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DEPARTMENT OF NATIONAL DEVELOPMENT.  
BUREAU OF MINERAL RESOURCES  
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REPORT OF INVESTIGATIONS FOR PHOSPHATE DEPOSITS IN  
THE KINGDOM OF TONGA, 1959.

111

by

O.N. Warin

The information contained in this report has been obtained by the Department of National Development, as part of the policy of the Commonwealth Government, to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.

# REPORT OF INVESTIGATIONS FOR PHOSPHATE DEPOSITS

IN THE KINGDOM OF TONGA, 1959.

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## SUMMARY

No deposits of phosphate were found on the islands visited in the Tonga Group. Reports of phosphate on Hunga Tonga, Hunga Ha'apai and on 'Ata are thought to have arisen because of guano stainings on the steep cliffs of these volcanic islands. No accumulation of phosphate was found on these islands.

The islands of Tonga are divided into four types: (a) Volcanic islands, (b) Islands composed of tuff and limestone, (c) Islands of raised limestone and (d) Vegetated sand cays on coral reefs. Brief notes are given on the geology of most of the islands visited during the survey.

## INTRODUCTION.

This survey for phosphate deposits in the Kingdom of Tonga was undertaken as part of the 1959 field season of the Bureau of Mineral Resources Phosphate Survey.

Towards the end of August, 1959, I was joined by Mr. H.E. Fyfe of the New Zealand Geological Survey in Suva, Fiji, and together we made a survey of the phosphate prospects of part of the Group, arriving back in Suva in Mid October.

The survey was carried out from a 100 ton auxiliary ketch, the A.K. 'Maroro', chartered in Suva.

We were seriously hampered by bad weather at the beginning of the survey; it was impossible to leave Suva for several days at the start and at one time it was impossible even to put down the ship's boat in the harbour at Nuku'alofa. Later, conditions improved and it was possible to make landings on all the islands we attempted.

Our assistants throughout the survey were S. Ratuyawa and L. Koto of the Geological Survey Department, Fiji.

I would like to acknowledge the great courtesy shown to us by H.R.H. Prince Tungi, the Prime Minister of Tonga, and the help that we received at every turn from the officers of the Government and from the people of Tonga. I would like especially to thank Mr. Miller, the Secretary to Government, Magistrate Foto, of 'Eua, and Mr. F. Sitoa, of Nomuka, for their help and hospitality.

## TONGA.

The Tonga group, or the 'Friendly Islands' as they were once known, consists of more than 150 islands lying between Lat.  $18^{\circ}\text{S}$  and  $23^{\circ}\text{S}$  and Long.  $173^{\circ}\text{W}$  and  $176^{\circ}\text{W}$ . Tonga's nearest neighbours are the Fiji Group to the west and north west and Samoa to the north east.

The Tongan people number about 35,000 and are a Polynesian people closely allied by their physique, their

language and their customs to the Samoan people. There are very few people of other race than Tongan in Tonga; possibly fewer than 500 Europeans. The Tongans are amongst the tallest people of mankind - the average height of the men being 5ft 8in. and of the women 5ft. 4in.

There has been some difficulty in the past in the spelling of written Tongan. Different Europeans used different letters to represent sounds in Tongan which are intermediate between two European sounds. For example 'p' and 'b' are often interchanged. In this record I use the official spelling of place names. Official spelling includes the glottal stop in such names as Vava'u and 'Eua.

The Kingdom of Tonga has had Treaties of Friendship and Protection with Great Britain since 1900.

The present ruler of the Kingdom is Her Majesty Queen Salote Topou, D.B.E., who ascended the throne in 1918.

#### PHOSPHATE DEPOSITS.

Phosphate deposits were reported to exist at two localities in the Tonga Group - at 'Ata, in the south, and at Hunga Tonga and Hunga Ha'apai towards the centre of the Group (See Plate 1).

