CHAPTER XVIII.

Formation of coral reefs—They are composed of shells as well as corals—Conversion of a submerged reef into an island—Extent and thickness of coral formations—The Maldiva isles—Growth of coral not rapid—Its geological importance—Circular and oval forms of coral islands—Shape of their lagoons—Causes of their peculiar configuration—Openings into the lagoons—Why the windward side both in islands and submerged reefs is higher than the leeward—Stratification of coral formations—Extent of some reefs in the Pacific—That the subsidence by earthquakes in the Pacific, exceeds the elevation due to the same cause—Elizabeth, or Henderson's Island—Coral and shell limestones now in progress, exceed in area any known group of ancient rocks—The theory that all limestone is of animal origin considered—The hypothesis that the quantity of calcareous matter has been and is still on the increase, controverted.

Corals and Coral reefs.

The powers of the organic creation in modifying the form and structure of those parts of the earth's crust, which may be said to be undergoing repair, or where new rock-formations are continually in progress, are most conspicuously displayed in the labours of the coral animals. We may compare the operation of these zoophytes in the ocean, to the effects produced on a smaller scale upon the land, by the plants which generate peat. In the case of the Sphagnum, the upper part vegetates while the lower portion is entering into a mineral mass, where the traces of organization usually remain, but in which life has entirely ceased. In the corals, in like manner, the more durable materials of the generation that has passed away, serve as the foundation on which living animals are continuing to rear a similar structure.

The calcareous masses usually termed coral reefs, are by no means exclusively composed of zoophytes, but also a great variety of shells; some of the largest and heaviest of known species contributing to augment the mass. In the south Pacific, great beds of oysters, mussels, *pinnæ marinæ*, and other shells, cover in great profusion almost every reef; and, on the beach of coral islands, are seen the shells of echini and the broken fragments of crustaceous animals. Large shoals of fish also are discernible through the clear blue water, and their teeth and hard palates are probably preserved, although a great portion of their soft cartilaginous bones may decay.

Of the numerous species of zoophytes which are engaged in the production of coral banks, some of the most common belong to the genera Meandrina, Caryophyllia and Astrea, but especially the latter.

The reefs, which just raise themselves above the level of the sea, are usually of a circular or oval form, and are surrounded by a deep and often unfathomable ocean. In the centre of each, there is usually a comparatively shallow lagoon where there is still water, and where the smaller and more delicate kinds of zoophytes find a tranquil abode, while the more strong species live on the exterior margin of the isle, where a great surf usually breaks. When the reef, says M. Chamisso, a naturalist who accompanied Kotzebue, is of such a height that it remains almost dry at low water, the corals leave off building. A continuous mass of solid stone is seen composed of the shells of molluscs and echini, with their broken off prickles and fragments of coral, united by the burning sun, through the medium of the cementing calcareous sand, which has arisen from the pulverization of shells. Fragments of coral limestone are thrown up by the waves, until the ridge becomes so high, that it is covered only during some seasons of the year by the high tides. The heat of the sun often penetrates the mass of stone when it is dry, so that it splits in many places. The force of the waves is thereby enabled to separate and lift blocks of coral, frequently six feet long and three or four in thickness, and throw them upon the reef. "After this the calcareous sand lies undisturbed, and offers to the seeds of trees and plants cast upon it by the waves, a soil upon which they rapidly grow, to overshadow its dazzling white surface. Entire trunks of trees, which are carried by the rivers from other countries and islands, find here, at length, a resting-place after their long wanderings: with these come some small animals, such as lizards and insects, as the first inhabitants. Even before the trees form a wood, the sea-birds nestle here; strayed land-birds take refuge in the bushes; and, at a much later period, when the work has been long since completed, man also appears, builds his hut on the fruitful soil formed by the corruption of the leaves of the trees, and calls himself lord and proprietor of this new creation *."

