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REPORT ON INVESTIGATIONS FOR PHOSPHATE DEPOSITS FIJI ISLANDS, 1959.

by

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CONTENTS

PLATES

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SUMMARY

During the 1959 field season an investigation of phosphate prospects in Fiji was made. Most of the islands visited are in the Lau group, eastern Fiji, and the general geology of this group is described.

Four islands, Vanua Vatu, Vatoa, Ogea Driki and Tuvuca were known to have some phosphatic material on them. Two more islands, Vatu Vara and Marabo were found to have small deposits.

The geology of the islands with phosphate deposits is described in detail and estimates of the tonnage and grade of the deposits are given.

The largest deposit, that of Vanua Vatu, has 200,000 tons of medium to good grade oolitic phosphate which might prove a useful source of cheap phosphate fertilizer within Fiji but is not likely to be exported. Ogea Driki has 77,000 tons of medium grade oolitic phosphate and phosphatic clay. Tuvuca has one to two millions of tons of clay, which is in part phosphatic.

Points of geological interest on the other islands visited are described briefly.

FIJIAN SPELLING.

Two systems of spelling Fijian names and words are in use in Fiji, the 'Fijian'System and the 'phonetic' System. Here I have used the 'Fijian'System. This system uses five letters to represent sounds that are different from the sounds they represent in English:

'B' is pronounced 'MB' as in'number' e.g. KOROBASAGA = KORO MBASANGA.
'C' is pronounced 'TH' as in 'that' e.g., CICIA = THITHIA.
'D' is pronounced 'ND' as in'end'e.g., DALICONI = NDALITHONI.
'G' is pronounced 'NG' as in 'sing'e.g., MAGO = MANGO.
'Q' is pronounced 'NG' as in'finger' e.g.,QELE LEVU = NGGELE LEVU.

INTRODUCTION

In 1958 the Australian and New Zealand Governments jointly undertook to survey all possible islands in the south-west Pacific in the search for new sources of phosphate suitable for the manufacture of superphosphate fertilizers, to supplement the material at present obtained from Ocean and Nauru islands in the Pacific Ocean and from Christmas island, Indian Ocean. The work here recorded, the survey of islands in the Fiji group, was part of the 1959 field season of the phosphate survey.

A 100 ton auxiliary ketch, the 'Maroro', was chartered for the survey. Most of the larger islands in the Lau group and two islands, Cikobia and Qele Levu, north of Vanua Levu were visited during the two months from June 18th to August 19th. A further brief visit was made to two islands in the Lau group from October 21st to 25th.

I would like to thank all the Departments of the Administration of Fiji for the help that I received in setting up the survey; my thanks are especially due to Dr. Guest, the Senior Geologist, and his staff at the Geological Survey Department. S. Ratuyawa, L. Koto and J. Romanu, of the Geological Survey Department were my able assistants during the survey.

In the Lau group the work would have been impossible without the help of Mr. William Wainiqolo, the Roko Tui Lau, and the Bulis and Turagas of the villages throughout the Lau.

I would also like to thank Commander Brown, the Master of the A.K.'Maroro' and his officers and crew.

THE LAU GROUP

The Lau group comprises about 100 small islands that make up the eastern part of Fiji (Plate 1). The largest of the Lau islands, Vanua Balavu, is about 24 sq. ml. in area; the smallest islets are less than ½ sq.ml. in area. 20 islands were visited; 5 of these were uninhabited.

The visits to all the islands were brief. 3 or 4 days were spent on those islands which were known to have phosphate deposits; but some islands were only visited for a few hours or for one day.

Geology of the Lau.

The geology of the Lau has been investigated by Ladd and Hoffmeister, (1945). Previously the islands had been visited by Dana (1849,1890), Gardiner, (1898,1931), Agassiz (1898), Andrews (1916), Davis (1928) and Foye (1917) all of whom were principally interested in the coral reef problem.

Ladd and Hoffmeister named six formations which are shown on the accompanying table.

TABLE 1. Formations in the Lau. (From: Ladd and Hoffmeister, 1945)

SYSTEM	East Indian Stage	FORMATION
Quaternary		MAGO ODINITE
		VULAGA LIMESTONE
Tertiary	h	DALICONI LIMESTONE
	g	KORO BASAGA VOLCANICS
	f	FUTUNA LIMESTONE
		LAU VOLCANICS

The rocks of the oldest formation, the Lau Volcanics, are andesitic flows and agglomerates and tuffs which are exposed as the cores of many of the islands and are believed to form the cores of those islands on which only limestone is exposed. Above the Lau Volcanics is the Futuna Limestone, tuffaceous limestone, coral limestone, and algal calcilutite. It is at least 600 feet thick and is dated as Tertiary 'f' stage (lower Miocene). The Koro Basaga Volcanics which occur above the Futuna Limestone in a few places consist of flows, agglomerates and tuffs, mostly of a basaltic composition. Flows are more numerous than in the Lau Volcanics. The most common rock type is an olivine basalt. In a very few places Ladd and Hoffmeister found a coral limestone which they named the Daliconi Limestone, above the Koro Basaga Volcanics and containing a fauna of fossil foraminifera, molluscs, corals and crabs which indicates a late Miocene - Pliocene age.

The younger formations, the Vulaga Limestone and the Mago Odinite, are not exposed in such a way that their relationship to each other and to the other formations can be established by superposition.

90% of the rocks of the Lau are of the two oldest formations, the Lau volcanics and the Futuna Limestone, and on the majority of the islands only these two formations have been recognized.

Ladd and Hoffmeister in their classification of the islands recognized the importance of the size of the island compared to the size of the platform from which it rises. The islands of the Lau can be usefully divided into two groups on this basis; some islands, such as the Exploring islands, Oneata and the Yagasa cluster, are circled by a wide lagoon indicating a platform many times the width of the enclosed islands; others, such as Kabara, Cicia, Mago etc., have only a narrow fringing reef.

A good example of the first group, the Yagasa cluster, has three small islands with a total surface area of less than one square mile enclosed by a reef that indicates a

foundation of more than 25 square miles in area. Also included in this first group are extensive reefs, for example the Bukatatanoa reefs, which have no islands with the lagoon.

Plotting these two groups on a map of the Lau the first are found to lie on a broad arc begining at the north end of Vanua Levu and narrowing towards Vatoa and Ono-i-lau in the south; while the second group all lie inside this outer arc apparently along north-east and north-west fractures. (E.g., the Lomaiviti fissure islands, Moala, Totoya, Gau, Batiki etc., referred to by Ibbotson (1959) and the line of islands Lakeba, Nyau, Cicia, Vatu Vara, further north.)

PHOSPHATE DEPOSITS IN FIJI

Hutchinson (1950) makes no mention of phosphate deposits in the Fiji islands, except to record that two rocks inside the Reid reef are reported to have some guano on them. However, a small deposit of phosphatic clay and oolitic phosphate on Ogea Driki in the south Lau was investigated in 1941 by F.T.M. White, who was then the inspector of mines for Fiji, (White, 1942). This deposit was investigated further in October, 1942, by Mr. Bridges, a representative of the British Phosphate Commissioners, with a view to its immediate utilization to replace supplies normally obtained from Ocean and Nauru islands (Bridges, 1942). In the last few years there has been a stimulated interest in the search for phosphates in this part of the Pacific. The Fiji Geological Survey found phosphate deposits on two other islands in the Lau group (Vatoa and Vanua Vatu) during 1957, and an aluminous phosphatic clay was reported on Tuvuca by Dr. J.A. Staargaard, of Aluminium Laboratories Limited, during a reconnaissance of the Lau islands made in 1958.

The present survey covered nearly all the islands of the Lau and led to the discovery of two new deposits, both very small. In addition the known deposits were assessed as regards tonnage by hand auger drilling and mapping and field estimates were made of the grade.

While none of the deposits in Fiji are large enough to be exploited comercially outside Fiji, the deposit on Vanua Vatu island should be investigated further by the Administration of Fiji as a possible source of cheap phosphate fertilizer within the Colony.

ISLANDS WITH PHOSPHATE DEPOSITS

Vanua Vatu

Position and Size. Vanua Vatu (Plate 2) is an almost circular island, with an area of a little more than one square mile, surrounded by a fringing reef. It is in the western part of the Lau, about 155 miles from Suva. There is a poor anchorage in a bight in the reef opposite Taira village, the only village on the island.

Previous Investigations. The island is mentioned by Ladd and Hoffmeister, though only a sketchy account is given as the visit, by only one of the authors, was very brief.

In 1957 renewed interest in phosphate throughout the south-west Pacific led Dr. Guest, of the Geological Survey Department, to make a brief reconnaissance of the raised limestone islands of the Lau. He visited Vanua Vatu and discovered the phosphate deposit. Later in the same year the boundary of the phosphate occurrence was mapped and the deposit extensively pitted by Ratuyawa of the Fiji Survey.

Physiography and Geology. The island has only a narrow fringing reef and is entirely of limestone, presumably of the Futuna Limestone. It lies well within the outer arc of the Lau but is not clearly aligned along any of the north-west or north-east features of the inner Lau. The island has a well defined rim on the north, west and south sides, reaching a maximum height of 330 feet above sea level. At the north-west corner there is a gap in the rim and a fairly gentle slope leads up from Taira village to the Maumi basin, where most of the phosphate is located.

The island's shape suggests a raised coral atoll but Ladd and Hoffmeister found foraminiferal rather than coral limestone along the rim. Possibly the island is an original atoll which has been sufficiently eroded to remove the coral limestone of the upper part of the rim while still preserving the basin shape.

The Phosphate Deposits. The phosphate occurs as oolitic grains and pebbles and phosphatic clay between pinnacles of limestone. In the Maumi basin, (See Plate 2) the tops of the limestone pinnacles protrude about a foot above the surface of the phosphate.

The oolites are up to 1/3 inch in diameter. Fresh surfaces of broken grains are white, gray, light brown or streaked with black, show signs of concentric structure particularly near their edges and have the typical vitreous lustre and conchoidal fracture of Collophane. The ollites are generally bonded by a small amount of clay but in some places the clay is almost entirely absent and the oolitic phosphate runs like a coarse sand and is not retained by a hand auger.

The majority of the pebbles occur with the oolitic phosphate on the western slope (Area 'B'). Most of these pebbles are formed of oolitic grains cemented together, though a few, which may be phosphatized coral fragments, appear structureless on broken surfaces. All the pebbles have the typical colloform exterior and do not appear to have been abraded.

The oolitic material grades over a short distance into phosphatic clay on the north, east and south sides of the deposit. There are scattered occurrences of the clay elsewhere on the island, notably at Bukidalivou.

Tonnage and Grade. An estimated 100,000 tons of medium to good grade phosphate is contained in the Maumi basin, (Area'A') from which it could be easily recovered. A further 100,000 tons of similar material from the sloping ground leading down to the north-west coast, (Area 'B') would be less easy to recover because it lies in shallow pockets between upstanding pinnacles. There is no overburden in either area.

Twelve determinations on this material are given in Table 2. The average phosphate content is 25.8% P_2O_5, with 21.6% Al_2O_3. The phosphatic clay which surrounds the oolitic deposit is of lower and very variable grade; the average of three determinations is 15.3% P_2O_5, while the content of Alumina is much higher, 38.4%. Also included in Table 3 are determinations and full analyses from earlier work by Guest.

Exploitation. The exploitation of this deposit by the villagers as a source of phosphate for use within the Colony would perhaps be a practical possibility and should not be overlooked. The land of Area 'A' is at the present planted with coconuts but with little else as the villagers find the oolitic phosphate is unsuitable for the planting of root vegetables. Most of the gardens seem to be in the Sapuga and Bukidalivou areas and on the phosphatic clay of Area 'C'. My impression was that the exploitation of the Maumi deposit and of Area 'B' would not seriously reduce the area of land under cultivation.

Recent work by Cassidy, (1959) suggests that this type of phosphate may have real value as a fertilizer for direct application to paddy rice. If this is so a study of the cost of local exploitation of this deposit should be made to see if it would be landed at Suva at a compeditive price. It could prove a valuable source of cheaper phosphate fertilizer for rice growers.

The deposit on this island is of a higher grade and tonnage than any other in the Lau.

OGEA DRIKI

Position and Size. Ogea Driki (Plate 3) is one of a group of three islands, known collectively as Ogea, which are encircled by a single extensive reef. Ogea is in the south Lau and is 220 miles from Suva. There is good anchorage within the reef at many points between Ogea Driki and Ogea Levu. The entrance to the lagoon is from the west.

There is one village on Ogea Levu, but Ogea Driki and Yanuia are uninhabited. It appears that most of the land of Ogea Driki is owned by men from Vulaga, rather than Ogea Levu.

Previous Investigations. The phosphate deposits of Ogea Driki were first investigated in 1941 when they were visited by Mr. F.T.M. White, who was then the Inspector of Mines for the Colony, (White, 1942). A comprehensive survey was made in October, 1942, by Mr. Bridges of the British Phosphate Commissioners he assessed the tonnage and grade and reported fully on the possibility of exploiting the deposits (Bridges, 1942). The islands were investigated geologically by Ladd and Hoffmeister, but they made no note of the phosphate.

Since then the island has been visited from time to time by geologists of the Fiji Geological Survey Department and an assistant of the Lands Department spent some time there remapping the boundaries of the phosphate deposits and prospecting over Ogea Levu for similar deposits.

Physiography and Geology. North-south faults form the cliff faces along the west side of Ogea Driki, and the elongation of the Ogea group as a whole is in this direction. Ladd and Hoffmeister also suggest a north trending fracture as the reason for the line of reef that run up from the north-east tip of Ogea Levu - Nuku Sogea etc.

