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THE SCOTTISH

GEOGRAPHICAL

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THE COCOS-KEELING ISLANDS.

By H. B. Guppy, M.B., F.R.S.E.

Part III.

COCOS-KEELING OR KEELING ATOLL.

(*Conclusion.*)

The Lagoon.—On referring to the chart of this atoll it will be observed that a large portion of the lagoon is less than a fathom in depth. In truth, taking the area of the lagoon at 25½ square miles, 12 square miles would be appropriated by the deeper northern portion, which ranges in depth from 1 to 8 fathoms, and 13½ square miles would belong to the flats in the southern part, which, with exception of the pits that stud them, are at low tide either dry or covered by less than a fathom of water. For the convenience of description, therefore, we may divide the lagoon into two parts, the shallow southern flats and the deeper northern basin.

The Shallow Southern Flats.—These flats, along the inner or lagoon-margins of the islands are for the most part bare chalky mud-banks, dry at low water, and varying from 250 yards to a mile in width. The greater part of the area of the flats, however, is covered by a depth of water varying between a few inches and six feet at low tide. Corals usually grow in luxuriance over this shallow region and in the deep pits that here and there vary its surface; but in one or two localities, in the bight of South Island, the muddy bottom is clothed with thick felt-like masses of algæ. I have here referred to the *usual* condition of these flats, because in 1876 occurred an event, so well described by Mr. Forbes, that led to the destruction or rather death of the corals in most of the eastern half of the lagoon. Following a cyclone in January of that year, there welled out from the eastern margin between New Selima and Gooseberry Islands a fluid, of an inky hue and possessing a rotten sulphureous odour, which within twenty-four hours destroyed every fish, coral, and mollusc in the eastern half of the lagoon excepting probably in the vicinity of Direction Island. Even three years after the occurrence Mr. Forbes described the poisoned area as "one vast field of blackened and lifeless coral stems, and of the vacant and lustreless shells of giant clams and other mollusca," with only here and there a young growing coral or a small living clam, and very few fishes. The poisoned corals would seem to have experienced some chemical change, since the blocks of a species of *Porites* employed by Mr. Ross for making hydraulic lime were in the poisoned state no longer available for the purpose.

The corals on the shallow flats naturally suffered most from the intensity of the destructive fluid, and even when I examined this locality twelve and a half years after the event much of it appeared a lifeless waste. The dead trunks and branches of the arborescent Madrepores that had once flourished here literally covered the bottom in places. Multitudes of the shells of *Tridacnæ*, rotten and decayed, strewed the ground; and even the pits still displayed on their bare slopes numbers of the dead detached plates of *Echinopora lamellosa* that once clustered thickly round their sides. Yet it was evident enough that the corals were in places beginning to resume their sway. Thus, the flats immediately south of New Selima have long since been clothed afresh with rapid-growing branching *Montiporæ* and other corals; and even where life seemed completely absent, a closer inspection usually discovered a few young growing corals and small living clams. However, at least a quarter of a century will have to succeed the event before the growth of corals can disguise the destructive effects of 1876.

I come now to the western half of the southern flats, a region which was not reached by the poisoned water. Here we find corals growing in great profusion, and until 1876 this was the general condition of the whole of the southern flats. However, although coral is very abundant, there are numerous interspaces of mud and sand, so that, probably, as Darwin similarly thought in 1836, not more than half of the area is actually clothed with living coral. The corals most abundant on the flats are the arborescent Madrepores, short-branched and massive species of *Porites*,[1] branching *Montiporæ*,[2] the foliaceous *Echinopora lamellosa*,[3] delicate white *Seriatoporæ*,[4] and *Pocillopora brevicornis*. This is a subject, however, to which I shall have further occasion to refer. Next to the corals I should mention the *Tridacnæ* of all sizes, from the full-sized *Tridacna gigas* downwards, which live in multitudes on the flats. The pits that stud the flats range in width from a few boat's-lengths to several hundred yards, and their depth varies from three or four to eight or nine fathoms. The

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[1] The two most frequent of the branching species of *Porites* are *P. palmata* (?) which turns black on removal from the water, and *P. clavaria*, which in a similar manner assumes a dark brown hue.

[2] Especially *Montipora digitata*.

[3] Mr. Darwin, comparing this coral to an *Explanaria*, remarks that it has polyps on both surfaces. Many of the specimens, however, which I examined, bore the polyps on one surface only. Perhaps the double-backed forms may arise from the plates growing in a more vertical position.

[4] Considered by Mr. Darwin to be *Seriatopora subulata*.

deeper pits descend rapidly at an angle of not less than 45°, and their slopes are usually covered with the foliaceous *Echinopora lamellosa* to the exclusion of almost all other corals. The shallower pits are mostly occupied by thickets of Madrepores, their sombre hue varied by the white cloudy patches of *Seriatoporæ*, with here and there a solitary specimen of *Echinopora lamellosa* almost lost amongst the other branching corals.

The Northern Basin.—Numerous coral patches separated by extensive sandy intervals are growing in the basin, but I doubt whether more than one-third of the bottom is covered with living coral. The soundings are often very irregular, the usual depth being about 5 fathoms, but within a boat's-length the water may suddenly shoal to 1½ fathoms and even less, or the lead may drop into a pit where there is a depth of 7 or 8 fathoms, so irregular is the growth of the coral. Massive species of *Porites* and the stout *Millepora verrucosa* appear to be amongst the more frequent of the corals that here thrive.

At the present time the only safe entrance for ships is that between Direction and Horsburgh Islands. The passage between the northern end of West Island and Horsburgh Island is divided into two channels by Turk Reef. The southern channel, where there is a depth of four fathoms, is unsafe even for small boats unless they are under the management of a person acquainted with the locality. On one occasion when I passed through this channel in the three-ton yacht of Mr. Ross, the water was quiet; but ten minutes afterwards a succession of huge rollers came up from the south-west, and after commencing to crest in 10 fathoms of water, they broke right across the channel and made its usually quiet waters white with foam. We had therefore to return by the channel on the north side of Turk Reef; but even this is not always safe for small craft. When there have been heavy gales in the Southern Ocean, the south-west rollers that break every fifteen or twenty minutes on the west side of this atoll are of still greater size, and break across the whole width of the passage between Horsburgh and West Islands. In truth the passage between these two islands is gradually being obliterated by coral growth, which is here very luxuriant, though mostly of the massive order. The process is well exhibited in the channel north of Turk Reef, which has been occasionally used by ships entering the lagoon, but now is dangerous although depths of 5 fathoms occur. Two curving lines of submerged reef, following the submarine contour, stretch across the inner part of this channel. They are separated by a sandy interval, 1½ to 2 fathoms deep, which is dotted with clumps of *Millepora verrucosa*, 2 to 3 feet across, and perhaps about 1½ feet in height, which, as Mr. Ross informed me, were not in existence thirty years ago. This locality affords an excellent example of the manner in which a reef extends seaward by throwing forward successive lines which may be fathoms deep, and are separated from each other by sandy intervals. In the course of time, as in this particular instance, the corals invade the sandy interspaces which become filled by the accumulation of reef *débris* and by coral growth, and the whole rapidly reaches the surface and forms a flat. In this fashion the passage between Horsburgh and West Islands will be in time obliterated. An island will be thrown up on Turk Reef, and a continuous reef-flat, such as now crosses the wide passage on the south side of the atoll, will connect Horsburgh and West Islands together.

