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THE SCOTTISH GEOGRAPHICAL MAGAZINE.

THE COCOS-KEELING ISLANDS.

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

PART I.

ALTHOUGH these coral islands have become familiarly known since they were described by Captain Fitzroy¹ and Mr. Darwin half-a-century ago, a detailed account of them has never been published. They have afforded materials for the pens of numerous visitors and sojourners, amongst whom I may mention Keating² and Van der Jagt³ in 1829, and Forbes in 1878.⁴ The northernmost island, however, has never been described, and I was fortunate to have the opportunity of visiting it.

My principal interest in these islands lay in their characters as coral islands, and here I was surprised to find that the description given by Mr. Darwin in his work on *Coral Reefs* was a very general one, and by no means a detailed account. During the ten days' stay of H.M.S. *Beagle* in this atoll in 1836, her young naturalist was also occupied in making notes and collections of the fauna and flora, so that but a moiety of his time could have been devoted to the observation of the coral reefs. In truth, when one reflects that this large atoll is about 25 miles in circumference, and that it possesses about two dozen islands and islets, of which the two greatest have a sweep of 6 and 5 miles, it will be at once perceived, as I found in my own experience, that a visit of several weeks is required for its satisfactory examination. Thus it was that in his few days' sojourn Mr. Darwin overlooked some of the most important features of this atoll, and fell into some errors which would have disclosed themselves to him had his visit been greatly pro-

¹ *Voyages of "Adventure" and "Beagle,"* by Fitzroy and King. London, 1839. Vol. ii. Darwin's *Journal and Coral Reefs*, and vol. iii. of *Voyages of "Adventure" and "Beagle."*

² Holman's *Voyage round the World*, 1835, vol. iv. p. 371.

³ *Verhandel Bataviaasch Genootschap der K.*, Deel xiii. (Batavia, 1832).

⁴ Forbes's *Eastern Archipelago*, Chaps. ii. and iii.

longed. Even during my stay of ten weeks in these islands, from August to October 1888, I left much to be done, although I examined every island and islet, and spent many days in exploring the lagoon.

It is singularly appropriate that through funds supplied by Mr. John Murray, the author of the rival theory of Coral Reefs, I was enabled to take advantage of the offer of Mr. G. C. Ross to visit the only atoll that Mr. Darwin ever examined, and but for which he would never have advanced his theory of subsidence. Through my agency Mr. Murray has been able to meet his opponents on their own ground, and to point out that a brief and incomplete examination of a large atoll, unaided by any other acquaintance with this class of reefs, formed the key of Mr. Darwin's position.

After these preliminary remarks, it would be more fitting perhaps to at once proceed to the proper matter of this paper; but in truth my collections are not yet examined, and my notes are not yet fully digested, and it is due to the courtesy of the Editor that I am enabled to gain time for these purposes by contributing my observations in the form of a series of papers to this Magazine. In consulting the works of the early voyagers and hydrographers of the last century, I have come upon an old plan of these islands; but as my researches are not yet complete, I will defer my remarks on the discovery of this group, and will occupy this paper with some general remarks on the climate, and other miscellaneous matters, together with a description of North Keeling Island, an island never before visited by a naturalist.

THE CLIMATE.—The Cocos-Keeling Islands possess a climate that for its salubrity cannot be excelled within the whole belt of the tropics. Although this small group lies only 12° south of the Line, one can live for the greater part of the year under conditions comparable to those of a fine summer day in Southern Europe. Previous to the recent introduction of beri-beri, now disappearing, sickness was rarely known in these islands, the inhabitants nearly all dying at an advanced age. The half-starved and stunted Javanese coolies, who engage themselves for a term of service on the coco-nut plantations, become in a couple of years plump, vigorous, and well-looking; and their wives, wont only to bear a family of three or four children in their native land, here rear up families of eight or nine. The South-east Trade prevails for 300 days out of the year, and under its bracing influence sickly Europeans have rapidly recovered their usual health. The hot close nights of the tropics are here an uncommon experience; and that continual perspiration, which is generally the bane of existence in these latitudes, is an inconvenience only rarely undergone. Malaria cannot linger in these islands, the searching blast of the Trade being its most powerful foe.

As this atoll has been placed under the British flag, I think it my duty to call attention to its salubrious climate, and to its suitability as a sanitarium, especially for tropical invalids, and also for patients suffering from some forms of consumptive diseases. For most of the following particulars I am indebted to the kindness of Mr. G. C. Ross, the owner of the islands, who placed at my disposal his journals between 1883

and 1886. I also kept a register of the temperature and the wind during the period of my visit, which commenced on August 13th, 1888, and lasted about ten weeks.

The temperature¹ throughout the year is but partially influenced by the seasons. However, the winter months, June to September, when the South-east Trade blows freshest and steadiest, are naturally the coolest. During this period the usual daily maximum temperature in the shade varies from 78° to 80° (Fahrenheit), and the minimum temperature from 73° to 74°, whilst only in six or seven days of each month does the thermometer rise above 82°. The hottest months are from December to March, when the Trade is less regular, and occasional westerly and northerly winds occur. Then the thermometer rises above 82° in eighteen or twenty days of each month, the usual daily maximum temperature being from 83° to 85°, and the minimum between 76° and 77°. The other months of the spring and autumn are of course, as regards their temperature, intermediate in character. The greatest temperature for the year is usually 88° or 89°, a height which is only reached on two or three occasions, and often the whole year passes without a register of 90° being recorded. During the twelve months, the minimum temperature rarely falls below 70°, except in three or four nights. Every few years, however, there is an occasional colder spell, when the daily temperature for a week or two ranges between 65° and 70°, an effect due to some unusual cause, such, perhaps, as the advance of the Antarctic ice. The annual mean temperature of these islands is about 78°·5.