The three islands together evidently form a raised coral atoll, the rim of which has gaps along the east and west sides, allowing part of the old lagoon floor to be re-flooded. It is possible that the north trending faults along the west edge of Ogea Driki may have caused the breach in the rim on this side. I did not see the east side. Much of the old lagoon floor is preserved on Ogea Levu. The present lagoon is very shallow at this northern end, drying extensively at low tide, and is dotted with undercut 'mushroom' islands of limestone.

Ladd and Hoffmeister found many corals in a position of growth at localities round the rim.

The old lagoon floor of Ogea Levu has a fairly extensive red clay soil. Similar soils were seen in many parts of the Lau, (Vatoa etc.).

The Phosphate Deposits. The phosphate deposits occur only on the north-west tip of Ogea Driki (See Plate 3). The phosphatic material consists of clay and oolitic phosphate, similar to that described for Vanua Vatu, but with a higher proportion of clay.

An unusual feature of the deposits is that they occur on the tops and slopes of rises rather than in basins. The three main deposits, Maumi, Navakatoga and Denipusi are all on gentle rounded rises. The yellow-brown phosphatic clay merges rather abruptly into the red clay soil which occurs on other parts of the old lagoon floor. Because of this I think these deposits originated from a bird colony which nested in a restricted area on these rises. Phosphatization took place only where the birds nested. There is no trace of phosphate elsewhere on Ogea Driki or Ogea Levu and is seems unlikely that the present deposits are all that remains of more extensive deposits which have been eroded.

Tonnage and Grade. Bridges estimated the tonnages of the three deposits as follows : -

DENIPUSI	39,000
Maumi	28,000
NAVAKATOGA	10,000
Total	77,000 tons

Analyses made at the same time gave the average P_2O_5 content as 25% with an average of 12% Al_2O_3 and Fe_2O_3.

A few auger holes were drilled during the present survey; these seemed to confirm Bridges estimate of the tonnage available.

White's estimates were larger but were based on a very short reconnaissance only.

TUVUCA.

Position and Size. Tuvuca (Plate 4(a), 4(b)) is in the centre of the Lau, 190 miles from Suva. It is 4 miles long and 2 miles wide, elongated in a direction north-north-west.

The only village, situated towards the south end of the west coast, is small and has no radio station. Suprisingly large areas in the central parts of the island have been cleared for gardens and the whole island is well served with tracks internally, though the first part of the track from the village has a steep climb over the limestone rim.

There is no sheltered anchorage but ships commonly hang on opposite the village.

Previous Investigations. The island was traversed extensively by Ladd and Hoffmeister. In 1958 the island was visited by Dr. Staargaard in the course of his investigations for bauxite on behalf of Aluminium Laboratories Limited. He reported finding a phosphatic bauxite on the island and his company has retained a Prospecting Licence for bauxite over the island.

Geology and Physiography. Tuvuca is of raised limestone with a series of discontinuous narrow limestone terraces with well marked rims reaching a maximum elevation of 750 feet, surrounding an irregular central basin.

The limestone of the island belongs, in the main to the Futuna Limestone, though Ladd and Hoffmeister found two small areas of Daliconi Limestone on the north coast.

The volcanic rocks which crop out as a long ridge at the south end of the central basin, along the south coast and along the north-east coast, belong to the Lau volcanics and consist of flows and some agglomerates. The long ridge of volcanics in the central basin appears to continue under a limestone cover and to crop out again along the south coast. The air-photograph suggest that there is a second ridge, parallel to the first and about ½ mile to the west of it, which is only exposed at its southern end, close to the village. (See Plate 4(a)).

A remarkable feature of the island are the large clay floored circular depressions in the limestone which are known in Fijian as 'Qilos'. These Qilos are commonly two or three hundred yards in diameter and have steep, almost vertical, limestone walls rising on every side to a height of fifty to one hundred feet above the level of the floor. Hand auger drilling on the floor of these Qilos showed that the clay filling is in places more than 30 feet thick and that below the clay is not limestone but a steady transition to a weathering volcanic rock. Similar, though smaller, features were later seen on Cikobia-i-lau island.

The Phosphatic Clay. Hand auger drilling was carried out over much of the floor of the central basin and the Qilos. The main areas of clay thus delineated are shown stippled on Plate 4(a). The hand auger drilling proved 700,000 tons of clay in the central basin and in the four Qilos numbered on Plate 4(b). There are more Qilos on Tuvuca that were not visited and drilled during the survey. In all there are probably between one and two million tons of clay in the central basin and the larger Qilos.

8 samples of the clay of Tuvuca, taken by the Aluminium Laboratories prospecting team, ranged from 9.8 to 21.3% P_2O_5. 5 samples taken during this survey were analysed and the results are shown on Table 2. They range from 4.7 to 21.4% P_2O_5. Further samples have been sent for analysis and these results will be added to Table 2 when they are available.

The clay appears to be only discontinuously phosphatic and the high content of Al_2O_3 and Fe_2O_3 (See Table 2) rule out its use in the manufacture of superphosphate. However, the clay may be useful within Fiji for direct application.

VATOA.

Position and Size. Vatoa island (Plate 5) is somewhat less than 2 sq.ml. in area and is in the far south of the Lau, 250 miles from Suva. It is actually slightly closer to Nuku'alofa, Tonga, than to Suva.

There is good anchorage within the reef at a number of places along the northern part of the west coast. The passage through the reef is at the north-west corner and is narrow. It is advisable to wait for a pilot from the village.

There is one village on Vatoa; it is close to the south end of the west coast on low lying land near the sea shore.

Previous Investigations. The island was not visited by Ladd and Hoffmeister. The phosphate was discovered by Dr. Guest during his 1957 phosphate reconnaissance in the Lau. Later in the same year Ratuyawa, of the Fiji Survey, investigated the deposit by pitting along the main tracks.

Geology and Physiography. The exposed part of the island is entirely of limestone; presumable of the Futuna Limestone - but no fossils were found to confirm this.

The island has a rather complex form. The highest part is a limestone rim running round the north-east and north-west sides of the Lomanivanua basin. This rim reaches 200 ft above sea level. There is a terrace at 60 to 80 ft above sea level on the north and east sides of this rim; inside the rim the basin floor slopes gently to the south-west and is about 80 feet above sea level. There are two prominent limestone hills close together at the south end of the island (Muanivatu) rising 40 to 50 feet from a gently shelving terrace at about 60 feet above sea level.

Much of the island is uneven and difficult to traverse.

Phosphate Deposits. The phosphate of Vatoa consists of a clay of very variable phosphate content, which occurs in pockets scattered over much of the island. A very small amount of oolitic phosphate occurs beneath the clay at the foot of the rise from the village to the school (Busabusa).

The clay was examined by hand auger drilling. It was found that no sizeable clay filled basins occur - the Lomanivanua basin having only scattered shallow pockets on its surface.

The clay is friable and brown to yellow brown in colour; lighter coloured clay being of higher grade. The very small amount of oolitic phosphate that occurs consists of oolites about 1/8th in. in diameter.

No estimates of tonnage are given as the deposits are too scattered to be assessed with any accuracy and are obviously too small to be worth exploiting. (N.B., if the island were covered to a depth of 6 in. all over its surface with clay, it would be less than ½ million tons.)

A fragment of weathering pumice was found in one auger hole, in the Lomanivanua area, at a depth of 5 feet.

VATU VARA.

Position and Size. Vatu Vara (Plate 6) one of the smallest islands in the Lau, is not more than one and a half miles across in any direction. It has a very irregular coastline - in particular a large bay at the south end of the west coast. It is in the northern Lau, 145 miles from Suva.

The island is not inhabited but it is leased as a copra plantation. Occasionally men from Yacata live for a few days on the island cutting copra for the owner. There are two huts and a water catchment.

There is no anchorage and the boat passage through the reef along the north-west coast can only be used at high tide. At other times it is possible to land on the edge of the reef and wade ashore.

Previous Investigations. There is no record of previous investigation of the island for phosphate deposits, nor was the island visited by Ladd and Hoffmeister.

Geology and Physiography. Vatu Vara is nick-named 'Top hat' island, and the nick-name aptly describes its silhouette. The only rock exposed on the island is limestone; the central mass rises to 1050 feet, making the island the highest in the Lau. The central mass is surrounded by a broad terrace the surface of which is about 250 feet above sea level.

The central mass is elongated north-east in plan and has a saucer shaped cross section. It has been cut across at the south-west end by a north-west trending fault with the downthrow on the south-west side. The outside slopes of the central mass are very steep and made up of jumbled blocks of limestone, commonly very large, stabilized by rain forest growth. On the south side signs of a recent slip were seen. The top 100 feet or so form a vertical cliff, free of vegetation.

The 250 foot terrace is not continuous round the island and has been affected by the same faulting which has cut the south-west end of the central mass. The terrace, from a distance, appears to slope slightly seaward; the surface of the terrace is actually very uneven and pitted by solution - the pits are commonly ten to twenty feet across and as much as twenty feet deep.

The highest point on the island is at the north-east end of the central block and there are some signs, on the south face, of bedding dipping to the west. The appearence of the

central mass suggests that it was tilted during the uplift which preceeded the formation of the lower terrace.

There are no volcanic rocks exposed on the island but I do not think a full 1000 feet of limestone can be claimed. A large part of the slope of the central mass is of scree material which may cover exposures of the volcanic core.

The Phosphate Deposits. Small deposits of phosphatic clay and oolitic phosphate were found on the north and south sides of the central mass at the foot of the scree slope. Close to the screeslope the otherwise empty hollows in the surface of the limestone of the 250 foot limestone terrace are filled or partly filled with this phosphatic material.

Traces of phosphate were found in cracks in the limestone most of the way up the side of the central mass, suggesting that the phosphate may have formed there by leaching of guano from birds nesting in the cliffs and then been washed down and trapped in its present position.

The deposits are very small and the total tonnage of phosphate available is estimated at 15,000 tons (See Plate 6).

MARABO

Position and Size. Marabo is a small island in the southern Lau off Kabara, ¾ sq.ml. in area and 190 miles from Suva. It is uninhabited but often visited by men from Kabara for fishing and copra cutting.

Geology, Physiography and Phosphate Deposits. The island is entirely limestone, the highest point being 160 feet above sea level. It has no easily described physiographic form but in general the highest limestone is in the centre and towards the north-east coast. The rest of the island is formed of discontinuous terraces and limestone ridges.

A narrow terrace along thesouth-west side contains a few hundred tons of phosphatic clay between limestone pinnacles. No analyses of this material have been made, but qualitative testing in the field show the clay is ow grade.

ISLANDS WITHOUT PHOSPHATE DEPOSITS

Islands on which no phosphate deposit was found will not be described in any detail. A brief note will be given of any points of geological interest. The position of the islands is shown on Plate 1. Maps of themore important islands are included and these maps show the extentof the prospecting carried out on each island.

Vulaga. (Plate 7). The island is sub-quadrate in outline, has a clearly marked rim of raised limestone which reaches a maximum height of 260 feet above sea level, and has a central lagoon which is open to the sea through a passage on the east side. Ladd and Hoffmeister from the evidence of the physiography and because of finding many corals in a position of growth in the raised limestone of the rim, concluded that the island was a raised coral atoll. It appears that the island may have been tilted during the uplift as the rim is higher and broader on the south-west side and becomes a number of lower, narrow islands along the north-east side. There are many 'mushroom' islands of limestone in the central lagoon, particularly at the south end which is very shallow and dries at low tide.

The soils of the island are purple-red in colour, in places up to 8 feet deep.

Namuka. (Plate 8). Namuka Island has a reef away from the shore enclosing a broad lagoon. The island is entirely of raised limestone, and is elongated in an east/west direction. It has a ridge of higher limestone all along its northern coast and a lower and less continuous ridge along the south coast, broken in the centre by a broad shallow bay across the front of which the southern ridge forms a chain of islands. Faulting seems to have been important in the formation of Namuka; two faults, one north and one north-east are visible on air photographs. The straightness of the north coast is very suggestive of an easterly fault although the cliffs along this north coast appeared, from the sea, to be fractured in some direction nearly normal to their trend.

The soils of the island are quite deep, particularly in the central area round the bay; depths of more than 8 feet being common. The soils are again a purple-red in colour, the purple colour being more marked than on Vulaga. The people of Namuka are known in this part of the Lau for the purple stain on their hands and clothes from this soil.

Kabara. (Plate 9). Kabara belongs to the younger group of the Lau islands, having a narrow fringing reef. It may be connected with a north-east trending feature as the north-west part of the original island has been faulted off by a north-east trending fault. The elongation of the island is, however, to the north. The island has the form of a raised coral atoll, the rim being rather even at a height of between 200 and 250 feet above sea level. The chief interest lies in the volcanic rocks which form a steep, double peaked hill, 440 feet high, north of the centre of the west coast. Ladd and Hoffmeister considered these volcanics were part of the Mago Odinite and of a younger age than the limestone.

The old lagoon floor is remarkable for its lack of soil. Much of the interior is simply of jumbled boulders of cavernous limestone overgrown with rain forest. What soil there is is derived from the volcanics and is purple-red in colour. Some Manganese occurs in a swampy area at the north end of the old lagoon floor. It appears to form by redeposition under swamp conditions after being leached from the volcanic soils.

Vuagava. Vuagava is a close neighbour to Kabara and is very similar in form. It clearly has the form of a raised atoll the rim being about 300 feet above sea level; it also has been truncated along the north-west coast by a north-east trending fault. It has, however, no outcropping volcanic rocks and much of the old lagoon floor is occupied by a brackish lake.

The soils are similar to those of Kabara.

Yagasa Levu. A small, narrow, north-east trending strip of raised limestone in the Yagasa lagoon. It has no clearly defined topographic form. The highest part of the limestone, 300 feet, is along the north-west coast; the rest of the island appears to be terraced when seen from a distance. The rugged nature of the limestone makes these terraces less obvious when they are traversed. There is very little soil between the pinnacles of the limestone.

