NEARSHORE MINERALS IN THE SOUTH PACIFIC

Member Country Papers from the

SOPAC-ICOD Nearshore Minerals Workshop
Savusavu, Fiji, 1988

December 1990 SOPAC Miscellaneous Report 103

Prepared for: South Pacific Applied Geoscience Commission (SOP AC)

Coastal and Nearshore; and Training Programmes

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LEGISLATION AND LICENSING

LOCAL SAVUSAVU GEOLOGY

EDITORIAL NOTE

The SOPAC-ICOD Workshop on Nearshore Mineral Resources of South Pacific Island Nations was held at Savusavu, Fiji from 29 September to 12 October 1988. The workshop was funded by the International Centre for Ocean Development (ICOD), a Canadian Government Crown Agency, and was also supported by the Fiji Mineral Resources Department, Dateline Carriers in Savusavu, and the Na Koro Resort. The work programme of the Workshop was wide-ranging, including a number of general technical contributions by experts from the SOPAC Technical Secretariat and other organisatiions, and a number of important contributions by the member countries themselves.

This report comprises the member country papers that were tabled at the Workshop -summaries of their nearshore mineral resources, descriptions of nearshore coastal surveys and developments, and legislative and Iicensing aspects of this work. Not only do they provide a useful "baseline" statement concerning the state of knowledge of nearshore mineral resources as at 1988, but they constitute a valuable case history guide, from one member country to another, in presenting the problems and the rewards of nearshore mineral development in the South Pacific. They therefore further the co-operative aims of SOP AC in the South Pacific.

A report on the formal part of the Workshop, including formal speeches, technical programme and exercises, list of participants, and recommendations is published as SOPAC Training Report 19. A selection of general papers on nearshore minerals is published as SOPAC Miscellaneous Report 104.

NEARSHORE MINERAL ACTIVITIES IN MEMBER COUNTRIES

[MR 103 - Technical Secretariat]

SUMMARY OF NEARSHORE MINERAL ACTIVITIES

COOK ISLANDS

by

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INTRODUCTION

The Cook Islands form an archipelago of 15 islands with a total land area of about 240 km^2. They can conveniently be subdivided into a northern and southern group. The southern group consists of a high volcanic island (9arotonga), uplifted limestone islands with volcanic cores (Mangaia. Atiu, Mitiaro, and Mauke), an almost-atoll (Aitutaki), the atoll Manuae, and the small reef island of Takutea. The northern group consists of 5 atolls (Pukapuka, Rakahanga, Manihiki, Penrhyn, and Suwarrow) and the small reef island of Nassau. The highest island is Rarotonga (1350 m) and the total population is just over 20,000 inhabitants.

The Cook Islands economy is based on produce export (bananas, copra, pineapples, and citrus) mostly to New Zealand, tourism, and the sale of stamps and coins. Potential mineral resources of the Cook Islands include Phosphate, construction materials, precious corals and possibly manganese on the volcanic islands.

PHOSPHATE STUDIES

A survey of land-based phosphate was conducted by Wood and Hay (1970) who tested nearly 200 surficial samples as well as reviewed previous studies. Consistently low phosphate values were measured in the southern group samples and the potential for the discovery of an economically viable deposit is low. Results in the northern group were more encouraging with samples containing more than 20% P_2O_5 on Pukapuka and Manihiki. Overall tonnage and grade appeared low; but they suggested a drilling programme, to determine the presence of buried deposits, would be desirable.

In 1986 the Cook Island Government and CCOP/SOPAC embarked on a lagoonal drilling programme which included participants and support from the US Geological Survey, Geological Survey of the Netherlands, and the University of California. To date the lagoons of three islands have been drilled - Aitutaki, Pukapuka, and Rakahanga, with plans to return to Manihiki in early 1989. The surveys have included continuous high-resolution seismic profiling, wire-line drilling, side-scan-sonar imaging, echosounder profiling, and surface sediment sampling. The final report on the Aitutaki core analyses has been completed (Hein and others, 1988) and samples from the other sites are presently undergoing analysis. Unfortunately no extensive sites of phosphatization have been located so far.

CONSTRUCTION MATERIALS

Except for Rarotonga and perhaps Aitutaki the demand for construction materials is low. Both Rarotonga and Aitutaki have quarries established to mine and crust volcanic rocks for use in roading and other activities.

The traditional source for construction materials on Rarotonga (and the other islands) has been beach mining. Because of coastal erosion problems beach extraction has been severely curtailed on Rarotonga. Currently there is a sand and gravel minirg operation at the mouth of the Avana River. Material extacted is mostly of volcanic origin with minor amounts of carbonates derived from adjacent reefs. The sediments are deposited at the head of Ngatangiia Harbour, a deep reef passage, and a area where extraction probably has a minor effect on nearby coastal stabiliti because the sediments are most likely eing transported downslope and offshore away from the active littoral zone. The sediments are extracted by a mechanical excavator from the shoreline. Offshore surveys for construction materials in Rarotonga were conducted by Gauss (1982) and Lewis and others (1980). Potential offshore deposits were discovered as channel fill sands at Avarua, Avatiu, and Ngatangiia, Coastal plain deposits were examined as part of the CCOP/SOPAC-USGS Coastal Mapping Workshop (Richmond, 1988).

Beach mining (using front end loaders) is still occurring at Aitutaki and is probably prevalant on other islands as well. Volumes of Aitutaki Holocene carbonate lagoon fill - mostly sands and gravel - were estimated as part of the lagoonal drilling programme (Richmond and Hein, 1987).

PRECIOUS CORALS

Thirty-nine dredgings for precious corals have been conducted in Cook Island waters with four recoveries of Corallium (Harper, 1988). One commercial grade piece of pink coral from intermediate water depths was collected and further surveys in the area are recommended. Additional reconnaissance programmes for intermediate water depth Corallium in the southern group and deepwater Corallium in the entire region are recommended (Harper, 1988).

MANGANESE

Manganese was reported from Mangaia associated- with, basaltic rocks and occurring both in a hard, dense form and as veins of friable material (Wood and Hay, 1970). No commercial ores were discovered and chances for future finds are slim. No mention was made of the potential for nearshore deposits.

REFERENCES

GAUSS, G.A. 1982: Sea bed studies in nearshore areas of Rarotonga, Cook *Islands. South Pacific Marine Geological Notes* 2: 131-153.'

HARPER, J.R. 1988: Precious corals prospecting strategies for the South Pacific region. CCOP */SOPAC Technical Report* 84: 80 pages.

HEIN J.R.; RICHMOND, B.M. and other 1988: Description; mineralogical, chemical, and isotopic compositions; petrography, diagenesis; and Uranium-series ages of drill cores from the lagoon of Aitutaki, Cook Islands. *US Geological survey Open File Report* 88-419: 151 pages.

LEWIS, K.8.; UTANGA, AT.; HILL, P.G. and KINGAN, S.G. 1980: The origin of channel-fill sands and gravels on an algal-dominated reef terrace, Rarotonga, Cook Islands. *South Pacific Marine* Geological Notes 2: 1-23

RICHMOND, 8.M. 1988: Coastal morphology of Rarotonga, Cook Islands. *CCOP /SOPAC Technical Report* 65: 42 pages.'

RICHMOND, B.M. and HEIN, J.R. 1987: Holocene carbonate sedimentation in Aitutaki lagoon, Cook Islands. South Pacific. *Book of Abstract MPG Annual Meeting, Los Angeles, California, June 7-10*: page 102 ...

WOOD, B.L. and HAY, R.F. 1970: Geology of the Cook Islands. *NZ Geological Survey Bulletin 82:* 1 3 pages.

EXISTING AND PLANNED EXPLORATION FOR NEARSHORE RESOURCES IN FIJI

by

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SUMMARY

The mineral deposits of Fiji are closely related to its volcanic activity. Very little is known of Fiji's offshore area, but preliminary nearhore work has shown potential for significant mineral deposits offshore.

The most likely minerals to occur offshore, based on geological investigations, include: hydrocarbons, phosphate and metalliferous minerals. Deposits identified in the nearshore areas f Fiji are manganese, and some gold showings. Work on the potential for gold placer deposits as been carried out mainly by commercial operators. The main exploration carried out so far, in terms of money spent, is on hydrocarbons. Strategic planning and further work for mineral exploration is one of the Government's top most priorities in its offshore development plans.

Fiji has an attractive mineral-development policy which has helped to attract and maintain interest in mineral exploration for the last seventeen years.

INTRODUCTION

This paper outlines the existing and planned exploration for nearshore mineral resources in Fiji. It was prepared for the SOPAC-ICOD Workshop on Nearshore Mineral Resources of the South Pacific Island Nations, held at Savusavu, Fiji, from 29 September to 11 October 1988.

Mineral Resources

The oldest rocks of Fiji date back to the Eocene period. Fiji's mineral resources are closely related to the volcanic activity of the Miocene, Pliocene and Pleistocene. The narrow range of minerals include the base metals copper, lead and zinc. Precious metals include gold and silver. Other minerals present are manganese, bauxite, iron and phosphate (Figure 1).

Future Prospects

Considering the small land area of 18,500 sq km, Fiji has large number of mineral assemblages. This fact encourages the hope that further significant mineral discoveries remain to be made (despite the limited success of exploration carried out over the last 15 years) both onshore and offshore.

Fiji's EEZ (with an approximate area of Just over 1 million km') is poorly known but the limited work so far undertaken has justified further exploration for hydrocarbons, precious corals, sulphides (encrustations, vents, enriched sediments) and lacer minerals.

Organisations Involved in Nearshore Minerals Exploration

The official body dealing with offshore prospecting in Fiji's offshore areas is the Mineral Resources Department (MRD) of the Ministry of Lands and Miner / Resources. MRD performs the task through its Offshore Section. From 1980 till early this ye r the Offshore Section carried out its geophysical and geological sampling programme from a 20 m research vessel, Latui, for deep sea work. For nearshore work an aluminium punt and a catamaran that came into service in 1986 are used. Since Latui has been de-comissioned (it ran aground), MRD has had to rely on its 7.5 m catamaran, Yauta/ei. This will obviously restrict the Section's work to nearshore areas only. The extensive work already achieved in Fiji's EEZ was for the most part only achievable by the cooperation and strategic planning of SOPAC with other international organisations. Other work has been carried out in nearshore areas by commercial bodies.

COASTAL AND NEARSHORE MINERAL DEPOSITS

Iron Sand

Fiji has two major titaniferous iron-sand deposits, located at Sigatoka and Ba on Viti Levu. The Sigatoka deposits occur on dunes and offshore. Investigations, here began onshore in

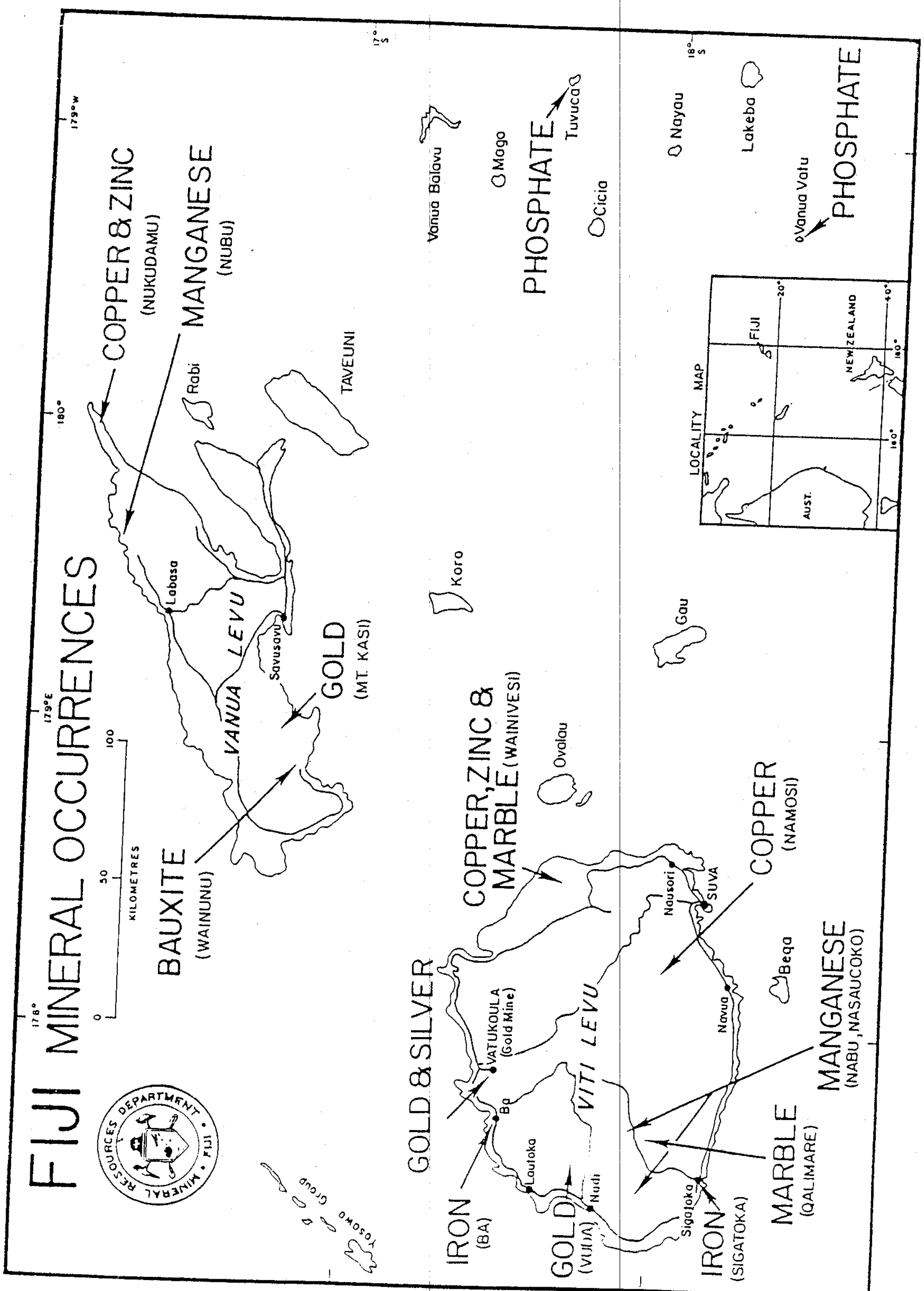
FIJI MINERAL OCCURRENCES
MINERAL RESOURCES DEPARTMENT • FIJI •
KILOMETRES
0
50
100
178°
179°E
180°
179°W
17° S
18° S
COPPER & ZINC
(NUKUDAMU)
MANGANESE
(NUBU)
BAUXITE
(WAINUNU)
GOLD
(MT. KASI)
Rabi
TAVEUNI
Labasa
Savusavu
VANUA LEVU
Vanua Balavu
Mago
PHOSPHATE
Tuvuca
Cicia
Nayau
Lakeba
Vanua Vatu
PHOSPHATE
Koro
Gau
Ovalau
COPPER, ZINC & MARBLE (WAINIVESI)
COPPER
(NAMOSI)
Nausori
SUVA
Beqa
MANGANESE
(NABU, NASAUCOKO)
Navua
VITI LEVU
GOLD & SILVER
VATUKOULA
(Gold Mine)
Ba
Lautoka
Nadi
Sigatoka
IRON
(BA)
GOLD
(VUDA)
IRON
(SIGATOKA)
MARBLE
(QALIMARE)
Yasawa Group
LOCALITY MAP
FIJI
AUST.
NEW ZEALAND
20°
40°
160°
180°

FIG. I

1951. A major survey was carried out in 1969-1972 by Manganex Ltd. The deposit was found to be of two grades, divided into eastern and western deposits, with the eastern deposit richer in magnetite. In 1967 Crawford Ltd did some work offshore with the aim of establishing the extent of the deposit offshore. Additional work was done in 1980 by RD and SOPAC, which confirmed the presence of an iron-sand extension offshore.

The Ba deposit was first investigated by Manganex Fiji Ltd in the early 1970s. The deposit occurs in the Ba River Delta and nearshore area. The delta covers an area of 20 sq km with average water depths of 1-3 m, a large area. of which is exposed at low tide. The prospect is 25 m thick, with the largest deposit being estimated to occur in the centre of the delta. Manganex estimated the inferred resources of the area to be approximately 8 Mt, distributed as follows:

Central delta	5.6 million tonnes
Eastern delta	1.4 million tonnes
Western delta	0.9 mil/ion tonnes

The concentrates produced from the deposits were assayed:

57 to 58%	Fe
6.7 to 7.5%	Ti02
0.7 to 0.1%	V_20_5
0.3 to 0.35%	Cr_20_3

Further work offshore is being presently carried out to establish the possibility of the deposit extending into the backwaters of the nearshore reef complex. Other work in these waters was done in 1980 and 1987 by MRD and SOPAC.

The world's wider availability of deposits of much larger size and higher grade than the Ba and Sigatoka sands precludes exploitation, and places the deposits as subeconomic.

Sand and Gravel

Apart from carbonate sand for cement manufacturing and coral blocks for rubble in drains, bridge abutments and causeways, Fiji's sand and gravel requirements are extracted from land-base operations.

Manufacture of cement in Fiji is carried out by Fiji Industries, whose factory is situated at Lami, 5 km west of Suva. The company supplies all the demand for cement in Fiji and exports to many countries in the South Pacific.

Carbonate sand and silica sand are the main raw materials for cement manufacture and in Fiji these materials are extracted from nearshore sites. Carbonate ("coral") sand is extracted from Laucala Bay and along the coast west of Suva, and silica sand is extracted from the mouth of Vunidawa River (located at the head of Laucala Bay) a branch of the Rewa River (Figure 2).

The carbonate sands occur as loose deposits along the backreef areas of Laucala Bay and are extracted by means of a bucket dredge from continuous pits to a depth of 9-10 m. In the shallowest areas, the sands are exposed during ebb spring tides and the deposits shelve gradually into the lagoon, becoming finer and containing a greater terrigenous component Iandwards from the reef (Penn 1980). According to Penn, the carbonate sand, which is generally described as "coral sand" consist of approximately 90% CaCO , $Si0_3$, $S2^03$' Na_20).

The sand deposits containing silica are also loose and are extracted using a suction dredge. The raw materials are transported by barge to the cement factory and are sufficiently fine for milling without pre-crushing, clearly of economic advantage.

Reserves of raw deposits are not known, but records kept by the Lands Department indicate that extraction has totalled approximately 1.4 million cubic metres for carbonate sand a d 0.5 million cubic metres for silica sand since 1965. This has provided the government with a royalty of approximately $0.65 million for the same period.

In the past, extraction of coral blocks in, Fiji has been carried out mainly in the Suva and Deuba areas. Apart from use as rubble, the coral blocks can also be crushed for use as base-course for roads and as housing foundations.

The type of coral extracted is Porites, taken from dead reel patches along the foreshore, probably representing ancient reef systems. In, most cases the coral reef patches are covered by a thin layer of unconsolidated sediments. Quarrying is undertaken in a haphazard manner. Apart from the occasional use of outboard motors for transporting the blocks to the sale sites, no machinery is used in extraction. The main tools are digging implements and sledge hammers

NEARSHORE CARBONATE/LITHIC SAND MINING AROUND SUVA

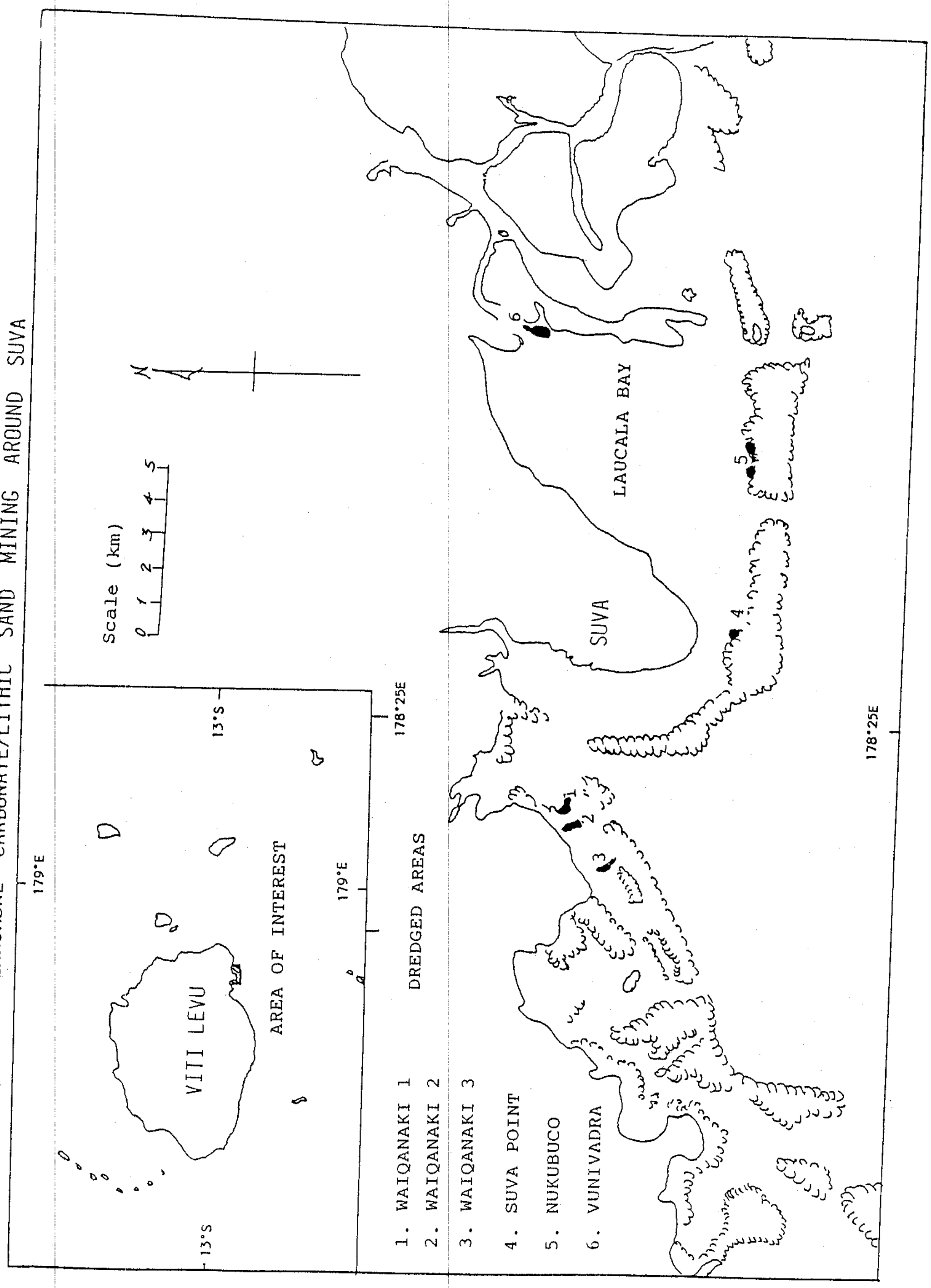

Fig.:2

and the operations are carried out on a very small scale with only a few people working on a deposit.

The coral blocks are sold from heaps along roadsides near the extraction sites. Reserves are not known and only records of extraction since 1965 are available. Though quarrying of the coral blocks have probably been undertaken since the early 1900s, records show that only 7000 m^3 of material has been extracted since 1965 earning a royalty of approximately $4000.

Other Hypothetical and Speculative Resources

The investigation of the potential of offshore and nearshore minerals of Fiji is in its infancy stage and very little is known. However under geological grounds, other minerals which can reasonably be expected to occur in the nearshore areas include:

a) hydrocarbons

b) phosphate (ocean insular type and shallow-lagoonal types)

c) coastal offshore gold placers; and

d) precious corals

Hydrocarbons

Following recognition of oil seepages on Eua and Tongatapu islands of the Tonga group, commercial interest in the presence of oil in the island-arc environment increased. In 1968 the first offshore petroleum licence to be issued in Fiji was granted. Approximately 32,000 km of coastal and nearshore area was placed under special prospecting license for hydrocarbons. Five deep and two shallow exploratory wells were drilled. None of the seven wells drilled reached the reefal limestone target. No drilling programme has been carried out since the mid-1980s. At present MRD is doing desk research and running an extensive source-rock sampling programme as its contribution to providing pre basic data for hydrocarbons exploration in nearshore areas.

Gold Placer Deposits

Crawford Marine Specialists Inc. worked on 13 offshore prospecting licences for minerals other than hydrocarbons (Figure 3). The licences were selected mainly on the basis of their relation to known mineral occurrences on the two main islands (Figure 4). Results gained from Crawford Marine Specialists work drew attention to the possible significance of small amounts of gold in the iron sands (see also Table 1). This attracted attention to special areas of the shallow marine environment of western and northern Viti Levu and southern Vanua Levu for the possible occurrerce of gold placer deposits associat1 with sediments trapped by basins and reefal structures. Reconnaissance surveys for commercial exploration have been completed. More work in these areas is presently underway by MRD in cooperation with SOPAC.

Phosphate

Phosphatic clay, oolite and nodules occur in association with limestone on several islands in Lau group with a demonstrated resource of 1.6 million tonnes containing 10.9% P_2O_5 on Tuvuca.

Fiji’s offshore areas have conditions favouring the formation of phosphorite. At present little if any work is being done in Fiji's EEZ on the assessment and investigations aimed at the delineation of areas where phosphorite nodules could be available for commercial exploitation.

Precious Corals

Investigation for precious corals in Fiji is in its early stages. Two preliminary searches have been carried out, by Gauss (1981) in Kadavu Waters and by Harper (1988) in the Lau Group. No Corallium was identified from the samples collected from the Lau Group, but Gauss collected one sample of Corallium in Kadavu waters, and this have raised the possibility of the presence of precious coral in Fiji. Apart from Corallium, black coral is presently exploited in at least one location in Fiji.

