THURSDAY, FEBRUARY 17, 1870

THE MEASUREMENT OF GEOLOGICAL TIME

I.

MODERN geological research has rendered it almost certain, that the same causes which produced the various formations with their imbedded fossils, have continued to act down to the present day. It has therefore become possible that, by means of changes which are known to have occurred in a given number of years, some measurement of the time represented by the whole series of geological formations might be obtained. It is true, that changes in the earth's surface, the records of which constitute the materials for geological research, occur very slowly, yet not so slowly as to be quite imperceptible in historical time. Land has risen or sunk beneath the sea, rivers have deepened their channels and have brought down sediment which has converted water into land, cliffs have been eaten away and the surface of the earth has been, in many ways, perceptibly and measurably altered during an ascertained number of centuries. But it is found that these changes are too minute, too limited and too uncertain, to afford the basis of even an approximate measurement of the time required for those grand mutations of sea and land, those contortions of rocky strata many thousands of feet thick, those upheavals of mountain-chains and that elaborate modelling of the surface into countless hills and valleys, with long inland escarpments and deep rock-bound gorges, which form the most prominent and most universal characteristics of the earth's superficial structure. Another deficiency in this mode of measurement arises from the fact, now universally admitted, that the record of past changes is excessively imperfect, so that even if we could estimate with tolerable accuracy the time required to deposit and upheave the series of strata of which we have any knowledge ; still that estimate would only represent an unknown proportion, perhaps a minute fraction of the whole time which has elapsed since the strata began to be formed.

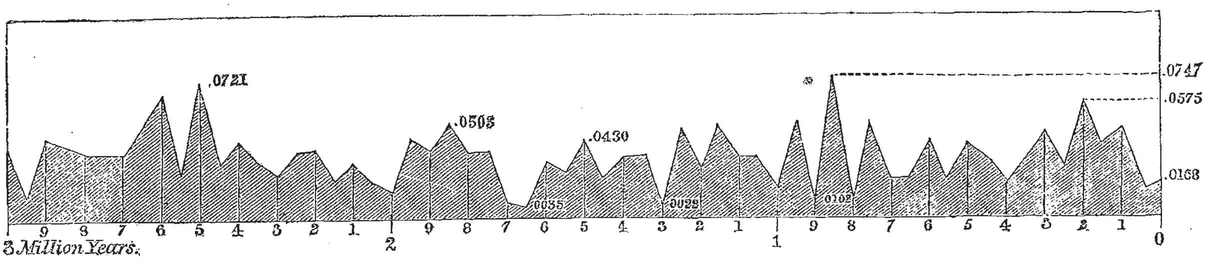
But there is another class of geological phenomena which enable us to measure those very gaps in the record of which we have just spoken, and it is now generally admitted that the continual change of the forms of animal and vegetable life which each succeeding formation presents to us, affords the best means of estimating the proportionate length of geological epochs. Though we have no reason to think that this change was at all times effected by a uniform and regular process ; yet believing, as we now do, that it was due to the action of a vast number and variety of natural causes acting and reacting on each other, according to fixed general laws, it seems probable that, with much local and temporary irregularity, there has been on the whole a considerable degree of uniformity in the rate at which organic forms have become modified. It may indeed be the case that this rate of variation has continually increased or diminished from the first appearance of life upon the earth until the present day, or has been subject to temporary changes ; but so long as we have no proof that such was the case, we shall be safer in considering that the change has been tolerably uniform.