The Pacific Islands Handbook (Robson, 1958) remarks on the presence of phosphate at these two localities; adding, in the case of 'Ata, that the deposits have not been worked owing to the lack of a good anchorage.

A landing was made on 'Ata during this survey. The geology of the island is described in a later section. The cliffs along the west coast and isolated rocks along the south coast are stained by bird droppings. No significant accumulation of guano appears to be taking place; nor is it likely that accumulation will take place on such steep slopes. The interior of the island is a fairly flat platform at about 300 feet above sea level with a strongly marked ridge rising to 900 feet along the west coast and a less marked rise (500 feet above sea level) towards the north east corner of the island (See Plate 2). The flat platform, where phosphate is likely to accumulate, was examined but no phosphate was found. The reports of phosphate deposits seem to have arisen from the guano stainings on the cliffs and rocks.

The same is probably true of Hunga Tonga and Hunga Ha'apai. Both are very steep islands, the remnants of the rim of a blown out volcano, with steep cliff faces on the inside and gentler slopes on the outside; (i.e., towards the north and west). From the sea it is clear that no place exists where large amounts of guano could accumulate; as at 'Ata there are a few sea birds and some guano stainings on the north side of Hunga Tonga.

Lalona island in the Otu Tolu Group along the east edge of the Nomuka platform has a few sea birds nesting in the trees and their droppings are noticable on the coral sand of which the island is formed. No

accumulation is taking place and no cementation or replacement of the coral sand was seen.

### THE GEOLOGY OF TONGA.

#### Previous work.

The geology of the Tonga Group has previously been reported on by Lister, (1891). He divided the islands into those formed entirely of limestone, those formed partly of limestone and partly of tuff, and those islands which are purely of volcanic origin. Hoffmeister has written a very full account of the geology of the most interesting island in the Tonga Group, - 'Eua, (Hoffmeister, 1932). He described two limestone and two volcanic formations, the older limestone containing Eocene foraminifera. He also visited other islands in the group but has not published an account of them.

#### Geology.

The islands of the Tonga Group (See Plate 1) divide simply into four types:

- (a) Volcanic islands
- (b) Islands of tuff and limestone
- (c) Islands of raised limestone
- (d) Vegetated sand cays on coral reefs, with only small areas of raised limestone.

The volcanic islands form a remarkably straight chain more than 700 Km long, from 'Ata (22°20'S) to Tafahi (15°51'S). Also along this line are a number of shoal patches of less than 100 metres depth. Several of the volcanoes have been active within recent historic time particularly Falcon Island, active 1885-6 and 1927, Tofua, active 1906 and at present emitting steam, Late, 1854, and Fonualei, 1847, as well as a number of submarine volcanoes along the chain. Falcon, in the 1885 eruption, produced a basic augite andesite, (Harker, 1891, p.257) and a diabasic pyroclastic in the 1927 eruption, (Hoffmeister, ladd and Alling, 1929). A hand specimen collected from Tafahi during the Capricorn Expedition was thought to be an andesite (Raitt, Fisher and Mason, 1955). Rocks collected on 'Ata and Tofua during this survey have not yet been examined under the microscope. A number of specimens collected on 'Ata appear to be basaltic andesites.

The islands of the other three types occur along the main Tonga ridge which is separated from the volcanic chain to the west by a shallow trough 25-35 Km in width and with a general depth of 1300 - 1700m. The islands rise from four large platforms on the ridge between 21°30'S and 19°30'S; The Tongatapu platform, the Nomuka platform, the Ha'apai platform and the Vava'u platform - which are outlined by the one hundred fathom contour (See Plate 1). The surface of the platforms slope gently to the west and they are separated from each other by narrow passages more than 400 fathoms deep. The platforms end rather abruptly to the north and the south.

The islands composed mainly of tuff, type (b), are concentrated on the western side of the two central platforms, Nomuka and Ha'apai. Some have raised limestone exposed beneath the tuff.