THE AGE of KEELING ATOLL.—This atoll, viewed as an organism, has its own life-history. It cannot, in truth, live for ever. It has had its birth, has long passed its maturity, and is now on the road to its ultimate effacement as an atoll. The fact that it is doomed to be filled up as ages roll by is the foundation on which I base my arguments. Accepting this fact, we can ascertain the span of life that lies yet before it by studying the agencies at present occupied in filling up its basin. When this is known we can throw the light of our observations back into the past history of the atoll, and by, at the same time, appealing to our knowledge concerning atolls in an earlier and less mature condition, we can penetrate the mystery that at present surrounds its age. Knowing the life-history of such an atoll, its future duration, and its probable past extent, we can point to any other atoll of similar size in the Indian and Pacific Oceans and obtain an approximate idea of its age, and with caution we may extend the reasoning to those of larger and of smaller size.

Nor is this all. After taking a comprehensive view of all reefs of this class, we shall be able to learn something of the duration of the present era of atolls by ascertaining whether the majority of these coral islands are in a state of maturity, or whether the most of them are young and still in the submerged condition, or whether, as in the case of Keeling Atoll, the greater number of them are approaching the stage of obliteration. We shall, in fact, be in a position to say whether we are in the commencement, in the middle, or at the close of the present age of atolls, and we shall be enabled with some confidence to gauge its duration. But with this unit of geological time presented to us in the life-history of an atoll, we shall be able to do more. We shall be in a position to ascertain in what parts of the oceans the oldest atolls occur, and this will naturally lead us to considerations concerning the ocean basins, their permanence or otherwise, and the stability or instability of their water-level. Other far broader fields of inquiry would open out, but I have said enough to indicate the general bearings of any conclusion concerning the age of these islands. The simple estimate of the duration of the life-history of an atoll is of little value in itself, but it derives a first-class importance considered as a measure of geological time. At some future time I may hope to consider the general bearings of this matter. In this paper, however, I have only to deal with Keeling Atoll.

It will be apparent to most people that any method for the calculation of the age of an atoll must of necessity be somewhat complicated, an intimate local acquaintance, an experience of the varied conditions of coral growth in other regions, and a general knowledge of the literature relating to the subject, being requisite qualifications on the part of the investigator for its success. My deficiencies in these respects I have done my best to remove, and I therefore enter upon the matter with some degree of confidence; but it should be remarked that the limits of this paper prevent me from giving much more than the general results I have attained. The details are somewhat bulky, and all data, such as the densities of various corals, sands, muds, etc., and the different rates of growth of corals, were obtained by my own experiment and observation *on the spot.*[1]

I have already estimated that 5000 tons of sand and sediment, derived from the action of the breakers on the outer edge of the reef, are annually transported through the passages between the islands into the lagoon (Part II.). Nearly five-sixths of these materials are deposited at and near the margins of the lagoon within a zone not usually exceeding a quarter or half a mile in width. The remainder, consisting of the finest chalky mud, foraminifera, diatoms, alcyonarian spicules, etc., is carried well into the lagoon, and in unusually calm weather some of it may be seen floating on the surface in a scum of confervæ and other vegetable matter. The marginal zone, which receives nearly five-sixths of these materials, also receives constant additions from the decay of innumerable small crabs and shell-fish, a few corals, etc.; and as the combined result of these agencies I estimate that the mud-flats bordering the lagoon, which are either dry or covered only by a few inches of water at low tide, are advancing on the lagoon at the rate of 1000 *yards, or about half a mile in a thousand years.* The process is of course not always regular, but the currents in course of time distribute much of the sediment around the shores of the lagoon, and the effect produced is fairly uniform. On these mud-flats the islands also advance, but at a slower rate, pushing forward their inner or lagoon margins by the process of reclaiming described in Part II.

Passing beyond the marginal zone that receives most of the sand and sediment brought in through the passages, we come to the great southern flats themselves, which I have already described. Going back to the time before the irruption of the poisoned water in 1876, when corals flourished over the greater part of this area, and allowing for the mud-banks and the sandy interspaces, we should perhaps avoid exaggeration if we assumed that half of this area—namely, five square miles—was at that time covered with living coral.[2] One and a half square miles would be occupied by the Madrepore thickets and similar corals, one and a half square miles by the *Porites* group and massive corals, one square mile by the branching *Montiporæ,* and one square mile by the corals in the pits, usually *Echinopora lamellosa.* It must be remembered that each of these principal factors I take as including and representing other factors not mentioned. Together, I believe they illustrate the different agencies engaged in building up these flats.

I take first the arborescent Madrepores of more than one species, which grow in thickets attaining a maximum height of about six feet. From my observations and those of others, and from information supplied to me on the spot, I have good grounds for assuming that these thickets grow at the average rate of four to five inches in a year, and that they

[1] Since the local conditions vary considerably in different atolls, especially in those situated in distinct coral reef regions, the future investigator in this field should obtain *all his data on the spot.*

[2] Without the marginal zone, the southern flats cover about ten square miles.

will attain their full height in about fifteen years. Many of the main trunks are usually dead, whilst the branches are alive, and when one of these dead trunks, weakened by boring plants and animals, and by other causes, suddenly gives way, others in a similar condition follow, and the whole thicket, which may be several paces in width, is suddenly levelled to the ground, a result which I have experimentally produced. The sites of old Madrepore thickets, strewn with their broken branches and finer *débris*, are frequently to be seen in places where these corals grow in great profusion; and the observer can readily satisfy himself that these thickets grow on a bottom formed of the remains of many previous generations of Madrepores which have accumulated to such an extent that a boat-hook sinks some feet into a friable material. Now I assume from my observations that only a few years will elapse, after a thicket has attained its full size, before it comes to the ground; and I think, therefore, we may safely take twenty years as the usual duration of a thicket. Its *débris*, formed of the sand produced by the decay of its more friable parts, and of the fragments of the more compact branches, would raise the surface originally covered by the thicket between 2 and $2\frac{1}{2}$ inches, which represents a rate of about one foot in a century. I made similar observations in connection with several other species of Madrepores in this atoll that possess more thickly clustered branches, and do not exceed two feet in height, and arrived at results so similar to that obtained in the case of the arborescent Madrepores that I feel confident in accepting this rate of one foot in a century as indicating the part taken by the lagoon *Madreporidæ* in building up their portion of these great southern flats.[1]

