During those early years when the "Beagle" was flitting from place to place in the wonder-world of the western half of the globe, multitudes of geological observations were made by its naturalist. These are in the main embodied in two volumes to-day. The one is that on "The Geology of Volcanic Islands and South America;" the other is on "Coral Reefs."

A.—Geological Observations on Volcanic Islands and on Parts of South America.

CHAPTER IV.

(1.) *Volcanic Islands.*

(*a.*) ST. JAGO.

DARWIN visited part of this island, one of the Cape de Verde Archipelago, and found its structure to be briefly as follows. The island is composed of central mountains several thousand feet high, rising from a plain whose boundary is a broken ring of cone-shaped hills. Another plain, broken here and there with other isolated hills, slopes from the cone-shaped hills to the sea cliffs.

The lowermost strata of the sea cliffs are basaltic and of sub-marine origin, and are identical with the tops of the hill ring. Overlying this basaltic stratum is a calcareous one of late tertiary age, the lowermost part whereof often passes into conglomerate sandstone or earthy tuff. It contains fossils characteristic of shallow seas. On this calcareous formation is another sub-marine basaltic formation, a lava flood long since cooled, the streams of which can be traced back through the valleys that separate the hills of the hill ring as far as the central plain. The detached hills of the coast-plain are of more recent date. They were volcanoes, and their streams of lava, imperfectly mixed with earthy lime derived from the calcareous strata underneath, may be traced flowing over the basalt coast-plain, and in some instances precipitating themselves over the sea-cliffs formed by its edges. The hills of the hill ring, like the lowermost strata of sea cliffs, are composed of basalt resting on trachyte. The central mountains which Darwin did not visit are, possibly, of trachyte. In this case the island would have throughout a trachytic basis, like Ascension and many others.

It would therefore appear that the history of the island is

somewhat as follows. Apparently, *on the whole*, persistent upheaval has taken place. From the central region of the island, the oldest basalt lavas, forming the tops of the hill ring and the lowest strata of the coast, have flowed over the lowermost rocks constituting the island basis, while the latter were submerged beneath the waves. Upheaval of the land has then taken place in such a manner that the central seat of volcanic agency has been lifted up out of the water to a less height than its periphery. An island whose cliff line was the present "hill ring" was thus produced. A period, such as that of to-day, of comparative freedom from volcanic disturbance seems to have succeeded, during which the sea wore out in the cliffs gullies that are now the valleys of the "hill ring," and deposited the calcareous stratum.

Through the gorges thus worn out into the sea, passed the second basaltic flood. Upheaval again succeeded, turning the new sea bottom into a new coast plain, the edges of which the sea has eaten away, forming the cliffs of to-day. Comparatively recent disturbances succeeding another period of rest, have produced the isolated hills with their lava streams of the third basaltic series.

Such is the history of St. Jago, and such in principle that of Mauritius, St. Helena, and Ascension, repetition of like changes succeeding regularly. After the present period of rest at St. Jago, with its sea now presenting a calcareous floor, like the old calcareous strata of the island—who shall say that a fifth basalt flood may not be poured forth to ring in again the old changes? An instance noticeable enough this, of how the record of the past may be interpreted in the language of the present!

(*b.*) MAURITIUS.

In this island we find an oval ring of high basalt mountains enclosing a central plain of a second more recent basalt, which has overflowed through the gap-like gorges of the ring to form the encircled basalt plain. The sea has worn the edges of this plain into the present cliffs. This coast plain is of submarine basalt, and bears evidences, such as the presence of stranded coral reefs and the fact of its being overlaid by a calcareous stratum, of recent elevation. Whether we have here a huge crater which has fallen in as Bailey suggests, or whether the central part of the island is

an upheaved region whose periphery has been elevated to a greater extent than its centre, Darwin does not decide, though he, while admitting the possibility of Bailey's view, decidedly inclines to the latter suggestion.

(*c.*) ASCENSION.

The basis of this island is trachytic rock, which forms the central and south-eastern regions of the island. The trachytic series present the usual conical hills with truncated summits, the latter often cut off obliquely and sloping towards the south-east, the quarter whence the trade wind blows. This structure is due to the fact that the ejected ashes and fragments of eruptions are blown towards one side more than another. Nearly the entire circumference of the island is covered by basalt, which can be traced to the central trachytes, and sometimes to the now long quiescent volcanoes themselves.

This basalt seems to have had but little fluidity, as it has frequently heaped itself up, as it were, on arriving at a place affording opposition to its regular flow. Its surface, on a stupendous scale, therefore, is in places like that of a brook traversing a pebbly watercourse. Numerous remarkable appearances result from this cause, and are examined in detail by Darwin. One of these is the solidification of the ends of lava streams into lofty walls or cliffs of basalt.

The beach in many parts is largely composed of broken shells and corals. These are perpetually being comminuted by the waves, the sea thus becoming saturated with carbonate and sulphate of calcium. This the waves of the sea again precipitate either as a very remarkable frondescent incrustation on the volcanic rocks round the shore, or in the interstices of the shell beach, cementing the shells and the stones of the beach into rocks of various degrees of hardness, some compact enough to be quarried for building stones, and some with a density as great as that of Carrara marble. This fact is very remarkable considering the absence of heat and pressure.

(*d.*) ST. HELENA.

This island of many memories has an extremely interesting geological history.

