

figures to illustrate the structure and parts of a Trilobite, to render the plates of Silurian forms more intelligible. In referring to the Graptolites we have quite a number of forms of *Virgularia*, *Sertularia*, etc., given as recent illustrations.

In the descriptive remarks on Corals in Part II. we have figures in the text to explain the several parts of a Coral and its mode of reproduction by budding from the calice, the side, the base, or by fission; also the distinction between Palæozoic and Neozoic types of corals are plainly shown by diagrammatic woodcuts.

Again, under the descriptive remarks on the Crinoids, we find the same useful method of teaching introduced, so that one afterwards readily seizes upon the leading features in a description of any particular species or genus.

The lithographic plates appear brighter and sharper in Part II., which we take to be a sign that even a distinguished palæontologist and draughtsman like Mr. Baily goes on improving, like good old port; but we hope to have occasion to enjoy the pleasure of recording the issue of fresh parts of Mr. Baily's work more often than we have of tasting "thirty-four."

VII.—GEOLOGICAL DYNAMICS.

BY SIR WILLIAM THOMSON, LL.D., F.R.S.

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Part I.—*Reply to Professor Huxley's Address to the Geological Society of London, of February 19, 1869.*

IN his Anniversary Address to the Geological Society of London, Professor Huxley directed attention to two sentences in a lecture on "Geological Time," delivered by Sir W. Thomson. They were as follows:—

"A great reform in geological speculation seems now to have become necessary. . . . It is quite certain that a great mistake has been made—that British popular geology, at the present time, is in direct opposition to the principles of natural philosophy."

In the first place he endeavoured to show that, even if geological time were limited to 100,000,000 years (a period to which Sir W. Thomson's calculations tend to show it may be restricted), no great reform in geological speculation would become necessary, and that the limitation may be accepted *without* a complete revolution in our ideas. Thus: estimating the total thickness of stratified rocks containing traces of life to be 100,000 feet, Professor Huxley shows that the whole thickness might have been deposited in 100,000,000 years, at the rate of $\frac{1}{1000000}$ of a foot, or say $\frac{1}{83}$ of an inch, per annum. In the second place, he examined the arguments upon which Sir W. Thomson's calculations were based, and pointed out that if the data upon which they are founded are loose and uncertain, as he himself admits, no amount of mathematical accuracy can render the deductions drawn from his calculations of any serious import to the geologist.

Professor Huxley asked whether it had ever been denied that the period to which Sir W. Thomson restricted geological time may be enough for the purpose of geology, and remarked that on him rested the *onus probandi* of his call for reformation. Accordingly Sir W. Thomson now brings forward evidence to support his statement, consisting of several passages from the works of Darwin, Jukes, and Page, wherein the necessity of unlimited time is taught. On the other hand, he quotes Professor Phillips' careful estimate of 96,000,000 years for the antiquity of the base of the stratified rocks, which agrees so remarkably with his own conclusions, and also quotes Mr. A. Geikie, who lately declared his opinion that all the erosion of which we have monumental evidence in stratified rocks, and in the shapes of hills and valleys over the world, could have taken place several times over in the period of a hundred million years.

Professor Houghton, whilst admitting Sir W. Thomson's restriction of time, expresses his belief "that the time during which organic life has existed on the earth is practically infinite, because it can be shown to be so great as to be inconceivable by beings of our limited intelligence," and, bearing this in mind, we do not see anything objectionable in the following passage from Darwin, which is quoted by Sir W. Thomson:—he who "does not admit how incomprehensibly vast have been the past periods of time may at once close this volume." Sir W. Thomson denies that he took Uniformitarianism to be the representative of geological speculation in general, he attacked it, but he did not attack geological speculation in general. The Evolutionism of which Prof. Huxley approves, he "always considered to be the substantial and irrefragable part of geological speculation."

Prof. Huxley doubted whether any geologist at the present day would be found to maintain absolute Uniformitarianism, to deny that the rapidity of the rotation of the earth may be diminishing, that the sun may be waxing dim, or that the earth itself may be cooling, and expressed the opinion that, true or fictitious, they have made no practical difference to the earth, during the period of which a record is preserved in stratified deposits.