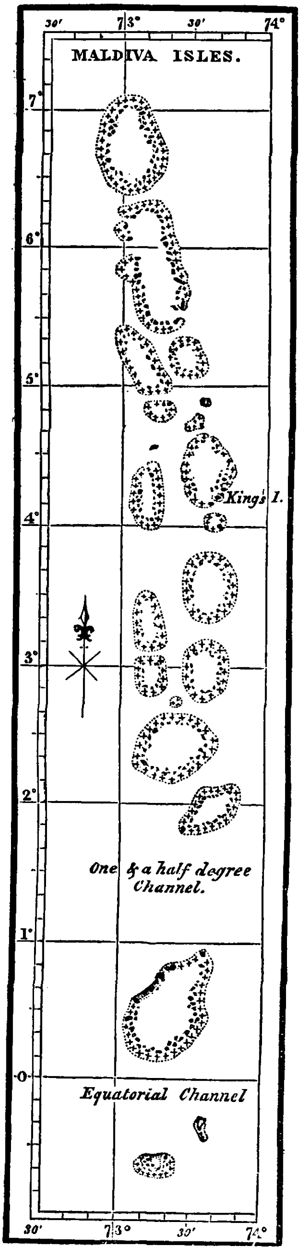
The Pacific ocean throughout, a space comprehended between the thirtieth parallel of latitude on each side of the equator, is extremely productive of coral. The Arabian gulf is rapidly filling with the same, and it is said to abound in the Persian gulf. Between the coast of Malabar and that of Madagascar, there is also a great sea of coral. Flinders describes an unbroken reef three hundred and fifty miles in length, on the east coast of New Holland; and, between that country and New Guinea, Captain P. King found the coral formations to extend throughout a distance of seven hundred miles, interrupted by no intervals exceeding thirty miles in length.

The chain of coral reefs and islets, called the Maldivas, situated in the Indian ocean to the south-west of Malabar, form a chain four hundred and eighty geographical miles in length, running due north and south. It is composed throughout of a series of circular assemblages of islets, the larger groups being from forty to fifty miles in their longest diameter. Captain Horsburgh, whose chart of these islands is subjoined, informs me that outside of each circle or atoll, as it is termed, there are coral reefs sometimes extending to the distance of two or three miles, beyond which there are no soundings at immense depths. But in the centre of each atoll there is a lagoon from fifteen to twenty fathoms deep. In the channels between the atolls, no soundings have been obtained at the depth of one hundred and fifty fathoms.

The Laccadive islands run in the same line with the Mal-

* Kotzebue's Voyages, 1815-18, vol. iii. p. 331—3.

No. 4.



divas, on the north, as do the isles of the Chagos Archipelago, on the south, so that these may be continuations of the same chain of submarine mountains, crested in a similar manner by coral limestone. It would be rash to hazard the hypothesis, that they are all the summits of volcanos, yet we might imagine, that if Java and Sumatra were submerged, they would give rise to a somewhat similar shape in the bottom of the sea; for the volcanos of those islands observe a linear direction, and are often separated from each other by intervals, corresponding to the atolls of the Maldivas; and as they rise to various heights, from five to ten thousand feet above their base, they might leave an unfathomable ocean in the intermediate spaces.

In regard to the thickness of the masses of coral, MM. Quoy and Gaimard are of opinion, that the species which contribute most actively to the formation of solid masses do not grow where the water is deeper than twenty-five or thirty feet. But the branched madrepores, which live at considerable depth, may form the first foundation of a reef, and raise a platform on which other species may build *, and the sand and

* Journ. of Geograph. Soc. of London, 1831, p. 218.

broken fragments washed by the waves from reefs may, in time, produce calcareous rocks of great thickness.

The rapidity of the growth of coral is by no means great, according to the report of the natives to Captain Beechey. In an island west of Gambier's group, our navigators observed the *Chama gigas* (Tridacna, Lam.) while the animal was yet living, so completely overgrown by coral, that a space only of two inches was left for the extremity of the shell to open and shut *. But conchologists suppose, that the chama may require thirty years or more to attain its full size, so that the fact is quite consistent with a very slow rate of increase in the calcareous reefs. In the late expedition to the Pacific no positive information could be obtained, of any channel having been filled up within a given period, and it seems established that several reefs had remained for more than half a century, at about the same depth from the surface.

