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ORDINARY MEETING, DEC. 17, 1866.

THE REV. WALTER MITCHELL, VICE-PRESIDENT, IN THE CHAIR.

The minutes of the previous meeting were read and confirmed.

The HONORARY SECRETARY announced that Mr. Alfred J. Woodhouse, M.R.I., had been elected a member of the Council.

The following Paper was then read :—

ON THE GENERAL CHARACTER OF GEOLOGICAL FORMATIONS. By EVAN HOPKINS, Esq., C.E., F.G.S.,
Mem. Vict. Inst.

ALTHOUGH it may not be the intention of the members of the VICTORIA INSTITUTE to support any geological theory, or, indeed, any of the doctrines of physical science which may be promulgated from time to time, I presume that papers describing the general facts of geology will be acceptable, inasmuch as they will furnish materials and data by which unreasonable speculations may be fairly met and checked.

Had the public at large been better acquainted with the leading facts of geology, many speculations with reference to the world would never have been entertained. It is not sufficient to point out the absurdity of some geological speculations: we should also be prepared to show what are the actual conditions of the surface of the globe, founded on direct observations, in order to satisfy the inquiring mind and lead it in the right direction. The object of this paper is to give a brief description of geological formations according to my own experience, as well as the experience of others, in various parts of the world, which I trust will be of some service in discussing and elucidating questions connected with geology, when they are brought forward at our meetings as arguments bearing upon the Mosaic account of the creation or the origin of the earth. The first step towards establishing the order of deposition of the *Sedimentary* rocks was made about the commencement of the present century by Mr. William Smith. He discovered, during his surveys in England, that there were

apparent sequences in the order in which the beds had been laid down; that the different strata could be distinguished by their fossils; that this order of succession of different groups was never inverted; and, further, that they might be identified at very distant points by their peculiar organic remains. This classification of the sedimentary rocks became then established, each division being marked by its peculiar fossils. The founders of the Geological Society of London thus directed their attention to this theory of deposition, and the active members of the Society have almost exclusively confined their attention to this view of the science from that time to this day.

The ideal geological sections have made this order of deposition familiar to all who have paid any attention to geological works. The ascending order of the sedimentary beds is as follows:—1st, Cambrian and Silurian; 2nd, Old Red Sandstone; 3rd, Carboniferous; 4th, New Red Sandstone; 5th, Lias; 6th, Oolite; 7th, Chalk; 8th, Tertiary. As far as the sedimentary beds of England are concerned, these sections might be accepted as representing the general order and character of the beds, provided they are not made to appear to cover each other over the whole area. Although this order of the beds is not inverted, they are not of equal extent, and are merely found in patches here and there, and partially overlapping each other, where the beds are reduced in thickness and taper away. Hence the sections which represent the beds as uniformly piled on each other, and as of equal extent, from the Silurian and Cambrian below to the Tertiary above, are erroneous. With regard to the Silurian formation, it has not only absorbed the Cambrian, but actually also embraces (very improperly) the *primary* slates. The first mistake made by geologists, in establishing this classification of the fossiliferous rocks, was in assuming that this variety of beds was *universally the same in all parts of the world*. They further erred in attempting to assign to each system a distinct creation, and in naming the series of beds in other countries according to the English type, without demonstrable proof of their correspondence. This hasty and very incorrect generalization, together with the assumption that the fossils were all remains of extinct species, different from those now existing, have caused a very great injury to the progress of geological science, by giving encouragement to extravagant theories.

A mere glance at a geologically coloured globe will show how insignificant, for instance, is the extent of the area of the carboniferous formation as compared with the entire surface of the earth. The same may be said of every other division of the sedimentary series, from the Cambrian below to the Tertiaries

above. As investigations have been extended to distant regions of the earth, more especially to South America, South Africa, Australia, New Zealand, and India, other combinations of beds have been brought to light, showing the total absence of almost two-thirds of the grand series represented on the ordinary geological sections of Europe. Again, instead of finding beds indicating distinct creations, as assumed at one time, the formations present the appearance of a gradual transition of one variety of fossiliferous beds into another as the rule, and those indicating apparent distinctions as the exception. Daily researches show that no real breaks exist between the remains of one formation and another, as was once supposed. We now learn that those forms of animal life which roamed over parts of the earth before man came to encroach and exercise dominion over them, were not destroyed before his arrival, but continued to co-exist with him, though in other localities, until the time came when they were to make way for man and domestic animals more suited to new conditions of life and to man's requirements.

Let us commence in the South, and reflect on the general character of the sedimentary deposits of Chili, Australia, New Zealand, and Tasmania in the south temperate zone. Chili is covered with a great thickness of gravel and sand-beds, in which are found marine remains of existing species. The plains of Patagonia present the same appearance: nothing but thick beds of gravel deposited on the edges of the primary crystalline rocks, as is seen by a transverse section from Rio Santa Cruz to the base of the Cordillera, and in another on the Rio Negro. Beds of recent shells are found as high as 1,300 feet from the level of the Pacific along this coast; and the apparent freshness of the shells indicates that all these deposits are comparatively of very recent date.