We find our old friend the basaltic ring again coming to

the fore. This time it forms cliffs, from a few hundred to 2,000 feet in height, around the island. As the coast is low on the south side of the island, the cliffs form a "horseshoe ring" open towards the south. Under this visible basalt is a basal formation of the same material still older and submarine, and over it a series of much metamorphosed feldspathic rock. Nevertheless some of these were originally lavas, whilst most of them were derived from scoriæ and ashes. So great, however, is the geological age of everything in this island that the lavas can no longer be traced, as at Ascension, to their craters. Yet Darwin discovered in the central mountainous region of the island the last remains of a great crater three miles long by a mile and a half broad, whose feldspathic lavas had filled up the trough between its outer side and the basaltic periphery. The trough was an oval space nine miles by four.

On the top of the central curved ridge, the last remnants of the tip of the crater, there still remain fragments of a wall or parapet which is perfect on Cotopaxi, the Peak of Teneriffe. At the Galapagos Islands a similar less perfect wall presents from a distance, the appearance of a small cylinder placed on a truncated cone.

Again, on the inward sides of this cold crater, are flat ledges left by the cooling lava, as during its shrinking its height decreased, "like ice round a pool from which the water has drained." So great have been the changes since the old crater poured forth its last feldspathic charge, that in places these very lava floods have been tilted to greater heights than that from which they originally flowed. Into the rents which such mighty convulsions have caused rock masses, while liquid, have been injected. These have taken the mould most faithfully, have cooled, have afterwards become exposed by denudation, and project at the present day in a hundred different grotesque forms. The whole forms a fine instance, as Darwin remarks, of the manner wherein the structure of volcanic districts may become obscure and finally obliterated. The basalt cliffs tell the same tale. Portions of the ring, two or three miles in length, by one or two in breadth, and from one to two thousand feet in height, have been worn away by the Atlantic swell. Even the more rapid erosion of the wind side of the island tells its tale after many centuries.

Among other interesting features of St. Helena are certain calcareous beds composed of minute equal-sized round particles of shells. These are found in some of the valleys several hundred feet above the sea, but protected from the prevalent winds. In vain are calcareous beds searched for around the modern coast to yield a dust whose sifted particles blown up the valleys by the wind might form such a deposit. We must therefore look back to a period when, before the land was worn into the present precipices, a shelving coast, like that of Ascension was favorable to the accumulation of shelly deposits.

(*e.*) GALAPAGOS ARCHIPELAGO.

This group of islands is, from a geological point of view, singularly uninteresting. All the islands are volcanic. In two of them, craters have been seen in operation, and some of the lava streams exhibit a recent appearance. Many of the craters appear to have been submerged during the time they were active, as Stromboli is submerged to-day. This is the explanation of the scarcity of ashes. As usual many of the craters are filled with solidified basalt. In some again are lakes of brine, evidently the result of elevation of submerged craters, and consequent concentration of the sea-water contained therein. The craters, of which there are many thousands in the Archipelago, appear to arrange themselves pretty definitely in parallel lines, and there is an absence of any one great vent in the group.

(*f.*) DISTRIBUTION OF VOLCANIC ISLANDS.

With the exception of St. Paul's Rocks, Falkland Islands, Seychelles, New Caledonia, and Georgia, and the Continental Island group (Australia, New Zealand, &c.), all the islands of the Pacific, Indian, and Atlantic are volcanic. This is evidently an extension of that law, and the effect of those same causes, whether chemical or mechanical, from which it results that a vast majority of the volcanoes now in action stand either as islands in the sea or near its shores.

To smooth away the apparent discrepancy of mountain chains being generally non-volcanic, while oceanic islands are volcanic, Charles Darwin suggests that volcanic eruptions reach the surface more readily through fissures formed during the first stages of the conversion of the ocean bed into

dry land. In all volcanic archipelagos, the islands are arranged in one, two, or three somewhat curved but fairly parallel volcanic rows. This phænomenon, Charles Darwin considers as in close relation to the formation of parallel volcanic chains, such as the Cordilleras of South America. The two cases are but different instances of the same general action.

Finally, the connexion between contemporaneous elevation and volcanic eruptions is entered into in the "Structure and Distribution of Coral Reefs," to be hereafter discusssed.

In considering these various accounts of islands we must be impressed by the great similarity of their structures. Almost always is there a trachytic basis, overflowed by basaltic lava of various ages and natures, flowing, in almost all cases, from "craters of elevation."

The absence of sedimentary rocks, with the exception of the calcareous deposits, renders the reference of these islands to definite geological periods nearly impossible. Even the calcareous stratum yields but few fossils, and these not of a very satisfactory nature; and, again, the Atlantic region of the earth seems to have continued to deposit calcareous matter in greater or less quantity from the chalk age down to the present time.

CHAPTER V.

(2.) *Geology of South America.*

THE first geological work of Charles Darwin that came under our consideration dealt with the geological structure of certain islands, at which the ship bearing the illustrious naturalist made pause. As the stoppages of the "Beagle" were not infrequently of but short duration, many of Darwin's accounts of these places are necessarily somewhat imperfect. In dealing, however, with that part of the New World south of the Tropic of Capricorn, he had time to make fuller investigation. The result is a most interesting and eminently suggestive work known as "Observations on the Geology of South America."