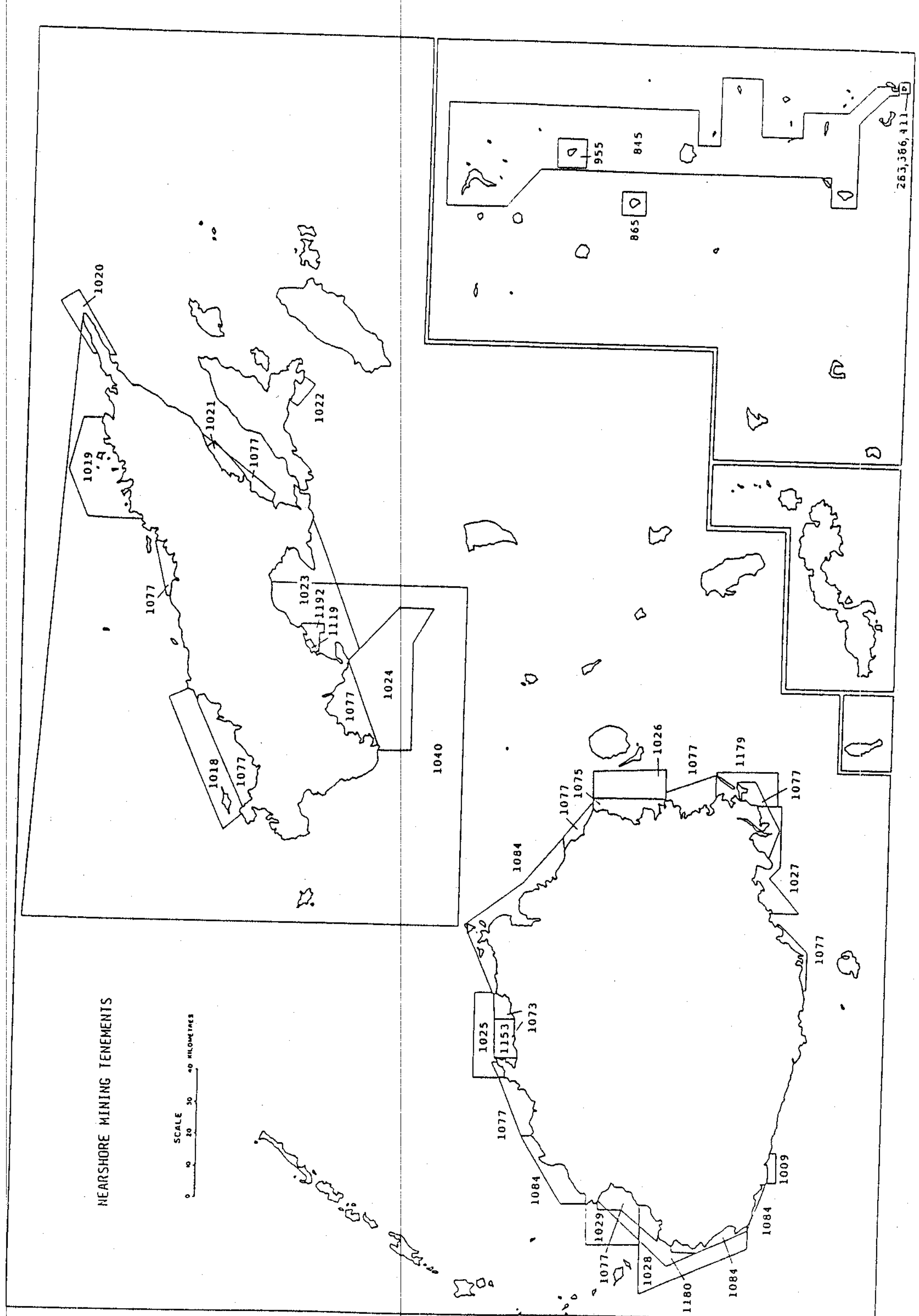
FIG. 3
NEARSHORE MINING TENEMENTS
SCALE
263,386,411
955
845
865
1020
1021
1022
1019
1077
1023
1192
1119
1024
1040
1018
1084
1075
1026
1179
1027
1073
1153
1025
1009
1029
1028
1180

The relationship of inland prospect to nearshore placers magnetite and gold

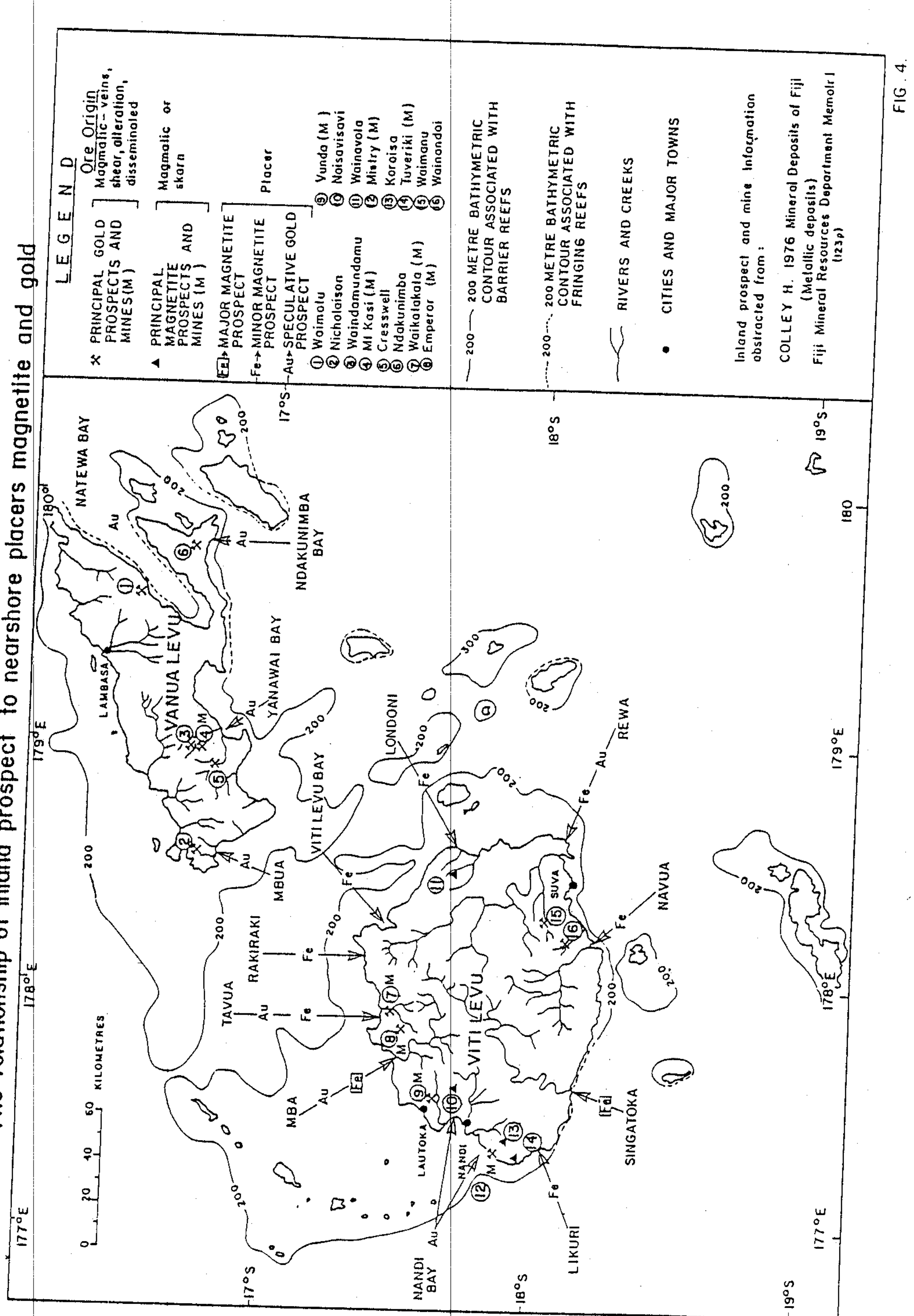

FIG. 4.

Mineral Classification

Fiji's mineral resources classification lean be presented as a modified Mckelvey box (Figure 5). The system of classification considers two criteria of a resource plotted on a two dimensional box diagram measuring "assurance of existence" on the horizontal axis while the vertical axis expresses the economical feasibility of extraction. The Mckelvey Systems are generally used to assess a "single mineral 'commodity". However, in this case the system is adapted to show the entire range of mineral resources present or likely to be present in Fiji. For such a small area as Fiji's, hypothetical resources cannot be shown with any stated statistical probability. Nevertheless the system illustrates in a basic way the resources long-term potential and provides a useful basis for analysing various factors that could change the overall resource picture from paramarginal to economical or vice versa due to variables such as production cost, metal prices and technology advances which are capable of changing the status of a resource.

OFFSHORE EXPLORATION

Planned programmes for offshore surveys and related activities have been carried out and regularly reviewed since the middle/late seventies, the start of government involvement in offshore survey. Beginning in 1980 long term reconnaissance survey and other commercial support projects have included research programmes for hydrocarbons, detrital minerals, hydrothermal minerals, phosphate, manganese nodules and crusts, precious corals, wave energy OTEC, engineering site surveys and data management. Hydrocarbons search and nearshore heavy-mineral exploration remain the major commercial and government activities in the Fiji EEZ.

Strategy for Future Nearshore Mineral Exploration

For future offshore activities, MRD has for survey purposes divided the seafloor of the Fiji group into:

- Shelf 0-100 m
- Slope 100-1000 m
- Ocean > 1000 m

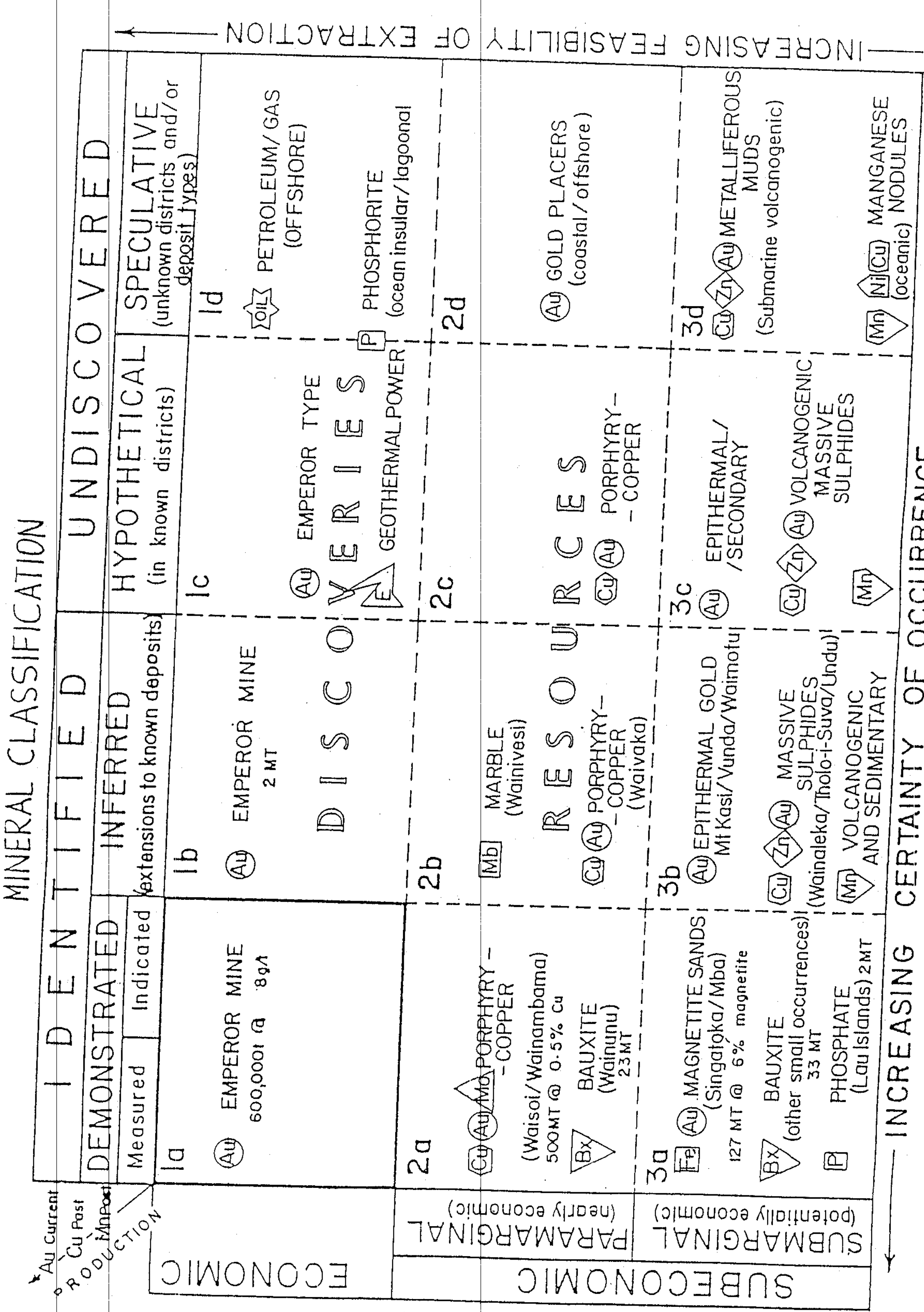
MINERAL CLASSIFICATION
INCREASING FEASIBILITY OF EXTRACTION
IDENTIFIED
UNDISCOVERED
DEMONSTRATED
Measured
Indicated
INFERRED
(extensions to known deposits)
HYPOTHETICAL
(in known districts)
SPECULATIVE
(unknown districts and/or deposit types)
ECONOMIC
SUBECONOMIC
PARAMARGINAL
(nearly economic)
SUBMARGINAL
(potentially economic)
Au Current
Cu Past
MnPast
PRODUCTION
1a
Au EMPEROR MINE
600,000t @ 8g/t
1b
Au EMPEROR MINE
2 MT
1c
Au EMPEROR TYPE
E GEOTHERMAL POWER
1d
OIL PETROLEUM/GAS (OFFSHORE)
P PHOSPHORITE
(ocean insular/lagoonal)
D I S C O V E R I E S
2a
Cu Au Mo PORPHYRY-COPPER
(Waisoi/Wainambama)
500MT @ 0.5% Cu
Bx BAUXITE
(Wainunu)
23MT
2b
Mb MARBLE
(Wainivesi)
Cu Au PORPHYRY-COPPER
(Waivaka)
2c
Cu Au PORPHYRY-COPPER
2d
Au GOLD PLACERS
(coastal/offshore)
R E S O U R C E S
3a
Fe Au MAGNETITE SANDS
(Singatoka/Mba)
127 MT @ 6% magnetite
Bx BAUXITE
(other small occurrences)
33 MT
P PHOSPHATE
(Lau Islands) 2MT
3b
Au EPITHERMAL GOLD
Mt Kasi/Vunda/Waimotu
Cu Zn Au MASSIVE SULPHIDES
(Wainaleka/Tholo-i-Suva/Undu)
Mn VOLCANOGENIC AND SEDIMENTARY
3c
Au EPITHERMAL/SECONDARY
Cu Zn Au VOLCANOGENIC MASSIVE SULPHIDES
Mn
3d
Cu Zn Au METALLIFEROUS MUDS
(Submarine volcanogenic)
Mn Ni Cu MANGANESE NODULES
(oceanic)
INCREASING CERTAINTY OF OCCURRENCE
FIG.5

TABLE I

NEARSHORE MAGNETITE AND GOLD PLACERS IN FIJI

Location	Environment	Magnetite: Approx. Recoverable Grade %	Magnetite: Approx. Reserve Million Tonnes	Gold	Comments
Ba	Offshore delta mouth	6.0 to 7.0 (1)	8.0 (1)	Traces (2)	Reconnaissance, 200 boreholes, follow up 55 boreholes, average depth 6m. 90% of reserves based on only 13 boreholes. (1)
Sigatoka	Onshore aeolian dunes	West 2.5 to 4.0, 2 Km²; East 4.7 to 6.7, 0.6 km² (1)	1.8 to 2.0 (1)	Not reported (2)	Reconnaissance and follow up. 231 boreholes at depth 13m average without reaching bedrock (1)
	Offshore marine, average water depth 20m	5.0 to 10.0 from superficial sampling only (2)	Not assessed (2)	Not reported (2)	Reconnaissance, 17 dredge stations, more sampling required for confirmation. (2)
Rewa	East Delta mouth. Low lying land, drying grounds and offshore	Approximately 10.0 (1)	0.5 (1)	Traces (1)	Reconnaissance, 51 boreholes. Gold formerly worked from consolidated alluvium on delta (1)
Tavua	Offshore delta mouth	1.8 to 2.4 (1)	0.9 (1)	Traces (1)	Reconnaissance, 22 boreholes to average depth 3m. (1)
Lodoni	Shallow marine nearshore	4.6 to 14.3 (1)	0.1 to 0.3 (1)	Not reported (1)	Reconnaissance, 12 boreholes. (1)
Navua	Offshore delta mouth and along-shore	0.4 to 1.8	Small and scattered	Not reported	Reconnaissance, 10 boreholes.
Rakiraki	Nearshore shallow marine	0.2 to 0.7	Small and scattered	Not reported	Reconnaissance, 2 boreholes.
Likuri	Estuarine to nearshore shallow marine	0.7 to 0.9	Small and scattered	Not reported	Reconnaissance, 3 boreholes.
Viti Levu Bay	Estuarine to nearshore shallow marine	0.4 to 1.0	Small and scattered	Not reported	Reconnaissance, 3 boreholes.

Location	Environment	Magnetite: Approx. Recoverable Grade %	Magnetite: Approx. Reserve Million Tonnes	Gold	Comments
Nadi Bay	Nearshore shallow marine	Not reported	Not reported	Traces	Reconnaissance, 20 boreholes, 8 dredge samples, 3 boreholes to 40 ft depth to test acoustic basement (1). High gold assays from (2) proved unreliable.

Key: Commercial Sources
(1) Viti Levu Manganex Ltd (1969 to 1974)
(2) Crawford Marine Inc. (1967 to 1973)

However for strategic planning purpose the wide-ranging government-involved programmes have had to be divided into two parts (Ocean, and Shallow Water) which to some extent define the boundaries in which active government participation and support is possible.

Ocean Research

The resources required for ocean research are well beyond the Government's capability. This type of work is best left for international research efforts within the Fiji EEZ, with SOPAC Playing the major role of international and regional coordination. By such coordination a very weIcome and very high level of international research activities on the ocean geology of the Fiji EEZ is achieved.

Shallow Marine Research

The greatest potential of impact on commercial and non-commercial development of Fiji resource is in the nearshore area. It currently includes an active hydrocarbons project of source-rock evaluation and prospectivity report on selected areas of Fiji. Future programmes are primarily aimed at identifying and detailing possible projects involving coordination between SOPAC and MRD. The programmes are also devised to allow survey to be undertaken by MRD's own in-house capability or in cooperation with other organisations.

Research Programme for Fiji's Potential Nea1shore Mineral Resources

Hydrocarbons

The hydrocarbons potential assessment of the Fiji group has been revised twice since the beginning of the assessment project. MRD has forked towards bringing together under one project all hydrocarbons studies in the nearshore area of Fiji. This will in part assist in the evaluation of hydrocarbons potential (Johnson 1987).

Recently valuable assistance has been provided by SOPAC on Fiji's hydrocarbons project. Tasks that are being considered for the assessment project are:

1. To assess the hydrocarbon potential of Fiji.

2. Seismic-reflection and geological/ geophysical investigation.
3. Interpretation of aeromagnetic data for selected sites.
4. Assessment of parameters for acquisition and processing of all multi-channel seismic. reflection data.
5. Assessment of hydrocarbon shows in exploration wells.
6. To seek and identify, by geochemical surveys, thermogenic hydrocarbons locations.
7. To determine crustal structure and estimate depth to economic basement of hydrocarbon locations.
8. To identify and coordinate with SOPAC the possibility of drilling exploratory bore holes for hydrocarbons potential of probable structures.

Nearshore Metalliferous Minerals

The development plan for metalliferous minerals includes preliminary geophysical and geological sampling of identified potential areas. Reports and maps are to be provided from results of preliminary surveys to provide the data base for further detailed work. Significant deposits are to be evaluated for the possibility of economical extraction.

Phosphate

Fiji's main objective for phosphate is the assessment of submarine deposits in shallow-water areas.

Tasks involved include:

a. The reconnaissance bathymetric and sampling survey of areas in the Lau Group where phosphate deposits are likely to occur.

b. Follow-up and detailed survey of promising occurrences of phosphates.

c. Economic evaluation of any extractable phosphate deposits found.

MINERALS-DEVELOPMENT POLICY

The viability of a minerals-development policy is guided by various factors ranging from the geological probability that a particular mineral deposit is present, is explorable (discoverable) and is extractable using modern methods, t political, economic factors and local cultural aspect that can affect its success. Substantial financial risk is involved in mineral exploration. The risks are usually so great that developing countries like Fiji are not prepared to take the burden of the not-inconsiderable cost involved; rather than gamble its limited resources it lets the mining companies bear the burden by stimulating private sector interest.

The fundamental requirement for miner exploration is a data base of essential geological information in the form of regional and detail geological maps, together with accompanying geological, reports.

In Fiji, 1:50,000 scale maps and accompanying bulletins are available for most of the country.

A standard condition of prospecting licences in Fiji requires the submitting of full detailed arts at the end of each year's work. The report should contain full details of all work done, including raw and interpretative essays, methodology, consultants reports, maps, plans, etc.

On termination of the prospecting licence it is a condition in Fiji that all data become the property of the Government, managed by MRD. The data are, in most instances, catalogued, indexed for reference and placed in the MRD library for public use. At present there are over 500 volumes available which are providing an extremely valuable stimulus for further exploration work.

Licensing Policy

In Fiji a Special Prospecting Licence is granted to a company wishing to carry out mineral exploration. The licences are usually granted for a period of one year at a time and are renewable provided the terms of the licence are not violated. Each licence is issued on the basis of an agreed expenditure and work-programme commitment. Also, as noted earlier, a full report on all work undertaken during the year is required as a condition of retaining the licence.

The exploitation rights are quite separate from exploration rights, and are subject to negotiation between the government and the company once the mineral discovery is made.

Government Policy and Legislative Actions

Fiji's future policy on nearshore exploration includes:

a) The carrying out of a systematic nearshore and shallow water geological survey.

b) Reporting, mapping and gathering basic information **on** hydrocarbons, metalliferous minerals, aggregates, geological hazards, development of reef engineering and environmental programmes.

c) Making available to government: and (commercial bodies data on nearshore mineral development prospecting, exploration and exploitation activities within Fiji's EEZ.

The strategy for the implementation of the policy will include:

1) The continuation of SOPAC coordination in specialised government projects and regional geological surveys of deep-water area within Fiji's EEZ.

2) Provision to government and commercial sectors of an adequate survey and advisory service of nearshore zones.

3) Provision of specialist training for local staff and recruitment of high-calibre staff of local origin.

SELECTED BIBLIOGRAPHY

COLLEY,'H. 1976: Mineral Deposits of Fiji (Metallic Deposits). *Fiji Mineral Department Memoir 1:* 123 pages.

GA SS, .A. 1980: Cruise Report. Fiji Offshore Survey Cruise FJ-80 (1). *CCOP /SOPAC Cruise Report* 46: 3 pages, 2 appendices.

GREENBAUM, D. 1982: Notes on the Preparation of Geotechnical Reports Required Under the Conditions of (Special) Prospecting Licences., *Fiji Mineral Resources Department Report 33.*

GREENBAUM, D. and PLUMMER, H. 1981: Mineral Development Policy and Resource Classification - Fiji Case Study. *Fiji Mineral Resources Department Note BP* 17/29. Unpublished.

HARPER, J. 1988: Offshore survey for precious corals in the Lau Group of Fiji, 10 to 27 May 19 8. *CPOP/SOPAC Cruise Report* 125: 54 pages.

HOLMES, R. 1981: Nearshore Magnetite and Gold Placers in Fiji. *Fiji Mineral Resources Department Note BP* 23/8. Unpublished.

HOLMES, R. 1982: Major Offshore Survey Plans. *Fiji Mineral Resources Department Note BP* 23 3. Unpublished.

JOHNSON. 1987: Revision of CCOP /SOPACI Project: Assessment of the Hydrocarbon Potential of Fiji *Mineral Resources Department Note BP* 48/2. Unpublished.

PENN, ,N. 1980: The Environmental Consequences and Management of Coral Sand dredging in the Suva Region. Institute of Natural Resources, USP. Unpublished.

MINERAL RESOURCES OF GUAM AND THE MARIANA ISLANDS

by

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INTRODUCTION

The 1200 km long Mariana Arc is at eastward bowing, 200-300 km wide ridge-like body lying between the Mariana Trough (2000-4000 m deep) on the west, and the Mariana Trough (> 800 m deep) on the east. Two, parallel but geologically distinct, island chains are present along the western margin of the arc.

The oldest of these island groups, spanning about 200 km, is located in the southern part of the arc and includes, Guam, Rota, Tinian, Aguijan, Saipan and some smaller ones (south to north). Guam and Saipan are known to consist of Eocene, Oligocene and Miocene volcanic rock (basaltic, andesitic and dacitic) and volcaniclastic sediments capped by Miocene- Pleistocene limestones (reef, reef flat, and bank facies). Rota and Tinian are reported to have "volcanic cores" surrounded by limestones similar in age to those on Guam and Saipan. [The long island, Aquijan, is omitted here for lack of data].

