ART. III. *Geological Observations made during the Voyage of H.M.S. Beagle.* By CHARLES DARWIN, M.A., F.R.S., &c. Part I. *On Coral Reefs.* — Part II. *On the Volcanic Islands of the Atlantic and Pacific Oceans.* — Part III. *On the Geology of South America.* London: Smith, Elder & Co. 1846.

THE most undeniable proof of the progress of geology, and of the advances it has recently made, is furnished by the class of questions that now especially engage the attention of inquirers. The period is not long past when this science was nothing more than a kind of cosmogony—a fanciful theory regarding the creation of the world, supported by a few ill-understood natural phenomena, or some passages of Scripture, often as much perverted from their right meaning. The true aim of geological inquiry, and the limits within which its speculations must of necessity be confined, were wholly forgotten, and when a few more sober-thinking men ventured to point them out, they were answered by accusations of atheism and irreligion. The *wild* theories of Burnet and Buffon were regarded with more favour than the philosophic affirmation of Hutton and his followers, that creation, being an event altogether of a peculiar nature, could not be brought about or explained by any of the existing physical laws, intended solely for the preservation of the system. The geologists of that time were unwilling to renounce the splendid visions of worlds struck from the fiery mass of *the sun* by the tail of some erratic comet, or of universal formations deposited from a fabled chaos, for the unpoetic belief in the regular order of nature, and the laborious study of rocks and minerals, or the humble and apparently uninteresting task of observing the methods in which nature now operates on the globe.

But this view of the aim and limits of geological inquiry seems at length to have attained the ascendancy; in a great measure, we believe, from the popular manner in which it has been expounded in the works of Mr. Lyell. All geologists of any name are now agreed that in order to understand this science, we must study nature, not in books and theories of the earth, but in mines and quarries, on the sea-shore, in the river bed, and the mountain ravine. No one now, like a celebrated writer in the beginning of the present century, would claim the confidence of the public to his theories of the former history of the earth, on the ground that he possessed no personal or practical knowledge *of* its actual structure to mislead him. The principle, that the only key to the ancient revolutions of the globe must be sought in existing laws and agents, is now generally admitted, and must

form a new era in the history of the science. Hence has arisen a more powerful impulse to study nature in all her various departments, to observe the changes now proceeding on the earth, and to understand the causes by which its surface is modified. Hence the high value now ascribed to accurate and minute descriptions of the phenomena of earthquakes and volcanos, of the rising and sinking of the land, of the ravages occasioned by floods or storms, of the distribution and motion of glaciers and icebergs, of the powers of these, or of rivers, waves, and currents, to move and transport stones, of the formation of peat, the growth of coral-reefs, of the geography of plants and animals, and many other similar subjects. But geology, by thus extending the field of its inquiries, has gained much in real importance and interest. From a dry catalogue of rocks and minerals, arranged according to some artificial system, or a list of harsh names of extinct plants and animals, it has become a living picture of the world as it actually exists, and of the powers and laws by which it is regulated. Geology is no longer an unreal fantastic hypothesis, but the history of events, in whose consequences all are interested, and of revolutions in which every one may be involved. It may, indeed, no longer presume to tell the way in which universal nature sprung into being at the word of Omnipotence, but rejoices when, by the careful study of existing things, it can interpret the wondrous chronicle of the past, inscribed in unfading characters on plain and mountain, on the surface of the earth and in its rocky strata, and when, from the wisdom and beneficence everywhere displayed in the structure and former history of the globe, it is enabled to look forward with humble confidence to all the changes and revolutions to which it may yet be subjected.

The works named at the commencement of this article are very favourable specimens of the new direction assumed by geological research. They are principally occupied with formations and discussions, which only a few years ago filled a very small space in treatises on systematic geology, and were generally thought to have little direct bearing on those mighty revolutions which the earth in former ages has undoubtedly undergone. The author is a grandson of Dr. Darwin, well known in the beginning of the present century, as a poet and speculator on philosophic subjects. When Captain Fitzroy was about to sail, in 1831, to complete the survey of the southern coasts of America, Mr. Darwin volunteered to accompany him as naturalist, and having remained with the ship until its return to England, in 1836, enjoyed many opportunities of examining countries seldom visited by scientific travellers. As his delightful journal and the

present volumes show, he made good use of his time, landing wherever it was possible, and then plying his hammer and pick-axe in good earnest, 'notwithstanding the smiles of his shipmates 'at the cargoes of apparent rubbish which he frequently brought 'on board.' This 'rubbish,' however, as we shall afterwards find, proved to be the remains of some most interesting extinct animals, remarkable not only for their peculiar forms, but for the recent period at which the species have perished.

The first of the volumes named, describes those most singular formations, the coral reefs of the Pacific ocean. These remarkable productions have attracted great notice from the time when they were made known to the western world in the voyages of the old buccaneers, who found the calm waters of the lagoon islands most convenient places for refitting their ships and dividing their spoil. The attention bestowed on them is, as Mr. Darwin remarks, 'not surprising, for every one must be struck with astonishment, 'when he first beholds one of those vast rings of coral rock, often 'many leagues in diameter, here and there surmounted by a low 'verdant island, with dazzling white shores, bathed on the out-'side by the foaming breakers of the ocean, and on the inside 'surrounding a calm expanse of water, which, from reflection, 'is of a bright, but pale green colour. The naturalist will feel this 'astonishment more deeply, after having examined the soft and 'almost gelatinous bodies of these apparently insignificant 'creatures, and when he knows that the solid reef increases 'only on the outer edge, which day and night is lashed by the 'breakers of an ocean never at rest.' These circular groups of coral-islands are named 'atolls' by the natives, a term now adopted into scientific language. From them Mr. Darwin distinguishes barrier-reefs, either encircling small islands, which rise up like a mountain summit in the centre of the lagoon, or extend for many hundred miles along the shores of Australia and New Caledonia, and also fringing-reefs, lying close to the shore, from which they are *not* separated by a broad channel of deep water. Mr. Darwin gives a detailed account of each of these varieties, from which we shall select a few of the more interesting particulars, which can be understood by our readers without reference to his plates and charts.

The extract above gives a good general idea of one of the smaller and more regular atoll or lagoon islands, consisting of a simple elongated ring of coral, rising in some parts into low islands covered by cocoa-nut trees, in others intersected by deep channels. The greater number are from less than one mile to about thirty miles in diameter, but a few attain considerably larger dimensions, as Vliegen atoll, in the Low Archipelago, sixty miles

long, and twenty broad, and one in the Marshall group of islands, is fifty-four long, and twenty wide at the broadest part of its irregular outline; whilst another, Menchioff island, is sixty miles long, and consists of three loops tied together by linear reefs. The average width of the annular reef is about a quarter of a mile, and in the islands surveyed by Captain Beechey, in no instance exceeded half a mile. The islets are first formed some way back, either on the projecting angular points of the reef, or on the sides of the main entrances into the lagoon, as if placed for beacons to point out the gateway into the inclosure. How very small the total area of the reef and land is in islands of this class, appears from a remark of Lutke, 'that if the forty-three rings or atolls in the 'Caroline Archipelago, were put one within another, and over a 'steeple in the centre of St. Petersburg, the whole would not cover 'that city and its suburbs.'

The structure of these reefs is in general very uniform. Keeling or Cocos atoll, situated in the Indian ocean, in 12° 5′ south latitude, and long. 90° 55′ E. is described by the author as characteristic of the structure of the whole class with some few peculiarities. The reef-building polypifers, the animals that erect the wondrous structure, can only exist where constantly submerged or washed by the breakers, and a very short exposure to the rays of the sun invariably causes their destruction. Hence they are only found alive on the outer margin of the reef, which it requires the most favourable circumstances of a low tide and calm water to reach. Mr. Darwin succeeded only twice in gaining this part, and found it almost entirely composed of a living porites, growing up in great irregularly rounded masses, from four to eight feet broad, and little less in thickness. These mounds are separated from each other by narrow crooked channels about six feet deep. On the furthest point he was able to reach, by the aid of a leaping pole, and over which the sea broke with some violence, although the day was quite calm and the tide low, the animals in the uppermost cells were all dead, but three or four inches lower they were living and formed a projecting border. The coral, thus checked in its upward growth, extends laterally, and further inwards forms masses with broad, flat, dead summits, whilst during the recoil of the breakers, he could see, that a few yards further seaward, the whole convex surface of the porites was alive. And what a mass of life it presents, we may learn from an estimate of Mr. Dana, the naturalist who accompanied the recent American expedition of discovery. This gentleman states, that in a porites dome, twelve feet in diameter, each animal was under a line in breadth, and 'there are here consequently 'five millions and a half mouths and stomachs to a single

'zoophyte, contributing together to the growth of the mass, by 'eating, and growing, and budding.'* Next in importance to the porites, is a species of millepore, which grows in thick vertical plates, intersecting each other at various angles, thus producing an exceedingly strong, honey-combed mass, which generally affects a circular form, the marginal plates only being alive. In the interstices and crevices of the reef a multitude of branching zoophytes and other productions flourish, but the two species mentioned alone seem able to resist the fury of the breakers on its upper and outer edge.