In the south of Australia, Tasmania, and New Zealand, are found some carboniferous strata of inferior kind and very limited area. These are deposited on the broken edges of the primary slate. The general superficial deposits are composed of loose gravel and sand, partially cemented here and there by ferruginous matter. These beds contain the same kind of shells as those now seen on the coast, and the bituminous beds inclose fern-trees with leaves of the same character as those now growing on the banks of the Yarra Yarra river and in Tasmania. In Equatorial America the sedimentary beds are better developed, and more numerous than in the south, and they can be examined on their escarpment from the plains of Mariquita to the plains of Bogota; that is, from about 800 feet to 9,000 feet above the level of the sea.

The plains of Mariquita are more or less covered with thick beds of *gravel*, in which are found fossil trunks of coniferæ, fern-trees, corals, and the remains of crocodiles, similar to those now flourishing in that zone. The old sedimentary beds resting on the primary base contain deep-sea shells and corals, similar to those seen along the beach on the Chilian coast. As we ascend the series, we find there seams of coal, containing in the inter-stratified black shale impressions of fern-leaves, but not very abundant. Above these are argillaceous beds inclosing a variety of shells and the remains of fishes. On these, again, are deposited several calcareous beds containing fossils in abundance, such as ammonites, hamites, &c., some of which were described and figured in the *Journal of the Geological Society* by the late Professor Forbes in 1844. These fossils were collected *in situ*, and presented to the Geological Society by me in 1843. Amongst them were eight new species. Finally, the upper part of this great sedimentary formation forms the plains of Bogota, where we find again deposits of sand and gravel containing the relics of gigantic ammonites and oyster-shells. I examined the eastern flank of this branch of the Andes to the sources of the rivers Orinoco and the Amazon, and found very extensive beds of similar character to those seen on the other side; but all their organic contents, with the exception of the ammonites and hamites, were of the same description as those now existing on the coast of South America. I have obtained from white clay seams, impressions of leaves with their green and yellow colours partially preserved, which indicates that the formation could not have been of great antiquity. As we proceed northward, we find the sedimentary beds much more developed than they are in the south, and containing tropical remains, even in high latitudes. If we take Nova Scotia, for example, we find the lower beds enclose only a few deep-sea shells, somewhat similar to those still living in the south. These are covered by the carboniferous beds, in which are entombed tropical vegetation, such as fern-trees, calamites, &c., with reptiles of the existing tropical character; and on these coal-seams, again, are various beds of sandstone-clay and gravels.

I need not dwell further on this subject, as I trust I have sufficiently shown that, although the *order* of the sedimentary beds is never found inverted, their development in different countries is not the same; and the periods of their deposition have been very variable, and that, therefore, they cannot be correlated as to their ages.

THE FORMATION OF THE PRIMARY ROCKS.

The preceding observations refer exclusively to the formation of the *sedimentary* beds, in which organic remains are enclosed. I shall now proceed to describe the fundamental crystalline rocks, on which the sedimentary rocks have been deposited, and in which there are no organic remains.

On reference to the ordinary geological sections, it will be observed that the primary crystalline rocks, which have a more or less laminated structure, such as the gneiss and argillaceous schists, are represented as sedimentary beds, like the superincumbent mechanical deposits; and their general vertical position has been attributed to a tilting action produced by upheavals, &c. During my residence and travels near equatorial America from 1834 to 1842, and again from 1844 to 1848, I had an opportunity of inspecting, surveying, and carefully studying the true character of this vertical structure of the fundamental crystalline rocks, in ravines, and in natural sections, from the surface to 3,000 feet deep. I then discovered that this structure did not arise from the subdivision of sedimentary beds, but had originated from a semi-crystalline action of the primary base upwards, in the direction of the grain; and that vertical cleavage planes gradually and imperceptibly became developed in the subterranean base during the changes and the transitions of the granites into the schistose rocks. I further found, by very extensive surveys across the three branches of the Andes, and for some hundreds of miles from south to north, that this structure was not only more or less *vertical*, but that it had also a *meridional bearing*. Having fully satisfied myself of this great fact, which, as far as I was then aware, had not been noticed before, I referred to the observations of others, thinking that such a striking phenomenon could not have escaped attention.

I naturally concluded that if such great facts as this vertical and meridional order in the structure of the primary rocks had been observed, the subject would have been pursued, and some hypothesis founded thereon. On referring to geological works, I found the following observations:—

Von Buch remarks that “the structure and cleavage-planes of the laminated granite, gneiss, and schist run in a south and north direction, in a position deflecting little from the perpendicular, in Norway, Sweden, and Finland. . . . The same order of structure was observed by M. Boué in Auvergne, and in many parts of Spain, Portugal, and Africa.”—“When I arrived on the coast of Venezuela,” says Humboldt, “and

passed over the lofty littoral chain and the mountains of granite gneiss that stretch from the Lower Orinoco to the basin of the Rio Negro, and the Amazon, I recognized again the most surprising parallelism in the direction of the beds (crystalline bands); that direction was from S.S.W. to N.N.E."