Oneata. (Plate 10). Only a few hours were spent on Oneata. It is [illegible] square miles in area; and is particularly interesting as it has outcrops of three formations, the Lau volcanics, the Futuna Limestone and the Koro Basaga Volcanics. A 60 foot thick bed of foraminiferal limestone occurs at the base of the Futuna Limestone and clearly establishes the age of that part of the formation as Miocene ('f' Stage). The soils of Oneata are mostly of a red or black colour and suggest that the volcanic rocks have a wider distribution than shown on the map prepared by Ladd and Hoffmeister. (See Plate 10).

Nyau. Only a few hours were spent on Nyau. The island was not examined in detail by Ladd and Hoffmeister and its geology is not well known. A rim of limestone about 550 feet high encloses an oval basin, elongated in a north-west direction. The flat floor of the central basin is estimated to lie about 250 feet above sea level. It is covered with a red-brown to purple soil, supporting a growth of reeds and short palms, suggesting that it may be underlain by volcanic rocks. The limestone rim is broken, on the north-east coast, by volcanic rocks which reach to about 500 feet above sea level. A deposit of manganese is being worked on the slope below these volcanics.

Cicia. (Plate 11). Cicia is roughly circular, 4 miles in diameter. Geologically it appears simple in construction. The centre is made of andesitic volcanics and the island has the appearance of a single eroded volcanic cone. The centre reaches 540 feet above sea level and is surrounded by a discontinuous terrace of raised limestone reaching to about 400 feet. The soils of the central area are commonly very thin, but valleys leading down to the coast have a thick fill of clay.

Mago. (Plate 12). Mago island was examined in detail by Ladd and Hoffmeister. Their map is reproduced here (Plate 12). The island is interesting in having two ages of volcanics exposed, one older and one younger than the Futuna Limestone.

Cikobia-i-lau. (Plate 13). The island is within the large lagoon which also encloses Vanua Balavu and Munia. It has two ages of volcanic rocks exposed; andesitic agglomerates and flows of the Lau Volcanics are exposed beneath the Futuna Limestone along the south-west coast and in various places in the centre of the island; whereas a large ridge of agglomerate which makes up the east coast of the island is placed by Hoffmeister in the Koro Basaga Volcanics (a conclusion with which Ladd did not agree). The fact that no limestone occurs at any point resting on this agglomerate and that one valley has limestone on one flank and the agglomerate on the other seems to be very strong evidence for the younger age for the agglomerate; clearly the agglomerate could not have been there during the time that the limestone was being deposited or it would have received a cover of limestone.

An interesting feature of the island are the 'Qilos' that occur there. They are similar in every respect to the 'Qilos' on Tuvuca, though they are smaller.

A fault running along the centre of the island in a north-east direction is an important tectonic feature. It is shown by scarps inland whose continuity can be seen on air photographs.

Katafaga. Katafaga is a small island in the central Lau. The south and centre of the island are of volcanics, andesitic flows and agglomerates of the Lau Volcanics; while the north end of the island is of Futuna Limestone. A small amount of manganese occurs in cracks in this limestone. In those places where manganese is now exposed it appears that the limestone previously was covered by eluvium from the weathering volcanics in the higher central part of the island. Manganese dissolved out of the volcanic eluvium was re-deposited at the limestone contact. Subsequent erosion of the eluvium has exposed the manganese in cracks and hollows in the limestone surface.

Yacata. (Plate 14). Yacata is a large island in the north Lau, although for administration it is considered part of Cakudrove Provence (Vanua Levu) rather than part of the Lau. It is composed of limestone and volcanics.

Naitaba. Not enough time was spent on Naitaba Island to get any clear picture of the geology. It has a basin shaped interior and may be a raised atoll.

Cikobia. (Plate 15). Cikobia is an island of about 6 sq. ml., north of Vanua Levu, 200 miles, in a straight line, from Suva. It is elongated slightly south of east, and may be structurally part of the outer Lau arc. This easterly elongation is continued under sea for some distance at the east end of the island.

The island is composed of raised limestone and volcanics. The limestone, which is terraced, makes up the west and central parts of the island. It is underlain by volcanics, chiefly an andesitic agglomerate, which crop out at the east end of the island. The highest point of the island, Nauluvatu, is a residual of limestone resting on the agglomerate.

A very cursory examination of the island suggests that the limestone has been a thin but complete cover over a steep sided narrow ridge of volcanic material which was extruded along an east trending fissure. The island has subsequently been raised above sea level and terraced and part of the limestone cover removed.

Some manganese occurs on the island in a similar geological setting to the other occurrences in the Lau.

Qele Levu. (Plate 16). Qele Levu is a very small island at the east end of a large lagoon. The island consists of deeply pitted limestone raised about 20 feet above sea level. There is practically no soil on the island but the inhabitants are able to grow bananas and other crops in soil scraped together in pockets in the limestone.

TABLE 2.

Analyses of samples from the Lau.

Analyses by Bureau of Mineral Resources, Canberra:

No.	Island	Type of Material	Auger Hole	P_2O_5%	Fe_2O_3%	Al_2O_3%
1.	Vanua Vatu	Oolitic phosphate.	V.R.1	29.6	7.47	17.9
2.	"	Oolitic phosphate and clay.	V.R.8	28.2	12.1	17.9
3.	"	Oolitic phosphate.	U.1	25.0	8.91	23.0
4.	"	"	V.R.11	25.1	4.47	16.0
5.	"	"	V.R.9	20.8	8.80	22.3
6.	"	"	V.R.13	27.7	7.19	18.5
7.	"	"	U.5	22.2	12.4	29.5
8.	"	"	V.R.5	27.5	8.1	19.4
9.	"	"	V.R.3	21.8	8.4	27.6
10.	"	"	T.1.	24.9	11.9	25.9
11.	"	"	U.3	27.2	7.9	21.3
12.	"	"	V.R.4	24.5	9.1	19.3
13.	"	Phosphatic clay	V.S.11	7.4	20.2	39.
14.	"	"	T.3	16.2	14.1	36.2
15.	"	"	T.5	22.4	14.9	40.1
16.	"	Phosphate pebble	V.R.12	38.6	0.6	Not detected
17.	"	Phosphate pebble	U.3	31.1	2.1	16.5
18.	Tuvuca	Clay	M_2	18.7	14.0	35.2
19.	"	"	M_8	8.3	15.0	33.9
20.	"	"	M_7	4.7	19.2	30.6
21.	"	"	M_{8b}	9.4	16.7	39.3
22.		"	M_1	21.4	16.9	23.0

Analyses made for Fiji Geological Survey Department by Overseas Geological Surveys, London.

No.	Island	P_2O_5%	Fe_2O_3%	Al_2O_3%	CaO
JG167	Vatoa	14.0			
JG170	"	17.4			
JG175	"	8.3			
JG178/M2	"	5.4			
JG181/M5	"	0.6			
JG190	"	26.2			
JG228	"	2.4			
JG250	"	20.9			
JG252	"	23.2			
JG255	"	21.2			
JG258	"	12.2			
JG262	"	21.2			
JG263	"	20.3			
JG266	"	22.0	12.1	21.2	15.3
JG272	"	4.4			
JG277	"	13.8			
JG280	"	20.6	7.90	26.5	14.1

Table 2. cont'd.

No.	Island	P_2O_5%	Fe_2O_3%	Al_2O_3%	CaO%
JG286	Vatoa	17.6			
JG296	"	13.5			
JG303	"	17.8			
JG311	"	13.9			
JG320	"	2.7			
JG323	"	6.5			
JG235	Vanua Vatu	22.1			
JG236	"	33.1	5.20	11.6	38.5
JG346	"	17.6			
JG350	"	24.6			
JG351	"	30.6	7.61	13.4	33.8
JG353	"	24.6			
S1	"	25.4			
S7	"	24.7			
S14	"	22.2			
S26	"	25.6			
S35	"	28.4	9.34	16.2	15.5
S39	"	21.2			
S48	"	23.1			
S55	"	23.5			
S63	"	22.6			
S70	"	23.2			
S75	"	19.2			
VV9(a)	"	22.3			
VV10	"	0.5			
VV13	"	17.7			

Analyses of Additional Samples of Clay from Tuvuca Island.

No.	Auger Hole	Depth	P_2O_5%	No.	Auger Hole	Depth	P_2O_5%
23	M_1	8' to 20'	15.9	41	M_{8d}	0' to 4'	5.9
24	M_1	2'	19.9	42	M_{8d}	4' to 8'	7.6
25	M_1	20' to 24'	15.5	43	M_{8d}	8' to 16'	7.8
26	M_1	24' to 28'	14.1	44	M_{8d}	16' to 18'	7.9
27	M_1	28' to 32'	2.1	45	M_{8e}	0' to 12'	8.7
28	M_{1a}	0' to 20'	14.3	46	M_7	0' to 16'	6.9
29	M_2	0' to 12'	20.6	47	M_{7b}	0' to 16'	4.9
30	M_{2a}	8' to 20'	22.9	48	M_{7c}	0' to 4'	5.5
31	ST_2	6"	3.9	49	M_6	0' to 4'	8.0
32	ST_3	4'	9.7	50	M_6	4' to 8'	7.8
33	ST_4	4'	12.4	51	M_6	8' to 12'	8.2
34	ST_5	4'	9.5	52	M_6	12' to 16'	8.3
35	ST_6	4'	3.4	53	M_6	16' to 19'	8.3
36	ST_7	4'	2.3	54	M_{6b}	0' to 3'	5.7
37	M_{8c}	0' to 16'	10.5	55	N_2	Surface	0.4
38	M_{8f}	0' to 9'	0.6	56	N_3		0.1
39	M_8	0' to 20'	10.9	57	N_4		0.5
40	M_{8d}	0' to 18'	10.3				

REFERENCES

AGASSIZ, A., 1898. The Tertiary Elevated Limestone Reefs of Fiji. Amer. J. Sci. 4 Ser. Vol.6 pp. 165 - 167.

ANDREWS, E.C., 1922. A Contribution to the Hypothesis of Coral Reef Formation. Roy. Soc. N.S.W. Jour. & Proc. Vol. 56 pp. 10 - 38.

BRIDGES, G., 1942. Phosphate Deposits of Ogea Driki. Report to British Phosphate Commissioners: Dept. of Lands, Mines & Survey, Suva, Fiji, file No. 701/11A.

CASSIDY, N.G., 1952. Lau Phosphate - Fiji Agricultural Journal March 1952.

DANA, J.D., 1849. Report of U.S. Exploring Expedition (Wilkes) Geology Vol. 10.

" 1890. Corals & Coral Islands. 3rd Ed. N. York.

DAVIS, M., 1927. A Migrating Anticline in Fiji. Amer. J. Sci. 5th Ser. Vol. 14, pp. 333 - 351.

FOYE, W.G., 1917. The Geology of the Lau Islands. Amer. J. Sci. 4th Ser. Vol. 43. pp. 343 - 350.

GARDINER, J.S., 1898. The Coral Reefs of Funafuti, Rotuma, Fiji. Phil. Soc. Camb. Proc. Vol.9 pp. 417 - 503.

" 1931. Coral Reefs & Atolls. London 1931.

HUTCHINSON, G.E., 1950. The Biogeochemistry of Vertebrate Excretion. Bull. Amer. Mus. Nat. Hist. Vol. 96. No. 3.

IBBOTSON, P., 1959. Structures & Lineations observed in the south eastern part of the Fiji Group. Geol. Survey Dept. Suva, Fiji. Report No. 57.

LADD, H.S. & HOFFMEISTER, J.E., 1945. Geology of the Lau, Fiji. B.P. Bishop Mus. Bull. 181 pp. 399.

STAARGAARD, J.A., Exploration Results on abandoned Areas of Prospecting Licences Nos. 845 & 865, Lau Group, Fiji. Report to Aluminium Laboratories Ltd., Montreal, Canada.

WARIN & JENSEN, 1959. Report of Investigation of Islands in the Territory of Papua & New Guinea, Phosphate Survey 1958. Bur. Min. Resour. Aust. Rec. 1959/58. (unpubl.)

WHITE, F.T.M., 1942. Report of Inspector of Mines on Ogea Driki phosphate deposits. Dept. of Lands, Mines & Survey, Suva, Fiji. File No. M. 701/11A.

177° 178° 179° 180° 179°

16°

17°

18°

19°

20°

Cikobia

Qele Levu

Udu Pt

Kubulau Pt

Natewa Bay

VANUA LEVU

Rabi

Laucala

Qamea

TAVEUNI

Yasawa

Yadua

YASAWA GROUP

Koro

Makodroga

Makogai

Wakaya

OVALAU

Batiki

Nairai

Gau

Malolo

VITI LEVU

SUVA

Bega

Vatulele

KADAVU

Yacata

Kanacea

VANUA BALAVU

Cikobia-i-Lau

Munia

Vatu Vara

Mago

Katafaga

Tuvuca

LAU GROUP

Ciciia

Nyau

Bukatatanoa Reefs

Lakeba

Vanua Vatu

Aiwa

Oneata

Moce

Komo

Namuka

Vuagava

Yagasa

Kabara

Marabo

Ogea

Vuliaga

Matuku

Toroya

Mbau

Na Vatu Reef

Varoa

FIJI ISLANDS.