To measure geological time, therefore, all we require is a trustworthy unit of measurement for the change of species : but this is exactly what we have not yet been able to get ; for the whole length of the historical period has not produced the slightest perceptible change in any living thing in a state of nature. Moreover, though, the much longer time that has elapsed since the Neolithic or Newer Stone age, has been sufficient for some changes of physical geography and has, to some extent, altered the distribution of animals and plants, it has not effected any alteration in their form. It is only when we get back to the Palæolithic or Older Stone age, when men used chipped flints for weapons and Europe was, probably, either just emerging from the severity of the glacial epoch, or in some of the intercalated milder periods, that we meet with a decided change in the forms of life. Elephants and rhinoceroses, bears, lions and hyenas then inhabited Europe ; but they were nearly all of species slightly different from any now existing, while the reindeer, the musk-sheep, the lemming and some other animals, were the same as those that still live in the Arctic regions : all the mollusca, however, were identical with living species. In the newer Pliocene Crag, on the other hand, which seems to have been deposited just as the glacial epoch was coming on, there are 11 per cent. of extinct species of shells and about 55 per cent. of extinct mammalia. What we want, therefore, is to be able to estimate, by means of the physical changes before alluded to, the time since the beginning or the end of the glacial epoch. Then we should have the unit we require for measuring geological time by the repeated changes in the forms of life as we go further and further back into the past; but before showing how this may perhaps be done, something must be said about physical and astronomical determinations of the age of our globe.

A few years ago, Sir W. Thomson startled geologists by placing a limit to the time at their disposal, which they had been in the habit of regarding as practically infinite. He showed, from the known laws of heat and the conservation of energy, that there are determinable limits to the age of the sun. Then, applying the same principles to the earth, he showed that, from the known increase of heat towards its interior and from experiments on the rate of cooling of various rocks, it cannot have existed in a habitable state for more than about one hundred million years. It is within that time, therefore, that the whole series of geological changes, the origin and development of all forms of life, must be comprised. But, geologists had been accustomed to demand a much vaster period than this for the production of the series of fossiliferous deposits in the crust of the earth ; while the researches of Mr. Darwin render it almost certain that, however vast the time since the Silurian and Cambrian epochs, yet anterior to these, at least an equal, and probably a much longer, series of ages must have elapsed since life first appeared upon the earth, in order to allow for the slow development of the varied and highly organised forms which we find in existence at those early epochs. Sir Charles Lyell is not disposed to admit the accuracy of these calculations, and Professor Huxley has criticised them in detail, with a view of showing that they are, in many respects, unsound ; while Mr. Croll as strenuously maintains that they are sound in principle and accurate within certain limits.

We have now to consider the bearing of Astronomy upon the problem. In a series of admirable papers in the *Philosophical Magazine*, Mr. Croll has fully discussed the question, how far variations in the excentricity of the earth's orbit, together with the precession of the equinoxes, have produced variations of climate in past ages. He has endeavoured to show that the date of the last glacial epoch and those preceding, may be determined by such considerations. With this view he has laboriously calculated tables showing the amount of excentricity for a period of three million years, at intervals of 10,000 years for a large portion of that time, and 50,000 for the remainder. These tables show that the amount of excentricity is alternately great and small at intervals of 50,000 or 100,000 years, as represented with sufficient accuracy in the diagram, which I have constructed by means of his figures. Owing to the precession of the equinoxes, combined with the revolution of the apsides, either pole will be presented towards the sun (constituting summer in that hemisphere and winter in the opposite one) at a different point in the earth's orbit on each succeeding year, the motion being such as to cause a complete revolution in 21,000 years. If, therefore, at any one period, winter in the northern hemisphere occurs when the earth is nearest the sun or in *perihelion* (as is the case now), in 10,500 years it will occur in *aphelion*; at the one period the winters will be shorter and warmer, at the other longer and colder. When the excentricity is great (say two, three, or four times what it is now), million years probably includes a large portion of the tertiary period, which therefore should have mainly consisted of alternations of warm and cold climates in each hemisphere, the latter generally forming true glacial epochs. This seems the legitimate deduction from Mr. Croll's reasoning and from the tables of excentricity with which he has furnished us; but, as he very justly argues, we cannot expect to find geological evidence of all these changes of climate. The warm and temperate periods will naturally leave the best records, while the cold epochs will generally be characterised only by an absence of organic remains. Besides, we must consider 10,500 years as a very small fragment of time in geology and we have good reason for thinking that several such periods might pass away without the occurrence of those exceptional conditions which Mr. Darwin and Sir C. Lyell have shown to be necessary for the preservation of any geological record. As to physical proofs of ice-action, very few could survive the repeated denudations, upheavals and subsidencies, which the surface must have undergone since any of the earlier glacial epochs; so that it may be fairly argued that these repeated changes of climate may have occurred and yet have left no distinct record by which the geologist could interpret their history.