For one or two hundred yards from the outer margin of the reef at Keeling atoll the water deepened very gradually to twenty-five fathoms, but beyond this the sides plunged into the unfathomable ocean at an angle of 45°, and at a distance of 2,200 yards from the breakers, Captain Fitzroy found no bottom with a line of 7,200 feet in length. To the depth of ten or twelve fathoms, the bottom is exceedingly rugged, and formed of great masses of living coral; from twelve to twenty fathoms it seems composed partly of coral, partly of sand, and at still greater depths the soundings showed only sand, though the sudden increase of depth at certain points, and the circumstance of the line having been cut, as if rubbed, indicate the probable existence of submarine cliffs.

Close within the line of dead coral three species of nullipora flourish. These organic bodies were at one time regarded as varieties of zoophytes, but De Blainville and others now reject them from the animal kingdom. One species grows in thin sheets like a lichen on old trees; the second in stony knobs, as thick as a man's finger, radiating from a common centre; and the third, which is less common, and of a beautiful bright peach-blossom colour, in a mass-like reticulation of thin, but perfectly rigid branches. These nulliporæ require to be bathed during the greater part of each tide by breaking water, and hence merely fringe the reef for a space of about twenty yards in width, in a layer formed by their successive growth, two or three feet in thickness. Within this natural breakwater, is a 'flat' of naked stone, composed of the mounds of coral, with the channels and hollows filled up with cemented fragments, converting its surface into a hard smooth floor, like an artificial one of freestone. At high tide the sea breaks entirely over this surface, and the water carried into the lagoon again flows out through the main entrance. It is on this reef, from two to three hundred yards from its outer edge, that the islets have been formed by the accumulation of a pile of fragments thrown together by some unusually strong gale.

* United States Exploring Exped., volume on Zoophytes, by J. S. Dana, p. 60.

They are, in general, from six to ten feet high above ordinary high-water mark, and under a quarter of a mile broad, though occasionally several miles long. According to Captain Fitzroy,* 'these islets are mere skeletons—little better than coral reefs, 'on which broken coral and dust have been driven by sea and 'wind, till enough has been accumulated to afford place and 'nourishment for thousands of cocoa-palms.' The Keeling islands were discovered in 1608, but seem to have been uninhabited till 1826, when they were taken possession of by an Englishman with a small party of Malay slaves, and a seraglio of Malay women. In consequence of his harsh treatment, his dependents revolted, and he was driven from the islands, when the Malays placed themselves under the protection of two other Englishmen who had fixed their abode in the same remote situation. This curious colony were all found living in one house, but the Europeans still treated the Indians very much like slaves. These small islands are distinguished by some other peculiarities, scarcely less remarkable than their social condition. The crabs eat cocoa nuts, boring a hole through the shell with one of their claws; the fish eat coral, and the dogs hunt fish in the shallow water on the reef; the men ride on turtle, and the shells (the gigantic chama,) are dangerous man-traps; the greater part of the sea-fowl roost on branches, and many of the rats make their nests at the top of high palm-trees.†

Returning from this digression to our more immediate subject, the coral reefs, the only part to be described is the lagoon. In Keeling atoll this is much shallower than that of most atolls of large size. A great part of it is almost filled with banks of mud and fields of coral both dead and alive. Large portions of it are, however, from three to four fathoms, and some small basins from eight to ten fathoms deep. In other atolls the depth of the lagoon is from twenty to thirty-eight fathoms, and in the Maldiva group there are large spaces with forty-five and some even forty-nine fathoms water. The bottom is generally filled with fine clay or soft calcareous mud resembling disintegrated chalk or fine sand. This mud is partly formed by the action of the surf on the rolled fragments, partly by a more remarkable and unexpected agency. There are large shoals of two species of fish, one living inside, the other outside of the lagoon, that subsist entirely by browsing on the living polypifers. The stomachs of these fish when examined were found distended by small fragments of coral and finely ground calcareous matter. Numerous worms and molluscs also perforate the coral in every direction; and much of it is consumed by the holothuriæ, which

* Voy. of the Beagle, vol. ii. p. 630.
† Capt. Fitzroy Voy. of Beagle, vol. ii. p. 631—635.

swarm on every part of the reefs in extraordinary numbers, so that many ship-loads of one species, the trepang, are every year freighted for China. These several creatures thus annually destroy and grind down into the finest mud an immense amount of coral, forming living checks to the growth of the reefs, and showing, as Mr. Darwin says, 'that the almost universal law of consume and be consumed,' holds good even with the polypifers forming those massive bulwarks, which are able to withstand the force of the open ocean.' The mud thus produced with the growth of the coral tends, though exceeding slowly, to fill up the lagoon; but as the reefs cannot possibly rise above the level of the lowest spring tide, its final conversion into land must be due to the accumulation of sediment. Both the reef and the islands on it grow most rapidly on the windward side, whilst the channels by which a ship can enter the lagoon, well compared to notches in the rim of the saucer-shaped hollow, are found on the leeward side. There are seldom more than two or three, generally only one such channel, which is kept open by the discharge of water thrown over the reef in other places.

The Maldiva archipelago, 470 miles long by about 50 miles in average breadth, lies in the Indian Ocean, a little westward of Cape Comorin. It consists of a double line of atolls, bounded not by linear reefs, but by groups of rings or miniature atolls, of an elongated form, and three to five miles in diameter. Other smaller ring-formed reefs rise up in the lagoon, which differ in nothing from the true atolls in the open sea, except in their position and mode of grouping on one large platform, with the marginal rings arranged in a rudely formed circle. These islands thus make up a compound group of atolls of very singular structure—'a great sandy and generally concave disk rises abruptly from the 'unfathomable ocean, with its central expanse studded, and its 'border symmetrically fringed with oval basins of coral rock, 'just lipping the surface of the sea, sometimes clothed with vege-'tation, and each containing a little lake of clear water.'

The barrier reefs differ in no respect from these atolls, except in the high land rising from within their central expanse. The land thus inclosed is of various formations, and rises to very different heights, as Tahiti to seven thousand, Manouai only to fifty feet. To the same class belong the barrier reef on the west coast of New Caledonia, 400 miles long and frequently eight to sixteen miles from the shore. A still more enormous formation is the Australian barrier, which extends, with a few interruptions, for nearly a thousand miles along the north-east coast of that continent. It incloses a great arm of the sea, on an average twenty to thirty, but in many places fifty to seventy miles wide,

and generally from ten to twenty-five fathoms deep, but increasing on the south to forty and in some parts to more than sixty fathoms deep. The reef consists of a hard white agglomerate of different kinds of coral, with rough projecting points, and is traversed by narrow gullies, and in a few parts by ship channels. The sea close outside is profoundly deep, and the thickness of the mass of coral must thus be enormous. We shall not stop to notice the fringing reefs, which differ from those just described in the narrowness and shallowness of the channels, sometimes altogether dry, by which they are divided from the land.

