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NOTES ON THE GEOLOGY AND THE PHOSPHATE DEPOSITS OF CHRISTMAS ISLAND, INDIAN OCEAN

by

O.N. Warin.

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SUMMARY

This report discusses the results of a visit paid by the author to Christmas Island, Indian Ocean, to study the phosphate occurrences and the methods of exploration drilling employed there. The general geology of the island is described. No economic mineral prospects appear to exist apart from the phosphate deposits. The phosphate deposits are described and their similarity to the deposits of Nauru and Ocean Islands is noted. Ideas about the mode of formation of the deposits are advanced.

INTRODUCTION

During November, 1957, the author paid a brief visit to Christmas Island, Indian Ocean, as the guest of the British Phosphate Commissioners who are quarrying the extensive phosphate deposits on the island. The visit was a preparation for the long range programme of searching for new sources of phosphate, particularly on islands in the Pacific Ocean, which is being undertaken jointly by the Australian and New Zealand Governments. The aim of the visit was to study the phosphate occurrences and the methods of exploration drilling and to examine the island geologically to assess the possibility of any other economic mineral prospects existing.

The British Phosphate Commissioners gave the author every assistance during his stay, making readily available all technical and survey data. The friendliness and helpfullness of the staff on the island contributed greatly to what it was possible to achieve during a short stay.

HISTORY OF EXPLORATION

The first recorded landing was made by Dampier in March 1688 and nothing further is recorded until the visit in 1866 of 'The Flying Fish' under the command of Captain Maclear, and a year later 'H.M.S. Egeria' under Captain Pelham-Aldrich, of the Royal Navy. Specimens collected by Captain Pelham-Aldrich were examined by Sir John Murray of the British Museum. He recognized some of these specimens as phosphate rock and, realizing the economic importance of the discovery, he informed the British Government. Christmas Island was annexed in the following year (1888) by the British Crown, and a settlement was founded on the previously uninhabited island by Mr. G. Clunies-Ross, the brother of Mr. Andrew Clunies-Ross of Cocos Island. Sir John Murray remained interested in the exploration of the island as an example of an oceanic type and under a grant from him Mr. W.C. Andrews, also of the British Museum, undertook a study of the island in 1897. The results of Andrews work were published in 1900.

More recently the phosphate deposits of the island have been quarried, first by the Christmas Island Phosphate Company. The Australian and New Zealand Governments aquired the undertaking on 1st January1949 and the British Phosphate Commissioners now work the deposits as managing agents for the Christmas Island Phosphate Commission which was appointed by the two Governments The British Phosphate Commissioners also mine the deposits at Nauru and Ocean Islands,Pacific Ocean,for the British, Australian and New Zealand Governments.

The Island was under the control of the Straits Settlement Government,with a resident District Officer from Singapore, until this year when it passed into Australian control.

PHYSICAL FEATURES OF THE ISLAND

Christmas Island is in a particularly isolated position 190 miles south of the coast of Java and 900 miles from the north-west coast of West Australia. The nearest islands are the Cocos-Keeling group 550 miles away in a direction a little to the south of west.

The island is 43 square miles in area and shaped roughly like the outline of the letter 'T'. The longest arm of the 'T' runs from north to south and is eleven miles long, the stem of the 'T' runs from east to west and is 9 miles long.

The island rises in a series of wave cut terraces and cliffs to a height of 1000 feet above sea level. The Maclear deep, to the north, and the Wharton deep, to the south and south-west, are both more than three miles deep.

The most constant of the terraces is the first shore terrace, which varies from rather less than 100 yards to half a mile wide. It represents a negative shore line movement of some 50 feet. The cliff at its seaward edge is an almost unbroken feature of the island's coast, making landing difficult. From the sea cliff the profile slopes gently up to the foot of the first inland cliff, some 250 to 300 feet high, with caves and wave cut notches at its foot. Less well marked cliffs and terraces occur at higher levels until the central plateau is reached. The central plateau is flat but slightly saucer shaped, rising slightly towards its eastern margin along the line joining Phosphate Hill and Limestone Hill and in a similar way rising towards its western margin at Murray Hill. The highest hills are a little over 1000 feet above sea-level.

GENERAL GEOLOGY OF THE ISLAND

The island is built up on a core of volcanic rocks rising precipitously from 14,400 ft. below sea-level. The oldest sedimentary rocks are the Eocene foraminiferal limestones which rest on the Lower Volcanic Series comprising alkali-trachyte, trachy basalts, olivine basalt, limburgites and probably nepheline basanite (Campbell-Smith, 1926). The Eocene limestones are succeeded by the Upper Volcanic Series of submarine basalt and limburgitic basalt flows and palagonite tuff, followed by the orbitoidal Miocene limestone which makes up the main mass of the island. In post Miocene times atoll conditions prevailed and detrital limestones were deposited, following which were a series of negative shoreline movements giving the island its present terraced structure.