The increase of coral limestone, however, may vary greatly according to the sites of mineral springs, for these we know often issue in great numbers at the bottom of the sea in volcanic regions, as in the Mediterranean, for example, where they sometimes cause the sea at great depths to be fresher than at the surface, a phenomenon also declared by the South Sea islanders to be common in the Pacific.

But when we admit the increase of coral limestone to be slow, we are merely speaking with relation to the periods of human observation. It often happens, that parasitic testacea live and die on the shells of the larger slow-moving gasteropods in the South Seas, and become entirely inclosed in an incrustation of compact limestone, while the animal, to whose habitation they are attached, crawls about and bears upon his back these shells, which may be considered as already fossilized. It is, therefore, probable, that the reefs increase as fast as is compatible with the thriving state of the organic beings which chiefly contribute to their formation; and if the rate of augmentation thus implied be called, in conformity to our ordinary ideas of time, gradual and slow, it does not diminish, in the

* Beechey's Voyage to the Pacific, &c. p. 157.

least degree, the geological importance of such calcareous masses.

Suppose the ordinary growth of coral limestone to amount to six inches in a century, it will then require three thousand years to produce a reef fifteen feet thick; but have we any ground for presuming that, at the end of that period, or of ten times thirty centuries, there will be a failure in the supply of lime, or that the polyps and molluscs will cease to act, or that the hour of the dissolution of our planet will first arrive, as the earlier geologists were fain to anticipate?

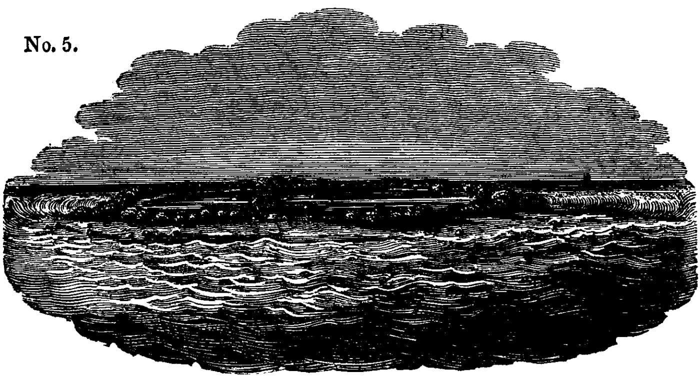
Instead of contemplating the brief annals of human events, let us turn to some natural chronometers, to the volcanic isles of the Pacific, for example, which shoot up ten or fifteen thousand feet above the level of the ocean. These islands bear evident marks of having been produced by successive volcanic eruptions; and coral reefs are sometimes found on the volcanic soil, reaching for some distance from the sea-shore into the interior. When we consider the time required for the accumulation of such mountain masses of igneous matter according to the analogy of known volcanic agency, all idea of extenuating the comparative magnitude of coral limestones, on the ground of the slowness of the operations of lithogenous polyps, must instantly vanish.

The information collected during the late expedition to the Pacific throws much additional light on the peculiarities of form and structure of coral islands. Of thirty-two of these, examined by Captain Beechey, the largest was thirty miles in diameter, and the smallest less than a mile. They were of various shapes, all formed of living coral, except one, which, although of coral formation, was raised about eighty feet above the level of the sea, and encompassed by a reef of living coral. All were increasing their dimensions by the active operations of the lithophytes which appeared to be gradually extending and bringing the immersed parts of their structure to the surface. Twenty-nine of the number had lagoons in their centres, which had probably existed in the others, until they were filled, in the course of time, by zoophytic and other substances.