Scale

Miles 0 10 20 30 40 50 Miles

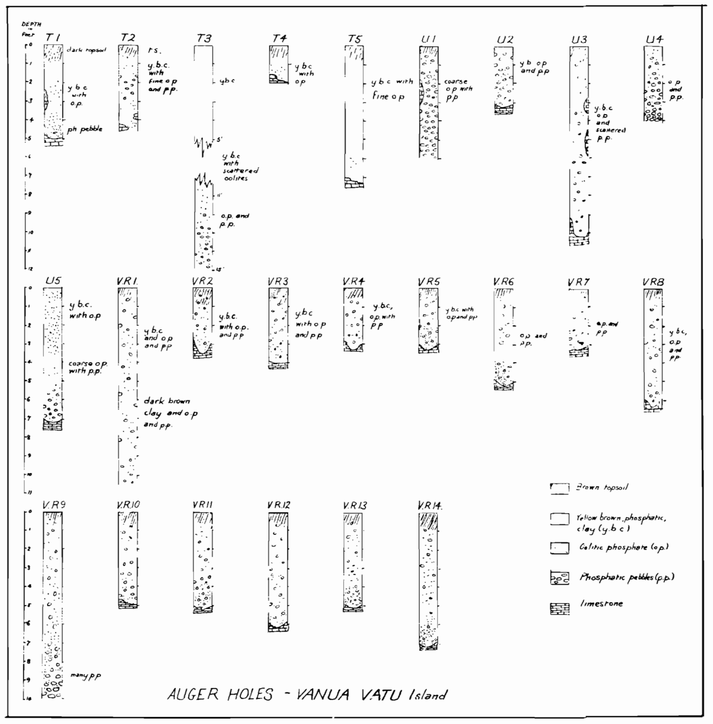
Islands with phosphate deposits underlined

Reef.

N

The PHOSPHATE DEPOSITS

Area		Symbol	Average depth	Estimated Volume (cu. ft.)	Deduction for limestone	Estimated tonnage	Grade	Availability
A	Oolitic and pebble phosphate in MAUMI basin.		5ft.	5,200,000	½	100,000		Recoverable
B	Oolitic and pebble phosphate between MAUMI and TAIRA.		6ft	8,160,000	⅔	100,000		Doubtfully recoverable
C	Phosphatic clay with some oolitic phosphate.		?			(30,000)		
					TOTAL	230,000		



AUGER HOLES - VANUA VATU Island

N (magnetic)

VANUA VATU I.

LAU Group,

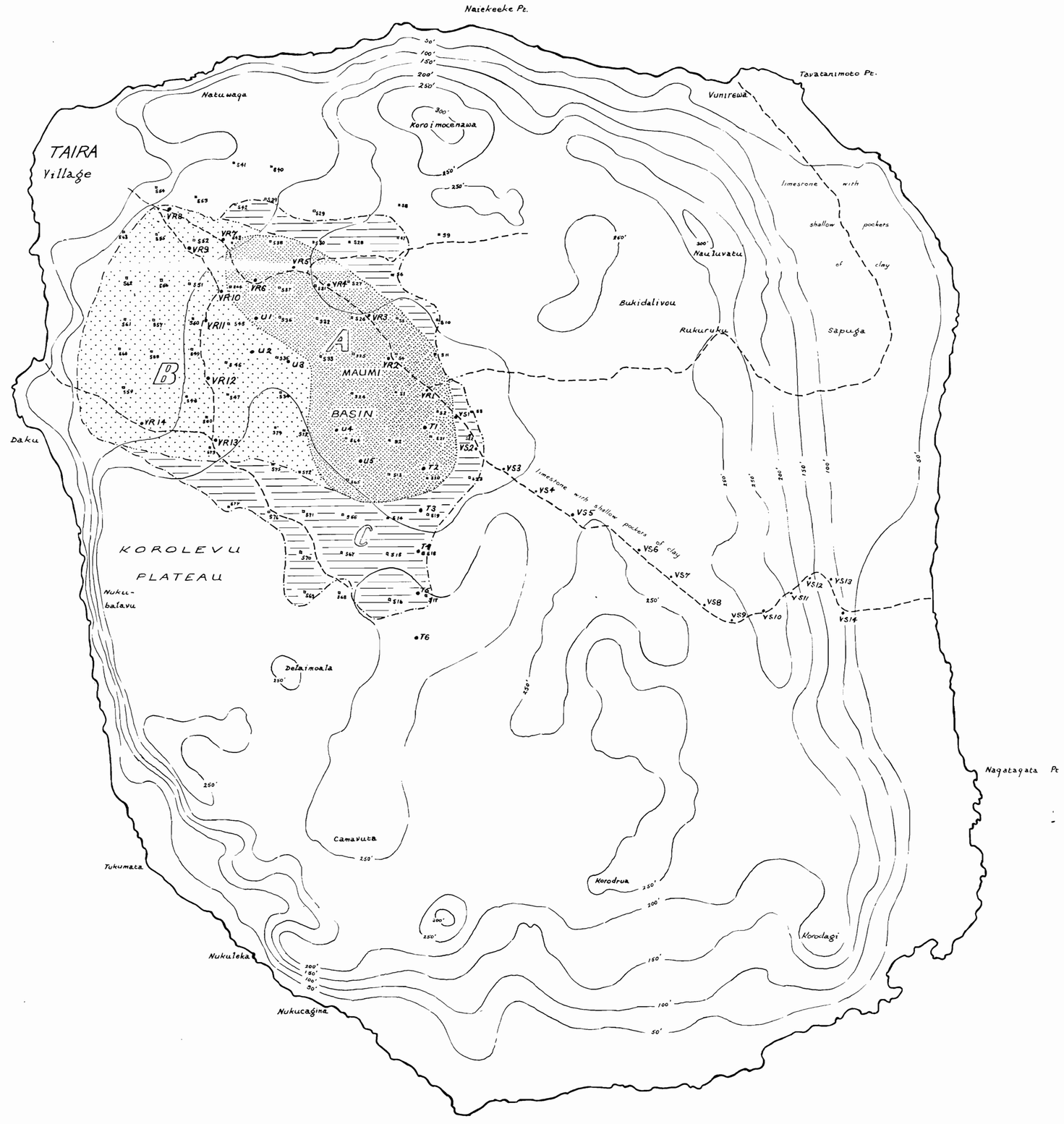
FIJI.

500 feet 0 300 900 1500 feet

0 ⅛ ¼ mile

- Boundary of phosphate deposit.
- Oolitic and pebble phosphate.
- Oolitic and pebble phosphate in pockets between limestone outcrops.
- Mostly phosphatic clay
- Tracks
- •T6 Position and number of auger holes, present survey.
- □ 816 Position and number of test pits, previous survey.
- 50' Form lines - Vertical interval 50 feet

Base map by Dept of Lands, Mines and Surveys, Suva, Fiji.