During my survey of the Isthmus of Panama and Veraguas, where the same vertical structure is observed, the Californian gold discoveries were made. American geologists surveyed that gold region, and in their official reports I find the following observations:—

"The auriferous gravel and clay are deposited on the edges of the primary slate rocks. The fundamental rocks are composed of bands of granite, chloritic and micaceous slate, and have been traced running on their edges in a north and south direction for hundreds of miles."

On my arrival in Australia in 1852 I surveyed a very large area of the gold districts, and found the same order of structure in the primary rocks as I had observed in South America and other places. I then published a pamphlet, with illustrated sections of the vertical and meridional structure of the Australian rocks, which was much appreciated by the gold-diggers.—But I shall quote from others who have travelled in Australia, though not geologists, this further account of the general appearance of the exposed crystalline rocks of that country:—

"A great portion of the Australian quartz ridges," says Mr. W. Howitt "runs from north to south over the hills of the gold regions. . . . The clay slates and other rocks are all perpendicular. . . . Some action has taken place which has left them standing *edgeways*. . . . They are always true to the north and south direction, and are nearly as good as a compass where they prevail; and you may trace them for twenty or thirty miles at a stretch, and, no doubt, they extend across the colony."

The official reports of the Gold Commissioners of New South Wales furnish similar descriptions. They all agree in representing the structure of the primary rocks as more or less vertical, and with a uniform bearing north and south. I therefore venture to maintain that the crystalline rocks have not been formed in beds, like the superincumbent sedimentary deposits, but that they have been produced by a semi-crystalline action under the influence of some universal power, which has given them the order of structure which they now present; and which is plainly exhibited in all deep natural sections of all the crystalline rocks in all parts of the world.

I communicated these results of my geological researches in

South America to the Fellows of the Geological Society in 1843, accompanied with large sections of the Andes. I then showed, by means of real geological sections, that the primary slates were not sedimentary beds, but the result of a semi-crystalline action, and that the structure presented a most beautiful geometrical order; that the crystalline rocks were ever active, and that the whole series crystallized from water, and did not present any indication of igneous action or dry heat. These views appeared so novel at the time that but few considered them worthy of attention. I then published the results of my investigations under the title of "Geology and Magnetism,"* so as to place them on record.

In 1850 I again, on my return from South America and the Isthmus of Panama (which I had been surveying), read a paper at the Geological Society, reiterating my former opinions, on the structure of the primary rocks and their aqueous character. An abstract of the paper was published in the Journal of that Society. My views were again strongly opposed, but more especially as regards the aqueous nature of the granite. I then saw it was useless to bring forward such geological facts in opposition to the prevailing igneous theory. Nevertheless, I again brought the subject forward in a long paper, with abundance of illustrations, before the geological section at the Meeting of the British Association at Glasgow in 1855; also in the Institution of Civil Engineers, where it gave rise to a discussion, which was prolonged for three evenings. This paper and my general views were much appreciated by mining engineers, who were acquainted with the true character of the rocks below. About that time, or soon after, Messrs. Daubrée and Bischoff made known their observations on hydrothermal action, or the influence of *water* in the formation of rocks. The result of their investigations was that the minerals which enter into the composition of granite were admitted not to have been formed by crystallizing from a state of fusion, but that they have been derived from liquid solutions, or formed in the wet way.

Professor Ramsay was one of the most determined opponents of my views regarding the aqueous nature of the granite. It is but justice to that gentleman to state that, in complimenting Messrs. Daubrée and Bischoff on the result of their investigations, when President of the Geological Society in 1862, he remarked that "he could not pass over the papers and observations of one of their own members (Mr. Hopkins) on

* *Geology and Terrestrial Magnetism.* By Evan Hopkins, C.E., F.G.S., (Lond. : Taylor & Francis, Red Lion Court, Fleet Street.)

this very same subject, which he had brought before them from time to time, many years before the investigations now referred to were undertaken." He also added, "That he believed that geological science was on the eve of a great revolution."—In the anniversary Address of Mr. Hamilton, President of the Geological Society last year, he made the following observations:—

"Recent investigations have upset the ancient theories. It was formerly supposed that the crystalline rocks, particularly granite, owed their origin to igneous action. Now, it is well known that these granites are chiefly arranged in layers. The granite passes into gneiss, and the gneiss into mica schist and talc schist, and this is again closely connected with the green and grey slates; and it is well known that many of these rocks, formerly considered as plutonic, are really metamorphosed rocks."