It is, then, with the geology of that part of America which lies south of the Tropic of Capricorn that we have in this particular chapter to deal. A careful study of the volume in question demonstrates that, whilst from the first page to the last the subject matter is of great interest, certain topics are dealt with that stand out from their fellows as of paramount import. Each of these is of moment, because in connexion with it there has been large accumulation of facts; but yet more, because of the generalisations induced by the acute mind of Charles Darwin from these several sets of facts.

(*a.*) The elevation of the Coasts of South America. As the Humber, upon the eastern coast of England, is nothing more than an estuary formed by the flowing together of the Trent, the Don, the Ouse, and the Swale, so the Rio de la Plata, upon the eastern coast of South America, is nothing more than an estuary formed by the flowing together of the rivers Paraguay and Uruguay. Examination of the shores of the Rio de la Plata, an examination extending some distance inland on either side of the estuary itself, reveals the presence of the shells of many Mollusca (soft-bodied

animals). These shells are identical with the shells of Mollusca that are alive at the present hour. But while the shells whose inhabitants and builders are dead are found imbedded in the land and in close proximity to fresh water, the shells of to-day with their living denizens are encountered in the *salt* waters of these latitudes.

Investigation by our naturalist of various other points on the eastern coast, to the south of the La Plata, revealed the same peculiarity of shell-bearing living beings in the sea, and of empty shells identical in nature with those in the ocean imbedded in the land, far from any water that was otherwise than fresh. Bahia Blanca, S. Blas, Port Antonio, S. Joseph, Port Desire, Santa Cruz, Tierra del Fuego, all yield similar results. It is a legitimate inference, therefore, that the whole coast will present this remarkable phænomenon.

Further, in Patagonia, where South America is almost at its narrowest, and but a thin strip of land bars the Pacific from the Atlantic, the structure of the "steppe plains," viewed side by side with the distribution of the shells upon this eastern coast, is very suggestive. Patagonia presents many level steppe-formed plains rising in steady succession one above the other. Each plain is covered with an irregular bed of gravel. This gravel is of the same kind as the gravel of the sea-shore to-day, and the lines of escarpment, that run longitudinally through Patagonia parallel with the sea shore, and separate the plains one from another, are of the same nature as the sea cliffs of to-day. Not only are these tiers of plains traceable along lines parallel to the sea coast, presenting the appearance of a colossal staircase, trodden by the foot of some gigantic Titan of the past as he stepped seawards, but at times, when in their course southwards they would strike into some river bed, they suddenly sweep inland and trace the course of the river, back and ever back towards the place where the huge stream was born of the embrace of tropical thunder clouds and the crags of the Andes. The Rio Santa Cruz presents an instance of this phænomenon. The river therefore flows through a plain that is bounded laterally by tier above tier of other plains. Each of these plains, running parallel to the river, is continuous at the mouth of the river with one of those running parallel to the sea. From the study of

this river, and others of like nature, Charles Darwin is led to believe that the Pacific and Atlantic Oceans were connected by two or three straits other than those of Magellan.

It has been said that the geological structure of these plains of Patagonia is identical with that of the sea shore, and that the structure of the escarpments bounding the plains is identical with that of the sea cliffs. Let it be added that the organic remains encountered in these plains are identical with those encountered in the sea. No question can exist therefore as to the identity of nature, and probably of origin of these inland structures and of the coast formation. But there is question as to the method whereby what were once marine have now become terrestrial. Two theories have been suggested. An account of them will be interesting, not only in connexion with the present subject, but as showing one of the chief thought-differences between the naturalists of yesterday and to-day. The old school was always on the look out for that which was startling and sudden. The modern school seems to see that the gradual, the imperceptible, the accumulative are more frequent. The former believed in special creation, the latter in evolution. The former looked upon Nature as working by cataclysms, the latter looks upon her as working by every day means, but ceaselessly and imperturbably until a new order of things has slowly unfolded itself from the old.

Hence D'Orbigny and the old geologists saw in the escarpments of the terrace plains the result of a sudden and violent upheaval of a sea beach of the past. They saw in the plain itself the result of a long period of quiescence. But Charles Darwin could find no marks of volcanic agency. He found, moreover, that the plains were not perfectly level. They sloped gradually upwards from the brink of one escarpment to the foot of the next. Therefore he has been led to believe that the formation of these plains, in the past and at the present, has been and is due to the elevation of the land out of the sea; and that this elevation has been most rapid during the periods when escarpments were in the process of formation, slowest during the years when the plains were a-building. As a test that may fairly be called crucial, of the greater accuracy of one or the other of these hypotheses, Charles Darwin brings forward, in his usual quiet fashion, one of his suggestions, at once simple and most

admirable. He points out that in the bed of ocean there is a very irregular arrangement of stone fragments according to size. Thus, the largest stones are always met with in the shallowest water, and the smallest are always present in the floor of the sea, where the sea is at its greatest depth. There is a regular decrease in size of the pebbles with the increase of the depth of the water. Therefore, if these plains were due to sudden elevation of a large area of the sea floor we should expect to find their pebbles of very variable size. But the pebbles of the plains present a most striking sameness as to dimensions, and this is easily reconcileable with a slow elevation of the land. For if the beach rose inch by inch out of the sea, only those pebbles near high-water mark would be slowly rescued from the waves. They would then be removed and their place would be occupied by others. These would be still the pebbles about high-water mark. Therefore in size they would be similar to their predecessors, and thus also would it be with succeeding layers of stone fragments, as the sea slowly sank away from the land.