Sir W. Thomson asks on what calculation this opinion is founded, and adds that:—"Fourier's theory of the conduction of heat renders it almost impossible to escape the conclusion that, if the earth has been solid and habitable continuously during the last 50 million years, its rate of increase of underground temperature per metre downwards must have been very sensibly more rapid 50 million years ago than now. The more recently discovered laws of thermodynamics render it certain that the sun must have been something very different 50 million years ago from what he is now; and almost certain that he must have been then very much hotter.

"There is," he continues, "surely good ground for Sir Roderick Murchison's opinion that metamorphic causes have been more active in ancient times than at present, because of more rapid augmentation of temperature downwards below the earth's surface; and it

cannot be reasonably urged that a hotter sun is not a probable explanation of the supposed warmer climate of the palæozoic ages." Whilst willingly agreeing with Sir W. Thomson that metamorphic action at depths beneath the surface may have been accelerated in the earlier, or pre-Cambrian times, still we cannot suppose it possible that such rocks now remain to tell of such increased telluric action. As regards the assumed warmer climate in palæozoic times, we see no palæontological grounds for such an inference.

It was suggested indeed by a pseudo-geological writer, some time ago, that the bony armour of the Devonian and Silurian fishes was given to protect them from the *hot water* of those early seas; but as the writer was neither a chemist nor naturalist, his opinion will not assist Sir W. Thomson.

Sir W. Thomson replies at some length to Prof. Huxley's examination of his arguments. The Professor, after pointing out that tidal retardation can be checked and overthrown by temporary conditions, asks "What becomes of the confident assertion, based upon the assumed uniformity of tidal retardation, that 10,000,000,000 years ago the earth must have been rotating more than twice as fast as at present, and, therefore, that we geologists are 'in direct opposition to the principles of natural philosophy,' if we spread geological history over that time." Sir W. Thomson answers "that tidal retardation cannot be permanently overthrown by temporary conditions; that its true amount may be considerably greater than that which we have estimated from the theory of the moon's motion; and that from million of years to million of years it must always be a positive retardation."

We could have wished for a more explicit reply to Prof. Huxley's objections, which appear to us to remain practically unanswered.

Professor Huxley asks if the cooling of the earth has been uniform, considering an affirmative answer to be necessary to the validity of the calculations on which Sir W. Thomson lays so much stress? To this Sir W. Thomson gives a negative answer, stating that investigation shows the greater rate of conduction of heat outwards in past times, and demonstrates a much closer limit for the whole time during which the earth has been solid, and continuously cool enough at its surface to be habitable without break of continuity of life, than can be estimated without taking into account the deviation from uniformity which he (Sir W. Thomson) asserts.

His calculations, he acknowledges, depend only on the assumption, that through geological history the temperature of the upper surface of land and water has been suitable for such life as now exists on the earth.

Although the limitation of time proposed by Sir W. Thomson may not of itself cause so great a revolution in geological speculation as some of the other considerations he has brought into notice, the general tendency of his observations is to support the teaching of Kant, upheld by Professor Huxley—"He reasons back to a beginning of the present state of things; he admits the possibility of

an end." There can be little doubt that the school which Professor Huxley terms "*Evolutionists*" will eventually absorb both the modern "*Uniformitarians*" and the older "*Catastrophists*."

Part II.—*On the Origin and Total Amount of Plutonic Energy.*

The store of energy to which the phenomena of volcanoes, earthquakes, and subsidences are due, is properly called plutonic energy.

In modern physical dynamics the performance of work may be described as the drawing of energy from one store and laying it out elsewhere. Any irreversible transformation of energy is called a dissipation of energy.

Plutonic action is to be defined as any transformation of energy going on within the earth, but it also involves something in the way of dissipation of energy. The phenomena of volcanoes and earthquakes probably give rise to much less dissipation of energy than the continual silent action of the conduction of heat outwards, the amount of which may be estimated in a thoroughly definite manner. It is found that from year to year the earth, at the present time, is parting with heat at the rate of 92 horse-power¹ per square kilometre.²

The store of energy (transformations of which constitute plutonic action) consists almost entirely of terrestrial heat. This, indeed, is the only description of energy proved to exist, in any considerable quantity, within the earth; but it is possible that there may be great masses of uncombined chemical elements, and that the potential energy of their mutual affinities may constitute a considerable portion of the plutonic energy in store, whether for the generation of future underground heat, or for immediate application to some of the more violent manifestations of plutonic activity.

