SOUTH AMERICAN GEOLOGY.

As containing some most valuable information, and exhibiting the results deducible from the close and careful manner in which geological investigations are now undertaken, we beg to call the attention of our readers to the following extract, from the lately published work of Mr. Darwin, entitled "*Geological Observations on South America, being the third part of the Geology of the Voyage of the* Beagle, *under the command of Captain Fitzroy, R.N., during the years* 1832 *to* 1836. *By Charles Darwin, M.A., F.R.S., F.G.S., Naturalist to the Expedition.*"

Summary on the Geological History of the Chilian Cordillera, and of the southern parts of South America.

We have seen that 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 exception of the tertiary basins, of metamorphic schists, plutonic rocks, and more or less altered claystate. 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 basil 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 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: I am far from pretending that any distinct line of demarkation can be drawn between this formation and the underlying porphyries and porphyritic conglomerate, but in a mass of such great thickness, and between beds of such widely different mineralogical nature, some division was necessary. 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. At the P. del Inca the fossils are embedded near the base of the formation; in the Peuquenes range, at different levels, half-way up, and even higher in the series; hence, in these sections, the whole great pile of strata belongs to the same period: the same remark is applicable to the beds at Copiapo, which attain a thickness of between 7000 and 8000 feet. The fossil shells in the Cordillera of central Chile, in the opinion of all the palæontologists who have examined them, belong to the earlier stages of the cretaceous system; whilst in northern Chile there is a most singular mixture of cretaceous and oolitic forms: from the geological relations, however, of these two districts, I cannot but think that they all belong to nearly the same epoch, which I have provisionally called 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 any tertiary basin. Most of these substances are easily fusible, and have apparently been derived either from volcanos 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 volcanos 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-orgillaceous matter was depositing. From Dr. Gillie's account, this gypseous or cretaceo oolitic formation extends as far south as the pass of Plancheon, and I followed it northward, at intervals for 500 miles; judging from the character of the beds with the *Terbratula æniqma*, at Iquique, it extends from 400 to 500 miles farther; and perhaps even for ten degrees of latitude north of Iquique to the Cerro Pasco, not far from Lima; again, we know that a cretaceous formation, abounding with fossils, is largely developed north of the equator, in Colombia; in Tierra del Fuego, at about this same period, a wide district of clayslate was deposited, which, in its mineralogical characters and external features, might be compared to the Silurian regions of North Wales. The gypseous formation, like that of the porphyritic breccia-conglomerate on which it rests, is of inconsiderable breadth; though of greater breadth in northern than in central Chile.

As the fossil shells in this formation are covered, in the Peuquenes ridge by a great thickness of strata, at the Puente del Inca by at least 5000 feet; at Coquimbo, though the superposition there is less plainly seen, by about 6000 feet; and at Copiapo certainly by 5000 or 6000, and probably by 7000 feet (the same species there recurring in the upper and lower parts of the series), we may feel confident that the bottom of the sea subsided during this cretacea-oolitic period, so as to allow of the accumulation of the superincumbent submarine strata. This conclusion is confirmed by or perhaps rather explains, the presence of the many beds at many levels of coarse conglomerate, the well-rounded pebbles in which we cannot believe were transported in very deep water. Even the underlying porphyries Copiapo, with their highly amygdaloidal surfaces, do not appear to have flowed under great pressure. The great sinking movement thus plainly indicated, must have extended in a north and south line for at least 400 miles, and probably was co-extensive with the gypseous formation.

