From the author

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ADDRESS

DELIVERED AT

THE ANNIVERSARY MEETING

OF THE

GEOLOGICAL SOCIETY OF LONDON,

On the 17*th of* February, 1871;

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.

1871.

Dr. G. Plarr

care of George Lidney Esq

St. Andrews

IV B

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PROCEEDINGS

AT THE

ANNUAL GENERAL MEETING,

17TH FEBRUARY, 1871.

AWARD OF THE WOLLASTON MEDAL.

THE Reports of the Council and of the Committees and Auditors having been read, the President, JOSEPH PRESTWICH, Esq., F.R.S., handed the Wollaston Gold Medal to Professor RAMSAY, F.R.S., F.G.S., addressing him as follows :—

PROFESSOR RAMSAY,—I have great pleasure in presenting you with the Wollaston Medal, which has this year been awarded to you by the Council of the Society, in recognition of your many researches in practical and in theoretical geology. Distinguished as your services have been in connexion with the Geological Survey since you entered upon it as the Assistant Geologist of Sir Henry De la Beche in 1841, and more particularly since your appointment as Local Director in 1845, during which period you have superintended and carried out the admirably minute style of mapping now general on the survey, and done so much in training its members in the field, you have not less distinguished yourself by your investigations of the higher problems involved in the study of geology. Your first work was on the Isle of Arran; and although then only a beginner, you, instead of taking the rocks to be what they looked, worked out what they were, and gave a new and independent reading of them, which has since in great part proved to be the right one. In 1846 your well-known memoir "On the Denudation of South Wales and the adjacent Counties of England" showed the enormous amount of denudation that the Palæozoic rocks had undergone before the deposition of the New Red Sandstone. At subsequent periods you dwelt on the power that produced "Plains of Marine Denudation," a term introduced, I believe, by yourself, and showed in all cases, by a series of true and beautiful sections, how this had operated in planing across the older strata, and how valleys had been scooped out by subsequent aqueous causes in the great plains so formed.

Whilst unravelling the complicated interior phenomena of the Welsh rocks, you were not unmindful of the very different order of phenomena exhibited on their exterior surfaces. Here you showed the vast extent and power of ice-action, and what a glacier-land Wales once was. Reasoning from the present to the past, you also boldly pushed your ice-batteries far back into geological time, and were the first to bring them to bear on rocks of Permian age. That advanced post you long had to hold alone; but other geologists have since followed your lead, and we have even lately had evidence in the same direction from Southern Africa, where it is asserted that boulders and glaciated surfaces have been found at the base of the Karoo formation of supposed Triassic age.

You have also held a prominent place among those who, by their public teaching, have done so much during the last twenty years to advance the cause of our science. To myself personally, whose geological career has run nearly parallel in time with your own, it is a source of much pleasure that it has fallen to my lot to hand you this the highest testimonial the Society has to bestow.

Prof. Ramsay made the following reply:—

Mr. President,—I cannot say whether I am more pleased or surprised by the unexpected award to me of the Wollaston Medal by the Council of this Society. Pleased I well may be, not because I ever worked for this or any other honour, but because I feel a sense of satisfaction that the work on which I have been engaged for the last thirty years has been esteemed by my friends and fellows of the Council of the Society so highly that they have deemed me a fit recipient of this honour. It is also a special satisfaction to me that this award has been bestowed by the hand of one of my oldest geological friends, who is so universally esteemed and beloved, and is himself so distinguished a contributor to physical and other branches of our science.

My first endeavour in geology (the construction of a geological map and model of Arran) necessarily drew my attention to the physical part of our science; and when, consequent upon that work, I was, through the intervention of my old and constant friend Sir Roderick Murchison, appointed by Sir Henry De la Beche to the Geological Survey of Great Britain, my whole subsequent life was thereafter necessarily involved in questions of physical geology; for no man can work on or conduct the field-work of such a survey who does not, aided by palæontology, necessarily make that his first aim.

If some of my theories, induced by that work, were long in being recognized, the recognition has been all the more welcome when it came. Probably I never should have been able to do what I have done but for the wise example of my old master Sir Henry himself, in his time the best thinker in England on the physical branch of our science, and to whose remarkable work, 'Researches in Theoretical Geology,' all geologists are to this day indebted.

The papers which I have written are mere offshoots from my heavier work on the Geological Survey. Perhaps they are enough for the readers; but I wish they had been more numerous, for I certainly have had many more in my mind. Two of these, on old physical geographies, I have lately given to the Society; and if they should be printed, I shall be well pleased should they soon or late be found worthy. The present physical geography of the world is but the sequel of older physical geographies; and to make out the history of these is one of the ultimate aims of geology. These are the subjects I have striven to master in part. I consider your award a sign that I have had some success; and if, before I cease to work, I have a little more, I may well be content.

Award of the Wollaston Donation-fund.

The President then presented the Balance of the Proceeds of the Wollaston Donation-fund to Robert Etheridge, Esq., F.G.S., in aid of the publication of his great stratigraphical Catalogue of British Fossils, and addressed him as follows:—

Mr. Etheridge,—The Council of the Society has awarded to you the Proceeds of the Wollaston Fund, to aid in prosecuting your valuable work on the fossils of the British Islands, stratigraphically arranged. In this work, on which you have been engaged during the last nine years, and which occupies nine volumes of MS., representing as many geological groups, you give the natural-history lists of each group, and trace the history of each species both in time and space. Of the magnitude of the work few can have any idea; nor would many have an idea of the marvellous extent of past life in our small portion of the globe without a comparison of our recent fauna with those (necessarily incomplete because only partly accessible) which you have enumerated in your most useful lists. This comparison shows:—

	Protozoa, Cœlenterata, Echinodermata.	Crustacea.	Mollusca*.	Pisces.	Reptilia.	Aves.	Mammalia.	Plants.	Total.
Number of Species in the existing fauna and flora of Great Britain	616	278	567	263	15	354	76	1820	3989
Number of Species found fossil in Great Britain	2574	746	7091	815	224	12	172	819	12453

I trust that this work will not be allowed to remain in MS., and that, presuming you will begin with the oldest, we may soon look for an instalment in the fauna of the Palæozoic rocks. I have much pleasure in presenting you with this token of the importance which the Geological Society attaches to your labours.

Mr. Etheridge made the following reply:—

I have great satisfaction in receiving from you, Sir, and the Council of the Geological Society, the award of the Wollaston-fund. It is given for work known to be nearly done, and faith in its completion. The time and labour devoted to my book upon the 'Stratigraphical Arrangement of the British Fossils' has extended over nearly nine years of incessant work, and has been an arduous yet pleasant undertaking, now made lighter by the recognition of those who know and value the researches made for so extensive a catalogue of the British organic remains, now numbering nearly 13,000 species. It is this estimation of my labour by the Council and Society that tends to increase the desire to make my work as perfect as possible, well knowing how difficult, if not impossible, it is to do so. This acknowledgment, Sir, from your hands will stimulate me to complete my researches into the literature of the British species, and trace their history through space and time throughout Europe.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

Joseph Prestwich, Esq., F.R.S.

Gentlemen,—I have to congratulate you on the Report of the Council, which announces the flourishing state of your finances, the addition to your number of Members, the extension of your library, and the increasing importance of your Journal.

* Testaceous species only.

It is my duty first to mention those of our fellow-workers whose loss during the past year we have to deplore. Although the number of deceased Members amounts to 23, there are but few whose active cooperation in the special work of the Society has to be recorded.

The name of Robert Hutton is associated with the earliest days of this Society, of which he was elected a Fellow in 1813. He spent the early years of his life in Dublin, which city he represented in Parliament from 1837 to 1841. He was the friend and associate of Greenough, Buckland, and other founders of this Society, in the proceedings of which he ever took the warmest interest. During various excursions through Ireland, he made a considerable collection of minerals and fossils, which, on his leaving Dublin in 1836, he presented to the Geological Society of Dublin, of which he had been a member since its commencement in 1832. In 1836 he was placed on the Council of our Society, in 1837 served as Secretary, and was one of the Vice-Presidents in 1845 and 1846. He took for many years an active part in the Society, but did not contribute any thing from his pen, although always ready to assist others by his advice and countenance. He was also one of the original promoters of the London University (now University College), and was on its Council for 30 years. He was born in 1784, and died in August 1870.

Colonel Sir Proby T. Cautley, K.C.B. In 1831 four young men, all of whom subsequently became eminent and distinguished, met, at the commencement of their professional and scientific career, at a remote up-station in India. Sir Proby Cautley, General Sir Henry Durand (whose untimely death the nation has had so recently to deplore), General Sir William Baker, Member of Council of India, then lieutenants in the army, and the lamented Hugh Falconer, had their attention drawn by the first-named and by an Indian Prince to the rich stores of mammalian remains in the Tertiary deposits of the Sewalik Hills. They all entered zealously upon the investigation of this new and unexplored ground; and, as Dr. Murchison observes, "by the joint labours of Cautley, Falconer, Baker, and Durand, a subtropical mammalian fossil fauna was brought to light, unexampled in richness and extent in any other region then known. It included:—the earliest discovered fossil Quadrumana; an extraordinary number of Proboscidea belonging to *Mastodon*, *Stegodon*, *Loxodon*, and *Euelephas*; several extinct species of *Rhinoceros*, *Chalicotherium*; two new subgenera of *Hippopotamus*, viz. *Hexa-*

protodon and *Merycopotamus*; several species of *Sus* and *Hippohyus*, and of *Equus* and *Hippotherium*; the colossal ruminant *Sivatherium*, together with fossil species of Camel, Giraffe, *Cervus*, *Antilope*, *Capra*, and new types of *Bovidæ*; *Carnivora* belonging to the new genera *Hyænarctos* and *Enhydriodon*, and also to *Drepanodon*, *Felis*, *Hyæna*, *Canis*, *Gulo*, *Lutra*, &c.; among the *Aves*, species of Ostrich Cranes, &c.; among the *Reptilia*, Monitors and Crocodiles of living and extinct species, the enormous Tortoise, *Colossochelys Atlas*, with numerous species of *Emys* and *Trionyx*; and among fossil fish, *Cyprinidæ* and *Siluridæ*. The general facies of the extinct fauna exhibited a congregation of forms participating in European, African, and Asiatic types. Of the mammalian remains all belonged to extinct species; but of the Reptilia and freshwater Shells some of the fossil species were identical with species now in existence on the continent of India: and from this fact, more than thirty years ago, Dr. Falconer was led to draw important inferences as to the antiquity of the human race" *.

Joint notices of these remarkable discoveries were sent in from time to time and published in your 'Transactions.' Independently of these, Sir Proby Cautley communicated to the Society separate papers "On the Structure of the Sewalik Hills, and the Organic Remains found in them," and "On the Finding of the Remains of a Quadrumanous Animal in the Sewalik Hills," whilst several others bearing on the same subject were published in the Journal of the Asiatic Society of Bengal, and elsewhere. These researches were continued by Sir Proby and Dr. Falconer during eight years with indefatigable perseverance and at great expense; in 1840 Sir Proby sent this unrivalled collection, which filled 214 cases, each weighing about 4 cwt., to England. This collection was offered to our Society; but for want of room it had to be declined, and it was placed in the British Museum. It was the intention of Messrs. Falconer and Cautley to describe and illustrate the whole of their large collections in a magnificent work entitled 'Fauna Antiqua Sivalensis,' of which 9 parts were published, but which, to the regret of the scientific world, yet remains to be completed.

In 1837 the Wollaston Medal was awarded in duplicate to Sir Proby (then Captain) Cautley and Dr. Falconer "for their geological researches and their discoveries in fossil geology in the sub-Himalayan Mountains." Although an artillery and not an engineer officer, Sir Proby's abilities were so highly valued that he was ap-

* 'Palæontological Memoirs' of Hugh Falconer, vol. i. p. 28.

pointed in 1841 to construct that important work the Ganges Canal. This difficult and great public work, probably the greatest then executed under British rule in India, its main channels being 820 miles in length, was equally to the honour of those who promoted and of him who projected and successfully carried it out. It was completed in 1854. Soon after this, Col. Cautley returned to England, where he was made a K.C.B., and in 1858 he was selected to fill one of the new seats in the Indian Council, which he held till 1868, when he retired into private life after a service of 50 years. Sir Proby Cautley was born in 1802, elected a Fellow of this Society in 1836, and died last month at his residence in Sydenham.

In Lord Chief Baron Sir Frederick Pollock, Bart., we have lost another early and distinguished Fellow. He was elected in 1818. I cannot ascertain that he ever wrote on any geological questions; but the Transactions of the Royal Society are enriched with several memoirs by him on the curious problems connected with mathematical theories of numbers.

Dr. Collier joined the Society in 1838. In early life he saw much of the world as a staff-surgeon in the army, and paid particular attention to the conchology of Ceylon when stationed there. He was also eminent as a Greek scholar. He died last May at the advanced age of 86.