The second island group (including associated seamounts) are volcanoes, of similar rock composition as the older group and some are active today. They are believed to have originated in latest Pliocene time and are distributed over nearly the full length of the arc along its western edge. These volcanoes are not capped or overlapped by any significant limestone deposits.

GUAM

Guam is 48 km-long and has a land area of about 550 km^2; it is the largest of the southern Mariana island group. The northern half of the island is a plateau underlain by Miocene -Pleistocene limestones; the southern half is mainly hilly and underlain by Eocene, Oligocene and Miocene volcaniclastic rocks, tuff, limestone, basalt flows, and intrusives. Some of the plateau limestones of northern Guam also extend south and into this area.

A northwest-trending normal fault separates these terrains across the approximate middle of the island.

Resources

Onshore

The major onshore resource recognised on Guam is limestone rock which is now being extensively quarried at two places in the northern plateau area. The rock is broken up to form aggregate for road and other construction work, or crushed to form calcareous sand for use in making concrete. There are no figures available on current production. Removal of beach sand is forbidden and dredging of reefs and lagoons tightly regulated.

With the possible exception of some informally reported (but unverified) small-scale manganese mining by the Japanese prior to World War II, published geologic reports do not indicate any significant mining operations prior to the 1960's on Guam and none apparently have occurred since. Manganese oxides have been noted staining and replacing Miocene limestones but these occurrences have evidently not have been considered of commercial significance.

Weathering has produced lateritic soils, some containing bauxitic material, but the general thin soil layers suggest that these deposits are not attractive future sources of iron and aluminium. Phosphatic deposits have not been reported on Guam.

Black sands, including magnetite (4-5 %) occur on beaches of southeast Guam and may offer some potential offshore as commercial placer deposits associated with submarine terraces.

Offshore

Offshore Guam, the sea floor drops rather quickly, especially along the southwestern flank of the island where the 1000 m depth contour lies 4 km from shore. Four, rather narrow submarine terraces can be traced around the island above the 100 m depth, and the detrital materials forming their surfaces may offer some limited possibilities for placer mining (e.g. magnetite). Phosphatic deposits may lie submerged beneath the submarine terrace deposits although the apparent lack of on-land phosphatic guano deposits suggests that chances of encountering buried phosphate offshore is probably nill. Calcareous sands carried offshore by au rents, if abundant, could be recycled back on the island.

Precious coral may be present offshore but its existence is not known to the writer.

At present there are no nearshore mining operations underway off Guam. In the near future, however, submarine salvage work on a Spanish galleon and possibly World War II wrecks, may begin and such operations may indirectly reveal resources of commercial value (e,g. magnetite, calcareous sand, etc.).

SAIPAN

The second largest island in the southern Mariana group is about 20 km long and possesses slightly less than 1/4 the land area of Guam. The stratigraphy of Saipan is similar to that of Guam but the geologic structure differs somewhat in that the island tends to be divided along its long axis by northeast-trending faults.

Resources

Onshore

Saipan was actively mined by the Japanese prior to and during World War II. Perhaps, 13,500 tons of high grade manganese oxide ore were shipped to Japan. Upwards of 12,000 tons of high grade ore may still exist on Saipan. The manganese oxide occurs as veinlets in dacitic rocks, and as stains and replacement deposits in limestones.

Literitic soils (crusts) occur on Saipan but do not appear to form a source for commercial iron. Phosphatic guano was mined by the Japanese with about 88,000 metric tons being taken and this resource is now reported to be depleted. The Japanese reported traces of gold and silver, associated with sulfides in quartz boulders, but no commercial production apparently ever occurred. Bauxite apparently does not occur on Saipan in commercial quantities if at all.

Quartz sands, apparently derived from dacitlc rocks, occur as terrace deposits and as beach sands. Total volume is small but this resource could be useful to the local economy in concrete production. Limestone is quarried on Saipan, apparently for construction purposes.

Offshore

Terrace-like features, some possibly developed by faulting, occur offshore around Saipan down a 1000 m. The deposits forming the surfaces of the shallower terraces (above 100 m depth) may conceal phosphatic rock and possibly manganiferous are deposits. About 5 km west of Saipan is an elongate, 9 km-Iong submarine bank (Saipan Bank) having a broad, nearly horizontal surface, lying at about a 20 m depth. This feature may be a source for placer minerals (e.g. gold) on the surface and phosphatic guano and manganese are beneath the bank sediments. Marine phosphorite may also have formed on top of the bank if upwelling has occured associated with an abundance of nutrients. Calcareous and siliceous sands may occur in large quantities offshore and if presence could be recycled back to the island for local use if onshore sand sources are depleted.

Black coral may be present offshore but its presence is not known to the writer.

No mining operations have been reported underway in the offshore area around Saipan at present although dredging in front of hotels has occurred to facilitate tourist recreation.

TINIAN AND ROTA

Both of these islands have "cores" of early Tertiary 'volcanic" rocks and are capped by younger Cenozoic limestones. Phosphatic guano was mined extensively on Rota by the Japanese, and a very small amount was also taken from Tinian. The future potential for phosphatic guano production on these islands is not clear but limited quantities may remain. It is estimated that led that about 50,000 tons remain on Rota. No current mining operations have been reported from either island, whether offshore or onshore.

YOUNG VOLCANO/ISLAND GROUP

Mineral resource studies of these islands are not known to the writer. These islands should be systematically studied to fully understand their mineral potential, if any.

SUMMARY

Limestone rock appears to be the principal economic mineral resource on Guam, Rota, Tinian, and Saipan. Previous concentrations of manganese (Saipan) and phosphatic guano (Saipan, Tinian, and Rota) are probably depleted but some re-evaluation of Rota and Tinian phosphate potential appears warranted. Onshore terrace surfaces of Guam and Saipan, and the Saipan Bank may be targets for placer deposits (gold, magnetite and quartz sands). Phosphatic guano and manganese oxide may lie beneath the terrace deposits of Saipan. The Saipan Bank may also include phosphorite as a surface deposit. Black coral may be present in the offshore but direct knowledge of this resource is not known to the writer.

RECOMMENDATIONS

Mapping of the nearshore and coastline areas of the southern Mariana Islands, especially Guam and Saipan, including bottom sampling and geophysical work to determine submarine topography, distribution and thickness of sediment and bedwork profile should be undertaken, long with hydrodynamic studies of coastal waters, as first "baseline" steps in the exploration for nearshore mineral resources, and as preparation for future physical development of the coastal area related to tourism, commercial activities, and governmental uses.

DATA ON NEARSHORE MINERAL RESOURCES POTENTIAL AND LICENSING REQUIREMENTS IN PAPUA NEW GUINEA

by

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October 1988

ABSTRACT

The majority of nearshore mineral resources identified throughout PNG are heavy mineral sand deposits, situated in beach type environments and nearshore dunes. Three major commodities are present. The most common commodity is represented by titaniferous magnetite sands which are mainly derived from Tertiary volcanics. Less abundant are chromite and olivine sands which originate from ultramafic rock of Cretaceous age. Exploration for these deposits was most active between 1965 and 1975 and resulted in the location of several beach sand deposits, all of which are presently not commercially exploitable. The legislative framework for eploration in Papua New Guinea is outlined in the Mining Act which is currently being reviewed. Exploration in offshore areas is, at present, prohibited since prospecting authorities are not granted for areas over water. This 1mb/em will be addressed by the new Mining Act which may become effective during 1989.

INTRODUCTION

The most important nearshore mineral resources in Papua New Guinea are situated in each type environments and are mainly represented by heavy mineral sands. Offshore deposit will not be addressed here because exploration in offshore areas of Papua New Guinea (PNG) is prohibited under the current mining act. Alluvial deposits are not directly associated with the nearshore environments and will also not be discussed here.

The shoreline of Papua New Guinea is more than 2000 km long and source rocks for heavy mineral sands are abundant (Figure 1). Hence there is a high potential along the shorelines of Papua New Guinea for heavy mineral beach sand deposits, and many deposits of this kind have already been identified (Power-Fardy, 1985). Important questions relate to the economic potential of these deposits as well as the licensing requirements for exploration. These questions will be addressed below.

Formation of nearshore mineral sand deposits:

The conditions that must initially be met for the formation of a heavy mineral sand deposit are essentially the same as for alluvial deposits. A suitable source rock area must be present which is exposed to erosion and effective drainage. However, the final concentration of heavy minerals forming a beach sand deposit is governed by processes different to those of alluvial placers in general, several depositional cycles are required before an economically viable deposit is formed. During transportation within a fluvial environment, the relative concentration of heavy. minerals is enhanced by removal of components that present little resistance to abrasion and weathering. The subsequent and most important process for the concentration of heavy mineral in beach deposits, is wave action assisted by tidal movements, and long-shore currents. The consistent action of waves very effeciently concentrates weathering resistant components and is also an effective gravity sorting process. With the help of tidal movements, large areas of the coastline are exposed to wave action at regular intervals. Long-shore currents facilitate transportation of heavy minerals parallel to the shoreline, and deposits of heavy mineral sands frequently form at natural traps such as headlands and other distinct morphological features of the shoreline.

Nearshore deposits are constantly changing. They are not only effected by long term variation, like relative sea-level changes, but also by short term episodic events such as storms. Hence nearshore deposits can be upgraded, downgraded, or even destroyed over short intervals of time.

Heavy mineral deposits may be present as beach sands, offshore bars or as aeolian lag type deposits. The latter are most likely to form on open beaches that have raised terraces. Lighter particles like feldspar and quartz grains are effectively separated from heavy minerals by wind energy. This process relatively enhances heavy mineral concentration and some of the richest deposits are located at the bases of dunes.

HEAVY MINERAL SAND DEPOSITS IN PAPUA NEW GUINEA

All the basic conditions for the formation at a heavy mineral sand deposit are met in Papua New Guinea. There is no shortage of potential source rock for heavy mineral sands since volcanic assemblages are abundant and ultramafic rocks, in particular ophiolites, are also represented (Figure 1). Transportation of heavy minerals is facilitated, since the climate is

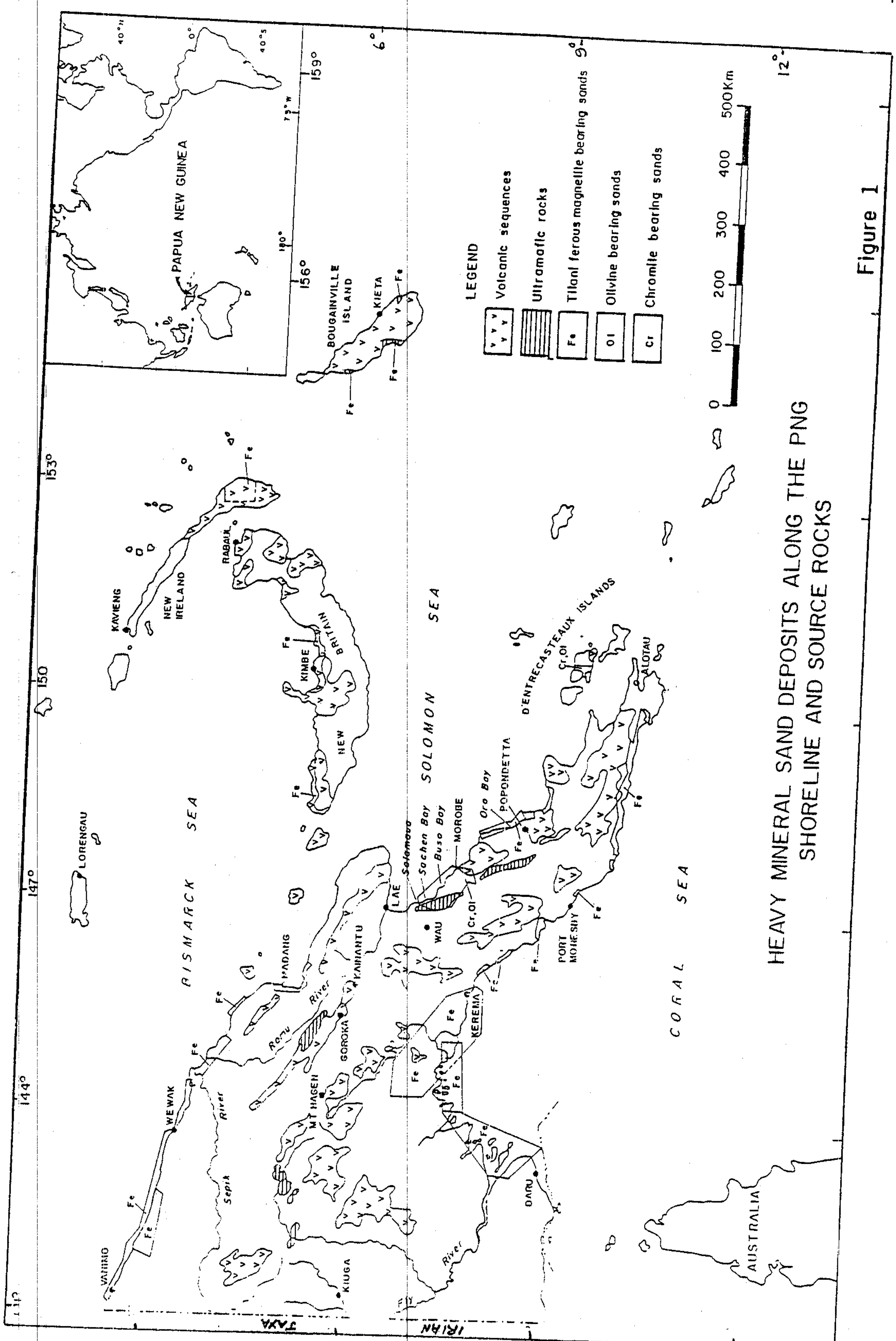

Figure 1. Heavy mineral sand deposits along the PNG shoreline and source rocks.

tropical equitorial and suitable river system, are abundant. Most rivers flow through steep mountainous terrain over long distances and maintain a high current energy enabling them to transport large quantities of bedload. Along an extensive shoreline, nearshore sediments above wave base are subjected to the energy of waves, which relatively concentrate heavy minerals. However, coral reefs, situated a few metres to several kilometres offshore, form a rim around much of Papua New Guinea. These reefs weaken the important process of wave reworking by shielding the shoreline from high energy waves.

Varieties and uses of heavy mineral sands in Papua New Guinea

Heavy mineral sand deposits occur in three major varieties throughout Papua New Guinea. These are titaniferous magnetite sands, chronite bearing sands and olivine bearing sands.

Titaniferous magnetite sands are used to produce the metal titanium. Titanium is strong, light and highly corrosion resistant. For these reasons it is widely used in the aerospace industry, e.g. for jet engine components. It is also a popular steel additive and finds further applications in the chemical industry.

Only a small percentage of chromite ore is ever converted into the metal chromium, while larger amounts are used as steel additives in the form of its ore (chromite). For these uses the purity of chromite generally determines its value.

Olivine is most widely mined for foundry sands, which are used to make forms for casting metals, ,and it also serves as a lining material for fire resistant furnaces. The mineral alternatively find applications as an ingredient of fertilizer at as raw material for the preparation of magnesium sulphate and chloride.

Locations and source rocks of heavy mineral sand deposits

The major areas of titaniferous magnetite sands are located in the Gulf of Papua between Daru and Kerema, on the southeast coast, on the north shore near Popondetta, on New Britain, on New Ireland and on Bougainville Island (as shown on Figure 1). These sands are mainly derived from volcanic source rocks of Tertiary and Quarternary age (Lowenstein, 1974).

Chromite bearing sands and olivine bearing sands are not as common as the titaniferous magnetite sands but major occurrences have been noted along the north coast between Salamaua and Morobe, near Vanimo and also on the D'Entrecasteaux Islands (Figure 1) and Lowenstein (1974). The source of these deposits are ultramafic rocks, mainly ophiolites. Chromite derived from ophiolites generally contains many impurities, mainly iron, and hence doe not represent a high quality ore.

Description of the major heavy mineral sand deposits in PNG

Titaniferous magnetitesands

Extensive deposits of magnetite bearing sands have been located on the north shore between Wewak and Vanimo (Figure 1). Unfortunately they are impure, contain a high percentage of silicate minerals , and the magnetic fraction is generally less than 3 % with an ilmenite content of less than 1 %. (Power Fardy, 1985). Rutile and zircon are present in traces. These deposits were evaluated by CRA in 1 70 -1971 and at that time were not considered to be economically viable.

Magnetite sands are also present on the north shore at Oro Bay (Figure 1) and contain a heavy mineral fraction of up to 25 %. The heavy mineral fraction primarily consists of titanomagnetite and ilmenite, with zircon, rutile and chrome oxide composing less than 0.1% (Steer, 1970). Based on these results, the deposit is considered uneconomical at this time.

Other titaniferous magnetite sand deposits have been located in the Popondetta area (see Figure 1). The magnetic fraction in these deposits was found to be less than 6 % and ilmenite, the main titanium mineral in these sands, constitutes generally less than 0.4 % of the magnetic fraction. The source rocks for these deposits are Miocene to Quaternary age volcanics. Trace amounts of rutile, zircon and chrome oxide have also been identified. Several companies evaluate the economic potential of heavy mineral sands in this area between 1970 and 1974; however none considered the deposits to be commercially exploitable. Extensive black heavy mineral land are present along the southeastern coastline of Papua (see Figure 1). These deposits were derived from volcanics of miocene to Pliocene age situated directly inland. Unfortunately, the average magnetic fraction of these deposits is generally less than 4 %. The predominant magnetic mineral is titanomagnetite, which locally exceeds 70 % of the overall composition. However, these locally high accumulations of titanomagnetite are of limited volume and are not extensive enough to form an economically viable reserve (Berkman, 1972).

The most extensive beach sand deposits in Papua New Guinea are located in the Gulf of Papua, between Daru and Kerema (shown Figure 1). The Source rocks are primarily the Quaternary volcanics partly covering the northernmost part of the Fly Platform. The percentage the fraction in these sands is highly variable and is commonly as low as 3 %, only exceeding 70 % locally. Titaniferous magnetic forms the largest portion of economically interesting mineral in these deposits with zircon, rutile, vanadium oxide and chromium oxide as minor components (Manser, 1971; Klammer, 1965). These sands have not been exploited because of a lack of high grade reserves. The potential for offshore deposits in this area was recognised by Manser in 1971, but offshore exploration was not conducted.

Magnetite beating sands occur on New Britain and New Ireland (see Figure 1). The islands are a part of the Melanesian Island Arc and the source rocks for titaniferous magnetite sands are miocene to Quaternary volcanics. However, the low titanium contents of the magnetite sands render the deposits uneconomical (Figure 1).

On Bouganville Iand (see Figure 1) many of the beach sands contain high concentrations of magnetite and the heavy mineral fraction may locally exceed 95 %, with titaniferous magnetite composing 99 % of that fraction (Burger, 1960; Thompson, 1961), The maximum titanium oxide content of this fraction is approximately 4 % (Thompson, 1961). However, the heavy mineral concentrations appear to be shallow and because of a lack of the sands are considered uneconomic.

Chromite bearing sands

Cummings (1969), identified local accumulations of chromite bearing sands northwest of Vanimo the Irian Jayan border (Figure 1). The heavy mineral content of these deposils was great than 80% with chromite being the most abundant mineral. The magnetite content was less than 8 % and minor constituents include ilmenite, zircon, rutile and monazile (Rebek, 1971). However, the deposits are small in volume and are not presently considered to be commercially exploitable.

The most important deposits of chromite bearing sands in PNG were discovered along the shoreline south of Lae between Salamaua and Morobe (Lowenstein, 1974; Nutter, 1972). The major outcrops of ultramafic rocks located directly inland of these chromite bearing sand deposits were identified as the source area. Metallurgical grade chromite is present in these deposits and samples with up to 35 kg of chromite per cubic metre were obtained. An overall potential of 153 million cubic metres of chromite was estimated at a chromite prospect at the mouth of the Sela River by Metals Exploration in 1971. Other prospects of chromite bearing sand were located in Sachsen Bay and Buso Bay (Figure 1). Resource estimates of chromite sands along the coast between Salamaua and Morobe have been placed at up to 200 million tonnes with an average grade of 1.5 % chromite (Lowenstein, 1974). These grades are at present not considered economical because of high concentrations of impurities within the chromite.

There are several chromite bearing beach sand deposits on the D'Entrecasteaux Islands that are derived from ultramafic rocks. The heavy mineral content of those sands are generally in the order of 10 % and less, with chromite having a share of up to 50 % in the heavy mineral fraction. Any further development is at present considered to be uneconomic because of the small reserve potential of the individual beach deposits (Power-Fardy, 1985) and the poor quality of the chromite.

Olivine bearing sands

Olivine be ring sands are present about 30 km south of Lae and also on the D'Entrecasteaux Islands (Figure 1). They are derived from ultramafic rocks of Tertiary age. High grades are local y present but the overall quantities are too small to justify development (Power Fardy, 1985).

LICENSING REQUIREMENTS

The main purpose of the Mining Act of Papua New Guinea is to provide a legislative framework which assures that exploration and mining are conducted to the benefit of both the title holder and he people of Papua New Guinea. The Mining Act is currently under review and the new act, which is expected to be released during 1989, will attempt to simplify procedures and address problems that are not handled satisfactorily by the existing Mining Act. One of the issues addressed ill be prospecting authorities over water. Under the present Mining Act a prospecting authority can only be granted over an area of land above low water mark. This makes exploration in offshore areas illegal. Under the new Mining Act this legislation is expected to be abandoned and prospecting authorities over water will be granted under similar conditions a those on land. The conditions are briefly outlined below.

Prospecting Authority Guidelines

In order to legally carry out prospecting in PNG, a prospecting authority is required. It is laid down in the Mining Act that a prospecting authority may be initially granted for up to 2 years. Subsequent renewal periods for up to 2 years are possible and are normally granted if past performance as been satisfactory. The area of a prospecting authority cannot exceed 2500 square kilometres. If larger than 250 square kilometres the area of the initially granted prospecting authority must be reduced by 50 % after each term. A fee of 2700 $US (2500 Kina) is payable with the initial application and the applicant is required to give evidence that he will be able to finance work programme meeting the Department of Minerals and Energy guidelines. Prior to granting of a prospecting authority, the applicant is required to pay the first annual rental, calculated at 51 cents (50 toea) per square kilometre and to lodge a security bond against non-performance. This is normally 1100-2200 $US (1000-2000 Kina), depending on the size of the prospecting authority.

The guidelines specify that during the initial 2-year period a minimum expenditure of 110 $US (or 100 Kina) f r each square kilometre within the prospecting authority is expected. With the departments agreement, this amount can be reduced if an acceptable programme is proposed. The amount of expenditure per square kilometre is doubled during the second two year term. However, the overall amount to be spent on the prospecting authority generally does no increase because the area is reduced by 50 %. For additional extensions, an expenditure of 55 $US (or 500 Kina) per year for each square kilometre is expected.

Joint ventures are rarely allowed during the initial 2-year term which in most cases will comprise a "grass rots" exploration programme. During subsequent terms, however, joint ventures are commonly approved. It is recognised that the addition of a new partner can bring needed risk capital and additional expertise to a prospect.

While holding a prospecting authority, companies are required to submit reports to the Department of Minerals and Energy on a regular basis. These serve the purpose of informing the government on the progress of the exploration and providing data base on the geology of Papua New Guinea. The following four report types are required, and additional reports may be requested in special circumstances.

1) Biannual expenditure and prospecting proformas

These give a very brief outline of the work performed during the previous 6 months and contain of expenditure, which remains confidential indefinetly.

2) Annual Reports

In annual reports all P.A. related work conducted during the previous 12 months is described and discussed, an outline of investigation methods is to be given, and all relevant information like geological and geophysical maps, assay results, drill core logs etc. must be provided. Annual reports remain confidential during currency of a prospecting authority.

3) Relinquishment Reports

If a company decides to surrender a prospecting authority or a portion of it, a relinquishment report must be submitted. This report shall outline all work conducted on the prospecting authority, or the surrendered portion, during the previous 12 months. A surrender is not effective until accepted by the minister.

4) Final Reports

A final report is due on expiry or termination of a prospecting authority. In this report all work conducted in the prospecting authority since the initial grant must be summarised and the conclusions reached should be presented and discussed.

It is beyond the scope of this paper to discuss in detail the development from an exploration project into a mining project. If a company decides to undertake mining, environmental studies and feasibility studies will have to be conducted. The kind of detail requested by the government depends on the expected scale of the project. Small projects can be readily approved within a short time, but large projects require a development agreement as well as an equity agreement, which will have to be negotiated with the government of Papua New Guinea. After all steps have been followed, the proposal for a large development has to be a provided in total before construction can start.

The flowchart shown on Figure 2 (from Evesson, 1988) shows in detail the procedures to follow for the licencing of major mining projects. For small scale projects many of the steps are simplified or omitted.

