wells, therefore, sunk below this line of saturation into the Chalk where it comes to or near the surface, are capable of yielding very large quantities of water. More than seven million gallons daily are in fact now so obtained from the Chalk on the south-east of London.

Numerous and useful as the London Artesian wells are, they sink into insignificance when compared with the application of the same system in Paris. Our deepest wells range from about 450 to 550 feet, and the water comes from the Chalk hills at a nearest distance of from 15 to 25 miles from London; whereas in Paris the well of Grenelle is 1798 feet deep, and derives its supplies from the rain-water falling on the Lower Greensands of Champagne, and travelling above 100 miles underground before reaching Paris. The well of Passy, sunk also through the Chalk into the Lower Greensands at a depth of 1923 feet, derives its supplies from the same source. The level of the ground above the sea at the outcrop of the Lower Greensands in Champagne averages about 350 feet, and the water at Grenelle well rises 120 above the surface of the ground, which is close on the level of the Seine, there 89 feet above the sea-level. The water-discharge is large and well sustained. These results were considered so encouraging, that in 1865 the Municipality of Paris decided on sinking two Artesian wells of unexampled magnitude. Hitherto the bore-holes of such wells have been measured by inches, varying from 14 to 4 inches, that of Passy alone having been 4 feet at the surface and 2 feet 4 inches at bottom. But it was resolved to exceed even the large dimensions of this well.

One of these experimental wells is in the north of Paris, at La Chapelle, St. Denis*,—157 feet above the sea-level. A shaft, with a diameter of 6½ feet, was first sunk through Tertiary strata to a depth of 113 feet. At this point the boring was commenced with a diameter of 5½ feet, and carried through difficult Tertiary strata to a depth of 450 feet, when the Chalk was reached. A fresh bore-hole was here commenced in August 1867, which in September 1870 had reached the depth of 1954 feet. The works were stopped on account of the war until June 1871, when they were resumed; and the bore-hole has now reached the great depth of 2034 feet, with a diameter still of 4 feet 4½ inches. It is now in the Grey Chalk; and it is calculated that the Lower Greensands will be reached at a depth of about 2300 feet.

The other Artesian well is at the Buttes-aux-Cailles, on the south-east of Paris, at an elevation of 203 feet above the sea. The Tertiary strata are there only 205 feet thick. This well is not on quite so large a scale as the other, and is still, at a depth of 1640 feet, in the White Chalk.

* Undertaken by Messrs. Degousée and Laurent, to whose successors, Messrs. Mauget, Lippmann & Co., I am indebted for these particulars. The other well is being executed by Messrs. Dru & Co

The discharge from these great wells will probably be equal to that of a small river. At Passy, notwithstanding some defective tubage, and the circumstance that the surface of the ground is there 86 feet above the Seine, the discharge at the surface is equal to $3\frac{1}{2}$ millions of gallons daily; and it has been above 5 millions, or enough for the supply of a town of 150,000 inhabitants.

The question may arise, and has arisen, why, with a like geological structure, should not the same results be obtained at London as at Paris; and, to a certain extent, it has been answered. At Kentish Town an Artesian well was, in 1855, carried through 324 feet of Tertiary strata, 645 feet of Chalk, 14 feet of Upper Greensand, and 130 feet of Gault. Instead of then meeting with the water-bearing Greensands which crop out from beneath the Chalk, both on the north and south of London, unexpected geological conditions were found to prevail, to which we shall have occasion to refer presently; and not only were the Lower Greensands found to be absent, but likewise all the Oolitic and Liassic series. The bore-hole passed at once from the Gault into a series of red and grey sandstones, probably of Palæozoic age, and not water-bearing. The Chalk has more recently been traversed at Crossness, near Plumstead, where its base was reached at a depth of 785 feet, and the bore-hole carried 159 feet deeper into, but not through, the Gault, when, owing to difficulties caused by the small size of the bore-hole, the work had to be abandoned. Although we were mistaken in our anticipations as to the results of the first of these works*, still it is evident, as the Lower Greensands, with a thickness of 450 feet, pass beneath the Chalk and the Gault in a line from Farnham, Reigate, to and beyond Sevenoaks—and they again occupy the same position north of London, on a line from Leighton Buzzard to Potton—that it is only a question of how far they may be prolonged underground towards London. They have as yet been followed only four miles from their outcrop under the Gault in Buckinghamshire, and one mile in Kent; and no attempt has been made to follow them under the Chalk. It is therefore quite possible that they may extend to under Croydon, or even to Sydenham, or still nearer London; but this depends upon the width of the underground ridge of Palæozoic rocks, which has not been determined. It is a matter for trial. As the sands are from 200 to 500 feet thick, and show no sign of an immediate approach

* Although the Lower Greensand was not in its expected place, our estimate of the thickness of the Chalk was right to within 3 feet ('The Water-bearing Strata of London,' p. 142).

to the old shore-line, there is every probability that in Kent and Surrey they extend at all events some miles northward, and in Bucks some miles southward, before they thin off against the underground range of old rocks; so that they might still be found available, as a supplementary source, for the water-supply of London.

Such is the geological structure of the ground on which this large city is dependent for its first and immediate water-supply by means of wells. The highest seam of water, that in the Drift-gravel, extends almost everywhere under the streets and houses of London, at depths of from 12 to 25 feet, forming what are called ground-springs. The Lower Tertiary Sands, with their greater thickness, and their larger and distant area of outcrop, contain the second and larger underground body of water beneath London. The third underground reservoir is the Chalk, which, from its large dimensions (500 to 1000 feet thick) and extensive superficial area, forms a still larger reservoir and source of water-supply.

With the increase of population, however, the need for larger quantities necessitated the recourse to river-supply; and this supply, equally with the other, is regulated by geological conditions; only, in this case, the question concerns those conditions which affect the strata throughout the catchment-basin of the river itself above the town which needs its supply.

It has been already mentioned that, below a certain level, permeable strata are necessarily always saturated and water-logged, and that any additional quantity added to this constant quantity cannot be held permanently. It follows that in all water-bearing strata, after allowing for any abstraction (usually comparatively small) by wells, the surplus rainfall must, when the stratum is full, find its escape by natural means, *i. e.* by means of springs. The power and size of these are necessarily dependent upon the dimensions of the strata by which they are supplied. In the gravel they are small, in the Lower Tertiary Sands moderate, while in the Chalk they are very large. The permanence of the spring depends on the lithological character as well as on the dimensions of the strata. Thus in Sands, where the water can permeate the mass, the stores are large and the delivery moderately quick; in Limestones, where the water is confined to cracks and fissures, the delivery is quick and not lasting, though often large; in rubbly Oolites, which are also practically porous, the springs are well maintained; while in Chalk, owing to the characters before named, the water-delivery is slow, and the springs are large and very permanent.

At the same time, the storage-capacity increases with the resistance. Taking the extreme case of the Chalk, the transmission of the rain-water is so slow, that, on the Chalk hills, it takes four or six months to pass from the surface to the line of water-level at the depth of 200 to 300 feet; so that the heavy rainfall of winter is not felt in the deep springs until the summer, and Mr. Beardmore* estimates that the maximum effect of a hot dry summer and autumn is not reached until the end of about sixteen months, or that the storing-power of the Chalk is of sixteen months' duration. To estimate this power, we have to take the height and extent of the hills, and to note the lithological characters of the permeable strata. If these latter are underlain by impermeable strata above the level of the rivers in two adjacent valleys, then the base of the underground water-store will be coincident with the level of the impermeable strata, and its surface-line will rise, as it recedes within the the hill, in proportion to the resistance offered to the water-escape by the character of the permeable strata, and it will thus form a curve between those two points, the height of which will vary in proportion to the rainfall. When, on the other hand the permeable strata continue down to a greater or less depth beneath the surface of the adjacent rivers, then, as there is no underground escape for the stored water, the line of water-level in those permeable strata will not be regulated by the impermeable strata, but will rise to, and be always maintained at, the level of the rivers, and therefore all the additional supplies furnished by the rain must, after traversing the interior of the hills, escape along the bottom of the valleys, and by the side or in the bed of those rivers. In the dry upland valleys of the Chalk and Oolites, the underground water, dammed back by the streams in the nearest river-valley, passes under those valleys at depths varying with the resistance offered by the lithological character of the formation, and by the gradient of the valley as it runs into the hills.

When again, as in the escarpments of the Chalk downs and Oolite hills, the outcrop of the permeable strata rests on impermeable strata at some height above the river-levels, and in the direction of their dip they pass below those levels, then the springs partake of the same divided character—one, a smaller set, flowing out on the sides of the hills, while stronger and more lasting springs issue, as it were, at the foot of the incline, on the level of the rivers. In any case, it is the distance between the two points of escape that gives us the measure of storage. If the distance is reckoned by miles, then the height of the water-level may be measured by tens of

* Minutes of Evidence, p. 204.

feet. It is highest where the breadth and altitude of the hills is greatest. In some instances the crown of the arch formed by the line of water-level will rise from 60 to 80 feet above its chord.

