caravan route, which is well known, they would have been content with two or three months' advance.

For two reasons I have been obliged to decide to wait for still another fortnight in Zanzibar before starting. The first is that so much of the country behind Dar-es-Salaam is under water: the rains are expected to be over in about six days, but it will take another week to make the path passable. The second is that food is very scarce at present in the Wazaramo country; no rice or mtama is to be got on the road just now, but in about three weeks the rice of the growing crop will begin to come into market. As it is, we shall need to carry food for the first week; and the means of transporting food for the men along with us through the frequent deserted tracts that lie in the way, will also need to be provided. I purpose sending two men on to Bagamoyo a few days before we start, to buy five Unyamwezi donkeys, and to drive them down to Dar-es-Salaam. These, I hope, will carry all the food that will be necessary in crossing the deserted tracts.

Geographical Evolution. By Professor Archibald Geikie, F.R.S.

(A Lecture delivered at the Evening Meeting, March 24th, 1879.)

In the quaint preface to his 'Navigations and Voyages of the English Nation,' Hakluyt calls geography and chronology "the sunne and moone, the right eye and the left of all history." The position thus claimed for geography three hundred years ago by the great English chronicler was not accorded by his successors, and has hardly been admitted even now. The functions of the geographer and the traveller, popularly assumed to be identical, have been supposed to consist in descriptions of foreign countries, their climate, productions, and inhabitants, bristling on the one hand with dry statistics, and relieved on the other by as copious an introduction as may be of stirring adventure and personal anecdote. There has, indeed, been much to justify this popular assumption. It was not until the key-note of its future progress was struck by Karl Ritter, within the present century, that geography advanced beyond the domain of travellers' tales and desultory observation into that of orderly, methodical, scientific progress. This branch of inquiry, however, is now no longer the pursuit of mere numerical statistics, nor the chronicle of marvellous and often questionable adventures by flood and fell. It seeks to present a luminous picture of the earth's surface, its various forms of configuration, its continents, islands, and oceans, its mountains, valleys, and plains, its rivers and lakes, its climates, plants, and animals. It thus endeavours to produce a picture which shall not be one of mere topographical detail. It ever looks for a connection between scattered facts, tries to ascertain the relations which subsist between the different parts of the globe, their reactions on each other and the function of each in the general economy of the whole. Modern geography studies the distribution of vegetable and animal life over the earth's surface, with the action and reaction between it and the surrounding inorganic world. It traces how man, alike unconsciously and knowingly, has changed the face of nature, and how, on the other hand, the conditions of his geographical environment have moulded his own progress.

With these broad aims, geography comes frankly for assistance to many different branches of science. It does not, however, claim in any measure to occupy their domain. It brings to the consideration of their problems a central human interest, in which these sciences are sometimes apt to be deficient; for it demands first of all to know how the problems to be solved bear upon the position and history of man and of this marvellously ordered world wherein he finds himself undisputed lord. Geography freely borrows from meteorology, physics, chemistry, geology, zoology, and botany; but the debt is not all on one side. Save for the impetus derived from geographical research, many of these sciences would not be in their present advanced condition. They gain in vast augmentation of facts, and may cheerfully lend their aid in correlating these for geographical requirements.

In no respect does modern geography stand out more prominently than in the greater precision and fullness of its work. It has fitted out exploratory expeditions, and in so doing has been careful to see them provided with the instruments and apparatus necessary to enable them to contribute accurate and definite results. It has guided and fostered research, and has been eager to show a generous appreciation of the labours of those by whom our knowledge of the earth has been extended. Human courage and endurance are not less enthusiastically applauded than they once were; but they must be united to no common powers of observation before they will now raise a traveller to the highest rank. When we read a volume of recent travel, while warmly appreciating the spirit of adventure, fertility of resource, presence of mind, and other moral qualities of its author, we instinctively ask ourselves, as we close its pages, what may be the sum of its additions to our knowledge of the earth? From the geographical point of view—and it is to this point alone that these remarks apply—we must rank an explorer according to his success in widening our knowledge and enlarging our views regarding the aspects of nature.

The demands of modern geography are thus becoming every year more exacting. It requires more training in its explorers abroad, more knowledge on the part of its readers at home. The days are drawing to a close when one can gain undying geographical renown by struggling against man and beast, fever and hunger and drought, across some savage and previously unknown region, even though little can be shown as the outcome of the journey. All honour to the pioneers by whom this first exploratory work has been so nobly done! They will be succeeded by a race that will find its laurels more difficult to win—a race from which more will be expected and which will need to make up in the variety, amount, and value of its detail, what it lacks in the freshness of first glimpses into new lands.

With no other science has geography become more intimately connected than with geology, and the connection is assuredly destined to become yet deeper and closer. These two branches of human knowledge are, to use Hakluyt's phrase, "the sunne and moone, the right eye and the left," of all fruitful inquiry into the character and history of the earth's surface. As it is impossible to understand the genius and temperament of a people, its laws and institutions, its manners and customs, its buildings and its industries, unless we trace back the history of that people, and mark the rise and effect of each varied influence by which its progress has been moulded in past generations; so it is clear that our knowledge of the aspect of a continent, its mountains and valleys, rivers and plains, and all its surface features, cannot be other than singularly feeble and imperfect, unless we realise what has been the origin of these features. The land has had a history, not less than the human races that inhabit it.

One can hardly consider attentively the future progress of geography without being convinced that in the wide development yet in store for this branch of human inquiry, one of its main lines of advance must be in the direction of what may be termed geographical evolution. The geographer will no longer be content to take continents and islands, mountain chains and river valleys, table-lands and plains, as initial or aboriginal outlines of the earth's surface. He will insist on knowing what the geologist can tell him regarding the growth of these outlines. He will try to trace out the gradual evolution of a continent, and may even construct maps to show its successive stages of development. At the same time he will seek for information regarding the history of the plants and animals of the region, and may find much to reward his inquiry as to the early migrations of the fauna and flora, including those even of man himself. Thus his pictures of the living world of to-day, as they become more detailed and accurate, will include more and more distinctly a background of bygone geographical conditions, out of which, by continuous sequence, the present conditions will be shown to have arisen.

I propose this evening to sketch in mere outline the aspects of one side of this evolutional geography. I wish to examine in the first place the evidence whereby we establish the fundamental fact that the present surface of any country or continent is not that which it has always worn; and the data by which we may trace backward the origin of the land; and, in the second place, to consider, by way of illustration, some of the more salient features in the gradual growth of the framework of Europe.

The first of these two divisions of the subject deals with general principles, and may be conveniently grouped into two parts:—1st, The Materials of the Land. 2nd, The Building of the Land.