The succession at Flying Fish Cove, after Andrews (1900) is as follows:

Upper Orbitoidal Limestone	160'
Upper Volcanic Series	180'
Yellow (Eocene) Limestone	60-140'
Lower Volcanic Series	200' +

A major fault, striking slightly south of west, runs right across the island from Gladys' beach on the east coast to Sydneys' Dale on the west. It cuts all the rocks on the island except the limestones on the first or 50 ft. inland terrace.

PALAEONTOLOGY

During his 1899 survey Andrews collected specimens of limestone containing Molluscs, Corals and Foraminifera.

All the Molluscs he collected were modern. The fossil corals (examined by Dr. J.W. Gregory) were mostly Astreans, all reef builders and none reckoned to grow at depths greater than six to eight fathoms. Dr. Gregory identified twelve species of Astreans, three PERFORATA one FUNGIDA and one species of Pocillopora.

The Foraminifera collected by Andrews were of particular interest. They were mostly Orbitoides and on the basis of them he assigned a Miocene age to his upper or C limestone. Discocyclina oceanica from the limestone exposed beneath the upper volcanic sequence at Flying Fish cove indicated an Eocene age for the Lower Limestone (Andrews 1900 and Nuttal 1926).

With more recent work on the Foraminifera of the Indo-Pacific region a great need has arisen for the re-determination and re-description of the Orbitoides of Christmas Island. Unfortunately the author was unaware of this at the time of his visit and he collected widely from localities not visited by Andrews, mostly on the higher land of the island, and ignored the older localities. The specimens collected have almost all proved to be altered recent lime-stones without Foraminifera of assistance in solving the problem of the Orbitoides.

ECONOMIC GEOLOGY

Apart from the phosphate deposits there seems to be no likelihood of any economic mineral deposits on Christmas Island. No indication of other minerals was seen during the present survey.

THE PHOSPHATE DEPOSITS

The present major sources of Australia's high grade phosphate for superphosphate manufacture are Nauru and Ocean Islands in the Pacific Ocean and Christmas Island. Nauru Island produces about one million tons of phosphate anually, Ocean Island about 700,000 tons and Christmas Island about 500,000 tons. The completion of new handling and drying plant on the island should soon greatly increase this last figure.

All three islands are formed of raised coral.

The phosphate on Christmas Island occurs as both incoherent and coherent material (Owen 1923). The incoherent phosphate consists largely of oolitic and pisolitic material up to ½" diameter deposited between tall limestone pinnacles probably the product of sub-aerial erosion. It is pure white to buff or even brown in colour, depending on the proportion of iron oxides and alumina present, and has with it a proportion of fine dust, which becomes a rather sticky clay when wet, and some irregular, angular lumps of phosphatized material. Photo No.1 shows a sectional view of the incoherent phosphate lying between the base of two limestone pinnacles. The limestone beneath the phosphate is being quarried for road building and the work is exposing the residuum of phosphate left between the pinnacles at the close of the quarrying for phosphate. The pisolitic and oolitic material is fairly closely packed and appears bedded, while against the pinnacles is a layer of vuggy, open, whiter phosphate which easily crumbles when disturbed.

As well as the more normal incoherent material there are deposits of phosphate pebbles and cobbles in banks and infilling between pinnacles. (Photo No.2). The Pebbles are rounded and smooth and are up to two and a half inches in diameter. The best exposure of this type of deposit is in a partly worked quarry near South Point. There is no interstitial finer material between the pebbles but this is possibly due to recent rainwash and may not be an original feature of the deposit.

The coherent phosphate occurs as,

(1) Amorphous Collophane ('Nauruite') filling narrow cracks in the limestone of the pinnacles. (Photo No.3).

(2) Phosphatized coral limestone with the macroscopic structure of the coral preserved. In thin section these are seen to be entirely of Collophane, with only a trace of the original structure preserved. The author did not see these phosphatized corals in situ.

(3) Large boulders at the surface in unworked areas, having the appearance of a broken crust. The boulders show some degree of banding or bedding and individual oolites are commonly visible. The colour is normally white or pale buff but may be brown or pale green. In thin sections even the part of this coherent phosphate which appears homogenous is found to be made of collophane oolites cemented together by Collophane or Dahllite to form a coherent phosphate rock.

The phosphate deposits are restricted in their areal extent. There are no deposits on the north side of the island. It is suggested that this distribution may have been controlled by a prevailing wind direction from the south. At the present time the nesting sites chosen by the Guanay flocks on Peruvian Islands are closely controlled by the prevailing wind, the windward side of the island having the cooler ground temperature. (Hutchinson, 1950 - page 15.)

The main deposits occur below the steep cliffs of the highest hills of the islands. Thus South Point quarry is backed by the cliff of Limestone Hill. Murray Hill has a steep cliff on its west side and a gentler slope to the east and north. The main deposits spread out broadly to the west and north west from the base of the cliff.

DISCUSSION OF THE MODE OF FORMATION OF THE PHOSPHATE DEPOSITS

The phosphate mined on Christmas Island seems to be in every important respect very similar to that of Ocean and Nauru Islands. (Power, 1905, 1925, Owen, 1923, and Hutchinson, 1950).