Coral reefs are principally found within the tropics, the Bermuda Islands in 32° 15′ N., being the point furthest from the equator where they are known to exist. It is remarkable, however, that there are certain large areas in the tropical seas where they are entirely absent. Thus none have been found on the west coast of America or in the wide zone of the Pacific within forty-five degrees of latitude from its shore. Though coral reefs are abundant in the West Indies, yet not one has been observed on the west coast of Africa, or in the central expanse of the Atlantic with the exception of Bermuda. This apparently capricious distribution cannot be explained by any obvious cause, such as difference of temperature, to which Mr. Dana ascribes their absence on the west coast of America, or the deficiency of calcareous matter in the ocean. It appears more remarkable, as several species of coral animals have a wide range on both sides of the equator, and one has even been fished up from deep water near the Zetland islands on the north of Scotland. It seems to depend on relations of a very complex nature, which with our present knowledge are quite inexplicable from second causes alone, and thus, in more than one respect, teaches a lesson of high import to the geological speculator. 'Changes,' says Mr. Darwin, 'in the conditions of the sea, not obvious to our 'senses, might destroy all the coral reefs in one area, and cause 'them to appear in another; thus the Pacific or Indian ocean 'might become as barren of coral reefs as the Atlantic now is, 'without our being able to assign any adequate cause for such a 'change.'

The corals composing the reefs are remarkable, not only for the beauty but the variety of their forms, which, from their similarity to some of the most elegant vegetable productions, have procured them the name of zoophytes or animal-plants. In the work formerly referred to, Mr. Dana says, 'The madrepores are 'crowded around in turfy clumps and miniature trees in bloom, or 'imitate spreading leaves and graceful vases filled with flowers; 'while astræas build up among the shrubbery large domes, em-

'bellished with green and purple blossoms, studding the surface 'like gems.' But these, though the best known, are not the only varieties, as the following interesting extract from the same author will show.

'Madrepore shrubs and trees, and the sea-fan and other gorgoniæ, from the West and East Indies, are common in collections. The hemispheres of brain-coral (Meandrina), and also of star-coral (Astræa), are often met with. It is very generally supposed that these are by far the most frequent if not the only shapes presented; but, on the contrary, the varieties are extremely numerous. Some species grow up in the form of large leaves rolled around one another like an open cabbage, and *cabbage-coral* would be no inapt designation for such species. Another foliated kind consists of leaves more crisped and of more delicate texture irregularly clustered—*lettuce-coral* would be a significant name. Each leaf has a surface covered with polyp-flowers, and was formed by the growth and secretion of these polyps. Clustered leaves of the acanthus and oak are at once called to mind by other species; a sprouting asparagus bed by others. The mushroom is here imitated in very many of its fantastic shapes; and other fungi, with mosses and lichens, add to the variety. The vases of flowers are common about the reefs of the Pacific. They stand on a cylindrical base, which is enveloped in flowers when alive, and consist of a network of branches and branchlets, spreading gracefully from a centre, covered above with crowded sprigs of tinted polyps. Besides these, we might describe columns, Hercules' clubs, and various strange shapes, which are like nothing but themselves.'

The principal reef-building polypifers appear to love the surf, and flourish most where freely exposed to the swell of the open sea. They do not seem to form continuous masses where the depth exceeds twenty to thirty fathoms, though detached portions have been found at far greater depths. Some authors affirm that corals only form a layer coating other rocks, from one or two feet to as many yards in thickness, and that their growth is exceedingly slow, their size and form remaining the same for many centuries. Ehrenberg even imagines that certain massive corals, which he saw in the Red Sea, may have been alive in the time of the Pharaohs, and continued to grow ever since. Mr. Darwin, however, adduces facts to show that their growth is far more rapid in favourable circumstances, and that they attain a thickness of an hundred yards, or even more. As they could not grow up from the bottom of a sea of this depth, various theories have been proposed to account for their appearance in the midst of the unfathomable ocean, and also for the circular form of the reef. One of the most popular of these placed them on the summit of volcanic cones, rising up in a living wall from the

rim of the crater. This theory would, however, imply the existence of chains of submarine volcanoes all rising very near to the surface level of the sea, and extending over areas of many thousand square miles,—a supposition so improbable that it is now generally rejected, and the following theory of Mr. Darwin has taken its place.

Mr. Darwin supposes the wide areas of the ocean, where these coral islands occur, to have been slowly subsiding for a long period. Before they began to sink, they were studded with islands of various size and elevation, whose shores were fringed with coral reefs. As the island gradually descends, the living corals, bathed by the surf, grow up to the surface level; and as the water encroaches on the shore, the space between it and the reef becomes gradually wider. In this state the coral forms an encircling barrier reef, with only the summits of the highest mountains at last visible, like islands in the lagoon, and, if the ground continues to descend so slowly, that the upward growth of the coral can keep pace with it, even the mountain tops will at length disappear, and nothing remain save a lagoon surrounded by a reef resembling the island in form, and composed of coral equal, at least, in thickness to the space through which the land has subsided. In this manner all the peculiarities in the structure of atolls may be explained,—their ring-like shape, their occasional union, their grouping as along a mountain chain, and the appearance of submerged and dead reefs, whose myriad artificers having been destroyed, can no longer rise to the surface. By the same theory, the barrier reefs along the coast of Australia and New Caledonia may be accounted for; together with the extension of the latter in the line of the former prolongation of the land. The secondary atolls in the Maldiva group mark the tops of the mountains on which they have grown up before they were finally submerged. On many of the islands supposed to have been thus formed by subsidence, proofs of changes in their external appearance are common, showing a round of decay and renovation, of the last vestiges of land on some, of its first commencement on others, of desolating storms sweeping away some with all their inhabitants, of earthquakes shaking and fissuring others. On the other hand, the shores fenced by fringing reefs have been either stationary or rising of late years; and independent proofs of this fact may be found in beds of upraised corals and sea shells, or even in the testimony of those who have lived in these localities.

This ingenious theory, deduced from the structure of coral islands, opens up some very wide and interesting views in the natural history of the globe. Where land has risen from the

ocean, even in times long anterior to the first records of authentic history, proofs of this fact can usually be obtained from the remains of marine productions left behind, or from other undeniable marks of the former presence of the ocean. But where the land is sinking, no such records remain in places accessible to human investigation. The very completeness of the process sweeps away the proofs of its existence, or hides them in regions where the foot of man can never tread, and the eye of the geologist in vain desires to look. Were any of our present oldest and most thickly-peopled continents to sink down into the ocean, with all their cities, towers, palaces, and temples, with their roads, canals, railways, and other monuments of human art and industry, no trace of their being would remain to the generations who might survive on the earth, and navies might sail over the place where London or Paris now stand, in utter ignorance of the wonders that lay buried below. But in the coral reefs we perceive minute animals, building up monuments more perennial even than the rocky mountains, and perpetuating the memory of continents long after they have perished below the ocean waves. Even somewhat of the form and dimensions of these continents is thus preserved, and the lines of coral islands tell of the direction its mountain chains may have followed. This appears in the chart of these islands, which Mr. Darwin gives in his interesting volume, in which the various kinds of reefs are distinguished by colours, so far as the notices of navigators, often very imperfect, would allow. On the same chart Mr. Darwin has marked the various volcanic vents in the same region, known to have been in activity in historical times. It is singular to observe how the blue colour marking the region of subsidence, separates from the shades of red, designating the upraised fringing reefs and burning volcanos; and with fuller information, it is probable the distinction would be still more complete. If a straight or slightly curved line be drawn from the equator, north of New Zealand, in a west-south-west direction, to near the Gambier islands, it will mark the limits of a region of subsidence on the north, of elevation on the south. The islands in the latter, as Mr. Dana has remarked, are generally very high, and consist of basaltic formations; all those on the north, with one or two exceptions, are composed of pure coral. Near the boundary also the islands are larger and more numerous than to the north, whilst from the equator to the Sandwich islands, there is a vast expanse of ocean, scarce broken by a solitary rock. In this wide vacant space subsidence must have been too rapid for the coral architects to keep pace with the rising water, and they with their works have been buried in the ocean. Nearer the above line,—the pivot on which the earth's crust has

turned,—the slower motion has enabled them to maintain the land on the level of the sea, and islands are numerous; whilst farther south the reefs have been carried upwards with the foundation of rock on which they are erected. It is singular to observe how numerous burning volcanos accompany the line of upraised reefs and islands, the power which has forced up this region being seldom far to seek. From the Friendly Islands and New Hebrides, a chain of volcanos runs by New Guinea and the Spice islands, through Timor, Java, and Sumatra, to the Indian coast near Pondicherry. The China sea is another region of subsidence, bounded on the east by the volcanic band of the Philippines, which extends by Loo Choo and Japan, to Kamtschatcka, where it turns east to unite with the magnificent group that burst forth at intervals along the line of the Andes. The whole shores of the Pacific, wherever marks of elevation appear, are thus fringed by an immense circle of burning cones, leaving a wide area in the centre, where, except in the Sandwich Islands, no volcano is known to exist. It is curious, that in the West Indies, where there are several volcanos, and the land seems generally rising, though the coral building zoophytes abound, no lagoon islands occur, but only fringing reefs.