In the above-mentioned islands, the strips of dry coral encircling the lagoons when divested of loose sandy materials heaped upon them, are rarely elevated more than two feet above the level of the sea; and were it not for the abrupt descent of the external margin which causes the sea to break upon it, these strips would be wholly inundated. "Those parts of the strip which are beyond the reach of the waves are no longer inhabited by the animals that reared them, but have their cells filled with a hard calcareous substance, and present a brown rugged appearance. The parts which are still immersed, or are dry at low water only, are intersected by small channels, and are so full of hollows that the tide, as it recedes, leaves small lakes of water upon them. The width of the plain or strip of dead coral, in the islands which fell under our observation, in no instance exceeded half a mile from the usual wash of the sea to the edge of the lagoon, and in general was only about three or four hundred yards *." Beyond these limits the sides of the island descend rapidly, apparently by a succession of inclined ledges, each terminating in a precipice. The depth of the lagoons is various; in some entered by Captain Beechey, it was from twenty to thirty-eight fathoms.

In the annexed cut (No. 5), one of these circular islands is

No. 5.



View of Whitsunday Island †.

* Captain Beechey, part i. p. 188.

† This plate and the section which follows are copied, by permission of Captain Beechey, from the illustrations of his valuable work before alluded to.

represented just rising above the waves, covered with the cocoa-nut and other trees, and inclosing within, a lagoon of tranquil water.

The accompanying section will enable the reader to comprehend the usual form of such islands. (No. 6.)

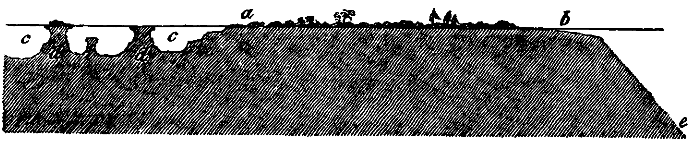
No. 6.

Section of a Coral Island.

(*a a*) Habitable part of the island, consisting of a strip of coral, inclosing the lagoon. (*b b*) The lagoon.

The subjoined cut (No. 7) exhibits a small part of the section of a coral island on a larger scale.

No. 7.



Section of part of a Coral Island.

(*a b*) Habitable part of the island.
(*b e*) Slope of the side of the island, plunging at an angle of forty-five to the depth of fifteen hundred feet.
(*c c*) Part of the lagoon.
(*d d*) Knolls of coral in the lagoon, with over-hanging masses of coral, resembling the capitals of columns.

The circular or oval forms of the numerous coral isles of the Pacific, with the lagoons in their centre, naturally suggest the idea that they are nothing more than the crests of submarine volcanos, having the rims and bottoms of their craters overgrown by corals. This opinion is strengthened by the conical form of the submarine mountain, and the steep angle at which it plunges on all sides into the surrounding ocean. It is also well known that the Pacific is a great theatre of volcanic action, and every island yet examined in the wide region termed Eastern Oceanica, consists either of volcanic rocks or coral limestones.

It has also been observed that, although within the circular coral reefs, there is usually nothing discernible but a lagoon, the bottom of which is covered with coral, yet within some of these basins, as in Gambier's group, rocks composed of porous lava and other volcanic substances, rise up, resembling the two Kameni's, and other eminences of igneous origin, which have been thrown up within the times of history, in the midst of the Gulf of Santorin *.

We mentioned that in volcanic archipelagos there is generally one large habitual vent, and many smaller volcanos formed at different points and at irregular intervals, all of which have usually a linear arrangement. Now in several of the groups of Eastern Oceanica there appears to be a similar disposition, the great islands, such as Otaheite, Owhyhee, and Terra del Spirito Santo, being habitual vents, and the lines of small circular coral isles which are dependent on them being very probably trains of minor volcanos, which may have been in eruption singly and at irregular intervals.

The absence of circular groups in the West Indian seas, and the tropical parts of the Atlantic, where corals are numerous, has been adduced as an additional argument, inasmuch as volcanic vents, though existing in those regions, are very inferior in importance to those in the Pacific and Indian seas †. It may be objected that the circles formed by some coral reefs or groups of coral islets, varying as they do from ten to thirty miles and upwards in diameter, are so great as to preclude the idea of their being volcanic craters. In regard to this objection we may refer to what we have said in a former volume respecting the size of the so-called craters of elevation, many of which, we conceive, may be the ruins of truncated cones ‡.