With regard to *humidity* I should remark that, during the settled Trade weather of the winter months, from May to September, the air is pleasantly dry, there being usually from 6° to 8° difference between the wet and the dry bulbs. During the less settled weather of the opposite season of the year, when these islands are at times affected by the monsoon, the Trade being then interrupted by westerly and northerly winds and by calms, the air is less dry; but it is rarely unpleasantly moist, the wet and dry bulbs in the dampest weather being usually from 2½° to 3° apart.

The rainfall has not been measured, but probably it does not exceed 40 inches in the year. From April to September it occurs more as passing showers, which often take place in the night. During the other part of the year it is heavier and more frequent. It would seem that the total number of days on which rain falls is not in excess of one hundred. The rainfall gives a lasting supply of water to the wells, and is sufficient to temper the climate without rendering it uncomfortably wet.

I have referred above to the Trade as from the south-east. It must, however, be understood that, though usually from this quarter, the Trade may vary in this latitude from east-by-south to south. I am, however, correct in saying that the regular wind, usually spoken of as the South-east Trade, prevails for 300 days out of the year. During the winter

¹ My observations were made on the Settlement Island, which, for reasons given below, probably possesses a rather more equable climate than the weather islands.

months it blows very fresh, especially in June, July, and August. Between November and February the Trade is less steady, and, as above mentioned, is interrupted by calms and by variable westerly and northerly winds.

The climate of these islands compares very favourably with that of Levuka, in Fiji,¹ notwithstanding that the latter locality lies nearly 6° farther south, and is situated on the weather or healthy side of the group. Compared with Levuka, the Cocos-Keeling Islands have about the same annual mean temperature, and much the same percentage of humidity; but the daily variation and the annual range of temperature are much smaller. Thus, in Levuka the daily variation amounts to 10° or 11°, and the annual range to about 27° (65°-92°); whilst in the Cocos-Keeling Islands the daily change is only about 7°, and the annual range covers scarcely 20° (70°-89°). Then, again, in the islands I am at present describing, the Trade blows more steadily throughout the year than at Levuka; there is no such marked distinction between the wet and hot and the dry and cool seasons as in Fiji; and the rainfall is probably not much more than a third.

It is singular how the variation in the temperature of the waters at the margin of the lagoon, a subject to which I shall subsequently allude, tempers the climate of some of the lee islands. Thus, in the morning, the waters within 1½ miles of the lagoon-margin have a temperature 7° or 8° lower than they have in the afternoon. In the later part of the day, impelled by the prevailing trade-wind, these warm waters are piled up against the islands in the northern part of the atoll, and in the evening are from *four to six degrees warmer than the temperature of the air*. The result of this is that the climate of Settlement Island, and also of Direction and Horsburgh Islands, is considerably equalised, the cooler temperature of the night hours being raised by the adjacent warm lagoon waters, and the morning heat being lessened by the cooler temperature of the lagoon.

Should it ever be the intention to establish a sanitarium on these islands, the cost of living will be found to be very cheap. Probably an invalid's total expenses, including that of his house, would fall short of £100 per annum. Fish and poultry are at present the staple articles of animal food, the former being very excellent, and in great variety. Rice supplements all the meals. The attire best suited for this cool tropical climate should be made of light grey flannel; and I would also suggest that, since the life at the best would not be characterised by the usual rounds of social life, the visitor should be able to appreciate the natural wonders of this coral atoll.

STRANDED PUMICE—A LARGE VOLCANIC BOMB—FLOATING CORALS.

Stranded Pumice.—I shall refer more than once in these papers to the part which the pumice derived from the great Krakatoa eruption of 1883 has taken in reclaiming land from the lagoon. Narrow inlets

¹ Horne's *Year in Fiji*.

have been obliterated, and the shallow water around the lagoon has been in places filled up by the fields of floating pumice that drifted inside the reefs. The Krakatoa pumice, readily known by its white and fresh appearance, and its unsodden texture, is to be found at present in great quantity on the beaches. It is often still to be observed in scattered fragments on the sea to the eastward, and every day there is some accession to the pumice drift already stranded. Only recently a large mass, nearly two feet across and covered with short-stalked cirripedes (barnacles), was drifted into the lagoon. The fragments of the Krakatoa pumice, as they are found on the beaches, are more or less rounded, and usually vary in size from a pea to a coco-nut. As bearing on the continual arrival of this pumice at the Cocos-Keeling Islands, I should observe that, in August and October 1888, I noticed a large quantity floating in scattered pieces in the Sunda Straits. A considerable amount of fine pumice also came up in my tow-net from the surface in that locality. Evidently a large amount of this material, at present found floating in the Straits, is washed off daily from the shores of Krakatoa.