The beds of conglomerate just referred to, and the extraordinarily numerous silicified trunks of firtrees at Los Hornos, perhaps at Coquimbo and at two distant points in the valley of Copiapo, indicate that land existed at this period in the neighbourhood. This land, or islands, in the northern part of the district of Copiapo, must have been almost exclusively composed, judging from the nature of the pebbles, of granite; in the southern parts of Copiapo, it must have been mainly formed of claystone porphyries, with some mica schist, and with much sandstone and jaspery rocks, exactly like the rocks in the gypseous formation, and no doubt belonging to its basal series. In several other places, also, during the accumulation of the gypseous formation, its basal parts and the underlying porphyritic conglomerate must likewise have been already partially upheaved and exposed to wear and tear; near the Puente del Inca and at Coquimbo, there must have existed masses of mica-schist or some such rock, whence were derived the many small pebbles of opaque quartz. It follows from these facts, that in some parts of the Cordillera the upper beds of the gypseous formation must lie unconformably on the lower beds; and the whole gypseous formation, in parts, unconformably on the porphyritic conglomerate; although I saw no such cases, yet in many places the gypseous formation is entirely absent; and this, although no doubt generally caused by quite subsequent denudation, may in others be due to the underlying porphyritic conglomerate having been locally upheaved before the deposition of the gypseous strata, and thus having become the source of the pebbles of porphyry embedded in them. In the porphyritic conglomerate formation, in its lower and middle parts, there is very rarely any evidence, with the exception of the small quartz pebbles at Juel near Aconcagua, and of the single pebble of granite at Copiapo, of the existence of neighbouring land; in the upper parts, however, and especially in the district of Copiapo, the number of thoroughly well rounded pebbles of compact porphyries make me believe, that as during the prolonged accumulation of the gypseous formation, the lower beds had already been locally upheaved and exposed to wear and tear, so it was with the porphyritic conglomerate. Hence, in following thus far

* Von Buch's Descript. Physique, des Iles Canaries, P. 428.

the geological history of the Cordillera, it may be inferred that the bed of a deep and open, or nearly open, ocean was filled up by porphyritic eruptions, aided probably by some general and some local elevations, to that comparatively shallow level at which the cretaceo-oolitic shells first lived. At this period, the sub-marine craters yielded at intervals, a prodigious supply of gypsum and other mineral exhalations, and occasionally, in certain places, poured forth lavas, chiefly of a feldspathic nature: at this period, islands clothed with fir trees and composed of porphyries, primary rocks, and the lower gypseous strata had already been locally upheaved, and exposed to the action of the waves:—the general movement, however, at this time having been over a very wide area, one of slow subsidence, prolonged till the bed of the sea sank several thousand feet.

In central Chile, after the deposition of a great thickness of the gypseous strata, and after their upheaval, by which the Cumbre and adjoining ranges were formed, a vast pile of tufaceous matter and submarine lava was accumulated, where the Uspallata chain now stands; also after the deposition and upheaval of the equivalent gypseous strata of the Peuquenes range, the great thick mass of conglomerate in the valley of Tenuyan was accumulated; during the deposition of the Uspallata strata, we know absolutely, from the buried vertical trees, that there was a subsidence of some thousand feet; and we may infer from the nature of the conglomerate in the valley of Tenuyan, that a similar and perhaps contemporaneous movement there took place. We have, then, evidence of a second great period of subsidence; and, as in the case of the subsidence which accompanied the accumulation of the cretaceo-oolitic strata, so this later subsidence appears to have been complicated by alternate or local elevatory movement—for the vertical trees, buried in the midst of the Uspallata strata, must have grown on dry land, formed by the upheaval of the lower submarine beds. Presently I shall have to recapitulate the facts, showing that at a still later period, namely, at nearly the commencement of the old tertiary deposits of Patagonia and of Chile, the continent stood at nearly its present level, and then, for the third time, slowly subsided to the amount of several hundred feet, and was afterwards slowly reuplifted to its present level.