Sir W. Thomson remarks that we have strong reason to believe the earth is not a mere thin shell filled with melted material of rock or metal, but is solid from surface to centre, with the exception of comparatively small spaces still occupied by fluid lava, or subjected occasionally to melting in volcanic action.³ He concludes that it is not at all probable that there is now within the earth a hundred times as much heat as that which would raise a quantity of average surface-rock equal in mass to the whole earth from zero to 200° Cent., since this would be certainly many times more than enough to melt that amount of any kind of surface-rock under any moderate pressure.

Inasmuch as energy is being continually lost from the earth by conduction through the upper strata, the whole quantity of plutonic energy must have been greater in past times than at present. Sir W. Thomson states that the only probable hypothesis in regard to its origin is that the earth has become warm by the conversion of mutual potential energy, whether of gravitational, or gravitational and chemical, attraction between its parts, into heat.

¹ One horse-power is a rate of performing work equal to 33,000 foot-pounds per minute.

² Kilometre = .62138 of a British statute mile.

³ On this subject see the valuable papers in the *GEOLOGICAL MAGAZINE*, by Mr. G. Poulett Scrope, Vol. VI., p. 145; M. Delaunay, Vol. V., p. 507; and Mr. D. Forbes, Vol. IV., 1867..

Part III.—*Note on the Meteoric Theory of the Sun's Heat.*

In this short note Sir W. Thomson gives his reason for concluding that meteoric supply for sun heat has not, within historical periods, come from distant space outside the earth's orbit. He regards it as highly improbable that the heat of the sun depends at all for its continuation upon a perpetual meteoric supply. In the present state of science, what appears to him most probable are Helmholtz's views—that the sun originally acquired his heat in being built up out of smaller masses falling together and generating heat by their collision, but that at present he is simply an incandescent mass cooling.

REPORTS AND PROCEEDINGS.

PROCEEDINGS OF THE WARWICKSHIRE NATURALISTS' AND ARCHÆOLOGISTS' FIELD-CLUB, 1868.—At the Annual Winter Meeting, held on the 20th February, 1868, the Rev. P. B. Brodie, M.A., F.G.S., Vice-President and Hon. Sec. of the Club, read a paper entitled "A Sketch of the Lias generally in England." Especial reference was made to the lower division in the counties of Warwick, Worcester, and Gloucester, and a particular account was given of the fossils. Mr. Brodie remarked upon the great uniformity of lithological character of the Lias taken as a whole; even certain Zones may sometimes be as readily recognised by this feature as by their zoological contents. The Insect-limestones, which occur at the base of the Lower Lias, immediately overlying the White Lias (Rhætic), and which consist of from two or three to five or six beds of limestone, have been identified by Mr. Brodie in Somersetshire, Gloucestershire, Warwickshire, and Leicestershire, where they present the same mineralogical character, and contain similar fossils. The remains of insects and also of plants are of considerable interest, because they afford the only evidence of terrestrial life in the Lias. The former occur in the Upper Lias, and in the "Insect limestones" of the Lower Lias. Well preserved remains have been met with in the Cotham marble at Aust Cliff, but are not known elsewhere on this horizon. Mr. Brodie speaks of this marble as the probable *equivalent* of the White Lias in Somersetshire; it undoubtedly belongs to the series, but should rather be called the *representative*. It occurs at the base of the White Lias in the Railway cuttings at Saltford, near Bath. The Summer Meeting of the Club was held at Oxford, in June, 1868. Numerous sections in the neighbourhood were inspected under the guidance of Professor Phillips and Mr. Parker. An interesting account is given of the visit, which lasted several days.

BOSTON SOCIETY OF NATURAL HISTORY, June 18th, 1869.—Prof. COPE exhibited the almost perfect cranium of a Mosasauroid reptile, the *Clidastes propython*. He explained various peculiarities of its structure, as the moveable articulation of certain of the mandibular pieces on each other, the suspension of the os-quadratum at the extremity of a cylinder composed of the opisthotic, &c., and other peculiarities. He also explained, from specimens, the characters of a