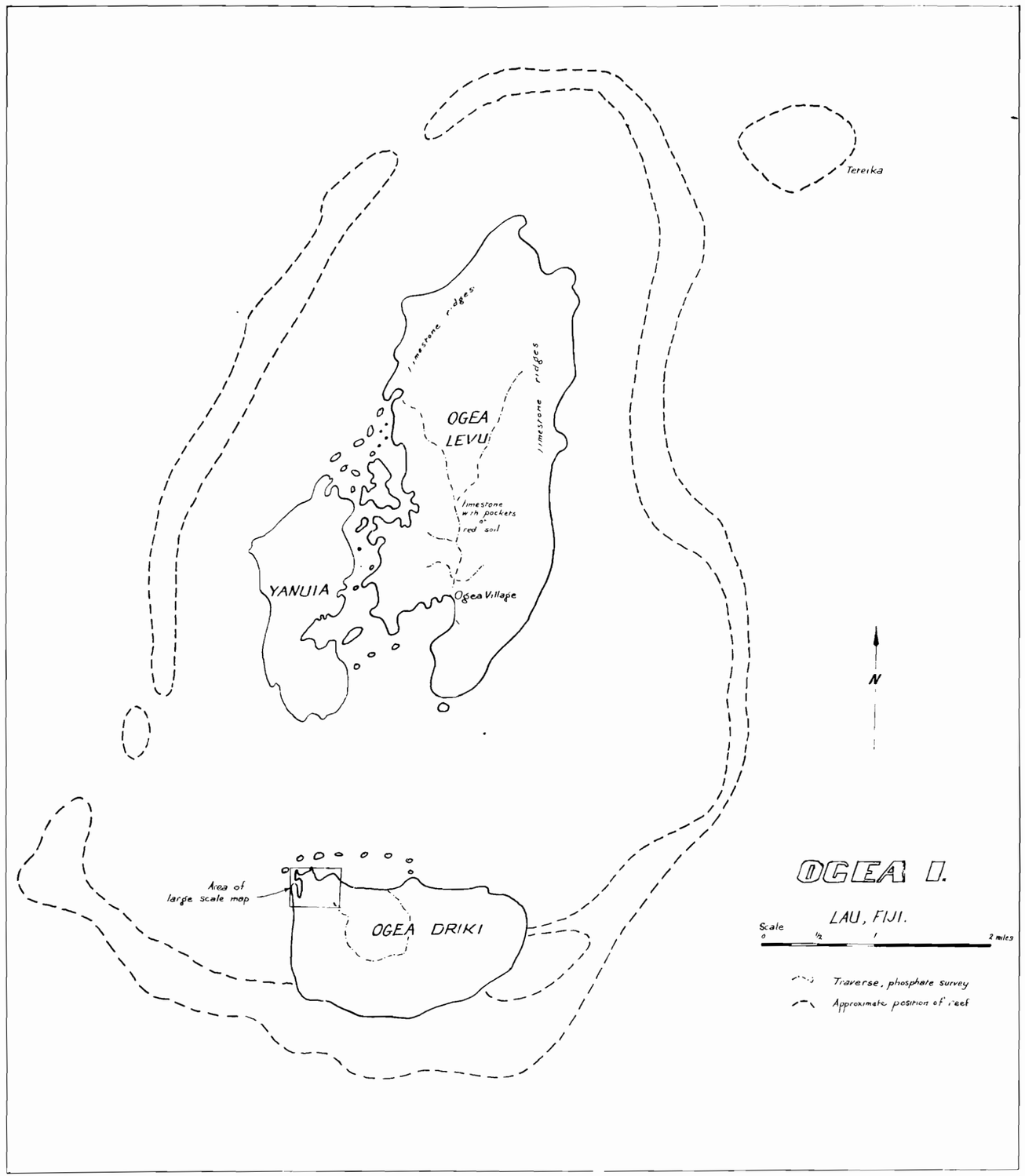
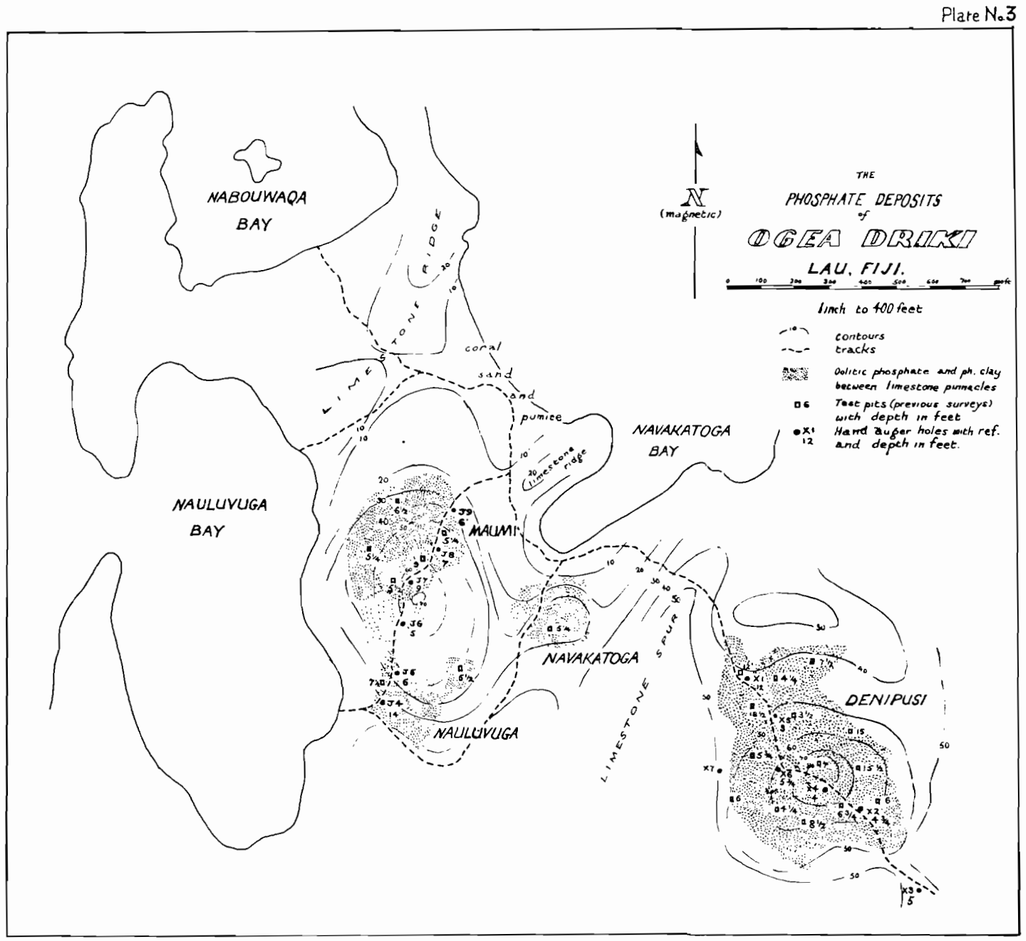
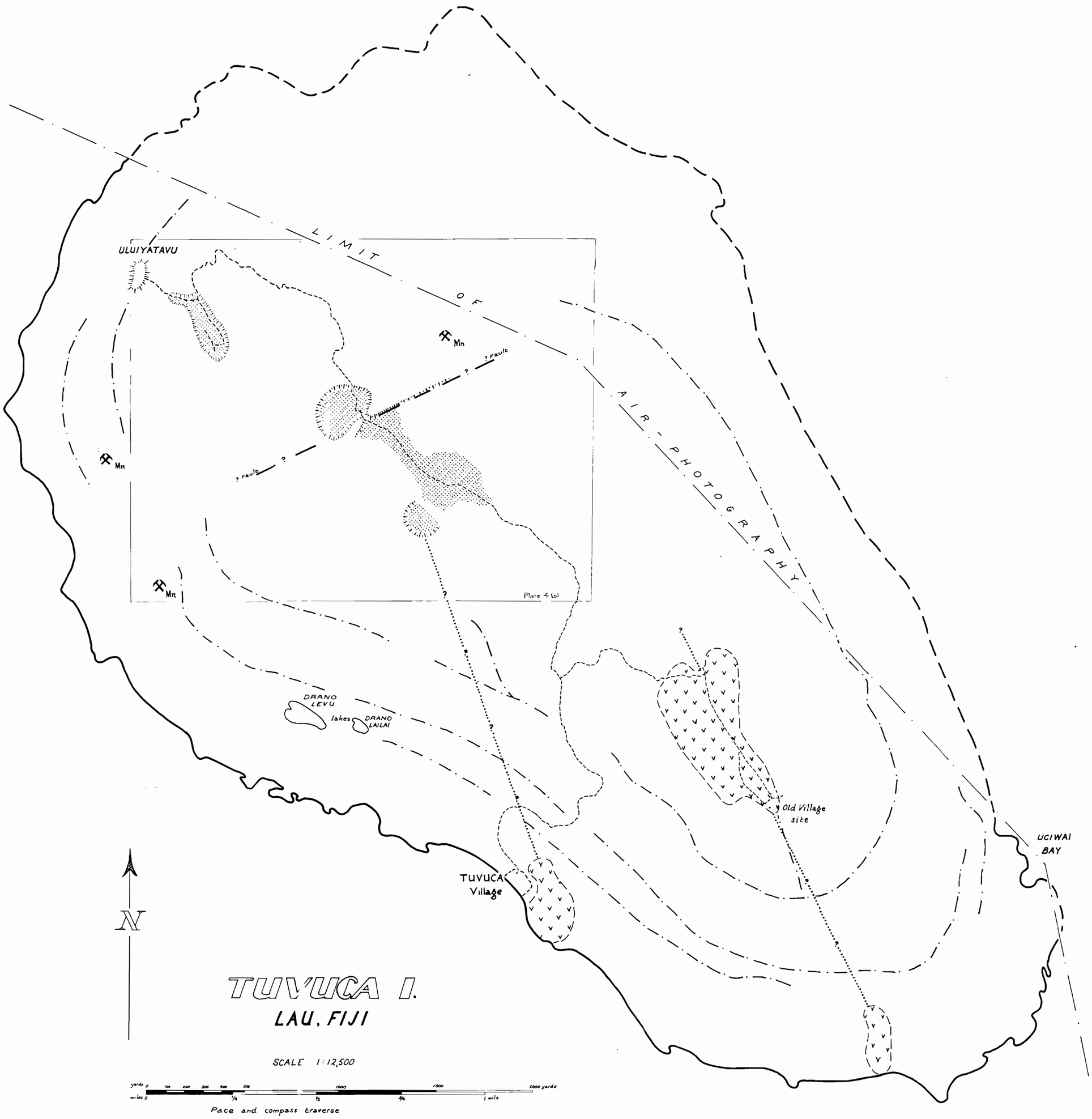
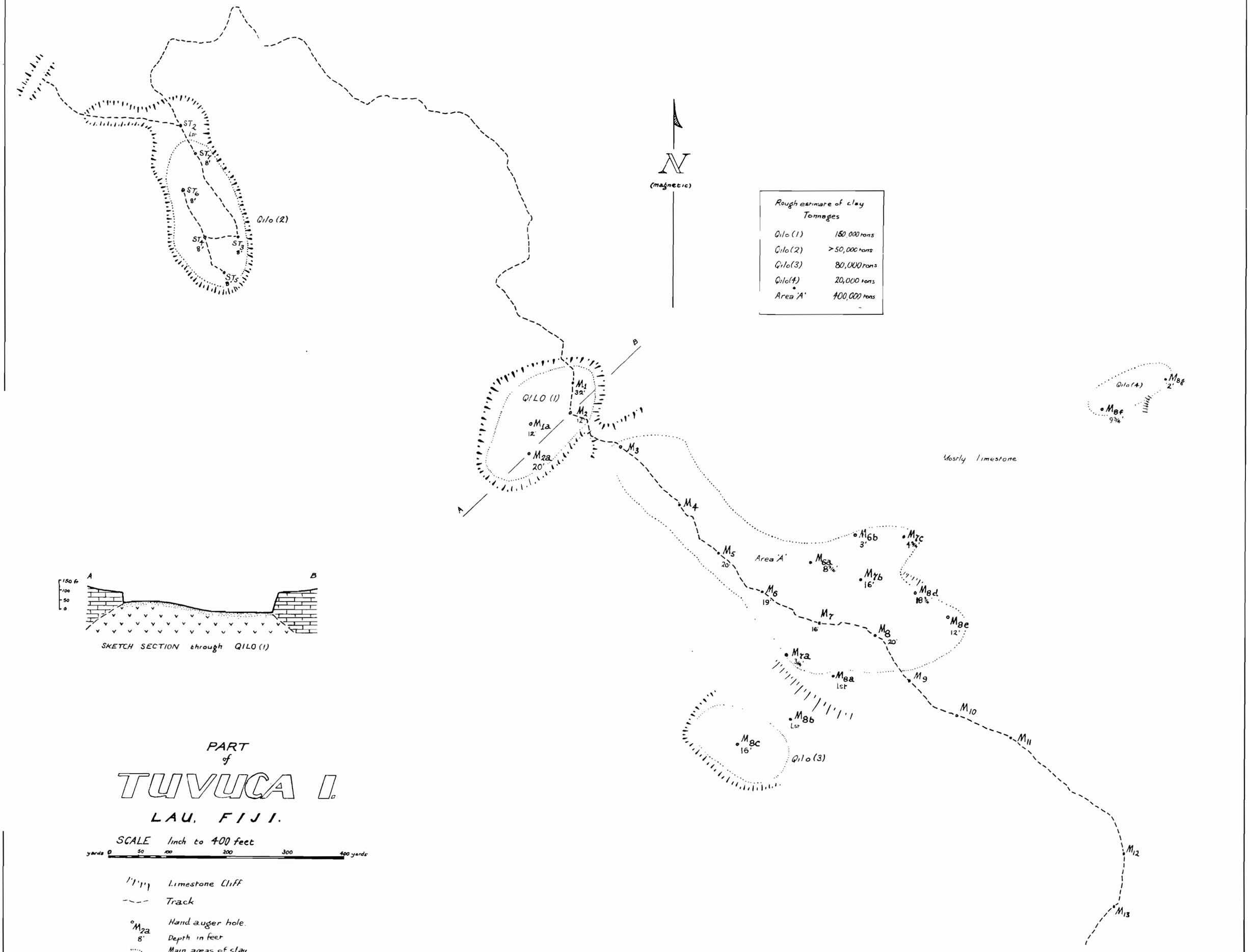
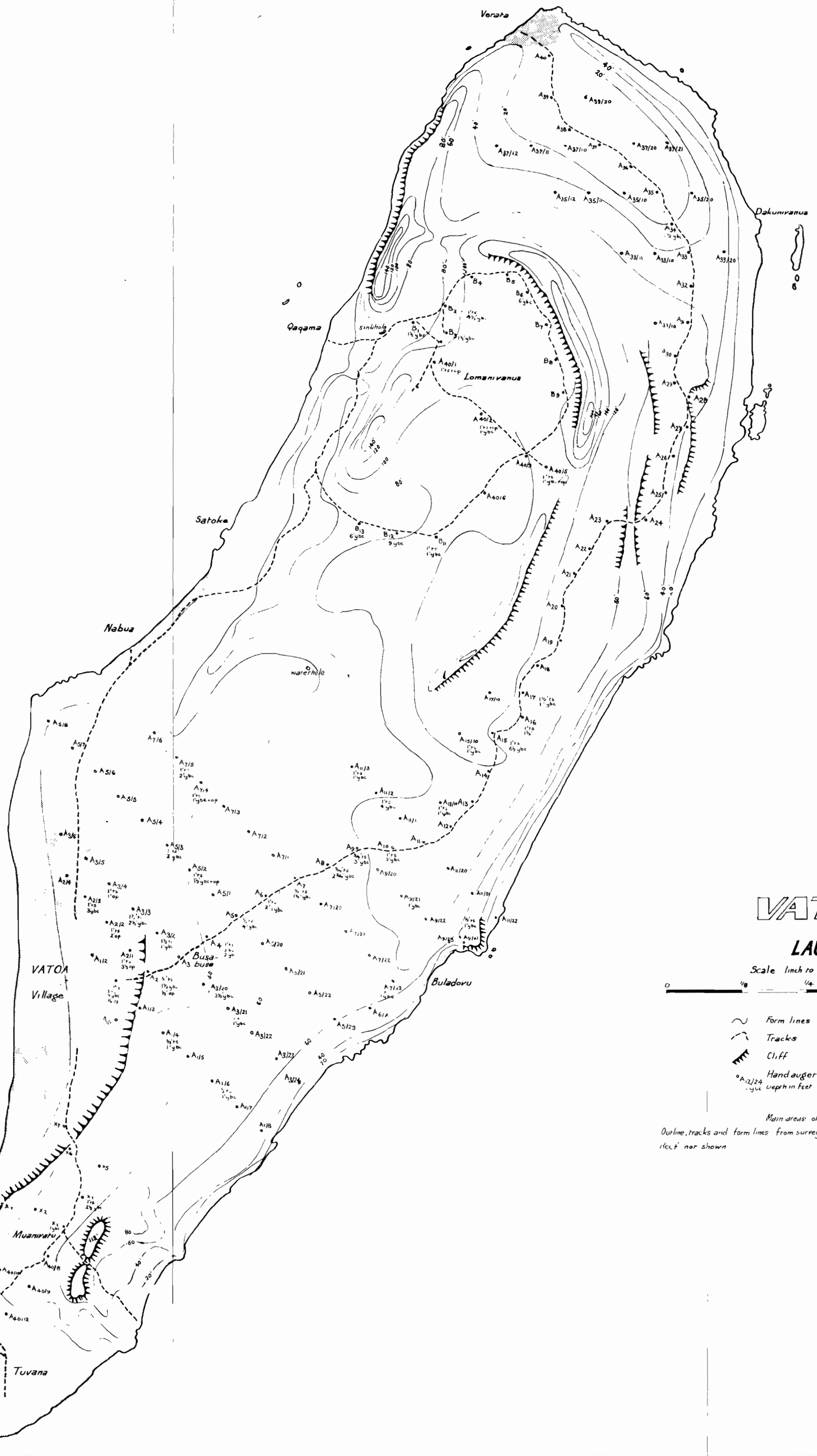

Tereika
limestone ridges
limestone ridges
OGEA
LEVU
limestone with pockets of red soil
YANUIA
Ogea Village
N
Area of large scale map
OGEA DRIKI
OGEA I.
LAU, FIJI.
Scale
0
½
1
2 miles
Traverse, phosphate survey
Approximate position of reef

Plate No.3


NABOUWAQA
BAY
NAULUVUGA
BAY
NAVAKATOGA
BAY
NAVAKATOGA
DENIPUSI
NAULUVUGA
LIMESTONE SPUR
LIMESTONE RIDGE
coral sand and pumice
N
(magnetic)
THE
PHOSPHATE DEPOSITS
of
OGEA DRIKI
LAU, FIJI.
1inch to 400 feet
contours
tracks
Oolitic phosphate and ph. clay between limestone pinnacles
Test pits (previous surveys) with depth in feet
Hand auger holes with ref. and depth in feet.


LIMIT OF AIR-PHOTOGRAPHY
ULUIYATAVU
Mn
Mn
Mn
? Fault
? Fault
Plate 4 (b)
DRANO LEVU
lakes
DRANO LAILAI
Old Village site
UCIWAI BAY
TUVUCA Village
N
TUVUCA I.
LAU, FIJI
SCALE 1:12,500
yards 0 100 200 300 400 500 1000 1500 2000 yards
miles 0 1/4 1/2 3/4 1 mile
Pace and compass traverse
Island outline, dashed where indefinite.
Traverse, phosphate survey
Limestone cliff.
Crest of limestone ridge.
Lau Volcanics.
Alluvium.
Mn Manganese prospect, position approximate.
Possible concealed volcanic ridges.
Possible fault


ST2 Lst
ST7 8'
ST6 8'
ST4 8'
ST3 8'
ST5 8'
Qilo (2)
N
(magnetic)
Rough estimate of clay Tonnages
Qilo (1) 150,000 tons
Qilo (2) >50,000 tons
Qilo (3) 80,000 tons
Qilo (4) 20,000 tons
Area 'A' 400,000 tons
B
A
QILO (1)
M1 32'
M2 12'
M1a 12'
M2a 20'
M3
M4
M5 20'
Area 'A'
M6a 8¾'
M6b 3'
M7c 1¾'
M7b 16'
M6 19'
M8d 18¾'
M7 16'
M8e 12'
M8 20'
M7a 3½'
M8a Lst
M9
M8b Lst
M10
M8c 16'
Qilo (3)
M11
M12
M13
Qilo (4)
M8g 2'
M8f 9¾'
Mostly limestone
A
B
150 ft
100
50
0
SKETCH SECTION through QILO (1)
PART of
TUVUCA I.
LAU, FIJI.
SCALE 1 inch to 400 feet
yards 0 50 100 200 300 400 yards
Limestone Cliff
Track
M2a Hand auger hole.
8' Depth in feet
Main areas of clay



VATOA I.

LAU, FIJI.