The two largest islands in the Tonga Group, Tongatapu and Vava'u, belong to the third type, type(c). Both islands have thick soils covering the raised limestone.

Islands of the fourth type, type(d), - vegetated sand cays on reefs - are usually small and occur scattered throughout Tonga, but particularly they occur along the eastern edge of the Nomuka Group (Telekitonga, Lalona, Telekivava'u etc.)

#### NOTES ON THE GEOLOGY OF ISLANDS

##### VISITED DURING THE SURVEY.

##### 'Ata Island.

'Ata, the most southerly of the Tonga group, lies at Lat. 22°20'S, Long. 176°12'W, 85 miles south west of Tongatapu.

The island has no trustworthy anchorage and even slight swells make landing difficult. It is completely surrounded by cliffs, at the foot of which are boulder screes.

The island is lozenge shaped, about 1½ miles along each coast. It is a volcanic remnant; but there is no record of activity during historic time. It is directly on line with the other volcanoes of the Tonga Group.

A traverse was made along the base of the cliffs on the north east and north west coasts into the centre of the island by way of an old landslip on the north east coast, and across the central platform to the high ridge along the west side.

There appear to have been two centres of eruption; one along the west coast, where the landing was made; the second, a smaller centre, at the opposite corner of the island. At the main centre dykes are common and the various stacks and pinnacles at the landing appear to be plugs or the remnants of a single plug. The second centre was only seen from the sea, but the lava flows exposed in the cliffs along the south east coast appear to rise towards this centre.

A fresh land slip along the north west coast exposes a great deal of fresh material from a flow (apparently an olivine andesite) about 40 feet thick. There is much scoriaceous material between the flows and some agglomerate. Strongly marked cross bedding was seen in one exposure of agglomerate along the north east coast about 200 yards west of the old village.

Dykes are common along the north coast. At the north tip three intersecting dykes occur; one radial to the

first centre, ( $230^{\circ}$ ), one radial to the second centre, ( $310^{\circ}$ ), and one slightly east of north, ( $5^{\circ}$ ),. The last is a significant direction in Tonga - it is the trend of the line of volcanic islands.

There may be a third centre of activity at the southern tip of the island.

#### 'Eua Island.

The geology of 'Eua Island was studied in detail by Hoffmeister (1932). His map, slightly modified, is included with this report, (Plate 3).

Hoffmeister described four formations: (1) the older volcanics, (2) the Eocene limestone, (3) the younger volcanics (4) the late tertiary, chiefly Pliocene, limestone.

(1) The older volcanics are exposed at two places where the cover of Eocene limestone has been removed along the rocky backbone of the island, and at one locality in the centre of the east coast at sea level. The older volcanics consist of tuffs, agglomerates, ash beds and rhyolitic flows. The high area in the central part of the main ridge appears to have been closest to the focus of volcanic activity. Hoffmeister discovered boulders of diabasic norite along the east coast.

(2) The older volcanics are overlain by a limestone which can be definitely determined as upper Eocene. The limestone consists chiefly of foraminifera, although molluscs and echinoids contribute appreciably to its bulk.

(3) Overlying the Eocene limestone are bedded tuffs which contain numerous foraminifera. Alling, (in Hoffmeister, 1932), says that these younger volcanics are similar in composition to the older volcanics, but suggests that the second volcanic outburst was more explosive and produced ash beds with less common flows.

(4) The younger volcanics are overlain by a coral reef limestone of Pliocene to recent age.

During the survey the soils of the central valley and the eastern terraces were examined. No phosphate was found. Hand auger drilling on the central valley floor showed that the soils there are underlain by weathering tuffs and not by the later limestone, as Hoffmeister believed.