There is yet another phenomenon attending the circular reefs, to which we have not alluded, viz., the deep narrow passage which almost invariably leads from the sea into the lagoon, and is kept open by the efflux of the sea at low tides. It is sufficient that a reef should rise a few feet above low-water mark to cause the waters to collect in the lagoon at high tide,

* See vol. i. p. 386.

† De la Beche, Geol. Man. p. 141.

‡ See vol. i. p. 388.

and, when the sea falls, to rush out violently at one or more points where the reef happens to be lowest or weakest. At first there are probably many openings; but the growth of the corals tends to obstruct all those which do not serve as the principal channels of discharge, so that their number is gradually reduced to a few, and often finally to one. This event is strictly analogous to that witnessed in our estuaries, where a body of salt-water accumulated during the flow, issues with great velocity at the ebb of the tide, and scours out or keeps open a deep passage through the bar, which is almost always formed at the mouth of a river.

When we controverted in our first volume Von Buch's theory of "elevation craters," we suggested that the single gorge leading from the central cavity to the sea, may have been produced by a stream of water issuing from a lake filling the original crater, and which had in process of time cut a deep channel *; but we overlooked the more probable cause, the action of the tides, which affords, we think, a most satisfactory explanation. Suppose a volcanic cone, having a deep crater, to be at first submarine, and to be then *gradually* elevated by earthquakes in an ocean where tides prevail, a ravine cannot fail to be cut like that which penetrates into the Caldera of the isle of Palma. The opening would at first be made on that side where the rim of the crater was originally lowest, and it would afterwards be deepened as the island rose, so as always to descend somewhat lower than the level of the sea. Captain Beechey's observations, therefore, of the effect of the tides on the coral islands, corroborate the opinion which we offered respecting the mode of formation of islands having a configuration like Palma; whereas the theory of the *sudden* upheaving of horizontal strata into a conical form, affords no explanation whatever of the *single* ravine which intersects one side of these circular islands.

In the coral reefs surrounding those volcanic islands in the Pacific which are large enough to feed small rivers, there is generally an opening or channel opposite the point where the

* Vol. i., p. 395.

stream of fresh water enters the sea. The depth of these channels rarely exceeds twenty-five feet, and they may be attributed, says Captain Beechey, to the aversion of the lithophytes to fresh water, and to the probable absence of the mineral matter of which they construct their habitations *.

But there is yet another peculiarity of the low coral islands, the explanation of which is by no means so obvious. They follow one general rule in having their windward side higher and more perfect than the other. "At Gambier and Matilda islands this inequality is very conspicuous, the weather side of both being wooded, and of the former inhabited, while the other sides are from twenty to thirty feet under water, where, however, they might be perceived to be equally *narrow* and well defined. It is on the leeward side also that the entrances into the lagoons occur; and although they may sometimes be situated on a side that runs in the direction of the wind, as at Bow Island, yet there are none to windward." These observations of Captain Beechey accord perfectly with those which Captain Horsburgh and other hydrographers have made in regard to the coral islands of other seas. Thus the Chagos Isles in the Indian Ocean are chiefly of a horse-shoe form, the openings being to the north-west; whereas the prevailing wind blows regularly from the south-east. From this fortunate circumstance ships can enter and sail out again with ease, whereas, if the narrow inlets were to windward, vessels which once entered might not succeed for months in making their way out again. The well-known security of many of these harbours, depends entirely on this fortunate peculiarity in their structure.

In what manner is this singular conformation to be accounted for? The action of the waves is seen to be the cause of the superior elevation of some reefs on their windward sides, where sand and large masses of coral rock are thrown up by the breakers; but there are a variety of cases where this cause alone is inadequate to solve the problem; for reefs

* Voyage to the Pacific, &c., p. 194.

submerged at considerable depths, where the movements of the sea cannot exert much power, have, nevertheless, the same conformation, the leeward being much lower than the windward side *.

I am informed by Captain King, that on examining the reefs called Rowley Shoals, which lie off the north-west coast of Australia, where the east and west monsoons prevail alternately, he found the open side of one crescent-shaped reef, the Impérieuse, turned to the east, and of another, the Mermaid, turned to the west; while a third oval reef, of the same group, was entirely submerged. This want of conformity is exactly what we should expect, where the winds vary periodically.