1.—*The Materials of the Land.*

Without attempting to enter into detailed treatment of this branch of the subject, we may, for the immediate purpose in view, content ourselves with the broad, useful classification of the materials of the land into two great series, (*a*) Fragmental and (*b*) Crystalline.

(*a*) *Fragmental.*—A very cursory examination of rocks in almost any part of the world suffices to show that by far the larger portion of them consists of compacted fragmentary materials. Shales, sandstones, and conglomerates in infinite variety of texture and colour, are piled above each other to form the foundation of plains and the structure of mountains. Each of these rocks is composed of distinct particles, worn by air, rain, frost, springs, rivers, glaciers, or the sea from previously existing rocks. They are thus derivative formations, and their source, as well as their mode of origin, can be determined. Their component grains are for the most part rounded, and bear evidence of having been rolled about in water. Thus we easily and rapidly reach a first and fundamental conclusion—that the substance of the main part of the solid land has been originally laid down and assorted under water.

The mere extent of the area covered by these water-formed rocks would of itself suggest that they must have been deposited in the sea. We cannot imagine rivers or lakes of magnitude sufficient to have spread over the sites of the present continents. The waters of the ocean, however, may easily be conceived to have rolled at different times over all that is now dry land. But the fragmental rocks contain within themselves proof that they were mainly of marine and not of lacustrine or fluviatile origin. They have preserved in abundance the remains of foraminifera, corals, crinoids, molluscs, annelides, crustaceans, fishes, and other organisms of undoubtedly marine habitat, which must have lived and died in the places where their traces remain still visible.

But not only do these organisms occur scattered through sedimentary rocks; they actually themselves form thick masses of mineral matter. The Carboniferous or Mountain Limestone of Central England and Ireland for example reaches a thickness of from 2000 to 3000 feet, and covers thousands of square miles of surface. Yet it is almost entirely composed of congregated stems and joints and plates of crinoids, with foraminifera, corals, bryozoans, brachiopods, lamellibranchs, gasteropods, fish-teeth, and other unequivocally marine organisms. It must have been for ages the bottom of a clear sea, over which generation after generation lived and died, until their accumulated remains had gathered into a compact sheet of rock. From the internal evidence of the stratified formations we thus confidently announce a second conclusion

—that a great portion of the solid land consists of materials which have been laid down on the floor of the sea.

From these familiar and obvious conclusions we may proceed further to inquire under what conditions these marine formations, so widely spread over the land, were formed. According to a popular belief, shared in perhaps by not a few geologists, land and sea have been continually changing places. It is supposed that while, on the one hand, there is no part of a continent over which sea-waves may not have rolled, so, on the other, there is no lonely abyss of the ocean where a wide continent may not have bloomed. That this notion rests upon a mistaken interpretation of the facts may be shown from an examination—(1) of the rocks of the land, and (2) of the bottom of the ocean.

Among the thickest masses of sedimentary rock — those of the ancient palæozoic systems—no features recur more continually than the alternations of different sediments, and the recurrence of surfaces covered with well-preserved ripple-marks, trails and burrows of annelides, polygonal and irregular desiccation marks, like the cracks at the bottom of a sun-dried muddy pool. These phenomena unequivocally point to shallow and even littoral waters. They occur from bottom to top of formations which reach a thickness of several thousand feet. They can be interpreted only in one way, viz. that the formations in question began to be laid down in shallow water; that during their formation the area of deposit gradually subsided for thousands of feet; yet that the rate of accumulation of sediment kept pace on the whole with this depression; and hence, that the original shallow-water character of the deposits remained, even after the original sea-bottom had been buried under a vast mass of sedimentary matter. Now, if this explanation be true, even for the enormously thick and comparatively uniform formations of older geological periods, the relatively thin and much more varied formations of later date can offer no difficulty. In short, the more attentively the stratified rocks of the crust of the earth are studied, the more striking becomes the absence of any formations among them which can legitimately be considered those of a deep sea. They have all been deposited in comparatively shallow water.

The same conclusion may be arrived at from a consideration of the circumstances under which the deposition must have taken place. It is evident that the sedimentary rocks of all ages have been derived from the degradation of land. The gravel, sand, and mud, of which they consist, existed previously as part of mountains, hills, or plains. These materials carried down to the sea would arrange themselves there as they do still, the coarser portions nearest the shore, the finer silt and mud furthest from it. From the earliest geological times the great area of deposit has been, as it still is, the marginal belt of sea-floor skirting the land. It is there that nature has always strewn "the dust of continents to be." The decay of old rocks has been unceasingly in progress on the land, and the building up of new rocks has been as unintermittently going on underneath the adjoining sea. The two phenomena are the complementary sides of one process, which belongs to the terrestrial and shallow oceanic parts of the earth's surface and not to the wide and deep ocean basins.

Recent explorations of the bottom of the deep sea all over the world have brought additional light to this question. No part of the results obtained by the *Challenger* Expedition has a profounder interest for geologists and geographers than the proof which they furnish that the floor of the ocean basins has no real analogy among the sedimentary formations which form most of the framework of the land. We now know by actual dredging and inspection that the ordinary sediment washed off the land sinks to the sea-bottom before it reaches the deeper abysses, and that, as a rule, only the finer particles are carried more than a few score of miles from the shore. Instead of such sandy and pebbly material as we find so largely among the sedimentary rocks of the land, wide tracts of the sea-bottom at great depths are covered with various kinds of organic ooze, composed sometimes of minute calcareous foraminifera, sometimes of siliceous radiolaria or diatoms. Over other areas vast sheets of clay extend, derived apparently from the decomposition of volcanic detritus, of which large quantities are floated away from volcanic islands, and much of which may be produced by submarine volcanoes. On the tracts furthest removed from any land the sediment seems to settle scarcely so rapidly as the dust that gathers over the floor of a deserted hall. Mr. Murray, of the *Challenger* staff, has described how from these remote depths large numbers of shark's teeth and ear-bones of whales were dredged up. We cannot suppose the number of sharks and whales to be much greater in these regions than in others where their relics were found much less plentifully. The explanation of the abundance of their remains was supplied by their varied condition of decay and preservation. Some were comparatively fresh, others had greatly decayed, and were incrusted with or even deeply buried in a deposit of earthy manganese. Yet the same cast of the dredge brought up these different stages of decay from the same surface of the sea-floor. While generation after generation of sea-creatures drops its bones to the bottom, now here, now there, so exceedingly feeble is the rate of deposit of sediment that they lie uncovered, mayhap, for centuries, so that the remains which sink to-day, may lie side by side with the mouldered and incrusted bones that found their way to the bottom hundreds of years ago.