Next we come to the group of the *Poritidæ*, which I estimate to cover $1\frac{1}{2}$ square miles of flats. The branching species, usually possessing short and crowded branches, are quite twice as numerous as the massive kinds, and I will assume that they occupy two-thirds of the area. Of the branching species the most frequent and typical is *Porites* (*palmata*?), which changes from a yellow to a black colour on removal from the water. Its level-topped clumps attain a maximum diameter of from 12 to 15 feet, and a height of from 2 to 3 feet. Before a clump has grown to half this size, it dies in the centre, which becomes coated with a Nullipore platform that bridges over the tops of the dead central branches. By the time the clump has reached its full size, the dead centre has fallen by the decay of the branches, and it presents the appearance of a ring enclosing a deep central cavity. Most of the lagoon corals with short closely-crowded branches go through this process when they attain any size; and it is only in rare instances that the patch of Nullipore incrusting the dead centre preserves the dead branches underneath until their interstices are filled with sand and other *débris*, when the clump is

[1] My method consisted first in measuring the ground covered by a typical specimen. Then, after weighing the coral, I determined by actual measurement the weight of a cubic inch of its materials. This gave me the bulk of the coral in a state of *débris*, and it was then easy to determine the rate at which the surface originally occupied by the living coral would be raised. A similar method, modified according to each special case, was adopted throughout my observations. Some of the corals, for instance, are preserved in a more or less complete condition, as in the case of the massive kind.

preserved entire. From my data I assume that this coral grows upwards at the rate of $1\frac{1}{2}$ inches in a year, but since such a large proportion of its mass rots away and decays, I think it will be safest to consider that it tends to raise the area it grows on in the form of sand. Its bulk when broken down into sand is only one-third of its mass as a living coral, so that the rate of growth of $1\frac{1}{2}$ inches in a year represents a raising of the surface of about half an inch in that period, and of about 4 feet in a century. To avoid an excessive estimate I will reduce this rate to that of 3 feet in a century.[1] This is three times as rapid as that computed for the branching Madrepores, but the mode of growth in either case is widely different; in the case of the Madrepores it is like that of a bush, whilst in that of the branching species of *Porites* the short branches are crowded together like so many fingers.

With regard to the growth of the massive species of *Porites*, I have been supplied by Mr. Ross with the necessary data for one of the commonest species in the lagoon, which in appearance resembles *Porites lutea*.[2] When not retarded in growth by the shallowness of the water, it grows in dome-shaped or round-topped masses that usually attain a diameter of 10 or 12 feet with a corresponding height. Taking its annual upward growth at only half an inch, this represents about 4 feet in a century. Most of these blocks are, I believe, preserved entire, but a few suffer partial decay. If reduced to sand, they would raise the surface about $2\frac{1}{2}$ feet in a century, and perhaps taking into consideration our limited acquaintance with the influences favouring or repressing coral growth, it would be best to accept an intermediate rate for these massive corals and place it at 3 feet in a century. These blocks, when growing in places where they are nearly exposed at low-tide, become flat-topped, and die and decay in the centre. In the shallow water of the flats one commonly observes flat-topped masses of this coral, about 12 feet across and 2 feet in height. Here the main growth has been lateral, and I estimate that each of these masses is about 125 years old.

I now come to the branching *Montiporæ*, of which *Montipora digitata* is most typical. These corals which cover extensive banks off the south side

1 The other common branching *Porites* (*P. clavaria*) has a very similar habit of growth, and evidently levels up the surface at a similar rate.

2 In October 1888 I measured the rate of growth of two masses of this coral originally weighing, in 1873, in each case 5 to 7 lbs., and probably measuring, judging from the specific weight of the coral, not more than 5 or 6 inches in height. One of them had grown to a height of 16 or 17 inches in a situation where it could not have been affected by the shallowness of the water, its weight in the wet condition being about 278 lbs., its form round but flattish on top, its vertical girth 5 feet 4 inches, and its horizontal girth 6 feet 7 inches, and showing little of decay. The other was crescentic or kidney-shaped, and had only grown to a height of 12 or 13 inches, its situation being less favourable for its growth; its weight when wet was 124 lbs., its horizontal girth 5 feet 3 inches, and vertical girth round the middle 3 feet 9 inches; covered with living polyps except at its concavity. It will be seen that, in the interval of fifteen years, the rate of annual upward growth of these corals was nearly $\frac{3}{4}$ of an inch in one case, and about $\frac{1}{2}$ an inch in the other. Mr. Ross had these corals replaced for future observation in a favourable position in October 1888; and with them were placed three small masses of the same coral varying between 5 and 10 lbs. in weight in the wet state. These data are noted in his copy of Mr. H. O. Forbes's *Eastern Archipelago*, on, I think, page 47.

of New Selima Island probably occupy about one square mile of the flats. Judging from the rate at which they have filled up a boat-channel excavated by Mr. Ross, I would place their annual upward growth at not less than 5 inches. They attain a height not usually exceeding 18 inches, and probably in about four years they attain their maturity, and commence to die. Some them are preserved entire, become incrusted with Nullipore in the centre of the clump, and have their interstices filled up with sand; but most of them go through the process of decay already described in the case of the branching species of *Porites.* Their style of growth is intermediate in character between that of the arborescent Madrepores and the closely-branched *Porites.* I estimate that successive generations of this coral would raise the surface with their *debris* at the rate of 3½ feet in a century. The *Montiporæ*, in fact, are very important agents in filling up the lagoon.[1]

The last square mile is appropriated by the pits which are usually occupied exclusively by the large plates of *Echinopora lamellosa,* but as they get shallow they are invaded by the arborescent Madrepores. When uninterrupted in their growth, these foliaceous *Echinoporæ* grow with overlapping plates around a low stump formed by the attached bases of successive plates themselves, somewhat after the fashion of a huge *Polyporus.* After noticing carefully their mode of growth, and after numerous observations on their size, and on their specific weights both in the solid and in the powdered condition, I formed the opinion that these fragile foliaceous corals are very unimportant agents in filling up the lagoon. The relative size of two solitary specimens that I saw in the midst of the poisoned area—specimens which must have grown since 1876—enabled me to roughly estimate their rate of growth; and I ultimately arrived at the opinion that these corals do not raise the surface on which they grow more than 3 or 4 inches in a century. It is evident then that the deeper pits in which these corals exclusively reign owe their preservation to the corals themselves. In the first place, these holes were doubtless due to the irregularity of general coral growth in the lagoon in past ages; but as soon as the foliaceous *Echinoporæ* selected the early hollows for their abodes, they ensured by their slow growth the safety of their homes. Whilst the coral beds all around were building up at an average rate of not less than a foot in a century, the pits occupied by these foliaceous corals were shoaling at the rate of only 3 or 4 inches in the same period. In time, however, some of these pits commence to fill up rapidly for a while in spite of the conservative efforts of the *Echinoporæ.* "Runs" of sand occur down their steep sides, and arborescent Madrepores invade their area, until as the pits get shallower and shallower the *Echinoporæ* are almost ousted altogether, and the Madrepores interspersed with *Seriatoporæ* reign supreme.

