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SEISMIC AND BATHYMETRIC PROFILING OF NUKUFETAU LAGOON, TUVALU, FOR EVALUATION OF PHOSPHATE POTENTIAL

18 February - 11 March 1985 by

Bruce M. Radke

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COMMITTEE FOR CO-ORDINATION OF JOINT PROSPECTING FOR MINERAL RESOURCES IN SOUTH PACIFIC OFFSHORE AREA (CCOP/SOPAC) WORK PROGRAMME PE/TU.9

As a contribution by:

UNDP PROJECT OFFICE
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INVESTIGATION OF MINERAL POTENTIAL OF THE SOUTH PACIFIC

SEISMIC AND BATHYMETRIC PROFILING OF NUKUFETAU LAGOON, TUVALU FOR EVALUATION OF PHOSPHATE POTENTIAL
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INTRODUCTION AND BACKGROUND:

There have been several reported land occurrences of low grade phosphatic soils on islands of Tuvalu atolls. White and Warin(1964) reported a sizeable deposit on Sakalua (Coal Island), Nukufetau.

On the basis of a comparable case study of phosphate in Mataiva Lagoon, Tuamotu Archipelago, French Polynesia, the prospectively of atoll lagoons has been upgraded for localized high grade subsurface phosphate deposits. Such deposits appear to originate from guano accumulations which have been modified and concentrated by repeated karstification during drops in sea level corresponding to past glacial episodes. The petrology of lagoon phosphate and models for these deposits has been documented by Braithwaithe (1980). Earlier reconnaissance drilling on other atolls of Tuvalu was based on this genetic concept (Geomarex,1978) but the survey failed to produce promising results.

All atolls of Tuvalu (Figure 1) have been reevaluated for phosphate prospectivity, on the basis of reported occurrences (Sollas, 1904; White and Warin, 1964; Flynn and Makin, 1976; Geomarex,1978; and Sahng- Yup Kim, 1981) and geological constraints. The preliminary prospectively rating is, in decreasing order;

Niulakita, Nukufetau, Nui, Nanumanga, Vaitupu, Funafuti,
Nanumea, Niutao, Nukulaelae.

It is emphasized that such a prospecting rating is very tentative because of the limited information available.

Most atolls in Tuvalua have very limited land resources. The consideration of competing needs for such limited land has influenced the decision to prospect only in areas where such conflicts of interest are not as great. This, however, does not mean that the surveyed area of Nukufetau is free from other utilization.

OBJECTIVES:

1. To conduct bathymetric and seismic profiling throughout Nukufetau lagoon.

2. To document and sample any observed phosphate occurrences.

PERSONNEL:

Bruce Radke	UNDP Marine Geologist
Ed Saphore	UNDP Electronics Technician
Falealuga Apelamo	Boatperson
Faiupu Samasoni	Boatperson

Individuals Contacted:

Tauaasa Taafaki, Secretary for Commerce and Natural Resources
Bikeni Paeniu, Acting Secretary, Ministry of Commerce and Natural Resources
Michael Batty, UNDP Fisheries Officer
Lene Matsui, Ministry of Commerce and Natural Resources
Semu Taafaki, Secretary for Works and Communication
Metia Tealofi, Minister for Works and Communication
Apinelu Kapoti, Island Executive Officer, Nukufetau
Nelisone Apelamo, Island Council President, Nukufetau
Malua Falani, Vice President, Island Council, Nukufetau
Simone Aleke, Member, Island Council, Nukufetau
Nelu Salemona, Member, Island Council, Nukufetau
Faimafile Tefulo, Member, Island Council, Nukufetau
Mono lelemia, Temaneapa, Nukufetau

EQUIPMENT AND FACILITIES:

The following items of UNDP equipment were used on this survey.

Del Norte Trisponder Navigation System
Compass Telescope
Raytheon DE 719B Fathometer High Resolution Boomer
Benthos 268 Hydrophone Cable
EG & G Power Supply
EG & G Capacitor Banks
Yamaha 600W generator
Yamaha diesel .3000W generator
EPC 4600 Graphic Recorder
Krohn Nite .3700 Bandpass Filters

Equipment and personnel were transported to Nukufetau on the M.V. Nivaga. Fisheries Department, Tuvalu Government provided a 5.5m aluminium dinghy and outboard motors for use as the survey vessel.