In Mr. Bradford the Society has lost a promising young Member, who took first-class honours in Natural Science at Cambridge, and afterwards during five years taught English Literature and Science at Hooghly College in India. He died at the early age of 32.

The Rev. C. Erle was elected a Fellow of the Society in 1837. For many years he was a very constant attendant at the evening meetings, and he will be remembered by many for the pleasant part he took in some of our discussions. He travelled much in France and Italy, and paid great attention to the volcanic phenomena of those countries. In 1833 he was appointed to the living of Hardwich, near Aylesbury, where he resided till his death last year. Of the Saurian remains of that district he made a large collection. Mr. Erle was also a distinguished classical scholar. He was born in 1790.

Amongst our foreign Members, science has sustained a great loss in Professor Gustav Bischoff, of Bonn, who died last year at the age of 78. At an early period of his life, he devoted himself to Chemistry and Physics; and his attention becoming afterwards directed to Geology, a science then in its infancy, he brought his knowledge of chemistry to bear upon the many difficult and interesting problems of Chemical Geology. In 1826 he published a paper "Sur l'origine des sources Minérales." In 1827 a paper "Sur les efflorescences des Roches Volcaniques." These were followed by various papers on Fossil bones, the inflammable gases of Coal-mines, Volcanic rocks, Glacier action, and others in the 'Neues Jahrbuch.' Many of his papers appeared in the 'Edinburgh New Philosophical Journal;' amongst them are to be found "On the Natural History of Volcanoes and Earthquakes," "On the Terrestrial arrangements connected with the appearance of Man on the Earth," "On the cause of the Temperature of Hot and Thermal Springs, and on the bearings of this subject as connected with the general question regarding the internal temperature of the Earth." He also treated of "The Glaciers in their relation to the elevation of the Alps," and of "The Formation of Quartz and Metallic Veins."

Most of his early papers were afterwards embodied in his great work the 'Lehrbuch der chemischen und physikalischen Geologie,' which appeared between 1847 and 1854. In the latter year a translation of this work by Dr. Paul and Dr. Drummond, made under the supervision of the author, was published by the Cavendish Society. This important work, more condensed than the German edition, is in some respects an independent work. In the first volume, the laws of combination of the mineral kingdom, pseudomorphic minerals, the action of water as a chemical and a transporting agent, the origin of springs, the action of rivers and of the sea, the mechanical and chemical deposits from water, and the character and origin of carbonaceous substances, of various gases, and of the simple salts occurring in the mineral kingdom, are treated of; while in the second the chemical reactions relating to the alteration of minerals, and the characters of and changes in Felspathic and various other minerals, especially those of volcanic and igneous origin, are considered. No geological studies can be complete without a knowledge, at all events, of the elements of Chemical Geology. In 1861, Professor Bischoff was elected a foreign Fellow of this Society; and in 1863 the Wollaston Medal was awarded to him by the Council, in recognition of the eminent services rendered by him to Geological science by his long-continued and laborious chemical investigations on the origin and changes of minerals and rock-substances, and especially by the production of his great work on Physical and Chemical Geology.

Many of the papers read during the past year have been of much interest and well serve to maintain the character of our discussions and publications. Those connected with glacial and drift-action continue to occupy an important place.

Glacial and Tertiary Geology.

The Rev. W. Bleasdell shows how a small island in the St. Lawrence has been removed piecemeal by river-ice floating off detached portions during floods; and Dr. Brown applies the result of his experience in the arctic regions of America to the explanation of the glacial phenomena of Scotland, the sub-azoic Boulder-clay of which country he considers analogous to the deposit under the ice-cap of Greenland, while the associated fossiliferous laminated clays were formed in the fiords and bays skirting the ice-covered land.

Professor Harkness objects to former hypotheses respecting the distribution of the Shapfell Granite boulders over the high hills of Yorkshire, and suggests that their transport could only have been effected by the agency of coast-ice during a depression of the land of 1500 feet.

The superficial drift-deposits of South Hampshire and the Isle of Wight have been carefully investigated by Mr. Codrington, who shows that the unfossiliferous gravels of the higher plains were probably not of river-origin, but were spread out in an inlet of the sea, when the land stood 400 feet lower, whilst the gravels on the lower levels, with mammalian remains and flint implements, were afterwards deposited by river-action.

Mr. De Rance has described the Preglacial and Glacial deposits of Western Lancashire and Cheshire. He considers that at the commencement of the Glacial period the land stood higher than it now does, and that the higher ground was covered with an ice-cap and great glaciers, that the higher Boulder-clay is referable to this land-ice, and that the lower Boulder-clay spread over the lower ground was formed during a period of subsidence when the land-ice was floated off. He infers also that, when the land stood higher, Ireland would have been connected with Wales, so as to render possible the migration of mammals and plants.

Mr. Searles Wood, jun., has reviewed the vexed question of the origin of the Weald Valley, and doubts the sufficiency of the various hypotheses that have been proposed to explain the denudation of that district. From the comparative absence of Lower Cretaceous or Wealden débris in the Thames valley, and the presence of Tertiary pebbles in gravels within the Wealden area, and the manner in which the transverse valleys open out, estuary-shaped, into the Weald, he infers that that was occupied in Postglacial times by an inlet of the sea, into which rivers flowed from the Thames-valley area, and that the denudation was chiefly effected by tidal erosion during a gradual upheaval of the land.

The Rev. John Gunn is now of opinion that the "Forest-bed series," which he has so long and carefully studied, is older than the Norwich Crag and the Chillesford Clays, and that the latter covers both the other deposits transgressively in proceeding from the coast toward the interior of the country.

Mr. Ray Lankester has made further contributions to our knowledge of the Crag-beds of Norfolk and Suffolk. He considers that the Stone-bed at the base of the Norwich Crag is not identical with the Bone-bed at the base of the Suffolk Crag, and shows the marked difference in their mammalian fauna. The Rhinoceros, Tapir, Hipparion, and Hyæna of the Bone-bed are introduced Miocene species; while the Elephants and Deer of the Stone-bed and Forest-bed are of Pliocene species not found in the Bone-bed. He describes from this latter bed a new ziphioid cetacean, and has determined the presence of *Mastodon arvernensis* in a sandstone nodule found in it. Of these nodules Mr. Lankester gave additional particulars, showing, by their organic remains, their derivation from beds of "Diestien" age.

In making excavations for the extension of the dockyard in Portsmouth Harbour, a fine section of the Lower part of the London Clay, with overlying gravel and alluvial beds, has been exposed; and a good account has been given of them by Mr. C. J. A. Meyer. Some of the beds are very fossiliferous, and contain an assemblage of species which have not been found elsewhere in the London Clay: one of the species is a Thanet-sand form, while another is the well-known *Cardita planicosta* of the Bracklesham beds and of the *Calcaire grossier*.

Secondary Formations.

The only communications we have had on the Cretaceous series are as follows. Mr. Whitaker describes the divisions of the Chalk of the south coast. He shows that the Chalk Marl and Lower Chalk thin westwards, while the Upper Chalk with flints passes transgressively over and beyond it, and thus are flints found so far west. Mr. Judd gives the result of his further examination of the Neocomian beds of Yorkshire and Lincolnshire, and shows their relation to those of Hanover, Westphalia, and Brunswick. The Specton-clay series he considers to be the keystone in the correlation of the beds over the whole area.

In a subsequent paper Mr. Judd gave an interesting account of a series of beds between the Neocomian and Wealden strata of the south coast. The section where they were first noticed some years since by Mr. Godwin-Austen and Prof. E. Forbes is at Punfield, in the Isle of Purbeck, whence Mr. Judd suggests the name of "Punfield Formation" for these beds, which he shows to be of considerable importance, having a wide range through France, and being closely related to the coal-bearing strata of the north of Spain described by M. de Verneuil. The fossils are mixed and of a peculiar type; and there are many species common to the English and Spanish series.

Mr. S. Sharp subdivides the Oolites of the Northampton district, and shows that the line of division between the Great and the Inferior Oolites in the neighbourhood of Northampton is marked by unconformity as well as by organic remains. He states that there are four areas, within a comparatively small space, in which the whole of the beds occurring in each, from the Great Oolite down to the Upper Lias inclusive, are accessible. The Northampton Sands he proposes to class in three divisions—the Upper, Middle, and Lower. Though the beds vary considerably in thickness, according to the different localities, the total thickness of the Northampton Sands may be taken on an average as about 80 feet.

Mr. Mitchell suggests that the valleys of the Oolitic district round Bath are due not so much to denudation as to the circumstance that many of the beds of Great Oolite are old coral-reefs of limited extent, while the argillaceous strata are true sedimentary deposits overlying and wrapping round them, so that the Oolitic beds never in fact extended across the present valleys, though the clay beds did.

Mr. R. Tate continues his researches on the fossils of the different divisions of the Lias in Gloucestershire, and shows the value of the Ammonite-zones over certain areas—also that although the conditions of depth and deposit of the upper part of the Lower Lias are repeated in the lower part of the Middle Lias, there is a total change in the fauna, whence he infers a break in the stratigraphical succession.

Prof. Ramsay states, in an interesting paper "On the physical Relations of the New Red Marl, Rhætic Beds, and Lower Lias," that there is a perfect physical gradation between the first two. He considers that the New Red Sandstone and New Red Marl were formed in inland waters—the latter in a salt lake of great extent. These conditions, and the abundance and peculiar condition of the oxide of iron, would, Prof. Ramsay thinks, be in accordance with those chemical characters of the waters, while he considers that the fossil footprints occurring in these beds are evidences of the absence of tides in the waters. He gives stratigraphical and palæontological reasons in proof of the New Red Marl being more closely related to the Rhætic beds, and even to the Lias than to the Bunter, and traces the sequence of events during the accumulation of these several formations.

Palæozoic and Metamorphic Rocks.

From Dr. Nicholson we have a paper on a part of the "Lower Green-slates and Porphyries" of the Lake district. They were so named by Prof. Sedgwick, and underlie his Skiddaw Slates. Over these are felspathic rocks, succeeded by a series of ash-beds, breccias, and amygdaloids, which are often worked as slates.

Mr. Jamieson divides the older rocks of Banffshire into three groups:—first, a lower arenaceous series more or less altered by metamorphic action into quartz-rock, gneiss, and mica-schist; next, a series of clay slates, with a subordinate bed of limestone; thirdly, an upper group of arenaceous strata. A main object of his communication is to give his reasons for considering that the granites of Banffshire are due to the fusion and recrystallization of the arenaceous beds.

Palæontology.

In the palæontological papers,—

Mr. Busk has pointed out that the Oreston fissure-cavern Rhinoceros is not the *R. tichorhinus*, but *R. leptorhinus*.

Three species of Elephant are now ascertained to have lived in Malta during the Cave-period. Dr. Caruana draws attention to the abundance of their remains in a particular part of the island, including one new locality.

Mr. Hulke has described an *Ichthyosaurus* supposed to have been found in the Isle of Gozo; and if so, it is the first one discovered in beds of Tertiary (Eocene ?) age. He has also described two species of *Plesiosaurus* from the Kimmeridge Clay of Dorsetshire; one of these is a slender-necked species 16 feet in length, and with Pliosaurian-like limbs, which are much larger, compared with the whole length, than those of the typical Liassic forms of this genus.

Professor Huxley communicates a letter from Dr. Bunzel, of Vienna, giving an account of a skull of Cretaceous age, belonging to a new order of reptiles with bird-like heads, for which the author proposed the name of *Ornithocephala*.

Messrs. Hancock and Howse describe a new Labyrinthodont amphibian from the Magnesian Limestone of Durham, and a new *Proterosaurus* (*P. Huxleyi*) from the marl-slate of the same district, associated with the *P. Speneri*. They also announce the discovery in the same rock of specimens of that peculiar fish the *Dorypterus Hofmanni*, showing the ventral fins and heterocercal tail.

A very interesting palæontological discovery has also been made by Mr. Maw of a fine skull of a Labyrinthodont in the middle of the Coalbrook-Dale Coal-measures.

Mr. H. Woodward has drawn attention to some new Crustaceans, including a species of the curious Secondary genus *Palæocorystes*, and also to two new forms referable to the family of Portunidæ, in the lower beds of the London Clay of Portsmouth, of which the section has been described by Mr. Meyer. Mr. Carruthers has described a silicified fern-stem, probably from the sands under the London Clay at Herne Bay. In structure this specimen agrees most closely with the living *Osmunda regalis*. The minutest structure of the original specimen is preserved in a remarkable manner, even showing the starch-grains and the delicate mycelium of a fungus contained in its cells.

Colonial and Foreign Geology.

We have had some excellent papers on Colonial Geology; and we are especially indebted to our correspondents in South Africa.