The highest peaks of the Cordillera appear to consist of active or more commonly dormant volcanos,—such as Tupungato, Maypu, and Aconcagua, which latter stands 23,000 feet above the level of the sea, and many others. The next highest peaks are formed of the gypseous and porphyritic strata, thrown into vertical or highly inclined positions. Besides the elevation thus gained by angular displacements, I infer, without any hesitation,—from the stratified gravel-fringes which gently slope up the valleys of the Cordillera, from the gravel-capped plains at their base, which latter are connected with the plains, still covered with recent shells on the coast,—that this great range has been upheaved in mass, by a slow movement, to an amount of at least 8000 feet. In the Despoblado valley, north of Copiapa, the horizontal elevation, judging from the compact, stratified, tufaceous deposit, capping the distant mountains at corresponding heights, was about 10,000 feet. It is very possible, or rather probable, that this elevation in mass may not have been strictly horizontal, but more energetic under the Cordillera, than towards the coast on either side; nevertheless, movements of this kind may be conveniently distinguished from those by which strata have been abruptly broken and upturned. When viewing the Cordillera, before having read Mr. Hopkin's profound Researches on Physical Geology, the conviction was impressed on me, that the angular dislocations, however violent, were quite subordinate in importance to the great upward movement in mass, and that they had been caused by the edges of the wide fissures, which necessarily resulted from the tension of the elevated area, having yielded to the inward rush of fluidified rock, and having thus been upturned.

The ridges formed by the angularly upheaved strata are seldom of great length; in the central parts of the Cordillera, they are generally parallel to each other, and run in north and south lines; but towards the flanks they often extend more or less obliquely. The angular displacement has been much more violent in the central than in the exterior main lines; but it has likewise been violent in some of the minor lines on the extreme flanks. The violence has been very unequal on the same short lines; the crust having apparently tended to yield on certain points along the lines of fissures. These points, I have endeavoured to show, were probably first foci of eruption, and afterwards of injected masses of porphyry and andesite.* The close similarity of the andesitic granites and porphyries throughout Chile, Tierra del Fuego, and even in Peru, is very remarkable. The prevalence of feldspar cleaving like albite is common not only to the andesites, but (as I infer from the high authority of Prof. G. Rose, as well as from my own measurements) to the various claystone and greenstone porphyries, and to the trachytic lavas of the Cordillera. The andesitic rocks have in most cases been the last injected ones, and they probably form a continuous dome under this great range; they stand in intimate relationship with the modern lavas, and they seem to have been the immediate agent in metamorphosing the porphyritic conglomerate formation, and often likewise the gypseous strata, to the extraordinary extent to which they have suffered.

With respect to the age at which the several parallel ridges composing the Cordillera were upthrown, I have little evidence. Many of them may have been contemporaneously elevated and injected, in the same manner† as in volcanic archipelagoes lavas are contemporaneously ejected on the parallel lines of fissures. But the pebbles apparently derived from the wear and tear of the porphyritic conglomerate formation, which are occasionally present in the upper parts of the same formation and are often present in the gypseous formation, together with the pebbles from the basal parts of the latter formation in its upper strata, render it almost certain that portions, we may infer ridges, of these two formations were successively upheaved. In the case of the gigantic Portillo range, we may feel almost certain that a pre-existing granitic line was upraised (not by a single blow, as shown by the highly inclined basaltic streams in the valley on its eastern flank) at a period long subsequent to the upheavement of the parallel Peuquenes range.‡ Again, subsequently to the upheavement of the Cumbre chain, that of Uspallata was formed and elevated; and afterwards, I may add, in the plain of Uspallata, beds of sand and gravel were violently upthrown. The manner in which the various kinds of porphyries and andesites have been injected one into the other, and in which the infinitely numerous dikes of various composition intersect each other, plainly show that the stratified crust has been stretched and yielded many times over the same points. With respect to the age of the axes of elevation between the Pacific and the Cordillera, I know little: but there are some lines which must—namely, those running north and south in Chiloe, those eight or nine east and west, parallel, far-extended, most symmetrical unicli-nal lines at P. Rumena, and the short N.W.—S.E. and N.E.-S.W. lines at Concepcion—have been upheaved long after the formation of the Cordillera. Even during the earthquake of 1835, when the linear north and south islet of St. Mary was uplifted several feet above the surrounding area, we perhaps see one feeble step in the formation of a subordinate mountain-axis. In some cases, moreover, for instance, near the baths of Cauquenes, I was forcibly struck with the small size of the breaches cut through the exterior mountain ranges, compared with the size of the same valleys higher up where entering the Cordillera; and this circumstance appeared to me scarcely explicable, except on the idea of the exterior lines having been subsequently up-

* Sir R. Murchison, and his companions state (Geolog. Proc. vol. iii. p. 747), that no true granite appears in the higher Ural Mountains; but that syenetic greenstone—a rock closely analogous to our andesite—is far the most abundant of the intrusive masses.