This curve is subject to great fluctuation, varying according to the seasons and amount of rainfall. Mr. Clutterbuck * has shown that, in the Chalk hills of Hertfordshire, it varies in height as much as 30 or 40 feet. From the crown or centre of its summit it decreases at a rate varying generally from 3 to 30 feet, or even more, per mile to all parts of the circumference. The height of the arch and the breadth of the base-line, taken together, give therefore the head of water supplying the large springs of the Chalk, such as those of Chadwell, Hoddesdon, Otter, Carshalton, Leatherhead, Ospringe, and others. But, besides these, there are innumerable smaller ones, not so easily seen, flowing out on the sides or in the bed of the rivers traversing the great permeable formations, as those along the Thames from Greenhithe to Faversham, on the upper Lea and its tributaries, and on the Medway and the Darent, where they traverse the Chalk hills. This class of springs has especial geological bearings.

The same general rules govern the springs of all the more varied strata of the upper part of the Thames-basin, where, in place of the Cretaceous and Tertiary series, we have a series of Jurassic and Liassic strata. Omitting the drift or gravel beds, the following are the average dimensions, character, and superficial areas of each of these formations in that area.

*The Strata constituting the Thames Basin above Wallingford.*

| | Area. | Thickness, in feet. | |
|---|---|---|---|
| | Square miles. | Permeable strata. | Impermeable strata. |
| Chalk† | 60 | 1000 | — |
| Upper Greensands | 62 | 100 | — |
| *Gault* | 129 | — | 130 |
| Lower Greensands | 23 | 200 | — |
| Purbeck and Portland beds | 46 | 60 | — |
| *Kimmeridge Clay* | 132 | — | 300 |
| Coral Rag and Grit | 103 | 40 | — |
| *Oxford Clay* | 307 | — | 400 |
| Great and Inferior Oolites | 327 | 450 | — |
| *Fuller's Earth* | 16 | — | 40 |
| *Lias* | 170 | — | 500 |

* Proc. Inst. Civ. Engineers, 1842–3 and 1850.

† Below Wallingford, but above Kingston, the area of the Chalk is 987 square miles, and of the Upper Greensand 140 miles.

But although, in the upper part of the Thames-basin, many of these water-bearing strata are of large dimensions and hold large water-stores, none of those below the Gault, except the Lower Greensands, are available for a well-supply at London. For the Upper Greensand, so important in Wiltshire, is reduced to a few feet of comparatively impermeable argillaceous sand under London; and the Oolitic series, so rich in springs in the district of the Cotswold Hills, have been ascertained to thin off as they range eastward. Mr. Hull has shown * that the Inferior Oolite and underlying sands in particular die out, in all probability, under the Oxford Clay about the centre of Oxfordshire †. Even apart, therefore, from the discovery made at Kentish Town, we should now have excluded the Oolitic series as a possible source of supply to deep wells in the London district, although, as sources of spring-supplies, they contribute so important a share to the permanent flow of the Thames. Few of those strata, however, are so homogeneous as the Chalk and the London Clay. The permeable formations often contain subordinate impermeable clays—seams which form water-levels of more or less importance; whilst the impermeable clays sometimes contain subordinate beds of sand or of rock which constitute small local water-bearing beds. It is for the geologist to assign its relative value to each of these subordinate features, and to distinguish the minor from the major sources.

Taking the Thames-basin above Kingston, there is, according to Mr. J. D. Harrison‡, an area of 1233 square miles of impermeable strata, and of 2442 miles of permeable strata§, and the average annual rainfall for that district amounts to about 27 inches. From the impermeable strata the rain flows off immediately as it falls, and is carried at once to sea; whereas a large portion of that which falls on the permeable strata is, as we have shown, stored for a greater or less time, and discharged in perennial springs. It is these which give permanence to our rivers. The evidence taken before the Commission showed that the daily discharge of the Thames at Kingston, even in the driest season (after weeks without rain), never falls below 350,000,000 gallons, while the average for 11 years is estimated by Mr. Harrison‖, in data furnished by Mr. Simpson, to

* Quart. Journ. Geol. Soc. vol. xvi. p. 63. † *Vide postea*, p. 55.

‡ Minutes of Evidence, p. 188.

§ See also Mr. Bailey Denton's evidence and map, and the geological map of the Commission.

‖ Minutes of Evidence, p. 183; see also Mr. Harrison's diagram, Appendix A, C.

give a daily discharge equal to 1353 million gallons. But Mr. Beardmore's * observations, extending over eighteen years, give only 1145 million gallons. Taking the mean of these estimates, we may consider the daily discharge at Kingston to be equal to about 1250 million gallons; this quantity is equal to a rainfall of 8 inches, or rather less than one third of the annual quantity, the other two thirds being lost by evaporation and absorbed by the vegetation. This seems the proportion usual under the like general conditions in these latitudes. M. Belgrand has shown that in the upper basin of the Seine there are 19,390 square kilometres of impermeable, and 59,210 of permeable strata; and careful measurements have proved that the discharge of that river at Paris is also equal to about one third of the rainfall. The exact proportion of the rainfall passing into the different permeable strata, and given out again in the form of springs, has yet to be accurately determined. Mr. Harrison estimates it in the Thames-basin at about one sixth of the rainfall.

In districts where impermeable strata predominate, the river-discharge will follow more closely upon the rainfall, instead of being, as where permeable strata predominate, stored in the hills and its delivery thereby spread over a greater or less period of time according to the dimensions of those hills. This is well exemplified in the case of the catchment-basins of the Thames and of the Severn, part of which latter extends over a large tract of the hard slate rocks of Wales. The former has an area above Kingston of 3670 square miles, with an annual rainfall of 27 inches, whereas that of the latter above Gloucester has an area of 3890 miles, with an average rainfall of probably not less than 40 inches; and the mean daily discharge for the year of the Thames is 1250 million gallons, and of the Severn about 1600 million gallons†. Yet the summer discharge of the Thames averages 688,700,000 gallons daily‡, against 297,599,040 gallons of the Severn §; and while the minimum discharge of the

* Minutes of Evidence, p. 477.

† Hawksley, Minutes of Evidence, p. 154.

‡ Applying this law to the case of London, the Commission remarks:—"The importance of such a condition of things for the supply of this large metropolis cannot be overestimated. It ensures that permanence and regularity which are necessarily among the most important elements in a metropolitan water-supply. With natural subterranean reservoirs extending over above 2000 square miles, a storage reserve is provided comparatively independent of the seasons, and maintained by the ordinary operations of nature, while no filtration can equal that effected through masses of Sand, Sandstone, earthy Limestones, or Chalk, from 50 to 300 feet thick," or more.

§ Beardmore, Hydraulic Tables, p. xxxi.

Thames in the driest seasons never falls below 350 million gallons, that of the Severn falls below 100 million gallons. Again, in the case of the Lea, where there is a still larger proportion of permeable strata, the daily discharge at Broxbourne is equal to 108 million gallons, while for the summer months it remains as high as 71 millions, and in the driest seasons does not fall below 42 million gallons *.

Let us now look at the geological bearing of the question connected with the solvent action of the water on the strata it traverses. The analyses, made for the Commission by Drs. Frankland and Odling, of the waters of the Thames and its tributaries in the Oolitic and Chalk area, show that the rain-water has taken up of solid matter in every 100,000 parts or grains a quantity varying from 25·58 to 32·95 parts or grains, or an average of 29·26, which is equal to 20·48 grains per gallon; another analysis of the Thames water at Ditton gives 20·78 grains per gallon of solid residue. It was also shown by Drs. Letheby and Odling and Professor Abel that the unfiltered waters of the Thames Companies, which take their supplies above Kingston, contained 20·82 of solid residue. If from the average of 20·68 we deduct 1·68 grain for organic and suspended matter, we have 19 grains of dissolved inorganic matter for every gallon of water flowing past Kingston. This is of course apart from the sediment carried down in floods. The ordinary monthly analysis, conducted by the same eminent chemists during the course of several past years, shows that this quantity is liable to very little variation, the only difference being that it is somewhat larger in winter and less in summer.

Some general estimates have already been made by Professors Ramsay † and Geikie ‡ of the quantity of mineral matter carried down in solution by the Thames; but the more exact data supplied to the Commission enables us to make some additions to previous results. Taking the mean daily discharge of the Thames at Kingston at 1250 million gallons, and the salts in solution at 19 grains per gallon, the mean quantity of dissolved mineral matter there carried down

* Beardmore, Minutes of Evidence p. 477–9.