Local assistance with housing of equipment close to the boat passage, assignation of labour for the survey, and accommodation for personnel were provided by the Nukufetau Island Council through the Island Executive Officer, Mr Apinelu Kapoti. Koloauti kindly provided use of his fale for storage of equipment close to the boat passage.

Coordination of the M. V. Nivaga schedule with requirements of the survey was kindly provided by the Ministers and Secretaries of both Commerce and Natural Development, and Works and Communication. Mr Lene Matusi, Ministry of Commerce and Natural Resources provided invaluable assistance with general coordination and attention to logistical matters that assured the success of the survey.

METHODS:

Naviaation

Horizontal control for the survey of Nukufetau lagoon was by use of transponder navigation and the D.O.S.1974 1: 12500 Nukufetau sheet based

on a Universal Transverse Mercator Grid. On arrival at Nukufetau, most of the trig points from this 1974 survey were located and cleared for use with trisponder navigation. The trisponder system was calibrated over a cleared 500m tract on Savave before commencement of the survey. On the survey vessel, the trisponder receiving station was offset by 2.5m from the depth-sounding transducer.

During running of seismic and bathymetric profile lines, ranges to two trig stations, time, and a consecutive station numbering were printed out by a printer linked to the Decca Master Unit.

Survey stations were plotted on the 1:12,500 base map using a two range intersection method. On some days, battery problems caused malfunction of some trisponder slave stations and the survey continued using a combination of range and compass bearing for a less precise navigation.

Vertical Control

The zero level of the Funafuti Tide Station was used as the datum for the survey. No tide monitoring is conducted at Nukufetau, nor was a station established. Tide prediction tables for Funafuti were used to reduce soundings to the zero datum.

A DE 719 B - precision fathometer was used for profiling. Daily the unit was readjusted for zero error if necessary and transducer depth and calibration checked.

Seismic Profiling

The seismic system comprised:

a high resolution boomer, powered by a 3 kw Yamaha diesel generator;

a Benthos 268 8 element hydrophone cable with pre-amplification;

two Krohn Nite 3700 bandpass filters, and

an EPC 4600 Graphic Recorder.

A 600W Yamaha petrol generator was used to power the capacitor bank interlock system, bandpass filters and graphic recorder.

Throughout most of the survey the boomer was operated at 200 joules, and keyed at 250msec, producing adequate penetration. In some areas of sandier bottom sediment, 300 joules was used to extend penetration. Generally a band pass width of 400 - 4000 hz was used in shallow water, and opened to 200 - 4000 hz in deeper water to highlight deeper events. The EPC recorder was operated at 4 sweeps per second.

Towards the completion of the survey, return signal strength was diminished. As a 300 joules pulse from the boomer did little for improvement, a toothbrush sparker was used at 200, 300 joules every 250msec, then 400, 600 joules and finally 700 joules every 0.75 seconds. Although no fault could be isolated in the hydrophone - filter - recorder system, it is felt that the problem existed in these units.

The EPC recorder and depth sounder were marked manually in synchronization with trisponder fixes.

Outcrop Sampling

Outcrops were inspected on several islands. Where suspected phosphate was observed, samples were collected and structures and stratigraphy described.

RESULTS:

Outcrop Sampling

Sakalua, also known as Coal Island, is a 350m long ovate sand clay that lies within the confines of the atoll in a shallow region between Te Ava Lasi (Teafua Pass) and Te Ava Amua on the western side (Figures 1,3).

There is a general local knowledge of phosphate on Sakalua, and the occurrence was reported by White and Warin(1964) to comprise a blanket of phosphatic sand up to 0.3 metres thick in the central part of the island. They estimated 5-10,000 tons at 15% P 205.

The central area of Sakalua is a slight depression, with a loose rubbly floor of large flags of limonitic and phosphatic porous calcarenite. The island has a large colony of terns, guano staining is abundant, and the vegetation is lush and prolific.

Sample 1 was collected from this rubbly outcrop and it comprises a porous grainstone with chalky white clasts enclosed in a limonitic sandy matrix. In-field stain indicator testing did not reveal any distinctively positive results.