† Volcanic Islands, &c., by the Author, p. 129.

‡ I have endeavoured to show in my Journal (2nd edit. p. 321), that the singular fact of the river, which drains the valley between these two ranges, passing through the Portillo and higher line, is explained by its slow and subsequent elevation. There are many analogous cases in the drainage of rivers: see Edinburgh New Phil. Journal, vol. xxviii. pp. 33 and 44.

thrown, and therefore having been exposed to a less amount of denudation. From the manner in which the fringes of gravel are prolonged in unbroken slopes up the valleys of the Cordillera, I infer that most of the greater dislocations took place during the earlier parts of the great elevation in mass; I have, however, elsewhere given a case, and M. de Teschudi* has given another, of a ridge thrown up in Peru, across the bed of a river, and consequently after the final elevation of the country above the level of the sea.

Ascending to the older tertiary formations, I will not again recapitulate the remarks already given at the end of the fifth chapter,—on their great extent, especially along the shores of the Atlantic,—on their antiquity, perhaps corresponding with that of the eocene deposits of Europe,—on the almost entire dissimilarity, though the formations are apparently contemporaneous, of the fossils from the eastern and western coasts, as is likewise the case, even in a still more marked degree, with the shells now living in these opposite though approximate seas,—on the climate of this period not having been more tropical than what might have been expected from the latitudes of the places under which the deposits occur; a circumstance rendered well worthy of notice, from the contrast with what is known to have been the case during the older tertiary periods of Europe, and likewise from the fact of the southern hemisphere having suffered at a much later period, apparently at the same time with the northern hemisphere, a colder or more equable temperature, as shown by the zones formerly affected by ice-action. Nor will I recapitulate the proofs of the bottom of the sea, both on the eastern and western coast, having subsided 700 or 800 feet during this tertiary period; the movement having apparently been co-extensive, or nearly co-extensive, with the deposits of this age. Nor will I again give the facts and reasoning on which the proposition was founded, that when the bed of the sea is either stationary or rising, circumstances are as less favourable than when its level is sinking, to the accumulation of conchiferous deposits of sufficient thickness, extension, and hardness to resist, when upheaved, the ordinary vast amount of denudation. We have seen that the highly remarkable fact of the absence of any *extensive* formations containing recent shells, either on the eastern or western coasts of the continent,—though these coasts now abound with the living mollusca,—though they are, and apparently have always been, as favourable for the deposition of sediment as they were when the tertiary formations were copiously deposited,—and though they have been upheaved to an amount quite sufficient to bring up strata from the depths the most fertile for animal life,—can be explained in accordance with the above proposition. As a deduction, it was also attempted to be shown, first, that the want of close sequence in the fossils of successive formations, and of successive stages in the same formation, would follow from the improbability of the same area continuing slowly to subside from one whole period to another, or even during a single entire period; and, secondly, that certain epochs having been favourable at distant points in the same quarter of the world for the synchronous accumulation of fossiliferous strata, would follow from movements of subsidence having apparently, like those of elevation, contemporaneously affected very large areas.