The extent of the area thus subsiding cannot of course be accurately known. Mr. Darwin estimates it as a great band having a length of 4000 miles by 600 broad; whilst Mr. Dana extends it to 5000 miles of longitude by 3000 of latitude, a space of fifteen million square miles, or a thirteenth of the whole surface of the globe. This will appear less remarkable, when we remember that the Lisbon earthquake of 1755 was felt over an equal extent, and that the continent of Asia contains a considerably larger space. But if the land is sinking in one place, it must undoubtedly be rising in another. No such vast depression of the earth's surface could long proceed without making itself known, and in quarters where it might be least expected. Laplace, in discussing the question of the secular refrigeration of the globe, has shown that a diminution of its radius by an hundred thousandth part, or a little more than 200 feet, would have sensibly shortened the day, whilst the observations of the Grecian astronomers prove that it has not varied even by the hundredth part of a second for the last twenty centuries. Here, then, is demonstrative proof that the earth must be rising in other quarters so as to compensate for its depression in this. One part of this compensatory elevation is, as we have seen, taking place in the southern ocean, but we have little doubt that a still more efficacious portion will be found in the great continent of South America—forming, as it were, the other end of the lever, the rising-

scale in the great cosmical balance. It is on this account that we consider the first and last of Mr. Darwin's works, mentioned above, wholly disconnected as they may at first seem, as yet most intimately related, and the one nothing more than an essential complement to the other.

The continent of South America contains about seven million square miles of land, or twice the area of Europe. The western border is covered by the lofty wide-spread mountain ridges of the Andes, crowned, even in the tropics, with perpetual snow, from amidst which the ever-burning fires of the volcano burst forth. No mountain chain on the globe is, perhaps, in all respects equal to this of the Cordilleras. Including its continuation in North America, it stretches from north to south for 8500 miles, spreading over a third of the continent. Though some summits in the Hymalayah surpass it in height, yet they rise from the centre of a vast continent, whereas the snowy peaks of the Andes look down on the wide Pacific which washes their immediate base. Towards the east, too, they overlook an expanse of level country unrivalled on the globe. Humboldt* has estimated that the Pampas of the Rio de la Plata and Patagonia alone cover above a million and a half square miles, or eight times the whole surface of France. It is to this vast region that the observations of Mr. Darwin principally apply, and a few notices of its peculiar appearance may not be uninteresting to our readers.

The valley of the Amazon river, equal in area to the whole European continent, watered by the frequent rains brought up by the trade winds from the Atlantic, is hid by a dense forest of palms and large dicotyledons, woven together by a thick mass of twining plants, bearing large beautiful flowers. In the valley of the La Plata on the south, the forests almost disappear, and the plains are covered only by grass or other herbaceous plants. In its northern portions, where it yet feels the influence of the warm suns and moist winds of the tropics, a rich vegetation of lofty grasses furnishes food for innumerable herds of wild cattle and troops of horses. In some places, marshes or swampy ground, in others, extensive shallow lakes and large beds of reeds, and in others again, salinas, in the winter full of briny water, in summer a level field of brilliant snow-white salt, break the uniformity of the grassy plains. Sometimes many square miles are covered by one mass of the prickly cardoon,—a descendant of the European artichoke, run wild in this new country—impenetrable to man or beast, and destroying all other vegetation. In other spots, great beds of a giant thistle, with variegated leaves,

* Asie Centrale, tom. iii. p. 196.

spring up higher than a man on horseback, and being only traversed by a few tracks, as intricate as those in a labyrinth, form a safe retreat to bands of robbers. 'In summer,' says Sir Francis Head, in his amusing journal, 'the whole region becomes a luxu-
'riant wood of enormous thistles, which have suddenly shot up to
'a height of ten or eleven feet, and are all in full bloom. The
'road or path is hemmed in on both sides; the view is completely
'obstructed; not an animal is to be seen; and the stems of the
'thistles are so close to each other, and so strong, that, indepen-
'dently of the prickles with which they are armed, they form an
'impenetrable barrier.' South of the Colarado, the great Patagonian plains have a different aspect. The greater part consists of saline, stony steppes supporting a miserable vegetation, or a large sand-desert, interspersed with morasses and shallow salt lakes, expressively described by the Indians by the name Huecuvu-mapu, or the Devil's country. Mr. Darwin says, 'The
'complete similarity of the productions throughout Patagonia, is
'one of its most striking characters. The level plains of arid
'shingle support the same stunted and dwarf plants; and in the
'valleys the same thorn-bearing bushes grow. Everywhere we
'see the same birds and insects. Even the very banks of the
'river (the Santa Cruz), and of the clear streamlets which en-
'tered it, were scarcely enlivened by a brighter tint of green.
'The curse of sterility is on the land, and the water flowing over
'a bed of pebbles partakes of the same curse.'

Such are the external features of the land whose geology occupies the third part of Mr. Darwin's 'Researches.' Its peculiar aspect is there shown to be intimately related to the no less remarkable character of its geological formations, and the revolutions that have successively swept over its surface. We cannot here describe the geological character of the whole continent, the northern and tropical parts of which have been so fully made known by Humboldt and his numerous talented successors. Colombia, Guiana, and Brazil consist chiefly of crystalline schists and older paleozoic rocks, covered in part by newer formations, and broken through by granite, diorite, and other igneous masses, to whose influence Brazil probably owes its rich veins of gold, platina, and iron, the diamonds, topazes, and other gems that fill its rocks. In Peru, these crystalline strata have been raised into lofty plateaux, surmounted by immense domes or bell-shaped masses of trachyte and old volcanic productions. However interesting may be these regions, we must pass on to the southern part of the continent, and to formations of more recent date, to which our author's researches are principally confined. In the course of his wanderings, Mr. Darwin made se-

veral excursions to different points of the vast valley of the La Plata, touched on several parts of the coast of Patagonia, and, in sailing up the Santa Cruz, saw nearly a complete section of that little known country, and twice crossed the chain of the Cordilleras, and has collected many interesting facts regarding each of these three regions. In each of them we find evidence of the elevation of the land, and on an equally majestic scale with the subsidence now taking place, as shown by the coral reefs in the Pacific. Of this fact the third part of Mr. Darwin's researches contains full proof, but our limits will only permit us to glean a few of the more striking particulars.

The plains of Patagonia do not slope gradually up from the shore of the Atlantic to the base of the Cordillera. They are modelled to the height of 950, or in one place 1200 feet, into seven or eight great, step-like, gravel-capped plains, or wide terraces, extending for hundreds of miles, with nearly uniform elevations above the sea. One terrace, about 250 feet above the sea level, has been traced for 750 miles along the coast, and another, an hundred feet higher, for 500 geographical miles from north to south. On these two plains, and on a lower one of an hundred feet, existing littoral shells are abundantly strewed, either on the surface or in a bed of superficial sandy earth. There can be little doubt, therefore, that the sea has been the active agent in moulding out their forms, and that too at no very distant period; and the higher terraces, though no shells occur on them, have in all probability been fashioned in a similar manner. The most remarkable feature in these terraces is the great mass of gravel by which they are covered. At the mouth of the Santa Cruz it is from twenty to thirty-five feet thick, but 110 miles from the coast increases to 212 feet; and Mr. Darwin says, that we may safely assume its average thickness at fifty feet over the whole area of 630 by 200 miles, where it has been observed. The transportal and origin of this vast bed of pebbles is an interesting problem. Mr. Darwin thinks they have come from the westward, from the Cordillera or unknown rocky ridges in the central districts of Patagonia, and been spread out and levelled by the long-continued action of the sea, probably during the slow rise of the land. His theory of the manner in which this has been effected is very curious. From the soundings between the Santa Cruz and Falkland islands, it appears that the pebbles found on the bottom gradually decrease in size as the distance from the shore and the depth of water increase. Three or four miles out, where the water is eleven fathoms deep, they are as large as walnuts; six or seven miles out, at seventeen to nineteen fathoms, the size of hazel nuts; whilst beyond twenty-two

miles, with more than forty-five fathoms water, they are only a tenth of an inch in diameter or fine sand. Hence Mr. Darwin concludes, 'that the sea has the power of sifting and distributing 'the loose matter on its bottom;' but the whole phenomenon seems merely a result of the finer materials being washed away where the water is much disturbed, and remaining where it is deeper and calmer—similar to what may every day be seen in the beds of rivers. According to Playfair, pebbles are not swept along by rapid currents, but, being gently lifted up and down by the undulations of the sea, are moved onwards even by a very small force. By this, or by other means, the great mass of shingle has been spread over the Patagonian plains, and left behind during the gradual elevation of the land. Perhaps more influence ought to be ascribed to the transporting power of ice than Mr. Darwin is willing to allow. The present rounded shape of the pebbles is no objection to this mode of transport, since, even on his own theory, each portion of the land has for a time formed the sea-shore, and the pebbles covering it of course been moved to and fro, and worn by friction. From the step-like outline of the terraces, it might be supposed that the elevation of the land had taken place by several sudden starts, but Mr. Darwin has shown that the facts may all be explained by a slow and gradual rise, interrupted by periods of repose, during which the sea ate deeply into the land.