#### Nomuka Island.

Nomuka and Nomuka Iki ("Little Nomuka") are two islands close together on the north west part of the Nomuka platform. Nomuka is a triangular island with sides about  $2\frac{1}{2}$  miles long; Nomuka Iki is about 1 mile long with a maximum width of a little more than  $\frac{1}{4}$  mile. About  $\frac{1}{3}$  of the interior of Nomuka is taken up by a shallow, four to five feet deep, salt water lagoon, the Ano Ava.

Nomuka Iki has good exposures of bedded andesitic tuff in a 40 foot high cliff along the southern part of its west coast. The tuff there is very soft and deeply weathered, in beds from 1 inch to  $\frac{1}{2}$  inch in thickness.

Hand auger drilling through the deep soils in the centre of Nomuka indicate that the soil there is underlain by tuff. Raised limestone, about 8 to 10 feet above sea level, crops out round the Ano Ava and forms three small islets in it. It also crops out round much of the coast of Nomuka, except along the low sandy southwest coast, facing Nomuka Iki, and at the northern tip of Nomuka Iki. Just back from the shore the limestone here is covered by a thick soil which appears to be derived from the weathering of tuff.

#### Tonumea and Kelofesia.

These two islands occur in a complex area of reefs and shoals just south of the centre of the Nomuka platform. Both islands are about  $\frac{1}{8}$  square mile in area; Tonumea is roughly circular and Kelofesia is elongated northwest.

50 feet of poorly sorted, coarse to fine, andesitic tuff crops out in the cliffs on the west side of Tonumea. Manganese nodules occur commonly over the surface of the island, particularly along the top of the northwest trending ridge which forms the cliffs along the west side of the island. The nodules are also found in the present reef.

Kelofesia is very similar to Tonumea; tuff is exposed in the cliffs at the north, southwest and southeast tips of the island. No manganese nodules were seen on Tonumea. No raised limestone was seen on either island.

#### Tofua.

A few hours were spent on Tofua. The island is a volcano with a lake filling part of the old crater floor. The rim has an average height of about 1500 feet, rising in places to over 1600 feet, the water level in the lake is about 140 feet above sea level. The island is roughly circular, with a diameter of about five miles.

The Volcano was in active eruption in 1890 and in 1939 it was emitting a great deal of steam. At present the largest of three scoria cones along the north of the central lake is emitting steam.

The flows which make up the main cone are exposed in cliffs along the north coast and appear to be andesitic in composition. No thin sections of specimens collected have so far been examined. The northerly slope of the cone is mostly of loose scoria. The rim along this northern side is triple; and the lava exposed is often ropey.

#### Tongva.

Tongva is a low, square island, in the southern part of the Ha'apai group, with an area of about  $\frac{3}{4}$  square mile. Much of the surface of the island is of coral sand only a few feet above sea level. However there are cliffs of raised limestone 25 feet high along the western coast and thick soil above them. This thick soil spreads out and thins to the east.



Oua.

Oua, in the south of the Ha'apai group, is about  $\frac{1}{2}$  square mile in area, entirely surrounded by cliffs of raised limestone about 25 feet high. Above the raised limestone the surface is covered with a deep soil.

Oua is on a large reef and has a rocky bar of 'beach rock' dipping to the north, extending out from its western coast the remnants of an island, Kangalota Island, which existed at the time of the Admiralty Survey, in 1898, but which the villagers of Oua say was destroyed by a hurricane in 1912.

Lofanga.

Lofanga, near the centre of the Ha'apai group, is about  $\frac{3}{4}$  square mile in area and has low cliffs of raised limestone round part of its circumference. The island is covered with a thick soil through which limestone does not protrude. A recently dug well near the village shows an excellent section through 20 feet of loose ash and pumice. A one foot thick bed of pumice, about 5 feet from the top of the well consists of rounded pumice fragments not more than 1 inch in diameter. Limestone is not exposed now at the bottom of the well, which has caved since it was first dug, but the villagers say the limestone occurs at a depth of about 25 feet.

Lifuka.

Lifuka is the main island of the Ha'apai Group and has on it the town of Pangai, the third largest town in Tonga and the ancestral home of the Royal family.