† Physical Geology of Great Britain, 2nd edit. p. 162.

‡ "On Modern Denudation," Trans. Geol. Soc. of Glasgow, vol. iii. p. 159. The author only incidentally touches on this branch of the subject; but he enters fully on the question of the amount of sediment carried down by rivers as bearing on subaerial denudation, and calculates the rate at which the surface of the land is being lowered by this agent. It is singularly little in excess of the rate we have arrived at for the matter in solution.

by the Thames every twenty-four hours is equal to 3,364,286 lbs. or 1502 tons, which is equal to 548,230 tons in the year. Of this daily quantity about two thirds, or say 1000 tons, consist of carbonate of lime, and 238 tons of sulphate of lime; while limited proportions of carbonate of magnesia, chlorides of sodium and potassium, sulphates of soda and potash, silica and traces of iron, alumina, and phosphates constitute the rest. If we refer a small portion of the carbonates, and the sulphates and chlorides chiefly, to the impermeable argillaceous formations washed by the rain-water, we shall still have at least 10 grains per gallon of carbonate of lime, due to the Chalk, Upper Greensand, Oolitic strata, and Marlstone, the superficial area of which, in the Thames-basin above Kingston, is estimated by Mr. Harrison at 2072 square miles. Therefore the quantity of carbonate of lime carried away from this area by the Thames is equal to 797 tons daily, or 290,905 tons annually, which gives 140 tons removed yearly from each square mile; or, extending the calculation to a century, we have a total removal of 29,090,500 tons, or of 14,000 tons from each square mile of surface. Taking a ton of chalk, as a mean, as equal to 15 cubic feet, this is equal to the removal of 210,000 cubic feet per century for each square mile, or of $\frac{9}{100}$ of an inch from the whole surface in the course of a century, so that in the course of 13,200 years a quantity equal to a thickness of about 1 foot would be removed from our Chalk and Oolitic districts.

I had some faint hope that this wear might furnish us with a rough approximate measure of time in reference to some of the phenomena connected with the Quaternary period; but we are not in a position to apply it. Those curious funnel-shaped cavities, called sand- and gravel-pipes, so common in many chalk districts, are the result of slow solution of the chalk at particular spots, whereby the superincumbent sand and gravel have been let down into the cavity so produced. Some of them are but a few feet deep, while others attain dimensions of 80 feet depth by 15 to 20 feet diameter at top, tapering irregularly to a point at bottom. It is evident, however, from the variation in size that the wear has been unequal; and it is also clear that the surface-waters have been conducted through these particular channels, where they existed, to the underground water-level, in preference to passing through the general body of the Chalk; so that the ratio of wear at these points is in excess. Nor can I see at present how otherwise to apply this measure. If it were possible to find a spot where the exposed surface of the Chalk has been worn uniformly, and, from the quantity of flints left after the removal of the Chalk, and the known original distance apart of the seams of flint, to determine the number of feet or inches removed, we might have a base to proceed upon, provided all the quantities remained constant. But such is not the case. Also, although the annual rainfall in the Thames-basin now averages 27 inches, and has probably not varied much from this amount during the present period, it was evidently much greater during the Quaternary period; for I have elsewhere * shown that, in the South of England and North of France, the rivers of those areas, with the same catchment-basins, were of much greater size than at present; and Mr. W. Cunnington had before noticed the same fact, at the head of the basin, with respect to some of the rivers of Wiltshire. M. Belgrand has attempted to estimate this quantity with reference to the Seine and its tributaries; and he arrives at the conclusion that, during the Quaternary period, the rainfall was so heavy that the discharge of the river was from 20 to 25 times as great as at present †. I do not altogether concur in this view; but I can conceive that our rivers formerly were of five or six times the size they now are, and the rainfall of course in proportion. This is an important element to be considered in all questions bearing on the denudation of the land-surfaces of that period.

There is yet another point which, although not in our direct field of research, yet depends so essentially upon the geological conditions we have discussed, and is one, in a public point of view, of such paramount importance, that I will, with your permission, say a few words on the subject. In an uninhabited country, the rain passes through the soil and issues as springs, bearing with it a certain proportion of mineral matter, and only traces of such organic matter as existed on the surface. This would be solely of vegetable origin, and the proportion would be in most cases very small. As man appeared, those conditions would be at first but little altered; for animal matters exposed on the surface rapidly decay and pass away in a gaseous form: but with increasing civilization and fixed residences the necessity of otherwise getting rid of all refuse would soon be felt. I have shown how population followed the range of shallow permeable strata and the course of valleys, so as to obtain readily that indispensable necessity of life, a sufficient water-supply. But with the art of well-digging it soon became apparent that, let

* Philosophical Transactions for 1864, part ii. pp. 265, 286, *et seqq.*

† La Seine, chap. xiv. p. 115 *et seqq.*

the well be carried down but halfway to the level of ground-springs, it would remain dry, and that then, so far from holding water, any water now poured into it would pass through the porous strata down to the water-level beneath, keeping the shallower well or pit constantly drained. So convenient and ready a means of getting rid of all refuse liquids was not neglected. Whilst on one side of the house a well was sunk to the ground-springs, at a depth, say, of twenty feet, on the other side a dry well was sunk to a depth of ten feet; and this was made the receptacle of house-refuse and sewage. The sand or gravel acting as a filter, the minor solid matter remained in the dry well, while the major liquid portion passed through the permeable stratum and went to feed the underlying springs. What was done in one house was done in the many; and what was done by our rude ancestors centuries back has continued to be the practice of their more cultivated descendants to the present day, with a persistency in the method only to be attributed to the ignorance of the existence of such a state of things amongst the masses, and to the ignorance of the real conditions and actual results among the few instrumental in perpetuating such an evil—an evil common alike to the cottages of the poor and, with few exceptions, to the mansions of the rich.

Instances occur from time to time to point out isolated consequences of this pernicious practice; but I believe no one who has not gone into the geological question can realize its magnitude. It is not confined to one district or to a few towns or villages. It is the rule; and only within the last few years have there been any exceptions. The organized supply of water now furnished by companies in all large towns has, to a great extent, done away with the evil in those situations (though the root of the mischief has too often been left unextracted); but, in villages and detached houses, great or small, it remains untouched and unchecked. Not a county, not a district, not a valley, not the smallest tract of permeable strata, is free from this plague-spot. It haunts the land, and is the more dangerous from its unseen, hidden, and too often unsuspected existence. Bright as the water often is, without objectionable taste or smell, it passes without suspicion until corrupted beyond the possibility of concealment by its evil companionship. Damage, slight in extent, or unimportant possibly for short use, but accumulative by constant use, may and does, I believe, pass unnoticed and unregarded for years. Nevertheless the draught, under some conditions, is as certain in its effects, however slow in its operation, as would be a dose of hemlock. Go where we may, we never know when the poisoned chalice may be presented to our lips. The evil is self-generating; for the geological conditions supplying our necessities lend themselves to its maintenance and extension. The knowledge necessary to remedy it is of very slow growth, and the too frequent want of that knowlege, or disregard of the subject, even amongst able architects and builders, is such that, without legislative enactments, I do not see how the evil is to be eradicated for many a long term of years.

This also is only one form of the evil; it is that where the water-bearing strata are thin and the wells of no great depth. It was one which prevailed in London, and in all towns similarly situated, up to a very few years back. It still lingers on in some private wells, and is moreover fostered among us by the bright, sparkling, and cool water of too many of our public pumps; for not only does the ground still suffer from the effects of the original contamination, but also from much, almost inevitable, obnoxious surface-drainage, much gas-escape, much rainfall on old open churchyards, which find their way to the one level of water supplying in common all these shallow wells. The evil exists also, although to a less extent, in towns where the wells are of greater depth—its effects varying as the depth and the volume of the springs are to the sewage-escape; it is a question of degree*.

But even our deeper and apparently inaccessible springs have not escaped contamination. As before mentioned, certain underground waters will, when tapped by Artesian wells, rise to or above the surface, according to the relative height of the surface of the ground at the well and at the outcrop of the water-bearing bed or beds, so that if the former is higher than the latter, or if by artificial means the line of water-level in a given area becomes lowered, then the surface of the water belonging to those great underground natural reservoirs will be established accordingly at a certain fixed depth beneath the surface. As each well deriving its supply from a stratum of this description represents a column of water communicating with one common reservoir, it follows that any cause permanently lowering the level of one well will tend to lower the level in the other wells in proportion to their relative distances; so, in the same way, supposing a column of water equal to a certain number of feet in height were added to one well, it would in like manner raise the

* Happily, however, with the distance from sources of impurity, the springs regain, by filtration through the strata, their normal purity.

level of the other wells in proportion to their number and distance. Further, it has been discovered that a well of this class can absorb a quantity of water equal to that which it can furnish; and as these wells give greater supplies than shallow wells, the absorbing wells of the same class are powerful in like proportion. The perverse ingenuity of man has here, again, taken advantage of these conditions to get rid of offensive waste waters by diverting them into such deep wells, whence they pass away in hidden underground channels, unseen and unsuspected, and mingle with those deep-seated water-sources feeding the Artesian wells dependent upon them for their supply.