Beds of recent shells have been found in several parts of the basin of the La Plata, elevated above high-water-mark, showing that the land is also rising thus far to the north. On the west coast Mr. Darwin likewise observed terraces and beds of existing shells. At Callao, the sea-port of Lima, not only shells, coral-lines, and roots of sea-weed occurred in these deposits, but also bones of birds, heads of Indian corn, a piece of woven rushes, and another of decayed cotton string. The plaited rush, the cotton string, the Indian corn, were undistinguishable from similar objects taken from the burial-grounds of the ancient Peruvians. The small quantity of sand or gravel with the shells, the absence of large stones, the width and thickness of the bed, and the time requisite for a ledge to be cut into the sandstone, all show that these remains were not thrown high up by an earthquake-wave: on the other hand, these facts, together with the number of dead shells, and of floating objects, both marine and terrestrial, both natural and human, render it almost certain that they were accumulated on a true beach, since upraised eighty-five feet, and upraised this much since *Indian man inhabited Peru.* Yet in this place there is evidence that the land has subsided since the arrival of the Spaniards, so that the original elevation must have been

'greater.' At Valparaiso, also, in 220 years previous to 1817, 'the rise of the land must have been less than nineteen feet; but 'it has been as much as from ten to eleven in the subsequent 'seventeen years, and of this rise only a part can be attributed 'to the earthquake of 1822, the remainder having been insensible 'and apparently still, in 1834, in progress.'

In summing up the results of his observations on this subject, Mr. Darwin states—

'That recent shells are found on the shores of the Atlantic, from Tierra del Fuego northward, for a space of at least 1180 nautical miles, and at the height of about 100 feet in La Plata, and of 400 feet in Patagonia. The elevatory movements on this side of the continent have been slow; . . . and the periods of denudation (which, judging from the amount of matter removed, must have been long continued) and of elevation were synchronous over surprisingly great lengths of coast. On the shores of the Pacific, upraised shells of recent species, generally, though not always, in the same proportional numbers as in the adjoining sea, have actually been found over a north and south space of 2075 miles, and there is reason to believe that they occur over a space of 2480 miles—a distance equal to that from the Red Sea to the North Cape of Scandinavia. The elevation on this western side of the continent has not been equable; at Valparaiso, within the period during which upraised shells have remained undecayed on the surface, it has been 1300 feet, whilst at Coquimbo, 200 miles northward, it has been within this same period only 252 feet. . . . At Coquimbo, in a height of 364 feet, the elevation has been interrupted by five periods of comparative rest. At several places the land has been lately, or still is, rising both insensibly and by sudden starts of a few feet during earthquake-shocks; this shows that these two kinds of upward movement are intimately connected together. For a space of 775 miles, upraised recent shells are found on the two opposite sides of the continent; and in the southern half of this space, it may be safely inferred—that the entire breadth of the continent has been uplifted.'—pp. 245, 246.

In the basin of the La Plata a wide area, at least two, perhaps five or six times larger than Great Britain, has been covered by a deposit, named from the place where it occurs, the Pampean formation. This consists of a very uniform mass 'of a more or 'less dull reddish, slightly indurated, argillaceous earth or mud, 'often, but not always, including in horizontal lines concretions of 'marl, and frequently passing into a compact marly rock,' named Tosca rock by the natives. From the absence of stratification and the number of embedded remains of terrestrial quadrupeds, M. d'Orbigny considers this formation as produced by a great debacle. But Mr. Darwin observed in it horizontal zones of

colour, and also differences of constitution between the upper and lower portions, which 'appeared to prove that mud differing slightly in composition was successively and quietly deposited.' Mr. Darwin's arguments against the theory of D'Orbigny are of much importance, as applicable not only to this special case, but to the general question of the occurrence of debacles as true causes of geological phenomena. Such sudden torrents of water, sweeping with irresistible violence over whole continents, have always seemed to us inconsistent at once with the physical laws of nature and the geological facts they were conjured up to explain. They may be described as the ultima ratio of geologists, and more an attempt to conceal our own ignorance of the manner in which certain formations have been produced, than a discovery of their veritable causes.

'On the theory of a debacle, (says our author) a prodigious amount of mud, without a single pebble, is supposed to have been borne over the wide surface of the Pampas, when under water; on the other hand, over the whole of Patagonia, the same or another debacle is supposed to have borne nothing but gravel:—assuredly directly opposite effects ought not to be attributed to the same agency. Where, again, could a mass of fine sediment, charged with calcareous matter in a fit state for chemical segregation, and in quantity sufficient to cover an area at least 750 miles long, and 400 miles broad, to a depth of from twenty or thirty feet to an hundred feet, have accumulated ready to be transported by the supposed debacle? To my mind it is little short of demonstration, that a great lapse of time was necessary for the production and deposition of the enormous amount of mud-like matter forming the Pampas.'—p. 98.

Mr. Darwin's own theory is, that this formation was slowly accumulated at the mouth of the former estuary of the La Plata and in the sea adjoining to it; the deposition of the mud being accompanied, at least in the southern part of the Pampas, by an elevatory movement, raising certain portions into dry land, on which the mammiferous animals embedded in other places lived. For the first origin of the reddish mud we must look to 'the 'enormous area of Brazil, consisting, in chief part, of gneissic and 'other granitic rocks, which have suffered decomposition, and 'been converted into a red, gritty, argillaceous mass, to a greater 'depth than in any other country which I have seen.'

Shells have been found in this formation only near Buenos Ayres, in some of the uppermost layers; but in the mud round a tooth of the mastodon, discovered high up the course of the Parana, Professor Ehrenberg observed twenty microscopic organisms, from which he infers that the bottom-most part was of brackish water origin. But the most remarkable remains are

those of extinct mammiferous animals, found in great abundance in the cliffs and steep banks of rivers, though until lately they excited no attention amongst the inhabitants. Among the more remarkable of these remains, are fragments of the skeletons of various extinct species, resembling the present sloths in form and structure, but far exceeding them in size. The sloths feed on the leaves and young twigs of trees, and their whole frame is, as Professor Owen remarks, specially and admirably organized for clinging to the boughs of trees, among which their existence is exclusively spent. But animals approximating to the elephant in size, cannot have sought their food by climbing like their light and diminutive congeners now living. Their whole structure, as the accomplished anatomist just mentioned has proved, is modified to suit another mode of acquiring their proper sustenance. The fore limbs of the mylodon, of which he has restored a complete skeleton, were formed not only for climbing or seizing, but also for grubbing up or digging away soil. The extraordinary size and massive proportions of the hind limbs, at once arrest and astonish the beholder, and imply powers and actions peculiar to the gigantic animals when living. With the strong and powerful tail, they have formed a firm tripod on which the animal might rest when uprooting the trees on which it was about to feed. According to Professor Owen, the mylodon first began by scratching away the soil, and laying bare the roots of the chosen tree, and then grasping the loosened trunk with its fore arms, endeavoured to prostrate it on the ground. 'And now let us picture to ourselves the massive frame of the 'megatherium, convulsed with the mighty wrestling, every 'vibrating fibre reacting on its bony attachment with a force 'which the sharp and strong crests and apophyses loudly be-'speak; extraordinary must have been the strength and pro-'portions of that tree which, rocked to and fro, to right and left, 'in such an embrace, could long withstand the efforts of its 'ponderous assailant.'