There is another point which deserves some notice, namely, the analogy between the upper parts of the Patagonian tertiary formation, as well as of the upper possibly contemporaneous beds at Chiloe and Concepcion, with the great gypseous formation of Cordillera; for in both formations, the rocks, in their fusible nature, in their containing gypsum and in many other characters, show a connection, either intimate or remote, with volcanic action; and as the strata in both were accumulated during subsidence, it appears at first natural to connect this sinking movement with a state of high activity in the neighbouring volcanoes. During the cretaceo-oolitic period this certainly appears to have been the case at the Puente del Inca, judging from the number of intercalated lava streams in the lower 3000 feet of strata; but generally, the volcanic orifices seem at this time to have existed as submarine solfataras, and were certainly quiescent compared with their state during the accumulation of the porphyritic conglomerate formation. During the deposition of the tertiary strata, we know that at S. Cruz, deluges of basaltic lava were poured forth; but as these lie in the upper part of the series, it is possible that the subsidence may at that time have ceased: at Chiloe, I was unable to ascertain to what part of the series the pile of lavas belonged. The Uspallata tuffs and great streams of submarine lavas, were probably intermediate in age between the cretaceo-oolitic and older tertiary formations, and we know from the buried trees that there was a great subsidence during their accumulation; but even in this case, the subsidence may not have been strictly contemporaneous with the great volcanic eruptions, for we must believe in at least one intercalated period of elevation, during which the ground was upraised on which the now buried trees grow. I have been led to make these remarks, and to throw some doubt on the strict contemporaneousness of high volcanic activity and movements of subsidence, from the conviction impressed on my mind by the study of coral formations,* that these two actions do not generally go on synchronously;—on the contrary, that in volcanic districts, subsidence ceases as soon as the orifices burst forth into renewed action, and only recommences when they again have become dormant.

At a later period, the Pampean mud, of estuary origin, was deposited over a wide area,—in one district conformably on the underlying old tertiary strata, and in another district unconformably on them, after their upheaval and denudation. During and before the accumulation, however, of these old tertiary strata, and, therefore, at a very remote period, sediment, strikingly resembling that of the Pampas, was deposited; showing during how long a time in this case the same agencies were at work in the same area. The deposition of the Pampean estuary mud was accompanied, at least in the southern parts of the Pampas, by an elevatory movement, so that the M. Hermoso beds probably were accumulated after the upheaval of those round the S. Ventana; and those at P. Alta after the upheaval of the Monte Hermoso strata; but there is some reason to suspect that one period of subsidence intervened, during which mud was deposited over the coarse sand of the Barrancas de St. Gregorio, and on the higher parts of Banda Oriental. The mammiferous animals characteristic of this formation, many of which differ as much from the present inhabitants of South America as do the eocene mammals of Europe from the present ones of that quarter of the globe, certainly co-existed at B. Blanca with twenty species of mollusca, one balanus, and two corals, all now living in the adjoining sea: this is likewise the case in Patagonia with the Macrauchenia, which co-existed with eight shells, still the commonest kinds on that coast. I will not repeat what I have elsewhere said, on the place of habitation, food, wide range, and extinction of the numerous gigantic mammifers, which at this late period inhabited the two Americas.

The nature and grouping of the shells embedded in the old tertiary formations of Patagonia and Chile, show us, that the continent at that period must have stood only a few fathoms below its present level, and that afterwards it subsided over a wide area, 700 or 800 feet. The manner in which it has since been re-brought up to its actual level, was described in detail in the first and second chapters. It was there shown 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 coast of Patagonia, up to the height in one part of 950 feet, and in another of 1200 feet, is modelled into eight great, step-like, gravel-capped plains, extending for hundreds of miles with the same heights; this fact shows that 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 coasts. On the shores of the Pacific, upraised shells of recent species, generally, though not always, in the

* Reise in Peru, Band 2, s. 8:—Author's Journal, 2nd Edition, p. 359.

* The structure, &c., of Coral Reefs, p. 140.

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. 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 Lima, the land has been uplifted at least eighty feet since Indian man inhabited that district; but the level within historical times apparently has subsided. 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 from the slope of the land up to the Cordillera, and from the shells found in the central part of Tierra del Fuego, and high up the river Santa Cruz, that the entire breadth of the continent has been uplifted From the general occurrence on both coasts of successive lines of escarpments, of sanddunes and marks of erosion, we must conclude that the elevatory movement has been normally interrupted by periods, when the land either was stationary, or when it rose at so slow a rate as not to resist the average denuding power of the waves, or when it subsided. In the case of the present high sea-cliffs of Patagonia and in other analogous instances, we have seen that the difficulty in understanding how strata can be removed at those depths under the sea, at which the currents and oscillations of the water are depositing a smooth surface of mud, sand, and sifted pebbles, leads to the suspicion that the formation or denudation of such cliffs has been accompanied by a sinking movement.