On the southeastern shoreline, erosion has exposed a shallow indurated profile of this phosphatic sequence (Figure 2).

Above a well-indurated subtidal carbonate pavement, there are isolated circular pods of limonitic, and presumably phosphatic, coarse calcarenite and breccia. These pods are residual cumulates in karstic depressions. (Sample 2). Above this irregular base, the phosphatic carbonate grades quickly up into a colour mottled pallid zone of a more friable nature. This zone is a grey-tan hue with both dark grey and rusty limonitic stains following root tubules and irregular patches. The staining increases upwards to a better indurated monitic crust which is presumed identical with that of Sample 1. Sample 4 from the beach on Northern Savave is representative of this mottled zone.

Phosphate is reported to also occur as podS on the reef flat east of Teafuone (near Sakalua), on the reef flat north of Motumua and in central Motumua. At the east end of the lagoon beach of Savave, phosphatic limonitic concretions are present within the beach profile in a Calcarina grainstone matrix. This part of the shoreline is under active erosion. These irregular pods of friable rock, mottled brown and red with decomposed root tubules, have most probably been eroded from within the soil profile, perhaps 0.5 to 1 metre below ground level. No in situ material was found. Sample 4 is representative of the pods.

Profiling

Approximately 91 Kilometres of combined seismic and bathymetric profiling was completed. Profile lines form a broad grid pattern over the whole lagoon on NNW-SSE and ESE-WNW axes (Figure 3). Additional short lines were run on the western side through both passes, Te Ava Lasi and Te Ava Amua, as well as in the close vicinity of Sakalua.

Seismic penetration in the deeper central area of the lagoon was excellent, up to 50 millisecs TWT into the lagoon floor. From here it was attempted to trace the deeper events upslope onto the lagoon margins near Sakalua but, with sandier sediments, resolution of events and penetration was significantly reduced near the island.

Te Ava Amua is a narrow, very deep pass through the atoll perimeter on the WNW side of the atoll. Hard-bottomed channels radiate out across the lagoon floor from this pass and preliminary observations of seismic profiles, which show seismic pullup, indicate that palaeo channels exist with indurated bottoms or dense material infill. Geomorphological evidence suggests that Te Ava Amua is a very old structure, with probable enhancement by erosional and karst processes during low stands of sea level.

Nukufetau atoll is unique in Tuvalu in having a crude rectangular outline (Figure 1). The presence of both passes on the west-northwestern side of the atoll, and an almost continuous island perimeter on the east-southeastern side may suggest a tilting of the atoll to the west-northwest. Karstification and palaeo drainage during low sea stands would therefore enhance the morphological effects of basement tilting.

CONCLUSIONS AND RECOMMENDATIONS

1. Approximately 91 kilometres of combined seismic and bathymetric profiling was completed in Nukufetau Lagoon.

2. Reconnaissance observations of outcrop and sampling for phosphate were conducted on Sakalua and Savave.

3. Preliminary petrographic evidence suggests that Holocene phosphate accumulations may exist on Sakalua and in smaller amounts on Savave, Motumua, Teafuone, and possibly on Lafanga.

4. The assessment of the geological history of Nukufetau and its phosphate potential, and recommendations for future reconnaissance drilling await interpretation of bathymetry, seismic profiles and geochemical analyses.

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Appendix 1

SURVEY LOG

18 February	0830	Depart Suva, 1145 Arrive Funafuti
	1600	Depart Funafuti on 'M.V. Nivaga'
	0000	Arrive Nukefetau
19 February	0800	Unload equipment on Nukufetau
	0900	Confer with island Executive Officer
	0930	Meeting with Island Council on visit and required assistance
	1400-1900	Inspect Trig control points around atoll
20 February	0800	Repair Survey aluminium dinghy
	1300	Prepare equipment, calibrate Trisponders
21 February	0700-1800	Locate Trisponders, retrieve due to bad weather
22 February	0800	Deploy Trisponders
	1300-1800	Survey lines A, B
23 February	0700-1800	Survey continued for lines C, D, E, F.
24 February	SUNDAY	
25 February	0700	Strong winds - no survey. Plotted data. Equipment maintenance.
26 February	0615	Deploy Trisponders
	0900-1830	Surveyed lines G, H, I
27 February	0615	Deploy Trisponders
	0900-1830	Surveyed lines J, K
28 February	0630	Deploy Trisponders
	0900	Commenced survey of lines L. Seismic equipment failure
	1830	Equipment overhaul and plotting of data
1 March		Strong winds. No survey. Plotting of data. Modification of seismic equipment continued
2 March	0700	Locate Trisponders.
	0900-2000	Surveyed lines L, M, N
3 March	SUNDAY	
4 March	0700	Dismantled survey equipment, unloaded vessel, packed equipment
	0900	Plotted data