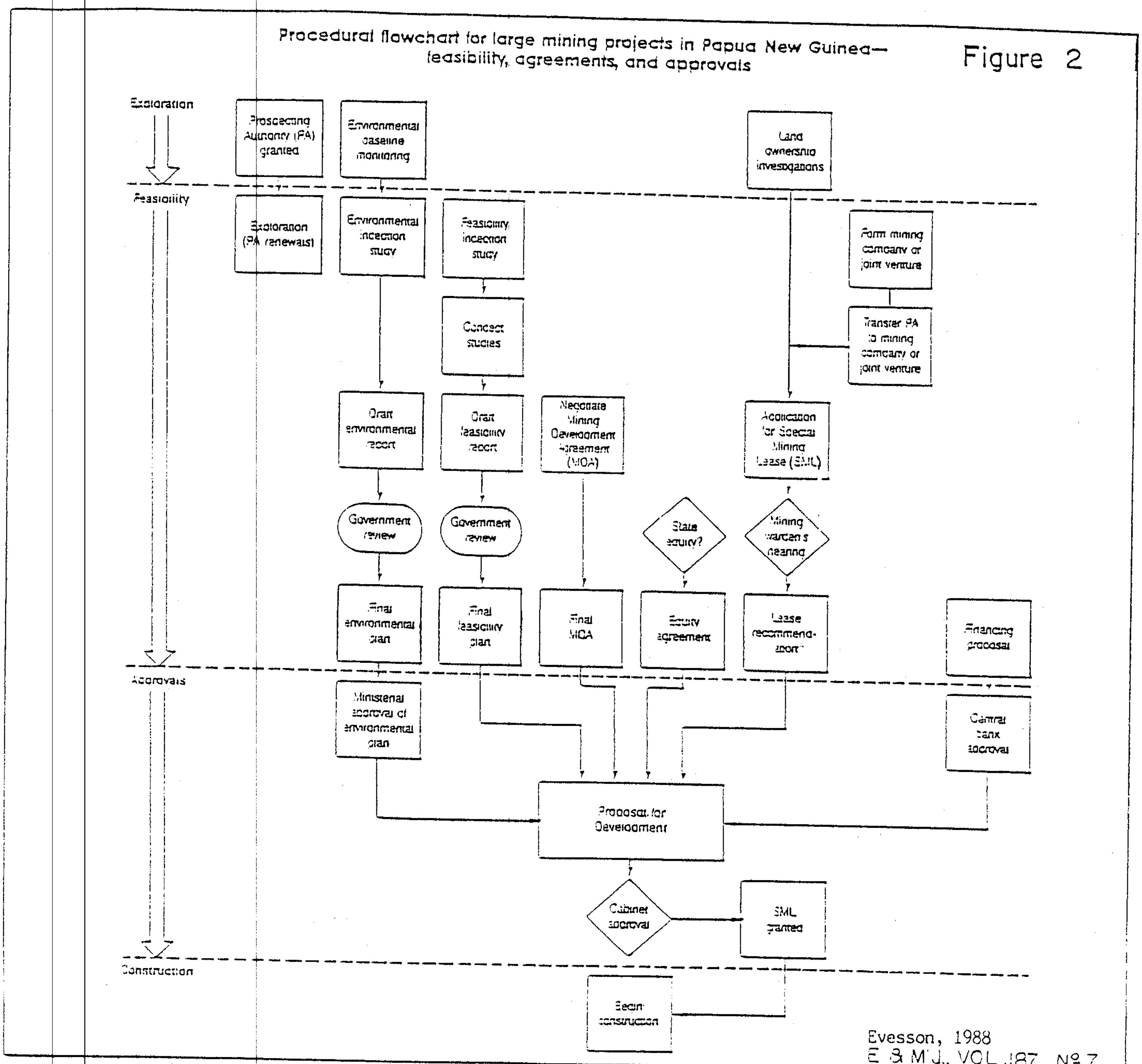

Figure 2. Procedural flowchart for large mining projects in Papua New Guinea - feasibility, agreements, and approvals.

SUMMARY AND CONCLUSIONS

The heavy mineral beach sand deposits which have been discussed in this paper have been all assessed as non-economic. The exploration on those prospects was mainly carried out prjor to 1975 and currently no prospecting authority is held by any company for exploration on any shoreline for heavy mineral sand deposits in Papua New Guinea. The various deposits have limited economic potential for following reasons. Most commonly the concentration of commercially interesting minerals are too low for profitable exploitation, and in some cases the volume of individual high grade deposits is insufficient. This mainly applies to magnetite and olivine bearing sands while the poor quality of the ore, at present, renders the chromite bearing sands of Papua New Guinea non-economic. A potential for offshore titaniferous magnetite sand deposits exists in the Gulf of Papua west of Kerema. Exploration in offshore areas, although not possible at present, is expected to be permitted in the near future under the new Mining Act.

REFERENCES

BERKMAN, D.A. 11972: Summary of mineral exploration in Eastern Papua, 1969 to 1972. AOG Minerals Pty Ltd. (unpublished).

BURGER, D. 196q: Beach sands from Bougainville Island. TPNG. *BHP Company Ltd, Petrological Report 50/60* (unpublished).

CUMMINGS, I.S. 1969: Information on beach sands, Vanimo. Geological Survey Papua New Guinea technical file.

EVESSON, D.T. 1988: Exploring for gold in Papua New Guinea. The rules and the costs. *Engineering and Mining Journal, Volume* 189, *Number* 7: page 37.

KLAMMER, G. 1965: Heavy mineral beach deposits and natural gas in Papua. Geological Survey of Papua New Guinea technical file. (unpublished).

LOWENSTEIN, P.L., 1974: Mineral sands in Papua New Guinea. *Geological Survey of Papua New Guinea Report 7:4/29.*

MANSER, W. 1971 Mineral sands in the beaches of the Gulf of Papua between Kerema and the Purari River, P,A 95 (P). Gumance Planations Ltd. (unpublished).

NUTTER, A.H. 1972: Quarterly report No.1 for P.A. 248 (NG) Morobe District, Eastern New Guinea. Amax EXploration (Aust). Inc. (unpublished).

POWER-FARDY, D., 1985: Commodity review: Beach sands of Papua New Guinea. *Geological Survey of Papua New Guinea Report 85/9.*

REBEK, R.J. 1971: Final Report on P.A. 221 (NG) - Wewak CRA Exploration Pty Ltd. (unpublished).

STEER, M.D. 1970: Final Report on P.A. 66 (P) - Gona, Papua. Exploration Enterprises Pty Ltd. (unpublished).

THOMPSON, J.E. 1961: Magnetite beach sands of Bougainville. *BMR Australia, Records 1961/97*.

NEARSHORE MINERALS, SOLOMON ISLANDS

by

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INTRODUCTION

Nearshore minerals have never been investigated thoroughly in the Solomon Islands. Both the Government and the private sector concentrated on onshore minerals more than nearshore minerals.

Initial investigation on nearshore minerals commenced in the 1950's and 1960's mainly by the Government and researchers like R.L. Stanton. Private companies were involved in the investigations more recently. These early investigations were confined mainly to heavy sands and gravels over the main islands with exception to San Cristobal (Makira).

Only two nearshore mineral deposit types were investigated - the placer deposits and precious corals.

PLACER DEPOSITS

Placer deposits covered in this report are heavy sands and gravels or beach deposits containing the following minerals; ilmenite, magnetite, zircon, gold, chromite, hornblende, pyroxene. The most important are ilmenite, chromite and magnetite. All three occur on Choiseul, Santa Isabel, Malaita and Guadalcanal. Magmetite occurs in nearly all of the islands whereas chromite occurs mainly on Choiseul (Sirika Slay), North Guadalcanal and San Jorge. A sub-economic olivine beach sand, containing about 2 million tonnes, was reported from Baniata Pint, Rendova Island (Thompson, 1965), and other olivine beach sands are known to occur at Ranongga. Minor occurrences of hornblende, pyroxene and zircon were reported from Guadalcanal and Malaita.

All these beach deposits are Quaternary in age. They originate from andesite, basalt or ultrabasic rock formations inland and are washed to the sea by rivers, and then deposited on the coasts by wave action.

Past investigations have reported only occurrences of these minerals. There was not enough follow-up to prove any possible reserves. However, a few resource estimates were made: 2 million tonnes of ferromagnesian (olivine) sand from Baniata Point, Rendova Island: and 9228 tonnes of magnetite at Lithogohira Bay, West Santa Isabel. Chromite occurs in the beaches of east, northwest and west San Jorge, and small prospects exist at the west and northwest of the island. Follow-up work is needed beyond the results obtained so far, if any possible reserves are to be established.

Placer gold is known only in north and northeast Guadalcanal, and Siruka Bay, Choiseul. The occurrence at North Guadalcanal was certainly derived from the Gold Ridge deposit via the Matepona River. In November 1975, a nearshore bottom sediment sampling programme and sub-bottom reflection profiling survey was undertaken off the north coast of Guadalcanal to investigate the gold content of terrigenous sediment transported from the Gold Ridge area by the Matepona River. Sampling of beach sands was also undertaken. Gold grades above detection limit of 0.02 ppm were obtained for offshore, wheareas beach samples yield grades of re than 2 ppm gold. No follow-up work was undertaken.

Perhaps the most promising nearshore placer deposits are the ilmenite beach sands of Malaita which occur at Kwai Harbour, Fakanakafo Bay, Ata'a cove and the area between Kwai Harbour and Kwaimba'ita River. Zanex Ltd in 1986 investigated these areas and concluded that he ilmenite is so intimately associated with magnetite that it cannot even be partially separated magnetite separation process, but other approaches might prove them to be economic.

PRECIOUS CORALS

Precious coral is another potential nearshore mineral in the Solomon Islands. The first known investigation on precious corals was in 1978 when staff of Solomon Islands, Papua New Guinea, Vanuatu, Kiribati, Western Samoa, Tonga and Cook Islands carried out some dredgings. result *Corallium* was found in the Solomon Islands, Vanuatu, Western Samoa, Tonga and Islands.

In the Solomon Islands, 30 sites are surveyed during this programme within a defined prospective zone from makira to Vella Lavella. *Corallium* has been found at twelve of these sites Three species of *Corallium* have been found. The most promising specimens were from an area spanning the Indispensable strait from North Malaita to Marau off eastern Guadalcanal.

As a result of this work CCOP /SOPAC (Seventh Session) made a recommendation for a systematic search for black coral. In this course a cruise was undertaken from 10 October to 25 November 1979 in the Solomon Islands and Papua New Guinea. This survey was confined to the prospective area previously defined.

Hard bottom corals were collected at 48 stations, out of which 18 species were collected. They ranged from the soft chitinous outer layers to purely calcareous species. The most common forms collected indicate a favourable environment for *Corallium* occurrence, and included calcareous hydrocorafs *(Sty taste* sp., *Stenoholia* sp., *Crypthetia* sp.), the dendrophyllid coral *Enallopsam,pia* sp., and non-commercial grogonian corals *Catyptrophora* sp., *Keroeides osaica,* and *Narella* sp.

Corallium was recovered at 14 stations and hard bottom at another 34 stations. Unlike the earlier survey, four species were found within the prospective area during this survey, and it also confirmed another *Corallium* prospective area from Ndai Island, through the Indispensable trait to Marau Sound. The following were collected from this area: one specimen of C. *konafoi. C. elatus* and another *Corallium* sp.

The existence of these specimens, the presence of several Grogonians and one Dendrophyllid frequently found in association with *Corallium,* and the favourable nature of many sites as seen from echo soundings and underwater photographs, indicate that the precious coral potential of the Solomon Islands is very promising.

PHOSPHATE

There has been no investigation of phosphate rock except for a suggestion by Cook (1975) that there is low priority possible accumulation area to the northeast of San Cristobal and Choiseul. However, there has been no fallow-up work on this suggestion.

CONSTRUCTION MATERIALS

The only known extraction of construction materials is that from Ranadi Beach inside Honiara. Sand and gravel were used intensively for various construction purposes.

LEQISLATION

There is one Iegislation (1969 Mining Act) for both onshore and offshore minerals, except construction materials. However, a new Mining Act is now ready to be tabled in Parliament for the second time, were construction materials were included. For this case a Building Materials Permit was introduced .

SELECTED BIBLIOGRAPHY

ARTHUR, J.W. 1979: Mineral occurrences in the Solomon Islands. *Solomon Islands Geological Survey Bulletin* 1~.

CONNOLLY, J.W. 1960: The beach sands of Santa Isabel, 1957. *British Solomon Islands Geological Record* (1957-1958): 57 pages.

COOK, P.J. 1975: Prospects for finding offshore phosphate deposits in the Southwest Pacific (Project CCSP-1/ **EG 11).** *Proceedings of the Third Session CCOP SOPAC (Apia, Western Samoa, 2-10 Sep ember* 1974): pages 75-85.

EADE, J.V. 1979: Precious coral: a review. *Proceedings of the Seventh Session CCOP/SOPAC Wellington, NZ, 9-16 October* 1978): pages 51-53.

EADE, J.V. 1981a: Cruise report: Solomon Islands/Papua New Guinea offshore survey SI-79(3), 10 October-25 November 1979. Section G of Part 3: Documentation, in Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific in *Proceedings of The Ninth Session CCOP /SOPAC (Tarawa, Kiribati, 20-28 October 1980):* page 74.

EADe, J.V. 1981 b: Review of precious coral in CCOP /SOPAC member countries. Proceedings of the Ninth Session CCOP /SOPAC (Tarawa, Kiribati 20-28 October 1980): pages 80-82.

GROVER, J.C. 1960: The beach Sands of Guadalcanal - Notes on J.W. Connollys investigations, 1957. *British Solomon Islands Geological Record:* pages 54-56.

RVER, J.C. 1958: Ilmenite gravels on Malaita, 1956. *British Solomon Islands Geological R cord* (1953-19581): pages 108-112.

GROVER, J.C. 1965: Notes .on a first map of Mineral Occurrences in The Solomon Islands. *British Soloman Islands Geological Record* (1959-62): pages 68-71.

PISARKI, J.P. 1968: Regional geochemical reconnaissance or beach sediments from the mouths of principal rivers in the B.S.I.P. (Aerial Geophysical Survey Project Report, UNDP-B.S.I.P. 19651 68), Honiara Government Printer, 50 pages + 6 maps and 4 figs.

PUDSEY-DAWSON, P.A. 1960: Ilmenite and garnet concentrates in the Kwai Harbour area of East Malaita, 1958. *British Solomon Islands Geological Record* (1957-1958): pages 59-60.

THOMPSON, R.B. 19~5: Olivine: green beach sands near Baniata Point, Rendova Island. *British Soloman Islands Geological Record* (1959-1962): pages 145-47.

TURNER, C.C.; EADE, J.W.; DANITOFEA, S.E.; OLDNALL, R. 1977: Gold-bearing sediments on the continentalshelf, Northern Guadalcanal, Solomon Islands. *South Pacific Marine Geological Notes* (6): pages 55-69.

INSHORE AND NEARSHORE MINERALS IN THE KINGDOM OF TONGA : COUNTRY REVIEW

by

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INlTRODUCTION

The Kingdom of Tonga consists of three major island groups (Figure 1):

Tongatapu;
Ha'apai;
Vava'u.

Nearshore mineral activity has been primarily restricted to mining sand from beaches, and harvesting precious corals. Further offshore there has been several cruises whose main aim has been the discovery of metalliferous sediments associated with submarine volcanism.

The major source of sand and aggregate for the construction industry in the Kingdom comes from mining of beaches for sand and quarries for aggregate. Sand is of major importance primarily in the construction industry, but is used extensively in burial grounds. Aggregate for roads and concrete is obtained by quarrying of palaeo-reefs and from older, finer gained recyrstallised limestone located in the south-east of Tongatapu and on Vava'u and Eua.

Before 1984 rand mining was not controlled, but because of the rising demand and importance an Act was passed whereby the Government maintains a monopoly administered by the Ministry of Lands, Survey and Natural Resources.

PROPOSED DEVELOPMENTS

There are several planned developments which will have a major requirement for sand and aggregate.

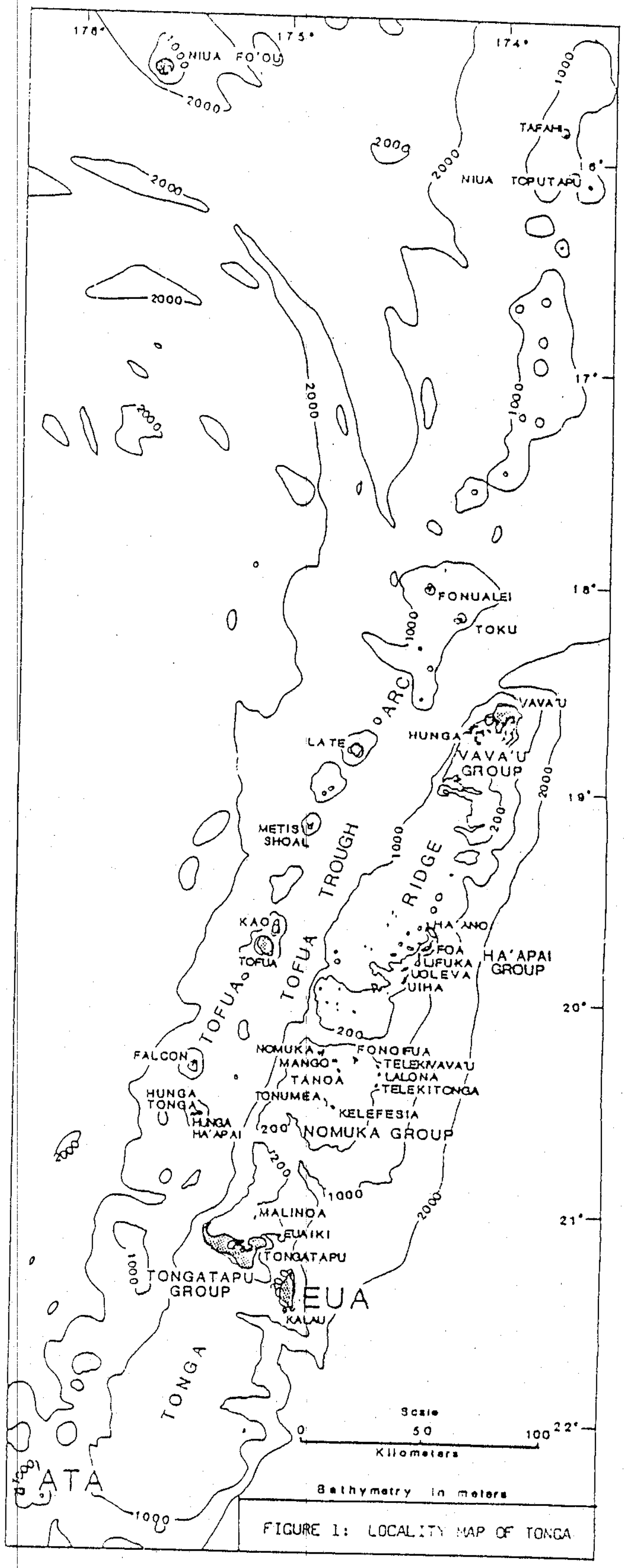

FIGURE 1: LOCALITY MAP OF TONGA

Tongatapu

- airport extension (Fua'amotu);
- causeways/bridges across Fanga'uta lagoon;
- maintenance and improvement of road system;
- extension of foreshore storm protection to the east and west of Nuku'alofa;
- major new buildings and house construction.

Vava'u

- sealing and lengthening of airport;
- major upgrading of roads;
- causeways;
- new buildings and houses.

TONGATAPU SAND AND AGGREGATE

Sand

The mining of beaches is the major source of sand in Tongatapu, where large-scale mining operations have taken place at twelve beaches, although only eight are currently being mined. Annual production is summarised in Table 1 and current rates are approximately 20,000 tonnes per annum.

The sand is stockpiled at six locations in Tongatapu and is sold at $T9.10 per tonne.

Sand reserves on the beaches are now estimated t less than 200,000 tonnes indicating that less than 10 years supply.

Table I. Weight of sand mined from beaches in Tongatapu (1987).

Name of beach
AHUA
HONONOU
FINEHIKA
KANOKUPOLU
LAULEA
LAVENGATONG
NIUTOUA
SAMALETANI
TOTAL

Aggregate

There are sixteen major quarries on Tongatapu either belonging to private contractors, Ministry of Works of Tonga Construction Company. The quarries are primarily in patch-reef deposit of Pleistocene age, although some recrystallised terrace limestones of Pliocene age are also worked.

Four of the quarries have a crusher on site and gravel is available sorted into 1", 1/2, 1/4 an "dust" grades. (Table II).

Table II. Aggregate Grades and Cost Per Tonne in Tongatapu (1987).

Grade	**Cost Per Tonne** ($)
1 inch	8.00
1/2 inch	8.00
1/4 inch	8.00
Dust	8.00

The above prices are net of tax and transport costs.

VAVA'U SAND AND AGGREGATE

Over the last few years demand for sand and aggregate has greatly increased in Vava'u.

Sand

There are about 6 beaches that are mined on the m in island (Uta Vava'u) and reserves are now very low.

The deeply indented and irregular coastline of Vava 'u results in many small sheltered beaches, many of which receive limited wave action and onIy small amounts of sand are produced. Deep water close to the shoreline also inhibits the accumulation of sand.

Since 1986 the Vava'u branch of the Ministry of Lands has mined sand from the island of Pepea and the sandbars near Olo'ua Island, which are exposed during low tide. The excavated sand is loaded onto a barge and removed at high tide. The recommended price for sand is 12.0 per tonne and $13.00 per tonne for sand mined from the beaches.

Aggregate

Aggregate is mined from several quarries in terrace and patch-reef limestones, similar tongatapu, and is sold at a similar price.

ALTERNATIVE SOURCES OF SAND AND AGGREGATE

As a result of limited reserves of sand, the Ministry of Lands. Survey and Natural Resources, together with CCOP/SOPAC has looked for alternative nearshore resources.

Surveys near Tongatapu and Vava'u have revealed several areas with potentially large reserves of sand. Early estimates for the area north of Nuku'alofa near Fafa Island indicate at least 3 million m^3 of sand. This figure is based on surface sampling and high resolution seismic. A future programme of vibracoring is planned, both in Vava'u and Tongatapu.

Future aggregate supplies are likely to come from onshore quarries, where an assessment project is planned for the near future in conjunction with New Zealand Geological Survey.

PRECIOUS CORALS

For many years there has been a small industry associated with harvesting and carving precious corals in Tonga. Black coral from shallow water has been the major coral export, although heads of braincoral etc. are also exported.

Several surveys to assess the potential and reserve of precious coral were completed by CCOP/SOPAC between 1977 and 1980, with a further survey in 1984 funded by SPREP. Many areas remain to be surveyed, particularly for deep water (1000 - 1500 m) pink corals (see Harper J.R. 1988: precious corals prospecting strategies for the South Pacific Region, CCOP/SOPAC Technical Report 84).

There is particular concern that stocks of black coral might be over-collected and legislation was considered to control the collection of coral. It was recognised that implementing controls on a very scattered industry based on individual divers and cavers was going to be time consuming an difficult.

It is currently policy to control the export of coral by limiting commercial exports to licence holders, and in particular restricting the export of uncarved coral.

OTHER MINERAL

At present there is no mining of other nearshore minerals in the Kingdom. No commercial deposits of phosphates or placers have been discovered. Further offshore, several cruises have sampled sediments in the Lau Basin, and areas of Mn-enrichment, Mn-crusts and metalliferous sulphide deposits have been sampled. A further cruise by Scripps Institution of Oceanography is planned for next year.

Onshore prospecting for gold mineralisation has take place during the last few years, but there has been no onshore prospecting primarily aimed at gold, possible associated with submarine volcanoes along the Tofua arc.

SUMMARY OF NEARSH RE MINERAL ACTIVITIES IN TUVALU

by

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INTRODUCTION

Tuvalu comprises nine atolls and islands in the central Pacific with a total land area of about, 26 square kilometres. The islands are all low-lying and seldom rise more than 5 m above sea level. They support a population of about 9000 people (1979). Sources of income are copra, philatelic sales, handcrafts, fishing, and to a large extent remittances from relatives living overseas.

Nearshore mineral potential is essentially limited to the discovery of submerged or buried phosphate deposit for possible export, precious corals, and sand and gravel deposits for local construction purposes.

PHOSPHATE STUDIES

There have been no economically viable discoveries of land-based phosphate in Tuvalu. In an on-land survey of all the islands and atolls of Tuvalu, White and Warin (1964) considered the subaerial deposits t be too small and scattered to be of economic importance. There is certainly nothing of export quality. However, there may be deposits suitable for local gardening uses.

A field survey involving drilling within atoll lagoons and islands conducted by Geomarex Corporation in 1978 at Nanumea, Nanumanga, Nui, and Vaitupu. Results were generally disappointing and no further work on those islands was recommended. Funafuti, Nukufetau, Niulakita, and Niuta were not drilled because they did not meet Geomarex' exploration criteria at the time. Nukulaelae was not examined because of logistical problems, but was considered a suitable target.

The on-land resources for each island were mapped as part of a Tuvalu Land Resources Survey by members of the Department of Geography, University of Auckland during the mid-

1980's (Professor J.F. McLean, Principal Investigator). They mapped soils of the islands and tested for phosphate content. As with previous studies they found no major deposits.

In 1985, CCOP/SOPAC conducted a pre-drilling geophysical survey in Nukufetau lagoon. Potential drilling sites were identified and a sample collected from Sakalua yielded moderately high phosphate co tent (28 % P 205).

During the 1987 CCOP/SOPAC-USGS Coastal Mapping Workshop held in Funafuti, the known phosphate deposits on Amatuku Islet were mapped. Samples collected were subsequently analysed by J. Hein of the US Geological Survey and confirmed the presence of the phosphate bearing mineral Carbonate apatite (Richmond and Howorth, 1988). These deposits appear to be entirely Holocene in age.