The Krakatoa pumice is confined to the present beaches; but there is another kind of this material, apparently elsewhere derived, though of somewhat similar composition, which is found inside the raised weather margins of the islands, and extends for some 20 paces or more amongst the trees. It is of much greater age; and whilst its outer surface is darkened by weathering, its interior is often sodden and half-rotten. There is also a black and heavier pumice, formed from a more basic lava, which is known (rightly or wrongly) amongst the residents as the Tomboro pumice, and is found amidst the vegetation 15-20 paces in from the weather beaches. It varies in size from a walnut to a coco-nut; and, unlike the two felspathic kinds of pumice above referred to, it withstands decay, so that although it has been known in the island for half a century and more, its internal substance is still unaltered. Pieces of the older pumice are occasionally found amongst the recent Krakatoa pumice on the beaches; but they have probably, in most cases, been washed off from the shore of some other of these islands.

In a chapter on Pumice in my small work on the Geology of the Solomon Islands, I have pointed out the part that this stranded material takes in the preparation of the soil of a coral island. This process is repeated amongst the atolls of the Indian Ocean; and here, in fact, the recent eruption of Krakatoa enables us to form a more comprehensive idea of the extent and character of this fertilising agency. Wherever, in these islands, a layer of old pumice overlies the sandy soil near the beach, an abundance of volcanic minerals, especially magnetite, occurs in the soil. By means of a magnet, a number of fine particles of magnetite can be collected from a saucer filled with the white calcareous sand that is found between the tide-marks upon the beaches. These particles are angular and irregular in shape; are sometimes coated red by oxidation; and vary in size from $\frac{1}{200}$ to $\frac{3}{100}$ of an inch, the mean usually being about $\frac{2}{100}$ of an inch, or about half a millimètre. Some of these grains are attached to small felspar crystals, which have a partially fused appearance; but such compound grains do not much exceed the maximum size

given above. As we might have expected, the drift sand that has been piled up through the agency of the wind on the coasts of some of these islands contains but little magnetite, the few particles that occur being relatively very minute.

It will, perhaps, be safer for me to leave to others to determine the source of these grains of magnetite with their occasionally attached semi-fused felspar crystals, which are of common occurrence amongst the beach sand of the Cocos-Keeling Islands. The local evidence would seem to show that they are derived from the decay of the pumice that is stranded in such large quantities on these beaches, especially since I found them in greatest abundance in the sandy soil underlying an old bed of pumice. Their large mean size, viz., half a millimetre, and the specific gravity of the mineral, would seem to favour this opinion. It should, however, be noted that during the night following the great eruption in the Sunda Straits, some 700 miles away, fine pumice dust fell over the Cocos-Keeling Islands in such quantity that on the succeeding morning it was found covering the deck of a schooner, that lay at anchor in the lagoon, with a layer a quarter of an inch deep.

That the pumice drift on these coral islands, as on those of the Pacific, is not phenomenal, is shown by the circumstance that Mr. Keating observed "large quantities" on all the islands in 1829.¹ In truth, these ocean waifs form a constant feature of the coral reefs in the Indian and Pacific Oceans.

A huge Volcanic Bomb in Horsburgh Island.—Near the middle of the breadth of Horsburgh Island, and about 300 yards from the sea, there was, when these islands were first occupied, some sixty years and more ago, a huge volcanic bomb about four feet in height. It was somewhat dome-topped, and was imbedded about six inches in the soil. By the islanders this large mass of foreign rock, with its unknown history, was regarded with much mystery. It lay concealed in the midst of an iron-wood forest of great antiquity, where it must have lain for ages; and its burnt-up appearance seemed to support the prevailing opinion that it was some meteoric stone, lying where it fell during those unrecorded centuries that preceded the occupation of the atoll. In more recent years, curiosity, perhaps assisted by superstition, led to the demolition of this so-called thunderbolt. Pieces have been taken away by the inhabitants at various times and for different reasons, the result of this practice being that at the time of my visit in 1888 only a few fragments, none much more than a foot in size, remained to illustrate the description given to me by Mr. Ross. They were, however, sufficient to disclose to me that this mysterious stone was a huge volcanic bomb of a dark reddish cellular lava, possessing a comparatively solid outer crust. The cellular fragments floated buoyantly on the sea; but the more solid parts, of the outer crust, on which I also experimented, sank. Nevertheless, as the greater part of the original mass, according to the description given

¹ Holman's *Voyage round the World*, 1835, vol. iv. The voyage and travels of this blind traveller are still well worthy of perusal, notwithstanding that half a century has since passed. His affliction was patiently borne, and his example should not be forgotten.

to me, was evidently cellular, I had no doubt in forming the opinion that the whole bomb originally floated.

Although, however, these facts proved very clearly that the volcanic bomb was but an ocean waif, still it was not so easy to explain its position near the middle of the island, some 300 yards from the sea, where it was originally found hidden in a forest of ironwood (*Cordia subcordata*). It may, of course, have been transported there in past ages by some cyclonic wave that swept it inland from the beach. This occurrence, however, would have probably preceded the existence of the ironwood trees, which are so slow in growth that a tree of twenty years' planting is scarcely more than a sapling. Such a forest must have been of great antiquity; yet the age of the bomb on this reasoning would be far greater. I am myself more inclined to the opinion that the volcanic bomb marked by its situation the former extension of the present lagoonlet, when it was open to the northward and possessed a far greater size. Judging from the localities where the ironwood still flourishes in these islands, viz., on and near the margins of the lagoons and lagoonlets, it would seem most probable that the volcanic bomb was originally drifted through the mouth of this lagoonlet of Horsburgh Island, and that in the course of time it was stranded amongst the overarching ironwood trees that bordered the water. As the lagoonlet decreased in size and depth, young trees soon occupied the mud-flats left by the receding waters. Hence, when the lagoonlet was finally closed, the vegetation gradually occupied most of its area, and thus left the bomb apparently in the middle of the island.