Dr. Sutherland describes an ancient Boulder-clay in Natal. It is an argillaceous deposit with boulders, reposing upon old sandstones, the surface of which is often deeply grooved and striated. He considers that this deposit may possibly be of Permian age.

Mr. G. W. Stow describes the Jurassic beds (with their *Trigonia*-limestones) and the Saliferous beds of Uitenhage, between the Cape and Natal. These are succeeded by Tertiary deposits, the newer of which follow the coast-line, and run in raised terraces up the river-valleys—the one being characterized by a large *Panopæa*, and the other by a species of *Akera*. The Karoo formation of the Stormberg, which is of Triassic age, with its plant-beds and *Dicynodont* fossils, are described in another memoir. The present surface-conditions of this part of the interior Mr. Stow considers especially due to ice-action; and he points also to the existence of *Roches moutonnées* and moraines in British Kaffraria and adjacent districts.

Mr. C. L. Griesbach has given an excellent account of Natal, and describes the succession of beds, commencing with the granitic and gneissic rocks and mica-schists, overlain by great plateaux of undisturbed sandstone, often capped by basalt. The sandstone is succeeded by the Karoo formation, containing occasionally subordinate beds of coal, and then near the coast by beds of Cretaceous age. Reference is made to various interesting theoretical questions connected with the former distribution of land and water between Africa and India, and to the economical mineral products (graphite, coal, gold, and copper) of Natal.

Some notes on the Diamond districts of the Cape of Good Hope have been given us by Mr. Gilfillan.

We have had only one communication from Australia, by Dr. Krefft, on certain of the later fossil Mammalia, including several species of Wombats and Wombat-Kangaroos of that remarkable continent.

The relations of the two gneissoid series of rocks of Nova Scotia have been discussed by Mr. H. Youle Hind, who believes them to be of Laurentian age, and covered in patches only by the Huronian or Cambrian rocks. The gold is found in Lower Silurian rocks, which formation is there 1200 feet thick, and is destitute of any great beds of limestone.

The Rev. T. G. Bonney describes the general appearance of the Lofoten Islands. Instead of being composed of granite, he thinks that, with few exceptions, the strata consist of highly metamorphosed rocks—quartzites and gneiss.

Foreign Palæontology.

Professor Owen has described some fossil mammals of late Tertiary or Quaternary age found in China. Among them are new species of *Stegodon*, *Hyæna*, *Tapir*, *Rhinoceros*, and *Chalicotherium*.

Principal Dawson has sent us the result of his further examination of the structure of the *Sigillaria*, *Calamites*, and *Calamodendron* of the Nova-Scotia Coal-field. A specimen of *Sigillaria* was described having a transversely laminated pith of the Sternbergia-type, the immediately surrounding tissues much resembling those of Cycads. He agrees with the opinion generally held with regard to *Calamites*, that their affinities were with *Equisetaceæ*, as pointed out by Mr. Carruthers, but more advanced than the modern *Equiseta*, while the *Calamodendra* were similar in general structure, but much more woody plants.

Professor Heer has described the flora of Bear Island, in latitude 74° 30′ N. He considers it to belong to the lower part of the Carboniferous series. There are eighteen species of plants, having a close relation with those of the Yellow Sandstones of county Cork and of the Greywacke of the Black Forest. Taking also the fossil flora of Parry Island and Melville Island, which he considers the equivalent of that of the Bear-Island beds, we have a total of 77 species of plants. Not less remarkable than the occurrence of this rich and luxuriant vegetation in those arctic regions during this Carboniferous period, is the appearance of a flora equally rich and varied, in the same regions, in the comparatively recent Miocene times.

Mr. Billings has made in the Lower Silurian rocks of Canada the interesting discovery of a Trilobite (*Asaphus platycephalus*) with its appendages preserved and the hypostome in position. It shows that the creature had eight pairs of legs; so that probably these Crustacea were walking rather than swimming animals. Mr. Woodward has found in a specimen presented some years since to the British Museum by Dr. Bigsby traces of similar appendages. He considers that the Trilobita should now be placed *next to*, if not actually with, the modern Isopoda.

Dr. Grey has sent us some interesting specimens of Dicynodont fossils, jaws of reptiles, and coal-plants, from the Karoo beds of South Africa.

Mr. Guppy is of opinion that he has detected an *Eozoon*, with a coral and echinoderms, in some Trinidad rocks, the age of which is uncertain, but considered by the author to be pre-Silurian.

The PALÆONTOGRAPHICAL Society continues its valuable publications. The volume for 1870 contains the concluding part of Mr. Davidson's great work on the Brachiopods. It completes the Silurian Brachiopoda, consisting of 28 genera and 210 species, while the whole work, by that author, forms three volumes, with 150 plates, all of which have been drawn and contributed by Mr. Davidson himself. Another paper of importance is the complete monograph of British Mesozoic Mammals by Prof. Owen, containing descriptions and illustrations of 15 genera and 27 species.

Independently of your own Society, the progress of geology is being actively advanced by local societies, the number of which is annually increasing. Many of them publish Proceedings of considerable merit; and others tend, by field-work, to spread a taste for your science.

Deep-sea Life and its Relations to Geology.

Among the collateral subjects which have engaged much attention during the past year, and which must exercise a considerable influence on future geological speculation, is that relating to the nature of the sea-bed, the temperature of the sea at great depths, and the range and distribution of animal life in those depths—investigations which have been so greatly promoted by the recent expeditions of H. M. surveying-steamers 'Lightning' and 'Porcupine.' Subjects of this nature have always been of much importance to the geologist, who has therefore ever followed with the keenest interest the researches of the naturalist and physicist. In studying the marine Invertebrata the early naturalists were long limited in their observations to the shore-line, and to such moderate depths as were within reach of the ordinary fishermen or their own small appliances. Now and then a deep-sea sounding would give a fragmentary insight into other zones of depth; but from their exceptional character they did not attract much notice. Lamarck, O. F. Müller, Montagu, Poli, and Risso furnished some facts relating to depth as well as to geographical distribution; but still, when we look to the short table by Mr. Broderip of the "Situations and Depths at which recent Genera of Marine and Estuary Shells have been observed," appended to Sir Henry de la Beche's 'Theoretical Geology,' it shows how scanty our information was so late as the year 1834. No Mollusca are there given from a depth greater than 420 feet, and no Brachiopoda from one greater than 540 feet.

In the various inquiries which engaged the attention of the eminent men who formed part of the many Arctic expeditions, that of the distribution of life in the sea was not lost sight of, although, from the imperfection of the means, the results were very scanty. The small quantity of mud or stones attached to the sounding-apparatus, or brought up by the deep-sea clam, furnished, in fact, all the glimpses they were able to obtain of the ocean-bottom. Although the specimens were often crushed and broken, still the evidence, so far as it went, was in many cases clear and definite.

Sir John Ross records, in his voyage to Baffin's Bay in 1817–18, three deep-sea soundings. In the first, at a depth of 2700 ft. *,

* I have in all cases expressed the sea-depth in feet instead of in fathoms, in order to conform with the terms applied to elevations on the surface and dimensions of strata.

and two miles off shore, they brought up gravel and two small live crustaceans (*Gammarus*); in the second, in 3900 ft. and eighteen miles off shore, pebbles and brown clay, with *Serpulæ*, corallines, crustaceans, and fragments of shells; in the third, in 6000 ft. and six miles off shore, soft mud, with some worms in it. Again, in a sounding where the depth was 6300 ft., a small starfish was found attached to the line below the point marking 2400 ft.

Mr. Alex. Fisher, in his account of the voyage of the 'Hecla' and 'Griper' in 1819–20, states that, in a sounding taken on approaching Lancaster Sound, they brought up from a depth of 5100 ft. mud, with small stones and pieces of broken shells of very delicate texture.

A curious case is recorded in the voyage of the French frigate 'Venus,' in the Pacific, by M. de Tessan in 1838. When near the Equator, a bottle full of fresh water and well corked was attached to the sounding-line near the lead, and let down to the depth of 7500 feet. The bottle came up with the cork forced in, and containing a small living shell of the genus *Venus*.

Sir James Ross, in his voyage to the Southern and Antarctic Seas, in 1839–43, obtained more definite results. At a depth of 1800 ft. he found "corallines and many animals;" at 1920 ft. "green mud, with a fragment of starfish and coral;" while the result of a haul 2400 ft. deep, subsequently examined by Mr. Charles Stokes and Edward Forbes, showed the presence of small corals, pieces of shells, and two joints of a small fossil (?) *Pentacrinite*, a spine of *Cidaris*, portions of *Echinus*, a small broken *Cerithium*, a fragment of *Cleodora*, and specimens of *Spirorbis* on some stones. With these there were Foraminifera of the genera *Textularia*, *Nodosaria*, and some others, in abundance.

That the specimens brought up on these occasions were generally fragmentary was almost to be expected.

With the application of the dredge to the purposes of deep-sea exploration, materials for a more exact classification of species according to their bathymetrical range rapidly accumulated; and in the year 1839 a Committee of the British Association was appointed to carry out a systematic investigation of the seas of the British coasts. In 1840, Prof. E. Forbes, then about to join the surveying-ship 'Beacon' as naturalist, was requested by the Association to furnish them with a report on the Mollusca and Radiata inhabiting the Ægean Sea. This report * marks an epoch in Natural History and Geology.

* Brit. Assoc. Reports for 1843, p. 173.

Besides giving the lists and range in depth of the Mollusca and Radiata, the Report entered into the question of their distribution considered in its bearing on geology. The observations of Prof. Forbes ranged over a period of eighteen months; and his lists are based on more than 100 fully recorded dredging-operations in various depths from 600 to 780 ft., besides numerous coast-observations. The result of this valuable and special inquiry was to determine more clearly than had hitherto been done the range of species in depth, and the division into zones first proposed by Risso. With regard to much that Prof. Forbes accomplished no question has arisen. Of the eight zones into which he divides the bathymetrical distribution of the Mollusca, the first seven, ranging from the surface to the depth of 630 ft., although possibly too much subdivided, may be applicable to other seas where the conditions are similar; but with respect to his eighth region, which extends from 630 to 1380 ft., Prof. Forbes's generalizations, although correct within certain areas, have been found inapplicable to the two great oceans and applicable only to parts of the Mediterranean. He observes, speaking of this eighth zone, "throughout this great and, I may say, hitherto unknown province, we find an uniform and well-characterized fauna;" but then he goes on to say, "within itself the number of species and of individuals diminishes as we descend, pointing to a zero in the distribution of animal life as yet unvisited." He placed this zero at about 1800 ft.

In a subsequent work *, however, in speaking of the eighth region of depth, E. Forbes remarks, "its confines are yet undetermined, and it is in the exploration of this vast deep-sea region that the finest field for submarine discovery yet remains." "In the Mediterranean, as might be expected, when we consider the peculiar condition under which that great land-locked basin is placed, there are peculiarities in the distribution of both animal and vegetable life which require special consideration;" and in speaking of animal life in the "Arctic province" of the Atlantic, he notices that the Mollusca appear to range much deeper in high latitudes than they do in more favourable climates, and mentions the capital haul made by Mr. Harry Goodsir in Davis's Straits, when a variety of shells, Crustacea, Echinoderms, and Corallines were brought up from a depth of 1800 ft.

In another Report †, on British Marine Zoology, E. Forbes divided the range of the Mollusca into only four zones of depth; and

* Natural History of European Seas, p. 27. † Brit. Assoc. Rep. 1850.

speaking of the fourth or lowest, he observes, "A more difficult task, and which can be hardly hoped for fulfilment without the aid of a steam-vessel and continued calm weather, is the dredging of the deeps off the Hebrides in the open ocean. Much of the deep sea round the Zetlands is sure to reward the explorer .... And lastly, though I fear the consummation, however devoutly to be wished for, is not likely soon to be effected, a series of dredgings between the Zetland and the Faroe Islands, where the greatest depth is under 700 fathoms, would throw more light on the natural history of the North Atlantic and on marine zoology generally, than any investigation that has yet been undertaken."

All who knew Edward Forbes must feel satisfied that, had his valuable life been spared, he would have been in the foremost rank of the investigators of those new fields to which he pointed, and the exploration of which has now been so successfully commenced. His untimely death unfortunately left his investigations with all the weight of his authority, at a point that he doubtless would have considered the first stage in the inquiry, instead of being accepted, as it has occasionally been, as an approximate conclusion.

In 1846, Capt. Spratt, R.N., the friend and companion of Forbes, dredged at a depth of 1860 ft., forty miles east of Malta, eight distinct species of Mollusca, among which was the *Pleurotoma carinata* *, a supposed extinct species of the Coralline Crag; and he observes † that he believed animal life to "exist much lower, although the general character of the Ægean is to limit it to 300 fathoms." In his survey of the Mediterranean, between Malta and Crete ‡, Capt. Spratt afterwards found at the depth of 9720 ft. "numerous dead shells and fragments of shells."