Proposed CCOP/SOPAC Field Surveys - 1988

Nukulaelae and Nukufetau appear to have the highest potential for submerged phosphate deposits of the unexplored Tuvalu lagoons. However, as a precursor to more expensive drilling operations it is recommended that further sampling of islet, reef flats, and submerged rock faces be carried out. Reconnaissance scale sampling at Nukulaelae and Nukufetau have demonstrated the occurrence of relatively high-quality phosphate deposits (Radke, 1985; - a Tuvalu Land Resources Survey also took place in 1986). Detailed sampling and mapping around known occurrences should provide further evidence whether a drilling programme is justified. Additional information regarding other resources such as construction materials or black coral habitats will also be gathered (SCUBA diving will form part of the sampling programme).

CONSTRUCTION MATERIALS

An extensive survey of Funafuti lagoon during April-June 1983 was made by Gibb Australia in connection with the Australia Development Assistance Bureau. The purpose of the geophysical sampling, and vibrocore survey was to locate suitable deposits of fill material on the Iagoon bed for remaining borrow pits on the atoll that ere created during the construction of the airport runway in the 1940's. The total amount of material needed to fill the borrow pits and Iow-Iying areas is nearly 800,000 m^3, Extensive areas of *Halimeda-rich* fine- to coarse-sands were identified on the lagoon floor. Several different dredging schemes were proposed including a pilot programme to test the feasibility of lagoon dredging and pumping the material ashore. Maximum pumping distance is about 2000 m; the average is closer to 1000 m.

At present construction materials are derived from small-scale beach mining operations and crushing of hurricane derived (Bebe-1972) gravel ramparts deposited along the ocean shoreline.

PRECIOUS CORALS

The resource potential of precious corals in Tuvalu is unknown as there have been no surveys completed. Habitats for black coral are believe to exist and it is recommended that a reconnaissance survey be initiated (Harper, 1988). Likewise there are several potential deepwater pink coral targets that should be examined.

REFERENCES

Australian Development Assistance Bureau 1983: Tuvalu Lagoon Bed Resources Survey, Draft Report, Volume 1 of 2 (149 pages; Prepared by Gibb Australia).

Harper, J.!R. 1988: Precious corals prospecting strategies for the South Pacific region. CCOP/SOPAC *Technical Report* 84: 80 pages.

Radke, B.M. 1985: Bathymetry and beach profiling, Funafuti, Tuvalu, September-October 1984. *CCOP/SOPAC Cruise Report 106:* 18 pages.

Richmond B.M.; Howorth R. 1988: Extended summary of techniques used and data collected during the Coastal Mapping Workshop, Funafuti, Tuvalu, June 1987. *CCOP /SOPAC Technical Report 89:* 33 pages.

White, W.C.; Warin, O. 1964: A survey of phosphate deposits in the Southwest Pacific and Australian waters. *Bureau of Mineral Resources, Geology and Geophysics, Bulletin 69.*

NEARSHORE AND COASTAL MINERAL RESOURCES OF VANUATU

by

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INTRODUCTION

The Vanuatu archipelago forms part of the narrow chain of Tertiary to Recent volcanicity which extends from Papua New Guinea to the Solomon Islands through to Fiji, Tonga and New Zealand.

The Islands (Figure 1) can be divided into four geological provinces based on age and composition. From the oldest to the youngest, these are the Western Belt of (Santo and Malekula) the Eastern Belt (Pentecost and Maewo), the Marginal Province, (Futuna and Mere Lava) and the Central Chain.

In the western and Eastern Belts, limestone capping is prominent and uplifted Quarternary reefal limestone terraces can be recognised along the casts of many islands. Perhaps, due to it recent age, no large sea shelf can be recognised within Vanuatu waters.

The Department of Geology and Mines is the government institution and assessment. Vanuatu is member of SOPAC and through this organisation is involved with mineral prospecting in offshore areas.

NEARSHORE AND COASTAL MINERAL RESOURCES

The mineral resources occurring nearshore and along the coast of the islands can be divided· into five categories. These are:

1. Limestones
2. Beach blacksands
3. Alluvial gold
4. Phosphate
5. Offshore minerals.

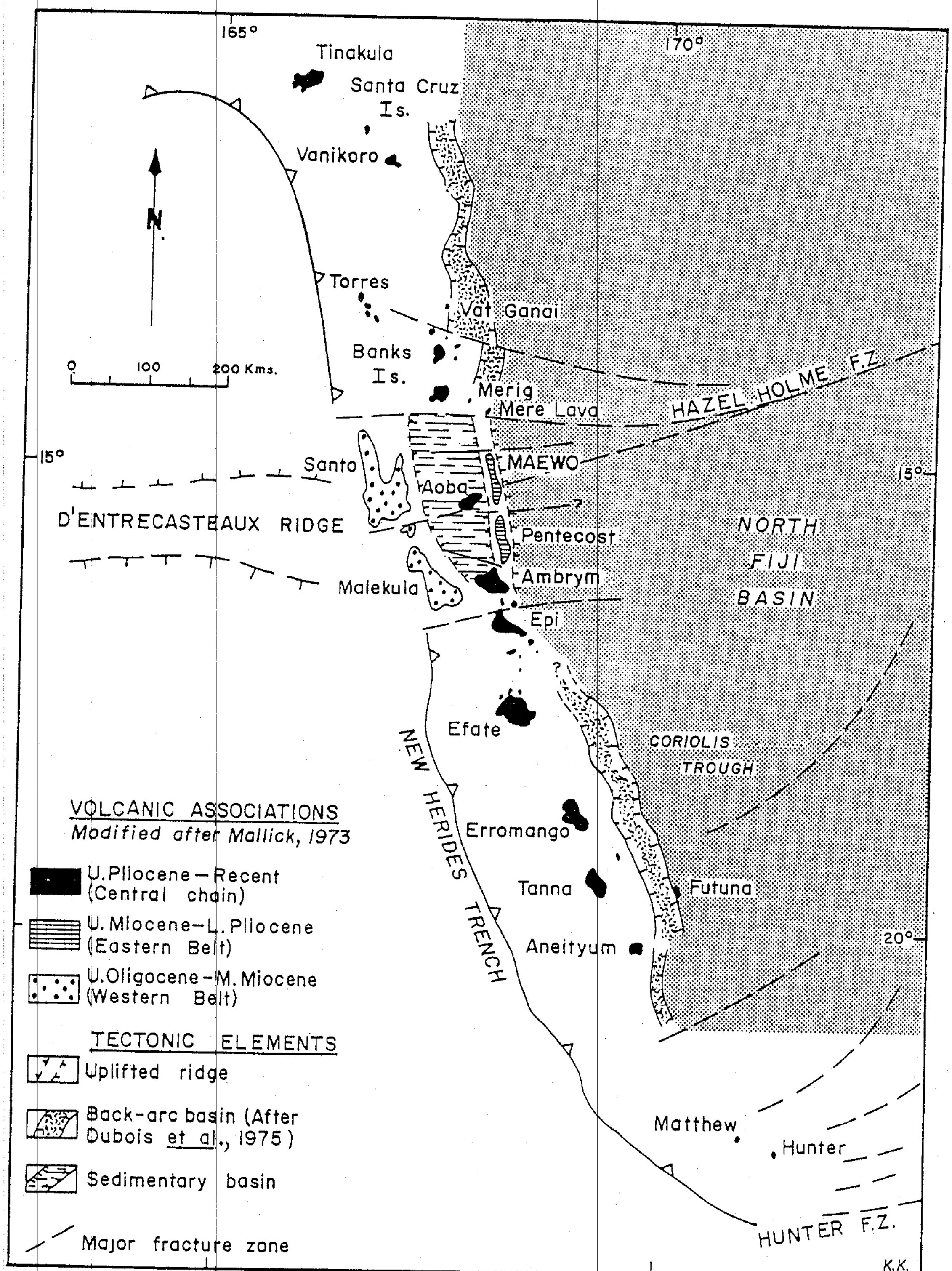

Figure 1. The islands of Vanuatu.

Limestones

Limestones occur on nearly all islands. The limes ones are used as a source of road dressing, and, in the two urban areas of Vila and Santo, they are also used as building aggregate.

Several limestone quarries are in operation around the urban areas, but no quarry production output data are available.

The raised reefal limestones are porous and in general well-crystallised and contain little on 60 million tonnes. The limestones are composed of 79.5 % $CaC0_3$ whilst the magnesium content as $MgC0_3$ (2.09 %) is significantly low.

The crystallised limestones in some areas can be compact, chemically very pure, and with low porosity. Impurities in samples collected from Santo, constitute no more than 2-2.5 % of the rock, with MgO (0.7-0.8 %), P (0.01 %) and S (0.02-0.0 %) in particular being very low. Physical stability and water activity tests indicate the rocks suitability for metallugical purposes. The chemical purity is sufficient for possible use in the chemical industry.

The absence of metallurgical and chemical industries in Vanuatu, and its geographic location in relation to countries with those industries in contrast to their more accessible supplies makes the exploitation of these limestones unlikely in the foreseeable future.

Beach Blacksands

Black sands bearing significant amounts of magnet are found on the present beaches of several islands. The magnetite, is derived from the erosion of volcanic of the islands, and is concentrated at the coast by a combination of marine and fluviatile action. The biggest single concentration is in southwest Efate where 370,000 tonnes of sand with 47 % magnetics could yield an estimated 173,000 tonnes magnetite. The average specific gravity is 4.84, and 62.8 % of the grains fall within the 125-180 micron size range. Other notabe deposits include the beach sands of east Erromango (35-37 % magnetics) and south Santo (6 9 % magnetics), with estimated reserves of 128,000 and 1,151,000 tonnes magnetite, respectively (Radford, 1976; Ash et al, 1978).

The small grain size and high titaniferous content (up to ca 7 %) mitigates against the use of these deposits as a primary source of iron ore. Another possible use would be in the production of heavy liquids for coal washing. The magnetite, however, does not appear to meet the required Australian standard specifications for such material.

Sand had been extracted from the beach at Mele Bay for some time. During recent preliminary investigation, 3 extraction sites were located (Figure 2).

Site 1. Extraction commenced in 1985; and 22,587 m^3 had been removed by September 1988.

Site 2. Recorded extraction commenced in May 1987, and the amounts removed are shown in Table 1.

Site 3. Small scale extraction had been by individuals, and no record can be retrieved.

In this mining operation an agreement was made between the Landowner and the construction companies for mining sand on a "one at a time" basis. The sand was at different rates according to the trucks' capacities (cubic contents).

Table 1. Sand quantities removed from Site 2 Mele Bay (in cubic metres)

May 1987	50
June 1987	132
July 1987	64
August 1987	249
September 1987	133
October 1987	432
November 1987	531
December 1987	406
January 1988	299
February 1988	1,047
March 1988	748
April 1988	887
May 1988	489
June 1988	800
July 1988	789
Aug '88	-----
Total (cu. m)	7,056

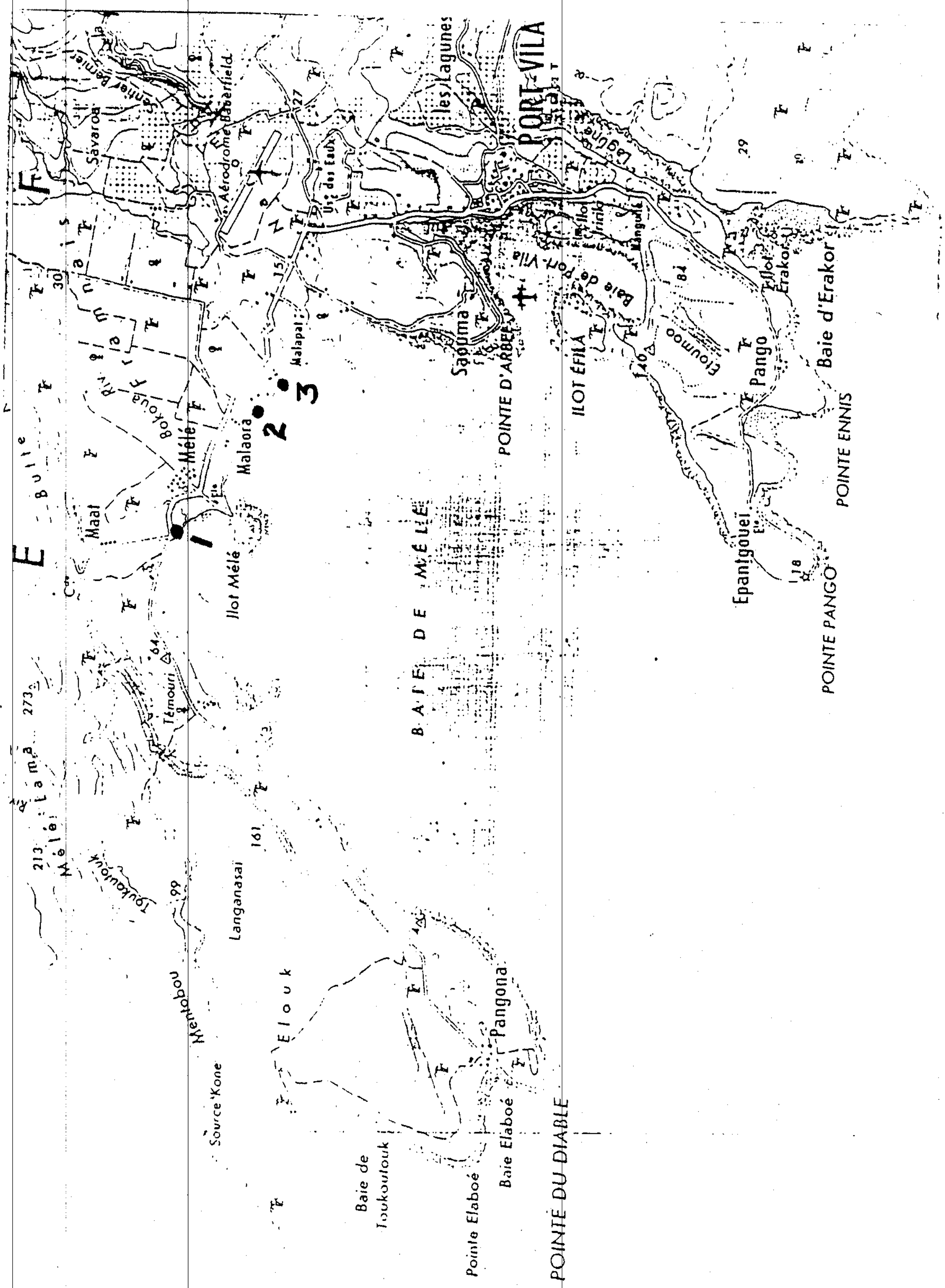

Figure 2. Beach sand extraction sites, Mele Bay, as numbered in text.

Serious beach erosion at Mele Bay is now recognised. Although its cause cannot be accurately defined, it can be assumed that sand extraction has contributed to the beach erosion.

A preliminary survey was carried out at Mele Bay, based on the coastal processes map of t e area prepared y Dr H. Gary Greene and the course participants at the CCOP /SOPAC Coastal Mapping Workshop in late April to early May 1983. That first survey was one of several carried out at Mele Bay, Port Vila Harbour, Port Havannah and some other areas as part of the CCOP/SOPAC Training Programme for regional development.

A comparison of the latest survey to that of the first survey of 1983, shows clearly that ring a five year period, beach morphology changed markedly due to a number of cyclones ring that time.

At the northwest end of Mele Bay the road was partly eroded away leaving a height of about 1 m from road surface to base. Along the golf course at the centre of the bay, trees were uprooted and removed which once overshaded the beaches. At the south-west end of the MeIe Bay, known a "Black Sand" beach, a cliff is developing.

Alluvial Gold

Exploration companies exploring for gold in the vicinity of Big Bay on North Santo (Figure 3) reported the presence of high concentrations of gold within stream sediments from rivers raining into Big Bay.

The source of he gold was not located but since the rivers are fault controlled, it was thought that the river had, through the years, progressively eroded gold from the fault zones and deposited it further down stream. A theory currently prevails that substantial amounts of gold may have been deposited in the sea and with the high organic content in brackish coastal seas, a possibility exists for the concentration and accumulation of gold in the bay.

No investigations were undertaken to substantiate the theory but future investigations for gold in Big Bay water may prove worthwhile.

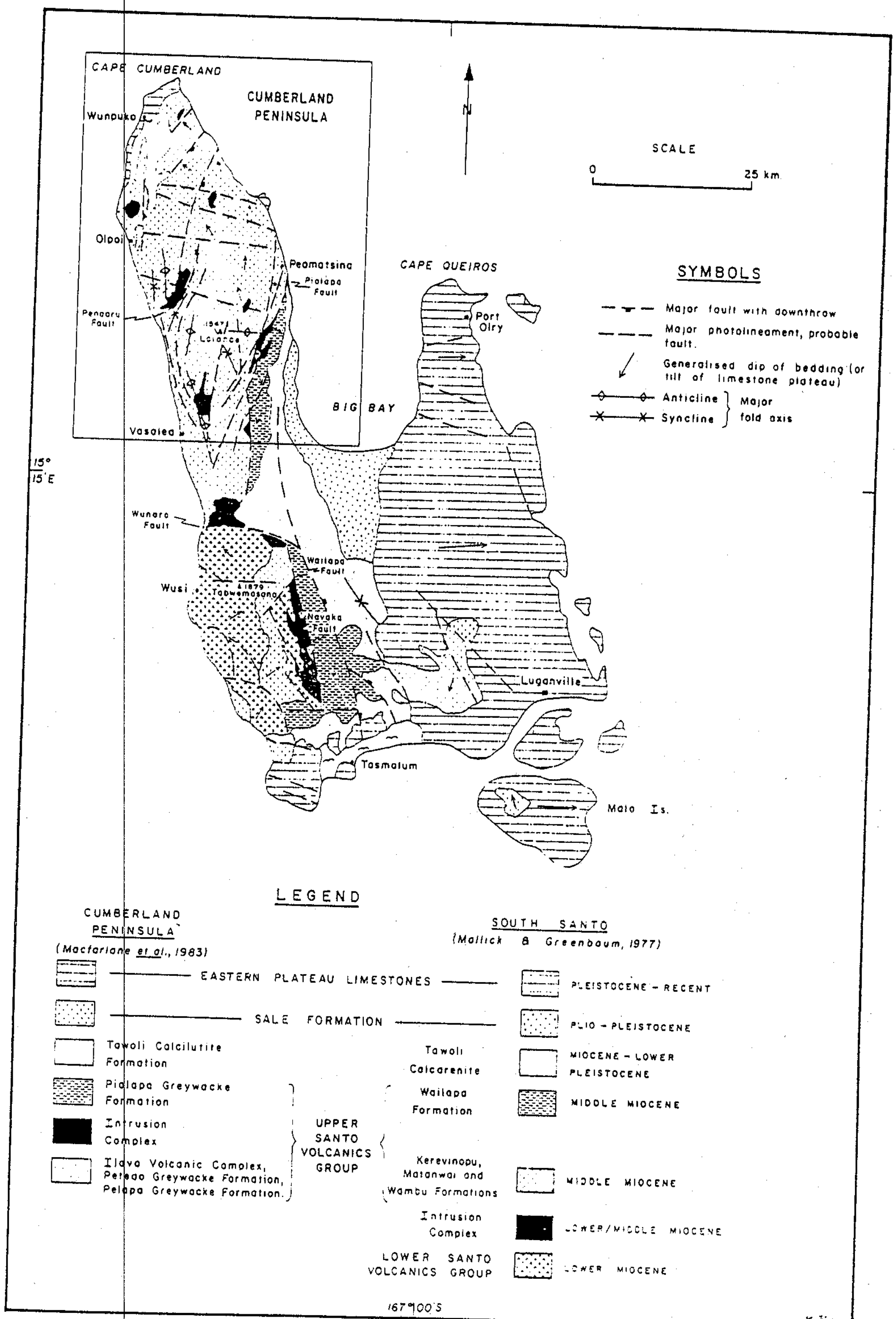

Figure 3. Location of Big Bay, Island of Santo (from Carney and Macfarlane, 1986).

Given the pr sent state of the mineral resources potential of Vanuatu, the phosphate potential cannot be overlooked.

Future phosphate investigations would be directed at the coral Torres Islands.

Offshore Minerals

Exploration for offshore minerals in Vanuatu is being carried out by CCOP/SOP AC. The potential for hydrocarbons, metalliferous muds and precious corals were studied.

Hydrocarbon potential exists in the central and Aoba Basins. Samples collected from karua and submarine volcanoes, and the extensional basins to the rear of the arc eg. Coriolis Trough, showed indications of metalliferous mineralisation.

Further work needs to be done to assess the potential.

REGULATIONS

The Mines and Minerals Act came into effect in mid 1986. This act controls mineral exploration, mining and quarrying in Vanuatu both onshore and offshore.

Regulations co trolling mineral exploration, including land acquisition for exploration, were ate devised and incooperated into the Act. Quarry regulations are currently being drafted. They would also cover be beach mining, and it is hoped that, with the appropriate environmental sections within the Act, that beach mining would be controlled.

COMMENT

In a small country with limited natural resources such as the New Hebrides an understanding of the mineral potential is fundamental to future development, both as a means of diversifying the economy and as a source of wealth. At first glance the mineral resource potential in the New Hebrides is not encouraging. Manganese reserves on Efate, once a major revenue earner, are depleted and alternative sources on Erromango are only likely to be marginally economic. Base and precious metal exploration has not been successful to date, although certain areas still require detailed evaluation and re-assessment. Offshore minerals are still an unknown quantity, and, with the possible exception of precious corals, are very much long term prospects.

However, ignoring the more exotic minerals, Vanuatu does have large resources of bulk minerals. To exploit the limestones profitably, steps should be taken to locate markets, and marketing studies should be undertaken.

The ease of sand extraction from beaches makes it very attractive; however strict controls must be applied o ensure environmental stability.

CONCLUSION

In conclusion, limestones appear to be the most viable resource in Vanuatu. Further investigations should be undertaken to assess the gold, phosphate, also hydrocarbon and the polymetalllic mineralisation in the waters of Vanuatu.

Strict regulations must, in the very near future, be devised to control beach mining.

REFERENCES

ASH, R.P.; CARNEY, J.N.; MACFARLANE, A. 1978: Geology of Efate and offshore islands. Regional report Geological Survey, New Hebrides. 49 pages.

CARNEY, J.N.; MAC ARLANE, A. 1986: Geology and Mineralisation of the Cumberland Peninsula North Santo. General report, Republic of Vanuatu, Department of Geology, Mines and Rural Water Supplies. 64 pages.

RADFORD, N.W. 1976: Magnetite-bearing beach sands. *Annual report of the Geological Survey for the year* 1974, *New Hebrides Condominium:* pages 17-18.

NEARSHORIE MINERALS SUMMARY
MEMBER COUNTRY REPORT - WESTERN SAMOA

by

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Apia Observatory

INTRODUCTION

The Independent State of Western Samoa is part of the 480-km-long Samoan archipelago and lies between Iongitudes 171 °20' and 172°50' west and latitudes *13°25'* and 14°05' south. It consists of: Upolu Island (approx. 1120 km^2) which is narrowly elliptical in outline, roughly 76 by 26 km, and has a rugged chain of volcanic cones forming the crestal ridge, rising to 1120 m; Savaii Island (approx. 1890 km^2), 76 by 44 km consisting of broad coalescing domes topped by numerous cones of which the highest rise to over 1860 m; and the small adjacent islets of Apolima, Manono, Niutele, Niulua, Namu'a and Fanuatapu. Gravel and sand for concrete aggregate are relatively abundant, but the full understanding and knowledge of their availability still requires a lot more exploration work.

CCOP/SOPAC INVESTIGATIONS

Sand and Gravel resources

Numerous surveys of the coastal areas mainly to assess existing sand and gravel resources and continuing to other new survey areas have been completed.

Commercial Activities

At present there are two nearshore dredging operations near Apia which provide most of the construction materials to the Public Works Dept, private contractors and the public. Private companies (e.g. Apia Concrete Products) also dredge on the other side of the same area for us in concrete blocks and other products. In August-September 1988, SOPAC marine geologists surveyed this particular area to determine the quality and amount of aggregate remaining. Also within the same work programme, at least 3 other main locations were investigated for the extent and potential of their sand and gravel resources.

Harbour Surveys

Harbour and channel surveys have been carried out for all existing and developing ports.

Precious Coral Survey

Precious corals investigations have also been carried out at the more likely areas of a occurrence around the islands.

Coastal Erosion

Coastal development studies with regard to erosion have been conducted at the more important areas, like the Mulinu'u Peninsula.

PROCEDURE FOR EXPLORATION/EXTRACTION

Lands and Survey Department is empowered with the Act to grant permission and licences for exploration and extraction. In reality, however, this appears to be true only within the designated government land and associated coastline (i.e. where no traditional village exists).

ENVIRONMENTAL CONCERNS

There has been very little or no consideration of environmental impact incorporated into the ranting of licenses. This matter is certainly of greatest importance, and procedures need to be established and enacted immediately.

PLACER MATERIALS

The United Resources (Vanuatu) Ltd carried out an extensive search for the existence of gold throughout the country. A report is pending.

Past phosphate surveys (Kear & Wood 1959) indicated that the Vini Tuff, although the "best source" was not a workable one (0.5% P_2O_S average).

FUTURE WORK

1. Environmental considerations - to be incorporated into legislation.

2. Sand and gravel - continue reconnaissance surveys in areas of interest and monitor present sites of extraction.

PLACER GOLD

[MR103 - Technical Secretariat]

PLACER GOLD
ITS SOURCE AND DEPOSITIONAL ENVIRONMENTS IN PAPUA NEW GUINEA

by

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ABSTRACT

Placer gold in Papua New Guinea was first discovered in 1873, but it was not until 1877 that a small gold rush gave the first recorded production at Laloki near Port Moresby. Small but workable discoveries were made in the outer islands and coastal mainland regions from 1888 to 1926. In 1922 William "Sharkeye" Park found gold at Koranga Creek and this led to major discoveries at Wau and Bulolo, which were the first large scale commercial gold operations in Papua New Guinea.