It seems impossible to refer the phenomenon now under consideration to any original uniformity in the configuration of submarine volcanos, on the summits of which we may suppose the coral reefs to grow; for although it is very common for craters to be broken down on one side only, we cannot imagine any cause that should breach them all in the same direction. But, if we mistake not, the difficulty will be removed if we call in another part of the volcanic agency—subsidence by earthquakes. Suppose the windward barrier to have been raised by the mechanical action of the waves to the height of two or three yards above the wall on the leeward side, and then the whole island to sink down a few fathoms, the appearances described would then be presented by the submerged reef. A repetition of such operations by the alternate elevation and depression of the same mass (an hypothesis strictly conformable to analogy) might produce still greater inequality in the two sides, especially as the violent efflux of the tide has probably a strong tendency to check the accumulation of the more tender corals on the leeward reef, while the action of the breakers contributes to raise the windward barrier.

The calcareous formations of the Pacific are probably all stratified, although single beds may sometimes attain a great thickness. The occasional drifting of sand from the exposed

* Voyage to the Pacific, &c., p. 189.

parts of a reef into the lagoon or the surrounding sea, would suffice to form occasional lines of partition, especially during violent tempests which occur annually among the South-Sea islands. The decomposition of felspathic lavas may supply the current which washes and undermines the cliffs of some islands with fine clay, and this may be carried to great distances and deposited in distinct layers between calcareous masses, or may be mingled with them and form argillaceous limestones. Other divisions will arise from the arrangement of different species of testacea and zoophytes, which inhabit water of various depths, and which succeed each other as the sea deepens by the fall of the land during earthquakes, or grows shallower by elevation due to the same cause, or by the accumulation of organic substances raising the bottom.

To these causes of minor subdivision must be added another of great importance,—the ejection of volcanic ashes and sand, often carried by the wind over wide areas, and the flowing of horizontal sheets of lava, which may interrupt suddenly the growth of one coral reef, and afterwards serve as a foundation for another. An example of this kind is seen in the isle of France, where a bed of coral, ten feet thick, intervenes between two currents of lava *, and in the West Indies, in the island of Dominica, Maclure observes that "a bed of coral and madrepore limestone, with shells, lies horizontally on a bed of cinders, about two or three hundred feet above the level of the sea, at Rousseau, and is covered with cinders to a considerable height †."

The reefs in the Pacific are sometimes of great extent: thus the inhabitants of Disappointment Islands, and those of Duff's Group, pay visits to each other by passing over long lines of reefs from island to island, a distance of six hundred miles and upwards. When on their route they present the appearance of troops marching upon the surface of the ocean ‡.

* De la Beche, Geol. Man. p. 142. Quoy and Gaimard, Ann. des Sci. Nat. tome vi.

† Observations on the Geology of the West Indian Islands, Journal of Science, &c., No. X., p. 318.

‡ Malte-Brun's Geog. vol. iii. p. 401.

A reference to our first volume will show that a series of ordinary earthquakes might, in the course of a few centuries, convert such a tract of sea into dry land; and it is, therefore, a remarkable circumstance that there should be so immense an area in eastern Oceanica, studded with minute islands, without one single spot where there is a wider extent of land than belongs to such islands as Otaheite, Owhyhee, and a few others, which either have been or are still the seats of active volcanos. If an equilibrium only were maintained between the upheaving and depressing force of earthquakes, large islands would very soon be formed in the Pacific; for, in that case, the growth of limestone, the flowing of lava, and the ejection of volcanic ashes, would combine with the upheaving force to form new land.

Suppose the shoal which we have described as six hundred miles in length, to sink fifteen feet, and then to remain unmoved for a thousand years; during that interval the growing coral may again approach the surface. Then let the mass be re-elevated fifteen feet, so that the original reef is restored to its former position: in this case the new coral formed since the first subsidence, will constitute an island six hundred miles long. An analogous result would have occurred if a lava-current fifteen feet thick had overflowed the submerged reef. The absence, therefore, of more extensive tracts of land in the Pacific seems to show that the amount of subsidence by earthquakes exceeds in that quarter of the globe at present the elevation due to the same cause.