In Paris, where there are several alternating beds of permeable and impermeable strata, and the depth to reach them is not very great, this system of absorbing wells connected with factories became, until regulated by the municipality, very common, to the great injury of many of the underground springs. From this and the other causes before alluded to, a great number of shallow wells have there become so contaminated as to necessitate their abandonment. Our own system of surface-drainage is generally too good, and the depth to the lower water-bearing strata too great, to have rendered the use of such wells here equally advantageous; nevertheless I have reason to believe that they do exist, and that the sources even of our deep-well water-supply in the Lower Tertiary Sands and in the Chalk are thus to some extent polluted and injured.

Nor do the great and perennial springs supplying our rivers altogether escape the evils arising from these condemnable practices. On the high Oolitic ranges and amongst the undulating Chalk hills, the line of water-level is often so deep below the surface, that only in few cases are wells made—the population being generally dependent on rainwater for their water-supply. But this does not prevent the construction of dry wells for the disposal of sewage and refuse. It is true that the population in these hills is sparse—here and there a farm, a few cottages, and scarcely a village. Still, as the ground is everywhere absorbent, and there are no streams even in the valleys (I am now speaking of the higher districts), every dwelling contributes its quota; for the rain and all liquid matter absorbed in these strata necessarily pass down to the great underground reservoirs of water feeding the springs thrown out in the deeper river-valleys. In these cases, however, the thickness of strata through which any liquid has to pass before reaching the line of water-level is such as to produce a more or less efficient filtration and complete decomposition; and as the injury caused is in proportion to the relative volumes of the water-sources and the artificial additions the great extent and dimensions of these water-bearing strata and the scanty population reduce it to a minimum.

Owing to these conditions, great as the evil is, experience teaches us that it has, in some cases, its vanishing-point. It may be considered at its maximum in some of the wells of Paris; our own London shallow-well pumps follow next in order; in some of the springs of the Chalk and Lower Greensands it is hardly appreciable, while in the deep-well waters, especially those of Caterham and Grenelle, it sinks to the minimum attained by any potable waters with the exception of rain-water *. It is also a fortunate circumstance that the wonderful powers of oxidation possessed by air and water, and the powers of absorption and decomposition by soils and earths, are such as, even in the surcharged gravel-bed of London, to remove all the more offensive characters, and leave its spring-waters at all events limpid and bright; whilst in our rivers, the quick eddy, the moving ripple, the bright sunshine, the brisk breeze, and living organisms are ever at work destroying the almost inevitable accompaniments of the presence of man, and restoring the waters to that original state of purity so essential to his health and welfare.

* This variation is shown in the following analyses, taken, with the exception of those of the Grenelle well, from those made for the Commission (Appendix, p. 103) by Dr. Frankland, or else since obligingly communicated by him to me. By "Organic Elements" is meant the combined weight of the carbon and nitrogen contained in the organic matter. The effect of filtration on the nitrates is very marked; and, as a test of the original condition of the water, I consider their presence or absence should be accepted with much reserve. The results are given in quantities by weight per 100,000 parts of water.

| Sources of the Water. | | Organic elements. | Nitrogen as nitrates. | Carbonate of lime. | Total solid residue. |
|---|---|---|---|---|---|
| Well, Royal Institution, London. | *Surface Gravel* | 0·525 | 4·355 | 20·8 | 93·70 |
| Well, Royal Mint, London | *Tertiary Sands* | 0·220 | none | 7·7 | 83·96 |
| Well, Barclay's Brewery | ,, | 0·065 | 0·035 | 4·1 | 71·56 |
| Thames water at Hampton | | 0·284 | 0·196 | 15·7 | 27·87 |
| Springs, Head of Thames | *Oolites* | 0·023 | 0·358 | 17·0 | 28·25 |
| Spring, Moor Park | *Lower Greensand* | 0·040 | 0·034 | none | 4·55 |
| Springs, Otter, near Watford | *Chalk* | 0·038 | 0·422 | 21·0 | 32·36 |
| Well, Croydon | *Chalk* | 0·047 | 0·551 | 12·9 | 32·00 |
| Well, Caterham | *Chalk* | 0·026 | 0·027 | 16·4 | 31·08 |
| Well, Grenelle | *Lower Greensand* | 0·021 | none | 6·8 | 14·09 |

It was on considerations of quantity of supply thus dependent on geological conditions, and of quality as dependent jointly on geological and artificial conditions, that the Commission was mainly so long and assiduously engaged. With regard to the character of waters as dependent on the geological nature of the strata, though the evidence showed that the waters flowing off hard and insoluble rocks were, from their much greater freedom from mineral matter, more economical for many domestic and manufacturing-purposes, yet for drinking-purposes, waters such as those derived from our Chalk and Oolitic districts were, on the whole, as good and wholesome as those from any other sources, while the conditions presented by a large catchment-basin of a varied geological structure were undoubtedly the most favourable to quantity and permanence of supply. And if, from any cause, it should at some future time be thought desirable to have a supply of a yet more assured and undoubted quality, the large springs of the Chalk and the Lower Greensand, and the great underground reservoirs of the most efficiently filtered water stored in those formations in Surrey and Hertfordshire, might, I believe, be resorted to with advantage, by means of ordinary and Artesian wells, as a separate auxiliary source of supply for domestic and drinking-purposes, supposing the engineering difficulty connected with a double water-supply could be overcome—a difficulty, however, which, it seems to me, would possibly be less one of construction to our engineers than of cost to the public. But in a great health-question there are other considerations than these which are of more primary importance.

### *Our Coal-measures and Coal-supply.*

While the presence of water has determined the early settlement of population, the existence of coal has given rise to exceptional local growths of that population, quite irrespective of the original cause of settlement. The existence of coal has created new wants, developed vast energies and enormous resources, and established great industries dependent upon it for their maintenance and prosperity. Natural causes, unceasing and ever renewing in their action, maintain our supplies of water in a condition of constant and unfailing operation. They are physical and geological agents, equally in force in the past as in the future time of the earth's history. Not so with coal, which is a store of the past, and of which we can look for no renewal. Our Coal-measures, great as they are, have defined limits, whereas our wants seem to have no bounds. With the increasing magnitude of the latter our fears of the extent of the former have increased, and have given rise to much speculation and much discussion. At first the estimates of the duration of our coal-fields were little more than guesses; but the subject has of late years been treated in a systematic manner, and in all its various bearings, in the able works of Hull*, Jevons†, and Warington Smyth ‡. To obtain more precise data on these important questions, the Royal Commission of 1866 was appointed, with your President-elect the Duke of Argyll at its head. On the practical and economical questions different members of the Commission and separate committees have made valuable reports. I wish on this occasion merely to direct your attention to some of the more special geological bearings of the questions discussed in one of the committees, of which the lamented Sir Roderick Murchison was chairman, the object being "*to inquire into the probability of finding coal under the Permian, New Red Sandstone, and other superincumbent strata.*"

On the evidence laid before this committee regarding England north of the Bristol coal-field, Professor Ramsay was deputed to report, while the south of England was relegated to myself. The one district embraces all the unproved older secondary tracts between the different well-known coal-fields of the central and northern portions of England. The other district takes in that occupied by the later Secondary and the Tertiary strata, already the subject of a valuable paper in our 'Journal' for 1856, by Mr. Godwin-Austen §. The excellent mapping of our coal-districts by the Geological Survey, and their accurate sections through the several coal-fields, furnished Professor Ramsay with data which have enabled him to prolong these sections across the intervening tracts with a degree of certainty which gives them very great value. He has presented us with 32 such sections, which, when published, will, with the text already before the public, show how great has been the task, and how successfully it has been accomplished.

The area of the exposed Coal-measures of England may be estimated at about 2840 square miles. To these Mr. Hull had added 932 square miles of Coal-measures overspread by newer formations. The investigations of Professor Ramsay lead him now to conclude that this latter total of unproved Coal-measures may be increased to

* The Coal-fields of Great Britain, 2nd. edit., 1861.

† On the Coal Question, 1865. ‡ Coal and Coal Mining, 1869.

§ "On the Possible Extension of the Coal-measures beneath the South-eastern part of England," Quart. Journ. Geol. Soc. vol. xii. p. 38.