Floating Corals.—If it has seemed incredible to some of the readers of this Magazine that a large volcanic bomb could be transported through the agency of the winds and currents to a coral island in mid-ocean, they will find it yet more difficult to believe that large blocks of massive corals, depending only on their own buoyancy, have been drifted in a similar manner across the sea to the Cocos-Keeling Islands, and that they are even now floating on the surface of the Indian Ocean. The stranding of these coral waifs on coral islands seems very much like carrying coals to Newcastle; yet such is undoubtedly the case.

My attention was first directed to this subject by my finding amongst the vegetable drift on the weather beach of South Island, at high-tide mark, a dead fragment of a species of *Pterogyra*, to which were attached a number of short-stalked cirripedes (barnacles) not yet dead. On throwing it in the water I found that it floated buoyantly, and at once perceived that it had been stranded at the last high-tide after floating for a long period on the open sea. It weighed then $1\frac{1}{2}$ lbs. Mr. Ross subsequently informed me that not infrequently large blocks of corals, mostly of the massive astræan type, and foreign to the atoll, are washed ashore, covered with barnacles, on the weather coasts of the eastern islands. He showed me one in his possession, a massive astræan coral, which was six feet in circumference and weighed 88 lbs.; and in order to convince me of its buoyancy he had it carried to the beach and thrown into the water, when it floated readily. A short time after this I noticed a similar block, stranded on the sandy shore of the lagoon,

which floated easily when I pushed it into the deeper water. It was rather larger, measured seven feet round, and probably did not weigh much under a hundredweight. Mrs. Ross gave me a smaller fragment of another astræan coral, about 2 lbs. in weight, which had been picked up on one of the beaches. I found that it floated buoyantly both in fresh and salt water. This specimen is now in the possession of Mr. John Murray.

Blocks even larger than the biggest of those above referred to are washed ashore at times on the eastern or weather beaches of this atoll, the living cirripedes or barnacles attached to them affording satisfactory evidence of their character as ocean waifs. I need scarcely say that all these floating corals are dead, and that most of them are ancient-looking. All of them are large-celled species, and it is evident that they owe their buoyancy to the closure of the innermost cells, as successive layers of new cells are added to the outer surface of the mass. Such floating coral blocks are to be seen in the Java seas, and, probably enough, after they were originally detached by the breakers and were washed high and dry on a beach, they underwent a lengthened process of drying before another huge roller swept them off oceanward again. The great sea-wave produced by the eruption of Krakatoa in the Sunda Straits in all likelihood carried not a few of such light coral blocks off the beaches, on which they had long been stranded, into the sea beyond. Numbers of such masses must now lie in the depths of the ocean, a circumstance that is at once suggestive of the past to the geologist and instructive also at the present time to the student of the deep-sea deposits.

But there is another means by which smaller masses of shallow-water or reef corals may be distributed over the floor of the ocean. It is already well known that corals can attach themselves to, and grow rapidly on, a ship's bottom. It has, however, also come under my observation that they can grow on floating pumice and on drifting timber, both of which, in the course of time, the one sodden and the other water-logged, sink to the bottom. Washed up on the weather coast of North Keeling Island I found a piece of Krakatoa pumice, on which had grown four bosses of a pretty incrusting species of *Pocillopora*, each of the size of a dollar, and $\frac{1}{4}$ to $\frac{1}{2}$ inch in thickness. This piece of pumice still floated buoyantly, and had evidently been caught in the reef for some time before it had been thrown up on the beach. Mrs. Ross showed me specimens about three times the size of the same species of *Pocillopora*, that had grown on a large log of timber, which, having been caught in the outer edge of the reef for about a fortnight, had then been rolled on shore. I have a specimen with the wood still attached. Nearly always the same kind of coral, so I was informed, is found on these floating timbers. Apparently this coral, which grows rapidly, thrives in the wash of the breakers.

NORTH KEELING ISLAND.—This small and little-known coral atoll is in the possession of Mr. G. C. Ross of the adjacent Cocos-Keeling Islands. It lies between 14 and 15 miles to the northward of the islands just mentioned; and since it is connected with them by a

NORTH KEELING ISLAND (ADMIRALTY CHART).

Thickly covered with Coco-nut trees and other vegetation.

With the exception of one or two pits about seven feet deep, the lagoon is less than a fathom deep at ordinary low tide, the greater part, in fact, being covered by less than half a fathom of water. The parallel lines indicate the situations of old passages.

This Plan was made by Captain Fitzroy in 1836. The in-curving arms of the lagoon-opening have since been added, and I have indicated the shoals prolonging them.