Scale 1 inch to 800 feet

0 1/8 1/4 3/8 1/2 mile

Form lines - interval 20 feet

Tracks

Cliff

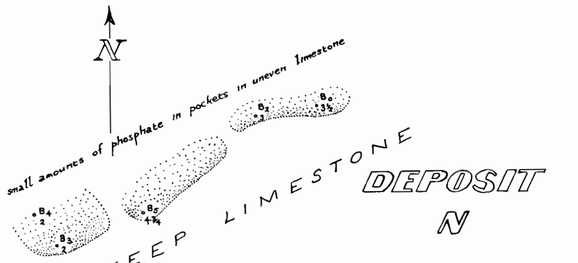
Hand auger hole

$^{\circ}\frac{A\ 12/24}{\text{depth in feet}}$ ybc = yellow brown clay; ts = topsoil; op = oolitic phosphate } Holes for which no depth given are in limestone limestone with shallow (<1') soil, or non-phosphatic clay

Main areas of coral sand

Outline, tracks and form lines from survey by Fiji Dept of Lands, Mines and Surveys

Reefs not shown



STEEP LIMESTONE

DEPOSIT N

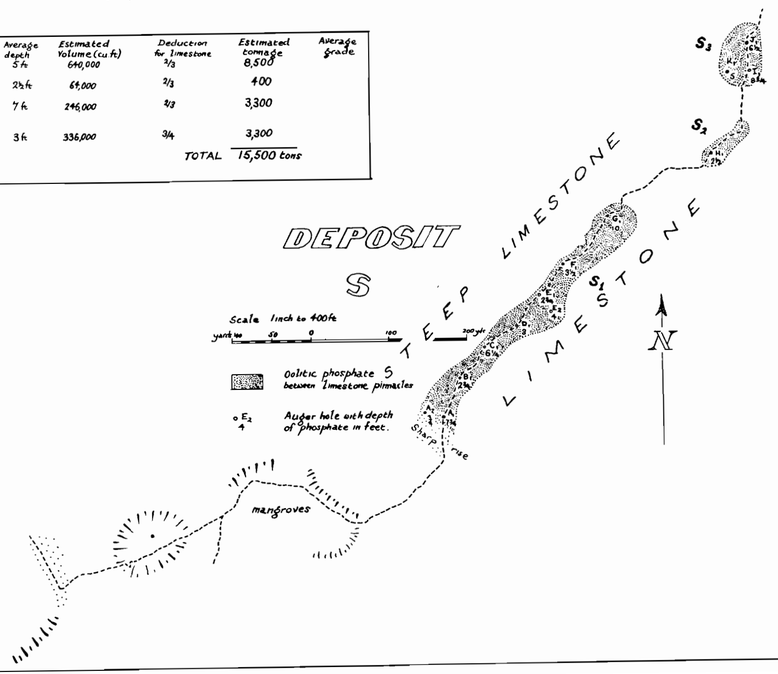
Scale 1 inch to 400 Feet

yards 100 50 0 100 200 300yds.

Oolitic phosphate between limestone pinnacles

Auger hole with depth of phosphate in feet

DEPOSIT		Average depth	Estimated Volume (cu ft)	Deduction for limestone	Estimated tonnage	Average Grade
S_1	Oolitic phosphate	5 ft	640,000	⅔	8,500	
S_2	Oolitic phosphate	2½ ft	69,000	⅔	400	
S_3	Oolitic phosphate	7 ft	246,000	⅔	3,300	
N	Oolitic phosphate	3 ft	336,000	¾	3,300	
				TOTAL	15,500 tons	



DEPOSIT S

STEEP LIMESTONE

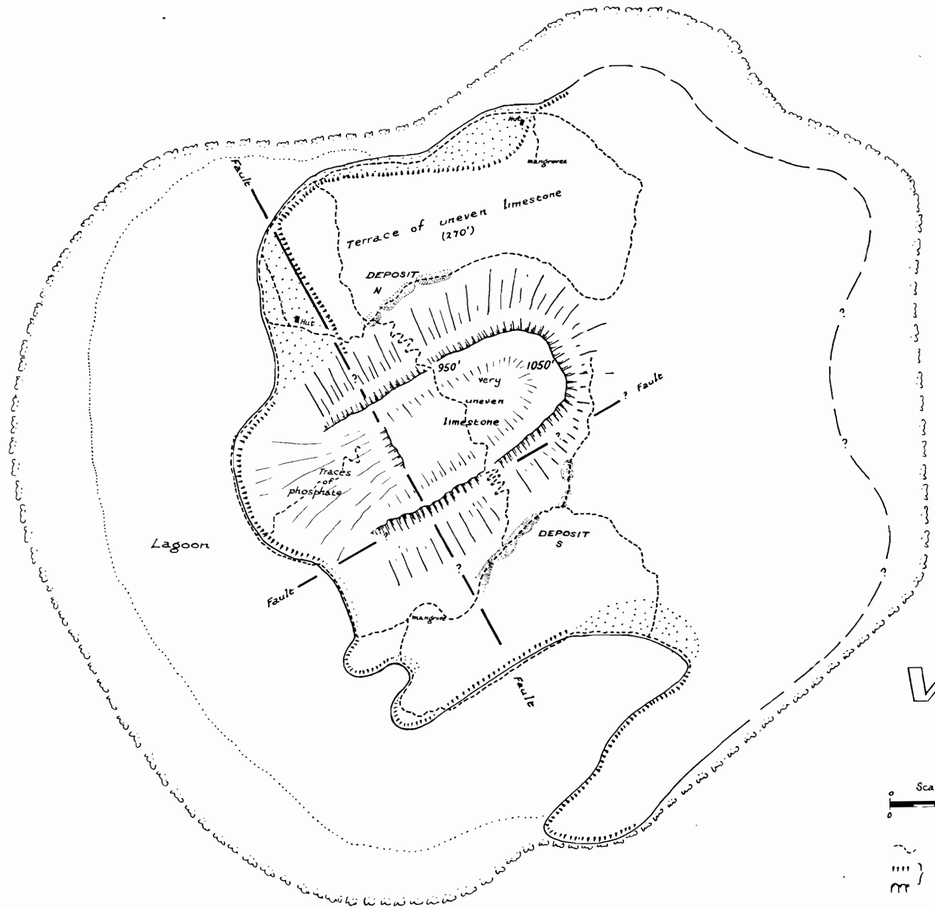
Scale 1 inch to 400 ft

yards 100 50 0 100 200 yds

Oolitic phosphate S between limestone pinnacles

Auger hole with depth of phosphate in feet.

N



VATU VARA

ISLAND

LAU GROUP. FIJI.

Scale 4 inches to 1 mile.

0 ¼ ½ ¾ mile

0 500 1000 yards

Traverses, phosphate survey

Cliff

Sand

Oolitic phosphate

Reef, position approximate.

N

VULAGA I.

LAU, FIJI.

Scale 0 1 2 miles

Traverse - phosphate survey

Reef

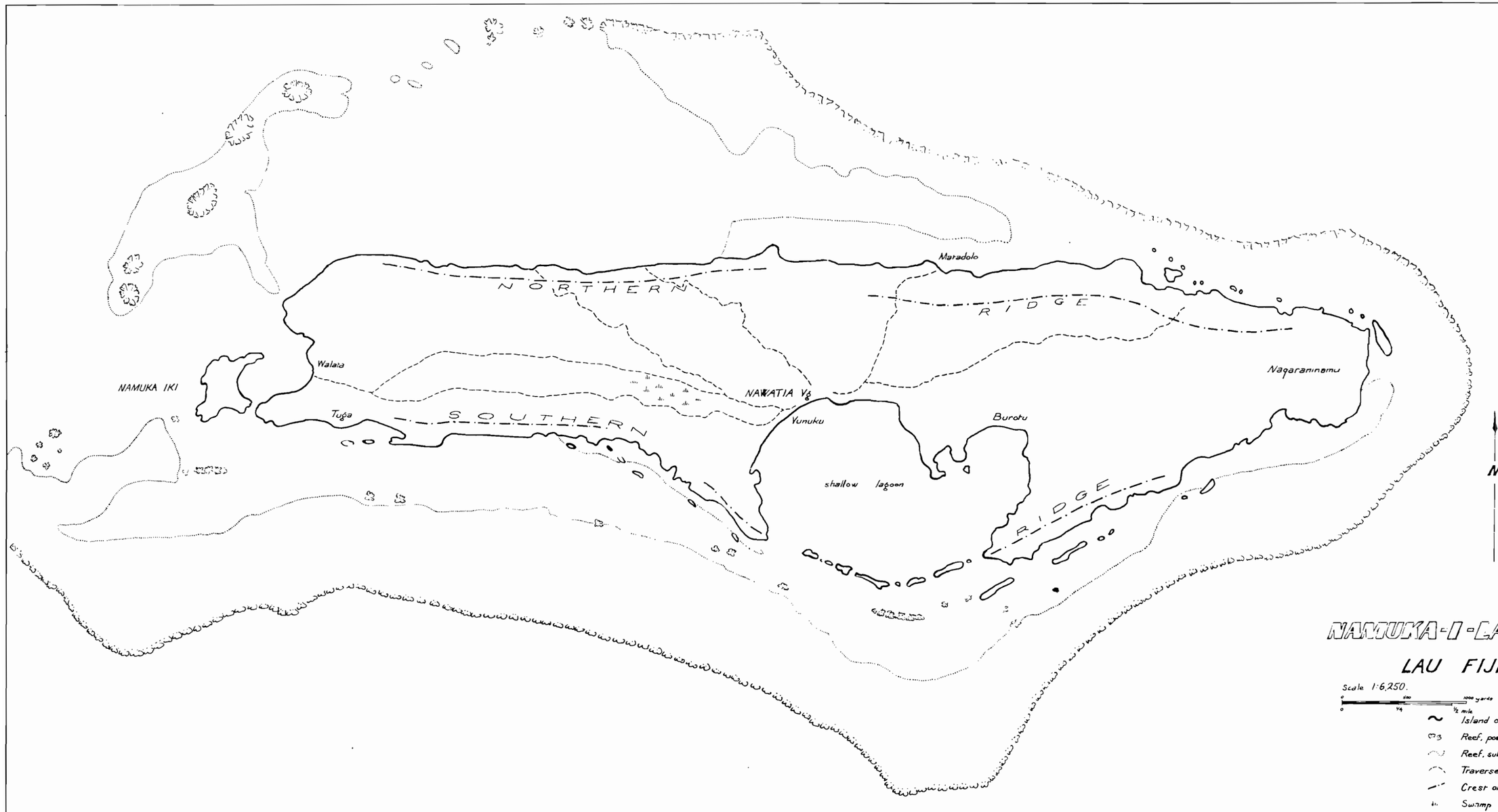
Hills

Vulaga limestone

Futuna limestone

Coral sand

Outline of island and reef and geological information from 'Geology of the Lau' - Ladd and Hoffmeister, 1945.



NAMUKA-I-LAU I.

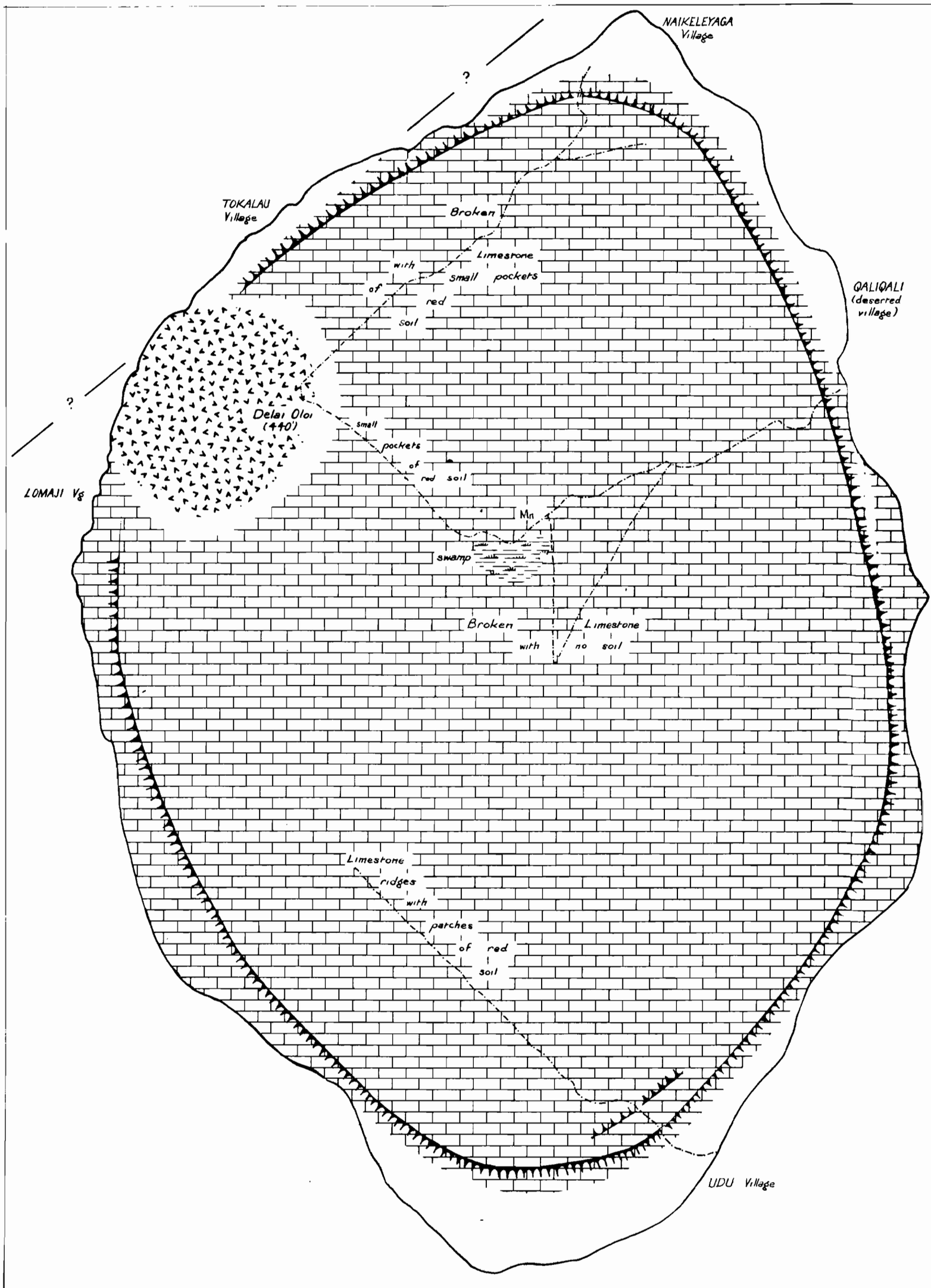
LAU FIJI

Scale 1:6,250.