We mentioned that one of the thirty-two islands examined by our navigators in the late expedition, was raised about eighty feet above the level of the sea*. It is called Elizabeth or Henderson's Island, and is five miles in length by one in breadth. It has a flat surface, and on all sides except the north, is bounded by perpendicular cliffs about fifty feet high, composed entirely of dead coral, more or less porous, honeycombed at the surface, and hardening into a compact calcareous

* According to some accounts between sixty and seventy feet.

mass, which possesses the fracture of secondary limestone, and has a species of millepore interspersed through it. These cliffs are considerably undermined by the action of the waves,

No. 8.

Elizabeth or Henderson's Island.

No. 9.

Enlarged view of part of Elizabeth or Henderson's Island.

and some of them appear on the eve of precipitating their superincumbent weight into the sea. Those which are less injured in this way present no alternate ridges or indication of the different levels which the sea might have occupied at different periods, but a smooth surface, as if the island, which has probably been raised by volcanic agency, had been forced up by one great subterraneous convulsion *.

At the distance of a few hundred yards from this island, no bottom could be gained with two hundred fathoms of line. It will be seen from the annexed sketch, communicated to me by Lieutenant Smyth, of the Blossom, that the trees come down to the beach towards the centre of the isle, a break which at first sight resembles the openings which usually lead into lagoons: but the trees stand on a steep slope and no hollow of an ancient lagoon was perceived. The reader will remark that such a mass of limestone represents exactly those horizontal cappings of calcareous strata which we sometimes find on hills which have tabular summits.

As we have at present no proof that Henderson's Island has been upheaved within the historical period, we deviate somewhat from our plan when we describe it in the present chapter; but, as earthquakes are now felt from time to time in this part of the Pacific, and as indications of very recent changes of level

* Beechey, ib. p. 46.

are not wanting*, it is by no means improbable that the era of the elevation of this island may not be very remote.

The calcareous masses which we have now considered, constitute, together with the associated volcanic formations, the most extensive of the groups of rocks which can be demonstrated to be now in progress. The space in the sea which they occupy is so vast, that we may safely infer that they exceed in area any group of ancient rocks which can be proved to have been of contemporaneous origin. We grant that each of the great archipelagos of the Pacific are separated by unfathomable abysses, where no zoophytes may live and no lavas flow, where not even a particle of coral sand or volcanic scoriæ may be drifted: we confine our view to the extent of reef ascertained to exist, and assume that a certain space around each volcanic or coral isle has been covered with ejections or matter from the waste of cliffs, and it will then be seen that the space occupied by these formations may equal, and perhaps exceed in area that part of our continents which has been accurately explored by the geologist.

That the increase of these calcareous masses should be principally, if not entirely, confined to the shallower parts of the ocean, or, in other words, to the summits of submarine ranges of mountains and elevated platforms, is a circumstance of the highest interest to the geologist; for, if parts of the bed of such an ocean should be upraised, so as to form large continents, mountain-chains might appear, capped and flanked by calcareous strata of great thickness, and replete with organic remains, while in the intervening lower regions no rocks of contemporary origin would ever have existed.

A modern writer has attempted to revive the theory of some of the earlier geologists, that all limestones have originated in organized substances. If we examine, he says, the quantity of limestone in the primary strata, it will be found to bear a much smaller proportion to the siliceous and argillaceous rocks than in the secondary, and this may have some connexion with

* See Captain Beechey's Voyage to the Pacific, &c., pp. 159 and 191.

the rarity of testaceous animals in the ancient ocean. He farther infers that in consequence of the operations of animals, " the quantity of calcareous earth deposited in the form of mud or stone is always increasing; and that as the secondary series far exceeds the primary in this respect, so a third series may hereafter arise from the depths of the sea, which may exceed the last in the proportion of its calcareous strata *."