Another striking indication of the very slow rate at which sedimentation takes place in these abysses, has also been brought to notice by Mr. Murray. Among the clay from the bottom he found numerous minute spherical granules of native iron, which, as he suggests, are almost certainly of meteoric origin—fragments of those falling stars which, coming to us from planetary space, burst into fragments when they rush into the denser layers of our atmosphere. In tracts where the growth of silt upon the sea-floor is excessively tardy, the fine particles, scattered by the dissipation of these meteorites, may remain in appreciable quantity. In this case, again, it is not needful to suppose that meteorites have disappeared over these ocean depths more numerously than over other parts of the earth's surface. The iron granules have no doubt been as plentifully showered down elsewhere, though they cannot be so readily detected in accumulating sediment. I know no recent discovery in physical geography more calculated to impress deeply the imagination than the testimony of this meteoric iron from the most distant abysses of the ocean. To be told that mud gathers on the floor of these abysses at an extremely slow rate, conveys but a vague notion of the tardiness of the process. But to learn that it gathers so slowly, that the very star-dust which falls from outer space, forms an appreciable part of it, brings home to us, as hardly anything else could do, the idea of undisturbed and excessively slow accumulation.

From all this evidence we may legitimately conclude that the present land of the globe, though formed in great measure of marine formations, has never lain under the deep sea; but that its site must always have been near land. Even its thick marine limestones are the deposits of comparatively shallow water. Whether or not any trace of aboriginal land may now be discoverable, the characters of the most unequivocally marine formations bear emphatic testimony to this proximity of a terrestrial surface. The present continental ridges have probably always existed in some form, and as a corollary we may infer that the present deep ocean basins likewise date from the remotest geological antiquity.

(*b*) *Crystalline.*—While the greater part of the framework of the land has been slowly built up of sedimentary materials, it is abundantly varied by the occurrence of crystalline masses, many of which have been injected in a molten condition into rents underground, or have been poured out in lava streams at the surface.

Without entering at all into geological detail, it will be enough for the present purpose to recognise the characters and origin of two great types of crystalline material which have been called respectively the Igneous and Metamorphic.

1. *Igneous.*—As the name denotes, Igneous rocks have risen from the heated interior of the earth. In a modern volcano, lava ascends the central funnel, and, issuing from the lip of the crater or from lateral fissures, pours down the slopes of the cone in sheets of melted rock. The upper surface of the lava column within the volcano is kept in constant ebullition by the rise of steam through its mass. Every now and then a vast body of steam rushes out with a terrific explosion, scattering the melted

lava into impalpable dust, and filling the air with ashes and stones, which descend in showers upon the surrounding country. At the surface, therefore, igneous rocks appear, partly as masses of congealed lava, and partly as more or less consolidated sheets of dust and stones. But beneath the surface there must be a downward prolongation of the lava column, which no doubt sends out veins into the rents of the subterranean rocks. We can suppose that the general aspect of the lava which consolidates at some depth will differ from that which solidifies above ground.

As a result of the revolutions which the crust of the earth has undergone, the roots of many ancient volcanoes have been laid bare. We have been as it were admitted into the secrets of these subterranean laboratories of nature, and have learned much regarding the mechanism of volcanic action, which we could never have discovered from any modern volcano. Thus, while on the one hand we meet with beds of lava and consolidated volcanic ashes, which were undoubtedly erupted at the surface of the ground in ancient periods, and were subsequently buried deep beneath sedimentary accumulations now removed; on the other hand, we find masses of igneous rock which certainly never came near the surface, but must have been arrested in their ascent from below, while still at a great depth, and have been laid bare to the light after the removal of the pile of rock under which they originally lay.

By noting these and other characters, geologists have learnt that, besides the regions of still active volcanoes, there are few large areas of the earth's surface where proofs of former volcanic action or of the protrusion of igneous rocks may not be found. The crust of the earth, crumpled and fissured, has been, so to speak, perforated and cemented together by molten matter driven up from below.

2. *Metamorphic.*—The sedimentary rocks of the land have undergone many changes since their formation, some of which are still far from being satisfactorily accounted for. One of these changes is expressed by the term *Metamorphism*, and the rocks which have undergone this process are called *Metamorphic.* It seems to have taken place under widely different conditions, being sometimes confined to small local tracts, at other times extending across a large portion of a continent. It consists in the rearrangement of the component materials of rocks, and notably in their recrystallisation along particular lines or laminæ. It is usually associated with evidence of great pressure; the rocks in which it occurs having been corrugated and crumpled, not only in vast folds, which extend across whole mountains, but even in such minute puckerings as can only be observed with the microscope. It shows itself more particularly among the older geological formations, or those which have been once deeply buried under more recent masses of rock, and have been exposed as the result of the removal of these overlying accumulations. The original characters of the sandstones, shales,

grits, conglomerates, and limestones, of which no doubt these metamorphic masses once consisted, have been almost entirely effaced, and have given place to that peculiar crystalline laminated or foliated structure so distinctively a result of metamorphism.

An attentive examination of a metamorphic region shows that here and there the alteration and recrystallisation have proceeded so far that the rocks graduate into granites and other so-called igneous rocks. A series of specimens may be collected showing unaltered or at least quite recognisable sedimentary rocks at the one end, and thoroughly crystalline igneous rocks at the other. Thus the remarkable fact is brought home to the mind that ordinary sandstones, shales, and other sedimentary materials may in the course of ages be converted by underground changes into crystalline granite. The framework of the land, besides being knit together by masses of igneous rock intruded from below, has been strengthened by the welding and crystallisation of its lowest rocks. It is these rocks which rise along the central crests of mountain chains, where, after the lapse of ages, they have been uncovered and laid bare, to be bleached and shattered by frost and storm.

2.—*The Architecture of the Land.*

Let us now proceed to consider how these materials, sedimentary and crystalline, have been put together, so as to constitute the solid land of the globe.

It requires but a cursory examination to observe that the sedimentary masses have not been huddled together at random; that, on the contrary, they have been laid down in sheets one over the other. An arrangement of this kind at once betokens a chronological sequence. The rocks cannot all have been formed simultaneously. Those at the bottom must have been laid down before those at the top. A truism of this kind seems hardly to require formal statement. Yet it lies at the very foundation of any attempt to trace the geological history of a country. Did the rocks everywhere lie undisturbed one above another as they were originally laid down, their clear order of succession would carry with it its own evident interpretation. But such have been the changes that have arisen, partly from the operation of forces from below, partly from that of forces acting on the surface, that the true order of a series of rocks is not always so easily determined. By starting, however, from where the succession is normal and unbroken, the geologist can advance with confidence into regions where it has been completely interrupted; where the rocks have been shattered, crumpled, and even inverted.