Appendix 1 – SURVEY LOG (continued)

5 March		Strong wind warning, plotted data
6 March		Strong wind warning, plotted data, report writing
7 March		Strong wind warning, plotted data
8 March		Strong wind warning, plotted data
9 March	0530	Depart Nukufetau on 'M.V. Nivaga'
	1930	Arrive Funafuti
10 March	SUNDAY	
11 March	0900	Discussions with Tauaasa Taafaki, Secretary of Commerce and Natural Resources
	1230	Depart Funafuti on Fiji Air
	1630	Arrive Suva

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Table 1

NUKUFETAU SURVEY LINE CONTROL

Date	Time	Leg	No. of Points	Comments	Station 1	Station 2
Thurs 22 Feb	1233-1558	A	122	NNE from Motumua N end	NFT 16	NFT 13
Thurs 22 Feb	1605-1723	B	79	SSW from Funaota Savave	NFT 16	NFT 13
Fri 23 Feb	0915-0945	C	17	Triangulation using	Matanukulaelae, east Motumua	NFT 12
Fri 23 Feb	1000-1100	D	23	Triangulation using	NFT17, 12, 3, 4, and 6	
Fri 23 Feb	1200-1340	E	56	Triangulation using	NFT 6, NFT 12, Matanukulaelae	
Fri 23 Feb	1500-1615	F	53	Triangulation using	NFT 17, NFT 12, Matanukulaelae	NFT 15, &
Tues 26 Feb	0940-1130	G	113	ESE from N of Savave to jetty at Motulalo	NFT 13	NFT 16
Tues 26 Feb	1400-1530	H	100	WNW from Niuelesolo to Sakalua 2nd Te Ava Lasi	NFT 12	NFT 16
Tues 26 Feb	1542-1620	I	38	ESE from Te Ava Lasi	NFT 1	NFT 16
Wed 27 Feb	1056-1535	J	155	NNE, Fatuvaenga E Savave to Teafuanonu	CS 13	NFT 8
Wed 27 Feb	1535-1720	K	95	SSW, Ova to E Savave Te Akaii Kalea	CS 13	NFT 8
Sat 2 Mar	1110-1310	L	45	from N.of Temotuloto to S Sakalua	NFT 13	NFT 16
Sat 2 Mar	1345-1445	M	62	from N Sakalua to moutn of Te Ava Amua	NFT 13	NFT 16
Sat 2 Mar	1600-1700	N	64	run ESE from Funaota to Niualuka	NFT 13	NFT 16

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Table 2

BASE STATIONS AND TIDAL CORRECTIONS USED FOR BATHYMETRIC SURVEY

Leg	Base Station 1	Base Station 2	Date	Time	Tidal Correction (m)
A 1 - 120	NFT 16	NFT 13	22 Feb	1400-1600	0.72 → 1.13
B 1 - 86	NFT 16	NFT 13	22 Feb	1605-1723	1.13 → 1.43
C 1 - 17	No Trisponders were operating. Bearing triangulation used.		23 Feb	0915-0945	1.19 → 1.00
D 18 - 40	Ditto		23 Feb	1000-1100	1.00 → 0.82
E 41 - 96	Ditto		23 Feb	1220-1340	0.55 → 0.46 → 0.55
F 97 - 128	Ditto		23 Feb	1500-1615	0.82 → 1.05
G 8 - 120	NFT 16	NFT 13	26 Feb	0940-1130	1.27 → 1.06
H 1 - 100	NFT 16	NFT 12	26 Feb	1400-1530	0.84 → 0.82
I 108 - 130	NFT 16	NFT 12	26 Feb	1542-1620	0.82 → 0.90
J 5 - 159	NFT 8	E. Savave (CS 13)	27 Feb	1056-1535	1.42 → 0.84
K 1 - 95	NFT 8	E. Savave (CS 13)	27 Feb	1535-1720	0.82 → 0.89
L 0 - 45	NFT 16	NFT 13	2 Mar	1110-1310	1.08 → 1.34
M 1 - 62	NFT 16	NFT 13	2 Mar	1345-1.445	1.47 → 1.33
N 1 - 64	NFT 16	NFT 13	2 Mar	1600-1700	1.19 → 1.05