If these propositions went no farther than to suggest that every particle of lime that now enters into the crust of the globe, may possibly in its turn have been subservient to the purposes of life by entering into the composition of organized bodies, we should not deem the speculation improbable; but when it is hinted that lime may be an animal product combined by the powers of vitality from some simple elements, we can discover no sufficient grounds for such an hypothesis, and many facts which militate against it.

If a large pond be made, in almost any soil, and filled with rain water, it may usually become tenanted by testacea, for carbonate of lime is almost universally diffused in small quantities. But if no calcareous matter be supplied by waters flowing from the surrounding high grounds or by springs, no tufa or shell-marl are formed. The thin shells of one generation of molluscs decompose, so that their elements afford nutriment to the succeeding races; and it is only where a stream enters a lake, which may introduce a fresh supply of calcareous matter, or where the lake is fed by springs, that shells accumulate and form marl.

All the lakes in Forfarshire which have produced deposits of shell-marl, have been the sites of springs which still evolve much carbonic acid, and a small quantity of carbonate of lime. But there is no marl in Loch Fithie, near Forfar, where there are *no springs*, although that lake is surrounded by these calcareous deposits, and although, in every other respect, the site is favourable to the accumulation of aquatic testacea.

We find those charæ which secrete the largest quantity of

* Macculloch's Syst. of Geol., vol. i. p. 219.

calcareous matter in their stems, to abound near springs impregnated with carbonate of lime. We know that if the common hen be deprived altogether of calcareous nutriment, the shells of her eggs will become of too slight a consistency to protect the contents, and some birds eat chalk greedily during the breeding season.

If on the other hand we turn to the phenomena of inorganic nature, we observe that, in volcanic countries, there is an enormous evolution of carbonic acid, mixed with water or in a gaseous form, and that the springs of such districts are usually impregnated with carbonate of lime in great abundance. No one who has travelled in Tuscany, through the region of extinct volcanos and its confines, or who has seen the map recently constructed by Targioni to show the principal sites of mineral springs, can doubt for a moment, that, if this territory was submerged beneath the sea, it might supply materials for the most extensive coral reefs. The importance of these springs is not to be estimated by the magnitude of the rocks which they have thrown down on the slanting sides of hills, although of these alone large cities might be built, nor by a coating of travertin that covers the soil in some districts for miles in length. The greater part of the calcareous matter passes down in a state of solution to the sea; and a geologist might as well assume the mass of alluvium formed in a few years in the bed of the Po, or the Ganges, to be the measure of the quantity deposited in the course of centuries in the deltas of those rivers, as conceive that the influence of the carbonated springs in Italy can be estimated by the mass of tufa precipitated by them near their sources.

It is generally admitted that the abundance of carbonate of lime given out by springs, in regions where volcanic eruptions or earthquakes prevail, is referrible to the solvent power of carbonic acid. For, as the acidulous waters percolate calcareous strata, they take up a certain portion of lime and carry it up to the surface where, under diminished pressure in the atmosphere, it may be deposited, or, being absorbed by animals and vegetables, may be secreted by them. In Auvergne, springs charged with carbonate of lime rise through granite, in which case we must suppose the calcareous matter to be derived from some primary rock, unless we imagine it to rise up from the volcanic foci themselves.

We see no reason for supposing that the lime now on the surface, or in the crust of the earth, may not, as well as the silex, alumine, or any other mineral substance, have existed before the first organic beings were created, if it be assumed that the arrangement of the inorganic materials of our planet preceded in the order of time the introduction of the first organic inhabitants.

But if the carbonate of lime secreted by the testacea and corals of the Pacific, be chiefly derived *from below*, and if it be a very general effect of the action of subterranean heat to subtract calcareous matter from the *inferior* rocks, and to cause it to ascend to the surface, no argument can be derived in favour of the progressive increase of limestone from the magnitude of coral reefs, or the greater proportion of calcareous strata, in the more modern formations. A constant transfer of carbonate of lime from the inferior parts of the earth's crust to its surface, would cause throughout all future time, and for an indefinite succession of geological epochs, a preponderance of calcareous matter in the newer, as contrasted with the older formations.