A like elevation of the western coast of this continent of wonders has also been demonstrated by our naturalist. And indeed South America seems to have been the Venus Anadyomene among earth's great tracts of land. Like the goddess it has risen from the sea, like her it is beautiful, and like her, there is something of the terrific and the fatal in its beauty. The stupendous importance of this elevation can scarcely be over estimated. An area of the earth's surface 1,180 miles long on the east coast of South America, 2,075 miles long on the western side, with a breadth in the south equal to the breadth of Patagonia added to the breadth of the sea as far as the Falkland Islands, equal in the north region possibly to the breadth of La Plata, has risen very slowly to heights varying from 100 feet (La Plata) to 1,300 feet (Valparaiso). This elevation has taken place during the period of existing shells, and geologists will tell us that the existing shells were preceded by others their allies, also lasting through countless ages. And from the history of this little fragment of earth some very faint conception may be formed of the cycles upon cycles upon cycles of ages during which earth, sweeping in her orbit round the central sun, has added her voice to the solemn music of the spheres.

(*b*) The Salt Beds. (i.) Near Iquique, in Peru, is the famous deposit of sodium nitrate, whereof even the geography books make mention. This nitre bed is some thirty miles from the sea. Between it and the sea lies a tract of land rich in common salt (sodium chloride) and gypsum, or alabaster, (calcium sulphate). The nitre bed itself extends for a distance of 120 to 150 miles along the western margin of a plain raised 3,300 feet above the level of the sea. Its average thickness is between two and three feet, and it is of such hardness that it has to be blasted by gunpowder. The bed rests on sand that contains vegetable remains and sea shells. Vegetable remains and sea-shells of kindred nature occur in the deposit itself. Overlying the nitre bed is a superficial deposit of sand, in nature closely allied to the sand on the salt-bearing tract that lies between the nitre bed and the sea. In reference to this remarkable deposit our author writes as follows: "With respect to the origin of this saline mass, from the manner in which the gently inclined compact bed follows for so many miles the sinuous margin of the plain, there can be no doubt that it was deposited from a sheet of water: from the fragments of imbedded shells, from the abundant iodic salts, from the superficial saligerous crust occurring at a higher level and being probably of marine origin. . . . there can be little doubt that this sheet of water was at least originally connected with the sea."

To Charles Darwin, therefore, the great nitre bed means this. A portion of the great sea that at one time overflowed this land became shut off in a basin-like valley as the main body of water retreated. Gradual evaporation of this isolated water took place with ever increasing concentration of such salt-containing water as was left. That is, the evaporation of pure water would leave the residual brine more and more "salt" in its nature. At last the solution would become so concentrated, that the less soluble salts would begin to crystalize out. These would be common salt (sodium chloride) and the salts of calcium. Deposits of these therefore will be found high up the sides of the basin, nearest its rim, at a level most remote from the centre of the sea-water lake. Then will follow the crystallizing out of the more soluble salts and the formation of the nitre beds.

(ii.) Beside the nitre beds South America abounds in

other saline deposits. Most notable among these are those of sodium sulphate or Glauber's salt. This salt occurs in mud banks. The mud banks are often in direct continuity with mud banks still rising from the sea. The Glauber's salt is mixed with common salt, and the nearer the deposit is to the sea, and therefore the more recent it is, the greater is the quantity of the common salt. Finally, the mud abounds in chalky matter, that is, calcium carbonate. Before stating Darwin's explanation of these chemical phænomena it were well to give an account of that which was observed at San Lorenzo. On the coast cliffs of this island are ledges filled with shells which are, of course, in the main calcium carbonate. These shells are cemented together by sodium chloride. The sodium chloride is the result of the evaporation of the sea spray. On the higher and older ledges a white powder is found, composed chiefly of calcium chloride, sodium sulphate, and the two other salts encountered on the cliffs below, namely, calcium carbonate and sodium chloride. And now we come to Charles Darwin's explanations. First, it is known that a moistened mixture of calcium carbonate (the shells) and sodium chloride (from the sea), results in mutual decomposition, and the formation of calcium chloride and sodium carbonate. Therefore the two original salts will be found close to the sea, the two ultimate salts in the upper cliff levels and in the mud banks. The great difficulty, however presented, is the absence of the sodium carbonate, and the presence of sodium *sulphate* in the more inland regions. It would seem therefore that the common salt (sodium chloride) in soaking through the mud, becomes first sodium carbonate, and then sodium sulphate. This last stage of the conversion of sodium carbonate into sodium sulphate presents difficulties even to Charles Darwin. It may be suggested that the necessary sulphuric acid for such change might result from the oxidation of the sulphur occurring in decomposing animal and vegetable matters that would be certain to be present in such geological formations.

(*c.*) The Pampas. The continent of America is the continent of vast plains. In each division of that continent exists a gigantic expanse that is larger than the whole of Europe. Parts of the great plain in North America are known as prairies, from the French word for meadow, or as

savannahs, from the Spanish *sabana*, a sheet. Parts of the great plain in South America are known as llanos, whilst other regions are called pampas. Llanos (levels or plains) are encountered in the northern region of the southern division of the New World. Pampas is the native name for the treeless plains of the southern part of South America.