2988, to which may be added 153 miles of the Bristol coal-field, making a total of 3141 square miles of coal-measures under the Permian, New Red, and Triassic strata of Central and Northern England, or of 301 square miles more than the area of all our exposed coalfields. This branch of the inquiry embraces curious questions of variations in the mass of the Coal-measures, in the thickness of the strata, and in the number and persistence of the coal-seams. The extent and magnitude of the faults bounding so many of our coal-fields is also a point of great difficulty, especially when it is complicated by denudations of pre-Permian and of pre-Triassic age; and in this intricate inquiry it must be borne in mind that it is not only a question of superposition and faulting, but one also of removal and replacement, involving a number of important geological problems. Especially is it necessary to distinguish steep old-surface and sub-marine-valley denudations from faults.

The other inquiry, relating to the possible range of the Coal-measures under the Jurassic, Cretaceous, and Tertiary strata of the south-east of England, involves questions of a much more hypothetical character, and can, in the absence of positive information, only be treated on purely abstract geological reasoning. Still it is one essentially within the range of inquiry; and the collateral geological data we possess are sufficient to guide and direct those inquiries. There are two primary points to be determined :—first, how much of the area under investigation remained dry land during the Carboniferous period, and was therefore never covered by coal-strata? secondly, supposing the coal-strata to have spread over a portion of that area, how much has escaped subsequent denudation? With regard to the first question it is comparatively easy, when the Palæozoic rocks now form the surface, to determine the antiquity of that surface; but where the old rocks are covered by great masses of other strata it becomes very difficult to determine the original conditions, and the inquiry is one of much complexity. Nevertheless Mr. Godwin-Austen has ingeniously sought to establish the position of the old coast-lines of the Carboniferous and other periods, the area of the old coal-growth, and the great features of the ancient physical geography of this period in Western Europe. I have here given more especial attention to those points which bear on the present relations of the Secondary and Palæozoic formations to one another. With regard to these we have to depend upon physical conditions connected with the nature of old disturbances and old denudations, the direction and position of the great anticlinal and synclinal lines, the correlation of certain strata, and the volume of the overlying masses.

The great lines of disturbance traversing Central and North-eastern England are subsequent to the Carboniferous period; and the many detached coal-basins separated by the Pennine chain and the Derbyshire hills, together with the Mountain Limestone forming those ranges, are held to be portions of one great Carboniferous formation, which, in its entirety, spread from the south of Scotland to Central England, and, as we shall observe presently, probably still further south. This great Carboniferous deposit was originally bounded on the north either by the uplands of the Scottish border-counties, or, possibly, by the Grampians; on the west by the high lands of Cumberland and Wales; while on the south we find no old exposed land-surfaces of older Palæozoic age until we reach Brittany and Central France. With respect to the deposits going on during the Carboniferous period in this area, Professor Phillips was the first to show that the lower Carboniferous series puts on, as it trends north from Derbyshire, more sedimentary conditions—that the Mountain Limestone there begins to show traces of proximity to land, which increase rapidly in proceeding northwards,—beds of shale and sandstone and subordinate beds of coal gradually setting in amongst the limestone series, and increasing in importance as they approach the older border land. In the same way the approach to an old barrier-land on the south and west is supposed by Professor Ramsay to be indicated in the overlying Coal-measures by the increase in number and thickness of the beds of sandstone in the south of the Staffordshire and Shropshire coal-fields; and Mr. Hull connects that old land with the Cambrian and Silurian rocks of Leicestershire.

If such was the case, the question arises, did this form a barrier which cut off the Carboniferous deposits from extending over the south of England, or was it only a partial barrier which in no way prevented the extension southward of the Carboniferous rocks?

It has been supposed that during the Carboniferous period a spur from the Silurian district of Wales extended into Central England eastward from Herefordshire, dividing the coal-fields of Shropshire and Staffordshire from those of Gloucestershire, and that against this old Silurian tract the Coal-measures of South Staffordshire die out. If carried further eastward it would limit the southern prolongation of the Coal-measures of Leicestershire, and then pass under the Oolites of Northamptonshire and the Cretaceous series of Norfolk. So great an expansion has been given to this old land southward, that it would exclude the Coal-measures from the whole area of the south-east of England. We have, however, no sufficient evidence of the continuous extension of these old rocks eastward of Staffordshire. Palæozoic rocks show, it is true, in Leicestershire; but the Coal-measures wrap round them, and the older rocks seem merely to be an island in their midst. At those spots in the southern counties where the palæozoic rocks have been proved underground, I imagine they were raised by disturbances of a later date than the Coal-measures, and did not form part of the land-surface of the Carboniferous period. As just mentioned, the older Carboniferous rocks show deeper-sea conditions as they trend from north to south; and the same deep-sea conditions that existed in Derbyshire are found to prevail in the Mountain Limestone of Belgium, while, at the same time, similar slight indications of distant land, in the presence of intercalated shales and imperfect coal, reappear, and increase westward in their range into the district of the Boulonnais, in France. There is nothing in fact to show but that the spur of old land stretching eastward from Herefordshire was merely a promontory ending in Warwickshire, and round which the Carboniferous sea passed and extended southward uninterruptedly to Belgium and the north of France, and westward to Somersetshire and South Wales, spreading over all this wide area first the Mountain Limestone and then, in due order, the Coal-measures. Of the existence of these formations over the south-western and south-eastern portions of this area we have proof in Wales, Somersetshire, and Belgium. The intermediate area is covered by Jurassic, Cretaceous, and Tertiary formations, which hide from us the older rocks whose position it is our object to determine.

Just as a disturbance at a later period caused the Mountain Limestone of the Pennine chain to break through the great expanse of Coal-measures originally spread over the central and northern counties of England, and brought up to the surface the disturbed and disjointed coal-strata, of which, after subsequent denudation, we have the isolated portions remaining in the existing coal-fields, so was the carboniferous area of Southern England broken through by the earlier axis of Palæozoic rocks of the Ardennes and Mendips, bringing up the Coal-measures in like manner along their northern flanks in separate basins and troughs, the higher of which are uncovered on the surface, while others may still possibly exist beneath the newer strata of the south-east of England. They have in fact been proved to exist under considerable portions of the same newer strata of North-western France and of Belgium, and under small portions of the older Secondary strata in the south-west of England.

The probable continuation of this great range of Palæozoic rocks from the Rhine to South Wales, passing underground in the south of England, was shadowed out by Buckland and Conybeare* in 1826, commented on by Dufrénoy and Elie de Beaumont† in 1841, by M. Meugy‡ in 1851, and more fully investigated and discussed by Mr. Godwin-Austen in 1856. These views having been controverted §, the subject was fully discussed by the Commission ||, and again in the separate Report drawn up by myself ¶.

All geologists are agreed upon the age of this great east-and-west axis of disturbance. It took place after deposition of the Coal-measures, and before the deposition of the Permian strata. Its effects, all through its range, are singularly alike. It was not so much a great mountain-elevation as a crumpling up and contortion of the strata for a breadth of many miles, and along a length of above 800 miles **. The Silurian and Devonian rocks are thrown up by it into a number of narrow anticlinals; and the flanking coal-strata are tilted, turned back on themselves, squeezed and contorted in the most remarkable manner,—the same type of disturbance being apparent whether in Westphalia, Belgium, France, Somerset, or Pembroke. These great flexures have also resulted in throwing the Coal-measures into deep narrow troughs, having a length of many miles and a width of but very few.

In France, these disturbed old strata are covered transgressively by Jurassic, Cretaceous, and Tertiary strata, and in England by Permian, Liassic, and Jurassic strata; and while the axis of disturbance sinks beneath the Oolites at Frome, it reappears in Belgium from beneath the Cretaceous strata. What becomes of it in the interme-

* Trans. Geol. Soc. 2nd ser. vol. i. p. 220.

† Explication de la Carte Géologique de la France, vol. i. pp. 724, 725.

‡ Essai de Géologie pratique sur la Flandre Française, p. 76.

§ Sir R. Murchison maintained the views he had advanced at Nottingham in 1866; and as the opinions of so distinguished a geologist were entitled to the most serious consideration, all the objections raised by him were discussed *seriatim* in my separate Report. This was published during his last illness, and only a few months before his death; and I have reason to believe that the protest appended by him to the final Report of the Commission was founded upon the conclusions alone of my Report there given in p. xii, and not on the perusal of the special Report itself. It is therefore necessarily based on his preconceived opinions, and without knowing how his arguments had been met.

|| See Minutes of the Evidence given in Committee D.

¶ "On the Probabilities of finding Coal in the South of England." Report D.