The bank, on which anchorage can be obtained, has been extending in recent years; and I have shifted the twenty-fathom line. Vessels can only anchor here during settled Trade weather. They must be prepared to weigh at once if the wind shifts to the northward. Landing is often dangerous, especially during the monsoon season, when it is at times impracticable. Careful steering is required to avoid the numerous patches of old reef that front the landing-place.—(H. B. G.)

submarine bank, the greatest depth over which is said not to exceed 100 fathoms, it should be considered as geographically included in the same Cocos-Keeling group. It did not fall to the lot of either Darwin in 1836, or of Forbes in 1878, to land on its shores; and in all the descriptions of this group that I have perused, the references to this small atoll are scanty in the extreme. On a later page I have referred to the sketch of this island made in 1749 by Captain Ekeberg, a Swede, and I have there given his notes. (The plan will be found accompanying this paper.) No landing, however, was then effected. In 1836 Captain Fitzroy, R.N., made another more complete plan showing the interior lagoon. This is also reproduced here with a few additions.

The chief points of interest in this island are to be found in the circumstance that it exhibits some novel and instructive features in its growth as an atoll, and also in the fact that since it has been less affected by human occupation than the islands of the neighbouring larger atoll, we can form some idea of the original flora of the group before it was finally occupied by man in the early part of the present century. The subject of the flora, however, will be dealt with in a later paper, when I shall describe it with especial reference to the dispersal of plants.

When we approached this island on August 18th, 1888, numerous frigate-birds and boobies came off to greet us, and we observed that the trees near the coast were dotted with these birds. We dropped our anchor at the only spot where a vessel can lie, off the west coast of the island; but in the best of weather it is an uncertain holding-ground, and if the wind shifts round to the northward at all, the vessel has to weigh immediately and leave the party on shore to their own devices. Scores of anchors have been lost here, and weeks have elapsed before the party could be taken off. The landing also is often impossible, and even with the most favourable conditions it is not altogether free from danger, unless local knowledge is possessed. When I landed with Mr. Ross we first visited the buildings to ascertain that nothing had been tampered with during the thirteen months that had elapsed since the previous visit. The proprietor, who has often rendered generous assistance to the crews of vessels shipwrecked in his group, keeps on this island a boat for the use of castaways. At one time it was his habit to keep here a store of provisions for their benefit; but the criminal escapade of a Norwegian skipper in 1881 led him to abandon this plan. It seems that in that year the master of a Norwegian ship landed and took away with him a skiff, together with provisions and other articles. On arrival in Norway, one of his crew informed against him, when an inquiry was held, and he was, I believe, punished. I should here remark that any castaways on this island would always find a plentiful supply of poultry, coco-nuts, and papaw fruits; but that any attempt of passing ships to help themselves would probably not escape the notice of those living in the neighbouring islands.

We spent six days on the island, living very comfortably on sea-birds and fish, supplemented by rice and biscuits. Our dinners were truly of a novel character, consisting generally of stewed frigate-birds, curried boobies, and other sea-birds, fish freshly caught in the lagoon, the flesh of the coco-nut crab (*Birgus latro*) torn into shreds and fried; and

as vegetables, we had the papaw fruit, which, when boiled in the green state, is a very good substitute for vegetable marrow; whilst coco-nut palm tops, nicely cooked, reminded us of tender cabbage. With our coffee we ate rice-biscuits, which were merely the rice-grains that had adhered to the inside of the pot after the boiled rice had been emptied out, the pot being afterwards placed again on the fire until a crisp kind of biscuit incrustated its sides. If Mrs. Ross had been present, I could have written a chapter on her different modes of cookery, as she has a thousand and one ways of adapting to her use the seemingly scanty produce of these islands. I had many subsequent opportunities of wondering at her skill, and tried in vain to persuade her to give the outside world the benefit of her knowledge. However, I would suggest that one of her daughters should copy her mother's recipes surreptitiously, and send them to the editor of the *Queen* newspaper.

Notwithstanding its occasional occupation, this small atoll is still the home of great numbers of frigate-birds, boobies, gannets, noddies, etc. The gannets build their nests on the ground on the weather coasts; whilst the frigate-birds and the boobies mostly frequent the north and south shores of the lagoon, where they almost cover the bushes of *Pemphis acidula* that border the water. So tame were the frigate-birds and the boobies, that we could catch hold of them as they sat on their nests on the bushes, and knock them down with a stick as they came around us. These proceedings did not seem in any way to discompose their neighbours, who sat unobservantly two feet away, and displayed no concern in the matter. After a day or two, however, the birds got more shy; and then it was curious to observe that the first to fly was the bird that had neither an egg nor a young one to protect; the next to fly was the bird over its egg; and the last to go left a featherless young one to our mercy. The nests are constructed of the twigs and light branches of the *Pemphis* bushes, and never, as far as I saw, contained more than a single egg. The prettiest of the sea-birds in North Keeling Island are the snow-white terns (*Gygis candida*), so well described by Darwin and Forbes.¹ They fluttered and hovered in pairs close over our heads, as if anxious to inquire our meaning in disturbing them. Mr. Ross especially endeavours to preserve these little birds, for they are the tiny pilots of these seas, and are often the means of checking a vessel from running past the islands. He has also been attempting to prevent, or at any rate to postpone, the extinction of all the sea-birds on the island. Half a century ago they were equally as numerous on the Cocos-Keeling Islands; but the islanders, who greatly prize their flesh, have driven them entirely away; and in spite of the vigilance of Mr. Ross, it is evident, as I am told, that through the clandestine visits of his people, their numbers are annually decreasing on North Keeling Island. During the time of the grandfather of the present proprietor, the birds on North Keeling Island are said to have numbered myriads where they now can only be counted in thousands. However, I may remark that they are yet to be seen in considerable numbers.