These remarks refer principally to the order of the structure, and notice that granite is divided into bands, and changes into the slaty structure, as was described in my sections, and explained in my papers written in 1837 and since.

I shall now quote Mr. Hamilton's observations, in his last annual Address, with reference to the igneous theory, which I had opposed for so many years, and which at length is being given up as untenable:—

"Another point," observed Mr. Hamilton, "to which I would invite attention is one of greater difficulty; it requires the serious aid of chemistry, mineralogy, and the laws of physical forces. The study of the older crystalline and metamorphic rocks has of late years greatly occupied the attention of many of those geologists who have examined the chemical and mineralogical conditions of formations. We are told that heat alone could not have produced the results we see; that water was an essential element in all these metamorphic operations; and we find, in the works of Sterry Hunt, Daubrée, Evan Hopkins, Delesse, Desor, and others, that even a high temperature was not necessary to produce these changes. Many of those results which have hitherto been considered as the effect of igneous action, are now believed to be owing to chemical action. It therefore appears that the time is come when it is desirable to investigate this question,—whether the theory of central incandescent heat is tenable? Whether the plastic conditions of the earth, to which its oblate spheroidal form has been attributed, be not owing to an aqueous rather than to an igneous origin? Water is an essential element in every rock, not only mechanically but chemically; and without attempting to revive the doctrine of Werner, it may be questioned whether we have not sometimes been disposed to overlook the importance of the part it has played in the construction and solidification of our earth."*

* *Quart. Journal of Geo. Society.* May, 1866. Vol. xxii.

Mr. Hamilton, in making these observations on the influence of water in the formation of rocks, appears to have been under the impression that it was reviving the doctrine of Werner. This is a misconception of the *modus operandi* of the semi-aqueous action in the subterranean base, and shows that geologists, with all the advantages of modern discoveries and experiments in hydrothermal action, have not yet been able to comprehend the subject in its true light. The chemical or electro-magnetic wet process of crystallization, the production of metals from solutions, and the aggregation of crystals into large and compact massive rocks, must not be confounded with the old, crude *mechanical* theory, called the "Aqueous," introduced by Werner. It is as different from that, as the formation of a crystal is from that of a brick or a sediment. The one operates by attraction and chemical action, and the other by mere mechanical deposition or precipitation. The former action produces the crystalline rocks, and causes their upward crystalline growth, and the latter produces the superincumbent beds of deposits from substances held in suspension, and carried to lower levels by water.

THE FORMATION OF CORALS.

Before I went to South America, I had been taught to believe that corals were *built* by marine animalculæ, in a way somewhat similar to the formation of the honeycomb by bees.

I have had the opportunity of studying the growth of corals, in great variety and magnitude, on the shores of South America, the coast of the Isthmus of Panama, in some of the islands of the Pacific, in the Red Sea, at Singapore, Ceylon, in the coral islands of the Indian Sea, and on the coast of Australia, but I never detected a single case of a coral being *built* by animalculæ. I have seen, as it were, plantations of corals, cultivated for lime. I have seen their stems transplanted, and have watched their growth, both the mushroom and the arborescent form. The former appears to grow in the water like a fungus or sponge, and the latter has a growth and development like arborescent crystals, such as aragonite, &c. In fact, corals are not *built up* by insects, but are formed and grow like vegetation, having a beautiful internal structure, like the fibres, rings, and medullary rays of the trunks of coniferæ, &c. There are siliceous as well as calcareous plants found growing in the sea, but I shall not on this occasion dwell longer on these formations. My object in thus noticing

the coral growth is to show how much we have yet to learn with respect to the formations and the productions of the earth.

THE GRADUAL FORMATION OF ISLANDS AND CONTINENTS.

We have abundant evidence that the continents were not suddenly formed in their present shape: they gradually acquired it by progressive enlargement of the crystalline growth, and successive elevations and depressions.

Australia presents a good example of this terrestrial action. The wharfs at Melbourne have risen six feet above the level of the sea during the last twenty years; *i. e.*, a rise at the rate of four inches per annum. The coast of Lacedpede Bay has upheaved eighteen feet in the last sixty years. This slow rate of upheaval, if it has continued during the last five hundred years, would be sufficient to raise two-thirds of Australia above the level of the sea. Indeed, a large portion of the interior of that country is still covered with lagoons of brackish water, and the whole of the low lands are strewed over with marine shells, similar to those seen on the bordering coast.

The upheaval is by no means uniform. In Western Australia it is less than in the south-east, and in some parts on the north the land is subsiding. The flat country in Western Australia is strewed over with beds of oysters and cockle-shells, of the species still existing in the adjacent seas, and these are found in various terraces, from two to twenty feet above the level of high-water mark. The remains of a vessel of considerable tonnage have been discovered in a shallow estuary near Vasse Inlet, which is now shut out from the sea. New Zealand, like Australia, is likewise more or less covered by comparatively recent beds of sands and gravel, containing marine shells similar to those now existing in the adjacent sea, occasionally mixed with the remains of terrestrial animals which have only recently become extinct, some of them having been seen alive in the last century.