The clue which guides us through these labyrinths is a very simple one. It is afforded by the remains of once living plants and animals which have been preserved in the rocky framework of the land. Each well-marked series of sedimentary accumulations contains its own characteristic plants, corals, crustaceans, shells, fishes, or other organic remains. By these it can be identified and traced from country to country across a whole continent. When, therefore, the true order of superposition of the rocks has been ascertained by observing how they lie upon each other, the succession of their fossils is at the same time fixed. In this way the sedimentary part of the earth's crust has been classified into different formations, each characterised by its distinct assemblage of organic remains. In the most recent formations, most of these remains are identical with still living species of plants and animals; but as we descend in the series and come into progressively older deposits, the proportion of existing species diminishes until at last all the species of fossils are found to be extinct. Still lower and older rocks reveal types and assemblages of organisms which depart further and further from the existing order.

By noting the fossil contents of a formation, therefore, even in a district where the rocks have been so disturbed that their sequence is otherwise untraceable, the geologist can confidently assign their relative position to each of the fractured masses. He knows, for instance, using for our present purpose the letters of the alphabet to denote the sequence of the formations, that a mass of limestone containing fossils typical of the formation B must be younger than another mass of rock containing the fossils of A. A series of strata full of the fossils of H resting immediately on others charged with those of C, must evidently be separated from these by a great gap, elsewhere filled in by the intervening formations D, E, F, G. Nay, should the rocks in the upper part of a mountain be replete with the fossils proper to D, while those in the lower slopes showed only the fossils of E, F, and G, it could be demonstrated that the materials of the mountain had actually been turned upside down, for, as proved by its organic remains, the oldest and therefore lowest formation had come to lie at the top, and the youngest, and therefore highest, at the bottom.

Of absolute chronology in such questions science can as yet give no measure. How many millions of years each formation may have required for its production, and how far back in time may be the era of any given group of fossils, are problems to which no answer, other than a mere guess, can be returned. But this is a matter of far less moment than the relative chronology, which can usually be accurately fixed for each country, and on which all attempts to trace back the history of the land must be based.

While, then, it is true that most of the materials of the solid land have been laid down at successive periods under the sea, and that the relative dates of their deposition can be determined, it is no less certain that the formation of these materials has not proceeded uninterruptedly, and that they have not finally been raised into land by a single movement. The mere fact that they are of marine origin shows, of course, that the land owes its origin to some kind of terrestrial disturbance. But when the sedimentary formations are examined in detail, they present a most wonderful chronicle of long-continued, oft-repeated, and exceedingly complex movements of the crust of the globe. They show that the history of every country has been long and eventful; that, in short, hardly any portion of the land has reached its present condition, save after a protracted series of geological revolutions.

One of the most obvious and not the least striking features in the architecture of the land is the frequency with which the rocks, though originally horizontal, or approximately so, have been tilted up at various angles, or even placed on end. At first it might be supposed that these disturbed positions have been assumed at random, according to the capricious operations of subterranean forces. They seem to follow no order, and to defy any attempt to reduce them to system. Yet a closer scrutiny serves to establish a real connection among them. They are found, for the most part, to belong to great, though fractured, curves, into which the crust of the earth has been folded. In low countries far removed from any great mountain range, the rocks often present scarcely a trace of disturbance, or if they have been affected, it is chiefly by having been thrown into gentle undulations. As we approach the higher grounds, however, they manifest increasing signs of commotion. Their undulations become more frequent and steeper, until, entering within the mountain region, we find the rocks curved, crumpled, fractured, inverted, tossed over each other into yawning gulf and towering crest, like billows arrested at the height of a furious storm.

Yet even in the midst of such apparent chaos it is not impossible to trace the fundamental law and order by which it is underlaid. The prime fact to be noted is the universal plication and crumpling of rocks which were at first nearly horizontal. From the gentle undulations of the strata beneath the plains to their violent contortion and inversion among the mountains, there is that insensible gradation which connects the whole of these disturbances as parts of one common process. They cannot be accounted for by any mere local movements, though such movements no doubt took place abundantly. The existence of a mountain chain is not to be explained by a special upheaval or series of upheavals caused by an expansive force acting from below. Manifestly the elevation is only one phase of a vast terrestrial movement which has extended over whole continents, and has affected plains as well as high grounds.

The only cause which, so far as our present knowledge goes, could have produced such wide-spread changes is a general contraction of the earth's mass. There can be no doubt that at one time our planet existed in a gaseous, then in a liquid condition. Since these early periods it has continued to lose heat, and consequently to contract and to grow more and more solid, until, as the physicists insist, it has now become practically as rigid as a globe of glass or of steel. But in the course of the contraction, after the solid external crust was formed, the inner hot nucleus has lost heat more rapidly than the crust, and has tended to shrink inward from it. As a consequence of this internal movement, the outer solid shell has been obliged to sink down upon the retreating nucleus. In so doing, it has of course had to accommodate itself to a diminished area, and this it could only accomplish by undergoing plication and crumpling. Though the analogy is not a very exact one, we may liken our globe to a shrivelled apple. The skin of the apple does not contract equally. As the internal moisture passes off, and the bulk of the fruit is reduced, the once smooth exterior becomes here and there corrugated and dimpled.

Without entering into this difficult problem in physical geology, it may suffice if we carry with us the idea that our globe must once have had a greater diameter than it now possesses, and that the crumpling of its outer layers, whether due to mere contraction or, as has been suggested, to the escape also of subterranean vapours, affords evidence of this diminution. A little reflection suffices to show us that, even without any knowledge of the actual history of the contraction, we might anticipate that the effects would neither be continuous nor everywhere uniform. The solid crust would not, we may be sure, subside as fast as the mass inside. It would, for a time at least, cohere and support itself, until at last, gravitation proving too much for its strength, it would sink down. And the areas and amount of descent would be greatly regulated by the varying thickness and structure of the crust. Subsidence would not take place everywhere; for, as a consequence of the narrower space into which the crust sank, some regions would necessarily be pushed up. These conditions appear to have been fulfilled in the past history of the earth. There is evidence that the terrestrial disturbance has been renewed again and again, after long pauses, and that, while the ocean basins have on the whole been the great areas of depression, the continents have been the lines of uprise or relief, where the rocks were crumpled and pushed out of the way. Paradoxical, therefore, as the statement may appear, it is nevertheless strictly true that the solid land, considered with reference to the earth's surface as a whole, is the consequence of subsidence rather than of upheaval.