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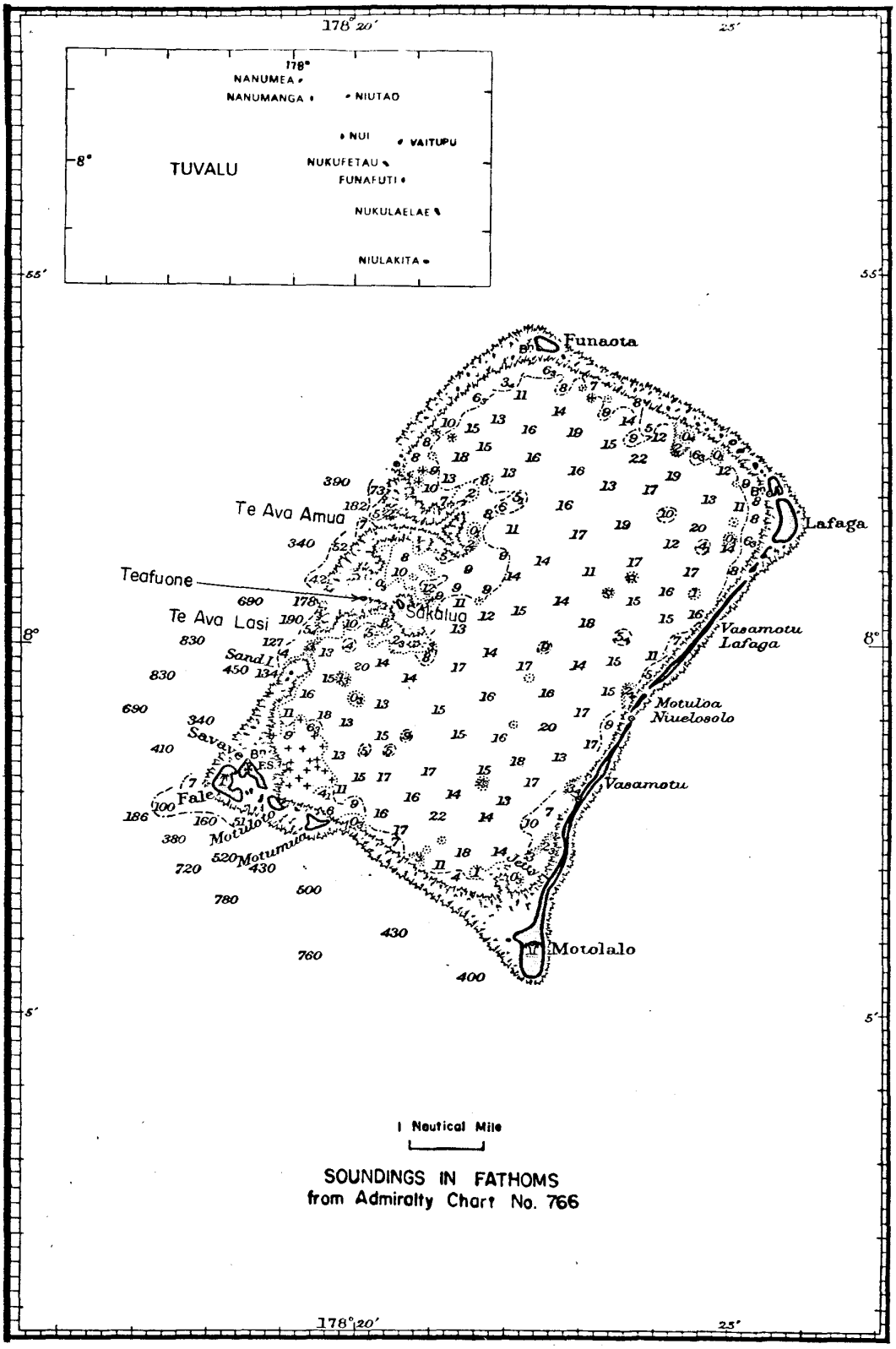