The elevation of Tasmania is comparatively of a recent date. A great portion of what now constitutes the site of Hobart Town had been under water at a not very remote period. This is proved by the extensive deposits of comminuted shells, all of recent species, which are met with, for miles, along the banks of the Derwent. Some of these deposits are at an elevation of upwards of one hundred feet above high-water mark, and from fifty to one hundred yards from the water's edge, plainly showing thereby that a very recent elevation of the land has taken place. Judging from the condi-

tion and comparative freshness of the shells and corals, the emergence of Tasmania from the sea could not be assigned to many centuries. Indeed, the general aspect of the southern part of Australia indicates comparatively modern upheaval, at first rapidly and then somewhat slowly, but, probably, subject to periodical increased intensity in the subterranean forces, as observed on the coast of Chili.

In the Bay of Panama, along the banks of the river Bayano, I have seen several terraces of marine beds, from the coast to about fifty feet above high-water mark, of comparatively recent origin. Since the town was built the upheaval has been sufficient to render the port worthless excepting for small boats and canoes. Hence the subterranean action is never at rest, and is constantly, although imperceptibly, rising or depressing the surface of the earth. The fundamental base of the dry land is composed of an aggregation of crystals, formed into masses of rocks of various degrees of compactness, from mere pasty consistency to the hardness of quartz, presenting various structures, from the compact granular to the laminated formations known by the names of granites, porphyries, gneiss, and schistose rocks.

The predominating crystals of which the fundamental base, or the primary rock, is composed, are quartz, felspar, mica, talc, hornblende, chlorite, schorl, carbonate of lime, sulphate of lime, fluor spar, &c., &c. Besides these conspicuous crystals there are also disseminated in the primary rocks, either in minute grains or in solution, all the known metals; and these are often seen gradually developed by crystallization from their solvents in subterranean *vacuities*, caverns, mineral veins, &c., and the aggregated crystalline compound becomes active *en masse*.

The crystals of which the primary rocks are composed could never be the production of incandescent matter, as they all require a certain proportion of water in combination for their formation, to which their transparency is in many instances referable.

Thus, crystals of sulphate of lime are of a glossy transparency, and of regular figure: this is due to water; heat them and they crumble into a white powder. Quartz contains from 5 to 20 per cent. of water; felspar from 3 to 10 per cent.; and many compounds as high as 45 per cent. of water. All the rocks, the most solid and compact, lose a large proportion of their weight on being exposed to the sun, and many decrepitate when exposed to strong heat: the weight thus lost being water. Indeed, there is scarcely a substance known but what is either found in solution, or may be dissolved in an

aqueous compound. The apparent insolubility of quartz was at one time the argument held in favour of the igneous theory, although silica was found in solution. Silica is now artificially dissolved, and can be obtained as plastic as clay; therefore there is not a single case connected with the materials of which the globe is composed to warrant the assumption that they originated from fire. On the contrary, all the observed facts confirm the belief that the crystals first came forth and grew from water, and that the lands have gradually risen from the deep.

The evidence of successive elevations and depressions is so manifest as not to require further remarks. The evidence is equally strong that the various deposits of organic remains have not only been lifted from the deep, but have also been carried *en masse* from clime to clime at a slow rate, inasmuch as the deposits of the northern hemisphere, as far as the Arctic region, contain all the organic productions of the world. This subject, however, will have to be treated separately, in connection with the probable ages of geological formations founded on astronomical data.

SUPERFICIAL CHANGES.

The changes going on over the face of the earth are much more rapid than the public at large appear to be aware of. The deposits in deltas are frequently formed in great thickness, in a comparatively short time, by mountain torrents, floods and avalanches. The great region between the rivers Orinoco and the Amazon is intersected by rivers, and covered here and there with shallow lagoons, subject to periodical floods. This country is so overloaded with thick and gigantic vegetation as to render it impenetrable to bulky animals. In these regions man is considered as a being not congenial to such a state of nature. The earth there luxuriates in its gigantic palms, fern-trees, club-mosses, and various rank and succulent plants. The crocodiles, sharks, iguanoes, &c., are masters of the rivers; and the jaguar, pecari, tapir, boa, and a variety of reptiles, rove and infest the banks, and the high grass surrounding the lagoons, nothing impeding their increase; and are almost the sole possessors of the country—as in the imagined primæval world—without fear and without danger of being disturbed by any human being. Were this region to sink 320 feet, the whole surface would be covered by the Atlantic ocean, and the eastern declivity of the Andes would become again what it was before, a shore of the ocean. In many parts of the country are large plains partially covered with gravel,

and periodically subject to droughts, rains, heavy floods, inundations, and denudations. Some of the lagoons become dry, and the thick mud at the bottom, when in a moist state, incloses alligators and other amphibious reptiles during the dry season. They remain entombed like eels, in a somewhat dormant state, and come to life again in the rainy season if the dry lagoons be not in the interim too thickly covered by gravel. In the upper regions during the rainy seasons landslips occur daily, and large masses of forests and trees of colossal dimensions are brought down, and the banks of the rivers and the lower plains become frequently strewed over with the *débris*. Some of the large marshes and lagoons are often changed in a day into plains of gravel, and the sandy plains are converted into lagoons teeming with life. The delta of the Amazon exposed to these periodical floods comprises an area equal to one-half of England.