Throughout the whole of his argument, Mr. Croll considers astronomical causes to be the most important



Mr. Croll shows that, from the known laws of heat in reference to air and water, winter in *aphelion* will lead to an accumulation of snow, in the polar regions, which the summer will not be able to melt. This will go on increasing for many thousand years, till winter occurs near the *perihelion*, when the snow will be melted and transferred to the opposite pole. When the excentricity was very great a glacial epoch would occur in each hemisphere for more or less than 10,500 years, the other portion of the period of 21,000 years being occupied by an almost perpetual spring, with two transition periods from that to the glacial epoch. By examining the diagram of excentricity, we see that during the last three million years there have been more than twelve periods of great excentricity, each long enough to admit two or three, and several of them eight or ten, complete revolutions of the equinoctial points, thus sufficing for the production of not less than fifty or sixty glacial epochs in each hemisphere, with intervening phases of perpetual spring or summer.

The diagram also shows us (and this is of very great importance) that the present amount of excentricity is exceptionally small. During the last three million years there have only been five occasions, always of very short duration, when it has been less than it is now, while periods of high excentricity have often lasted for two hundred thousand years at a time. This period of three and effective agents in modifying climate, while Sir Charles Lyell maintains that the distribution of land and water, with their action on each other by influencing marine and aerial currents, are of prepondering importance. He has certainly shown that these causes have an immense influence at the present time. The effects which, on Mr. Croll's theory, ought to be produced by the existing phase of precession combined with even the small amount of excentricity that now exists, is not only neutralised, but actually reversed by terrestrial causes. Dove has shown that the whole earth is really warmer when it is furthest from the sun in June, than when it is nearest in December, a fact which is to be explained by the northern hemisphere (turned toward the sun in June) having so much more land than the southern. So, the northern hemisphere being three millions of miles nearer the sun in winter than in summer, while the southern hemisphere is the reverse, the northern winter ought to be warmer and the northern summer cooler than the southern; but this, too, is the opposite of the fact, for the southern summer is more than 11° Fahr. cooler than ours, while its winter is nearly 5° Fahr. warmer. The immense differences of temperature of places in the same latitude, sometimes amounting to nearly 30° Fahr., can also be traced, in almost every instance, to the distribution of land and water and of winds and currents. Sir Charles Lyell further argues that the existing distribution of land is so extremely irregular—such an undue proportion being near the poles, while there is such a deficiency at the equator and in the south temperate zone—that whatever differences may have occurred in past time, they can hardly fail to have often been such as to cause a more uniform climate. Therefore he believes that if the poles were tolerably free from land, so as to admit of the uninterrupted circulation of the warmer equatorial waters and to afford no lodgment for great accumulations of snow and ice, a glacial epoch would be impossible even during the most extreme phases of excentricity.

We have now much evidence to show that three distinct modifications in physical geography occurred just before or during the Glacial epoch, which would each tend to lower the temperature. The first is the submergence of the Sahara, which would have caused the southerly winds to be charged with aqueous vapour, condensing on the Alps into snow instead of being, as now, dry and heated and acting powerfully to melt the glaciers. The second is the submergence of Lapland, which would have admitted the cold iceberg-laden waters of the Arctic Sea into the very heart of Europe. The third is the probable submergence of part of Central America, causing the Gulf Stream to be diverted into the Pacific. The only proof of this is the fact that one-third of the known species of marine fishes are absolutely identical on the two sides of the isthmus of Panama; but it is impossible to conceive any means by which such an amount of identity could have been brought about except by a recent, if only a temporary, communication. A subsidence and elevation no greater than what occurred in Wales about the same time—as proved by Arctic shells of existing species in drift 1,300 feet above the sea—would have effected the communication by a broad and deep channel. Now if any two of these changes of physical geography occurred together, we may be sure that a very small increase of excentricity would have led to a more severe glacial epoch than would be possible, under existing conditions, with a much larger excentricity. We must keep this in mind when attempting to fix the most probable date for the last glacial epoch. A. R. WALLACE

FARADAY

The Life and Letters of Faraday. By Dr. Bence Jones. Two vols. 8vo. (Longmans, 1869.)