There are three major sources of placer gold in Papua New Guinea, large intrusive bodies, individual vein systems, and ultramafic/ophiolite complexes. Porphyry copper type ore deposits throughout the mainland of PNG and also on North Solomons are important sources of both lode and alluvial gold. These large intrusive systems shed gold into nearby drainages forming alluvial gold deposits, such as the Kieta Goldfield. Probably of most importance are the placer old deposits formed from weathering of vein individual vein systems or vein clusters as at Wau-Bulolo where approximately 3.2 million ounces of placer gold was won from alluvial workings between 1926 to 1977.

Three main types of placer gold deposits in PNG are presently being worked by small-scale panning and sluicing methods. These can be classified into alluvial, residual, and landslide deposits. These three types can form as independent or overlapping occurrences, or can be connected by colluvium deposits. Of primary importance are the true alluvial gold deposits which are represented by both paleo-river channels and active river channels. Landslide deposits have recently been recognised as a result of the Mt Kare discovery.

Of the 16 proclaimed alluvial goldfields throughout PNG only 3 districts are recognised as current major gold producers. These are the Mt Kare, Wau-Bulolo, and Porgera goldfields. Mt

Kare is the most recent discovery and one of the richest alluvial gold districts ever to be discovered in PNG.

INTRODUCTION

Location of Goldfields in Papua New Guinea

Currently there are 16 proclaimed alluvial goldfields throughout Papua New Guinea. Of these, 15 are located within the mainland of Papua New Guinea and the remaining one is located on Bougainville Island (Figure 1). The goldfields are: Amanab (West Sepik Province); Maprik, April River and Yuat River (East Sepik Province); Timun River & Porgera (Enga Province); Simbai (Madang Province); Kuta (Western Highlands Province); Kainantu - Goroka (Eastern Highlands Province); Wau - Bulolo and Waria River (Morobe Province); Gira - Yodda (Northern Province), Lakekamu (Gulf Province); Keveri (Northern Province), Milne Bay (Milne Bay Province); Kieata (North Solomons Province); and Mt Kare (Southern Highlands & Enga Province's).

History of Placer Gold Production

In 1873 Captain Moresby reported minor amounts of gold in the hills surrounding what is now Port Moresby Harbour. The Port Moresby discovery was not worked until 1877 and resulted in what is probably Papua New Guineas first gold rush of approximately 100 European in Miners prospecting the Laloki and other rivers inland of Port Moresby.

The first significant gold discovery in Papua New Guinea was made in 1888 when 142 ounces of gold was reported to have been found by David Whyte on Sudest Island. The discovery on Sudest Island was alluvial and was fairly quickly worked out. Production from Sudest Island between 1888 and 1893 is estimated at 10,000 ounces of gold. In 1889 gold was discovered on Misima Island, located approximately 100 km north of Sudest. Due to the relatively small size of these deposits, the alluvial gold was fairly quickly mined out. Between 188 and 1914 alluvial gold miners on Misima produced only 2173 ounces of gold. At the turn of the century Robert Boyd discovered the Umuna Lode system on Misima, and from that time attention was diverted from alluvial mining to hard rock (reef) mining.

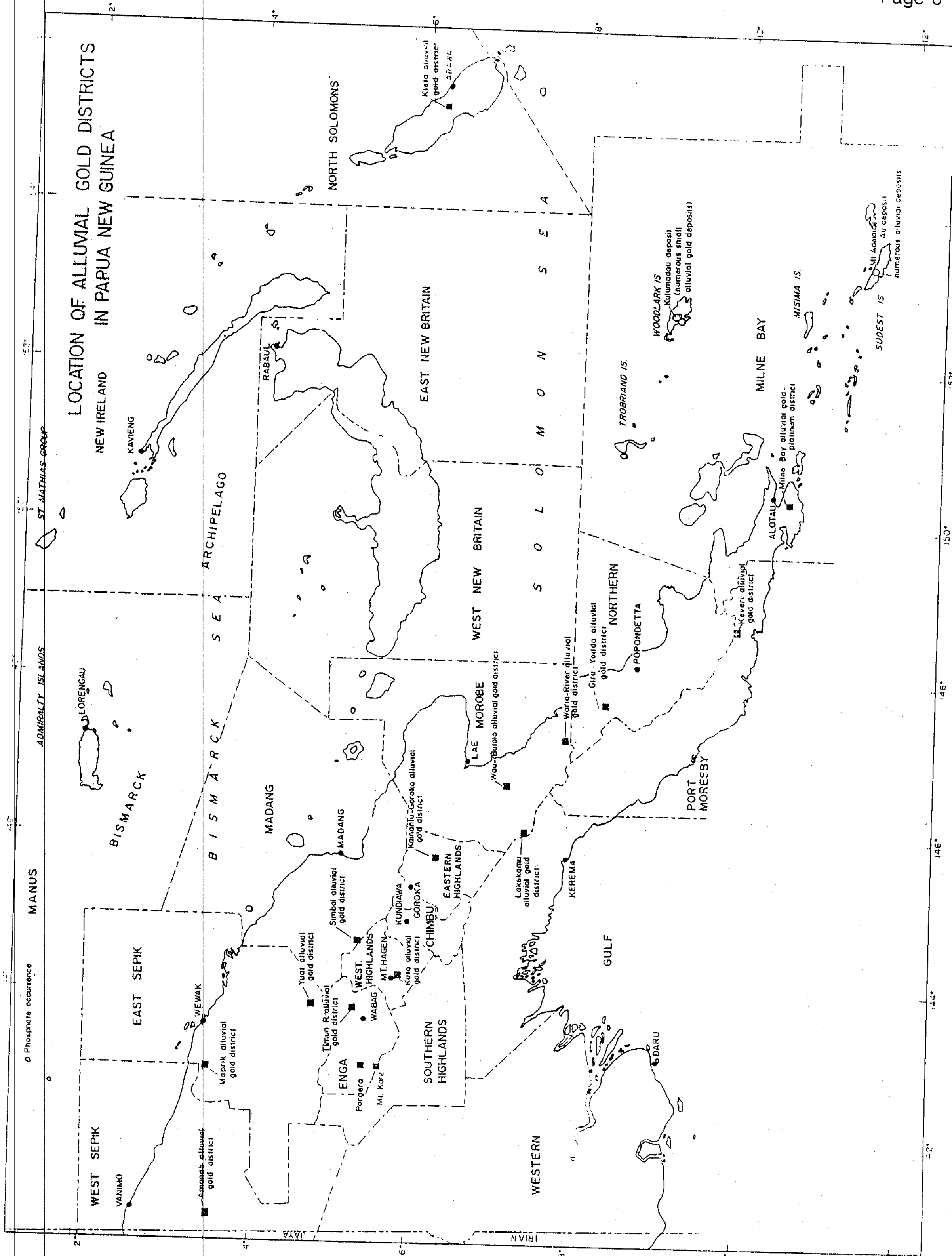

Figure 1. Location of alluvial gold districts throughout Papua New Guinea.

By 1895 prospectors in Misima had migrated 150 km northward to Woodlark Island. There 200,348 ounces of gold was won by the miners from alluvial working between 1895 and the mid 1900's. From Woodlark the prospectors crossed over to the mainland of PNG; where, on the northern side of the Owen Stanley Rangers, gold was discovered along the Mambare River in 1896, the Gira River in 1897 and the Yodda River in 1899. Together these three areas were proclaimed the Gira Goldfield in 1898. At about the same time, gold was found in Milne Bay and a goldfield proclaimed the same year. Miners moved westward from Milne Bay, along the southern coast of Papua, discovering gold in Cloudy Bay in 1901. Further north, along the southern coast of Papua, Mat Crowe and the Pyke brothers discovered gold in Iron stone creek a tributary of the Lakekamu River in 1909, and in December of that year the area was proclaimed the Lakekamu Goldfield.

By mid-1926 the total gold produced from the Papuan goldfields was about 542,000 ounces (15,300. 70kg). This total production includes both alluvial and hardrock deposits (Table 1).

To the north, in what was then German New Guinea (1884-1914), large scale prospecting for gold was not being carried out. However, a minor discovery of alluvial gold was made by both German and Australian prospectors along the Waria River. The first significant gold discovery in New Guinea was made on the Bulolo River near Koranga. William "Sharkeye" Park and Jack Nettleton began working the gravels of Koranga in 1922 with excellent results. A year later when the area was proclaimed the Morobe Goldfield 15 additional miners were working the gravels at Koranga. The goldfield reached its peak production of 404,000 ounces of gold for one year in 1938,and in that year there were approximately 700 Europeans and 6200 National gold miners employed. The first gold dredge used in PNG became operational in the Bulolo valley in 1932. This same year hard rock mining commenced in the area. By 1939 there were a total of eight dredge in operation within the Bulolo valley. The total pre-war (pre-1942) alluvial 01 production from the Wau-Bulolo goldfield was approximately 54,000 kilograms (1,700,000 ounces). Dredging along the Bulolo River started again after the war and operations continued until 1966, after which only small-scale sluicing and alluvial mining has taken place.

Table 1. Total gold yield from the Papuan Goldfields to 30 June 1926

(After Loudon, 1987)

Name of Goldfield	Gold Production Recorded Ounces	Date Field Proclaimed
Misima Island	138,049	1889
Woodlark Is.	200,000	1895
Gira River	67,242	1998
Milne Bay	14,230	1899
Yodda River	76,822	1900
Keveri River	4,770	1904
Lakekamu River	37,170	1909
Astralabe (Port "f0resby)	3,300	1906

Post was grid production from dredging was approximately 25,000 kg (about 804,000 ounces). Total alluvial gold produced from the area to June 1977 was approximately 90,000 kg about 3.2 million ounces), of which 34,300 kg was from sluicing operations and 65,720 kg from dredging.

The discovery in Wau-Bulolo area sparked further exploration into both the hinterlands of New Guinea and the outer islands. Gold was found in Kainantu in the early 1930s and a few years later alluvial gold was discovered in the Lagaip River, a tributary of the Strickland. There, Jim Taylor & J.R. Black, traced the alluvial gold back to Porgera. However, the source of the alIuvial gold wasn't discovered until 1945, when H.J. Ward located gold cropping out on the east side of Mt Waruwari (Handley, 1987).

In the New Guinea Islands the giant Panguna copper-gold deposit was discovered by miners prospecting for gold at Kupei in 1930 and later near Panguna. Alluvial gold occurrences were discovered on several of the PNG islands, including New Ireland and New Britain.

The most recent discovery, and one of the richer goldfields to be discovered in the 20th Century, is the Mt Kare alluvial goldfield located in the Central Highlands of Papua New Guinea about 18 km sout1west of Porgera. It was discovered in February 1988, and by April of the same year, when news of the discovery spread out, there were a total of 1000 locals working the alluvials. The overall size and grade of the deposit is yet to be established. However, an estimated 6-7 tonnes (about 200,000 oz) of gold has been produced in the first 8 months since the discovery. Production has been restricted exclusively to national miners employing panning methods, and up to 5000 people are presently working the goldfield. Production at Mt Kare is continuing at this rate today and is expected to last for quite sometime.

SOURCES OF PLACER GOLD IN PAPUA NEW GUINEA

There are three important sources of alluvial gold in PNG: large intrusive bodies, individual vein systems, and ultramafic/ophiolite complexes.

Porphyry copper type ore deposits throughout the mainland of PNG, and also on Bougainville Island, are important sources of both lode and alluvial gold. Frequently these large in intrusive systems shed gold into nearby drainages forming alluvial gold deposits that range widely in size, from minor occurrences with little or no production to major goldfields. The Kieta goldfleld, on Bougainville Island, is one example of an alluvial gold deposit having formed from erosion of a porphyry copper intrusive complex, the Panguna deposit. Major, and as-of-yet untapped, alluvial grid reserves are also present in rivers and streams draining the gold-rich OK-Tedi porphyry copper deposit. Other, non-porphyry copper type, intrusive complexes such as the gold-rich lamprophyric complex at Porgera (Rock and Finlayson, 1988, pers. comm.), and the intrusive complex at Mt. Victor, are also major sources of both hard rock and alluvial gold.

The size and morphology of gold grains found in alluvial systems is not only a function of distance transported but also the type of source deposit from which they were eroded. The author has made certain empirical observations regarding the relative differences in the morphology and size of gold grains in alluvial deposits throughout PNG. For instance, one generalisation is that placer gold from a prophyry copper source is often fine grained and exhibits few, if any, crystal faces. Because of its relatively small grain size, gold grains flatten quickly and impurities such as silver and copper are readily leached. Placer gold from the Wau-Bulolo area is quite different in that its grain size is generally much larger, it often exhibits dendritic patterns, and frequently contains abundant silver. This placer gold is eroded primarily from individual veins land vein-clusters located in the Edie Creek and Upper Bulolo River. The Wau-Bulolo alluvials are known for hosting large nuggets, which have been produced throughout the history of the goldfields (since 1922) and continue to be produced at present. Within the last year to large nuggets, one about 1000 gm (32 oz) and the other 715 gm (23 oz), have been won from the Bulolo River and Edie Creek by small-scale placer operations. However, the nuggets found in the Wau-Bulolo area are secondary in nature, that is, they formed in the upper portions of local veins from the oxidation of a gold-bearing manganocalcite protore. Native gold in the unoxidised portion of these veins is volumetrically insignificant. At Porgera, native old is present in large quantities in both the oxidised and unoxidised portion of the veins, with few solid gold veinlets approaching 1 cm in thickness. In other areas native gold is present as fine web-works cementing breccia zones. The erosion of this material provides an abundance of large, planer nuggets to the local drainages. At Mt. Kare the gold is very coarse and large nuggets are frequently won. Of the several tens of kilograms of alluvial gold that the author has examined from Mt. Kare it is estimated that over 80 percent is highly crystalline. One nugget was reported to have the dimensions roughly similar to a man's hand and most nuggets at Mt Kare, even the smaller ones, are planer.

Over 100 tonnes (2.7 million ounces) of placer gold have been won from the creeks and rivers of the Wau Bulolo goldfield, attesting to the important role of vein systems as sources of alIuvial gold. Other alluvial gold deposits throughout PNG that formed primarily from gold bearing vein systems include those on sudest, Misima, and Woodlark Islands, and most likely hose in the Amanab and Maprik districts.

There are several gold-bearing alluvial systems where the source of gold is totally unknown, problematic, or only suspected. Several of these alluvials are spatially proximal to, or within, slabs of obducted oceanic crust or other mafic to ultramafic rock units. Examples of these areas are Timun River, Simbai, Waria River, Gira-Yodda River, Keveri and Milne Bay. associated with these deposits are minor to moderate amounts of the economically important platinum group elements. For several reasons the presence of gold and platinum group elements is difficult to detect through hardrock sampling of ophiolite and ultramafic rocks. However, the presence of these rock types proximal to the above listed alluvial gold-platinum deposits is not seen as fortuitous, and in the opinion of the author these oceanic crustal rocks represent an important source of alluvial gold-platinum deposits throughout PNG. Included in these oceanic-crustal source alluvial deposits are a group in which a significant amount of their contained gold care from erosion of volcanogenic massive sulphide deposits. For instance, the alluvial deposits at Laloki and also those in the Jimi Valley.

ENVIRONMENT OF DEPOSITION

There are three main types of gold deposits in PNG that are presently being worked by small-scale planning and sluicing methods. These can be broadly classified into alluvial, residual and landslide deposits. These three types can form as independent or overlapping occurrences, or can be connected by colluvial deposits.

Of primary importance are the true alluvial gold placer deposits. In PNG these alluvials are represented by both active river channels, and by paleo-river channels that are either buried beneath present-day river systems, or crop out as elevated terrace channels. For instance, in the Lakekamu goldfield the primary exploration targets are paleo-river channels that formed in a braided river system. These channels are tens of metres below the present-day meandering river system of the Olipai River, Twisty Creek, Fish Creek and represent targets that would have to be dredged. Secondary exploration targets, but ones amenable to small-scale mining techniques, are the gold placer reserves in PNG are tied up in present-day or paleo-river alluvial systems.

However, residual (or eluvial) placer deposits should not be underrated as an important source of gold for small-scale miners. Because of their process of formation these deposits are often quite rich, although generally being of limited volume. In Upper Edie Creek, residual placer deposits are common and the Sai Mine is a good example. There, in the upper (oxidised) portions of narrow manganocalcite veins, gold nuggets range up to several centimetres in size. Local small-scale miners wash colluvium and eluvium from the hillside, and channel it through sluice boxes where the coarsely crystalline gold is trapped. On a much smaller scale, the mining of residual placer gold deposits also takes place on Sudest Island, which was the site of the first major gold rush in PNG. Production of gold on Sudest Island has dwindled to a trickle during this century, as prospectors found richer alluvials elsewhere. At present, few of the locals exhibit an interest in getting up small-scale min1ing operations. However, occasionally one or two will go out after a rainstorm and pick small nuggets off the surface of hillsides. These small nuggets and wires of gold are part of a residual deposit that formed much in the same way as the deposits of Upper Edie Creek, although on Sudest the eluvial deposits are considerably less rich. There are several other occurrences of residual gold placers throughout PNG, yet none are known to host large reserves of gold.

Only with the discovery of Mt. Kare, have landslide-hosted gold deposits been recognised in their own right, as potential hosts of major gold reserves that are easily won by employing simple panning and sluicing techniques: Mt. Kare is by far the most extensive and richest of these deposits discovered to date, with an estimated 200,000 ounces (between 6 and 7 tonnes) gold extracted by local gold panners in the first 8 months of operation. Local slump and landslide features are common in several of the lode gold deposits in PNG, and downhill mass wasting of residual deposits throughout the Wau-Bulolo goldfield may have been an important method of transporting gold nuggets into the river systems.

MAJOR ALLUVIAL GOLD PRODUCING DISTRICTS IN PAPUA NEW GUINEA

There are currently 3 major alluvial gold producing districts in Papua New Guinea with Mt Kare being the most recent discovery and probably one of the richest. The other two districts are Wau-Bulolo, and Porgera with Lakekamu as a past major alluvial gold producer. Apart from the major goldfields, minor quantities of placer gold are won by locals in most of the goldfields throughout Papua New Guinea.

Mt Kare

The Mt Kare alluvial goldfield is located 18 km southwest of Porgera and about 30 km north-northeast of Tari in the border between Enga Province and Southern Highlands Province Figure 2). The goldfield is within Prospecting Authority 591, which is presently held by CRA. It is situated at the head of a high mountain valley above 2800 m, near the base of Mt. Kare. Access to the gold field is by helicopter or walking track, as no roads exist in the area.

Discovery

Initial reconnaissance sampling work by CRA in 1985 outlined anomalous gold bearing areas within the PA. Geochemical anomalies led CRA geologists to the Mount Kare area, where an extensive soil sampling programme was initiated. The result of this soil survey indicated a very large area highly anomalous in gold, silver and base metals. In February 1988 CRA set up a base camp at the head of the valley near Mt. Kare for support of a drilling programme. The camp was then left in the hands of security guards while geologists returned to Tari and Madang to organise the transportation of drilling equipment. On their return to the prospect site they discovered a large group of national miners In the process of digging pits In alluvial gravels and landslide deposits, then panning the material in nearby creeks, and recovering large quantities of coarsely crystalline gold and gold nuggets.

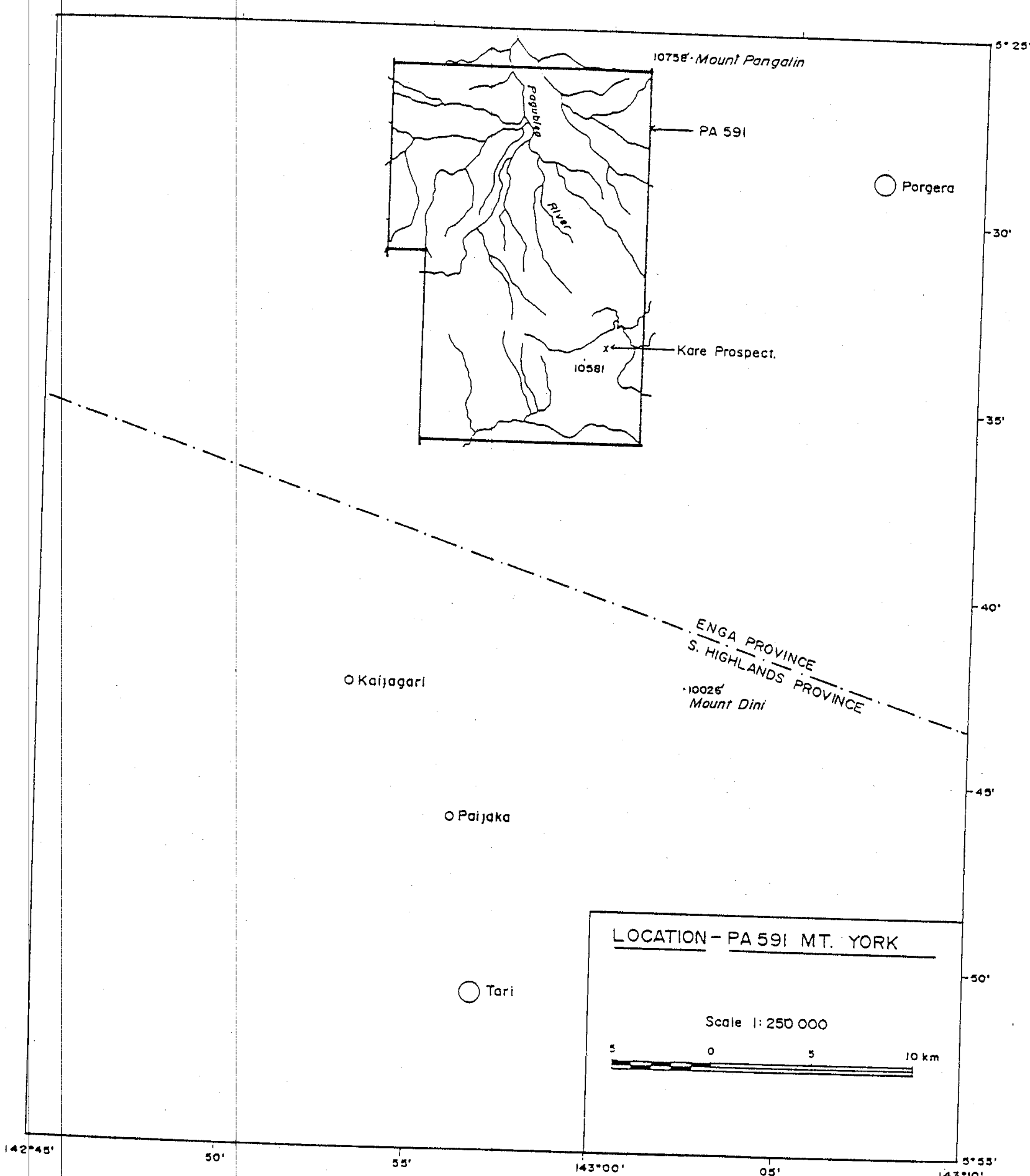

Figure 2. Location map of the Mt Kare Goldfield.

Deposit Type

The deposits presently being worked by local miners are composed primarily of coarse crystalline gold, hosted by landslide and mudflow debris. The gold deposits presently being mined lie directly at the base of a hill, which suggests that the landslide debris has not moved far from its original source. The morphology of these deposits, represented by hummocky topography and sharp borders, is clearly not alluvial in character. However, the landslide deposits are locally dissected by creeks that do contain alluvial gravels. These alluvial gravels are rich in gold, put are of limited volume.

The landslide deposit is covered by a zone of black soil, decaying vegetation and grass that is up to 1.5 thick. The organic layer is interpreted as having formed in a shallow lake or swamp, is generally barren of gold and is stripped by local miners before panning. Directly below the black organic layer are grey coloured coarse, unsorted, landslide deposits that have a very high matrix to clast ratio, with clasts being supported within a matrix of mud. Clasts range widely in size, from pebbles to boulders and blocks, and are poorly sorted to unsorted. Clasts are primarily composed of sandstone, siltstone, and carbonaceous mudstone.

Current Placer Gold Production

Present mining of the placer gold from the Mt Kare prospect is from near surface (1-2 m) exposures within the landslide deposit, along the creek beds dissecting it. The surficial parts of the deposit are easily extracted by hand mining using spades, shovels and crowbars, and the gold is recovered by panning. Only a few sluice boxes have been observed to be used by the miners, and the use of mechanised equipment is presently banned by the National Government.

Within the first few weeks of its discovery up to one thousand miners were working the deposit. Each miner was extracting an estimated average of 16 to 32 ounces of gold within the first couple of weeks. An estimated production from the Mt Kare area for the first 8 months is 6-7 tonnes (about 200,000 ounces) of unrefined gold (about 800 fine). Future production from this area is expected to remain at high levels for several years.

Wau-Bulolo

Past Gold Production

The Wau-Bulolo goldfield is perhaps best known for the large scale dredging operations that were carried out between 1932 and 1965 by Bulolo Gold Dredging Company in the Bulolo River valley (Figure 3). Dredging was by far the most productive alluvia/gold producing method used in the Morobe Goldfields. Pre-war annual dredge production commenced in 1933 and reached a peak of over 180,000 ounces (5600 kg) in 1940 when all eight dredges were in operation. Post-War production, although high, never reached the pre-war levels due to diminishing grades on the alluvial deposits (Table 2).