The preliminary observations necessary before laying the different lines of Atlantic telegraphs next came in aid of natural science. In 1855 a United-States steamer made a series of deep-sea soundings across the Atlantic. The fine calcareous mud brought up from depths of from 6000 to 12,000 ft. was examined by Prof. Bailey, who discovered in it numerous shells of *Globigerinæ* and *Orbulinæ*, with Diatoms and sponge-spicules. He doubted whether these Foraminifera could have lived on the sea-bottom, and thought they might rather have fallen upon it from upper sea-zones.

* 'Nature,' vol. i. p. 166, Dec. 1869.

† Brit. Assoc. Reports for 1848, p. 81. The depth given above is corrected on Capt. Spratt's authority.

‡ 'Travels and Researches in Crete,' vol. ii. p. 329.

Ehrenberg, on the other hand, believed that they had lived at those depths.

Similar results were obtained on a line of still deeper soundings, extending to 14,400 ft., made in 1857 by Capt. Dayman; and Prof. Huxley, who reported on them, concluded that in all probability the *Globigerinæ* did live at those depths.

In 1860 Dr. Wallich* carried out an important series of deep-sea researches in connexion with the soundings made on board H.M.S. 'Bulldog,' and obtained some very interesting results. He not only confirmed the prevalence of a *Globigerina*-mud in the great depths of the Atlantic, but also gave much evidence in favour of the *Globigerina* living at those depths. Dr. Wallich also brought up two living Crustacea from a depth of 2670 ft., and living *Serpulæ, Spirorbes*, and Polyzoa from a depth of 4080 ft. His most remarkable discovery, however, was that of living starfishes at a depth of 7560 ft. Dr. Wallich's researches mark another epoch in the history of deep-sea explorations.

The following year further discoveries were made in the Mediterranean, between Sardinia and Algiers †. It having become necessary to raise the French telegraph cable after it had been submerged five years, it was found that at places various Mollusca, Corals, and Bryozoa had grown upon it. Portions of the cable, stated to have been raised from depths of from 6500 to 9000 ft., were submitted to M. Milne-Edwards, who determined the following species, to which I have added their geological range:—

Ostrea cochlear.	Coralline Crag.	Caryophyllia arcuata.
Pecten opercularis.	Coralline and Red Crag.	—— electrica, sp. n.
		Thalassiotrochus telegraphicus, sp. n.
—— Testæ.	Pliocene beds of Italy.	Salicornaria farciminoides.
Monodonta limbata.	Pliocene beds of Italy.	Serpula.
Fusus lamellosus.	Pliocene beds of Italy.	Gorgonia.

The Swedish expedition to Spitzbergen in the same year (1861) also determined the presence, at a depth of 8400 ft., of various Mollusca, Crustacea, and Hydrozoa.

Between 1860 and 1868 a series of most valuable researches was carried on off the coast of Upper Norway by the late Professor Sars and his son, at depths of from 1800 to 2700 feet. At the former depth they found an abundant fauna; at the latter the collections

* 'Notes on the Presence of Animal Life at Vast Depths in the Sea,' 1860, and 'On the North Atlantic Sea-bed,' 1862.

† Ann. des Sciences Nat. 4e sér. vol. xv. p. 3.

were smaller, but still considerable. I annex a list of the number of species dredged at the depth of 2700 feet, for the purpose of showing how these researches already affected questions depending on the relative proportion of recent and extinct species, as to the age of the newer geological deposits :—

	Known species.	New species.	Total.
Mollusca	7	4	11
Crustacea	2	1	3
Echinodermata	3	0	3
Foraminifera	20	4	24
	32	9	41

In 1867 Count Pourtales * dredged, between Florida and Cuba, in depths of about 3000 ft., and found a rich fauna of Mollusca, Crustacea, Corals, and Echinoderms.

Impressed with the value of these observations, and with the importance of a more systematic and yet deeper exploration of the ocean-bed, Dr. Carpenter, at the suggestion of Prof. Wyville Thomson, brought the subject before the Royal Society in June 1868. As the undertaking was beyond the reach of private enterprise, an application was made by the President and Council of the Society to the Government for a vessel for the purpose. The request was readily and liberally responded to; a Government steamer was then, and again in 1869 and 1870, placed at the disposal of the Committee appointed for the purpose; and a most important series of deep-sea dredgings have been carried out by the above-named naturalists and Mr. Gwyn Jeffreys. Only the general results have as yet been laid before the Royal Society. These, however, are quite sufficient to show that the expeditions have proved of the highest service to natural science, whether as regards the existence and distribution of animal life at great depths of the ocean, the temperature at various depths, the direction of the great oceanic currents, or the bearing of such investigations on the past history of our globe.

Almost everywhere the deep bed of the Atlantic was found covered in its greatest depth with a light-coloured calcareous mud, abounding in *Globigerinæ*, rich in siliceous sponges, and often supporting a varied fauna of Mollusca, Crustacea, and Echinoderms. Numerous valuable observations were also made on deep-sea tem-

* 'Bulletin of the Museum of Comp. Zoology,' Cambridge, U. S., 1867, and 'Silliman's Journal' for Nov. 1868.

peratures and currents, with instruments prepared for the occasion. I must refer to the papers by Dr. Carpenter and his colleagues (to whom I am much indebted for the perusal of the last Report, now going through the press), in the 'Proceedings of the Royal Society'*, for the varied information respecting the composition of sea-water at different depths, the gases contained in it, and the speculations on oceanic currents. The points that more particularly interest us are those bearing on geological investigations.

In first drawing the attention of the Royal Society to the importance of undertaking deep oceanic researches, Prof. Wyville Thomson referred to the recent discovery by Prof. Sars of a small crinoid belonging to an order supposed to be extinct, and which flourished from Jurassic to Cretaceous times; he suggested the probability of the continuity of the ancient chalk-sea with the present abyssal depths of the Atlantic, as such depths would be but little affected by any of the later oscillations of the earth's crust in the northern hemisphere, as, since the commencement of the Tertiary epoch, they probably had not much exceeded 1000 ft. The result of the first expedition was more than sufficient to confirm the most sanguine anticipations. Dr. Carpenter, on its return, reported that, of the higher types of marine animals which they had discovered, "many carry us back in a remarkable manner to the Cretaceous epoch;" and, again, it "seems on general grounds highly probable that the deposit of *Globigerina*-mud has been going on from the Cretaceous epoch to the present time (as there is much reason to suppose that it did elsewhere in anterior geological periods), this mud not being merely a chalk formation, but a continuation of the chalk formation." These views have a high significance and interest. Let us see how far we can adopt them.

The Atlantic abyssal mud has been found to contain from 50 to 60 per cent. of carbonate of lime, 20 to 30 of silica, with small variable proportions of alumina, magnesia, and oxide of iron. Its appearance, when dry, is chalk-like; but it is to be observed that our white chalk is a much more homogeneous rock, containing from 95 to 99 per cent. of carbonate of lime, while even our grey chalk contains from 80 to 90 per cent †. The larger proportion of cal-

* Proc. Roy. Soc. vol. xvii. pp. 168–200; vol. xviii. pp. 397–492; and vol. xix. pp. 146–222.

† Since writing the above, Mr. David Forbes has kindly obliged me with the following observations:—"The specimens of Atlantic mud or soundings which I have examined, differ very essentially from chalk in composition; and no single one of them (if consolidated) could be entitled to the appellation of

careous Foraminifera in the chalk, and of siliceous Polycystina and vitreous Sponges in the Atlantic mud, may, however, render this rather a question of proportion than of radical difference. I would point out that the White Chalk (Terrain Sénonien) of Touraine varies in colour from white to light yellow, or greyish yellow, is a much less pure carbonate of lime, and is wonderfully rich in siliceous sponges. In fact there s one portion of it, from 28 to 30 ft. thick, which contains no carbonate of lime at all*. At other places in France, and in Europe, the chemical composition of the chalk differs considerably, and the colour varies from white to dark grey.

Mr. Lonsdale†, many years since, pointed out that white chalk was composed largely of microscopic organic débris, consisting chiefly of minute Foraminifera; and Dr. Mantell‡ afterwards estimated that more than a million of such remains are contained in a cubic inch of some of our chalk. I would further draw attention to a remark by Dr. Mantell in the same work (p. 315). Speaking of the chalk,

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chalk, as ordinarily understood by geologists or chemists. In order to make a correct comparison of their composition with that of chalk, I was obliged to make analyses of the latter rock, two of which I annex.

	Grey Chalk (base of), Folkstone.	White Chalk, Shoreham (Sussex).
Carbonate of lime	94·09	98·40
Carbonate of magnesia	0·31	0·08
Insoluble rock débris	3·61	1·10
Phosphoric acid	traces	0·42 (Phosphoric acid with Alumina and loss)
Alumina and loss in analysis	,,	
Chloride of sodium	1·29	...
Water	0·70	...
	100·00	100·00

On the other hand, the specimens of Atlantic mud received from Mr. Gwyn Jeffreys, Dr. Carpenter, and others (about eight in number), and examined by me, contain at highest not 60 per cent. of carbonate of lime, along with very much siliceous and aluminous matters, oxide of iron, &c.; and if we were even to subtract the amount of water, organic matter, and marine salts found by analysis in them, as these substances would be in greater part removed before such mud could, in the process of ages, be converted into solid rock, the amount of carbonate of lime would be still far less than that present in what would ordinarily be regarded as chalk; in fact the resulting rock would have the exact composition of many of the older marls or impure limestones."

* Mém. Soc. Géol. de France, sér. 1, vol. ii. p. 239.

† Lyell, Anniv. Address Geol. Soc. for 1836, p. 13.

‡ Wonders of Geology, 6th edit. 1848, vol. I. p. 305.

he says, "The whole forms such an assemblage of sedimentary deposits as would probably be presented to observation if a mass of the bed of the Atlantic, 2000 ft. in thickness, were elevated above the waters, and became dry land; the only essential difference would be in the generic and specific characters of the imbedded animal and vegetable remains." Whether viewed by naturalists or by geologists, the similarity of origin seems to have occurred to both; and I am not aware that the question of depth ever seriously interfered with this view amongst geologists, who, on the contrary, rather considered the mass and fossils of the chalk to be an indication of the possibility of life at great depths. Both deposits were also found to contain numerous peculiar and simple organisms, which were named Coccoliths * and Coccospheres (noticed by Wallich, Huxley †, and Sorby), while the profusion of the particular Foraminifer the *Globigerina*, and the later discovery of siliceous Sponges, are other features in common. Except by Mr. Bailey, the presence of Diatoms has not been noticed ‡.

Prof. Rupert Jones has kindly filled up for me the following Tables, the results being based chiefly on Messrs. Parker and Jones's excellent account of the Foraminifera from the North Atlantic and Arctic oceans §. They determined 110 species as now living in those seas; and of these they recognized 19 as fossil in the Chalk.

* Mr. Carter now considers this to be a calcareous unicellular alga, the frustules of which form the Coccospheres. He proposes for it the name of *Melobesia unicellularis*. It occurs in abundance in the Laminarian zone off the Devonshire coast. Another species, the *M. discus*, he considers peculiar to the deep Atlantic. Ann. & Mag. Nat. Hist. for March 1871.

† Prof. Huxley states that Dr. Gümbel of Vienna has now discovered these bodies in all sedimentary strata.

‡ Count Ab. Castracane, of Rome, however, has since examined some of the mud obtained in the first 'Porcupine' expedition at a depth of 14,610 feet, for Diatoms, and reports that he discovered a rare species of *Asteromphalos*, which he found, for the first time in Europe, in the Adriatic in 1863. He states also that "Specimens of *Hemidiscus* occur in greater number, and perhaps also some allied species like *Euodia*, of which I am not aware that, up to the present time, any examples have before been found in Europe; at least I have not discovered any mention of them in the various authors I possess on the subject. Besides these, the species of Diatoms most abundant in this deposit are the *Coscinodisci*; and of these the *Coscinodiscus lineatus*, Ehr., is the most frequently met with. There are numerous *Melosiræ*, *Bacteriastra*, *Triceratia*, *Bacillariæ*, *Pleurosigmata*, *Synedræ*, *Naviculæ*," &c. Count Castracane is unable to determine whether these lived at the bottom of the ocean or near the surface. (Accademià Pontificia de' Nuovi Lincei, sess. del 3 Aprile 1870.)

§ Transactions of the Royal Society for 1865.

Mr. Jones remarks that the numbers in the following Tables are liable to modification with further research.