We are now in a position, after assigning to each agency its due proportion, to ascertain the average rate at which the great southern flats, 10 square miles in area, have been built up by coral growth. We

[1] Amongst the miscellaneous corals not infrequent in the lagoon is *Pocillopora brevicornis,* which levels up the surface it grows on at a rate not less than a foot in a century.

have assumed that only half of this area is at one time actually covered with living coral, and putting all the results together we arrive at the conclusion that the corals on this area build up the surface they grow upon at the rate of two feet in a century. To apply this result to the whole of the southern flats we must halve it, and then we get an estimate of one foot in a hundred years. But corals, though by far the most important agents in building up a reef, are not the exclusive agents. Molluscs, including the huge Tridacnæ, add their shells in considerable numbers to the growing mass; and to allow for their co-operation I will adopt the suggestion of Professor Dana when speculating on this matter, and will consider that "shells add one-fourth as much as corals to the reef material."[1] I will make, however, this addition more comprehensive by including in it the more solid remains of numerous other living things that infest coral reefs, such as those of crustaceans, fish, alcyonarians, the corallines, calcareous algæ, etc. Thus we make the rate of increase for the whole of these flats $1\frac{1}{4}$ feet per century; but this estimate requires further modification, since we have not yet considered the retarding influences of coral growth.

As the most disastrous of these influences I will refer to the welling up in vast quantities of dark water in 1876, by which almost half of the coral in the lagoon was killed. For at least a decade nearly half of the area was a waste, and there was almost a complete cessation from labour on the part of the coral polyps in the poisoned part of the lagoon. At least a quarter of a century will have to follow the catastrophe before the wonted activity of the little builders will be restored. I have found, however, no evidence that a like event has occurred since the atoll was first occupied some sixty years ago. Mr. J. C. Ross writing of his own islands in 1855 makes no reference to such an occurrence;[2] and it should be remarked that huge masses of *Porites*, that must have been more than a hundred years in age, and large *Tridacnæ*, with shells more than three feet in length, that had probably been alive for an equally long period, were destroyed by this poisonous water. It is evident, therefore, that events like those of January 1876, being rare in time though frequent perhaps in the lapse of ages, must have no very important repressive effects. Occurrences, however, on a much smaller scale are not infrequent, and some of them have been recorded by Darwin and Forbes. The long continuance of heavy rains is often destructive of corals near the surface in the southern part of the lagoon. After standing for some time in the interior of the bigger islands, the fresh water drains off into the lagoon in a semi-putrid condition, and fish and corals are by this means at times destroyed. Then, again, during a particular wind-season the tides may have been unusually small, allowing the surface corals to grow a few inches above their general level. When the season changes, the tides assume their usual rise and fall, and the extra few inches of coral become permanently exposed, and the result may be a field of dead

[1] *Corals and Coral Islands* (1872), p. 251.

[2] "Review of Mr. Darwin's Theory of Coral Formations," published in the *Natuurkundig Tijdschrift voor Nederlandsch Indie,* deel VIII., Batavia, 1855.

coral. At times, again, the thick felt-like masses of algæ found in the bight of South Island are washed up on the shore of the lagoon in large quantities by a heavy north-westerly swell, and there they rot, and by tainting the water injuriously affect the corals. At most times, however, these vegetable masses in this locality render the water in their vicinity too impure for coral growth and give it a rusty hue.

It will have been noticed that these lesser catastrophes only affect the corals near the surface, and their results do not extend far beyond the margins of the lagoon. They can but little affect the general coral growth, and in the earlier history of the atoll they could have but little delayed the building up of the southern flats. Mr. J. C. Ross, in fact, in the paper before quoted, dwells on the local effect of such occurrences as unusually heavy rains, and confirms my opinion concerning their unimportant influence on general coral growth.

There is, however, another retarding influence to reef-growth and that is the solution of the dead coral in sea-water. I do not, however, consider this as a very effectual repressive agency in the present closing scene of the atoll. The accumulation of coral *débris* is too patent a fact. When we walk through a field of madrepore and sink knee-deep into the friable *débris* of many preceding generations of this coral, we realise the fact that dead coral accumulates and is but partially removed in solution. The residents year by year see their favourite anchorage shoaling by some rapid growing coral that finds on the *debris* of preceding generations a suitable station. Still there can be no doubt, as shown by Murray, Irvine, J. G. Ross and others that the solvent action of sea-water has a repressive effect on the rate of reef-growth, and to allow for its agency and also for the other retarding influences before enumerated, I will reduce my estimate for the building-rate of the great southern flats by one-fifth which will make it *one foot in a century.* Probably this rate is in excess of the growth of the corals on the flats at the present day, since they are exposed to the repressive influence of shallow water. My observations, however, were made on corals growing under normal conditions and unaffected by the shallowness of the water, and the estimate, therefore, represents the historical rather than the existing rate of the building up of the great southern flats now mostly covered by less than a fathom of water.

It is now necessary to obtain some data with reference to the basin occupying the northern half of the lagoon. I have already spoken of the proportion of sand to coral being at least two to one.[1] Its bottom is

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[1] It is probable that only a small proportion of the sand in the interior of the lagoon has been derived from the materials transported through the passages. Five-sixths of the 5000 tons annually carried into the lagoon are deposited, as I have already remarked, near the margins, and the remainder would only raise the general surface of the interior at the rate of one foot in 1700 years. The greater part of the sand away from the vicinity of the margins of the lagoon is first produced by the degradation of dead coral through the agency of the boring-molluscs, annelids, echinoids, sponges, etc., which there find a home. The trituration of the coarser sand and gravel is effected in the digestive systems of the echinoderms, crustaceans, molluscs, fish, and other organisms that swarm upon a reef. The solvent agency of sea-water evidently prepares the way assisted by the decay of the animal matter. Mr. Darwin held the opinion that the Holothurians, which live in great numbers on a reef,