¹ This bird deposits its solitary egg on the bare leaf of a young coco-nut palm in such a manner that it is difficult to understand how it can retain its position when the leaves are waving in the wind (*vide* Forbes's *Eastern Archipelago*, p. 33).

Although there is no collection of guano proper on the island, owing to its surface being thickly vegetated, the droppings of the great numbers of birds that have resorted here for ages have fertilised the soil to such an extent that it forms an excellent manure. So productive is the soil itself that the vegetation is much more luxuriant and rapid in its growth than in the adjacent islands; and fruits, such as those of the papaw-tree, become unusually large and numerous. It would appear that all over the island the soil and surface-stones have become impregnated with guano-salts to a greater or less extent. In two pits that were dug to a depth of a couple of feet, in different localities, there was about a foot of dark soil overlying a light-coloured limy earth. I found that the dark soil, which probably also contains ammonia, possessed from 30 to 35 per cent. of phosphates; whilst the light earth beneath, which contained a good deal of carbonate of lime, proved to possess from 20 to 25 per cent. of phosphates. Scattered about on the surface and in the soil are numbers of reddish-brown friable nodules, still exhibiting the coral structure, which contained as much as 60-70 per cent. of phosphates; and the outer portions of many of the larger coral stones are formed of this reddish-brown friable high-percentage material. It is evidently through the agency of rain that the soil and the coral stones have become more or less soaked with the guano-salts; and it should be noticed that this effect is dependent on an unfailling supply of bird-droppings; for in the neighbouring Cocos-Keeling Islands, which the birds have deserted during the last half-century, I found only a trace of phosphates, as I shall subsequently remark, and the friable reddish-brown nodules have long since been broken down. Here, in fact, the rains have washed the guano-salts away, there being no longer a supply of bird-droppings.

It is probably owing to the presence of guano-salts in the soil and in the ground beneath that a well sunk in North Keeling Island has recently attracted some notice as supplying a mineral water which is a reputed cure for "beri-beri." Otherwise, I am at a loss to explain why the well-water of all coral islands should not possess similar curative qualities. When we reflect that often the water from a well sunk in such islands is a little brackish, one would be inclined to consider, judging also from the analysis given below, that this mineral water, so called, is merely brackish water that has obtained its additional characters and its reputed medicinal qualities by permeating a ground into which the rain has carried guano-salts. Since it is important that a remedy of this kind should be properly inquired into, I append the description and analysis of Mr. W. S. E. Hekmeyer, Chief of the Chemical Laboratory of Batavia, for which I am indebted to Mr. G. C. Ross. The Dutch Government at Batavia have lately given an order for a number of samples of this water from North Keeling Island; and I trust that it may be found of service in checking the ravages of "beri-beri" amongst the troops of Netherland India. In that event, if my opinion of the true character of this water is correct, a cure for "beri-beri" will be found in many other coral islands where sea-birds congregate.

ANALYSIS OF NORTH KEELING WATER.

Description.—"Clear; somewhat yellowish; taste faintly bitter, and a little saltish; no smell; on boiling, a precipitate of lime carbonate; spec. grav. 1.0034

at 27.5° C. On analysis the water contains potash, soda, lime, magnesia, carbonic, sulphuric, and hydrochloric acids; also traces of nitrous and phosphoric acids, alumina, silica, iron, and bromine."

Carbonate of Lime,	0.336 grammes.
Sulphate "	0.435 "
Chloride of Calcium,	0.138 "
" Magnesium,	0.488 "
" Natron,	2.840 "
" Kalium,	0.236 "
Phosphoric acid, bromine, silica, iron oxide, } ammonia, alumina, }	Traces.

4.473 grammes per lit.

It will be an interesting study for the naturalist who next visits the Cocos-Keeling group to make a complete collection of the insect fauna of North Keeling Island and of the islands of the large Cocos-Keeling atoll for the purposes of comparison. I doubt, however, whether any very important difference will be found, since there has been such free communication between the two atolls during the last half-century that the distinction which once existed is probably in great part lost. The introduction of numbers of new insects from Java and elsewhere since the visit of Mr. Darwin in 1836 has been dwelt upon by Mr. Forbes;¹ and for my own part, I must confess that, being more especially interested in these islands, not only by reason of their characters as coral atolls, but also from the important light which my examination of their original flora threw upon the subject of the dispersal of plants by natural agencies, I felt little tempted to inquire into the disturbing influences of man.

Viewed as an atoll, North Keeling Island, which is rather over a mile in length, encloses a shallow lagoon that has a single opening leading into it on its east or *weather* side, a very unusual circumstance with this class of coral reefs. This opening, however, across which the surf is always breaking, is not a break in the reef, but is merely a gap in the otherwise continuous land-margin, and neither ship nor boat can enter the lagoon (see Plan). The width of the belt of land is generally between 300 and 350 yards, and the usual height is 10 to 12 feet—never, as far as I could perceive, exceeding 15 feet. The reef-flat invests the outer border of the island, except, as shown in the map, on the west and north-west sides, which are the sheltered or lee sides during the greater part of the year, and here there is but little living coral; there are, however, the remains here of an ancient reef-flat, now being gradually broken up by the sea, from which, during cyclones, huge fragments are occasionally torn off and washed upon the beach. Near the landing-place on the beach there is one such huge mass of *Porites*, which, judging from its measurement, cannot weigh less than twenty-five tons. It is partly covered with sand, and is washed at high tide. I was informed that it has been in its present position as long as the residents can remember.