Grasping, then, this conception of the real character of the movements to which the earth owes its present surface configuration, we are furnished with fresh light for exploring the ancient history and growth of the solid land. The great continental ridges seem to lie nearly on the site of the earliest lines of relief from the strain of contraction. They were forced up between the subsiding oceanic basins at a very early period of geological history. In each succeeding epoch of movement they were naturally used over again, and received an additional push upward. Hence we see the meaning of the evidence supplied by the sedimentary rocks as to shallow seas and proximity of land. These rocks could not have been otherwise produced. They were derived from the waste of the land, and were deposited near the land. For it must be borne in mind that every mass of land as soon as it appeared above water was at once attacked by the ceaseless erosion of moving water and atmospheric influences, and immediately began to furnish materials for the construction of future lands, to be afterwards raised out of the sea.

Each great period of contraction elevated anew the much-worn land, and at the same time brought the consolidated marine sediments above water as parts of a new terrestrial surface. Again a long interval would ensue, marked perhaps by a slow subsidence both of the land and sea-bottom. Meanwhile the surface of the land was channelled and lowered, and its detritus was spread over the sea-floor, until another era of disturbance raised it once more with a portion of the surrounding ocean-bed. These successive upward and downward movements explain why the sedimentary formations do not occur as a continuous series, but often lie each upon the upturned and worn edges of its predecessors.

Returning now to the chronological sequence indicated by the organic remains preserved among the sedimentary rocks, we see how it may be possible to determine the relative order of the successive upheavals of a continent. If, for example, a group of rocks, which, as before, may be called A, were found to have been upturned and covered over by undisturbed beds C, the disturbance could be affirmed to have occurred at some part of the epoch represented elsewhere by the missing series B. If, again, the group C were observed to have been subsequently tilted, and to pass under gently inclined or horizontal strata E, a second period of disturbance would be proved to have occurred between the time of C and E.

I have referred to the unceasing destruction of its surface which the land undergoes from the time when it emerges out of the sea. As a rule, our conceptions of the rate of this degradation are exceedingly vague. Yet they may easily be made more definite by a consideration of present changes on the surface of the land. Every river carries yearly to the sea an immense amount of sand and mud. But this amount is capable of measurement. It represents, of course, the extent to which the general level of the surface of the river's drainage basin is annually lowered. According to such measurements and computations as have been already made, it appears that somewhere about $\frac{1}{3000}$ of a foot is every year removed from the surface of its drainage basin by a large river. This seems a small fraction, yet by the power of mere addition it soon mounts up to a large total. Taking the mean level of Europe to be 600 feet, its surface, if everywhere worn away at what seems to be the present mean normal rate, would be entirely reduced to the sea-level in little more than three and a half millions of years.

But of course the waste is not uniform over the whole surface. It is greatest on the slopes and valleys, least on the more level grounds. A few years ago, in making some estimates of the ratios between the rates of waste on these areas, I assumed that the tracts of more rapid erosion occupy only one-ninth of the whole surface affected, and that in these the rate of destruction is nine times greater than on the more level spaces. Taking these proportions, and granting that $\frac{1}{6000}$ of a foot is the actual ascertained amount of loss from the whole surface, we ascertain by a simple arithmetical process that $\frac{1}{12}$ of an inch is carried away from the plains and table-lands in seventy-five years, while the same amount is worn out of the valleys in eight and a half years. One foot must be removed from the former in 10,800 years, and from the latter in 1200 years. Hence we learn, that at the present rate of erosion a valley 1000 feet deep may be excavated in 1,200,000 years—by no means a very long period in the conceptions of most geologists.

I do not offer these figures as more than tentative results. They are based, however, not on mere guesses, but on data which, though they may be corrected by subsequent inquiry, are the best at present available, and are probably not far from the truth. They are of value in enabling us more vividly to realise how the prodigious waste of the land, proved by the existence of such enormous masses of sedimentary rock, went quietly on age after age, until results were achieved which seem at first scarcely possible to so slow and gentle an agency.

It is during this quiet process of decay and removal that all the distinctive minor features of the land are wrought out. When first elevated from the sea, the land doubtless presents on the whole a featureless surface. It may be likened to a block of marble raised out of the quarry—rough and rude in outline, massive in solidity and strength, but giving no indication of the grace into which it will grow under the hand of the sculptor. What art effects upon the marble block, nature accomplishes upon the surface of the land. Her tools are many and varied—air, frost, rain, springs, torrents, rivers, avalanches, glaciers, and the sea—each producing its own characteristic traces in the sculpture. With these implements, out of the huge bulk of the land she cuts the valleys and ravines, scoops the lake-basins, hews with bold free hand the colossal outline of the mountains, carves out peak and crag, crest and cliff, chisels the courses of the torrents, splinters the sides of the precipices, and leaves her impress upon every lineament of the land. Patiently and unceasingly has this great earth-sculptor sat at her task since the land first rose above the sea, washing down into the ocean the *débris* of her labour, to form the materials for the framework of future countries; and there will she remain at work, so long as mountains stand, and rain falls, and rivers flow.

The Growth of the European Continent.

Passing now from the general principles with which we have hitherto been dealing, we may seek an illustration of their application to the actual history of a large mass of land. For this purpose, let me ask your attention to some of the more salient features in the gradual growth of Europe. This continent has not the simplicity of structure elsewhere recognisable; but without entering into detail or following a continuous sequence of events, our present purpose will be served by a few broad outlines of the condition of the European area at successive geological periods.

It is the fate of continents, no less than of the human communities that inhabit them, to have their first origin shrouded in obscurity. When the curtain of darkness begins to rise from our primeval Europe, it reveals to us a scene marvellously unlike that of the existing continent. The land then lay chiefly to the north and north-west, probably extending as far as the edge of the great submarine plateau by which the European ridge is prolonged under the Atlantic for 230 miles to the west of Ireland. Worn fragments of that land exist in Finland, Scandinavia, and the north-west of Scotland, and there are traces of what seem to have been some detached islands in Central Europe, notably in Bohemia and Bavaria. Its original height and extent can of course never be known; but some idea of them may be formed by considering the bulk of solid rock which was formed out of the waste of that land. I find that if we take merely one portion of the detritus washed from its surface and laid down in the sea, viz. that which is comprised in what is termed the Silurian system, and if we assume that it spreads over 60,000 square miles of Britain with an average thickness of 16,000 feet, or 3 miles, which is probably under the truth, then we obtain the enormous mass of 180,000 cubic miles. The magnitude of this pile of material may be better realised if we reflect that it would form a mountain ridge three times as long as the Alps, or from the North Cape to Marseilles (1800 miles), with a breadth of more than 33 miles, and an average height of 16,000 feet, that is, higher than the summit of Mont Blanc. All this vast pile of sedimentary rock was worn from the slopes and shores of the primeval northern land. Yet it represents but a small fraction of the material so removed, for the sea of that ancient time spread over nearly the whole of Europe eastwards into Asia, and everywhere received a tribute of sand and mud from the adjoining shores.