The prairies or savannahs are fertile seas of grass that go billowing onwards from your feet to the very horizon. The llanos are now fertile, richly clad with tall, strong, green grass—now dry, sterile, baked by the vertical rays of a tropical sun to a rock-like hardness. South of 34° S. lie the pampas. From 34° to 40° S. they are the pampas of Buenos Ayres; from 40° S. southwards those of Patagonia. These plains are almost always dry. Upon them "the gentle rain from heaven" rarely falls. Much of them is grass-covered, but over wide areas stretch sandy deserts, and in the extreme north lies a waste of salt, 30,000 square miles in extent, called Las Salinas. The investigation of Charles Darwin into the nature of the remarkable formations known as pampas is our next subject of consideration. Following him as leader—and, for my part, I know none worthier—I shall consider the extent, the structure, the theories as to the origin of the pampean formation.

(i.) The extent. Longitudinally and laterally the pampas have huge extent. In length this strange region has been traced by Darwin himself from the river Colorado, almost at the southernmost part of the Argentine Republic, as far north as Santa Fé de Bajada, placed on the river Parana and nearly in the midst of the far-reaching district of Argentina. For some 250 miles further north than even Santa Fé, D'Orbigny was able to trace the form of earth-structure characteristic of the pampas. From side to side the extent varies. Measure it at the latitude of the Rio de la Plata and a width of between 300 and 400 miles is encountered. Even if this width be regarded as above the average, the whole extent is at the very least equal to that of France. It is probably nearer the truth to say it is twice or thrice as great as the area of that country. Thus much for its superficial extent. Vertically the pampean formation varies in thickness from 20 to 100 feet, and at Buenos Ayres the boring for an Artesian well revealed a depth of 210 feet as that of the strata characteristic of this special region.

(ii.) The structure. In the southern parts of the pampas the upper layers of the earth show some traces of having been deposited in successive strata. They consist of hard rock known as Tosca rock. Below lies the peculiar pampean mud, dull-red of hue, slightly hardened, and of clay-like nature. This mud is generally traversed by horizontal lines that are of chalk. The mud does not, however, contain any traces of calcium carbonate, no matter how close to the concretions of chalk is the mud whereof examination is made. The Tosca rock also contains calcium carbonate as concretions, and in finely divided form, resulting from the comminution of shells and coral. Whence comes this enormous mass of mud? The answer of the naturalist is that the mud of the pampas is traceable to the rocks of Brazil. These rocks are of granite nature. They have in the dim past suffered abrasion and disintegration. They have been turned into a red, gritty, clay-like mass that has formed the "mud." To-day the Rio de la Plata sweeping towards the South Atlantic waters bears with it large quantities of mud. In the past ages, in all probability, mud was drifted in a course running more directly south, for it travelled as far southward as Colorado. The fossils of this formation comprise corals, barnacles and Mollusca still existent, certain rodent or gnawing animals, and the great-toothed Machairodus of the Carnivora or flesh-eaters. To name the other animals is to name the majority of the gigantic, sloth-like, herbivorous quadrupeds whose very names sound huge. Megatherium, Megalonyx, Mylodon, Glyptodon, Equus, Scelidotherium, Mastodon, all the mighty brutes that made earth shake as they moved in their slow, ponderous, dreamy fashion over its surface in the time that was but yesterday, and yet was ere man lived, are here entombed.

It is noteworthy, moreover, that the evidence is strong in favor of the view that, at the epoch of formation of the pampean region, the animals of the north and those of the south halves of the continent were similar, if not identical.

(iii.) Theories. Speculation has been rife concerning the origin of the pampean formation. Three theories have been broached. In studying them we shall once more see that the suggestion of Charles Darwin leads us in the direction of the quiet, long-continued, imperturbable action of

nature as opposed to her performance of work by cataclysmic change.

(α) Of D'Orbigny. D'Orbigny is, as usual, on the side of the startling. A great catastrophe suddenly cast hecatombs of the mud, to-day called pampas mud, somewhence. The mud entombed myriads of living beings that happened to be in the way. To this mud winding sheet theory Darwin objects that there is distinct evidence of the formation having been at least partially deposited in layers, an arrangement not possible on the D'Orbigny theory; that it is difficult to conceive the formation, storing-up, and sudden use of material enough to cover an area 750 miles by 400, to a depth of from 20 to 100 feet; that on this view a mass of mud without one single pebble has been carried under the sea over the wide surface of the pampas, while by the same or a similar cataclysm Patagonia was covered, not by mud, but by gravel.

(β) Of Sir W. Parish. That the pampean formation is due to the throwing down of mud upon low marshy plains by the rivers of South America, when they flowed in courses other than those they traverse at the present hour. Objections to this view urged by Charles Darwin, in his usual sedate, irresistible fashion, are the composition of the deposit, the way wherein it slopes up the primary ranges, the nature of the strata beneath, the *sea*-shells on the surface, the sandstone beds that at certain places overlie the pampas formation, the non-discovery of a single skeleton of a mammal in the erect position that would be probable had it been overwhelmed with a fatal mud wave.

(γ) Of Charles Darwin. That the pampean deposit was slowly accumulated at the mouth of the former estuary of the Rio de la Plata and in the adjoining sea. All that has been stated in the preceding paragraphs in favor of this idea is indeed only understandable upon acceptance thereof. And to the evidence already adduced the patient accumulator adds yet other, until even he, most reluctant to give assent to any theory of his own, unless supported by all fact, is sure.