0 500 1000 yards
0 ¼ ½ mile

- Island outline
- Reef, position approximate
- Reef, submerged.
- Traverse, phosphate survey
- Crest of limestone ridge
- Swamp

Outline of islands, reefs and topographic detail from air-photographs
Traverses by pace and compass.



KABARA I.

LAU, FIJI

N

SCALE : 2 inches to 1 mile

½ 0 ½ 1 mile

- Traverse - phosphate survey
- Cliff
- Swamp
- Limestone
- Volcanics
- Coral sand

Boundaries approximate

? Inferred fault

Outline enlarged from Admiralty Chart No 441.
Traverses by pace and compass.

Votu Votu Pt.

Lawakilevu Bay

Mautabi Pt.

Lawakilailai Bay

Kede Kede Pt.

Mana Bay

Kalokalo Pt.

Naikobowaga Beach

Vatu Tuva Pt.

DAKUILOA Village

Toyovo Pt.

Nailoilo

Nalau Pt.

WAIGORI Village

Jiro Bay

Sovilolo Pt.

Korosiga Pt.

N

ONEATA I.

LAU, FIJI.

Scale 0 1/8 1/4 3/8 1/2 mile

Traverse – phosphate survey

lake and coastal flats

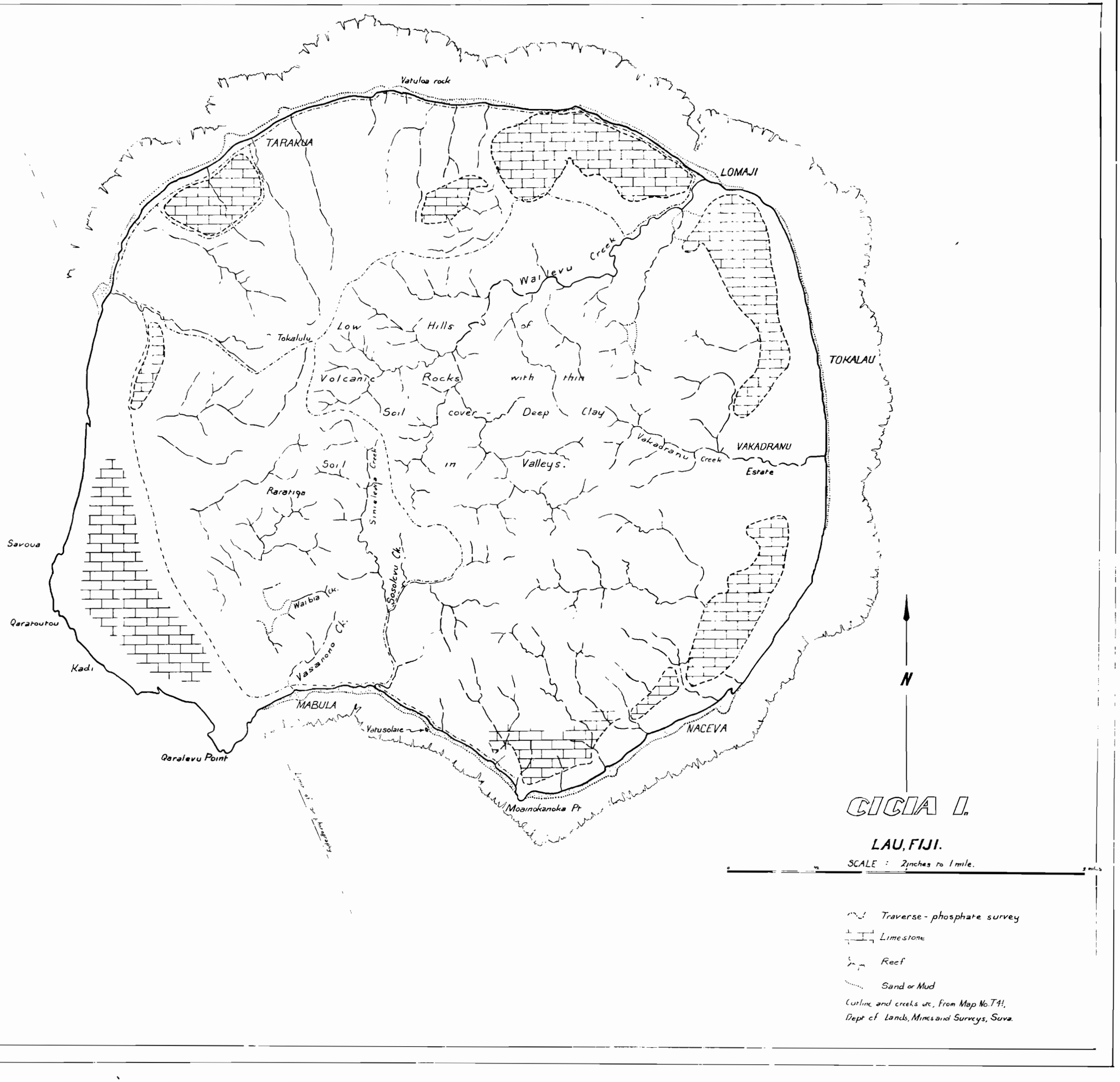
Koro Basaga Volcanics

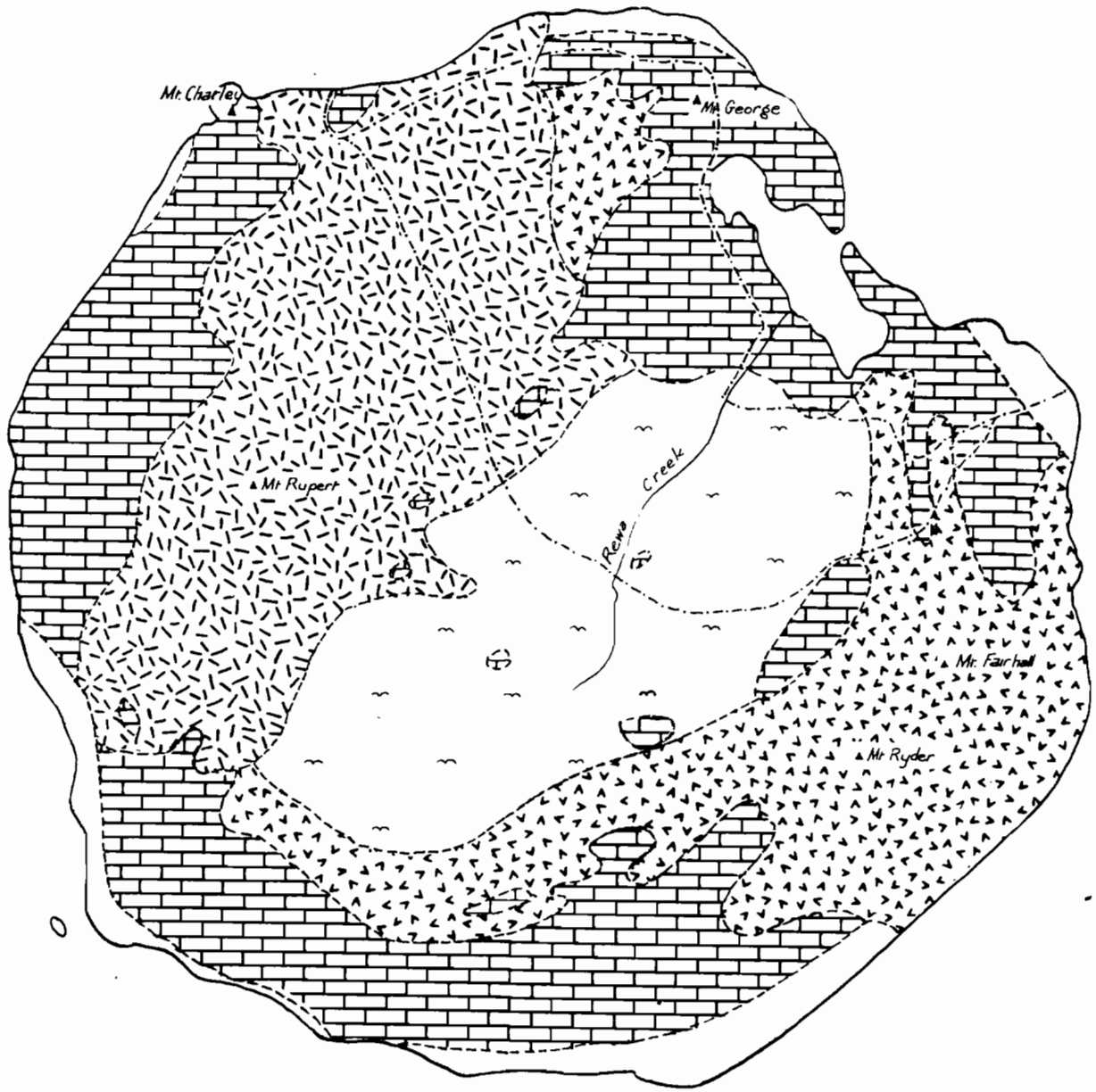
Crystalline } Futuna Limestone

Foramaniferal }

Lau Volcanics

Outline and geology from 'Geology of Lau' – (Ladd and Hoffmeister, 1945)


Vatuloa rock
TARAKUA
LOMAJI
Wailevu Creek
Low Hills of Volcanic Rocks with thin Soil cover - Deep Clay in Valleys.
Tokalulu
TOKALAU
Vakadranu Creek
VAKADRANU Estate
Soil
Raratiqa
Sinielewa Creek
Savoua
Sosolevu Ck.
Waibia Ck.
Qaratoutou
Vasanono Ck.
Kadi
MABULA
Yatusolaie
NACEVA
Qaralevu Point
Moainokanoka Pt
Limit of Topography
N
CICIA I.
LAU, FIJI.
SCALE : 2 inches to 1 mile.
0
1
2 miles
Traverse - phosphate survey
Limestone
Reef
Sand or Mud
Outline and creeks etc, from Map No. T41,
Dept of Lands, Mines and Surveys, Suva.



N

MAGO I.

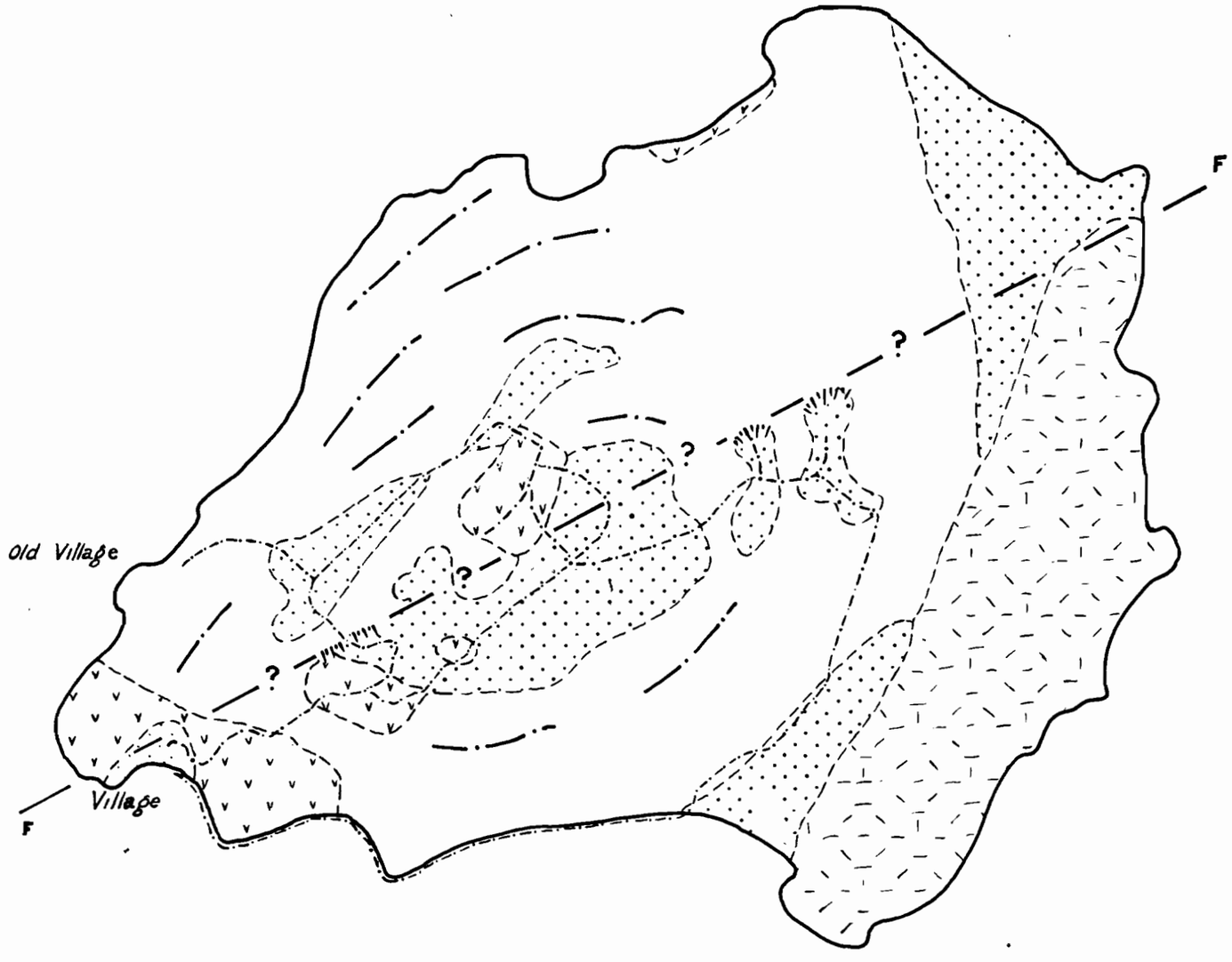
LAU, FIJI.