Remains of several other allied genera of animals have also been found, which we cannot now describe. Along with them, at Punta Alta, near Bahia Blanca, there was a double piece, about three feet long and two wide, of the bony armour of a large quadruped like the armadillo. Its two sides were pressed nearly close together, and from between them parts of the feet were extracted, and hence one or more of the limbs must have been attached to the dermal case when it was embedded. The tooth of an extinct species of horse also occurred; and another tooth, probably of the macrauchenia, of which more perfect remains were obtained at Port St. Julian, in Patagonia. This animal,

according to Professor Owen, was a gigantic and most extraordinary pachyderm, allied to the palæotherium, found fossil in Europe, but with affinities to the ruminants, especially to the guanaco or llama, and other American representatives of the camel. Several of the vertebral and other bones were found embedded in their proper relative positions; and 'hence the 'skeleton was certainly united by its flesh or ligaments when 'enveloped in the mud.'

Along with these remains, shells of existing species were found at both places. 'Undoubtedly it is a marvellous fact that 'these numerous gigantic quadrupeds, belonging, with the ex-'ception of the equus curvidens, to seven extinct genera, and 'one, namely, the toxodon, not falling into any existing family, 'should have coexisted with molusca, all of which are still living 'species; but analogous facts have been observed in North 'America and Europe. During the late tertiary deposits of 'Britain, an elephant, rhinoceros, and hippopotamus, co-existed 'with many recent land and fresh water shells; and in North 'America we have the best evidence that a mastodon, elephant, 'megatherium, megalonyx, mylodon, an extinct horse and ox, 'likewise co-existed with numerous land, fresh water, and marine 'recent shells.' The same species of the megatherium, megalonyx, and horse, seem even to have extended from the southern United States of North America to the coast of Patagonia. As Mr. Darwin remarks, a similar fact occurs at the Cape of Good Hope at the present day, the elephant and rhinoceros ranging from the equator to latitude 35° south.

'The case of the mastodon andium is one of more difficulty, for it is found from latitude 36° south, over, as I have reason to believe, nearly the whole of Brazil, and up the Cordillera, to regions which, according to M. d'Orbigny, border on perpetual snow, and which are almost destitute of vegetation: undoubtedly the climate of the Cordillera must have been different when the mastodon inhabited it; but we should not forget the case of the Siberian mammoth and rhinoceros, as showing how severe a climate the larger pachydermata can endure; nor overlook the fact of the guanaco ranging, in the present day, over the hot low deserts of Peru, the lofty pinnacles of the Cordillera, and the damp forest-clad land of southern Tierra del Fuego; the puma, also, is found from the equator to the Straits of Magellan, and I have seen its footsteps only a little below the limits of perpetual snow in the Cordillera of Chili.'—p. 105.

Since Mr. Darwin visited America, a very great number of remains of extinct animals, a few of the same species, and several of the same genera with those of the Pampas, have been discovered by MM. Lund and Clausen in caves in Brazil. At

that time, therefore, the two Americas must have swarmed with quadrupeds, many of them of gigantic size.

'If Buffon,' as Mr. Darwin observes, 'had known of these gigantic armadilloes, llamas, great rodents and lost pachydermata, he would have said, with a greater semblance of truth, that the creative force in America had lost its vigour, rather than that it had never possessed such powers. It is impossible to reflect on the changed state of this continent without the deepest astonishment, and without speculating on the causes by which this change has been produced. Formerly, America must have swarmed with great monsters, like the southern parts of Africa, with mastodons, elephants, horses; now we find only the tapir, guanaco, armadillo, and capybara, mere pigmies compared to the antecedent races. The greater number, if not all, of these extinct quadrupeds lived at a very recent period. Since their loss, no very great physical changes can have taken place in the nature of the country. What, then, has exterminated so many living creatures? In the Pampas, the great sepulchre of such remains, there are no signs of violence, but, on the contrary, of the most quiet and scarcely sensible changes. What shall we say of the death of the fossil horse? Did those plains fail in pasture, which afterwards were overrun by thousands and tens of thousands of the successors of the fresh stock introduced with the Spanish colonists? In some countries, we may believe that a number of species, subsequently introduced, by consuming the food of the antecedent races, may have caused their extermination; but we can scarcely credit that the armadillo has devoured the food of the immense megatherium, the capybara of the toxodon, or the guanaco of the camel-like kind. One is tempted to believe in such simple relations as variation of climate and food, or introduction of enemies, or the increased numbers of other species, as the cause of the succession of races. But if they did, they must have been changes common to the whole world, and although scarcely sufficient to affect moluscous animals either in Europe or South America, yet able to destroy many quadrupeds in regions now characterized by frigid, temperate, and warm climates. These cases of extinction forcibly recall the idea (I do not wish to draw any close analogy,) of certain fruit-trees, which, it has been asserted, though grafted on young stems, planted in varied situations, and fertilised by the richest manures, yet, at one period, have all withered away and perished. A fixed and determined length of life has in such cases been given to thousands and thousands of buds, (or individual germs,) although produced in long succession. On such grounds, it does not seem a necessary conclusion that the extinction of species, more than their creation, should exclusively depend on the nature (altered by physical changes,) of their country. All that at present can be said with certainty is, that, as with the individual, so with the species, the hour of life has run its course and is spent.'*

* Darwin Journal, (1st edit.) p. 210—212.

To these remarks of Mr. Darwin, which we have ventured slightly to abridge, we shall only add, that this is one of those instances in which geology almost forces the most unwilling to admit the presence in nature of higher powers and laws than such as are merely physical. The special case, too, is a striking refutation of that theory of development which affirms that the present species of animals have gradually grown up, with ever-increasing powers and capacities, from the simpler races of former ages. Here, on the contrary, the progress has been in the opposite direction; and whilst the powerful giants of the old world have perished from the earth, their weaker contemporaries still survive in their descendants. Among the causes of their extinction, Mr. Darwin does not perhaps allow sufficient weight to the influence of the introduction of man; probably placing it long previous to this event. Yet Dr. Lund has found human bones, and skulls shaped like those of the ancient Peruvians, in the same caves with remains of the megatherium and other extinct species, and affirms that both are of equal antiquity. This discovery has been looked upon with suspicion, as inconsistent with the recent origin of man on the earth—a fact established by geology not less than by history; but, as it seems to us, altogether without reason. The formations in which these remains are entombed are among the most modern on the earth, and no precise date, expressed in years or centuries, can be assigned them. They may easily be supposed to have been formed within the six or eight thousand years during which man has undoubtedly existed on the globe. We should regard this and similar facts, if well established, not as proving the vast antiquity of the human race, but the recent period within which certain species of animals have become extinct. It is always the larger and apparently more powerful animals that first fall victims to the encroachments of man on their native haunts; as in our own island, the wolf and bear have perished, whilst the fox and wild-cat still survive. The mighty proportions of the mylodon, that fitted it to wrestle with the sturdy saplings of the forest, would only render it a more desirable prey, a more easy victim, to a tribe of fierce and hungry savages.

In Patagonia, some very remarkable tertiary formations also occur. One of these is a white pumiceous mudstone, with abundant gypsum, which is certainly continuous along the coast for 230 miles, or, as Mr. Darwin believes, for 570 miles. At Port St. Julian, it is from 800 to 900 feet in thickness; and on the Santa Cruz, extends, with a slightly altered character, up to the Cordillera.

'From its microscopic structure, and from its analogy with other formations in volcanic districts, it must be considered as originally of volcanic origin: it may have been formed by the long-continued attrition of vast quantities of pumice, or, judging from the manner in which the mass becomes, in ascending the valley of the Santa Cruz, divided into variously coloured layers, from the long-continued eruption of clouds of fine ashes. In either case, we must conclude that the southern volcanic orifices of the Cordillera, now in a dormant state, were at about this period over a wide space, and for a great length of time in action.'