very irregular, and numerous coral patches seriously obstruct its navigation, some of them, as in the case of Dymoke Shoal, rising to within a fathom of the surface, whilst others are awash at low-tide. When we come to consider the changes that have occurred in this atoll since it was first occupied some sixty years ago, we enter on very uncertain ground. The present chart of these islands is of little use for this purpose, since it is merely Captain Fitzroy's plan of 1836 to which only a few additions have since been made. In it the shoals and shallow patches are with few exceptions marked just as they were half a century ago, and in truth to obtain any comparative results of scientific value another Admiralty survey is absolutely necessary. In the plan of these islands reproduced by Mr. Forbes in his *Eastern Archipelago*, the author endeavoured to indicate the changes that took place in the atoll between the *Beagle's* survey in 1836 and his own visit in 1879; but the most reliable results can only be obtained by the comparison of two Admiralty surveys. Even under such circumstances great caution will be necessary so as not to regard as recent changes what may only have been omissions in the previous survey. Thus, with reference to the lakelet or lagoonlet in Horsburgh Island, it might be inferred that it has recently been formed, because it is not found in the original plan of 1836 (given in the third volume of Fitzroy's *Voyages of the Adventure and Beagle* (1839)). As a matter of fact, however, it is marked in Van der Jagt's plan of 1829.[1] This last plan will be found very useful in association with Fitzroy's chart when a comparison between the past and the present comes to be made. Mr. Ross has also in his possession a sketch of these islands made by his grandfather about 1825.

I followed up the two lines of soundings carried by the officers of the *Beagle* across the basin, and came to the conclusion that whilst the general shallowing since 1836 has been slight, the growth of coral patches has been in some places rapid. This is evidently the mode by which the basin of the lagoon will be filled up, and it will be undoubtedly a slow one. In the space of half a century the sandy intervals will shoal but little, whilst the coral patches may rise up considerably.

General impressions concerning changes in an atoll are often not reliable.[2] It would be folly, for instance, to conclude that a lagoon was

actually browse on the living coral (*Coral Reefs*, 1842, p. 14). Nearly all other observers, such as Dana, A. Agassiz, Semper, Saville Kent, etc., have controverted his view, and I have never myself seen an instance of the kind. This subject I have treated at length in a paper on the Solomon Island reefs (*Proc. Roy. Soc. Edin.*, 1885-86, p. 894).

[1] *Verhandel. Batav. Genootschap der K.*, Batavia, 1832.

[2] Whilst in these islands I was led to believe that during the last sixty years vessels had been gradually crowded out of the centre of the lagoon-basin by the growth of coral and that now Port Refuge was alone left to them. However, I find that the anchorage recommended has always been in Port Refuge, except when, as in the early days of Van der Jagt and others, an anchorage off the NW. side of Direction Island, outside the lagoon, has been also suggested. In the plan of Van der Jagt of 1829, in that of Keating of about the same date which is given in Holman's voyage, in a sketch-map, apparently by Captain J. C. Ross, which accompanies a description of these islands published in the second volume of *Gleanings in Science* in 1830, and in Fitzroy's chart of 1836 we find the anchorage marked within Port Refuge and usually near the entrance or under Direction Island. In truth it was not considered safe in those early days, except in case of war, for a vessel drawing

rapidly filling, merely because within a few years a boat-channel became choked with some rapid-growing *Montipora* or *Madrepora*, a possible mistake, which, however, did not entrap the young naturalist of the *Beagle.* I have endeavoured to show in this paper that any mode of estimating the rate at which a lagoon fills must of necessity be somewhat complex, and Dana long since pointed this out with reference to general reef-growth (*Corals and Coral Islands*, 1872, p. 249).

The best way to obtain an estimate for the rate of the filling up of this basin will be to employ the data we have already obtained in the case of the southern flats, assigning, however, a much more important part to the massive corals. Of the 12 square miles of its area, I assume that only 4 square miles are at any one time occupied by living coral. Half of the coral area would be occupied by massive corals (of which the prevailing species of *Porites* may be taken as types) that would shoal the waters at the rate of 3 feet in a century. The other half, covered with millepores, stout-branching corals, as *Isopora labrosa*, and a variety of other corals, and numerous reef organisms, would probably shoal at the rate of 1½ feet in a century. This gives a rate of 2¼ feet in the time for the whole coral area, and a rate of three-fourths of a foot per century for the total surface of the basin. Taking the average depth at 5 fathoms, the lagoon would be, for the most part, filled up at the end of four thousand years.

But in fact the process will be more rapid, though less simple in its operation. Whilst the basin is slowly shoaling, the great southern flats will be rapidly encroaching on its area. Upon their advancing slopes corals grow very luxuriantly, and more abundantly than on the flats, and their building-rate would probably be not less than 1½ feet in a century. After examining the locality and character of these slopes, I have arrived at the conclusion that during the next twelve hundred years these southern flats will advance about two-thirds of a mile. During that time the basin will have shoaled about 1½ fathoms, and the next advance will be considerably more rapid, so that in about two thousand years from the present time, the edge of the southern flats will be in all likelihood within half-a-mile of Dymoke Shoal. Meanwhile all the sides of the basin will be closing in. The passage between Horsburgh and West Islands will have long since been closed, partly through coral growth and partly through the constructive agency of the breakers. There will be an island of some size on Turk Reef, and a continuous reef-flat joining it on either side with Horsburgh and West Islands. The northern basin itself, that at present occupies half of the lagoon, will probably be not more than a mile wide and a couple of fathoms

more than twelve feet of water to sail up into the lagoon (*Ibid.*). Two Dutch navigators, J. J. Duintjer and J. W. Retgers, who visited these islands in 1842 and 1844, anchored within Port Refuge (*Verhand. . . . het Zeewezen*, Amsterdam, 1844 and 1845). In fact, it has never been the rule for vessels to anchor well up in the lagoon, except in the case of the island schooners. It is true, however, that in this instance Mr. Ross has within the last few years had to anchor his schooners within Port Refuge owing to the difficulty of keeping the anchorage off the Settlement clear of coral; but this is the only reliable evidence I can find to support the idea that vessels have been crowded out of the lagoon.

deep, and its size then will probably be roughly indicated by the dotted line that in the present chart defines the anchorage. The greater part of the present southern flats will then be covered with the mud-banks, and on these banks the islands will have advanced their margins half-a-mile or more. The great southern passage, between South and West Islands, will then be blocked up, and probably these two large islands will be joined; whilst, without a doubt, many of the islands on the east side of the atoll will then be united.

Such will be the condition of this atoll two thousand years hence; but the process then will be by no means complete. Most of the present northern basin will be in the existing condition of the great southern flats, covered by less than a fathom of water, and studded here and there with deep holes; and there will still be the shallow basin of the dimensions, and in the situation of the present anchorage. Another thousand years will probably elapse before the interior of the atoll is in a condition of *terra firma*; yet even then we shall find many of the pits represented by lakelets of salt water. But the salt water will be brine, the effect of ages of evaporation since the lakelets were cut off from the sea; and around their borders will be deposited great quantities of salt marking their diminishing size as time progresses; and in their briny waters, stronger than any artificial brine, will be found dead fish in an excellent state of preservation, "sweet and wholesome."[1] What a contrast will these fields of salt, and these lakelets of brine, with their pickled fish, present to the departed beauties of this coral atoll! One would scarcely realise then that there was a time when shoals of fish

> "Grazed the sea-weed their pasture, and through groves
> Of coral strayed, or sporting with quick glance
> Showed to the sun their waved coats, dropt with gold."