I remember a great flood and an avalanche which occurred on February 19th, 1845, on the eastern flank of the central Andes. Immense masses of ice and boulders gave way on the upper part of the Paramo de Ruiz, in latitude 5° north, and came down the ravines in awful torrents of muddy water, with ice, large granitic and porphyritic boulders, broken fern-trees, &c., laying waste many square leagues of the hot plains below. The destruction of human beings, animals and property was immense. Two or three rivers in the plains were choked, and their channels changed; and over many square miles of the fertile plains were deposited several feet of sand and gravel, inclosing trunks of trees belonging to the upper cold regions mixed with those flourishing in the hot countries below. The tobacco, sugar and guinea-grass plantations were completely destroyed, and upwards of 1,000 natives perished by this glacial deluge, or avalanche, in less than twelve hours. The quantity of sand and gravel deposited on that day was estimated at upwards of 250 millions of tons. The ice and boulders brought down from the snowy region to the hot plains below killed a very large quantity of fish and reptiles. The beds of sand and gravel may be still seen occupying a very large area, and in places clothed with rank vegetation, but the catastrophe is almost forgotten amongst the inhabitants. Were an ardent young student of geology, trained in the recently-accepted geological theory, to visit this district now, and examine the formation, he might possibly conclude that it belonged to the glacial period, and was of very remote antiquity. I could mention various and extensive changes which have taken place in the interior and along the coast of South America since the Spanish conquest, but I need not

dwell on them on this occasion. I shall conclude with noticing some of the changes which have been, and still are, going on in Africa and Asia.

M. Charles Martins, of Montpellier, gives the following account of the physical characters of the great Sahara, or desert, in the province of Constantine :—

“ We entered a district composed of grey, blue, yellow, and red marles, associated with conglomerates and limestones, cut up into deep ravines by the torrents which, during the rainy season, descend from the rock-salt mountains. These ravines, from fifty to sixty yards in depth, were so close to each other that it would have required several days to reach the foot of the mountain, distant only a few miles in a straight line, through this labyrinth of gorges separated by sharp narrow ridges. Let those geologists who wish to describe the erosive action of pluvial waters set aside the wretched examples they quote to illustrate their argument ; let them visit Algeria, and gain their inspirations from the ravined district of Djebel-el-Mela and the mountains of the Kabyle. There they will see how the erosive power of water is able, under our very eyes, to transform a level plain into a mass of mountains as varied and broken in their forms as those which have been caused by the elevation and fracture of strata.”

The Sahara itself is a dried-up sea-bottom. No correct estimate can be made when the inland sea disappeared, but the indications presented by the marine deposits favour the idea that the event was not very remote. M. Martins observes :— “ When it took place, the Mediterranean existed as it is now, for we find in the Sahara the shells of the same mollusca which still live on its shores.” Indeed, a very large area of the Sahara is still below the level of the Mediterranean Sea, from which it is separated by an isthmus of sand and gravel. The communication having been thus closed, the inland sea-waters have been absorbed and evaporated. “ Were this isthmus broken through, a large area of the Sahara would again become a sea.” These changes bordering the African coast appear to have been brought about more from the influence of prevalent winds and currents, tropical rains, and the sand-storms of the desert, than from any great upheavals. Drifted sands in eastern Africa have overwhelmed the temple of Jupiter Ammon and the villages on the west side of the Nile, and have thus converted the scenes of habitation and cultivation into a barren, sandy desert during the last three thousand years. Look at Thebes and behold its colossal columns, statues, temples, obelisks, all desolated and dilapidated. Yet its hundred gates were celebrated by Homer, and its magnificence praised during its decline even by the Romans. It and other great cities, including Carthage, flourished within the last