An examination of the reef-flat skirting the island, especially on the weather, southern and eastern coasts, discloses to the observer the inter-

¹ *Eastern Archipelago*, p. 31.

esting circumstance that it has grown seaward by a series of "jumps" rather than by a continuous outward extension. This mode of growth has long been a subject of observation with Mr. Ross both in this atoll as well as in the Cocos-Keeling Islands, and I shall have further occasion to refer to it in detail. Here I may briefly say that the successive steps in the outward growth in the reef are indicated by the parallel lines of old reef-margins that protrude above the flat.

The lagoon is very shallow, by far the greater part of it at ordinary low tide being less than 3 feet deep, with depths here and there of from 4 to 5 feet, and one or two pits where my soundings showed 7 or 8 feet. The passage leading into the lagoon, or rather the break in the land-margin, since there is no gap in the reef, has a depth at ordinary low tide varying between 3 feet just within the breakers to $1\frac{1}{2}$ feet further inside. At spring low tides, however, the sand-flats lining either side of this pseudo-passage are exposed to such an extent that they almost fill it up, leaving only a narrow channel, 1 to $1\frac{1}{2}$ feet deep. It may be generally stated that corals do not at present grow in this lagoon, the bottom being of fine sand and mud, mostly covered with turtle-grass. Here and there a dead coral mass may be seen in the southern part, but the conditions for coral growth are most unfavourable, except of course at the seaward mouth of the passage leading into it. The most unfavourable repressive agency appears to exist in the circumstance that large quantities of sand and mud are carried through the passage into the lagoon, the product of the incessant action of the breakers. Then again, though there is a small counter-current running out through the passage, it is not of sufficient extent to keep the waters of the lagoon wholesome, and suited for coral growth. That they do not circulate freely is shown in the fact that, whilst the temperature of the sea in the wash of the breakers was 83° , I found the water in the lagoon to be $86\frac{1}{2}^{\circ}$ where it was a foot deep, and $85\frac{1}{2}^{\circ}$ where it was 2 feet deep. This observation was made soon after mid-day, the temperature in the shade at the time being $82\frac{1}{2}^{\circ}$.

Though it is evident enough from the facts to be given below that the lagoon has been filling up in recent times, the early references to it appear to offer testimony at conflict with this assertion. However, as a matter of fact, these references were often second-hand, and do not accord with the recollections of the present proprietor and his people. Mr. Keating, writing of its condition in 1829, speaks of the "tide overflowing its centre at high water, so as to give it the appearance of a basin."¹ His brief mention of the island, however, does not suggest a personal acquaintance with it. Deriving his information from Mr. Leisk in 1836, Mr. Darwin speaks in his journal of the lagoon being "nearly filled up with coral mud," and in his work on Coral Reefs, of its being "dry at low water." Captain Fitzroy, who surveyed the island, refers to it as "a strip of low coral land almost surrounding a small lagoon."¹ It would appear probable, however, that his plan of the island, which does not enlighten us further on the subject, was made from a running survey, and that his information of the interior was derived from Mr. Leisk. He makes no reference to any landing being effected on the island. . . .

¹ Holman's *Voyage*, vol. iv.

For my own part, I should add that within the memory of the present proprietor of the island, recollections that go back some thirty years and more, the lagoon has never been in the condition of a basin dry at low water.

That all the changes observed during the past thirty years are tending to fill up the lagoon, there is abundant evidence to show, notwithstanding that the testimony of earlier years is somewhat conflicting. The curving in of the margins of the passage leading into it is a very curious feature in this obliteration of the basin, and one not indicated in the *Beagle's* early plan; and the curve is continued or prolonged by sand-banks or shoals, giving the whole land-margin of the atoll the outline of a double scroll. These in-curving arms were originally sand-banks that have since become clothed with vegetation. They have extended considerably into the lagoon in recent years, *pari passu* with the extension inwards of the sand-banks that prolong them. During the last quarter of a century the increase has been especially noticed in the instance of the northern arm, and young trees and shrubs now grow where not long since there was a sand-bank covered at high tide. Mr. Ross also follows up this process by planting coco-nut palms on the newly formed land.

Very noticeable changes also have taken place in the lagoon, particularly since the Krakatoa eruption in 1883, when large quantities of pumice were collected and pent up in its interior. Since that date its shores, especially in its northern part, have in many places advanced from twenty to thirty yards, and young trees, such as *Cordia subcordata*, together with young coco-nut palms, now grow where the waters stood then. The pumice was heaped up in the shallow water, and there the sea-weeds common on the lagoon shores caught and collected, and, decaying rapidly, soon formed a suitable ground for the growth of *Sesuvium Portulacastrum* that usually covers the shore flats. A coarse grass subsequently clothed the new surface, and the neighbouring vegetation began to occupy the new land. One could perceive this process in all its stages. In some parts the bare flats exposed at low water were composed entirely of fine pumice six inches deep. In another place the pumice was more or less covered with the weed, whilst near by the last stage would be exhibited; and in such newly formed ground, which the vegetation was beginning to occupy, my stick sank readily half-a-foot deep into nothing but decayed weed and rotting pumice.