On the banks of the Santa Cruz river, sixty-seven miles from its mouth, there is associated with these beds a great platform of black basaltic lava, in one place divided into magnificent columns, each face twelve feet in diameter. 'This great deluge of lava is 'worthy, in its dimensions, of the great continent to which it be-'longs. The aggregate streams,' of which it consists, 'have flowed 'from the Cordillera to a distance (unparalleled, I believe, in any 'case yet known) of about an hundred geographical miles. Near 'their furthest extremity their total thickness is 130 feet, which 'increases, thirty-five miles farther inland, to 322;' and nearer its source in the mountains is probably even more. According to Elie de Beaumont, the least inclination of the surface of a subaërial lava stream known, is that of the great eruption, in 1783, from the Skaptar Jokul, in Iceland, which is 30′: whilst the ground over which it flowed has a mean inclination of less than 20′. But the beds over which this lava stream has been spread have a slope of only 7′ 52″, and the upper surface of the platform, for the first 14½ miles, of 7′ 20″. Hence it is probable that these beds owe their wide and uniform diffusion to the pressure of the ocean below which they have been formed, though the surface on which they rest had perhaps a smaller inclination, the continent having been more raised in the interior than on the coast. The bottom of the present sea, in a line from the mouth of the Santa Cruz river to the Falkland Islands, between the depth of seventeen and eighty-five fathoms, only declines at an angle of 1′ 22″.

Tertiary formations likewise occur on the west coast of the continent. In both regions the fossils show that these beds probably verge on the commencement of this era, or are of nearly contemporaneous origin with the Eocene formations of the northern hemisphere. From the character of the fossils, Mr. Darwin has endeavoured to estimate the probable nature of the climate under which they lived.

'If,' says he, 'instead of comparing the fossils of Navidad (on the coast of Chile, in lat. 34° S.) with the shells now living on the west

coast of South America, we compare them with those found in other parts of the world, under nearly similar latitudes; for instance, in the southern parts of the Mediterranean or of Australia, there is no evidence that the sea off Navidad was formerly hotter than what might have been expected from its latitude, even if it was somewhat warmer than it now is when cooled by the great southern polar current. In Patagonia there is even still less evidence, in the character of the fossils, of the climate having been formerly warmer.'

This, as Mr. Darwin observes, is a highly important conclusion—

'For we must believe, in accordance with the views of Mr. Lyell, that the causes which gave to the older (contemporaneous) tertiary productions of the quite temperate zones of Europe a tropical character, *were of a local character, and did not affect the whole globe.* On the other hand, I have endeavoured to show, in the Geological Transactions, that, at a much later period, Europe and North and South America were nearly contemporaneously subjected to ice action, and consequently to a colder, or at least more equable climate, than that now characteristic of the same latitudes.'

These are truly strange revolutions in the history of the earth; its solid crust rising and sinking like the scales of a balance, the living beings it nourishes created, destroyed, replaced by others—the very heavens above, with the climate, changing their nature and influence. But when we look to the structure of the Cordillera, as described by Mr. Darwin, we obtain as it were some glimpses into the working of the mighty agency by which these wondrous mutations are effected. Mr. Darwin twice crossed the whole chain, by different passes, near Valparaiso, and from the lofty summit enjoyed a 'glorious view,' perhaps unsurpassed upon the earth.

'The atmosphere resplendently clear; the sky an intense blue; the profound valleys; the wild, broken forms; the heaps of ruins, piled up during the lapse of ages; the bright coloured rocks, contrasted with the quiet mountains of snow; all these together produced a scene I never could have figured to my imagination. Neither plant nor bird, except a few condors wheeling round the higher pinnacles, distracted the attention from the inanimate mass. I felt glad I was alone: it was like watching a thunder-storm, or hearing a chorus of the Messiah in full orchestra.'

Mr. Darwin's summary of the geological history of this chain of mountains is highly interesting, though it is only the study of the details, with the assistance of the coloured sections in his work, that can enable us in some small measure to comprehend the vast number and complexity of the phenomena that it embraces.

'The shores of the Pacific, for the space of 1200 miles, from Tres Montes to Copiapo, and I believe for a very much greater distance, are composed, with the exceptions of the tertiary basins, of metamorphic schists, plutonic rocks, and more or less altered clayslate. On the floor of the ocean thus constituted, vast streams of various purplish claystone and greenstone porphyries were poured forth, together with great alternating piles of angular and rounded fragments of similar rocks ejected from the submarine craters. From the compactness of the streams and fragments, it is probable that, with the exception of some districts in northern Chile, the eruptions took place in profoundly deep water. The orifices of eruption appear to have been studded over a breadth, with some outliers, of from 50 to 100 miles; and closely enough together, both north and south, and east and west, for the ejected matter to form a continuous mass, which in central Chile is more than a mile in thickness. I traced this mound-like mass for only 450 miles; but judging from what I saw at Iquique, from specimens, and from published accounts, it appears to have a manifold greater length. In the basal parts of the series, and especially towards the flanks of the range, mud, since converted into a feldspathic slaty rock, and sometimes into greenstone, was occasionally deposited between the beds of erupted matter: with this exception, the uniformity of the porphyritic rocks is very remarkable.

'At the period when the claystone and greenstone porphyries nearly or quite ceased being erupted, that great pile of strata which, from often abounding with gypsum, I have generally called the gypseous formation, was deposited, and feldspathic lavas, together with other singular volcanic rocks, were occasionally poured forth..... At about the commencement of the gypseous period, the bottom of the sea here seems first to have been peopled by shells, not many in kind, but abounding in individuals.'

These shells, being found from the base to high up in the series, show that the whole great pile of strata, from 5000 to 7000 or 8000 feet thick, belongs to the same period; which, from the singular mixture of cretaceous and oolitic forms, in the fossils, Mr. Darwin names the Cretaceo-oolitic.

'The strata in this formation, composed of black calcareous shaly-rocks, of red and white, and sometimes siliceous sandstones, of coarse conglomerates, limestones, tuffs, dark mudstones, and those singular fine-grained rocks, which I have called pseudo-honestones, vast beds of gypsum, and many other jaspery and scarcely describable varieties, vary and replace each other in short horizontal distances, to an extent, I believe, unequalled even in a tertiary basin. Most of these substances are easily fusible, and have apparently been derived either from volcanoes still in quiet action, or from the attrition of volcanic products. 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, siliceous, ferruginous matters, and gypsum or sulphuric acid, to an amount surpassing, perhaps, even the existing sulphureous 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 was depositing.'

As these shells are in several places covered by from 5000 to 6000 or 7000 feet of strata, Mr. Darwin thinks the bottom of the sea must have subsided during this period, to allow of the accumulation of the superincumbent submarine beds; and that this 'great sinking movement' must have extended in a north and south line for at least 400 miles, and probably was co-extensive with the gypseous formation. But at the same period that the bed of the sea over a wide area was sinking for several thousand feet, and submarine craters yielded at intervals a prodigious supply of gypsum and other mineral exhalations, or occasionally poured forth lavas; in other places, islands composed of porphyries, primary rocks, and the lower gypseous strata, were already upheaved, exposed to the action of the waves, and clothed with fir trees, partaking of the characters of the Araucarian tribe, but with some curious points of affinity with the yew.

These trees, fifty-two in number, measuring from three to five feet each in circumference, are now partly silicified, partly converted into coarsely crystallized calcareous spar, and project a few feet from the ground like snow-white columns. But we must allow Mr. Darwin to tell in his own words the marvellous story which this scene on the western flank of the Uspallata range unfolded:—

'I confess I was at first so much astonished that I could scarcely believe the plainest evidence of it. I saw the spot where a cluster of fine trees had once waved their branches on the shores of the Atlantic, when that ocean (now driven back 700 miles) approached the base of the Andes: I saw that they had sprung from a volcanic soil which had been raised above the level of the sea, and that this dry land, with its upright trees, had subsequently been let down to the depths of the ocean. There it was covered by sedimentary matter, and this again by enormous streams of submarine lava—one such mass alone attaining the thickness of a thousand feet; and these deluges of melted stone and aqueous deposits had been five times spread out alternately. The ocean which received such masses must have been deep; but again the subterranean forces exerted their power, and I now beheld the bed of that sea forming a chain of mountains more than 7000 feet in altitude. Nor had those antagonist forces been dormant, which are always at work to wear down the surface of the land to one level: the great piles of strata had been intersected by many wide valleys; and

the trees, now changed into silex, were exposed projecting from the volcanic soil, now changed into rock, whence formerly in a green and budding state they had raised their lofty heads. Now, all is utterly irreclaimable and desert; even the lichen cannot adhere to the stony casts of former trees. Vast and scarcely comprehensible as such changes must ever appear, yet they have all occurred within a period, recent when compared with the history of the Cordillera; and that Cordillera itself is modern, as compared with some other of the fossiliferous strata of South America.'*