Lifuka is about  $4\frac{3}{4}$  miles long (north/south) and  $2\frac{3}{4}$  miles across at the wide, southern end but only  $\frac{3}{4}$  mile wide for most of its length.

A traverse was made round much of the south coast and across the southern part of the island.

The west coast is generally low and shelving and composed of coral sand. The north and south ends of the east coast have a low, narrow terrace (10 feet high) of raised limestone. Behind this terrace the ground rises gently for a further 6 feet or so. Pumice fragments are very common along the top of this rise. The soil inland is similar to soils seen elsewhere in the group. Along the south coast there is an exposure of beach rock, apparently marking an old strand line, curving out from the present beach. This beach rock is black when seen from a distance and in hand specimen is seen to be crowded with fragments of brown clay material similar to the volcanic clay soil on the south east point.

Uiha.

Uiha has the same general form as Lifuka. It is about  $2\frac{1}{4}$  miles long (north-northeast) and about  $\frac{3}{4}$  miles wide. The west part of the island is, as on Lifuka, low and shelving, and composed of coral sand. The eastern

half is higher, with a thick yellow-brown clay soil formed from weathering tuff or ash. The north half of the east coast has a narrow 10 yards wide, terrace of raised limestone-highest in the north (about 10 feet above sea level) - and becoming gradually lower and narrower until in the centre of the east coast it has disappeared altogether. A bank of soil rises gently some six feet or so higher than this limestone terrace and has commonly a lot of pumice fragments along its top. A hand auger hole drilled near the centre of the island passed through 10 feet of yellow-brown clay with purple flecks before passing into coral sand. This clay was not phosphatic.

Along the central part of the east coast a  $\frac{3}{4}$  inch band of black sand, consisting of augite and olivine crystals, occurs in the present beach.

#### Vava'u.

The island of the Vava'u Group form the north end of the main Tonga chain. The group comprises about 40 islands, all close together; the area of the largest, Vava'u itself, being about 30 square miles. The town of Neiafu, on Vava'u, has a good harbour and is the second largest town in the Kingdom of Tonga. Vava'u is well served with motor roads.

The islands of the Vava'u Group are very different to the other islands in Tonga, as they are of high raised limestone. The highest part of the Group is along the north coast of the main island, Vava'u, where the cliffs rise 500 feet from the sea and the highest points are 670 feet above sea level, and at the isolated ridge of Mo'ungalafa on the southwest tip of Vava'u where the limestone is 610 feet above sea level.