(*d.*) The Patagonian formation. South of Argentina lies the country of the giants, Patagonia. The land is of stupendous nature. Its shores are washed by the Atlantic wave. Its rocks are allied to those of the realm that lies to

its north, but great lava-rivers have flowed over them from the awful Cordilleras that creep solemnly down into its northern lands. The immense formation known as the Patagonian reaches from the Colorado on the north to Santa Cruz and even further south. To the north of the river Colorado it underlies the pampean formation, coming to the surface again at Banda Oriental. Its eastern boundary is the ocean. Its western is the mountains. Its thickness, vertically, at the coast is 800 feet. Consider this formation and that of the pampas. Are they not colossal? It is as if from the Straits of Gibraltar to the southern coast of Iceland stretched one continuous line of structure, not in one single observed instance unequally tilted or dislocated by a fault. The whole has been slowly, steadily, evenly upraised from the sea.

The Cordilleras are quiet now. The Titans beneath them are at rest to-day. But whilst this huge formation was a-building the Cordilleras were active enough. Travel up the rivers from the mouth. Sixty-seven miles inland streams of basalt meet you, frozen now, once on a time hot, flowing lava. Follow them up on the north side of the river valley 100 miles: note that this deluge of lava is from 130 to 300 feet in thickness; see how two or three streams have flowed side by side, and at places have flowed one over the other; see the clear demarcation of each stream by the vesicular layer on its summit where the up-struggling bubbles of steam have been caught: remember that this, the largest lava-stream in the world, has been formed beneath the sea in the dead ages, and has fought its slow way onwards against the resisting pressure of huge water-masses, and here once again you will have borne in upon your mind that this is in truth the continent of wonders.

(*e.*) The absence of extensive shell deposits in the South America of to-day. The fortunate unfortunate to whose lot falls the attempt to explain to the many the principles of Evolution is over and over again met with the inquiry: "Where are the missing links?" The believer in the theory of special creation and the man who without any actual belief in any theory as to the origin of the many species of plants and of animals now existing is afraid of Evolution, these alike constantly cry: "You say that the species of the Now are the result of gradual development

from the species of the Then. Where are the forms of living beings that represent the transition stages between the plants and animals now existent and their ancestral forms? " To this ever-repeated question there are replies and replies. In connexion with our present object of study only one of those replies need be quoted: " Lost through the imperfection of the Geological record."

Of old it was thought that every organic being of the dead past, as it became one of the dead past, was preserved in fossil condition to be for a lesson unto man. It was thought that Earth held hidden in her breast all forms that broad and bounteous bosom had ever borne. It was believed that in the rocks were lying the records of all that had lived. Would it were true! The longer Geology is at work the more clearly does it demonstrate that the record of the past preserved to be read by the eager eye of man is but a fragment. Myriads of plants, myriads of animals have been born, have lived and have passed away, whose very structure has been of such nature that their preservation in the museum of the rocks was impossible. Again, years, centuries, cycles, æons have passed during which the earth-conditions were such that no possibility was of the storing-up of such living things as had structure that admitted of preservation. The naturalist who has most clearly demonstrated this all-important fact is Charles Darwin. The 10th chapter of the " Origin of Species " is devoted to the Imperfection of the Geological Record. Those who are interested in the study of rudimentary, of embryonic forms, those who like to see the germ of new thought and to compare it with its fuller, riper growth will do well to compare the thoughts on the absence of shell-deposits in South America in the volume we now investigate with the 10th chapter of the great book.

The sub-division of the Kingdom Animalia whereof the Cuttle-fish, Snail, Oyster are types, with its soft-bodied, shell-clad animals is known as the sub-kingdom Mollusca. It is known that Mollusca live within a sea-depth of 100 fathoms: that the number and variety of Mollusca existing at the present day upon the coast of America is very great: that in geological periods not very remote, as the history of this old, old earth goes, there was enough and to spare of the sediment needed for the preservation

of Molluscan remains. And yet, the vast deposits upon the South American coast are very nearly devoid of Molluscan shells. Let us, following our master, try to understand how this state of things came about.

First, it is clear that if any deposit is to remain as a record of the past it must be of great extent and of great longevity. It must have been accumulating during a vast space of time, for its thickness represents the amount of sinking of the neighboring land. And in the special case under consideration matters are intensified, for these creatures live not in depths greater than 100 fathoms. Hence only to the margins of slow-building formations can shells of Mollusca be added.

Next, let us consider what are the conditions that determine the size of the shell-bearing zone, whether it shall be large or small. Charles Darwin has shown that everything depends upon the relative condition of the bed of the sea, during the deposition of the shells. The bed of the sea may be still, the bed of the sea may rise, the bed of the sea may fall. Hence three cases may present themselves. (i.) Where the floor of the sea whereon the shells are being deposited is through long time at rest. Clearly in this case the shell layers can only accumulate to a thickness equal to the maximum depth within which the shell-formers can live, *i.e.*, to a thickness of not more than 100 fathoms. Such layers could only form to any great width upon very gently sloping coasts. So shallow would the sea be that the water pressure upon the rocks formed out of the shells would be very slight and the consolidation of the rocks but feeble. In this first case therefore the best conditions for obtaining the maximum of shell-bearing formation do not exist. The formation would be small in extent, and when raised into dry land would afford but little resistance to the denudating action of the sea-waves. (ii.) When the floor of the sea whereon the shells are being deposited is through long time slowly rising. Slow but persistent upheaval occurs. This is the condition that Charles Darwin has shown to have obtained in byegone times on the shores of South America. This case resembles case (i.) in the main, adding, however, to the difficulties in the way of shell-bearing deposit under case (i.) the fact that the shells would have to undergo the ordeal of the beach. The tendency of the beach-waves