3,000 years. The drifting of the sands of the Nubian desert produces remarkable changes in a comparatively short time. The encroachment of the Nubian sandy desert is irresistible, and the population is gradually emigrating to Lower Egypt. Where the land has been abandoned, the advance of the sand on the cultivated districts is becoming more apparent. About sixty-five miles north of Wadi Halfeh the desert has covered a great alluvial plain, which had formerly been under cultivation, and is approaching the river, so that the trunks of the palm-trees are completely surrounded with sand for upwards of fifteen feet from their roots. Although rain seldom falls in Nubia, yet, when such is the case, the fall is remarkable for its violence, as testified by the magnitude of the water-courses and the heaps of boulders, gravel, and sands. I could mention numbers of other changes which have been brought about during a few centuries, of the same character as those which geologists have ascribed to many thousands of years. Even the cities of Pompeii and Herculaneum, which have been discovered entombed in the vicinity of Vesuvius, were all but lost to history. Had it not been for Dion Cassius incidentally noticing their destruction, about a century and a half after the catastrophe (which occurred about 1,785 years ago), their ages would, doubtless, have been computed as of many thousands of years. If, then, these changes have been so much overlooked in the centre of the civilized world, we cannot expect to obtain complete accounts in other and less favoured regions.

Had it not been for the records of Holy Writ and of profane history, the relics found in the mounds of Nineveh would, doubtless, have been assigned to countless ages past, like the mounds in the basin of the Mississippi, which have been computed as 50,000 years old. Two thousand five hundred years ago Nineveh flourished in all its grandeur. Never did any city equal it in greatness and magnificence, yet it is now buried in oblivion, and its site overwhelmed with sand. Where is Babylon, the glory of kingdoms? The very ground on which it stood is a scene of desolation—drifted sands and pools of water. Yet this great capital of the Chaldeans was in all its splendour as late as about 2,200 years ago.

The scenes of our terrestrial habitation are not permanent, but ever changing. I have appealed to demonstrable facts; but the alleged myriads of years required to effect such changes are purely imaginary, totally unworthy of those who seek the fundamental facts of science; and they ought not to be used as the foundation of arguments against the veracity of the Mosaic record. It is my firm persuasion that the more closely we study the actual conditions of the earth and its true geo-

logical changes, setting aside all rash speculations, the stronger will become our convictions of the substantial truth and marvellous accuracy of the Holy Scriptures; in the account of the Creation in *Genesis*, and in other allusions to the facts of nature throughout the sacred text.

The CHAIRMAN.—I need scarcely call upon you to return thanks for this valuable paper, the more valuable as it is bristling with facts, gathered from a very extensive survey of the globe. It is not a paper made up from researches in geological works. It bears the impress of actual investigation, and of such investigation as few men have opportunities of making. I cannot but conceive that the vast mass of facts brought before us must be of very great value in the records of this Institute, and that they will be quoted from those records by many with great satisfaction.

Professor OLIVER BYRNE.—I have been viewing this subject from a different stand-point to that of Mr. Evan Hopkins; but I think that the conclusions and calculations I have come to will establish without much doubt the truth of his observations, carried further down than he was able to see. Astronomers say that this earth has six motions—the annual, diurnal, precession of the equinoxes, solar nutation, lunar nutation (established by theory and not by observation), and the collapsing of the planes of the equator and ecliptic. I say there are only three—the annual, diurnal, and the right motion of the earth's axis. I have travelled over the whole country Mr. Evan Hopkins has surveyed; I have been in South America and up the Nile, and had an opportunity of seeing that he is perfectly correct in his statements, as far as I could investigate. But the mathematical reason of all this is simple indeed. The earth being an oblate spheroid, revolving on its axis, has a protuberance at the equator, making the diameter there twenty-six miles greater than the diameter through the poles. If this earth was a perfect globe, the action of the sun and moon upon it—as a perfect globe—would have no influence to change the spinning position of the body. It is not a change of the whole body, axis and all, but a swinging of the body upon a consecutive axis, that changes the latitude of any place. There are twenty-six miles of a bulb always changing their position; and the action of all the particles must be perpendicular to tangent planes and in the direction of the plumb-line, from this combined motion. The fact is, that sand being loose, it nearly obeys the same laws of motion as a fluid like water; but the hard rock of the earth changes altogether and all at once. This protuberance progresses continually round the earth; and twenty-six miles of a mountain moving on consecutively, causes all these changes. And that this motion of the earth is in existence can be proved as easily as anything in the multiplication table. Then if we take and examine the changes that have taken place in sun-dials—the one dug up in Herculaneum for instance,—we find that the position of the dial at the time it was in use, would not tell the time correctly now. Take another instance—the city of Philadelphia, in our own time:—Market Street and Broad Street

cross at right angles, and the instrument with which Philadelphia was laid out is still in existence ; yet the whole city of Philadelphia has moved in accordance with this law. The bases of all churches, laid out east, west, north, and south, have changed. There is not a single observatory in the world in which an astronomer has taken his latitude where such astronomer does not differ from his predecessor ; and that this does not arise from errors is proved, because the difference is always in one way. It is very extraordinary that all the "errors" run one way, and in every place, according to this law. In our own country, on the plains of Norbury, in Wiltshire, the Druids erected their stones in an ellipse, to receive the rays of the sun at the period of the summer solstice ; but it is now $12\frac{1}{2}$ degrees from that position. You can get any number of facts to prove the soundness of Mr. Evan Hopkins's views, that the rocks are perpendicular, and that changes of position take place ; and that not so much time as millions of years is required, as some suppose. It would not take 500 years, under certain circumstances, to change the whole country altogether, or even to raise the whole of the bed of the Pacific Ocean. Geologists tell me that insects are there building upwards from the bottom at the rate of $4\frac{1}{2}$ inches a year. Fancy insects doing this over the entire bed of the Pacific ! No. It is the foundation rising. We are gradually going out of our present latitude ; and so our climates change, and everything else changes in accordance.