Scale 2 inches to 1 mile

0 ½ 1 mile

- Traverse - phosphate survey
- Geological boundary
- Alluvium
- Coastal sand
- Mago Odinite
- Futuna Limestone
- Lau Volcanics

Island outline and geology from 'Geology of the Lau' - Ladd and Hoffmeister, 1945.



N

CIKOBIA I

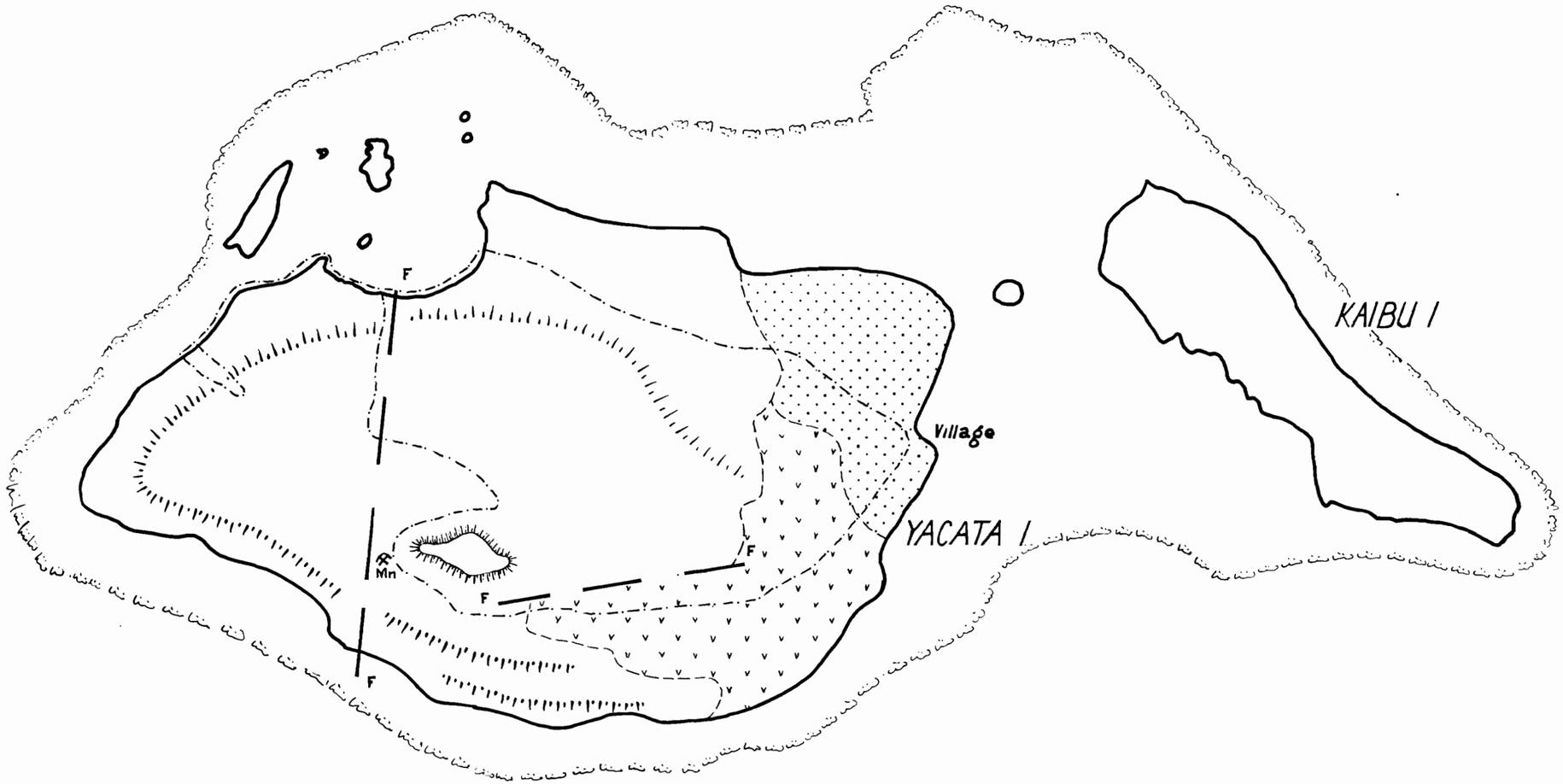
LAU FIJI

SCALE 1:12,500 (approximate)

yards 0 100 200 300 400 500 1000 yards

miles 0 1/4 1/2 miles

- Island outline.
- Traverse, phosphate survey.
- Cliff.
- Crests of limestone ridges.
- Geological boundary.
- Probable fault.
- Alluvium.
- Younger volcanics. (Korobasaga volcanics)
- Limestone. (Futuna limestone)
- Older volcanics. (Lau volcanics)



N

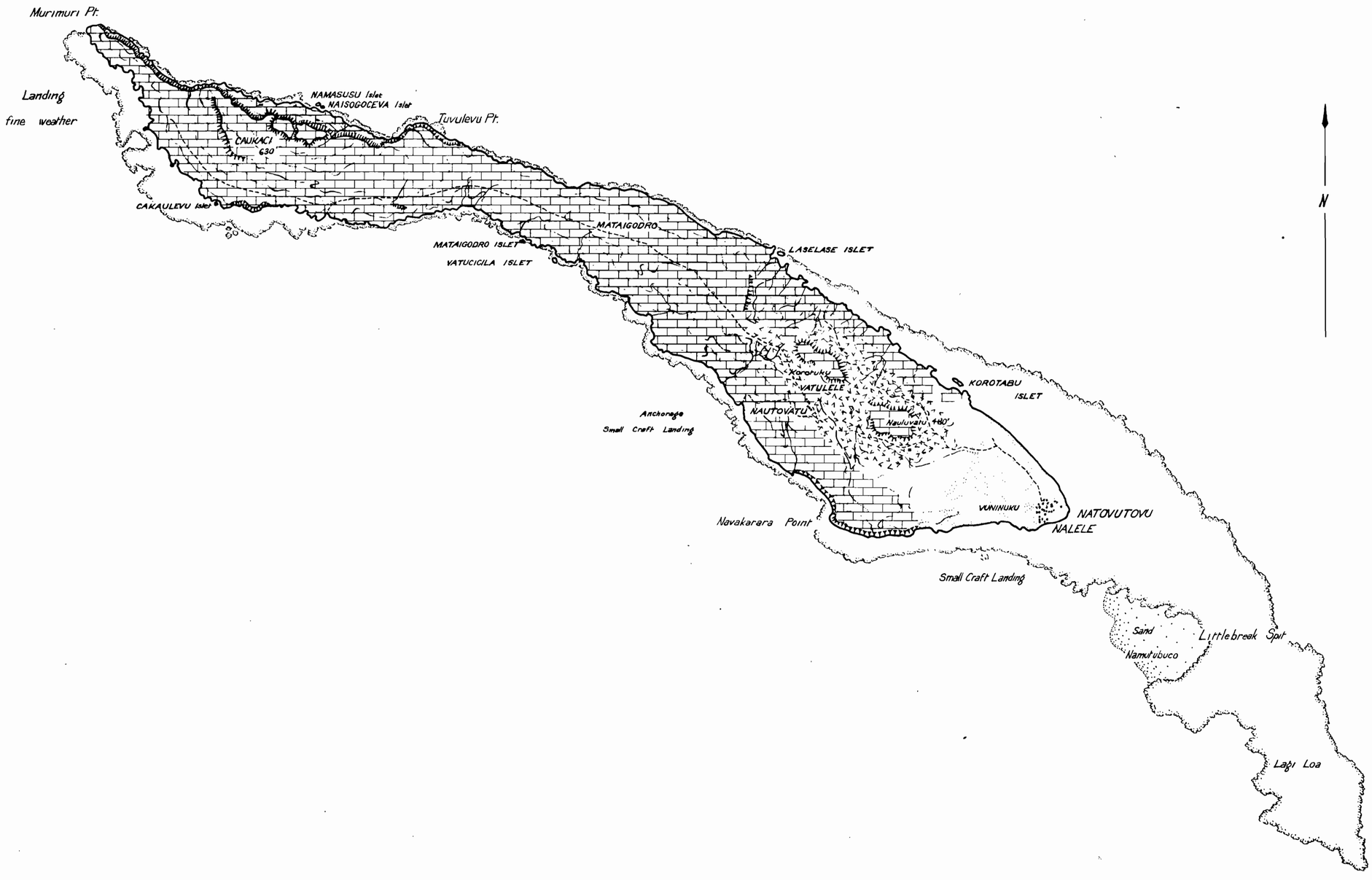
YACATA I
FIJI

SCALE 1: 12,500 (approximate)

yards 0 200 300 400 600 1000 yards

miles 0 1/4 1/2 mile

- Island outline
- Reef, position approximate.
- Traverse, phosphate survey.
- Geological boundary.
- Limestone cliffs.
- Mn Manganese prospect.
- F Probable fault.
- Limestone.
- Volcanics.
- Coral sand.



CIKOBIA I.

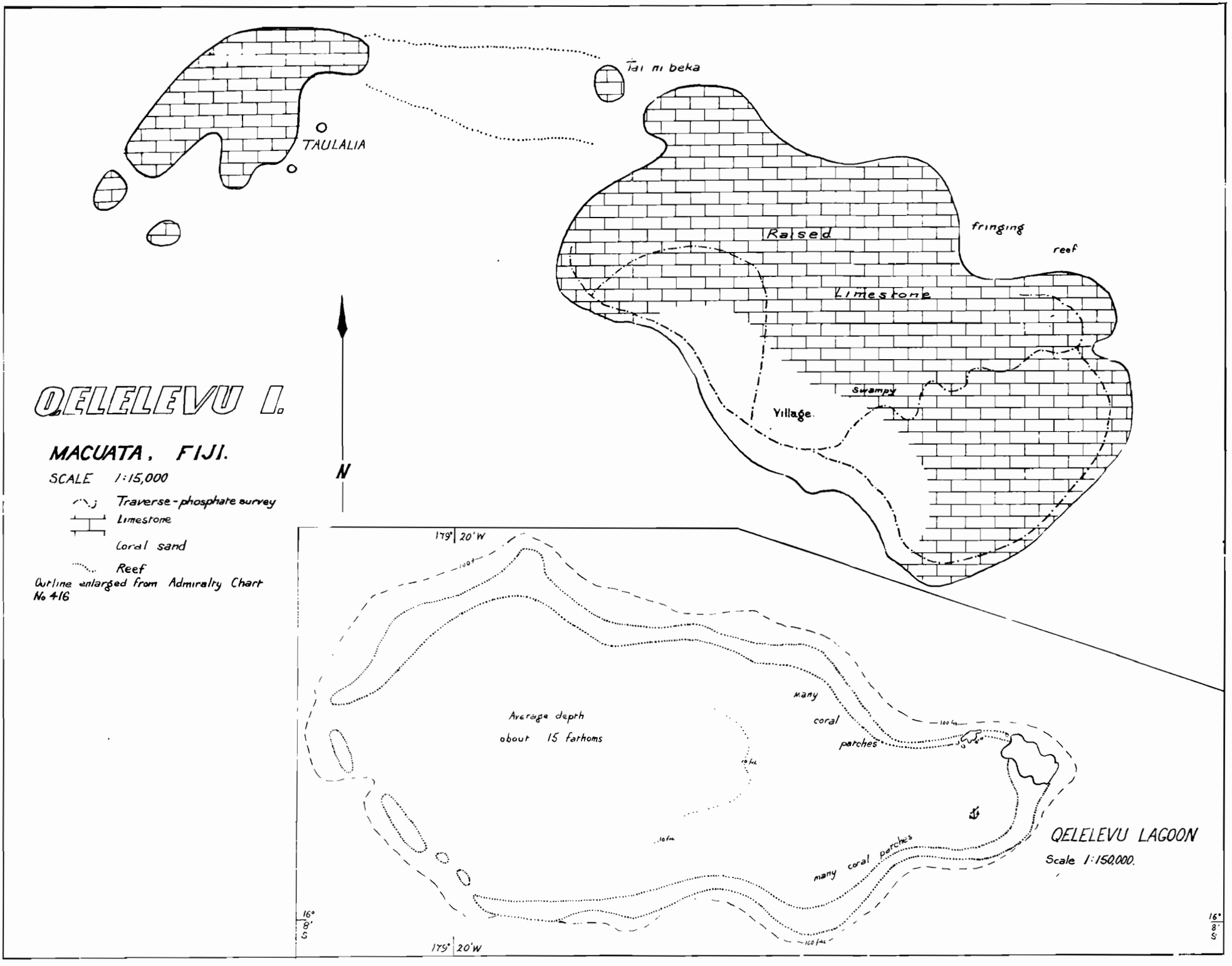
MACUATA, FIJI.

SCALE 1:31,680

Chains 80 — 0 — 1 mile

- Track
- Formlines – interval about 100 ft.
- Cliff
- Reef
- Limestone
- Coral sand
- Volcanics, chiefly agglomerate.

Outline and topographic detail from Plan No. T 40 of Dept. of Lands, Mines and Surveys, Suva, Fiji.



QELELEVU I.

MACUATA, FIJI.

SCALE 1:15,000

Traverse - phosphate survey

Limestone

Coral sand

Reef

Outline enlarged from Admiralty Chart No 416

QELELEVU LAGOON

Scale 1:150,000.