	Species† of Foraminifera found in both the Atlantic mud and the Chalk of England and Europe.	Other, older Formations in which they are also found.				
		Upper Jurassic.	Lower Jurassic.	Rhætic and Trias.	Permian.	Carbonife-rous.
Subgenera of the genus *Nodosarina.*	Glandulina lævigata, *D'Orbigny* .	*	......	*	......	......
	Nodosaria radicula, *Linn*..........	*	*	*	......	......
	—— raphanus, *Linn.*	......	*	*	......	......
	Dentalina communis, *D'Orb*.......	*	*	*	*	*
	Cristellaria cultrata, *Mont.*	*	*	*	......	......
	—— rotulata, *Lam.*	*	*	*	......	......
	—— crepidula, *F. & M.*...........	......	*	......	......	......
	Lagena sulcata, *W. & J.*	......	......	......	......	......
	—— globosa, *Montag*........................	......	......	......	......	......
	Polymorphina lactea, *W. & J.*..............	*	......	......	......	......
	—— communis, *D'Orb.*	......	......	......	......	......
	—— compressa, *D'Orb.*	*	*	*	......	......
	—— Orbignii, *Ehr*.........................	......	......	......	......	......
	Globigerina bulloïdes, *D'Orb*...............	......	......	......	......	......
	Planorbulina lobatula, *W. & J.*	......	......	......	......	......
	Pulvinulina Micheliana, *D'Orb*.............	......	......	......	......	......
Subgenera of *Textularia.*	Spiroplecta biformis, *P. & J.* ...	......	......	......	......	......
	Verneuilina triquetra, *v. M.*	......	......	......	......	......
	—— polystropha, *Rss.*	......	......	......	......	......

Besides the above, *Bulimina* (*Bolivina*) *punctata*, D'Orb., is found in the Atlantic mud and in the Upper Jurassic, and *Nodosarina* (*Dentalina*) *pauperata*, D'Orb., occurs in the Atlantic mud as well as in the Lower Jurassic and the Upper Trias.

Number of Species of Foraminifera common to the Atlantic Mud and to the several undermentioned Geological Formations in England.

Total in the deep Atlantic.	Common to the following Formations.							
	Crag.	London Clay.	Chalk.	Upper Jurassic.	Lower Jurassic.	Rhætic & Upper Trias.	Permian strata.	Carbo-niferous strata.
110	53‡	28§	19	7‖	7‖	7	1	1

† Accepted species and noticeable varieties.

‡ There are 12 other species in more recent beds.

§ The total in the Lower Tertiaries is 36.

‖ Common to both Upper and Lower Jurassic, 9.

With the Foraminifera, however, end the specific identities between the Chalk and the Atlantic mud. Beyond this group we find resemblances or affinities only. Siliceous sponges, of which no less than 20 genera have been dredged, abound, it is true, as they do in the Chalk; but they are either new forms, or are Mediterranean and Azorean species. Professor Thomson * remarks that the Ventriculites of the Chalk are represented by the group of Porifera Vitrea, that the species of *Sympagella*, *Holtenia* (*Sphæroma*), and *Farrea* approach the Siphonias and Ventriculites very nearly, but that they form a distinct subsection of the order. Echinoderms abound, as in the Chalk; and species of the genus *Cidaris* are numerous, while some forms of *Diademidæ* approach the curious *Echinothuria* of the Chalk. The "Saleniæ, Cassidulidæ, and Dysasters approach their Cretaceous antetypes more closely than any known forms; but they are generally dwarfed, and otherwise diverge so far as to require in most cases the establishment of new genera for their accommodation." The *Bourgueticrinus* of the Chalk is represented by the beautiful *Rhizocrinus*, first found by Sars off the coast of Norway, and afterwards by the 'Porcupine' expedition in the North Atlantic; and the Brachiopoda are represented by the smooth forms of *Terebratula* so common in the Chalk; while the *T.* (*Waldheimia*) *cranium* may be considered a Chalk type.

Dr. Carpenter further remarks upon the occurrence of numerous arenaceous forms of Foraminifera analogous to the gigantic forms discovered in the Upper Greensand by Prof. Morris; and there is one that can certainly be identified with a form lately discovered by Mr. Brady in a clay-bed of the Carboniferous Limestone †. The presence of the *Xanthidia*, so frequently preserved in chalk flints, is also observed in the Atlantic mud. Some southern forms of starfishes are found dwarfed from a diameter of 6 inches to one of 2 inches, together with a number of Echinoderms previously known only as Norwegian or Arctic. On the other hand the Foraminifera are large, as in warm climates or in Tertiary beds, or as with the Cristellarian and Milioline groups. Amongst fishes a *Beryx* was found, a genus of which there are 4 species in the English Chalk.

It is also to be noticed that we have in the Chalk the first representatives of the cycloid fishes, which have their maximum development in existing seas, and that, of the 103 genera of testaceous

* 'Nature' for July 1870.

† It was in beds of this age that Prof. Phillips, some time since, indicated the presence of *Globigerina*.

Mollusca found in the Chalk, 80 (of which 19 make their first appearance at that period) are living at the present day. At the same time it is not in the deep Atlantic, but rather on its warmer coasts, that we now find the widest dispersion of this group of cretaceous genera.

These constitute the main points of resemblance. Striking as they are, their limits are confined; and, on the other hand, the divergences are great. The great feature of the Chalk-fauna is the abundance of Cephalopods and its large reptiles, so very few genera of which have descended to present times. The relative distribution of genera of the principal Invertebrata was, according to D'Orbigny*, before the late discoveries, approximately as under:—

	Number of genera.		
	In the White Chalk.	Extinct with the Chalk.	Living.
Cephalopods	13	12	1
Gasteropods	41	9	32
Lamellibranchs	52	11	41
Brachiopods	10	3	7
Echinoderms	34	27	7
	150	62	88

With the Cretaceous series disappear the many genera of Cephalopods allied to *Ammonites* which range through the Triassic and Jurassic formations, together with the Rudistes, so peculiar to the Chalk period.

The Mollusca of the deep Atlantic are still undergoing investigation at the hands of Mr. Gwyn Jeffreys. Enough, however, is already known of the remarkable results to form some opinion of its great value in a geological point of view. The total number now dredged may probably exceed 300 species. Of these, 86 species have been recognized and are noticed in the Reports now published. A very large number are altogether new. With the aid of Mr. Jeffreys, I have drawn up the following lists, which will serve to show the light which may be thrown on the palæontology of our more recent Tertiary strata by these inquiries. Of the 86 determined species, 67 were known before as living, though chiefly as high Northern and Arctic species (while the wider range of some few of the species is very remarkable), and 19 are fossil species

* Paléontologie et Géologie stratigraphiques, vol. iii. § Terrain Sénonien.

previously supposed to be extinct. Of the 67 known living species, there are :—

Species living in the North Atlantic and Arctic seas	51
Species living in the Mediterranean	11
Species living in the Gulf of Mexico...........................	2
Species living in the Japanese seas	3
	67

Among these 67 species, 45 were known as fossil also in the Pliocene beds of Italy and Sicily or in our Crag.

Fossil in Italy and Sicily...............	25
Fossil in the Crag	20
	45

Of the 19 species which had hitherto been known only in a fossil state, I give, with Mr. Jeffreys's assistance, the list in full, for the purpose of showing their geological range and position.

List of Mollusca known hitherto as Fossil only, and now discovered to be living in the depths of the Atlantic.

Depths dredged *.	Species.	Locality where found fossil.
feet.		
1932 to 2184.	Cancellaria mitræformis.	Italy and Coralline Crag.
1932 to 2184.	—— subangulosa.	Coralline Crag.
5694.	Cylichna ovata.	Sicily and Coralline Crag.
1542 to 4140.	Leda obtusa.	Sicily and Calabria.
4308.	—— pusio.	Calabria.
1752 to 2244.	Limopsis minuta.	Sicily.
4308.	—— pygmæa.	Sicily.
1680 to 1824.	Odostomia plicatula.	Italy.
3600 to 6570.	Omphalius monocingulatus.	Sicily.
1542 to 4140.	Pleurotoma decussata.	Calabria, Sicily, and Coralline Crag.
4140.	Rhynchonella sicula.	Sicily.
1542 to 4140.	Rissoa subsoluta.	Sicily and Calabria.
3600 to 6570.	Scalaria frondosa.	Italy and Coralline Crag.
3600 to 6570.	Siphonodentalium coarctatum.	Italy.
3600 to 6570.	Trachysma delicatum.	Sicily.
1680 to 1824.	Trochus crispulus.	Sicily.
1542 to 4140.	—— reticulatus.	Sicily and Calabria.
2148 to 4302.	—— suturalis.	Sicily and Calabria.
3402.	Turbo filosus.	Calabria.

* Other species of mollusca continued to be dredged down to depths of 14610 feet.

Mr. Jeffreys informs me that, in addition to the above, there are many other species in the same category, though they have not yet been specially recorded. According to him, the total number of species which were, until lately, considered extinct, but which he has now ascertained to be living, is at least thirty.

In the Mediterranean, there is at present little to record. 15 species were dredged from a depth of 8490 feet. They consisted of:—

Northern species	5	Fossil in Italy	9
Lusitanian	9	Fossil in the Crag	4
Oceanic	1	New species	2

Some new species of much interest were discovered in less depths (of from 100 to 1000 feet) in and at the entrance of the Mediterranean. Amongst these there were 31 northern species, also 12 species before known only as fossil in Italy, and 3 species common to our Crag.

Thus, so far from showing any relationship to the Cretaceous fauna, the deep Atlantic mollusca have their nearest allies in Pliocene (and possibly Upper Miocene) forms of Italy and in those of the Crag-beds of this country. Mr. Jeffreys's anticipations, made in 1862 *, that "it is highly probable that all the mollusca which lived during the periods represented by the newer strata still survive in some part or other of those vast tracts of sea-bed which lie between the North Pole and the Pillars of Hercules," and that the deeper recesses of the ocean would be found inhabited, receive therefore great confirmation, though it yet remains to be seen to what extent they may be fully realized. Almost all the species yet found at these great depths are, like so many of our Coralline-crag species, very small.

Prof. Duncan has described † 12 species of corals dredged from depths of from 2000 to 4200 feet; and he informs me that he has under description many others, some of which were obtained from a depth of 6570 feet. Owing to the great range in depth and temperature of the Atlantic sea-bed, the variation in form of some of the corals has been so excessive that Prof. Duncan has absorbed 9 old species in the 12 now established. The range and distribution of these species thus obtained in the first and second expeditions is very remarkable.

* 'British Conchology,' Jeffreys, vol. i. p. xci.

† Proc. Roy. Soc. vol. xviii. p. 289.

Allopora oculina, *Ehren.*—Original locality unknown.

Caryophyllia cyathus, *Ellis & Sol.* sp.—British Seas, Mediterranean. Lophohelia prolifera, *Pallas.*—British Seas, Mediterranean, Florida Seas. Flabellum laciniatum, *Ed. & H.*—British Seas. Ceratocyathus ornatus, *Seg.*—Fossil. Amphihelia miocenica, *Seg.*—Fossil.	Sicilian, Older Pliocene.

—— atlantica, *Dunc.* New.
—— oculata, *Linn.* sp.—Mediterranean.
—— ornata, *Dunc.* New.
—— profunda, *Pourt.* New.—West-Indian Seas, Mediterranean and Norwegian Seas.

Balanophyllia socialis, *Pourt.* New. Pliobothrus symmetricus, *Pourt.* New.	Florida Seas.

Thus out of 12 species there are as many as 5 which were before known as fossil only; or if we take the annulled species, there were 8, all of which had hitherto been confined to the newer Tertiary beds of Sicily or southern Italy. Unlike the Testacea, which show a relationship to northern forms and to those of our Crag, there is not a single species that Prof. Duncan has been able to refer to the Crag, whilst the connexion with the Mediterranean area and with the seas of Florida and the West Indies is most noticeable. Prof. Duncan regards one or two of the new species as allied to Miocene forms; but he does not instance a single case of an approach to Cretaceous forms, except possibly in the case of *Lophohelia* (to the *Synhelia* of the Chalk) and *Diplohelia*, which is really an *Amphihelia*.

Among the Corals, however, now under examination from the second expedition of the 'Porcupine' the *Sphenotrochus* of the Crag is found (locality Tangier Bay), and some *Caryophylliæ* and *Bathycyathi* of Cretaceous types are to be noticed.

Thus while the Foraminifera obtained in these deep-sea explorations show a strong community of genera and a partial identity of species with chalk Foraminifera, the Sponges markedly representative forms, the Echinoderms allied genera, and the Brachiopoda a similarity of groups, on the other hand, as we ascend in the scale, so far from any resemblance being maintained, we find actual identities with the Upper Miocene*, Pliocene, and Quaternary fauna of western Europe. This seems to point to a possible direct descent in the one case of all those lower forms of life, less influenced by temperature and depth, from the epoch of our chalk, and in the other case to a change of physical conditions, resulting from the

* There is nothing which has the facies of the Eocene Molluscan fauna.

different arrangement of our seas and continents, destructive of the higher forms of life, and accompanied by the introduction of northern forms of partly corresponding classes.