** It has been traced from Westphalia to the south of Ireland.

diate area? It is not to be supposed that a line of disturbance of such great magnitude could have been intermittent. The coal-trough has, in fact, been followed from near Charleroi, where it passes under the Cretaceous and Tertiary strata, to Mons, Valenciennes, and Béthune, a distance of 86 miles. Along the whole of this line, the Chalk and overlying beds extend, with a thickness varying from 500 to 900 feet around Mons, decreasing to from 250 to 300 near Valenciennes, and increasing again towards Béthune. At Guines the Chalk was found to be 670 feet thick, and at Calais 762 feet. On the other side, the coal-trough of Somerset passes eastward under the older Secondary rocks, which in their turn pass under the Cretaceous and Tertiary strata of Wiltshire *; but no attempt has been made to follow Coal-measures beyond a distance of 6 miles from their outcrop, where the overlying strata were found to attain a thickness of about 450 feet.

The original supposition, that the Secondary strata maintained in the main their regular sequence, and to a certain extent their thickness over large areas, has long been proved to be erroneous; but we were hardly prepared until lately to learn how rapid the variation in their thickness is. Mr. Hull has now shown that the Great and Inferior Oolites thin out from a thickness of 792 feet in Gloucestershire to 205 feet in Oxfordshire, and the Lias and Trias from 1090 feet to 400 (?) feet; while in like manner the Trias decreases from 5600 feet in Lancashire and Cheshire, to 2000 in Staffordshire, and 600 feet in Warwickshire. We also know that on the northern flank of the Mendips, the Trias, Lias, and Oolites tail off, although their dimensions in Gloucestershire are so considerable. It would appear that all the Secondary rocks, except those of the Cretaceous series, show a distinct thinning-out in their range southward, which is doubtless due to the existence of an old pre-Triassic land on the south—such as would have been formed by the prolongation of the Palæozoic rocks of the Ardennes and Mendips through the south of England. It has been urged on the other hand, that this thinning-out is a proof of the existence of a still older land in that area; but as the argument is based on the evidence of rocks of post-Carboniferous age, it is clear that, whether the land were of Cambrian and Silurian, or of Devonian and Carboniferous age, the result, as affecting the Secondary rocks, would be the same.

This thinning-out of the Secondary strata has now been proved

* In the neighbourhood of La Marquise, near Boulogne, a similar relation of Secondary to the Palæozoic rocks exists, the latter being overlain by unconformable Oolites, succeeded by other Secondary strata and then by the Chalk.

not to be merely hypothetical. At three points, on or near the presumed line of the old underground range, the Tertiary and Cretaceous strata have been traversed in well-sections, and Palæozoic rocks found to underlie them at once, without the intervention of any Triassic, Liassic, or Oolitic strata. Thus at London the presence of red and grey sandstones, apparently of Palæozoic age, has been proved under the Chalk at a depth of 1114 feet. Again, at Harwich and at Calais, strata of early Carboniferous age have been found also immediately under the Chalk, at depths respectively of 1026 and 1032 feet. There is therefore reason to believe that the underground ridge of the Mendips and the Ardennes passes in a line from Frome through North Wiltshire, Berkshire, Middlesex, North-east Kent, and between Calais and Boulogne, at a depth beneath the Secondary strata of not more than from 1000 to 1500 feet, while the coal-troughs which may flank this range on the north would, judging from the analogy of the structure and relations of the same rocks at Mons and Valenciennes, be met with at depths very little, if at all, greater.

To the north of this area it is probable that the thickness of the overlying rocks is greater; but we have no means of knowing exactly. In Northamptonshire the Great and Inferior Oolites and the Lias have been found not to exceed together 880 feet, at which depth the New Red Sandstone was reached; but its thickness was not proved beyond 87 feet; while at Rugby the Lias was found to be about 905 feet thick; below which 136 feet of the New Red Sandstone was passed through. Looking at the proved thinning-out from north to south of the New Red and Permian strata, there is no reason to suppose that they would be found of any very great thickness in the southern counties. Even immediately to the south of the known coal-fields of the Midland counties, the trials for coal have not yet proved any very great thickness of these rocks. It would seem that the extensive tracts of Chalk, Oolites, and Trias forming the substrata of our Midland and Southern counties constitute but a comparatively shallow crust filling up the plains and valleys of Palæozoic rocks, of which the great framework stretches apparently at but a moderate depth under our feet, and the highest ridges only, such as those of the Ardennes and the Mendips, now rise above ground.

It is clear that in any search for coal, as in relation to one another the Secondary and the Palæozoic groups of rocks are perfectly independent, the latter must be considered entirely on their own internal evidence, and apart from the bearing of the newer rocks covering them and forming the present surface*, except possibly in a few cases where old lines of disturbance have proved points of least resistance, and again yielded to later movements which have equally affected the overlying formations.

It may be asked if any correlation can be established between the Coal-measures of Bristol and South Wales, and those of France and Belgium. So far as the identity of any particular bed of coal or of rock, it is impossible, and we should not expect it; for the variation in all the beds of any coal-basin is well known to be so great and rapid that in the different parts of the same basin it is often difficult, and sometimes impossible, to establish any correlation, while in adjacent basins, such as those of Wales and Bristol, or of Hainaut and Liége, such attempts have, with few exceptions, hitherto utterly failed. There are, however, general features which serve to show some relationship. The great dividing mass of from 2000 to 3000 feet of rock called Pennant exists in both the Welsh and Bristol Coal-field; and the total mass of Coal-measures is not very different, it being, say, 10,500 feet in the one, and 8500 in the other, and there being in Wales 76, and in Somerset 55 workable seams of coal. In the Hainaut (or Mons and Charleroi) basin, the measures are 9400 feet thick, with 110 seams of coal; in the Liége basin 7600 feet, with 85 seams; and in Westphalia 7200 feet, with 117 seams. On the other hand, none of our central or northern coal-basins, with the exception of the Lancashire field, exceed half this thickness, and more generally are nearer one fourth. Further, the difference which exists between the northern coals and those of Wales and Somerset, the preponderance of caking-coals in the north, and of anthracite, steam, and smiths' coal in the south, equally exists between our northern coals and those of Belgium, which latter show, on the other hand, close affinities with those of Wales and Bristol†. I am informed by two experienced Belgian coal-mining engineers and good geologists, who have twice visited our coal-districts, that the only coals they found like those of Belgium were the coals of South Wales and Radstock; there was the same form of cleavage, the same character of measures, and the same fitness for like economical purposes‡. Organic remains afford us a

* On this point Mr. Godwin-Austen holds more advanced views.

† Mr. Greenwell has noticed this similarity, as well as the fact that in Somerset and in Belgium the strata are at places so contorted that the shafts sometimes traverse the same coal two or three times. (Proc. Manchester Geol. Soc. vol. v. p. 34, 1864.)

‡ See the Letters of MM. Briart and Cornet, Report D, p. 154.

little help; but not sufficient is yet known of their relative distribution. The plants are, as usual, the same; so also are shells of the genus *Anthracosia*, and a number of small Entomostraca; while there is a scarcity of the marine forms which are more common in some of our central and northern fields. That, therefore, which best indicates the relation between the coal-fields of the south-west of England and those of the north of France and Belgium, is the similarity of mass and structure, uniformity of subjection to like physical causes, and identity of relation to the underlying older and to the overlying newer formations.

It was in the north that the conditions fitted for the formation of coal first set in. The common *Stigmaria ficoides* and various Coal-measure plants appear at the base of the Carboniferous or in the Tuedian series of Northumberland, which there overlies conformably the Upper Old Red Sandstone; and productive beds of coal exist low down in the Mountain-Limestone series. These disappear in proceeding southward, and the great productive coal-series becomes confined to beds overlying the Millstone Grit. If the coal-growth set in earlier in the north, it seems to have been prolonged further south, under more favourable conditions, to a later period. What those conditions were—whether the proximity of a greater land-surface, of a longer and greater subsidence, with more numerous rests—we cannot yet pretend to say.

Of the prolongation of the axis of the Ardennes under the south of England there can be little doubt; nor can there be much doubt that the same great contortions of the strata, which in Belgium placed the crown of the anticlinal arch at a height of four or five miles above the level of the base of the reversed synclinal arch, to the bottom of which the Coal-Measures descend*, and were the cause of similar folds in the Coal-measures of Somerset and Wales, were continued along the whole line of disturbance, and that the preservation of detached portions of the same great supplementary trough is to be looked for underground in the intermediate area, just as it exists above ground in the proved area; for the intermediate subordinate barriers dividing the coal-basins can, I conceive, in no way permanently affect the great master disturbance, by which the presence of the Coal-measures is ruled. Admitting, however, that the Coal-measures were originally present, to decide whether they have been removed by subsequent denudation is another question.

* Mr. Godwin-Austen has estimated, from the great folds and numerous twistings of the Belgian Coal-measures, that they have been squeezed into a space one fourth only of that which they originally occupied.