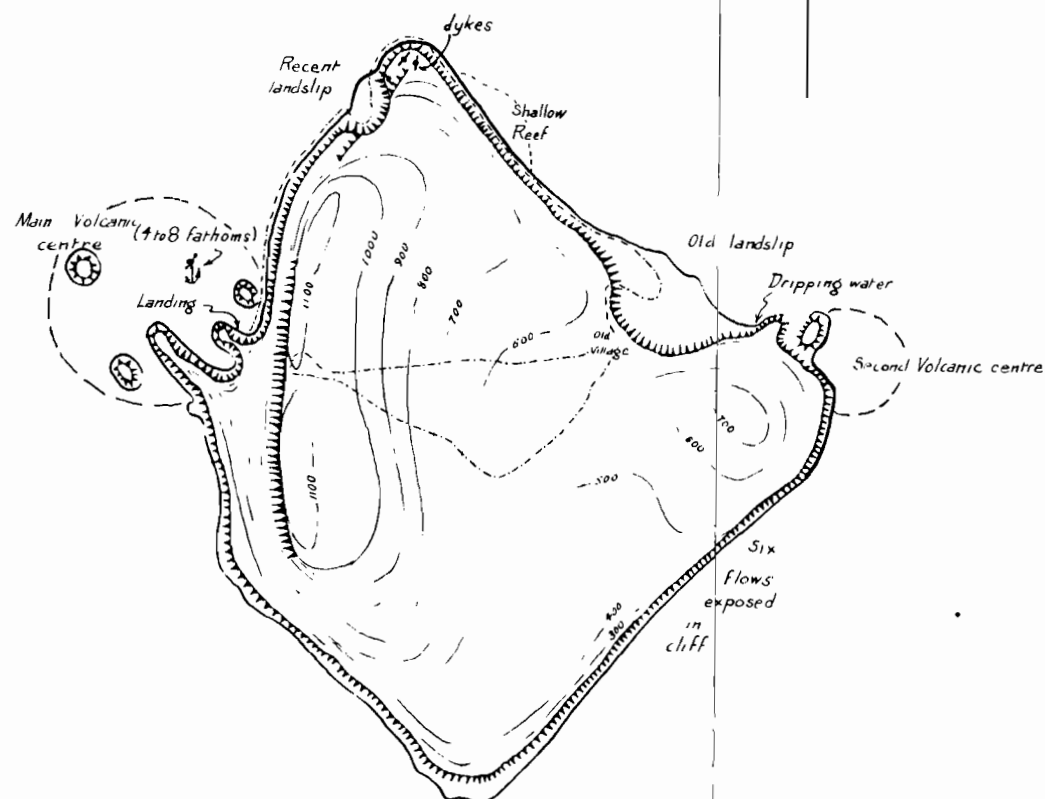
It was not possible, in the time available, to form anything more than a general idea of the geology of Vava'u. The raised limestone is terraced and is covered with a thick mantle of red volcanic ash, probably derived from the activity of such nearby centres as Late and Fanualei. Gardens were spoilt in Vava'u by ash from an eruption of Fanualei in August 1847 and again in 1937 and 1938.

The channels between the various islands are unexpectedly straight and the intersections between the different channels unexpectedly angular - the channels may be situated on a series of northeast and northwest fractures.

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Sydney.





# 'ATA I.

(22°20'S, 176°12'W)

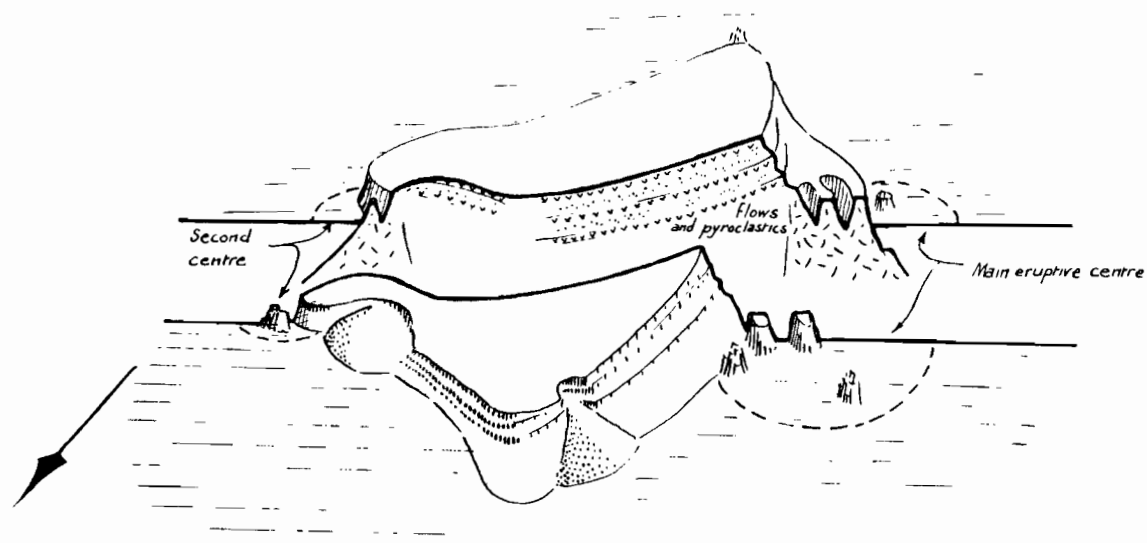
the

TONGA Group

Outline, contours and cliffs approximate only.