is to wear down and disperse all things exposed to their action. (iii.) Where the floor of the sea whereon the shells are being deposited is through long time slowly sinking. Here at last we have the best conditions for the formation of shell-bearing deposits. The sea is slowly encroaching upon the land, and the land thus conquered is forming a shell-bed beneath the waters. The shell-bed is constantly pushed slowly out seawards, is constantly renewed upon its shoreward edge. Here thickness of far more than 100 fathoms is possible. Here extent even of many miles is possible. Here hardness that can resist wave-action is possible. In short, here are the best conditions for the formation of shell-bearing deposits. But here are *not* the conditions met with on the coast of South America, or indeed for the most part anywhere upon earth. Therefore organic remains, at least of this particular kind, will not be preserved.

The old idea that wherever sediment is falling present life is undergoing preservation for future observation must therefore be abandoned. Three essentials are each of rare occurrence and the conjunction of the three most rare. They are long continued supply of sediment, an extensive shallow area, the slow subsidence of this area to a great depth. To quote our author: "In how few parts of the world probably do these conditions at the present day concur." Looking at the shore of the continent of America as it is to-day, Charles Darwin sees that but a little while hence those who live upon this earth will find no more record of the shells of our time than we can find of those of the recent past, unless the existing conditions of coast-elevation be altered. And yet the series of shells is incalculable in number and is of a nature peculiar to South America. In the hereafter a huge gap will be in the series of organic forms, due to the non-preservation of these South American Mollusca of to-day.

It is impossible for the earnest student of Charles Darwin's works to leave this subject without a word upon the result of these suggestions to scientific thinkers. It would indeed be a distinct omission upon the part of one who strives, unworthily enough, to point out in some measure the nature of the genius of this remarkable man. These suggestions as to the imperfection of the geological record were pub-

lished in 1846. To-day they form part of the accepted creed of scientific thinkers. Only thirty-four years and the man who produced the new thought still amongst us! To those who know how very, very slow is the comprehension and extension of new ideas that overthrow a score of antique notions and remorselessly slay a hundred old-fashioned, orthodox, eminently respectable falsities; to those who remember how few of the great have beheld with their own patient eyes their own greatness in some faint degree recognised during their own lives, their own thoughts accepted as true guide by the thoughtful, assuredly there is cause for comfort here.

The arguments of the tenth chapter of the "Origin of Species" would now be questioned by no competent geologist. Now-a-days one reads with a half-smile the quotation from Professor H. D. Rogers and the solemn, diffident way wherein Charles Darwin utters his criticism thereanent. Professor Rogers, addressing the American Association of Geologists had said: "I question if we are at all aware how completely the whole history of all departed time lies indelibly recorded with the amplest minuteness of detail in the successive sediments of the globe, how effectually in other words every period of time has written its own history, carefully preserving every created form and every trace of action." Very gravely, with that gentle doubt of his own power of reasoning that is always the accompaniment of his genius, Charles Darwin replies; "I think the correctness of such remarks is more than doubtful." And multitudes of thinkers set a-thinking by his words have so observed, reflected and spoken that it is to-day for an assured thing that the history of the dead years is in no sense completely recorded and that there have been, alas! long periods of time when living forms rose into being and passed away into the mineral products of their decay, leaving no vestige of a trace of what they were during their life-journey.

(*f.*) The Structure of the Cordilleras. Of the great topics considered by Charles Darwin in this the second of his purely geological works, the last and not the least interesting is the structure of the vast mountain chains known as the Cordilleras. The Andes run uninterruptedly through South America from north to south. They are always close to the western coast of the continent. So near are they

to the Pacific waves in Southern Chili and in Patagonia that their rugged heights are the sea cliffs. One hundred miles is the greatest distance they are ever found inland. This occurs about the middle of Chili. Save in the south the Andes form for the most part a double range, or even in some regions a triple one, and between the lines of mountains stretch long valleys. Thus at about 19° S. latitude the range is double. Between its two divisions, at the height of 13,000 feet, lies a large table-land embosoming a lake. The mountain boundaries of this table-land are the Cordilleras or girdles, lying east and west and moving into each other once again at 13° S. Volcanoes are many and busy in the Cordilleras. There is food therefore for reflexion in the structure of these huge ranges. Of old the belief was that their origin was wholly cataclysmic: that the giants were cast skywards in one paroxysmal throe of earth's agony. It will be found that our great teacher, after patient observation and patient reflexion has arrived at a conclusion other than this. Once more he is upon the side of gentle and long combined action rather than upon that of the forcible and the sudden.