Figure 1. Location and Geography of Nukufetau

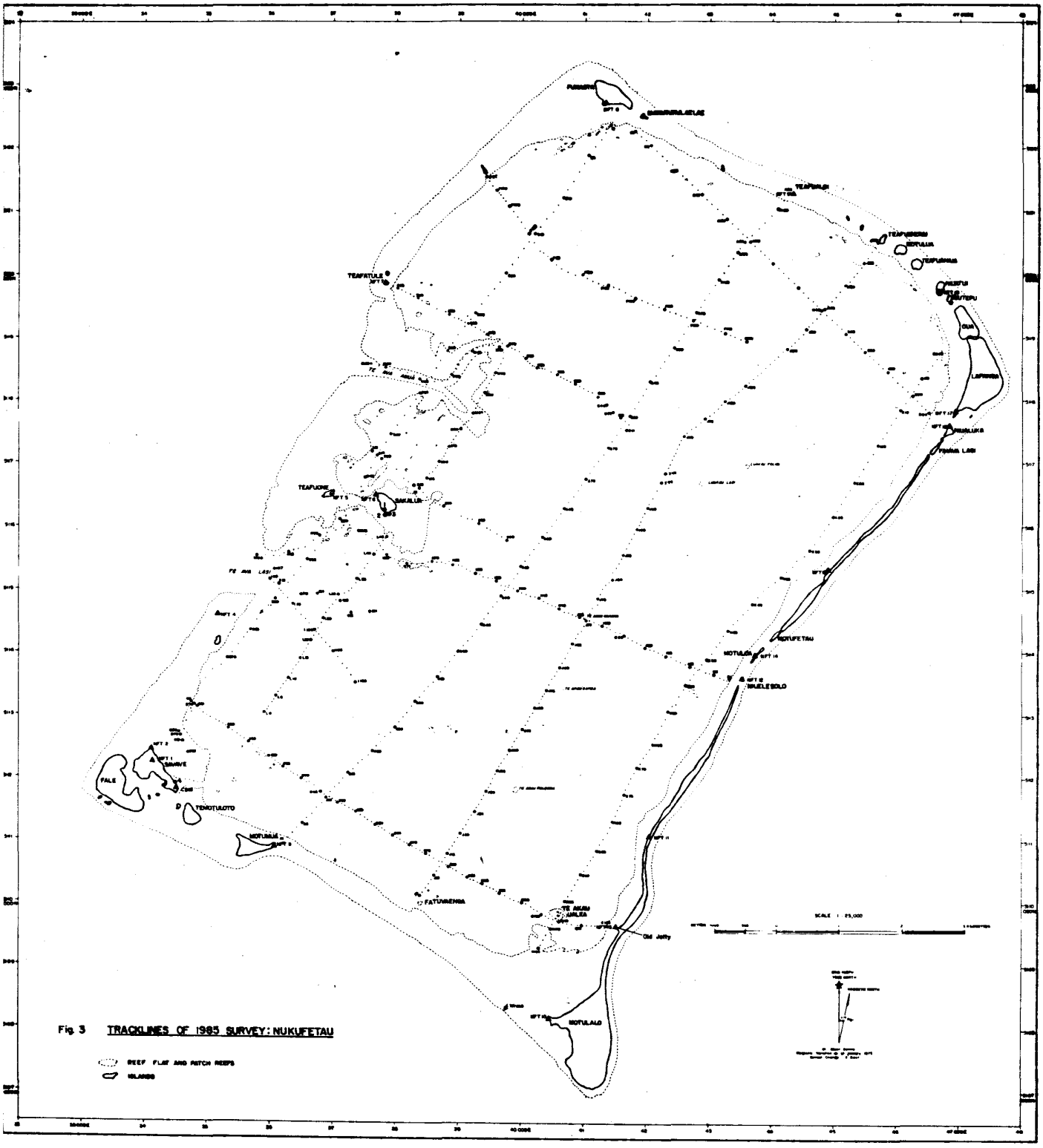

Fig. 3 TRACKLINES OF 1985 SURVEY: NUKUFETAU

REEF FLAT AND PATCH REEFS

ISLANDS