Scale  
Feet 0 1000 2000 3000

- Traverse, phosphate survey
- Contours - Vertical interval 100'
- Cliff



Perspective, sectional, view of 'ATA Island, looking SW.

# 'EUA I.

(21°20'S, 174°57'W.)

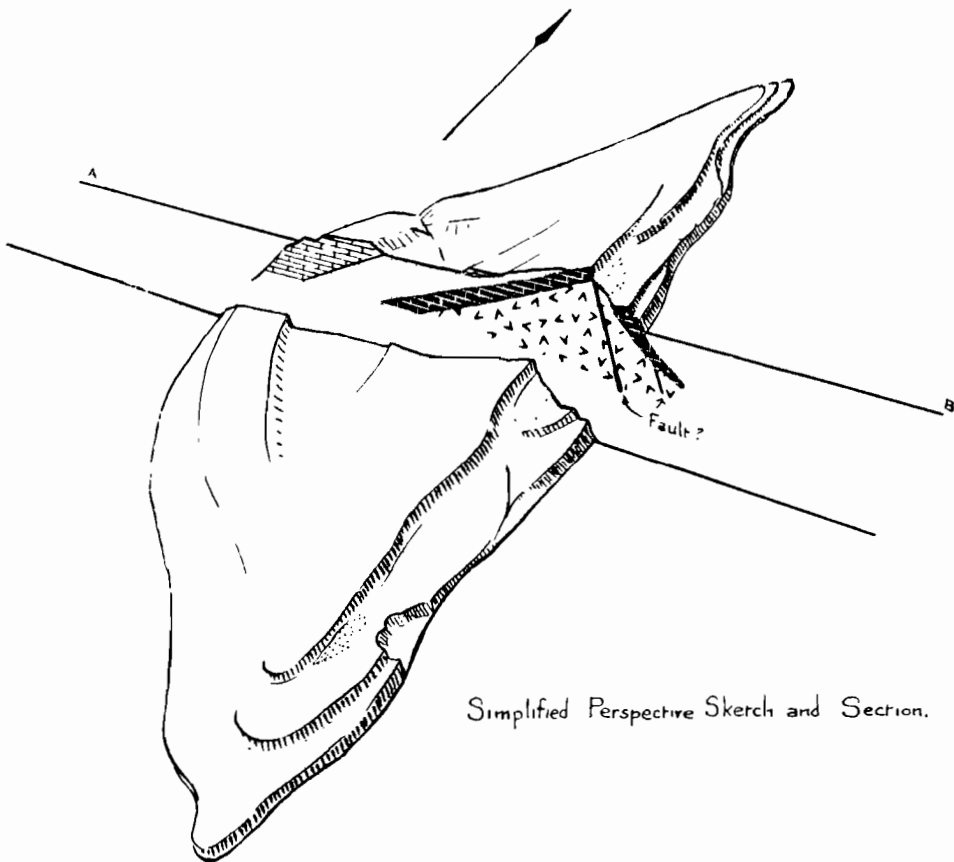
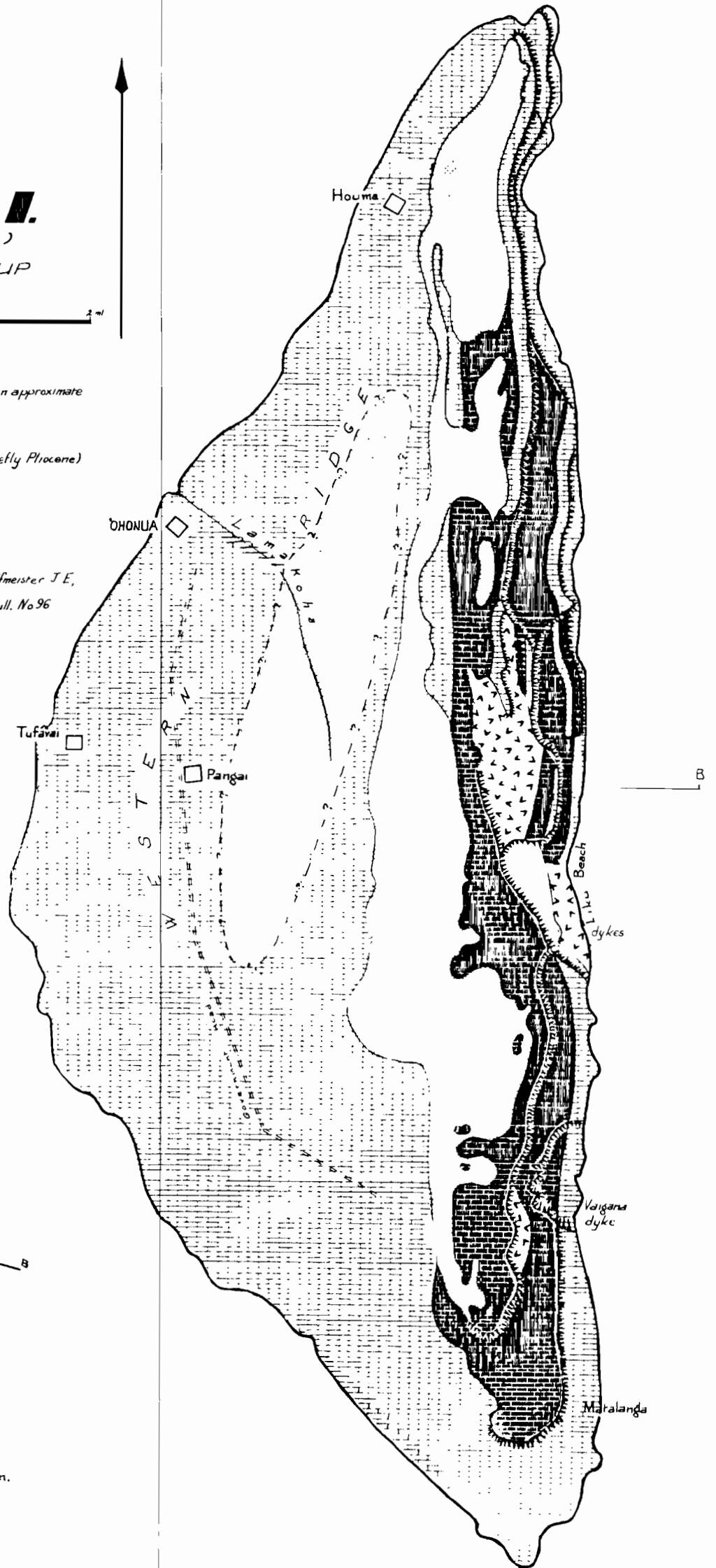
TONGA GROUP

SCALE 1 inch to 1 mile



- Geological boundary
- Geological boundary, position approximate
- Cliff
- Late tertiary limestone (chiefly Pliocene)
- Younger Volcanics.
- Eocene limestone
- Older volcanics.

Geology and position of terraces, mostly from Hoffmeister J.E., 1932, 'Geology of 'Eua, Tonga', B.P. Bishop Museum Bull. No 96



Simplified Perspective Sketch and Section.

KALLAU I.



# **NAMUKA I.**

## TONGA

SCALE 1 inch to 1 nautical mile (6080 ft)

- Raised limestone
- Soil derived from weathering tuff
- Coral sand
- Seaward edge of reef
- 5 fathom contour
- Spot heights in feet
- Road
- Traverse, phosphate survey
- Outline of islands and reefs from Admiralty Chart No. 474