It has been urged as a fatal objection to the discovery of coal in the south-east of England, that the Coal-measures become unproductive, and thin out under the Chalk, as they range from Valenciennes towards Calais, and, therefore, that the coal-trough or basin ends there. It is perfectly true that the Coal-measures do thin out between Béthune and Calais, but not in the sense of their dying out owing to their deposition near the edge of a basin. In that case, each seam, each stratum would gradually become thinner and disappear ; but such is not the fact. None of the beds of the Belgian coal-field are thick ; the average does not exceed $2\frac{1}{4}$ feet. At Valenciennes it is the same ; whereas M. Burat states that the mean thickness of the beds actually increases westward of Béthune to more than $2\frac{1}{2}$ feet. With respect, also, to the extreme end of this basin, the lower beds there brought up correspond with the bottom beds of the Hainaut basin, where the lower 650 feet consist altogether of unproductive measures. The thinning-out is, in fact, due to denudation, just as the Bristol coal-field thins out at Cromhall to resume in the Forest of Dean, or the coal-field of Liége thins out at Nameche to resume at Namur in the great field of Charleroi and Mons.

The deterioration of the coal in the small coal-field of Hardinghen, near Boulogne, has also been adduced against the occurrence of workable coal in South-eastern England ; but Mr. Godwin-Austen has shown that this Hardinghen coal-field is one of those small local developments of coal-bearing strata intercalated in the Mountain Limestone, and is of older date than the great Belgian coal-field. It has, therefore, no bearing on this part of the question.

Another objection, to which much weight has been attached, is, that as the coal-field of Bath and Bristol forms an independent basin, cut off both on the east and on the west by ridges of Millstone Grit and Mountain Limestone, we have there reached the eastern boundary of the Coal-measures. This is quite correct so far as regards the western edge, and is probably the case on the eastern, though, as the edge of the basin is there covered by Secondary rocks, some uncertainty still exists about the disposition of the Palæozoic rocks under them. Admitting, however, the basin to be complete and isolated, that is no proof that the older Palæozoic rocks prevail exclusively to the east ; for the Coal-measures of the Somerset basin maintain their full development to the edge of the basin, and are there cut off by denudation, and not brought to an end by thinning out. They form really part of a more extended mass, of which we have there one fragment, while on the west another portion exists in the Welsh basin, and another in the newly discovered small basin of the Severn valley.

This last basin is entirely covered by the New Red Sandstone; and as the Welsh basin is bounded on the east and the Bristol basin on the west by Mountain Limestone, the same argument might have been used in either case to show the impossibility of coal occurring in this intermediate area.

But the fact is, it is the very nature of this great line of disturbance to have minor rolls and flexures of the strata at, or nearly at, right angles to it, and so causing breaks in the coal-trough, which would otherwise flank it without interruption; thus the Aix-la-Chapelle coal-field is separated by older rocks from that of Liége, which is again separated by a ridge of Mountain Limestone from that of Hainaut. So in the case of South-western England, we have the separate basins of South Wales, Severn valley, and Bristol,—the extremes of the intervening belts of older rocks being two miles at Nameche and eighteen miles in Wales. These barriers are clearly only local; and the division of the Coal-measures into separate basins appears to be their ordinary condition along this great line of disturbance. The length of the two known portions of the axis included between Pembrokeshire and Frome, and between Calais and Westphalia, is 472 miles; and in this distance we find eight separate and distinct coal-fields. The combined length of these eight coal-fields is about 350 miles, leaving about 122 miles occupied by intervening tracts of older rocks; so that nearly three-quarters of the whole length is occupied by coal-strata. I consider that a structure which is constant above ground, so far as the axis of disturbance can be traced, is, in all probability, continued under ground in connexion with the range of the same line of disturbance; and I see no reason why the coal-strata should not occupy as great a proportional length and breadth in the underground and unknown as in the above-ground and explored area.

With respect to the possibility of denudation having removed the intervening Coal-measures, enormous as the extent of denudation must have been previously to the deposition of the Permian strata, we cannot admit its exceptional action in this case. Denudation has removed from the crest of the Mendips a mass of strata possibly equal to two miles or more in height, and from that of the Ardennes as much as three or four miles; and it has also worn extensive channels between many of our coal-fields; so that the power of such an agent cannot be denied. But it is a power of planing down exposed surfaces rather than of excavating very deep troughs. Notwithstanding its immense planing-down action on the Mendips and Ardennes, deep troughs of Coal-measures are left flanking their northern slopes. These troughs descend to more than a mile beneath the level of the sea; and I do not think it probable that the intermediate underground portions of the trough, where the axis is lower, have suffered more than those on the higher levels*, except to the extent caused by the later denudation which preceded the Cretaceous period. But this would not affect the main bulk of the Coal-measures. The Belgian coal-field, which was exposed to the action of both these denudations, still retains vast proportions.

The pre-Cretaceous denudation was very irregular in its action. At one place near Mons the Chalk and Tertiary strata are above 900 feet thick; whilst at another, on about the same level, and at but a short distance, they are not 100 feet thick—an old under-ground hill of highly inclined Coal-measures giving rise to this difference, and rising in the midst of the uncomformable newer strata. This shows that in the English chalk-area we may possibly find irregular old surfaces of this kind, so that the Coal-measures may exist at places nearer the surface than we have estimated†.

We have alluded before to the great length and small width of the Belgian coal-fields. That of Liége is forty-five miles long, with a mean width of less than four miles, whilst that of Hainaut and Valenciennes, with a width scarcely greater, is 119 miles long. The presence of Lower Carboniferous rocks under Harwich, and the wider range north and south of the Bristol coal-field, render it possible that the trough in the intermediate area may have a greater expansion than in Belgium; but we have nothing else to guide us, unless it be that the lateral pressure in the intermediate lower ground was probably less than in the Ardennes and the Mendips, where it has exercised its maximum elevatory force. In that case the coal-trough in this intermediate area would be less compressed and more expanded, and we might consequently look to find larger coal-basins than those of either Somerset or Liége—a view in which, I believe,

* The pre-Permian and pre-Triassic denudations were, I believe, more effective in producing discontinuity of Coal-measures in the northern and central than in the southern area.

† The well-section at Diss, given by Mr. Taylor in our Transactions, shows that the Chalk extends probably to a much less depth there than at Harwich. More lately a well has been carried at Norwich through the Chalk and into the Gault, to a depth of 1158 feet.

Mr. Godwin-Austen agrees. The position of these basins, however, I am disposed, for reasons given in my Report, to place further north than Mr. Godwin-Austen, and should therefore look for them not in the valley of the Thames or on the line of the North Downs, but under South Essex, Middlesex, or Hertfordshire, Oxfordshire, and North Wiltshire.

The strata on the south side of the Liége coal-field rise abruptly against highly inclined and faulted Devonian rocks, and on the north side they rise, at a less angle, beneath Cretaceous or Tertiary strata. In the Hainaut coal-field the overlying strata have a greater extension. Further north the Coal-measures are succeeded by Mountain Limestone, and then by Devonian or Silurian strata; but, with one or two limited exceptions, their outcrop is hidden by the newer strata which stretch uninterruptedly northward over the rest of Belgium. The Palæozoic strata, however, have been met with near Brussels under Tertiary strata, at a depth of about 600 feet, and at Ostend at a depth of 985 feet, of which 682 consisted of Lower Tertiary strata, 210 feet of Chalk, and 93 of coloured marls*. It appears, therefore, not improbable that the Tertiary and Cretaceous strata of all Belgium may repose directly on a floor of Palæozoic rocks; and as there is reason to suppose that these rocks have a strike parallel with that of the Ardennes, folds in the strata may bring in some underground coal-basin or basins in parallel lines to the north, in the same way that small troughs of Coal-measures are brought in again in the Ardennes to the south of the great coal-trough. On the other hand, the great Palæozoic axis of the Ardennes, consisting of Silurian and Devonian rocks, Mountain Limestone, and Coal-measures, passes westward under the Chalk of the north of France, and has been followed underground as far as Calais, where it lies at a depth of 1032 feet; while in the direction of Boulogne it keeps nearer the surface, crops out from beneath the chalk downs surrounding the Boulonnais, and disappears westward under an unconformable series of Jurassic and Wealden strata.

We may, I think, look for a prolongation of this old Palæozoic surface of highly inclined, contorted, and faulted rocks at no great depth under the same Wealden, Chalk, and Tertiary area of the south-east of England. For, although the old Palæozoic surface descends rapidly from 200 feet above the sea-level in the Boulonnais to 1030 feet below it at Calais, it rises at Ostend 47 feet higher

* A red chalk or marl, 49 feet thick, immediately underlies the Chalk in this well. A similar red marl was met with under the Chalk in the deep well at Stowmarket.

than at Calais; and, crossing the Channel, it is found at Harwich within a few feet of the same depth as at Calais, from which it is eighty miles distant in a northerly direction. Passing westward, we find the Palæozoic rocks under London, 105 miles distant from, and 102 feet higher than under Calais, and 106 feet higher than at Harwich. Allowing for irregularities of the old surface as evinced by the well at Crossness, near Plumstead, which was still in the Gault at a depth of 944 feet, or some 14 feet below the level of the Palæozoic rocks at Kentish Town, we may still consider that in the area between these three points, and parts of the south-east of England, the Palæozoic rocks will probably be found not to be more than from 1000 to 1200 feet beneath the sea-level.