In time, however, the fields of salt and the briny lakelets will be replaced by extensive deposits of gypsum, such as occur in some of the obliterated atolls of the Central Pacific, Jarvis's Island to wit. No guano will probably be formed in this island, such as we find in the ancient uninhabited atolls of the Central Pacific, just alluded to, since the frigate-birds, the gannets, and the boobies, will be scared away by the presence of inhabitants, who, if they are the descendants of Mr. Ross, will have already effected the third renewal of the original lease of one thousand years. But little vegetation will grow on the sterile soil in the central area of the obliterated lagoon. Here and there will be found some scrubby grass or a patch of brushwood or a thicket of low leafless trees, and in this condition the surface will remain for ages. Should it be my fate to visit this spot again in that distant epoch, my vessel would anchor outside the atoll in a deep and sheltered bay of its north-west shore, formed on the north by the extension of Horsburgh Island for a mile or so along the submarine bank that trends away to North Keeling Island, and on

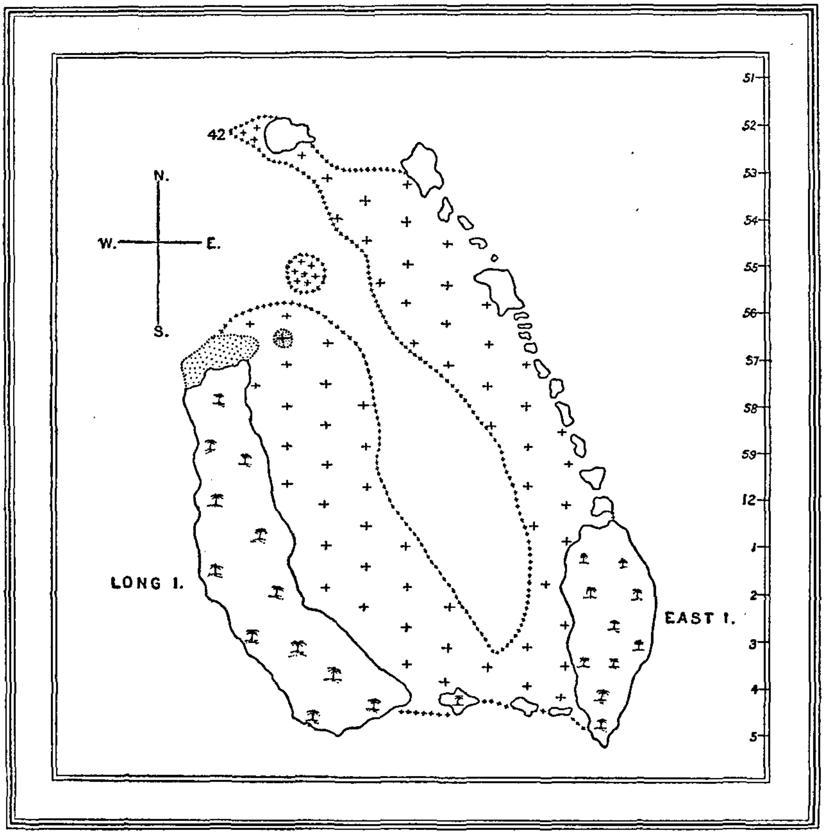
[1] This is no fanciful picture of the future condition of this atoll. It is in reality taken from a description of Christmas Island, in the Pacific Ocean, by Captain Hooper in 1858 (Rosser's *North Pacific Pilot*, Part II. p. 274 (1870).) This obliterated atoll well represents the future state of Keeling Atoll.

the south by a continuous wooded coast marking the closed-up passage between Horsburgh and West Islands.

I must now attack the problem of the previous age of this atoll, and endeavour to ascertain what period of time has elapsed since, as a submerged coral bank, it first lipped the waves. A certain familiarity with coral reefs, and with the charts of coral islands enables me to recognise in this coral island an atoll that, as regards the size of its lagoon, is entering on the last quarter of its history. We have estimated that it has at least another three thousand years before it, but probably the last stage will be rather more rapid, and in duration it may only represent one-fifth of the total life of the atoll, which, in that case, would extend over a period of fifteen thousand years. It must, of course, be remembered that an atoll can never be in a stationary condition. From the time when its margin is only indicated by the foam of the breakers to its mature stage when, as a ring of wooded islands surrounding a lagoon, it presents "a quiet scene of wood and lake," admirably set off by the contrasting ocean (Dana), its interior must be ever shoaling through coral growth.

We may attack the problem of the age of this atoll in another way, by assuming from the data I have collected that from its first appearance at the surface, when the lagoon had probably a maximum depth of 30 to 35 fathoms, to the final obliteration of its basin, it would be filling up at the average rate of a foot in a century. This would give its life-history a duration of about twenty thousand years. Again, assuming that the southern flats have a depth of 25 fathoms of coral *débris* beneath them, or a thickness of 150 feet at their edge, they would require a period of fifteen thousand years for their formation, if, as is probable, the average building rate has been one foot in a century. Supposing, however, that they had built themselves up half as rapidly again, say $1\frac{1}{2}$ feet in a century, they would require then a period of ten thousand years. Their origin would, of course, begin with the first appearance of the atoll, and if we add to these estimates the three thousand years which the atoll has yet to run, we obtain a life-history of eighteen thousand years in the one case, and thirteen thousand years in the other. On the whole, therefore, I should be inclined to say that, from its first appearance at the surface to its final obliteration, this atoll will require *a period of between fifteen thousand and twenty thousand years.*

On the Discovery and Early History of these Islands.—The discovery of these islands is usually attributed to Captain William Keeling during his return from Bantam in 1609; but I have failed to find any reference to such a discovery in the narrative of the voyage given by Purchas, Prevost, and other compilers of the early voyages. It is, however, evident from the accounts there given that his homeward track lay in the vicinity of these islands. That the discovery was made by the English, and probably by Keeling, is shown in the circumstance that these islands are laid down in Dudley's *Arcano del Mare*, published in 1646-47, where it is expressly stated that they were discovered by the English. In the maps of this atlas their size is much exaggerated, but their position, about 500 miles SW. of the Sunda Strait on the 11th and 12th parallels, leaves no doubt as to their identity. The northernmost in the text and in two maps is named Killing Island (in one instance Riling I., evidently a misprint), the present North Keeling Island; whilst the islands of Keeling Atoll indicated by three wedge-shaped islands are named in this ancient atlas the Triangular Islands. Both Killing Island and the Triangular Islands are stated to have been discovered by the English, and it would almost appear that they were



EARLY DUTCH CHART OF KEELING ATOLL.