Captain FISHBOURNE.—I may mention a fact which is rather relevant to this discussion. When, in the reign of the Empress Catherine, the city of Krasnajask was discovered in Siberia (it is some twenty-five years since I read the narrative, but to the best of my recollection that was the name), M. Pallas, a Frenchman, was sent to report upon the discovery ; and he found amongst other things sun-dials, but the gnomons were not set at an angle to suit the latitude. His explanation was that these sun-dials had been imported from a previous centre of civilization, and that the people were ignorant of their inaccuracy. But that, of course, is not likely ; for if they used them they would have found that they would not give time correctly. This would quite agree with the supposition of Mr. Byrne, that the situation itself had altered in latitude ; and so that the sun-dials found there were suitable to the place—to the city of Krasnajask, when it was in its original position, and when founded.

Mr. REDDIE.—As bearing upon some of the views put forward in the paper read by Mr. Hopkins, I will quote a paragraph which I observed in the Dublin *Daily Express* of the 20th of November. It states, that at a meeting of the Royal Dublin Society,

"Mr. Robert H. Scott read his translation of a paper by Professor Oswald Heer, of Zurich, 'On the Miocene Flora of Atane-kerdluk and North Greenland.' The paper was interesting both from a botanical and geological point of view, and it went to prove from fossil specimens of forest trees at Atane-kerdluk, in North Greenland, especially the *Sequoia sempervirens* (red-wood), that the climate of Greenland had formerly been thirty degrees higher than at present ; the ordinary temperature of the locality being now twenty-one degrees, while the most northern latitude in which that plant

now grows in Europe is about fifty-three degrees. The paper concluded by stating that it would be impossible, by any arrangement of the relative positions of land and water, to produce for the northern hemisphere a climate which would explain the phenomena in a satisfactory manner. It must only be admitted that we are face to face with a problem whose solution, in all probability, must be attempted, and, doubtless, completed, by the astronomer."

I have now in my hands a paper which I am about to read, after a few words of explanation. It is written by a gentleman, a practical chemist, who had heard that Mr. Hopkins's paper would be read here this evening, and among other things that it would call attention to the now impugned doctrine that granite is an igneous formation. A friend of mine, and a member of the Institute, now present, knowing that this gentleman had been engaged in making experiments on granite, and that his conclusions were opposed to those of Mr. Hopkins, let him know that we were about to discuss this subject; and I requested that he might be invited to send us a paper giving his results, that we might hear both sides. He had said that he supposed we did not care for "facts" in this Institute; to which I replied that *facts* were what we especially cared for. I am, therefore, about to read what he has sent me,—not as a regular paper, that has been presented in the ordinary way and passed the council,—but I wish to bring it before you with this explanation; and I wish myself individually to do so, all the more, because I have, in the *Scientia Scientiarum*, and on other occasions, called public attention to the fact that the theory of granite being an igneous formation had been given up by geologists. I believe Mr. Hopkins was one of the first, if not the very first, who impugned that doctrine; for he did so nearly thirty years ago. It is certainly now acknowledged by Sir Charles Lyell, and Mr. Hamilton, the President of the Geological Society, and indeed by all "authorities" among geologists, that it was an error to suppose that granite is an igneous crystallization, or that the centre of the earth is now in an incandescent state, heated up to 195,000 degrees of temperature, as had been deduced from the nebular hypothesis. I cannot, however, say that this paper (which is by Mr. Lewis Thompson, M.R.C.S.), carries conviction to my mind. I rather think Mr. Hopkins will claim some of its facts as being rather upon his side, but that is the author's look-out. I only wish to put the arguments forward, even although I am not convinced by them, because we do wish in this society to hear all sides of every question we take up. But Mr. Thompson, I must add, although he does not believe in the aqueous formation of granite, is by no means a supporter of the nebular theory; and he endeavours to destroy that hypothesis, while believing in the igneous formation of granite. So that if Mr. Thompson's experiments are sufficient and his reasons sound, we shall have the nebular theory twice slain—first by water, and now again by fire! But let us hear Mr. Thompson himself. His paper is as follows:—

The object of the present paper is to institute an unprejudiced comparison between certain well-established facts and a particular theory of the formation of the earth, known as the "Nebular Theory." According to this theory,