Projecting the line another 100 miles westward, we reach the neighbourhood of Bath and Frome, where the Coal-measures are (as before mentioned) lost, at a depth of about 450 feet, beneath Liassic and Jurassic strata. In the intermediate area between that place and London no trial-pits and no wells have been carried to a depth of any thing like 1000 feet beneath the sea-level. The deepest well with which I am acquainted is one near Chobham, in Surrey, through Tertiary strata and Chalk to a depth of about 800 feet, or 550 feet beneath the sea-level.

There are, however, in all this area certain indications of the proximity of old land and of pre-Cretaceous denudation, in the presence of quartz and Lydian-stone pebbles accompanied by extraneous secondary fossils in the Lower Greensands of Surrey, and in the like old-rock pebbles, with the addition of slate-pebbles, in that formation in North Wiltshire; while the banks of shingle, Bryozoa, and sponges of the same age at Farringdon point to still and sheltered waters, probably of no great depth, and to adjacent dry land *. Again, on the north of London, we have in the Lower Greensand of Buckinghamshire and Bedfordshire shingle-beds consisting almost entirely of fossils derived from Jurassic strata, with a remarkable collection of larger quartz, quartzite, and other rock pebbles, derived probably from the old Palæozoic axis.

On the south also of the great Mendip and Ardennes axis coal-strata may possibly be found, just as they are found on both sides of the Pennine chain; for in both cases the measures are cut off and

* Mr. Godwin-Austen remarks that "true littoral Lower Greensand shingle occurs near Devizes and thence on to Calne." He also refers the occurrence of some fresh-water shells in the Isle-of-Wight beds to their having been washed into them from adjacent dry land. Old-rock pebbles are also found in the Wealden beds.

runcated by these chains of elevation. In South Wales certain folds of the older strata seem to render it probable that the Coal-measures may pass under the Bristol Channel, forming a trough which, prolonged, would pass along the south side of the Mendips. Trials in the latter area, however, have shown that the New Red Sandstone, Lias, and Oolitic series attain an infinitely greater thickness than on the north flank of that range ; so that it is not likely that the Coal-measures would lie at a less depth than from 1500 to 2000 feet.

On further consideration, it seems to me a question whether we should not rather take a broader view of this great east-and-west axis, and assign to it a width varying from 30 to 80 miles or more, looking at the Mendips and the Exmoor hills as the bounding flexures of the same line of disturbance in South-western England, while the ridges of the Ardennes, the Eifel, and the Hundsrück (in part ?) are exhibitions of the same parallel series of anticlinals*. In that case the great coal-basins of South Wales and Somerset would represent the synclinal trough on one side of the axis of disturbance, and on the other side the Lower Carboniferous or Culm-measures of Devon ; while on the Continent the deep narrow synclinal trough of the Liége and Aix-la-Chapelle basin may be regarded as lying on one side of the arch, and the great coal-basin of Saarbrück on the other. This important coal-basin has already been followed under the New Red Sandstones of the Vosges for a distance of from twenty-four to thirty miles in the direction of Metz, still on the strike of the Ardennes. Further westward, a trial for coal near Donchery led to the discovery of palæozoic rocks, at a depth of 1090 feet under that thickness of Lias and Infralias; but the line of the coal-trough should, I think, pass a few miles to the south of this spot. Thence this underground coal-trough would range in an irregular east-and-west line, keeping parallel, or nearly parallel, with the Mons and Valenciennes troughs, under the north of Champagne, Normandy, the Channel, between the Isle of Wight and Cherbourg, Dorset, cropping out again in North Devon. The only deep sections that I know of on this line are those furnished by a well sunk many years since, nine miles east of Dieppe, to a depth of 1092 feet in the Kimmeridge Clay and other strata, and another by a boring at Sotteville, near Rouen, through a thin capping of Cretaceous strata, to a depth of 1050 feet in the same Kimmeridge Clay

* See Sedgwick and Murchison's paper "On the Palæozoic Rocks of North Germany and Belgium." Trans. Geol. Soc. 2nd ser. vol vi. p. 221, and 'Siluria,' 4th edit. pp. 403 and 404.

—in both cases without reaching the Palæozoic rocks. At Paris no Palæozoic rocks have been reached at a depth of 2000 feet*.

In this country the newer strata, overlying the Palæozoic rocks on the presumed anticlinal line, have been sunk through without result—in the lowest beds of the Wealden at Hastings to a depth of 486 feet, in the upper beds at Earlswood, near Reigate, to about 900 feet, and, on the presumed synclinal line of Carboniferous rocks, through Chalk at Chichester, to 945 feet, and at Southampton, through Tertiary strata and Chalk, to a depth of 1317 feet.

To the south of all the area we have now described there existed, during the Carboniferous period, the ranges of the older Palæozoic rocks of the Hundsrück and Vosges, of the old crystalline rocks of Central France fringed on the east and north with small outlying coal-basins, of the old Palæozoic rocks of Brittany, and of the Silurian rocks of South Cornwall—forming the old land-surfaces, fringed by the great coal-growths subtended northwards through Northern France, Western Prussia, Belgium, and England, to the Silurian uplands of Central Scotland on the north and those of the Welsh and Cumbrian highlands on the west, and possibly to those of the Scandinavian hills on the north-east. After the formation and consolidation of the coal-strata, the southern area of this great Carboniferous basin was then subjected to that remarkable disturbance which, for a distance of above 800 miles, exercised that excessive lateral pressure by which the older underlying strata were squeezed and forced up into the series of sharp anticlinals forming the axis of the Mendips and Ardennes †, while portions only of the Carboniferous series were preserved from the denudation which followed, in deep synclinal troughs flanking the main axis.

The central and northern portions of the great Carboniferous basin, which were not thrown up by this disturbance, were then overspread by strata of the Permian series; after which this northern section of the original coal-area was traversed by that other great disturbance at nearly right angles to the former one, by which fresh portions of the Coal-measures were brought up in our central and northern counties, leaving other deeper-seated portions to be covered by Triassic and Jurassic strata.

At a much later period the emerged southern area of Palæozoic

* For much information on this great axis and on the French coal-fields see 'Explication de la Carte Géol. de France,' vol. i.

† Mr. Godwin-Austen informs me that he also considers that productive Coal-measures probably exist under the Paris basin.

rocks, including the westward prolongation of the great coal-trough of Belgium, or portions thereof, was submerged and covered over by those strata of Greensand, Chalk, and Lower Tertiaries now forming the surface of the south-east of England and Northern France.

The trials to discover these possibly productive coal-basins must necessarily be attended with considerable uncertainty. We shall have to feel our way. Of our hope of their ultimate success I have given you the reasons. Nor could such trials near London fail to yield some important results; for, even if we did not hit at first upon the *Coal-measures*, it is probable that the *Lower Greensands* * would at some spots be reached, and the further inestimable benefit of a large and steady supply of pure water might also be obtained, and, with proper care to prevent undue interference, might be maintained for all time.

And now, Gentlemen, in retiring from the Chair, which I have had the honour to occupy during the last two years, allow me to express the sincere satisfaction I have experienced in witnessing the continued prosperity of the Society, and the unanimity and cordiality with which its labours are carried on. It was a post I long hesitated to accept, but which your kind forbearance and the friendly cooperation of your Officers has not only rendered easy, but as pleasant as it has been gratifying. I feel assured of the continued prosperity and usefulness of the Society when I resign my trust into the hands of a nobleman so distinguished as a statesman, so able as a writer, and so long known amongst us as an active and zealous geologist, as the Duke of Argyll.

* The Lower Greensand would no doubt offer great difficulties to the sinking of shafts; but by the new process of sinking Artesian wells of enormous size, they have now succeeded in Belgium in traversing strata equally permeable. The Lower Tertiary sands, the Chalk, and the Aachenian Sands, are all heavily charged with water, and through these the tubes have been successfully carried without pumping. (See paper by Mr. W. W. Smyth, in Trans. N. of Engl. Inst. of Mining Engineers, vol. xx. pt. iv.)

With regard to the difficulty arising from depth of working under so considerable a thickness of newer strata, I would observe that although the higher temperature at depths exceeding 3000 feet may be found a serious disadvantage, still the imperative necessity which would then arise of more efficient ventilation for the purpose of refrigeration would in itself be a great gain and advantage to the health of the men and the safety of the mines.