From the sixth volume of Van Keulen's Atlas, Amsterdam, 1753, p. 19. In the original chart occurs the following note:—"All very low and steep-to, except where 42 is marked, and thus entirely inaccessible." North Keeling Island is also there included.

independent discoveries. But this is not the first appearance of these islands in the charts of the old cartographers. They are correctly placed, but without a name, in Blaeu's appendix to the *Theatrum Orbis Terrarum* of Ortelius, which was published at Amsterdam in 1631. In the earlier editions of this atlas, those of 1606 (London), and 1570 (Antwerp), the situation of these islands is represented by a blank.

Strange to say, the Dutch, doubtless for good reasons, have never accepted the name of Keeling for these islands. In one of the maps of a large atlas published at Amsterdam in 1659, they are called the Cocos Islands, and this is the name by which they are always known in the Dutch charts of last century, such as those of the celebrated house of the Van Keulens; and it is remarkable that in most, if not all, of the French marine and general atlases of last century, those of Delisle (1700), Vaugondy (1757), Bellin (1764), D'Anville (1786), etc., they bear this name of the "Cocos Islands." The English hydrographers, however, preferred the name of Keeling; but it is noteworthy that Thornton in a map of the world given in his *Oriental Navigation* of 1703, and of later dates, writes the name as Kelling. Dalrymple in his charts and writings of about a century ago, refers to these islands under both names; and Horsburgh, the hydrographer of the East Indian Company, followed in his steps. All the evidence, therefore, derived from English geographers of the 17th and 18th centuries points to Keeling as the discoverer, and it is noteworthy that I did not find these islands laid down in any of the maps I examined of a date prior to that of Keeling's voyage.

During last century the passing navigator occasionally landed on these islands, but few if any of them trusted their vessels in the unsurveyed waters of the lagoon. The earliest description I have found occurs in the sixth volume, published in 1753, of Van Keulen's *Zeefakkel* (page 19), where they are described as low and wooded, reef-girt, with the appearance of deep water inside, and as possessing an abundance of cocoa-nuts, but no inhabitants; "so that it would seem," as the account naïvely runs, "that nature herself has produced these trees." In a plan of these islands which occurs in this volume, there is a note to the effect that they are "all very low, and steep-to, except where 42 is marked (off the west end of the present Horsburgh Island), and therefore entirely inaccessible." Further on in this paper I refer to the interest connected with this map with regard to the changes in this atoll. I need scarcely point out that its date must be prior to 1753, when the sixth volume of Van Keulen's atlas appeared. Mr. G. D. Bom, a member of the firm that has succeeded the ancient house of the Van Keulens of Amsterdam, informs me that it was made in 1729-30 by Jan de Marre, the noted Dutch navigator and poet, when in command of the *Heesburg*. I have, however, not yet obtained the necessary reference.

Coming to the early part of the present century we find, according to Keating,[1] that these islands were temporarily occupied in 1825 by Captain Le Cour of the brig *Mauritius*, his name, together with those of his crew, being found on the cocoa-nut trees by subsequent visitors. However, in December of this year Capt. J. C. Ross in the *Borneo*, a ship belonging to Hare and Son of London, took formal possession of these islands, and after first returning to England to consult with his firm, he settled here with his family in November 1827. During his absence Mr. Hare, a brother of one of the partners, established himself

[1] *Holman's Voyage*, iv. 371.

here, and there ensued on the arrival of Capt. Ross a period of dual rule in the islands, Mr. Hare asserting that he had previously asked Capt. Ross to examine the islands for him, whilst Capt. Ross maintained that he understood Mr. Hare to have referred to Christmas Island. However, after some years, Hare departed for Singapore. Meanwhile these proceedings had attracted the attention of the Batavian authorities, and in October 1829 arrived Mynheer Van der Jagt in the *Blora*, appointed as commissioner to make a report on the islands.[1] The Dutch commissioner was followed by Capt. Sandilands, who arrived in H.M.S. *Comet* in the following February (1830) for the purpose of inquiry. I have not been able to discover his report; but in the succeeding October an account of these islands, derived, as the editor remarked, from official documents, was published with a sketch-map in the second volume of *Gleanings in Science*, a Calcutta publication. This is the most complete of all the early accounts of these islands, and evidently most of its information was originally derived from Capt. Ross himself. A short paper from Rear-Admiral Owen, identical, as far as it goes, with the preceding, was read before the Royal Geographical Society, and was published in the first volume of their Journal (1831). In 1836 Capt. Fitzroy and Mr. Darwin arrived in H.M.S. *Beagle*, and the islands were properly surveyed. The descriptions both of Capt. Fitzroy and of Mr. Darwin are to be found in Fitzroy's *Voyages of the Adventure and Beagle*. Subsequently other accounts of these islands were given by Mynheer J. J. Duintjer in 1842, and Mynheer J. W. Retgers in 1844.[2] However, neither the Dutch nor the English could be persuaded to take the islands over until 1878, when they were definitely placed under the Government of Ceylon.

The early Dutch map of Keeling Atoll, attributed to Jan de Marre, 1729-1730. This map, as I have remarked, was published in Van Keulen's atlas in 1753. Though on an exaggerated scale, the plan is in many of its main features correct; but it is apparent from the form given to East Island (the present South Island) and from the great extension of the basin of the lagoon, that those who made the plan could not have entered very far into the lagoon. Disregarding the errors, which are inseparable from what is merely a sketch of these islands, we may safely conclude, on making a comparison with the present condition of the atoll:—

(*a*) That for a century and a half Turk Reef has been awash with the breakers without the formation of an island upon it.

(*b*) That 150 years ago the larger islands were as entire as they are now, and were not divided by passages.

(*c*) That no new island has been formed in this period, and that with the exception of Workhouse Islet, the islands possess the same relative size as when the plan was made.

(*d*) That 150 years make but little alteration in an atoll.

[1] This report is given in vol. xiii. of *Verhand. Bataviaasch Genootschap der K.*, Batavia, 1832.

[2] *Verhand. . . . het Zeewezen*, Amsterdam, vols. for 1844 and 1845.

Summary of the conclusions arrived at in this paper.

(*a*) That these islands possess a very salubrious climate. (Part I. pp. 282-284.)

(*b*) That besides pumice there has been drifted to these islands a huge volcanic bomb. (Part I. p. 286.)

(*c*) That large blocks of floating corals have been stranded on these islands. (Part I. p. 287.)

(*d*) That the lagoon of North Keeling Island has always been shallow and was formed after the reef reached the surface, by islands thrown up on its margins and subsequently united. (Part I. p. 294; Part II. p. 466.)