Edward Forbes concluded from his researches in the Ægean *that parallels in latitude are equivalent to regions in depth*; and he subsequently showed this hypothesis to hold good by the occurrence at various depths in southern seas of northern species of mollusca. Hence cold-water species of Testacea can have a much wider range in latitude than warm-water species. MM. D'Archiac and De Verneuil had already, on purely palæontological grounds, concluded *that those species which were found at many places, and in districts distant one from the other, are almost always those which have lived through many successive formations* (*systèmes*)*; or, as it was better expressed by Mr. Rogers, "*the species of which the geographical distribution is the widest have also the greatest vertical range.*" Reasoning from these data, M. D'Archiac observed that those geologists who saw "beds of different age everywhere where they found different fossils, were liable to make serious mistakes; for the same bed taken at two distant points and having a natural difference of level, say of 300 feet, might present very distinct groups of species, and might lead to the erroneous conclusion that these two parts of the same bed were not contemporaneous"†. Edward Forbes also observed

* Bull. Soc. Géol. de France, vol. xiii. p. 260, 1842.

† Bull. Soc. Géol. de France, 2nd ser. vol. ii. p. 484, 1845. As the discussion which ensued on this communication bears on the subject of these deep-sea investigations, I give a few extracts from it, which may be new to some present:—

"M. de Verneuil ajoute que, sur les côtes de Suède et de Norvége, là où la mer est assez profonde, M. le Professeur Lovén, de Stockholm, a observé parmi les mollusques une distribution verticale correspondant à leur distribution horizontale, suivant les latitudes. Ainsi, entre Gothenbourg et la Norvége, M. Lovén a trouvé à 80 toises de profondeur, des espèces qui, sur la côte du Finmark, habitent à 20 toises; plusieurs espèces s'élèvent même sur cette dernière côte jusqu'à la région littorale, tandis que dans le sud, elles se tiennent toujours à 12 ou 15 toises au-dessous du niveau de la mer."

"M. Élie de Beaumont fait remarquer . . . . Aujourd'hui la température à la surface de la mer à l'équateur est de 27¼° [C.], tandis qu'au fond elle est de 2°. Il n'y a aucune raison de croire à ces différences autrefois." . . . . "La très-grande masse de la mer équatoriale est à une température très-basse et seulement d'un petit nombre de degrés au-dessus de zéro."

M. Pouillet also, in his 'Éléments de Physique,' vol. i. p. 166, 1847, speaking of deep-sea fishes, observes: "On peut juger par là que les régions de la mer ont leurs peuples différents, non seulement suivant les climats, mais encore suivant les profondeurs."

"that all climatal inferences drawn from the number of northern forms in strata containing assemblages of organic remains are fallacious, unless the element of depth be taken into consideration" *.

I mention these observations (made many years since, and which of late have generally been taken into account in all geological inquiries) to show that geologists have still to be guided by the same primary natural-history rules, which have lately received so wide an extension and application in these recent deep-sea dredgings.

The mistake made by Edward Forbes was his assigning the too narrow limit of 1800 feet in vertical depth as the probable zero of animal life in the ocean. Dr. Wallich afterwards extended the probable limits of life to 15000 feet; and now the important researches of Carpenter, Jeffreys, and Thomson show that it must in all probability be carried very much lower, as they have found a highly organized fauna living in abundance at the vast depth of 14,610 feet, and no indication of an approach to the zero of life. It had, in fact, been long felt that the proposition involved in these bathymetrical limits was open to question.

The many interesting problems connected with the temperature and currents of the ocean have often engaged attention since the early part of this century. It was one of the subjects respecting which a large amount of data was collected on the several scientific naval expeditions sent out by the French Government between 1820 and 1840. Humboldt states † that he showed in 1812 that the low temperature of the tropical seas at great depths could only be owing to currents from the poles to the equator.

D'Aubuisson, in 1819, also attributed the low temperature of the sea at great depths at or near the equator to the flow of currents from the poles ‡.

Lenz §, in 1831, gave the results of some experiments he had made at great depths in the ocean, and concluded that between the equator and 45° of lat. the temperature decreases regularly to the depth of 6000 feet, when the decrease becomes insensible. The lowest temperature he recorded was 36° Fahr.

* Edinb. New Phil. Journ., April 1844.

† Fragmens de Géol. et de Climatol. Asiat. 1831.

‡ Traité de Géognosie, p. 450.

§ Edinb. Journ. of Science, vol. vi. p. 341.

Pouillet * briefly discusses ocean temperatures, and concludes that, although all the difficulties of the case are not solved, it seems certain that there is generally an upper current carrying the warm tropical waters towards the polar seas, and an undercurrent carrying the cold waters of the arctic regions from the poles to the equator.

The early evidence on the subject was necessarily contradictory, as the instruments were often imperfect, and the temperature in the early experiments was often taken by means of water or mud brought to the surface. Off the coast of Greenland, Scoresby always found the temperature in descending to increase, in some cases, to 36° or 38° F., while the surface-temperature was only from 28° to 30°. He mentions, however, that in lat. 72° 7′ N., long. 19° 11′ W., where the temperature was 34° F. at the surface, it was 29° at a depth of 700 feet. Sir Edward Parry found the surface-temperature off Spitzbergen to vary from 28° to 31°, and at depths of from 400 to 600 feet to be from 30° to 28°. Sir John Ross found the temperature at a depth of 2520 feet in Melville Bay to be $29\frac{1}{2}$°; in Lancaster Sound, depth 7900 feet, 29°; and in lat. 72° 33′ N. and long. 73° 7′ W. the surface-temperature was found to be 35°, decreasing gradually to $28\frac{3}{4}$° at a depth of 6000 feet. More lately the carefully made observations of M. Chas. Martins in the Spitzbergen seas led him to the following conclusions:—

1st. In the months of July and August the temperature of the surface, although near freezing-point, is always somewhat above it.

2nd. From the surface to a depth of 240 feet, the temperature here increases, there decreases.

3rd. From 240 feet to the bottom the temperature always decreases.

4th. The mean temperature of the water at the bottom of the sea is 28·84° F. (− 1·75° C.).

The greatest depths of the soundings seem to have been from 2000 to 2800 feet.

These low deep-sea temperatures have not only been found to prevail in high northern latitudes, but to extend, though in somewhat diminished force, to the equator, and thence to the Antarctic regions.

* Élém. de Phys. vol. ii. p. 667, 1847.

The following instances, taken from the many made on different voyages of discovery, will suffice to illustrate this fact:—

Temperatures of the Atlantic.

Latitude.	Longitude (corrected to Greenwich).	Depth.	Temperature. Surface.	Temperature. Bottom.	Observer & Date.	
° ′	° ′	ft.	°	°		
42 0 N.	34 40 W.	4688	62·0	44·0 F.	Chevalier	1837.
29 0 N.	34 50 W.	8399	76·0	43·0	"	"
7 21 N.	20 40 W.	3030	80·0	36·0	Lenz	1832.
4 25 N.	26 6	6037	80·8	37·9	Tessan	1841.
15 3 S.	23 14 W.	7200	77·0	39·5	"	"
25 10 S.	7 59 E.	5315	67·4	37·6	"	"
29 33 S.	10 57 E.	6310	66·4	35·8	"	"
32 20 S.	43 50 E.	6444	71·0	36·5	Lenz	1832.
38 12 S.	54 80 W.	2000?	62·4	37·6	Tessan	1841.

In the Antarctic regions Sir James Ross made a considerable number of observations in 1839–43. Whatever the temperature of the surface, he found the temperature from 2800 to 3600 feet to be from 38° to 39·8°, the higher temperature being at the lower depth. He concluded that below 1800 feet there was very little variation in temperature, and inferred that in lat. 56° 14′ S. there is an ocean belt, the temperature of which from top to bottom is of 39·5°. This conclusion seems to have been based on an erroneous idea of the specific gravity of sea-water, and is possibly in some degree attributable to errors of the instruments used. Captain Willis, however, came to the same conclusion with respect to a belt of uniform temperature. I cannot find that there is any sufficient foundation for this hypothesis, which is in no way confirmed by the observations of others. As the other observations were nct generally known, this hypothesis has unfortunately been too often accepted. Later experience has shown that in many instances there is an error in the earlier observations, in consequence (where proper precautions were not used) of the pressure on the thermometer at great depths. Dr. Carpenter has determined this to amount to as much as 2° or 3°, or even more. Consequently a deduction to this extent has often to be made in order to get a true reading of some of the older observations. In many of the French expeditions, however, great care was taken to guard against the influence of pressure.

If we turn to the Pacific, we shall find similar low temperatures prevailing at great depths both in the temperate and torrid zone. I again take merely a few cases in illustration.

Temperatures of the Pacific.

Latitude.	Longitude (corrected to Greenwich).	Depth.	Temperature.		Observer & Date.	
			Surface.	Bottom.		
		ft.				
51° 34′ N.	161° 41′ E.	5741	53·2°	36·6°	Tessan	1832
28 52 N.	173 9 E.	3600	78·0	41·0	Beechy	1828
18 5 N.	174 10 E.	4261	76·6	40·8		1836
4 32 N.	134 24 W.	12271	81·0	35·2	The 'Bonite'	1837
Equator (near)	179 34 W.	6000	86·0	36·6	Kotzebue	1824
21 14 S.	196 1 W.	5500	81·0	36·0	Lenz	1834
32 57 S.	176 42 E.	4692	61·4	41·8		
43 47 S.	80 6 W.	6400	55·6	36·2	Tessan	1841

These observations tend to show that in the greatest depths, both of the Atlantic and Pacific Oceans, the temperature is not higher than from about 36° to 40°; and allowing for correction of the instruments, the actual temperature will probably be found to be in many cases 2° or 3° or more below this. A more systematic mode of proceeding, however, is needed; for though the general rule may be considered to be established, local variations and exact measurements have to be ascertained. Notwithstanding, less attention has been paid to the subject of late years than formerly. Dr. Carpenter has now taken up the investigation, and has during the last three years carried out a series of observations in the North Atlantic which must prove of high value. Every care has been taken to guard against error; and we shall soon no doubt have tables of temperature at all depths in this part of the ocean, which it is to be hoped will, concomitantly with the dredging-operations, be extended over the whole of the oceanic area.

Time will not allow me to enter upon the question of the course and cause of the cold under-stratum of the great oceans. As before observed it has been generally referred to undercurrents from the poles; and later observations tend to confirm this; but whether in the mid-Atlantic the flow is from the north or the south pole remains to be decided by more accurate inquiries. My own opinion inclines to an undercurrent from the North Pole. The occurrence of boreal and Scandinavian forms of life far south in the Atlantic favours this view. Whatever the cause, the fact of cold undercurrents, which must have a powerful effect in bringing northern and southern forms into close vertical juxtaposition, is indisputable. All seas open to the Arctic and Antarctic oceans are doubtless subject to these conditions of warm surface-currents from the equator and cold undercurrents from the poles. In seas where there is no direct communication with the Polar seas, the case must assume a very different aspect.

Dr. Carpenter in his last cruise made also a number of observations in the Mediterranean, showing that while the surface-temperature in August and September varied from 69·5° to 77°, it fell in all cases to about 56° at a depth of 600 feet, and maintained that temperature through all the depths below that line. This confirms the experiments made in 1840–1845* by M. Aimé, who found that the average temperature of the sea at a distance from land, for the twelve months of the year, was 64·4° Fahr., that of the air being 64·8°; and that the former decreased gradually to 54·6° at a depth of 1148 feet, below which to a depth of 4050 feet it was not found to vary 1° †. He considered that the diurnal variation of temperature ceased at 59 feet, and the annual variation at from 1148 to 1640 feet, although, in fact, his tables show little variation after 656 feet. The mean shore-temperature of January, February, and March, taking together the two stations of Toulon and Algiers, was ascertained to be 54·8°, with which the temperature of this part of the depths of the Mediterranean corresponds almost exactly.

The subject of the currents and temperatures of the Mediterranean engaged also the attention of Captain Spratt for a series of years, and a number of carefully made experiments are recorded by him. He also determined that while the temperature from the surface to a depth of 12 feet ranges generally from 76° to 84° Fahr., gradually decreasing to a depth of 600 feet, there was little variation below that line, and that the temperature of the depths of the eastern basin of that sea is about 59°, and of deep seas off Greece 55½°—that while on the Mediterranean side of the Straits of Gibraltar there is a deep-sea temperature of 59°, there is one of 39½° on the Atlantic side ‡.

* Ann. de Chimie et de Physique, 3rd ser. vol. xv. 1845.

† The following is M. Aimé's summary:—

"Températures moyennes annuelles de la mer à diverses profondeurs.

	Températures.	Maxima des variations entre les moyennes mensuelles.
à la surface	18·2° C.	10·2° C.
à 25 mètres	16·3	6·3
à 50 „	14·4	2·8
à 100 „	13·7	2·0
à 200 „	13·0	1·0
à 350 „	12·6	0·0"

‡ British Assoc. Report (Sections), 1848; and 'Travels in Crete,' vol. ii. p. 345.