IF none but Apelles was fit to paint Alexander, where shall we find a biographer worthy of Faraday? Shortly after his death, many sketches of his character and work appeared, among which that of De la Rive may be specially mentioned. These were succeeded by Tyndall's two Friday evening discourses on "Faraday as a Discoverer," which were afterwards embodied in an admirable little book. But a more complete biography was wanted, and the question was frequently asked, "Who understood him sufficiently well to draw his portrait?" Eventually it was rumoured that the materials had been placed in the hands of Dr. Bence Jones. First there appeared an unusually long obituary notice in the Proceedings of the Royal Society, consisting of little else than a catalogue of the papers published, lectures delivered, reports written and honours won by the great philosopher in each year during half a century; showing that Dr. Jones had a rare collection of interesting documents, so as to whet our appetite for the coming work. Now it is before us—"The Life and Letters of Faraday"—in two goodly octavo volumes.

The preface tells us what we are to expect: not a complete likeness either of the man or of the philosopher; but a kind of "autobiography"—for, as the author truly says, "from his letters, his laboratory note-books, his lecture-books, his Trinity-house and other manuscripts, I have arranged the materials for a memorial of Faraday in the simplest order, with the least connecting matter." The very abundance of that material was a source of embarrassment, and the necessity for omissions seems to have been felt more strongly as the work advanced; so that while very nearly half the first volume is devoted to three years of Faraday's life—when he was between twenty and twenty-three years of age and before his "earlier scientific education at the Royal Institution" commenced—the latter years of his life are so rapidly passed over, that some of his latest scientific work—for instance, the adjustment of apparatus in lighthouses—is not even alluded to.

An autobiography has great advantages, especially when it is, as in this instance, an unconscious one; but it is not without its defects. It gives a picture only from one point of view, and Faraday was too modest always to do himself justice. We want to know what impressions other people formed of him, and those who have enjoyed his company would wish to find, in the book, some reflex of his own brightness, some of those characteristic anecdotes which are told in scientific circles. The best, almost the only sketch of this kind in the book, is by one of his nieces, Miss Reid, who gives charming details of her uncle's treatment of her when a little girl, and of his habits both at work and play. Tyndall's book, though professing to describe Faraday only as a discoverer, gives a far more vivid impression of the man. I propose at some time to write down my own reminiscences of him; but at present there is not room to deal with more than the way in which he is presented to the world in the "Life and Letters."

The career of Michael Faraday was marked by steady progress rather than by striking events; there were few changes in his life save such as rose naturally from his increasing knowledge and ever-growing fame. We find him born in London in 1791, of poor parents, taught little more than the rudiments of reading, writing, and arithmetic; beginning active life as an errand-boy at a bookseller's in Blandford Street, and shortly afterwards apprenticed to a bookbinder. Here, however, we see him taking every opportunity of gaining knowledge, making experiments in natural science, and presently, on introducing himself to the notice of Davy, obtaining the post of assistant in the laboratory of the Royal Institution. That was in March 1813. His travels with Sir Humphrey about the Continent, for a year and a half, are minutely described in copious extracts from his diary and his letters home: we see here how he came into contact with many other bright intellects, and learned what to copy and what to avoid. In 1816, at the City Philosophical Society, he gave his first lecture, and, in the *Quarterly Journal of Science*, he published his first paper—on native caustic lime—the beginning, in each case, of a series which for many years delighted and instructed his contemporaries. In 1821 commenced his happy domestic life, through his marriage with Miss Sarah