It will be wiser if I defer the explanation of the origin of this small atoll until after the description of the large Cocos-Keeling atoll. The key to its peculiar history is there to be found, and it is to the past acute observations of its proprietor that I am largely indebted in this respect. I shall then proceed to consider the agencies now working in these coral islands, and the processes there in actual operation; and it will be perceived that the study of the one atoll throws considerable light on the other.

It should, however, be remarked that North Keeling Island originally consisted of three or more islands, and that the old passages may yet be traced as indicated in the plan. In the early days of Mr. Ross, the old situation of one of these passages through the northern portion was

¹ *Voyages of "Adventure" and "Beagle,"* vol. ii. p. 630.

clearly shown by the narrow width of the land belt, by the young trees, and by the scanty soil, whilst the water cut nearly across the island from the lagoon side. Similarly, about a quarter of a century ago, the southern part of the island was almost separated, except at its seaward or outer margin, the water of the lagoon overflowing most of the original passage. The outer mouth of this passage is still indicated by a partial gap in the reef, and by the extensive exposure of the old reef conglomerate that once bounded its seaward entrance. In the next place, I should refer to another recent alteration of this island. During the past ten or fifteen years the shore opposite the landing-place on the west coast has advanced some fifteen or twenty paces, the old line being indicated by the overhanging coco-nut palms now removed that distance from the sea. It was largely the work of a night, a huge pile of coral blocks being piled upon the beach during a cyclone.

Note. The size of this Island is greatly exaggerated a common failing of the earlier navigators (H.B.G.)

Off the west side of the island there exists a sandy shoal, not marked in the Admiralty Plan, which has been extending in recent times to a marked degree, so that the schooner of Mr. Ross cannot now anchor where it did several years ago. This shoal is indicated in the old plan of Captain Ekeberg, made in 1749, and reproduced in 1787 by Dalrymple, the English hydrographer, in his "Plans and Charts." Although the old plan merely represents the coast-line and the outlying dangers, being in fact nothing more than a running sketch on a scale much exaggerated,

still it is of some value to those who attach importance to the past condition of a coral island as affording a clew to its origin. This, I say with emphasis, is a line of investigation which was closed by a theory like that of Mr. Darwin, and one which, strange as it may appear to philosophical minds, was until the last quarter of a century but little pursued. In a subsequent paper I shall allude to the conclusions deducible from all the old plans of the Cocos-Keeling group.

Captain Ekeberg's remarks on the island in 1749, extracted from his Swedish journal,¹ and placed in a note in Dalrymple's reproduced plan, are as follows:—" . . . On the E. side of the Island could see no landing-place, being full of Breakers from a Reef stretching towards the S.E., where we saw five Rocks above-water as high as a Ship's Boat, about which were many white Birds and Mews. At the N. End there stretched out a Reef on which the water broke. Within the N.E.-most Breakers

¹ The extract was translated some years afterwards, and, as will be seen, is in the style of the old English navigators.

saw a plain Beach of reddish sand. On the W. side of the Island saw a long flat Bank, on which the water was smooth, with the appearance of good landing. The whole Strand was full of Coco-nut Trees, on which were many nuts. It is unknown if there be other refreshments. The Island was full of Trees. This was the Northmost of the Cocos; it is 5' or 6' long. and 3' or 4' broad: we saw two other Islands, which lay from this Island; one S. $\frac{1}{4}$ E. 4 or 5 leagues, the other S. b. W. 3 or 3 $\frac{1}{2}$ leagues; they did not look to be so large as this Island. We soon lost sight of it, and were followed by a Flock of Men of War Birds."

From the comparison of the new and old plans of this island, it will be observed that the five rocks off the southern part are now gone, though memories are still retained of them. The reference to a "plain beach" within the "north-eastmost breakers" evidently applies to the break in the land-margin corresponding to the passage into the lagoon on the east side. The size of the island is of course much exaggerated, and it is strange that there should be no reference to the lagoon. However, when dealing with a still older chart of the whole Cocos-Keeling group, in which the relative position of this island is correctly indicated, I shall have further occasion to refer to this subject.

(To be continued.)

SOUTH AMERICAN RAINFALL SOUTH OF THE TROPICS.

(With a Map.)

BY WILLIAM B. TRIPP, M. INST. C.E., F. R. MET. SOCIETY.

THE rainfall records of the immense continent of South America are few indeed compared with the vast area over which they are scattered.

Of the interior region of Brazil, who has any exact information extending over a long series of years?

For the most part, a few stations round the coast give all the available information of South American rainfall of the tropical regions.

Of that part, however, lying to the southward of the tropic of Capricorn, and occupied by the southern portion of Bolivia, Paraguay, and Brazil, the northern parts of the Argentine and Chilian republics, and the republic of Uruguay,—a region comprising some of the most fertile and favoured regions of the globe, and which appears destined to play no unimportant part in future history—there has been published, within the last dozen years or so, much interesting information.

The Cordoba Observatory has issued six splendid volumes of Meteorological Annals, under the administration of its successive Directors; and although it must even now be said that the information published is far from being so complete as might be desired, still it may be hoped that this may be remedied by the publication of subsequent volumes.