(*e*) This small atoll of North Keeling, when compared with the neighbouring large atoll, exemplifies the relation, dwelt upon by Murray, which exists between the periphery and the superficial area of the lagoon in atolls of different sizes. A small atoll not a mile square, as North Keeling Island, can have never had a deep basin on account of the large amount of sand carried into its lagoon from its relatively great extent of outer reef.

(*f*) The growth of corals in the lagoon is probably affected by the variations in the surface-temperature of the water. Whilst the temperature in the centre of the lagoon is nearly constant during the day, that of the waters near the margins varies considerably, being 2° to 3° F. cooler in the morning than the central temperature and 4° to 5° warmer in the evening. This variation, as already shown (Part I. p. 284), affects the climate.

(*g*) That when a section of an atoll is drawn on a true scale it is shown to be merely a level patch of coral reef with a slightly raised border, and has no basin in the true sense of the word. (Part II. pp. 457, 458.)[1]

(*h*) That a reef grows outward on its own talus rather by jumps than by a gradual outward growth. (Part I. p. 294; Part II. p. 461.)

(*i*) That the islands have three modes of increasing their extent. They may *advance seaward on the reef-flat by the formation of successive ridges of reef-débris* thrown up by the wash of the breakers. Their *extremities are extended and curved lagoonwards* by the sand and *débris* carried in by the currents through the passages between the islands, which thus become crescentic in form. After several of these horse-shoe or semi-crescentic islands have been united into larger islands, *their inner margins advance on the lagoon by a reclaiming process*, the bays or lagoonlets being gradually silted up through the reclaiming influence of the bush-covered bars or banks that more or less cross their mouths. (Part II. pp. 463-475.)

[1] Captain Fitzroy gives sections of this atoll in his *Voyage of the Beagle, etc.*, which afford a good illustration of the true dimensions of an atoll. He, however, makes the seaward slope less rapid than I have done in my section.

(*j*) That all the original islands on the reef tend to assume the crescentic or semi-crescentic form through the extension and curving lagoonwards of their extremities by the deposition of the sand carried in by the currents over the reef, just as a stake in a river's bed gives rise to a V-shaped ridge of sand (Part II. p. 472); but that when such islands join to form the larger islands, their original crescentic form is often disguised.

(*k*) That the passages once dividing the larger islands have not been filled up within the last 150 years. (Part II. pp. 467, 469, and Part III. p. 585.) Mr. G. C. Ross, who succeeded his father in the proprietorship of the islands, remarking in 1855 on the antiquity of these passages, observed that they must have been closed before Europeans first doubled the Cape. He had a copy of the old chart which Mr. Liesk described to Mr. Darwin as exhibiting South Island cut up into a number of islets (*Coral Reefs*, 1842, p. 15). Though without date, the old chart had the appearance of having been made in the early part of last century. It was the opinion of Mr. Ross that it had been sketched some distance out at sea, when, from the relatively smaller height of South Island at the sites of the original passages, these portions of it would be below the horizon.[1]

(*l*) That at least 5000 tons of sand and *débris* derived from the breaker-edge of the reef are annually transported by the currents through the passages between the islands into the lagoon, nearly all of which is deposited at and near the lagoon's margin. (Part II. p. 474.)

(*m*) That of the whole area of the lagoon, about 25½ square miles, only about 9 square miles are usually covered with living coral. (Part III.)

(*n*) That catastrophes like that of the irruption of poisoned water in 1876, through which nearly half of the corals in the lagoon were killed, are rare in time, though frequent perhaps during the lengthened life of the atoll. Some of the massive corals, then killed, must have been more than a century old. Such an event has not happened before within the memory of the present proprietor, and no such occurrence was referred to in 1855 by his father when writing of his own islands in his criticism of Mr. Darwin's views. (Part III. p. 577.)

(*o*) That whilst arborescent Madrepores in the lagoon do not raise by their *débris* the surface on which they grow more than a foot in a century, the massive species of *Porites* fill up the lagoon at three times that rate. (Part III. pp. 573-575.)

(*p*) That branching Madrepores and *Montiporæ*, and branching and massive species of *Porites* are the principal agents engaged in filling up the lagoon.

(*q*) That the deep pits in the lagoon owe their preservation to the foliaceous corals that appropriate them. (Part III. p. 576.)

[1] *Natuurkundig Tijdschrift voor Nederlandsch Indie,* deel. VIII., Batavia, 1855.

(*r*) That the great southern flats have been built up at the rate of a foot in a century, and that they are at present advancing on the deeper part of the lagoon at the rate of $\frac{2}{3}$ of a mile in 1200 years. (Part III. pp. 578-580.)

(*s*) That the deeper parts of the lagoon are not shoaling at a faster rate over their whole surface than $\frac{3}{4}$ of a foot in a century. (Part III. p. 580.)

(*t*) That the total life-history of this atoll will cover a period of between 15,000 and 20,000 years, and that it has yet another 3000 years to run before the obliteration of the lagoon is complete. (Part III. p. 582.)

(*u*) That the main features of this atoll change but slowly in the course of centuries. (Part III. p. 585.)

(*v*) That neither of upheaval nor of subsidence is there any evidence of an unequivocal character. After an existence of many thousands of years, the islands still retain their low elevation, due originally to the constructive action of the breakers assisted by the accumulation of blown sand; so that there is scarcely room for the belief even if the evidence of upheaval apparently existed. The apparent signs of subsidence to which Mr. Darwin alludes, were otherwise explained by the late Mr. J. C. Ross when he somewhat vigorously took up the cudgels in 1855 on behalf of the stability of his own atoll. In his paper, which is referred to on page 587, he gives the same explanation which his son, Mr. G. C. Ross, the present proprietor, also pointed out to Mr. Forbes and to myself. Both ridicule the idea of deducing a movement of subsidence from such flimsy evidence as Mr. Darwin advances. During their lifetimes on this atoll there have been in some places, owing to the gales and the local currents, temporary encroachments of the waters of the lagoon, during which cocoa-nut palms have been undermined and brought to the ground; but more often the contrary has occurred, and we can point to many a clump of young cocoa-nut palms which they have planted on ground naturally *regained* from the lagoon. If Mr. G. C. Ross were to follow his father's example and give to the world his own ideas on Keeling Atoll, he would write with a greater authority to be heard than could be claimed for any one who has visited these islands. In truth, without the advantage of his experience, I should have missed over much that was important.

(*w*) All the evidence goes to show that these islands were never inhabited before the early part of this century; but it would seem that cocoa-nut palms have abounded on them ever since their discovery in the early part of the seventeenth century.

Note.—If I should be able to throw further light on the discovery of these islands, I may, with the Editor's permission, send a few lines on the subject to a future number of this Magazine.

My observations on the stocking of these islands with their plants are embodied in a long paper at present before the Council of the Victoria Institute, London.