A total of approximateIy, 2,112,898 ounces (65,000 kg) of gold was recovered by dredging, which represents 561 % of the total gold production from the goldfield between 1926 and June 1977 (Table 2). Dredging exceeded the production from all other sources, in spite of the fact that it did not commence until 1933, and effectively ceased in 1966.

In addition to dredging, gold production by sluicing has always been an important contributor to the total output of the Morobe Goldfield, particularly throughout the early period of development. During the pre-war period several hundred expatriate miners worked in the goldfield, many usinq sophisticated sluicing and hydraulic mining methods, and for most of this time production exceeded 1000 kg per annum. Post-war production levels have never approached those of the pre-war period, partly owing to the exhaustion of the richest gravels and also to the reduced scale of operations.

Alluvial gold mining by national miners commenced in the late 1950s and by 1977 about 77% of the alluvial goId and 42 % of the total gold production of the Morobe Goldfield was won by national miners using simple, small-scale, alluvial gold mining methods. A total of 1,10 ,318 ounces (34,309 kg) of gold has been produced from small-scale alluvial workings, which is 29 % of the total gold production from the Morobe Goldfields to 1977.

Source of Gold

Upper Edie Creek. Alluvial gold won from the Upper Edie Creek area originated from veins, veinlets and a few major lodes. Local veins generally contain an assemblage of

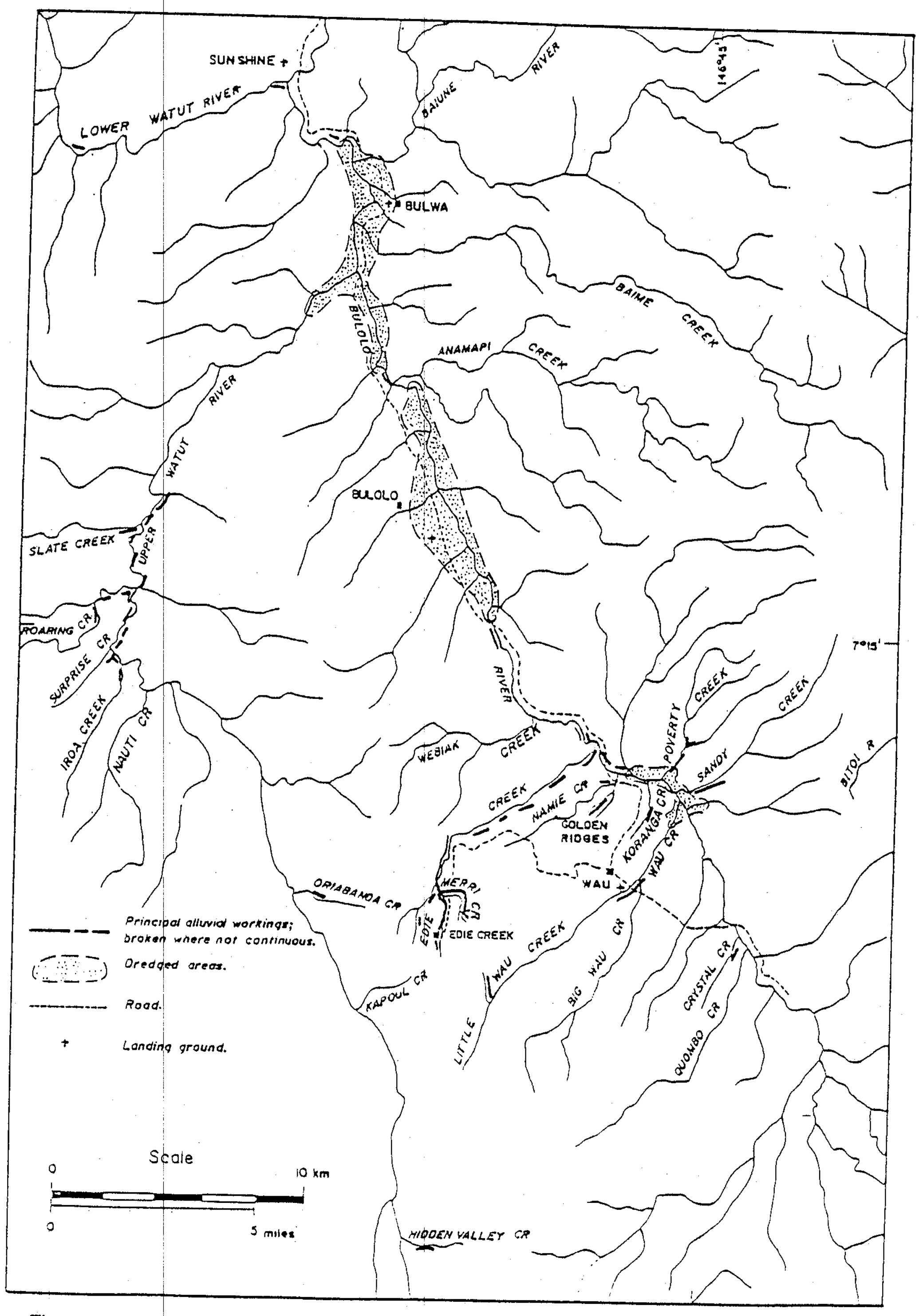

Figure 3. Distribution of alluvial gold workings in the Bulolo-Watut rivers system (after Fisher, 1975).

Table 2. Pre-war and total alluvial gold production from the Morobe Goldfields from all sources.

Period of Production	Total	Lode	Alluvial	
			Sluicing	Dredging
	Au Kg	Au Kg	Au Kg	Au Kg
Pre-War	69267	6587	22686	40354
Post-War to June 1977	46765	9776	11623	25366
Total to June 1977	116392	16363	34309	65720
Percentage of Total Production		14.1%	29.5%	56.5%

calcite, manganocalcite and quartz, gangue minerals hosting various base metal sulphides, electrum, gold, silver, and silver sulphosalts. These vein systems are genetically related to the emplacement of Pliocene age stocks and endogenous domes of the Edie Porphyry. Veins that host the gold mineralisation transect both the Owen Stanely metamorphic rocks, adjacent to endogenous domes of Edie Porphyry, and the intrusive complexes. Most of the vein systems in the Upper Edie Creek area have undergone extensive near surface oxidation, often to a depth of about 25 m. As a result of this oxidation, gold was mobilised in the upper parts of many of these veins and selectively deposited in zones of enrichment, where local accumulations of gold nuggets grew in situ. The subsequent release of these gold nuggets during mechanical weathering led to the formation of locally rich alluvial gold placers.

Wau-Bulolo Flats. Most of the placer gold won from the Wau-Bulolo area is derived from either oxidised manganocalcite veins and lodes of Upper Edie Creek or from the hydrothermal gold-silver mineralisation at Upper Ridges, Wau. The latter is hosted by a hydrothermal breccia unit called the Oavidsons Breccia, which in turn is genetically related to the emplacement of the Edie Porphyry Intrusions and the formation of the Wau diatreme. Here, gold-silver-base-metal mineralisation was deposited as gently dipping, lenticular, 'bodies of vein stockworks up to 10m thick and 300 m long. Placer gold from this mineralisation is about 500-600 in fineness. Another less important source of placer gold in the Wau-Bulolo area is mineralisation associated with intrusion of the Middle Miocene aged Morobe Granodiorite. Gold associated with this source is reported by Lowenstein 1982) to have a fineness of about 860-890.

Current Small-scale Mining Activities

Figure 3 shows areas of the Morobe Goldfield that are presently being worked by local miners using small-scale placer mining methods. These include Upper and Lower Edie Creek, Bulolo River Gorge, the Wau and Bulolo Valleys and scattered workings along tributaries of the Upper Bulolo River. Most of the small-scale alluvial workings are concentrated below river flood Ievels, and miners attempt to work gravels 1-2 m below the normal river levels by using river cannel diversion techniques and small pumps. Most of these gravels have been worked before o at least one or two occasions, but in some areas considerable quantities of gold are still won. Mining methods presently consist of sluicing or panning. The only major alluvial working that is presently in operation is run by PNG Forest Products. They use hydraulic monitors to wash auriferous gravels through one of two 50 ft sluice boxes set up in the Bulolo Valley.

Potential Resource Remaining

There are still sufficient reserves of near-surface, low-grade, alluvials present to justify the continued operation by small-scale gold miners. In addition to shallow deposits, there may be substantial reserves of gold-bearing alluvium in the Bulolo Valley at depths below those reached by the gold dredges.

Porgera River Goldfield

Past Production

Alluvial gold was discovered in the Porgera River by J.L. Taylor and J.A. Black in 1938.

However, no further prospecting was carried out in the area until the end of World War II. From 1948 to June of 1962 alluvial gold mining was restricted to the indigenous population. Within this period a total of 4128 ounces (128 kg) of gold was won from the goldfield. In June 1962 the goldfield was de-restricted and became open to general alluvial mining and prospecting. From the time when the area was declared open (1962) to 1968 a total of 5911 ounces (184 kg of gold was extracted from the goldfield using simple sluicing and panning techniques. This brings the recorded total gold production between 1948 and 1968 to 10,039 ounces (312 kg).

From 1973 to 1985 Mount Isa Mines conducted a small hydraulic sluicing operation that resulted in the production of approximately 5800 ounces (180.4 kg) of gold from auriferous colluvial deposits on the Yakatabari Creek. Apart from this hydraulic operation MIM also conducted minor sluicing operation on Denys Creek, winning about 771 ounces (24 kg) of gold within the same period.

Source of Gold

Of all the alluvial deposits throughout PNG the source of gold in the alluvials at Porgera is perhaps the best documented. There, placer gold has been traced directly to outcropping quartz-carbonate vein stockworks that contain native gold. These veins are genetically related to the Porgera Intrusive Complex, a Miocene aged suite of lamprophyric type intrusions. Reserves of lode gold at the Porgera deposit stand presently at 387 tonnes (about 12.5 million ounces), and will probably be increased soon. Native gold at Porgera occurs primarily in vein stockworks composed of quartz, magnesium carbonate (dolomite or ankerite), vanadium rich mica (roscoelite), pyrite, and less commonly hematite or magnetite. These auriferous vein stockworks cross-cut both Iocal intrusive rocks and carbonaceous sedimentary rocks of the Chim Formation. Alluvial gold close to the source at Porgera is frequently attached to, or included within, fragments of vein material and often exhibits a crystalline or dendritic morphology.

Current Small-scale Mining Activity

Current smelt/I-scale mining activity by locals consists of sluicing and panning of alluvial gravels that are present as elevated terraces along the flank of the Kogai, Kaiya and Porgera Rivers (Figure 4). These gold-bearing gravels form benches up to 50 m above the present day river level. It is estimated that a total of 700-800 miners are currently working these elevated terraces.

Apart from mining the elevated terraces 50-100 local miners are working the eluvial and weathered material associated with high-grade gold-quartz-carbonate veins that crop out locally on Waruwari Hill. Various mining methods are employed, including panning and sluicing, fire setting of outcropping veins and chisseling or hammering deeper into the veins.

Potential Resource Remaining

The main potential alluvial gold resources in the area are the elevated terraces and active river channels located along Yakabatari Creek, Kogai River and upper and Middle Porgera River (Figure 4). All these sites are suited for small-scale placer mining operations.

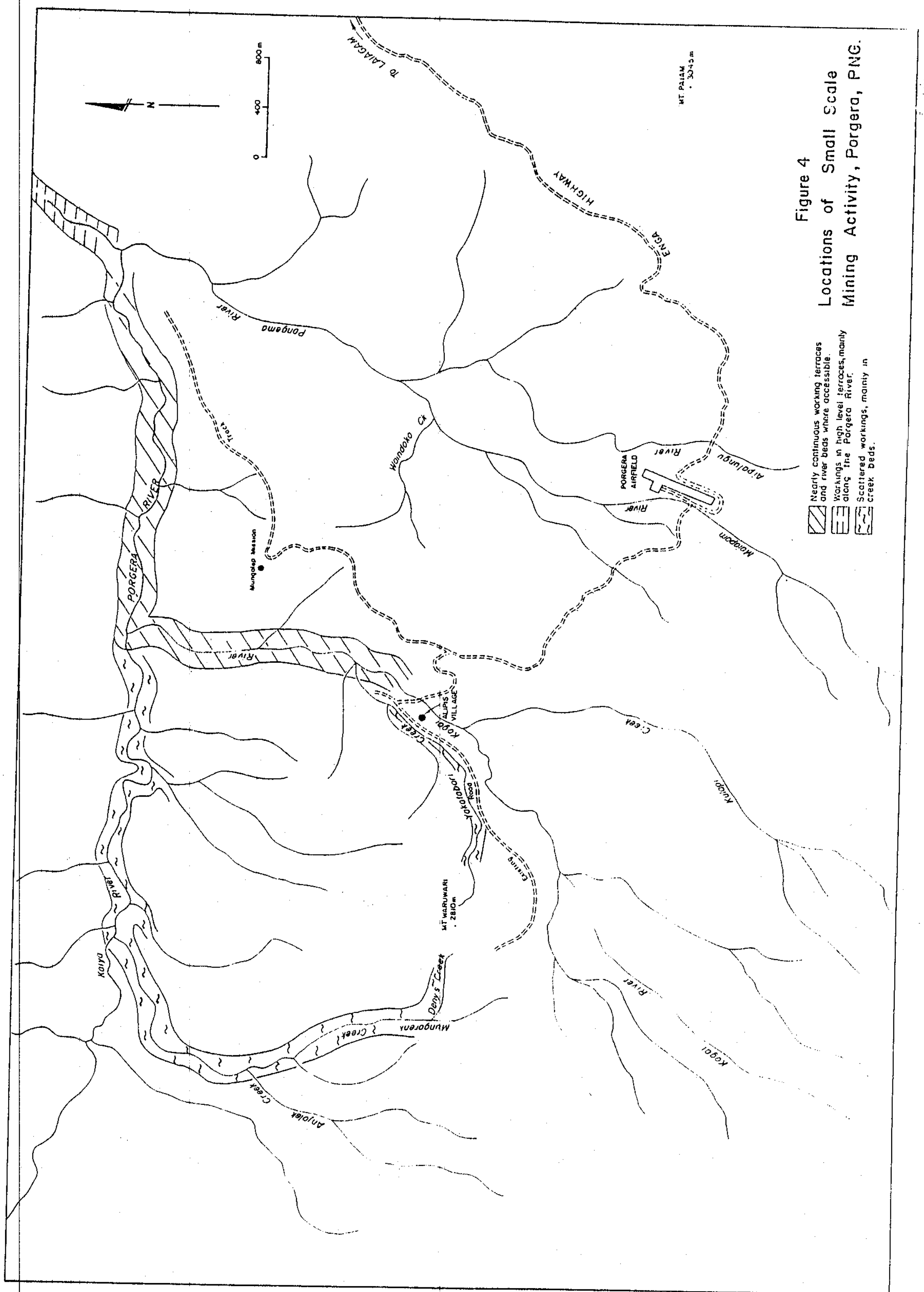

Figure 4. Location of small-scale mining activity at Porgera.

Lakekamu Goldfields

Past Production

Gold was first discovered by Mat Crowe and the Pyke brothers on Ironstone Creek in early 1909 and the area was proclaimed as the Lakekamu Goldfield (Figure 5) in December the same year. In 1910 a gold rush took place with about 150 European miners prospecting the Olipaii River and iits tributaries (Figure 6). Between 1909 and 1932 a total of 37,910 ounces (1179 kg) of gold was recovered from the field by sluicing and panning operations. In 1933 Tiveri Gold Dredging Company was created and the same year the company applied for dredging claims on Kau Creek. The dredges commenced production in 1934, and between then and 1939, when they ceased operations, 2322 ounces (72 kg) of gold was produced. Little mining activity has taken place within the L.akekamu goldfield since 1939. However, presently the area is been evaluated for its deep dredging potential.

Source of Gold

The source(s) of alluvial gold in the buried river channels and elevated river terraces of the Lakekamu goldfied are yet to be discovered. However, it is suspected that the source of gold is similar to that found in the Wau-Bulolo and Hidden Valley region, directly northeast and over the Owen Stanley divide from the Lakekamu River System. There, Pliocene age intrusive porphyries of andesitic to dacitic composition are principally responsible for local gold mineralisation. Production from this area includes about 90 tonnes (3.2 million ounces) of alluvial gold and there are presently known reserves of over 75 tonnes of lode gold. To the south of the Wau-Bulolo area, over the Owen Stanley Range, tributaries to the Lakekamu River system probably drain terrain that hosts as-of-yet undiscovered Miocene to Pliocene age intrusions, and associated intrusive-related precious metal mineralisation.

Current Small-scale Mining Activity

Current small-scale mining activity is concentrated along the Olipai River (Figure 6). It consists of about a dozen local miners working the elevated terraces using simple sluicing and panning techniques. Apart from that, mining activity has not taken place on the goldfield since 1938 when the field was deserted.

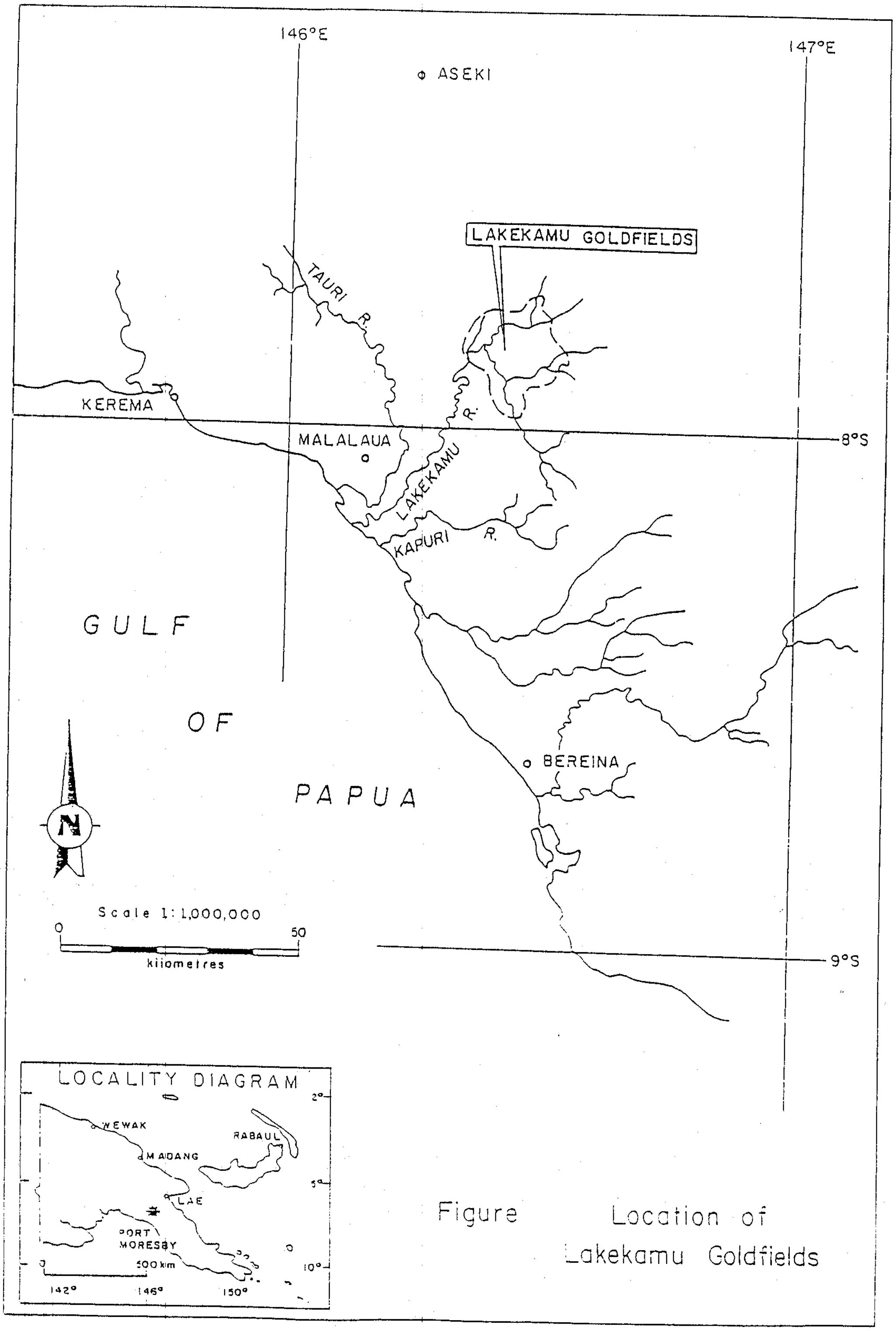

Figure 5. Location of Lakekamu Goldfield.

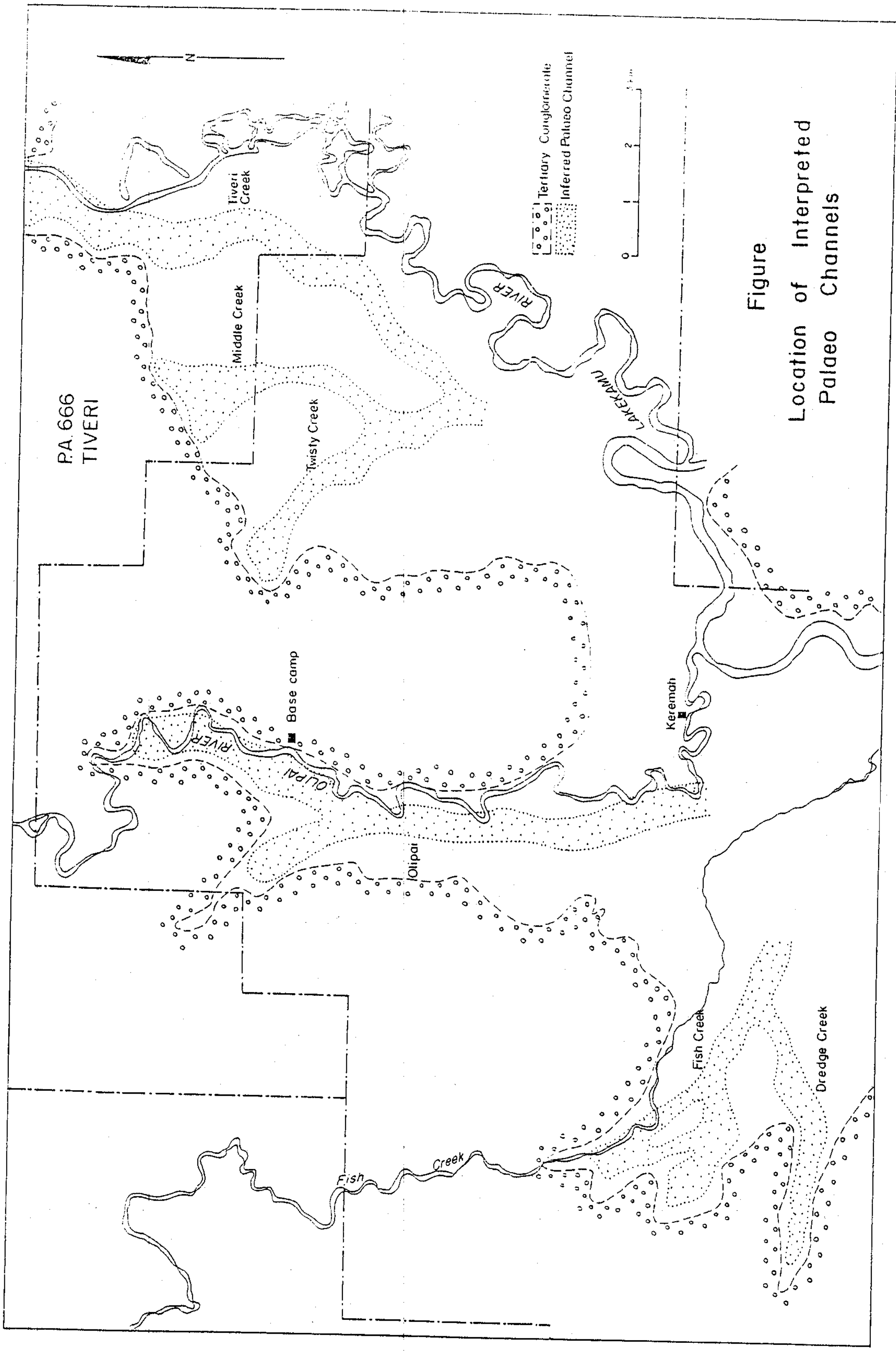

Figure 6. Location of interpreted paleochannels at Lakekamu.

Potentia! Resource

Lakekamu goldfield is presently being evaluated for its potential of hosting dredgable auriferous river gravels that deposited in a braided river system. These gravels are tens of metres below the present day meandering river systems of Olipai River, Twisty Creek, and Fish Creek. Along sections of the Olipai River, City Resources has outlined reserves of 11 million m3 of dredgable gable gravels with a grade of 0.12 g/m. These auriferous gravels are a few tens of metres below the present day surface and their profitability is still being evaluated.

Another potential resource are the auriferous paleochannels present today as elevated terraces. This is a potential resource for local small-scale miners that could be worked using simple mining techniques such as sluicing and panning.

SUMMARY

Of the many placer gold deposits in Papua New Guinea that have been worked since the initial discovery of placer gold on Sudest in 1888, alluvial gold placer deposit is by far the bigest producer of placer gold in PNG as exemplified by Wau - Bulolo system producing 3.2 million ounces of gold from alluvial workings between 1926 and 1977. Though of less importance residual deposits have contributed to placer gold production in PNG. Only with the disc very of Mt. Kare have landslide hosted placer gold deposits been recognised as potential host of major gold reserves that can be easily won by employing simple panning and sluicing techniques.