There is perhaps no mass of rock so striking in its general aspect as that of which this northern embryo of Europe consisted. It lacks the variety of composition, structure, colour, and form, which distinguishes rocks of more modern growth. But in dignity of massive strength it stands altogether unrivalled. From the headlands of the

Hebrides to the far fiords of Arctic Norway it rises up grim and defiant of the elements. Its veins of quartz, felspar, and hornblende, project from every boss and crag like the twisted and knotted sinews of a magnificent torso. Well does the old gneiss of the north deserve to have been made the foundation stone of a continent.

Whether vegetation clothed this earliest prototype of Europe, and if so, what were its characters, are questions to which at present no answer is possible. We know, however, that the shallow sea which spread from the Atlantic southward and eastward over most of Europe was tenanted by an abundant and characteristic series of invertebrate animals—trilobites, graptolites, cystideans, brachiopods, and cephalopods, strangely unlike on the whole to anything living in our waters now, but which then migrated freely along the shores of the Arctic land between what are now America and Europe.

The floor of this shallow sea continued to sink until over Britain at least it had gone down several miles. Yet the water remained shallow because the amount of sediment constantly poured into it from the north-west filled it up about as fast as the bottom subsided. This slow subterranean movement was varied by uprisings here and there, and notably by the outburst at successive periods of a great group of active submarine volcanoes over Wales, the Lake District, and the south of Ireland. But at the close of the Silurian period a vast series of disturbances took place, as the consequence of which the first rough outlines of the European continent were blocked out. The floor of the sea was raised into long ridges of land, among which were some on the site of the Alps, the Spanish peninsula, and the hills of the west and north of Britain. The thick mass of marine sediment was crumpled up, and here and there even converted into hard crystalline rock. Large enclosed basins, gradually cut off from the sea, like the modern Caspian and Sea of Aral, extended from beyond the west of Ireland across to Scandinavia and even into the west of Russia. These lakes abounded in bone-covered fishes of strange and now long-extinct types, while the land around was clothed with a club-moss and reed-like vegetation—*Psilophyton*, *Sigillaria*, *Calamite*, &c.—the oldest terrestrial flora yet known in Europe. The sea, dotted with numerous islands, appears to have covered most of the heart of the continent.

A curious fact deserves to be noticed here. During the convulsions by which the sediments of the Silurian sea-floor were crumpled up, crystallised, and elevated into land, the area of Russia seems to have remained nearly unaffected. Not only so, but the same immunity from violent disturbance has prevailed over that vast territory during all subsequent geological periods. The Ural Mountains on the east have again and again served as lines of relief, and have been from time to time ridged up anew. The German domains on the west have likewise suffered extreme convulsion. But the wide intervening plateau of

Russia has apparently always maintained its flatness either as sea-bottom or as terrestrial plains.

By the time of the coal growths, the aspect of the European area had still further changed. It then consisted of a series of low ridges or islands in the midst of a shallow sea or of wide salt-water lagoons. A group of islands occupied the site of some of the existing high grounds of Britain. A long, irregular ridge ran across what is now France from Brittany to the Mediterranean. The Spanish peninsula stood as a detached island. The future Alps rose as a long, low ridge, to the north of the eastern edge of which lay another insular space, where now we find the high grounds of Bavaria and Bohemia. The shallow waters which wound among these scattered patches of land were gradually silted up. Many of them became marshes, crowded with a most luxuriant cryptogamic vegetation, specially of lycopods and ferns, while the dry grounds waved green with coniferous trees. By a slow intermittent subsidence, islet after islet sank beneath the verdant swamps. Each fresh depression submerged the rank jungles and buried them under sand and mud, where they were eventually compressed into coal. To this united co-operation of dense vegetable growth, accumulation of sediment, and slow subterranean movement Europe owes her coal-fields.

All this time the chief area of high ground in Europe appears still to have lain to the north and north-west. The old gnarled gneiss of that region, though constantly worn down and furnishing materials towards each new formation, yet rose up as land. It no doubt received successive elevations during the periods of disturbance, which more or less compensated for the constant loss from its surface.

The next scene we may contemplate brings before us a series of salt lakes, covering the centre of the continent from the north of Ireland to the heart of Poland. These basins were formed by the gradual cutting off of portions of the sea which had spread over the region. Their waters were red and bitter, and singularly unfavourable to life. On the low intervening ridges a coniferous and cycadaceous vegetation grew, sometimes in quantity sufficient to supply materials for the formation of coal-seams. The largest of these salt lakes stretched from the edge of the old plateau of Central France along the base of the Alpine ridge to the high grounds of Bohemia, and included the basin of the Rhine from Bâle down to the ridge beyond Mayence, which has been subsequently cut through by the river into the picturesque gorges between Bingen and the Siebengebirge. This lake was filled up with red sand and mud, limestone, and beds of rock salt. Where the eastern Alps now rise the enclosed water-basins were the scene of a long-continued growth of dolomite, out of which in later ages the famous dolomite mountains of the Tyrol were carved.

These salt lakes of the Triassic period seem to have been everywhere quietly effaced by a wide-spread depression, which allowed the water of the main ocean once more to overspread the greater part of Europe. This slow subsidence went on so long as to admit of the accumulation of masses of limestone, shale, and sandstone, several thousand feet in thickness, and probably to bring most of the insular tracts of Central Europe under water. To this period, termed by geologists the Jurassic, we can trace back the origin of a large part of the rock now forming the surface of the continent, from the low plains of Central England up to the crests of the northern Alps, while in the Mediterranean basin, rocks of the same age cover a large area of the plateau of Spain, and form the central mass of the chain of the Apennines. It is interesting to know that the north-west of Britain continued still to rise as land in spite of all the geographical changes which had taken place to the south and east. We can trace even yet the shores of the Jurassic sea along the skirts of the mountains of Skye and Ross-shire.

The next long era, termed the Cretaceous, was likewise more remarkable for slow accumulation of rock under the sea than for the formation of new land. During that time the Atlantic sent its waters across the whole of Europe and into Asia. But they were probably nowhere more than a few hundred feet deep over the site of our continent, even at their deepest part. Upon their bottom there gathered a vast mass of calcareous mud, composed in great part of foraminifera, corals, echinoderms, and molluscs. Our English chalk which ranges across the north of France, Belgium, Denmark, and the north of Germany, represents a portion of the deposits of that sea-floor. Some of the island spaces which had remained for a vast period above water, and had by their degradation supplied materials for the sediment of successive geological formations, now went down beneath the Cretaceous sea. The ancient high-grounds of Bohemia, the Alps, the Pyrenees, and the Spanish table-land, were either entirely submerged, or at least had their area very considerably reduced. The submergence likewise affected the north-west of Britain; the western highlands of Scotland lay more than 1000 feet below their present level.