In South America, everything has taken place on a grand scale, and all geological phenomena are still in active operation. We know how violent at the present day the earthquakes are, we have seen how great an area is now rising, and the plains of tertiary origin are of vast dimensions; an almost straight line can be drawn from Tierra del Fuego for 1600 miles northward, and probably for a much greater distance, which shall intersect no formation older than the Patagonian deposits; so equable has been the upheaval of the beds, that throughout this long line, not a fault in the stratification or abrupt dislocation was anywhere observable. Looking to the basal, metamorphic and plutonic rocks of the continent, the areas formed of them are likewise vast; and their planes of cleavage and foliation strike over surprisingly great spaces in uniform directions. The Cordillera, with its pinnacles here and there rising upwards of 20,000 feet above the level of the sea, ranges in an unbroken line from Tierra del Fuego, apparently to the Arctic circle. This grand range has suffered both the most violent dislocations, and slow, though grand, upward and downward movements in mass: I know not whether the spectacle of its immense valleys, with mountain-masses of once-liquefied and intrusive rocks now bared 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.

The Cordillera from Tierra del Fuego to Mexico, is penetrated by volcanic orifices, and those now in action are connected in great trains. The intimate relation between their recent eruptions and the slow elevation of the continent in Mass,* appears to me highly important, for no explanation of the one phenomenon can be considered as satisfactory which is not applicable to the other. The permanence of the volcanic action on this chain of mountains is, also, a striking fact; first, we have the deluges of submarine lavas alternating with the porphyritic conglomerate strata, then occasionally feldspathic streams and abundant mineral exhalations during the gypseous or cretaceo-oolitic period; then the eruptions of the Uspalata range, and at an ancient but unknown period, when the sea came up to the eastern foot of the Cordillera, streams of basaltic lava at the foot of the Portillo range; then the old tertiary eruptions; and lastly, there are here and there amongst the mountains much worn and apparently very ancient volcanic formations without any craters; there are, also, craters quite extinct, and others in the condition of solfataras, and others occasionally or habitually in fierce action. Hence it would appear that the Cordillera has been, probably with some quiescent periods, a source of volcanic matter from an epoch anterior to our cretaceo-oolitic formation to the present day; and now the earthquakes, daily recurrent on some part of the western coast, give little hopes that the subterranean energy is expended.

Recurring to the evidence by which it was shown that some at least of the parallel ridges, which together compose the Cordillera, were successively and slowly upthrown at widely different periods; and that the whole range certainly once, and almost certainly twice, subsided some thousand feet, and being then brought up by a slow movement in mass, again, during the old tertiary formations, subsided seven hundred feet, and again was brought up to its present level by a slow and often interrupted movement; we see how opposed is this complicated history of changes slowly effected, to the views of those geologists who believe that this great mountain-chain was formed in late times by a single blow. I have endeavoured elsewhere to show,* that the excessively disturbed condition of the strata in the Cordillera, so far from indicating single periods of extreme violence, presents insuperable difficulties, except on the admission that the masses of once liquefied rocks of the axes were repeatedly injected, with intervals sufficiently long for their successive cooling and consolidation. Finally, if we look to the analogies drawn from the changes now in progress in the earth's crust, whether to the manner in which volcanic matter is erupted, or to the manner in which the land is historically known to have risen and sunk; or again, if we look to the vast amount of denudation which every part of the Cordillera has obviously suffered, the changes through which it has been brought into its present condition, will appear neither to have been too slowly effected, nor to have been too complicated.

* On the Connection of certain Volcanic Phenomena in South America. Geolog. Transact., vol. v., p. 609.

* Geolog. Transact., vol. v., p. 626.