The fauna of the Mediterranean naturally presents a considerable difference from that of the Atlantic, especially from that portion which inhabits the greater depths of the latter. There is an absence of the numerous recent arctic forms which follow the cold currents of the Atlantic, although there are many northern forms of Quaternary and Pliocene age, which seem to have been introduced into the Mediterranean area at a period when the communication between the two seas may have been more open—an inference made by several observers both on natural-history and on geological grounds. Newer Tertiary strata extend, in fact, a great part of the way across from the Bay of Biscay to the Mediterranean, and the watershed between the two seas is not higher than about 600 feet above their levels. At one point on this line, and at an elevation of 560 feet above the Mediterranean, M. Virlet d'Aoust many years since discovered, in a fossil state, the *Ostrea hippopus* and *Murex trunculus*, species still living in that sea.

From these considerations the question arises whether the deep sea in which the Chalk, with its more tropical genera, was deposited, may not also have been a sea shut out from direct communication with Arctic seas. The Old and New continents have a north and south extension, with intervening oceans in the same direction; but the distribution of land and water must have been very different during the Cretaceous period. Beds of this age stretch from England through France, Germany, Poland and Southern Russia to Persia and India, and they also traverse the southern portions of the North-American continent. Throughout much of Europe and parts of Asia the Chalk has the common character that it possesses in England, and which has led it to be likened to the Atlantic deep-sea mud. On the other hand, there is no Chalk north of Denmark, in North Russia or Siberia, or in Arctic America. If the direction of the deep Chalk-ocean followed this east and west belt across the present continents, then we must look for dry land on the confines of that ocean; and it is probable that the latter may have been, to the north, in the direction between Greenland and Scotland and Scandinavia, where the present ocean is some hundreds of fathoms shallower than further south. We know that towards the end of the Cretaceous period, a change took place in the fauna, arising apparently from the shallowing of the sea that preceded the deposition of the Maestricht beds, as well as of the *Calcaire pisolitique* of Laversine and Mont Aimé. Many of the great Cephalopods disappeared, and reptiles increased in numbers; at the same time the Lamellibranchiate Mollusca became more predominant. Dry land appeared further south, as evinced by the lignite and freshwater beds intercalated in the Cretaceous series of Southern France. At the close of this period the continent of Europe may have acquired larger dimensions, although it was not until after the great Nummulitic sea of Lower Eocene age (which also stretches through southern Europe to India) had become in part dry land that the "relief" of the continent approximated to that of the present day. On the western edge of the new land formed by the elevation of a portion of the old Chalk ocean more littoral deposits then began to form; and the same thing took place on the sea-belt of the American continent.

The Cretaceous formation of the south-west of England and west of France and north of Ireland passes out under the Atlantic, and reappears on the south-east coast of the North-American continent. As it thus trends in the same direction on both sides of the Atlantic, there would be nothing improbable in supposing that old Cretaceous ocean prolonged further in the same given direction across the present Atlantic.

It is well known that at a distance varying from 50 to 200 miles off the coasts of western Europe, the sea-bed deepens rapidly to 600, then to 1200 feet, and again almost suddenly to depths of from 6000 to 15,000 feet. Does this mark a boundary of the materials drifted out to sea during Postcretaceous times? or is it a line of still older date?

The great and distinctive feature of the Tertiary series is that, with few exceptions, the whole of them were deposited in shallow seas. The London Clay even, which is from 400 to 500 feet thick, does not represent a sea-bed deep in proportion, as there is evidence to show that it was probably deposited during a period of gradual depression of the sea-bed. The total thickness of all the English Tertiaries does not exceed 2000 feet, or that of the Paris-basin Tertiaries 1500 feet*. Therefore, while the deep Atlantic area continued submerged, movements of elevation and depression affecting the continental European area (leaving out the changes during the Glacial period) may have gone on during the Tertiary period to the extent of from 2000 to 5000 feet, leaving abyssal depths of from 10,000 to 12,000 feet unaffected by these movements, even supposing they extended over the oceanic as well as the continental area. It is the same on the American coast of

* Though further south the Tertiary beds attain possibly a thickness of from 3000 to 4000 feet.

the States, which is bordered by Tertiary strata of a like character with their European equivalents.

It is true there have been elevations of the Cretaceous and Tertiary strata during the Tertiary period far greater than the depths first mentioned; but it has been in mountain-chains which have little affected the great plains of continental land. In the same way there may have been partial elevations in the bed of the Postcretaceous Atlantic; but there is nothing to indicate that it has ever been entirely raised. I think, therefore, that the hypothesis with regard to the continuity of that sea-bed from the period of the Chalk to the present period is one of high probability.

If such a northern land barrier as that which I have alluded to existed at the period of the Chalk, and that barrier was submerged during the early part of the Tertiary period, it would (taken in conjunction with the very different conditions of depth under which the Chalk and Lower Tertiaries were formed) go far to account for the great break in the fauna of the two periods. Some years since I had occasion to show on other grounds that the Thanet Sands, which repose on the Chalk in the south-east of England, exhibited a fauna essentially of temperate or cold latitudes, and I inferred the inset of currents from the north. As those remarks bear upon the present question, I will quote some of the passages in the paper to which I refer *.

"In viewing the London Tertiaries as a group, and comparing them directly with the underlying Chalk, it is to be observed that we are not comparing like terms of the two periods. That a great and essential difference existed between these periods must be admitted; but it is a question how far that difference is widened by the comparison being instituted between the deep and shallow sea deposits, instead of between strata deposited under like conditions during those two periods. . . . . The adaptation of this area at the Thanet-Sands period to the existence of the numerous shallow-water burrowing Lamellibranchiates, whatever the duration of the intervening time, would necessarily unfit it for the deeper-sea Cephalopoda, Brachiopoda, and other families which prevail in our Cretaceous series.

"We have therefore, in viewing the Tertiary strata in relation to the underlying Chalk, to take into consideration that the existence of certain classes of fossils in the former of necessity implies the non-existence of other classes found in the latter deposit—and

* Quart. Journ. Geol. Soc. vol. x. p. 443, Nov. 1854.

this, even should the two have been in consecutive and uninterrupted sequence in time.

"The somewhat Cretaceous *facies* which exists, however, in the Lower Landenian [of Belgium] and the Thanet-Sands fossils, is to be recognized in some portion of the fauna of the London Clay itself. Thus among the Echinodermata the *Hemiaster*, a common Cretaceous genus, has three species in the London Clay, and but one in the Barton Clay; whilst the prevalence of Crinoids, amongst which is a species of *Bourgueticrinus*, hitherto considered a Chalk-genus, and three species of *Pentacrinus*, and the new *Cainocrinus* of Forbes, are features more resembling those prevailing in Mesozoic than those usual in Tertiary strata. The two genera of *Asteridæ* (*Astropecten* and *Goniaster*) which occur in the London Clay are common in the Cretaceous strata, the Oolites, and Lias."

"The London Tertiary group seems to have resulted in that order of changes which, commencing with the elevation of a portion of the Chalk area at the end of the Maestricht period, was followed by subsequent depressions which led to the transgressive accumulation of the Lower Tertiaries from north to south. . . . . . I have before shown the probability of the existence of dry land to the south and an open sea to the north during the Thanet-Sands period, and of more insular conditions during the Woolwich and Reading series period; and now with respect to the London Clay the evidence tends in the same direction."

"To have just terms of comparison, we need a Cretaceous series with a similar varied marine, æstuarine, and fluviatile fauna, such as flourished during the successive Tertiary periods. We have already in the Maestricht beds a change in the fauna—a dying-out of many old forms, and the appearance of many genera common in the Tertiary series."

"In considering all these singular vicissitudes, and in contemplating the extent to which certain more northern influences operated in giving to a large portion of the fauna of the London Tertiaries an aspect much more closely resembling that of the present day than is found to exist in many more recent deposits, the question suggests itself of how far that law, enunciated by Prof. E. Forbes, and according to which the distribution of Molluscs in depths of southern seas is equivalent to their appearance at lesser depths or at the surface in parallels of latitude of more northern seas, may by analogy be applied geologically in accounting for any abnormal condition in the vertical succession of organic remains such as here occurs? Can it be that such a group of generic forms, allied to and closely resembling those found in the same zoological province at the present day, had a yet older existence in more northern provinces—that generic forms of temperate regions have travelled from the north, and have been gradually spread further south, giving, when they encroached upon the more southern forms, a more recent aspect to the faunas of such various geological periods than prevailed in those of the same localities when changes in the distribution of land and water brought back for a time the southern forms which had been temporarily displaced?"

That much of the difference between the fauna of the Chalk and the Lower Tertiaries must be due to the elevation of the old Chalk ocean-bed (by which the deep-sea life was exterminated and a shallower-water fauna introduced) is now evident from the recent deep-sea dredgings. Suppose, for instance, a portion of the present bed of the Atlantic were raised to the level of the sea-bed of the present English channel, whereby the depth of water would be reduced from 12,000 or 15,000 to 100 or 600 feet. The deep-sea fauna would be destroyed, and the fauna and sandy beds of the English coast would succeed it; and when these were raised, we should have sand and gravelly beds containing a shallow-water fauna overlying calcareous beds with a deep-sea fauna, and there would be but very few, if any, species common to the two deposits.

As old coast-lines and the oceanic currents changed during the Tertiary periods, we may suppose corresponding changes in the fauna of the littoral and laminarian zones, while the deeper-sea fauna (which was not subject to these changes of conditions) may have had a much longer and more permanent existence. Together with the recurring bathymetrical conditions, the lithological character of the sea-bed further influenced the vitality and persistence of species. The Mollusca of the *Calcaire grossier* of the Paris basin are, according to M. Deshayes, essentially southern in their character and relations. This formation is separated from the Chalk by the London Clay or its equivalents, and the Woolwich series and Thanet Sands, with the fauna of which it has few species in common, whilst, as I have before mentioned, the species of the Lower Eocene beds have a more northern facies. It is not, however, long since MM. Cornet and Briart found under the equivalents of all these English series in Belgium a friable calcareous bed full of fossils, not like those of the overlying Lower Eocene, but resembling, and in many cases identical with, those of the more recent *Calcaire grossier*. Again, in the Barton Clay, many species of the London Clay, which had disappeared during the period of the intervening Bracklesham Sands, reappeared with the reoccurrence of argillaceous strata. One of the most remarkable cases, however, is that of the *Argile de Boom*, which forms the very top of the Eocene series of Belgium,—the Oligocene of German geologists. This deposit is so like the London Clay in lithological character that it would be almost impossible to distinguish them, while the shells (especially the several species of *Fusus*, *Pleurotoma*, and *Natica*) so closely resemble those of the London Clay, from which it is separated by the four or five divisions of the Upper Eocene, that they might easily be mistaken for London-Clay fossils. The exceptional appearances of *Colonies*, whether in the older or newer rocks, are, no doubt, mainly due to the recurrence at certain intervals of similar lithological, thermal, and bathymetrical conditions.

During the Middle Tertiary or Miocene period, it would seem that a different distribution of land and water prevailed. The Miocene beds of Skye and of Greenland, with their remarkable floras, indicate land and fresh-water conditions, while at the same time the Miocene marine beds of France and Germany are rich in subtropical forms of Mollusca. Assuming part of the area which now constitutes the Northern Atlantic area to have been then dry land, the migration southwards of arctic species of Mollusca would have been for a time interrupted.

Approaching nearer to our own times, we have Pliocene beds in Iceland, Quaternary deposits in Spitzbergen and on the western flanks of the Scandinavian peninsula, while in this country Glacial or Preglacial beds range to the height of from 1000 to 1400 feet above the sea-level. There is reason, therefore, to believe that the bed of the North Atlantic may have been from 1500 to 1600 feet or more deeper during the Pliocene and Glacial period than it now is. If northern submarine currents are now checked, as Prof. Wyville Thomson supposes, by the shallower seas between Scotland and Greenland, such an addition to its depth as these emerged portions indicate would materially have affected those conditions, and have allowed of a freer passage of the north-polar waters, and consequently of a freer dispersion of its fauna to the abysses of the mid-Atlantic, where, in fact, so large a number of them are now found to exist. This more open communication gave rise, I conceive, to that great migration of northern Mollusca which are now found fossil in Italy and Sicily, and some of which still survive in the Mediterranean and mid-Atlantic.

It is more difficult to understand the absence of later Quaternary shells, such as those of the Clyde beds, only three of which have been recognized among the late dredgings. Does it arise from the more littoral and shallow forms of that class being stayed by climatal conditions near our shores, while the deeper-sea forms passed on southward free from the influences which affected the others? That a great proportion of the deep-sea forms had migrated during and since that period is probable from their wide diffusion and large numbers. Mr. Jeffreys has enumerated fifty of these more recent northern Mollusca which are not known in a fossil state; and of the Echinoderms and Crustacea mentioned by Dr. Carpenter and Prof. Wyville Thomson a large proportion are Norwegian, Spitzbergen, and other high-northern forms.