When we turn to the succeeding geological period, that of the Eocene, the proofs of wide-spread submergence are still more striking. A large part of the Old World seems to have sunk down; for we find that one wide stretch of sea extended across the whole of Central Europe and Asia. It was at the close of this period of extreme depression, that those subterranean movements began to which the present configuration of Europe is mainly due. The Pyrenees, Alps, Apennines, Carpathians, the Caucasus, and the heights of Asia Minor mark as it were the crests of the vast earth-waves into which the solid framework of Europe was then thrown. So enormous was the contortion that, as may be seen along the northern Alps, the rocks for thousands of feet were completely inverted, this inversion being accompanied by the most colossal folding and twisting. The massive sedimentary formations were crumpled up, and doubled over each other, as we might fold a pile of cloth. In the midst of these commotions the west of Europe remained undisturbed. It is strange to reflect that the soft clays and sands under London are as old as some of the hardened rocks which have been upheaved into such picturesque peaks along the northern flanks of the Alps.

After the completion of these vast terrestrial disturbances, the outlines of Europe began distinctly to shape themselves into their present form. The Alps rose as a great mountain range, flanked on the north by a vast lake which covered all the present lowlands of Switzerland, and stretched northwards across a part of the Jura Mountains, and eastwards into Germany. The size of this fresh-water basin may be inferred from the fact that one portion only of the sand and gravel that accumulated in it even now measures 6000 feet in thickness. The surrounding land was densely clothed with a vegetation indicative of a much warmer climate than Europe now can boast. Palms of American types, as well as date palms, huge Californian pines (Sequoia), laurels, cypresses, and evergreen oaks, with many other evergreen trees, gave a distinctive character to the vegetation. Among the trees too were planes, poplars, maples, willows, oaks, and other ancestors of our living woods and forests; numerous ferns grew in the underwood, while clematis and vine wound themselves among the branches. The waters were haunted by huge pachyderms, such as the dinotherium and hippopotamus; while the rhinoceros and mastodon roamed through the woodlands.

A marked feature of this period in Europe was the abundance and activity of the volcanoes. In Hungary, Rhineland, and Central France, numerous vents opened and poured out their streams of lava and showers of ashes. From the south of Antrim, also, another great line of active orifices ran up the west coast of Scotland and by the Faroe Islands to Iceland, whence it extended even far into Arctic Greenland.

The mild climate indicated by the vegetation in the deposits of the Swiss lake, prevailed even into Polar latitudes, for the remains of numerous evergreen shrubs, oaks, maples, walnuts, hazels, and many other trees, have been found under the sheets of lava in the far north of Greenland. The sea still occupied much of the lowlands of Europe. Thus it ran as a strait between the Bay of Biscay and the Mediterranean, cutting off the Pyrenees and Spain from the rest of the continent. It swept round the north of France, covering the rich fields of Touraine and the wide flats of the Netherlands. It rolled far up the plains of the Danube and stretched thence eastwards across the south of Russia into Asia.

By this time not a few of the species of shells which still people the European seas had appeared. So long have they been natives of our area that they have witnessed the rise of a great part of the continent. Some of the most stupendous changes which they have seen have taken place in the basin of the Mediterranean, where, at a comparatively recent geological period, parts of the sea-floor have been upheaved to a height of 3000 feet. It was then that the breadth of the Italian peninsula was increased by the belt of lower hills that flanks the range of the Apennines. Then, too, Vesuvius and Etna began their eruptions. Among these later geographical events also we must place the gradual isolation of the Sea of Aral, the Caspian, and the Black Sea from the rest of the ocean, which once spread from the Arctic regions down the west of Asia, along the base of the Ural Mountains into the south-east of Europe.

The last scene in this long history is one of the most unexpected of all. Europe, having nearly its present height and outlines, is swathed deep in snow and ice. Scandinavia and Finland are one vast sheet of ice, that creeps down from the watershed into the Atlantic on the one side, and into the basin of the Baltic on the other. All the high grounds of Britain are similarly buried. The bed of the North Sea as well as of the Baltic is in great measure choked with ice. The Alps, the Pyrenees, the Carpathians, and the Caucasus send down vast glaciers into the plains at their base. Northern plants find their way south even to the Pyrenees, while the reindeer, musk-ox, lemming, and their Arctic companions roam far and wide over France.

As a result of the prolonged passage of solid masses of ice over them, the rocks on the surface of the continent, when once more laid bare to the sun, present a worn, flowing outline. They have been hollowed into basins, ground smooth, and polished. Long mounds and wide sheets of clay, gravel, and sand have been left over the low grounds, and the hollows between them are filled with innumerable tarns and lakes. Crowds of boulders have been perched on the sides of the hills and dropped over the plains. With the advent of a milder temperature the Arctic vegetation has gradually disappeared from the plains. Driven up step by step before the advancing flora from more genial climates, it retired into the mountains and there to this day continues to maintain itself. The present Alpine flora of the Pyrenees, the Alps, Britain, and Scandinavia, is thus a living record of the ice-age. The reindeer and his friends have long since been forced to return to their northern homes.

After this long succession of physical revolutions, man appears as a denizen of the Europe thus prepared for him. The earliest records of his presence reveal him as a fisher and hunter, with rude flint-pointed spear and harpoon. And doubtless for many a dim century such was his condition. He made no more impress on external nature than one of the beasts which he chased. But in course of time, as civilisation grew, he asserted his claim to be one of the geographical forces of the globe. Not content with gathering the fruits and capturing the animals which he found needful for his wants, he gradually entered on a contest with nature to subdue the earth and to possess it. Nowhere has this warfare been fought out so vigorously as on the surface of Europe. On the one hand, wide dark regions of ancient forest have given place to smiling cornfields. Peat and moor have made way for pasture and tillage. On the other hand, by the clearance of woodlands the rainfall has been so diminished that drought and barrenness have spread where verdure and luxuriance once prevailed. Rivers have been straitened and made to keep their channels, the sea has been barred back from its former shores. For many generations the surface of the continent has been covered with roads, villages and towns, bridges, aqueducts and canals, to which this century has added a multitudinous network of railways, with their embankments and tunnels. In short, wherever man has lived, the ground beneath him bears witness to his presence. It is slowly covered with a stratum either wholly formed by him or due in great measure to his operations. The soil under old cities has been increased to a depth of many feet by the rubbish of his buildings; the level of the streets of modern Rome stands high above that of the pavement of the Cæsars, and that again above the roadways of the early Republic. Over cultivated fields his potsherds are turned up in abundance by the plough. The loam has risen within the walls of his graveyards as generation after generation has mouldered into dust.