(i.) Facts. The observations of Charles Darwin were in the main conducted upon two of the passes that seam the Cordilleras. These twain were the Peuquenes or Portillo pass and the Cumbre or Uspallata pass. Both of these lie in the region of South America between Santiago and Mendoza. The Peuquenes range in the one pass and the Cumbre in the other are to the west and nearer the sea. The Portillo range in the one and the Uspallata in the other are to the east and lie more inland. Crossing the Cordilleras by these two passes Charles Darwin observed accurately the structure of the mountain ranges. He gives record of his observations thus. The lower layers of rock are partly of the kind known as igneous or Plutonic as opposed to sedimentary or Neptunian. That is, they have been formed by the sudden action of volcanic agency, not by slow deposit of material from suspension in water. With these are associated clay-slate and other rocks. Overlying these basal strata of the Cordilleras are great masses and thick layers of the rocks known as porphyries. Intercalated with these are layers of slaty rock that all evidence shows were once on a time so many layers of mud. Above these again are the rocks

named by our naturalist the gypseous formation. This formation presents a series of rocks fairly well supplied with fossils. The rocks are at times of sand structure, at times give indication of formation from materials of volcanic origin, but most frequently are of chalk. Vast deposits of gypsum, one form of calcium sulphate, form a characteristic feature of this part of the Cordilleras, point to its origin in the vicinity of volcanic disturbances, and give it the name mentioned above. These three chief regions of rock, the igneous and the clay slate, the porphyries and the slates, the gypseous formation are encountered in both the passes and would seem to be characteristic of the whole length and breadth of the Andes.

When it is borne in mind that the very summits of the highest mountains are of the gypseous formation, and that the summits of the less lofty parts of the range also present this structure, it would be expected that the strata have been tilted and twisted in a myriad different ways. Such expectation would be realised. Finally, subsequently to the period of the formation of the gypsum deposits an immense mass of conglomerate was formed, filling up the valley that lies between the western and the eastern range of mountains in the Peuquenes Pass, whilst in its fellow pass, between the Cumbre and the Uspallata chains, trees buried but still upright bear witness to changes of level of many thousand feet.

(ii.) Theories. After this array of facts that must be, I fear, to the non-technical reader rather uninteresting, let us ask what explanations have been suggested as to the structure of this gigantic mountain-range. There is first the old view hinted at above, that the Cordilleras are the result of one huge upheaval of rock. But Charles Darwin is a sore disperser of old theories, forasmuch as he has a rare power of observing facts and the rarer power of reflecting upon them until some general truth dawns upon him: a truth new to the world of thought until he has enunciated it—a truth old often as the world that has been waiting these many ages to be first seen of these deep-searching eyes. Opposed, therefore, to the old cataclysmic view is the second explanation that is found in the book now under discussion.

The Darwinian view as to the origin of the great mountain system is as follows. The basal igneous rocks though

volcanic in origin were formed beneath the waves of the sea. On to the bed of this ancient sea from many an orifice of eruption beneath the waters was ejected a mighty flood of porphyritic fluid that became anon solid rock. This flood has stretched multitudes of miles in extent, and in central Chili is more than a mile in thickness. That it was ejected at very great depths below the surface of the sea seems more than probable. Finally, when the eruptions producing these rocks had nearly or quite ceased, from the sea-water was deposited as a sediment the gypseous formation. In the words of Darwin himself: "If we picture to ourselves the bottom of the sea rendered uneven in an extreme degree with numerous craters, some few occasionally in eruption, but the greater number in the state of solfataras, discharging calcareous (chalky), silicious (flint), ferruginous matter (matter containing iron), with sulphuric acid to an extent surpassing perhaps even the existing sulphurous volcanoes of Java, we shall probably understand the circumstances under which this singular pile of varying strata was accumulated. The shells appear to have lived at the quiescent periods when only limestone or calcareo-argillaceous matter (chalk and clay) was depositing."

A period of subsidence over an area at least 400 miles in length, probably of far greater extent, now occurred. This is indicated by the presence in certain places of strata 7,000 feet in thickness capping the gypsum formation over a long range of miles. Elsewhere during this time upheaval had taken place and certain islands of granite, notably in the neighborhood of Copiapo, had emerged from the sea and upon them were growing fir-trees.

Next came upheaval following upon the subsidence, and the Cumbre and Peuquenes ranges came into being. Again was this upheaval succeeded by a slow subsidence. Of this last movement proofs are found in the trees buried in an upright position at Uspallata, buried formerly under thousands of feet of strata in the conglomerate of the valleys thousands of feet in thickness, yet in structure and in its fossils giving clear proof of having been formed in shallow water.

Finally there is strong evidence showing that at the beginning of the Tertiary period the South American continent stood at about its present height out of the sea and

then for the third time slowly subsided several hundred feet to be once more raised to its present level.

It can thus be seen how opposed is this complicated history of series of changes slowly effected to the view that regards this great mountain system as formed at one blow. And further, remembering how many have been these changes, through what long series of years each of them was at work, we have once more borne in upon us the fact of the stupendous age of earth. And let it not be forgotten that this era of mountain formation is not yet completed.

Truly is this the continent of wonders. Think only of the main points it has been considered well to consider here: remember that these are but a selected few out of many, and you will agree with the writer whom we are studying, that "in South America everything has taken place on a grand scale, and all geological phænomena are still in active operation. . . . . I know not whether the spectacle of its immense valleys, with mountain-masses of once liquified and intrusive rocks now bored and intersected, or whether the view of those plains, composed of shingle and sediment hence derived, which stretch to the borders of the Atlantic Ocean, is best adapted to excite our astonishment at the amount of wear and tear which these mountains have undergone."