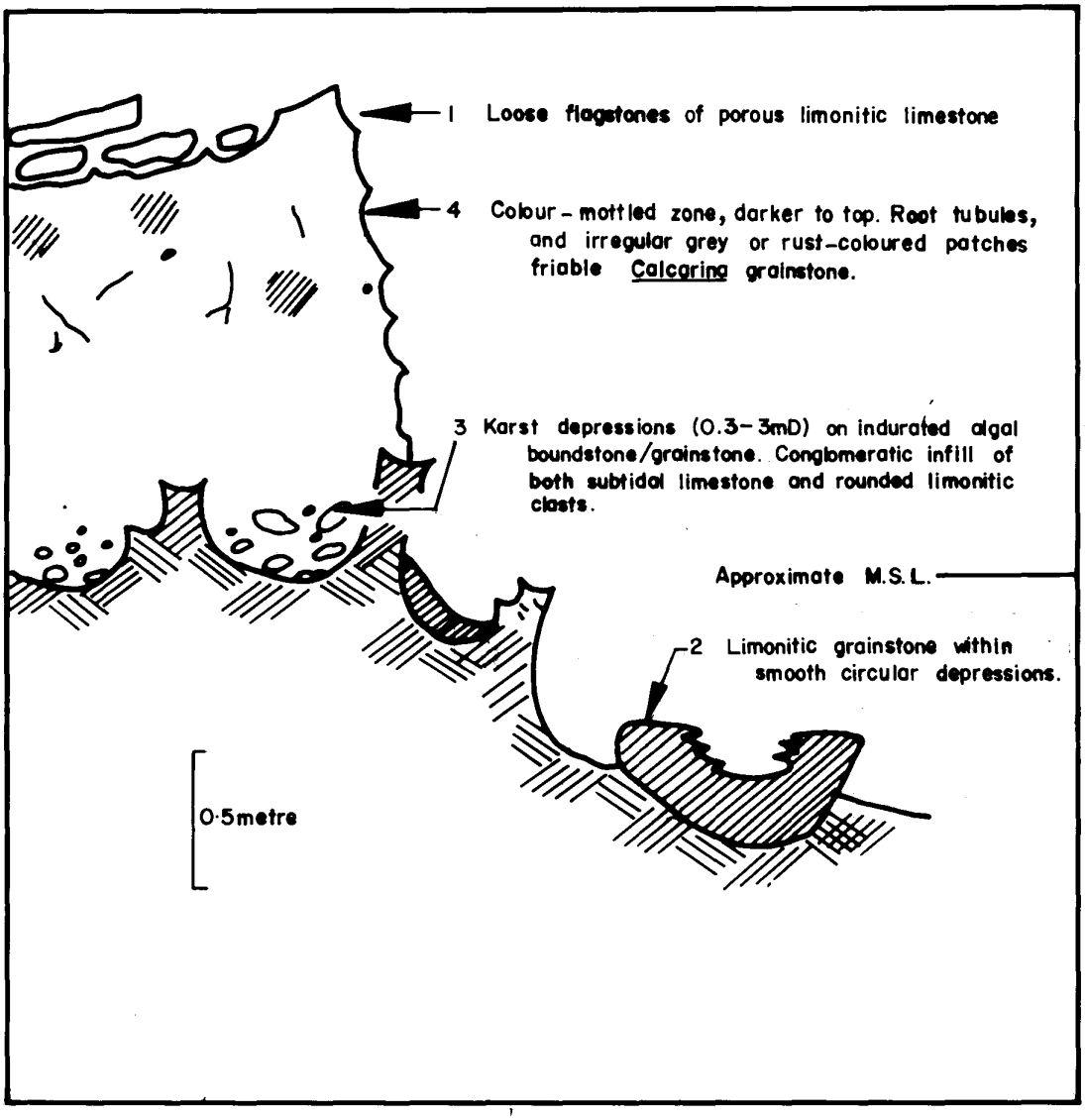

Figure 2 Stratigraphic Profile on South - East Sakalua, Nukufetau

Numbers 1–4 indicate relative positions of samples collected for phosphate analysis.