It must be owned that man, in most of his struggle with the world around him, has fought blindly for his own ultimate interests. His contest, successful for the moment, has too often led to sure and sad disaster. Stripping forests from hill and mountain, he has gained his immediate object in the possession of their abundant stores of timber; but he has laid open the slopes to be parched by drought, or to be swept bare by rain. Countries once rich in beauty, and plenteous in all that was needful for his support, are now burnt and barren, or almost denuded of their soil. Gradually he has been taught by his own bitter experience, that while his aim still is to subdue the earth, he can attain it, not by setting nature and her laws at defiance, but by enlisting them in his service. He has learnt at last to be the minister and interpreter of nature, and he finds in her a ready and unrepining slave.

In fine, looking back across the long cycles of change through which the land has been shaped into its present form, let us realise that these geographical revolutions are not events wholly of the dim past, but that they are still in progress. So slow and measured has been their march, that even from the earliest times of human history they seem hardly to have advanced at all. But none the less are they surely and steadily transpiring around us. In the fall of rain and the flow of rivers, in the bubble of springs and the silence of frost, in the quiet creep of glaciers and the tumultuous rush of ocean waves, in the tremor of the earthquake and the outburst of the volcano, we may recognise the same play of terrestrial forces by which the framework of the continents has been step by step evolved. In this light the familiar phenomena of our daily experience acquire an historical interest and dignity. Through them we are enabled to bring the remote past vividly before us, and to look forward hopefully to that great future in which, in the physical not less than in the moral world, man is to be a fellow-worker with God.

On the termination of the lecture,

The CHAIRMAN (Mr. Francis Galton) said many thoughts must have occurred to the minds of the members in listening to Mr. Geikie's brilliant and lucid address. They must have felt regret that they did not possess pictures of typical geographical scenery that should be true to the eye of the geologist, and faithfully represent the fauna and flora of the country, and the chief physical aspects of nature. He would say more on the subject of the lecture, were it not that he saw present several very distinguished geologists, including Mr. Evans, the recent President of the Geological Society. But he would content himself with calling upon the gentleman whose geological pupil Mr. Geikie originally was, and of whom in his public writings Mr. Geikie had uniformly spoken with the greatest respect. He alluded to Professor Ramsay, the successor of Sir Roderick Murchison as Director of the Geological Survey of England, and, he might be permitted to add, the President designate of the British Association for the year 1880.

Professor A. C. RAMSAY congratulated the Society on having had the opportunity of listening to a lecture which showed such a profound knowledge of the structure of the earth, and of those causes which had led to the modern physical geography of the world. In a general way, half-a-dozen lectures would scarcely have been sufficient to give all the information that Mr. Geikie had condensed into one. He did not quarrel with him for putting so much in such an excellent epitome, but he regretted that it had not been spread over several lectures, so that the large number of topics touched upon might have been dealt with *in extenso*, and thus the Meeting might have been able to carry away a little encyclopædia of physical geography. The physical geography of the modern world was but the result of all the various changes that had taken place for all time past, or at all events for all the ages which the study of the rocks indicated. Geology had only to do with the history of the world since the solid rocks were formed, but none of the first solid rocks were now in existence, for the oldest strata that man had ever yet seen on the surface of the earth were metamorphic rocks, which implied the wasting of a still older land. All that was known was that that first land was spread about as ordinary sediments of sand, mud, limestone, and then through some of those revolutions which afterwards took place it was heaved up, and turned into mountain chains. Then the sea flowed over it and new sediments were formed, and the same process was repeated for a long period of time. Modern physical geography was the temporary result of all those changes, but had not lasted nearly so long as many of the old conditions that had entirely vanished, except to the skilled eye of those who had a thorough knowledge of present geological information. To the vulgar eye those ancient relics simply looked like little bits here and there of the scenery of the modern physical geography of the world. When the modern appearance of the earth was analysed and anatomised, when the integuments were taken off, then a great number of fragments of old skeletons were laid bare. This process was similar to that with which students of Darwin's profound speculations on life and time were acquainted. They took the modern fauna of the world, and going back in time they found that they had predecessors which were not quite the same:—two-toed horses; further back three-toed horses: pigs of the present day; further back ruminant pigs—pigs, so to speak, more or less allied to cows, and so on. The longer the time the greater the difference, but yet all was consistent, and each formed a part of one great demonstration of the development of life. So was it with the physical world, which no doubt began before there was any life upon it. The rocky life of the world, like the animal life, had been going through successive phases, and at length the present temporary conditions had been developed. This was an epitome of the general tendency of the subject, of which Mr. Geikie had given so admirable a sketch in his lecture.

Explorations in Western Tibet, by the Trans-Himalayan parties of the Indian Trigonometrical Survey.

THE 'Report on the Survey of India for 1877–78,' a few copies of which have just reached this country, contains a very interesting Report on the Trans-Himalayan operations (trigonometrical), conducted under Mr. E. C. Ryall, in Hundes, a district in the western part of Chinese Tibet, and adjoining tracts.

This officer had been engaged in triangulating, in connection with the Kumáon and Garhwál Survey, for some few seasons past, and this work has led him in several instances to extend his operations across the frontier into Chinese territory, with which the British possessions are here conterminous. In 1877, the Surveyor-General directed Mr. Ryall to continue the Milam Valley series up to the frontier of Hundes, or Nari-Khorsam (the name applied to that portion of the Upper Sutlej or Karnali basins which is under the Government of China), and from thence to lay down some of the distant peaks in Chinese Tibet. This Mr. Ryall successfully accomplished, and the number of triangles measured by him were thirty-eight in number, exceeding 100 miles in length.

At first the mountains encountered were of an average height of 9700 feet, well wooded, and not over rugged, their slopes being studded with numerous villages and extensive patches of cultivation. On Mr. Ryall's arrival at the loftier stations, the inclemency of the weather and the very great depth of fresh snow, covering the mountains down to their very bases, were such that he anticipated his further progress would escape the knowledge of the Chinese officials, owing to the deserted state of the passes at that early season. After five days' cutting through the snow, Mr. Ryall succeeded in crossing over into Hundes on the 8th June. By that time his arrival became known to the Chinese officials, but by informing them that his object was simply to survey the northern limits of British territory, which he found it impossible to do from the southern faces, he succeeded in satisfying them and in obtaining permission to remain. With great despatch (for the monsoons were fast approaching), he fixed the most prominent points, which included the snowy peaks across the Sutlej and at the head of the Manasarowar lakes, and others lying at the head of the Darma and Byans Valley, as well as the well-determined peaks in Kumáon and Garhwál, as a check on the new work. The remarkable peak Leo Pargial (of which a striking