But though these geological phenomena have taken place on such a grand scale in former ages, they are very far from having exhausted the cycle of their changes or the powers by which they are produced. The highest peaks of the Cordillera rising upwards of 20,000 feet above the sea level, consist of active volcanoes or of cones which, though now apparently dormant, may soon again burst forth. Nor has the series of violent dislocations and grand, though slow, upward and downward movements in mass, ceased. At the very time Mr. Darwin was on the coast, on the 20th February, 1835, an awful overpowering earthquake-shock spread devastation over Chile, and in less than six seconds laid the city of Conception in ruins. 'The stunning noise,' says Captain Fitzroy, 'of falling houses; the horrible cracking of the 'earth, which opened and shut rapidly and repeatedly in numerous 'places; the desperate, heart-rending outcries of the people; the 'stifling heat; the blinding, smothering clouds of dust, the utter 'helplessness and confusion, and the extreme horror and alarm, 'can neither be described nor fully imagined.' At Talcahuano the sea retired and three times returned in a huge wave, twenty-five to thirty feet high, which 'roaring as it dashed against every 'obstacle with irresistible force, rushed, destroying and over-'whelming, along the shore.'† All observers seem to agree that one of the most striking and appalling circumstances connected with a violent earthquake is the sudden destruction it causes in all our old associations, which look on the earth as the very emblem of solidity that can never be moved. And this, too, is probably the most important scientific truth that these convulsions teach. When the raging wave had spent its fury on the shore, the sea returned to its usual quiet repose, with no sign, no trace of the disturbance it had so lately exhibited. But not only was the land strewed with the ruined dwellings of man, but cracked and fissured in every direction, the surface of the hardest rocks shivered by the vibrations into innumerable fragments, and the whole coast, the plains and mountains raised permanently

* Journal, (1st ed.) pp. 406, 407.
† Voyage of the Beagle, vol. ii. pp. 403—406.

above their former level. So widely opposed to reality is the common prejudice that speaks of the earth as fixed and solid, of the ocean as unstable and mutable!

The phenomena of the coral islands of the Pacific and of the tertiary and more recent formations in South America thus coincide in proving that the surface of the earth over wide areas is rising or sinking, and that the same region may at successive periods be alternately subjected to each of these movements. The true causes of this oscillation of the solid crust of the globe is one of the most interesting, yet most obscure questions in geology. In South America, the strata have undergone two kinds of elevatory motion: by one of which the whole continent has been raised in mass; by the other, portions of the strata have been tilted up on edge, at various angles, and now form a large part of the lofty chain of the Cordillera. The latter phenomenon is evidently closely connected with the volcanic action going on in that region. The igneous powers, pushing up the strata from below, must rend them into vast fissures, immediately filled by veins of molten matter, sending out branches in a horizontal direction between the beds of rock. These injected masses cool, harden, and prevent the beds from falling back into their original position; when a new eruption again expands the mass, throwing the rocks upwards and outwards. In this manner, the mountain grows, like a palm or other endogenous tree, by continual additions from within; and a section of such a mountain would present a series of veins and beds of igneous rock, crossing and intersecting each other in the most intricate modes, and the most recent of which is probably the lowest and deepest situated.

The movement of the land in mass, and in so equable a manner, that, as Mr. Darwin says, throughout a long line of 1600 miles northward from Tierra del Fuego, not a fault in the stratification or abrupt dislocation was anywhere observable, is a far more difficult problem. A true theory must here explain not only the rise of the land in one place and at one time, but also its subsidence at other places, and during other periods; it must comprise the phenomena of the coral reefs and sinking channels of the Pacific, as well as those of the gravel-capped terraces of Patagonia and the mud-like beds of the Pampas. Mr. Darwin ascribes the upward movement of the land to the intrusion of vast lakes of fluid lava on which the solid rocks repose. By the removal of this fluid basis from one part of the earth's crust to another, it is easy to conceive how the ground over the place it leaves may sink down, and that above the place into which it forces itself may rise up. But this theory leaves the great difficulty still untouched: it gives no account of the reason why the

subterranean fluid masses should move from one place to another; why in this geological period they should be elevating South America, and causing the bottom of the Pacific to subside; raising the north of Scandinavia, and depressing the southern shores of the Baltic—whereas in a former geological period, the opposite motions took place in these regions. The only person who seems to have looked at this question in its full generality is Mr. Babbage, in his remarkable fragment, 'The Ninth Bridgewater Treatise.' This accomplished mathematician has there shown how the aqueous agents wearing away the surface of the dry land, and reducing the thickness of the solid covering, permit the inferior masses to cool, and consequently to contract and subside; whilst the same matter deposited in the bottom of the sea, and increasing the thickness of the superior crust there, must cause the temperature below to increase, and the crust of the earth consequently to expand and rise up. In this theory, an actual and true cause is assigned for the alternate rising and sinking of vast areas of the earth. But there still remain many difficulties on this subject, as for example, the sources of this internal heat, its connexion with active volcanic vents, with the form of continents, the direction of mountain chains, and the distribution of heat and magnetism on the surface. On so vast a subject as this, the close of an article already too long is no place to enter, though many of the facts detailed in the volumes before us furnish important materials for such speculations.

It is these vast general views, having a direct bearing, not on the history of an isolated province, country, or even continent alone, but on the revolutions of the whole planet, that give to geology an interest similar to that attaching to the sublime discoveries of astronomy. In one point of view, the interest is even greater as the scene of these revolutions is more familiar to our minds, and forms the theatre on which all the memorable deeds in the history of humanity have been transacted. It is the constant reference to these general questions and the pointed manner in which particular facts are brought to bear on them, that gives to Mr. Darwin's books their peculiar charm and highest value. It is this that destroys the littleness of detail that would otherwise attach to the enumeration of the mineralogical peculiarities of rocks, to the superposition of strata, or lists of fossils. Another interesting peculiarity of geology is the remarkable manner in which minute facts regarding the structure of distant regions of the globe come to illustrate disputed questions in the physical history of our own country. The blue or reddish boulder clay forming the superficial covering of almost every portion of Britain, has been described as originating in a great debacle,

sweeping, like an earthquake-wave, from the western Atlantic across the length and breadth of the land; and this enormous wave was affirmed to have been produced by the sudden elevation of the chain of the Andes and the American continent, whose recent origin was assumed, probably, on no better foundation than that it was frequently designated the New World. But Mr. Darwin has not only rendered this theory very improbable, by showing that similar formations in America have been produced in a different way, but has given it a more decided blow by proving that the elevation of the land generally is probably slow and gradual, and that at all events this has been the manner in which the western world and its colossal mountain-chain has originated. He has thus put certain fact in the place of vague imagination, and the reality, as is often the case, is more wonderful than the fiction; inasmuch as it is assuredly more wonderful that the quiet and noiseless processes of nature, guided by the wise laws to which they have been subjected by the Creator, should produce such mighty, such all-important revolutions, than that they should be brought about in a moment of wild confusion and unregulated convulsion.

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ART. IV. *The Pre-Adamite Earth: Contributions to Theological Science.* By JOHN HARRIS, D.D., author of the 'Great Teacher,' &c. London: Ward and Co.

'THE Pre-Adamite Earth!' Is there no offence in it? Ought not the very title to put us on our guard? In this age of daring speculation—in which it is confidently maintained that theology is a progressive science, and in which adventurous spirits are pushing their inquiries beyond the boundaries prescribed by reason into the awful regions of faith and mystery—does it not become those who reverence the Scriptures, to pause before they sit down to the perusal of a work whose very announcement seems to be little less than a verbal impeachment of the Mosaic account of the six days' work of creation? We have heard talk of this description. We pity the weakness that could indulge in it, while we yet unfeignedly respect the profound, though unenlightened homage, which it pays to the sacred oracles. We admit that the time is past when everything in religion was taken upon trust—when theology was regarded as the mere dictum of an authority to be believed—when it was altogether limited to revealed, as distinguished from natural truth, and faith and philosophy were placed at an immeasurable distance from