In an arid climate guano is stable after the loss of volatiles. Hutchinson (1950) states that in areas of higher rainfall solutions from the guano may react with the underlying rock. If the underlying rock is limestone the following reaction may occur:

$$2H_3PO_4 + 3CaCO_3 \rightarrow Ca_3P_2O_3 + 3H_2O + 3CO_2$$

Hutchinson (1950) believes that the phosphoric acid solution would be sufficiently concentrated to attack the limestone only above the water table. This he thinks is the reason for the restriction of the deposits to raised coral islands.

The evidence for the occurrence of this type of reaction is indirect only as present day guano accumulations are being formed only in arid zones. There are cases of phosphatization of rocks other than limestone that are clearly attributable to the action of solutions leached from guano; (e.g., Phosphatized trachyte of Clipperton Atoll - Teall 1898, and phosphatization of volcanic flows exposed at a cliff face near Minas, Uruguay - Eckel and Milton, 1953).

Considerable contention exists as to the precise conditions under which a deposit of the type seen at Ocean, Nauru and Christmas Island is formed. Hutchinson, (1950) following Power and Owen, envisages emergence of the island and the formation of the limestone pinnacles by subaerial erosion; a second stage, of submergence, with removal of the residual soil from the pinnacles and the deposition of loose oolitic limestone material between them; followed by re-emergence and the colonization of the island by guano producing birds. Phosphatization of the oolites between the pinnacles by solutions leached from the guano is the final stage, producing the incoherent phosphate.

Rodgers, (1948) believes that on some at least of the islands he visited, the pinnacles were formed beneath a cover of acid humus at the same time that the guano is being deposited.

The additional fact that has emerged in this brief study of the deposits of Christmas Island that may be of significance is the existance of the pebble and cobble deposits and the bedded nature of the oolitic and pisolitic part of the incoherent phosphate. These bedded deposits suggest that there has been transportation of the phosphate from its original position of formation. The colonies of guano producing birds may have inhabited the higher land and the phosphate produced from their guano may have been washed down into its present position.

The author suggests that the sequence of events at Christmas Island may be:

(1) Three coral islets, developed on a platform of Miocene limestone at the present Murray, Limestone and Phosphate Hills.

(2) First uplift, or fall of the sea level, and the development of a large fringing reef connecting the three islets.

(3) Second uplift with the development of the pinnacle fields in the limestone and colonisation of the higher ground by birds.

(4) The accumulation between the pinnacles of phosphate derived from the guano, in part directly by the loss of volatiles and soluble constituents and in part by phosphatization of limestone, particularly the limestone of the higher ground.

(5) Further negative shore line movements with the development of the lower terraces.

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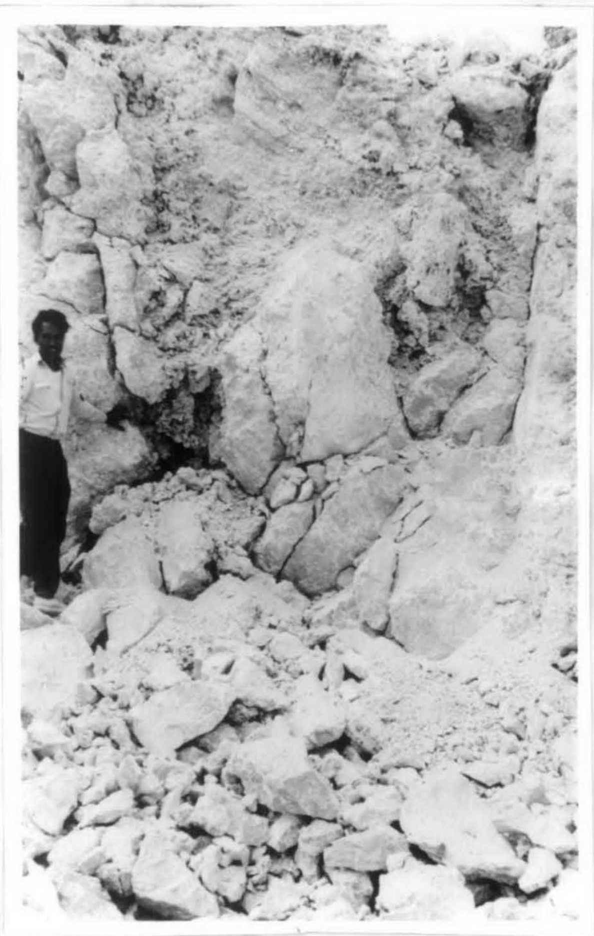

Photo 1. Incoherent phosphate between limestone pinnacles, limestone quarry, South Point.

Photo 2. Bank of pebble phosphate, South Point.

Photo 3. Surface of limestone pinnacle showing Nauruite in cracks, South Point quarry.

Photo 4. Bedded incoherent phosphate, (Photo 1).

Photo 5. Quarrying phosphate, South Point quarry.

Photo 6. General view of worked out part of South Point quarry, showing limestone pinnacles.

PLATE No. 1

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