From what I have previously said, you will have understood that, lithologically, there is but little resemblance between the Atlantic mud and our typical white chalk, none that could have ever led a geologist into any error of determination. In fact, in no part of the area yet explored is there any thing at all to be identified lithologically with the true white chalk. Even if it were found that the superposition were conformable, the difference of mineral character is too marked. At the same time it is to be observed that the area of the Atlantic is so vast that, variable as the deposit now going on seems to be, it is probably little, if any, more so than that which went on in some parts of the Chalk series in the bed of the Chalk-ocean over the old European area. Of the rate of the present deposit we know nothing. Is it even going on everywhere over the deep Atlantic?

Therefore, although I think it highly probable that some considerable portion of the deep sea-bed of the mid-Atlantic has continued submerged since the period of our Chalk, and although the more adaptable forms of life may have been transmitted in unbroken succession through this channel, the immigrations of other and more recent faunas may have so modified the old population, that the original chalk element is of no more importance than is the original British element in our own English people. As well might it have been said in the last century, that we were living in the period of the early Britons because their descendants and language still lingered in Cornwall, as that we are living in the Cretaceous period because a few Cretaceous forms still linger in the deep Atlantic. Period in geology must not be confounded with "system" or "formation." The one is only relative, the other definite. A formation is deposited or takes place during a certain time; and that time is *the* period of *the* formation; but *a* geological period may include several formations, and is defined by the preponderance of certain orders, families, or genera, according to the extent of the period spoken of; and the passage of some of the forms into the next geological series does not carry the period with them, any more than would any particular historical epoch be delayed until the survivors of the preceding one had died out. Period is an arbitrary time-division. The Chalk or the "London Clay" formations mark definite stratigraphical divisions. We may speak of the period of the London Clay, or we may speak of the Tertiary period. It merely refers to the "time when" either were in course of construction. The occurrence of Triassic forms in the Jurassic series, of Oolitic forms in the Cretaceous series, and of Cretaceous forms in the Eocene, in no way lessens the independence of each series, although it may sometimes render it difficult to say where one series ceases and the other commences. The land and littoral faunas are necessarily more liable to change than a deep-sea fauna, because an island or part of a continent may be submerged and all on it destroyed, while the fauna of the adjacent oceans would survive; and as we cannot suppose the elevation of entire ocean-beds at the same time, the marine fauna of one period must be in part almost necessarily transmitted to the next.

Thus while continental Europe and the sea-bed, as far as from 200 to 300 miles west of the British Islands, was subject to successive changes of level, giving rise to a series of Eocene, Miocene, and Pliocene strata with their diversified and varying faunas, the adjacent depths of the Atlantic may have continued with little variation, except that produced by currents and relatively small differences of depth. Of the nature of that deep-sea fauna we were until lately entirely ignorant. At the same time it may be observed that geologists held to the opinion of deep-sea deposits; and the views of E. Forbes, with regard to the bathymetrical limits of life in the sea, were by no means generally accepted. The Chalk, attaining as it does a thickness of 1000 to 1500 feet, and having a special fauna, was always looked upon by geologists as the deposit of a very deep sea. Even supposing the conclusions of E. Forbes to have been accepted, no geologist could have safely inferred, from a rock being non-fossiliferous, that it had been deposited in a sea the depth of which exceeded the limits he assigned to marine life. In the first place, the sediment of which the rocks are formed may have been of a nature unsuited for the existence of life over the original sea-bed. It is now evident that the absence of life in the depths of the Ægean is due to the fine tenacious mud (which, by the by, E. Forbes likened to chalk), in the same way that those areas of the Mediterranean, discovered by Capt. Spratt, and of the Atlantic at the entrance of the Straits of Gibraltar, discovered in the 'Porcupine' expedition, to be covered by fine mud, apparently in a state of continual slow deposition, were found to be almost entirely barren. On the other hand, where the rocks consist of sandy strata, any fossils composed of carbonate of lime may have been dissolved out, and all traces of them lost by the percolation of rain-water, after their elevation into dry land, as happens in the Bagshot Sands, in which it is only by chance in the few instances where the sand happens to be consolidated by a ferruginous cement that the impressions and casts of shells are preserved. Another well-known cause for the absence of fossils in a sedimentary deposit is the circumstance of the strata having undergone metamorphic action. I should hardly have thought it necessary to mention these various causes to account for non-fossiliferous rocks, but for a recently expressed opinion of a presumed more general acceptance of Forbes's hypothesis amongst geologists than has been at all the case.

As bearing also upon the distribution of life in the same stratum at points in near proximity, Dr. Carpenter notices that there are areas in the North Atlantic in which the temperature varies considerably at the same relative depths; and he infers that there are permanent warm and cold areas, distinguishable not only by differences of from 10° to 15° of temperature, but also by a difference of marine life, such as might present a geological difficulty. He notes the presence of *Globigerinæ* and abundance of vitreous sponges on a fine muddy bottom in the one, and of northern forms of Echinodermata and Crustacea on a bed of sand and stones in the other. Mr. Jeffreys, however, did not find the same difference in the Mollusca. He states that the result of his examination shows that there are forty-four species in the warm area and fifty-five species in the cold area, and these latter included all the forty-four of the former; and he accounts for the absence of *Globigerina* on the ground that "the strength of the submarine current in the cold area is sufficient to sweep away and remove these slight and delicate organisms," which, from later observations by other naturalists and himself, he believes inhabit only the superficial stratum of the sea. The slight difference in temperature seems hardly sufficient to account for the absence of

Globigerina in the cold area, while the extent of the other differences loses much force by the identity of the Mollusca. We know not also whether there is not a passage from one area to the other. We require therefore more evidence before the geological value of the distinction of the two areas can be fully accepted; at the same time the importance and interest of such an influencing cause must be kept in view.

I will now say a few words on one of the most important bearings that these deep-sea researches have on chronological geology. Objections have been taken on various grounds to the percentage test of Sir Charles Lyell, as evidence of relative age. The data of the deep-sea dredgings furnish us with curious and apparently paradoxical results and such as might seem fatal to this test. Suppose an isolated portion of the deep-sea Atlantic bed had been elevated at some late period, and that we were yet ignorant, as we were only twelve years since, of what was to be found in the unexplored depths of the ocean. Suppose further that the Atlantic deposit had taken place on such rocks as the Palæozoic strata of Cornwall or South Ireland. A chalky-looking deposit would then have been found overlying old rocks, with nothing to indicate stratigraphically its geological position, and with fossils to a great extent new. In the absence of a complete knowledge of the deep Atlantic fauna, I will take, as a specimen of what they might have been, the result of one deep dredging in 5964 feet. Mr. Jeffreys obtained in this single dredging 186 species of Mollusca. Of these he found:—

91	species	recent or living.
24	„	formerly known as fossil only, and belonging to the Pliocene strata of Sicily; some of these are undescribed.
71	„	new or undescribed.
186		

The conclusion would have been that 95 out of the 186, or 51 per cent., were of extinct species; and of these, 24 would be referred to Pliocene age. What would have been the inference as to the age of the beds? Certainly, on palæontological evidence alone, there could have been but one conclusion. They must have been classed as Pliocene or older, although these researches have now shown all the species to be recent.

The case, however, is an extreme and exceptional one. It is true that, in future speculations, the possibility of such a case happening must be taken into consideration; but the depths of the Atlantic are so great that, unless in case of a disturbance such as that of the elevation of the Alps or the Andes, we are not likely to find it brought before us in recent geological times *. Apart from such an exceptional case, I consider that, if all disturbing causes be properly taken into account, the percentage test is a good and useful guide for the chronological arrangement of the newer strata; nor, notwithstanding its exceptional character, do I consider that a case like the one just referred to need perplex the geologist, who would seek elsewhere, in superposition or in some points of physical structure, for evidence as to place. Palæontology is an excellent counsellor, but it should always be kept subordinate to stratigraphical geology. It indicates what *may* be the case, but it does not tell us what *must* be the case. The one has rigid, the other flexible lines; and these lines are rarely parallel. The geologist should first determine rigorously the order of superposition, before he speculates on the distribution of the fauna. Stedfast in that mode, there need be no cause for error, however exceptional and varying the fauna may be. It is his business to determine the fact, and then, with the aid of the palæontologist, to discover the cause and amount of variation, and to detect the principle on which the distribution of life in the period under investigation has been regulated. Palæontology must be our guide, but not our master. It is this which gives life and interest to so many of the higher problems of palæontological geology.

In one point of view, the geologist has the advantage over the naturalist. The latter examines the coasts and dredges in the ocean, but he can only skim the surface, whereas the former has the old sea-beds opened out to him. He can see, at any given time, what has been below the surface. The dredge may penetrate a few inches; but the old shoals and shell-banks of the Coralline Crag sea, for example, can be opened out to the depth of 10, 20, 30 feet or more, exposing the range of life both in time and in horizontal distribution at any given epoch. What may be under the surface of the Atlantic mud we know not. Is there a succession of strata extending down to the equivalents in time of our chalk strata? or would the equivalent of the latter prove to be merely one part of a series, the other end of which would convey us back to Oolitic, Jurassic, Triassic, or even to Carboniferous times? Many of the forms of life indicate a sequence in this great chain. Some of our present marine Foraminifera go back

* The absence of any known deposits in our Tertiary series of a character like the present deep Atlantic mud is another proof that none of that part of the old ocean-bed has been raised since the Chalk period.

to these Mesozoic and Palæozoic times; and we know not yet what further resemblances to old forms of life may yet be detected in the vast field just opened to us.

The present explorations, full of interest and valuable as they are, are insignificant compared with the vast area of the ocean; so that when we look at what has been accomplished in these tentative researches, we can only take them as indicative of the rich mine that yet remains to be explored, and look forward to discoveries that will probably modify and throw much new light on the relations between the marine life of the present and the past.

One of the great subjects which these researches may put before us in this new light is, that instead of the imperfect record which geology usually gives us of the life of the old world, with its interrupted succession in local descent, we may have, if the hypothesis of an area continuously submerged from the Cretaceous period should prove true, the lineal descendants of some portion of those creatures which lived in the Chalk seas. If so, naturalists will be able to see the exact amount of changes wrought, and to study in what direction they have been effected. We shall see the effects of continuity in time in conjunction with continuity of conditions, and whether any and what new forms have been evolved, and where no progress has been made. We see already that the Foraminifera, Sponges, and Echinoderms claim relationship with their fossil antetypes, though in an unequal degree. How will the fully ascertained results agree with the theory of Natural Selection? Beautiful, ably handed, and ingenious as this theory is, it seems to me—I will not say to fail, because I am not competent to pronounce on the natural-history bearings; but it fails to satisfy me. Natural Selection is founded primarily on Sexual Selection; and this latter seems to me an implant so strong, and to have an object so definite, viz. that of maintaining the species in full vigour, strength, and health, that, in the absence of any more direct evidence to the contrary, I would believe in the force of this law of life to perpetuate the special type unaltered, rather than in a divergent natural selection, leading, concurrently with changes of condition, to aberrant forms. We have had curious and remarkable evidence of elasticity of structure in certain directions; but does not the rebound, in almost all cases, show the existence of a spring which, while it admits of considerable play, tends to readjustment as soon as the restraint is removed. That there have been gradual changes in structure in all classes of animal life, concurrent with the passage of time, is evident, especially to geologists ; but of the way in which these changes have been carried out, I own to not yet seeing a sufficient explanation. Have terraqueous changes led to variations in the structure of animal life by the law of Natural Selection among the few that best adapted themselves to the changed conditions ? or was it by a gradual modification induced in the many, in consequence of the general change to which they were all subjected ? or was there some law in time, or of a character yet unknown to us, cooperating with the change in conditions, to produce those singular and extraordinary changes and variations of structure of which we have now such full evidence as to fact, but so little as to theory ?

These are some of the problems towards the solution of which I look with great hope in the continuance of these most interesting deep-sea researches, important alike to the naturalist, the physicist, and the geologist.

P.S. The few particulars in this Address relating to deep-sea temperatures were collected some twenty years since for a paper never published. As they form fitting antecedents to the more important recent researches, I have incorporated part of them here, leaving possibly some of the intermediate work rather incomplete.

Note.—Since the greater part of this Address was printed, Mr. Jeffreys informs me that he has now, through the kindness of Prof. Lovén, examined the shells procured in the Swedish expedition of 1869 by dredging on the Josephine Bank and off the Azores, at depths ranging from 110 to 790 fathoms ; and that nearly all these shells belong to the same species as those procured in the 'Porcupine' expeditions at similar depths.