In terms of major potential resources, Lakekamu has major potential for dredgable targets in the form of buried paleo-river channels. Potential for small-scale panning and sluicing projects exists throughout the 16 proclaimed goldfields and other areas of Papua New Guinea and finally the discovery of Mt. Kare has sparked off explanation by national miners prospecting for a Mt. Kare type gold deposit.

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REFERENCES

HANDLEY, G.A. 1987: Exploration of the Porgera gold deposit. Pages 145-149 in Proceedings of Pacific Rim Congress 87, Australasian Institute of Mining and Metallurgy, Parkville, Victoria.

L UDON, A.G. 1987: Gold in Papua New Guinea. Pages 767-722 in Proceedings of Pacific Rim Congress 87, Australasian Institute of Mining and Metallurgy, Parkville, Victoria.

LOWENSTEIN, P.L. 1982: Economic geology of the Morobe Goldfield. *Geological Survey of Papua New Guinea Memoir 9.*

COASTAL AGGREGATES RESOURCES, DEVELOPMENT/ENGINEERING AND MAPPING

SAND MINING ON RAROTONGA AND AITUTAKI AND THE EFFECTS ON THE ADJACENT FORESHORE AREAS

by

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COOK ISLANDS

The early missionaries, during the first half of last century introduced the use of concrete for the construction of buildings or dwellinq houses using burnt lime mixed with water and coarse coral sand and gravel for the walls and floor, poured in situ.

Coral stones found on storm-ridges along the foreshore areas were used for concrete reinforcement in the walls which are usually about 300 mm thick for the average-size dwelling houses to about 1 m thick for larger buildings including churches.

Sticks from selected trees were often used for reinforcement inside the walls. Iron was never used inside the lime walls of these old buildings many of which are still standing after over a century.

The top-plates and the wooden frames for windows and doors were carefully set into the concrete walls to support the wooden framework of the building.

The first of these buildings were built about the 1830s. By the end of last century the newly established modern settlements on Rarotonga, Aitutaki and the other islands, centred around the church building and pastor's house were, as described by visiting sea-captains beach of the houses from the coral-surfaced road 7 m wide.

The walls on the buildings were plastered using a mixture of fine coral sand and burnt lime to archieve a smooth surface. Burnt Iime mixed with water provided the white-wash for the external walls of the buildings and the stonework marking the edges of the footpaths.

Coral stones or boulders, to be burnt in huge lime pits lined with huge green logs for firewood, were selected from the foreshore areas or from the bed of the lagoon or the nearby reef. The preparation and fixing of the huge Iime pit was usually a social occasion in the spirit of mutal self help for socio-economic reasons.

The exploitation of the natural resources suited the requirements of the society, and the slow pace of the building development was never a threat upon the resources that were "a free gift from nature". Accessibility to the source of the materials for the needs of the individuals in the community was never a problem following the simple rules of a society free of the usual commercial exploitations and greed.

Up to fifty years ago sand and gravel, even in the more modern setting were easily obtainable from the nearest beach fronts, and the quantity of these beach materials removed for concreting, road surfacing, and land fill were insignificant and there was no immediate threat upon the supply.

The period from the end of the Second World War was the beginning of a new era when extensive construction work began on Rarotonga and Aitutaki. Major construction work of any significance actually began with the construction of the war-time airfields on each of Penrhyn in the Northern Cook Islands, Aitutaki and Rarotonga.

Materials for the runway were dredged from the nearby lagoons and foreshore areas to provide the compacted coral runway to take military aircraft.

The post-war development in the Cook Islands saw the construction of more modern concrete class rooms and other public buildings an Rarotonga and some of the other islands. Up to this period the use of concrete blocks for buildings was quite insignificant. Nearly all concrete buildings up to the period 40 years ago were constructed using the form-work for the concrete poured in situ.

The post-war years brought better opportunities for the people to earn regular income from sale of their agriculture produce to the New Zealand market, or local employments. The style of housing began to change in the 1 950s.

Traditional wooden and thatch houses were slowly replaced with the more permanent concrete and wooden buildings.

With the increased buying power of the people, reflecting the development of trade and commerce between the Cook Islands and New Zealand, and the easy availability of cement, the use of the traditional burnt-lime in concrete buildings began to decline to the point where it is no longer in use today as a building material. Yet very old lime buildings that are still standing today, and for over one hundred years have survived several severe cyclones, proving their structural strength. Even where the buildings have been properly maintained there is minimal visual sign of deterioration of the better maintained buildings.

Over the past 40 years the change in the life-style and the improved living standards of the people generally brought the inevitable changes in the designs and sizes of the dwelling houses. Concrete blocks became a common building material particularly during the 1960s when the Government Housing Loan Scheme was introduced under the New Zealand Administration.

As more buildings were erected on Rarotonga and Aitutaki the demand on the natural resources on the foreshore areas of these islands brought about many significant changes in the configuration of the foreshore areas that are now most vulnerable and exposed, through the exploitation and disturbance of the sloping natural beach fronts.

Within the past 20 years, particularly with the opening of Rarotonga's international airport in 1973, the building industries began to accelerate at a very fast rate as modern hotels and other larger buildings began to appear all around Rarotonga. Similar trend is occurring in Aitutaki, though on a much smaller scale.

Several building contractors have beer registered in Rarotonga to cope with the demands of a relentless and fast-growing building industry. The Building Control Division within the Ministry of Works is responsible for the administration and enforcement of the Cook Islands Building Standards to ensure that all safety aspects for the structure is strictly complied with as stipulated in the Building Codes that need to be revised or rewritten to keep pace with the modern requirements for the Cook Islands.

With the exploitation of the vulnerable foreshore areas which for decades have been the main source for construction materials such as beach sand and gravel used as concrete mix or fills for the concrete floor and driveway, the Cook Islands Conservation Act 1987 was passed in Parliament to protect the beach fronts against further destruction.

On Rarotonga and Aitutaki the foreshore areas have receded significantly, as much as 30 m, further inland, as shown on survey plans lover a fifty-year period.

The damage already done to the beachfronts on these two islands is irreparable. Protective measures, however, have been considered and proposed to resurrect some of the more important beach areas that have lost sand and gravel through the indiscriminate mining of the beach materials with use of heavy plant and machinery especially over the past two decades.

Beach materials were also used not only as land fill, but as fill for roads that are usually poorly drained and badly prepared so that during heavy rain the beach materials already spread-out on the road surface have been quickly washed away and lost.

The Government Ministry of Works produces annually about 52,000 concrete blocks for Government Projects and for sale to the general public. Other concrete products are also processed including concrete culverts for storewater drains, bridge beams, water-tank staves etc requiring over 2000 m^3 of sand annually for the concrete mix of cement, sand, and crushed metal from the Government-owned and -operated rock quarry in Rarotonga.

Two other large private contractors also produce concrete blocks and other concrete products for sale to the general public with a large quantity of sand consumed annually.

On Rarotonga's narrow coastal strip running almost right around the island about twenty five percent of the total area is pure coral sand and gravel averaging about 2 to 3 m deep. A large section of this sandy area with an overlay of centuries of rich humus soil is already occupied by buildings and other things making it impossible for the mining of sand and gravel from these areas.

The enforcement of the Cook Islands Conservation Act 1987, however, prevents further mining of sand and gravel at least from these vulnerable foreshore areas, stipulated as the area of land 50 m inland measured from the low water mark.

Mining of sand is now confined to selected vacant sections further inland, subject to the approval of the land owners, with certain conditions stipulated in the bi-lateral agreement between the operator and the interested land owners.

Sand, mined from these inland localities is good-grade salt-free sand for concrete work and for plastering, and excavation can go down to over 2 m deep, or until the water table is reached.

Usually, the two parties entering into Ian agreement would agree for the operator to remove the sand from within a stipulated area in exchange for volcanic soil from elsewhere to rehabilitate the mined area.

During the construction of Rarotonga's international airport sand for the backfill, and the concrete runway was obtained from borrow pits on adjacent land alongside the construction area. After the sand had been successfully mined down to a depth of 3 m the inferior soil and organic material excavated earlier from the construction area were used as back fill for the arrow pits. Some of these rehabilitated lands have now been used for agricultural purposes or animal grazing.

This is one example of controlled mining of sand, and the land properly rehabilitated after the sand has been mined.

On the island of Aitutaki the sand deposits on the mainland, some 1600 ha in area, are fund on the north part of the island extending south half-way along the west coast of the island in a narrow strip not more than 200 m wide at the widest point.

As a result of the uncontrolled removed of sand and beach gravel in Aitutaki for concrete work, land fill and road works the foreshore areas or beach fronts have receded significantly to about 20 to 30 m inland, exposing the adja6ent areas to further storm destruction that is evident everywhere.

The once beautiful gently sloping beaches on Aitutaki's north and west coasts are now scorned by steep embankments where the sand and the protective coral stone have all been removed or washed away by successive severe storms, never to be replaced or restored.

Like the situation on Rarotonga mining, of coral sand and gravel for construction work by the Ministry of Works on Aitutaki are located further inland subject to special arrangements with the landowners for the removal of the sand and the rehabilitation of the mined area.

Government Harbour Works on Rarotonga, with the continued dredging of the harbour basin provides the dredged materials in large quantities which can be used as ideal material for land fill and roadworks. The dredging operation is properly controlled and monitored.

Another private contractor, in a written contract with the Government, has been licensed for about 5 years to undertake the dredging operation in the Avana Passage on the east coast of Rarotonga. A Government employed Environmental Consultant was assigned to study the area which accommodates breeding places for certain species of marine life, and made recommendations to Government where the dredging operation can or cannot take place.

The dredged materials of coral sand and river gravel deposited in the passage by the Avana Stream, have been used as ideal material for road fill, by the Ministry of Works at a negotiated price paid to the contractor.

The building industry on Rarotonga shows an upward trend with multi-storey commercial buildings and visitor accommodation going up around the island, in concrete.

Although the situation is not yet critical, there is a move to identify suitable areas on Rarotonga and Aitutaki for the mining of sand for the construction work that is inevitable within at least the next 10 years.

Construction plans have been designed for the rehabilitation or restoration of some foreshore areas particularly to protect public assets and amenities including sections of the public roads which have been badly undermined by the sea as the unprotected beachfronts continue to recede further inland.

The fragile and unprotected coastlines of Rarotonga and Aitutaki are exposed to the destructive forces of wave erosion despite the warning signs that have been seen clearly, but ignored and taken for granted by successive generations. There is a need for immediate attention to this problem, and for study to protect the heritage of the people of the Cook Islands against self-destruction.

The last severe Tropical Cyclone Sally in January 1987 drastically altered the configuration of a large section of Rarotonga's northern coastline which receded more than 30 m inland. Model studies are needed to determine the effects, of construction work along the foreshore areas, on the adjacent beach fronts, along with the tidal movements and currents along the unprotected coastlines of these islands.

CONSTRUCTION MATERIAL FIELD SURVEY UPOLU,

WESTERN SAMOA - 1988

by

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and

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INTRODUCTION

During August and September, 1988 a 3-week field investigation of nearshore construction materials was conducted in Western Samoa by Techsec and Apia Observatory staff. The primary objective of the survey was to asses the nearshore sand and gravel resources around the greater Apia area of northern Upolu. The following specific objectives were determined at the start of the field work:

- Determine the quality and amount of aggregate remaining in the Mulinu'u Peninsula/Vaiusu Bay area. This site has been the main source of aggregate for the Apia area for the last 15 years or so, and it is desirable to determine the extent of the resource.

Conduct reconnaissance surveys in the greater Apia area of northern Upolu to determine the location and extent of other potential sand and gravel resources. In particular, the Faleolo area was of considerable interest because of plans to extend further the airport runway.

Collect additional information in lagoonal areas of Aleipata for possible use as roading material in planned upgrading of the Richardson Track.

- A reconnaissance survey of Savai'i in preparation for an NZOI nearshore survey for construction materials scheduled for late 1988.

- Wherever and whenever possible re collect additional data for use in the compilation of coastal maps of Upolu - a programme initiated in 1987.

- Provide in-the-field training for staff of the Apia Observatory in various marine geological techniques.

BACKGROUND

Apia is the seat of government and largest population centre of Western Samoa resulting in the area with the greatest demand for construction materials. Currently there are two full-time nearshore dredging operations near Apia - an extensive series of causeways and draglines opposite Mulinu'u Peninsula which provides most of the construction materials to the Public Works Department and private contractors, and a smaller operation, Apia Concrete Products, which dredges material for use in concrete blocks and other products. Other sources of aggregate include occasional excavations (about 3 to 4 times per year) at the mouth of the Vaisigano River in Apia Harbour and small-scale beach mining.

Exact present rates of extraction are unknown. Estimates based upon conversations with the dredging operators are as follows:

Mulinu'u Peninsula

- 90 m^3 */day* = 540 m^3 /week = 28,000 ~3/*year* = 420,000 m^3 in 15 years of operation.

Concrete Products

-150 m^3 /week = 7800 m^3 /*year* = - 54,00 m^3 in 8 years of operation

These values are gross estimates and are presented to give an indication of the magnitude of the operations and provide information regarding construction material requirements for the area.

METHODS

A variety of techniques were used during the course of the survey including echosounding, sub-bottom acoustic profiling, surface sediment sampling, and jet-probing.

Geophysical techniques have been described elsewhere in the workshop proceedings; surface sediment samples were collected either by hand or using a small pipe dredge; a jet-probe system was put together in Samoa because vibrocore equipment was missing from the shipment from Suva. The jet-probe system consists of a gasoline-powered water pump; rigid, flexible, 3 m long intake line, about 15 m of flexible firemans' hose, and a probe of 3 m length x. 2.5 cm diameter galvanised steel pipe. A high pressure stream of water is forced through the pipe which is placed vertically on the seabed. The water jet excavates a hole and, depending on the character of the sediment, the entire 3 m probe may penetrate the seabed. The easiest and quickest probing occurs in muds or well-sorted fine to medium sands. Gravels and coral rubble are the most difficult to probe. A qualitative assessment of the sub-bottom stratigraphy can be estimated by the ease of probe penetration.

PRELIMINARY RESULTS

Sampling, jet-probing, and geophysical surveys in the Mulinu'u area suggest there are sufficient aggregate reserves to supply most needs in the Apia area for at least the next five years and probably longer (preliminary gross estimate - 1.1 x 10^6 m^3). The deposits are a mixture of back-reef calcareous sand, rubble, and in-situ coral (-70-80 %) with river-drived basaltic material. These deposits appear to overlie framework reef at about 3-5 m sub-bottom depth.

Similar surveys in the Faleolo reef areas documented an extensive deposit of carbonate and and rubble (preliminary gross estimate -8 x 10^5 m^3). Jet-probing indicated sediment thicknesses exceeding 3 m for much of the reef flat in this area. Water depths average 2-4 m.

A smaller deposit (preliminary gross estimate - 5 x 10^4 m^3) of volcanic-rich (-50-70 %) coarse sands, suitable for concrete product manufacture, were discovered near Valala, east of Apia. The sand body appears to be prograding into deeper water associated with a reef passage. Sediment thicknesses exceeded 3 m in many of the probes.

Other sites examined along the north coast of Upolu failed to reveal any large sources of a aggregate material.

The extensive reef flat and shallow lagoon at Aleipata on the east coast contains large deposits of carbonate sand and rubble which may be suitable for roading in the area.

COASTAL MAPPING IN WESTERN SAMOA

by

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INTRODUCTION

SOPAC has conducted numerous nearshore surveys in Western Samoa primarily to search for nearshore sand and gravel deposits or to provide background information for harbour development projects. Areas investigated in the field have included the greater Apia area, Faleolo, Manono-Apolima, Aleipata, Mulifanu, and Solosolo of Upolu, and Asau and Salelologa of Savai'i. It was recognised that a framework was needed in which to incorporate results of previous surveys and input new information in a systematic fashion. A coastal mapping programme was undertaken as a means of integrating previous surveys into an understanding o the entire Upolu coastal system. By understanding the dynamics and distribution of deposits of the coastal zone, a more effective nearshore programme can be developed.

Objectives of the exercise are summarised as follows:

a) to describe the geology and morphology of sedimentary deposits in coastal areas; this may cover zones extending over many tens to hundreds of square kilometres;

b) to make preliminary assessments of potential mineral resources such as construction materials and placer deposits in the coastal zone;

c) to provide a scientific framework within which to evaluate broad geological trends, identify environmentally sensitive areas, and assess potential coastal developments;

d) to develop an understanding of Samoa's recent geological evolution and to relate this to present day erosion and accretion trends; and

e) to train local personnel in the techniques of regional coastal and nearshore mapping and resource assessment.

METHODS

The mapping exercise was conducted by examining published maps and reports, aerial photographs, student maps prepared during the 1985 CCOP/SOPAC-USGS Coastal Mapping Workshop held on Upolu, and sample collection and field observations.

Preparations of Base Maps

Published maps available at the Department of Lands and Survey in Apia consisted of 1:20,000 topographical map series (contour interval = 50 feet), and a 1:20,000 orthophoto map series produced for the Agricultural Development Programme (contour interval = 10m). Both series use the same sheet numbering system; paper multicolor topo maps are available for the entire coastline, and stable-base blackline orthophoto reproductions were available for all but two coastal sheets (Apia and Lefaga).

The maps were used to provide baseline information on size and features of the reef flats and coastal plains, location of rivers and reef passages, and accessability for field inspection. Wherever possible the orthophoto maps were used as the primary source of information because they provide more detail concerning reef flat features, and the reef edge and submarine terrace are more accurately depicted than on the topo maps.

Base maps were prepared at the Data Management section of the Technical Secretariat by digitizing features from the orthophoto maps. Mylar plots were made of the digitized shorelines, contours, and reef boundaries. These formed the base maps upon which other information was added.

Aerial Photograph Interpretation

1981 vertical aerial photographs (including the negatives) of Western Samoa are held at the Lands and Survey Office, Apia. Earlier photographic surveys were completed in 1954 and

1970 and were used in the production of the topographic and orthophoto maps (these photos are not available in Samoa). The air photos were used in stereo pairs to identify morphological features of the coast.

Draft interpretations were made which depicted features such as: beaches, river mouths and deltas, man-made structures, swamp, depressions, mangroves, and a variety of reef features. Where possible, indicators of long-term littoral drift direction were also identified. This information was then transposed to the b se maps.

Limited follow-up field checking was done at selected sites to test the accuracy of the interpretations and to collect and describe samples.

PRESENT AND FUTURE RIVER DREDGING AND BANK PROTECTION ACTIVITIES IN FIJI

by

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INTRODUCTION

Background

Fiji, an archipelago in the South Pacific comprises of two main islands of Viti Levu and Vanua Levu, along with over 300 other smalIer islands.

Only a small percentage, about 15 %, of the total land area of 18,333 square kilometres is suitable for sustainable agricultural production.

As Fiji's economy is dependent mainly on sugar production, our Development Plans have recognised agriculture as one of the strategic sectors of the economy. Investment in this sector has continued to receive high priority.

The major river systems of Fiji are remarkably large in relation to the land area. This is largely a function of our high rainfall coupled with relatively steep and rugged topography. The major river systems of the two principal islands of Viti Levu and Vanua Levu have always caused considerable damage by the flooding of downstream alluvial plains.

These floods are usually generated by tropical cyclones, which are accompanied by torrential rains that pour over the catchment areas of the rivers.

As documented in official hurricane records which date back to 1840 the average frequency of these flood-generating cyclones in Fiji has been one approximately every six years. However, since the early seventies, Fiji has been struck almost every two years, e.g. Bebe, Wily, Oscar and more recently, by four in succession, Eric. Gavin, Hina and Higel, between

January and March 1985. Also, in *view* of the intensive agricultural development of the plains and the rapid suburban growth of the coastal towns located along the major rivers, such as Navua, Nadi, Ba, Sigatoka and Labasa (Figure 1), the damage caused by flooding has achieved new dimension ..

The disastrous floods generated in April 1980 by cyclone Wally in Viti Levu and, more particularly, in the Navua area, prompted the Government to undertake a programme to rehabilitate the flood-damaged areas, and to alleviate the flooding. The latter was attributed primarily to sedimentation by the rivers with the consequent raising of their bed levels. The programme would also encourage further agricultural development in low-lying areas.

The present Development Plan 9 recognises the need for measures against widespread flooding prevalent in parts of Fiji, a programme for drainage construction and maintenance works, dredging of rivers and proper watershed management.

PRESENT POSITION

Government Dredging Activities

The Ministry of Primary Industries recognised that a dredging programme would be necessary to alleviate future floodings. In 1982, it therefore acquired from Holland the first cutter-suction dredger - Beaver 1000 named *Manabatibati,* equipped with 1 km on-and off-shore pipelines for discharging the spoils. *Manabatibati* commenced dredging of the Navua River in 1982. This exercise was subsequently completed by June 1984 with the dredge spoil being in the construction of some 8 km of levee banks.

In the process a total of 1.5 M m^3 of spoil was dredged, extending from Vunivau to Navua Town. Sediment dredged were gravel and coarse sand.

Flood alleviation in Navua proved so effective that a second larger cutter-suction dredger, Beaver 1500 named *Dauqeuqeu,* equipped with 700 m of on-and off-shore pipeline, was again purchased from IHC - Holland in December 1984, together with anew workboat. This allowed the initiation of dredging of Rewa River, and the acceleration of the National dredging programme.

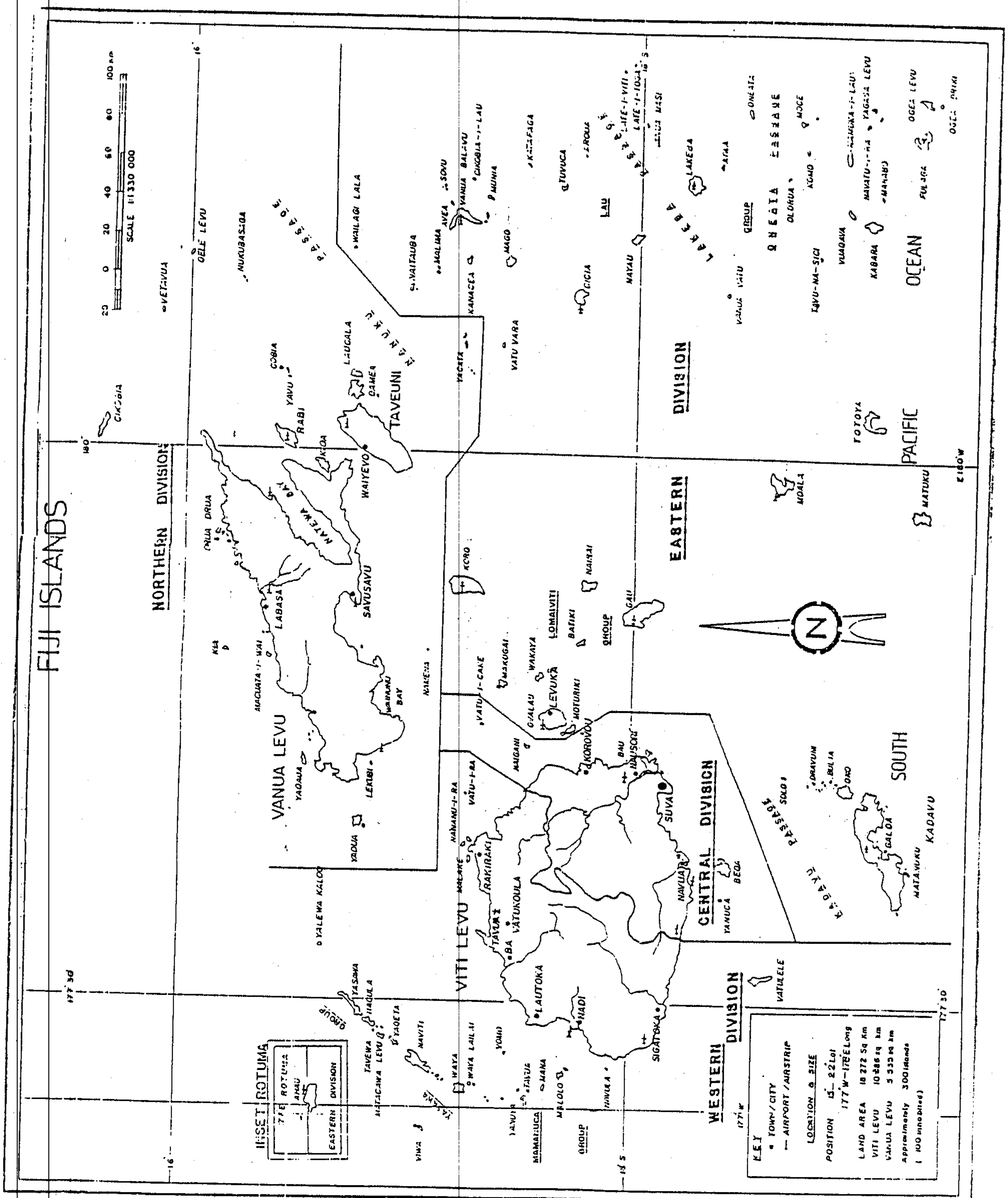

Figure 1. The islands of Fiji.

A drilling rig was also purchased in 1986. Attachments and modification to convert it to off-shore drilling were completed in 1987, and the rig is now undertaking off-shore soil investigations.

The Manabatibati commenced dredging in Rewa River in October 1984, and was joined by the new

Dauqeuqeu in 1985.

Material type in Rewa River is coarse sand, getting finer towards the mouth, and at places having clay deposits.

Up to June 1988, 5.36 M m^3 of sediments have been dredged from the Rewa river.

Private Dredging

Over the last two years, private commercial concerns have dredged a total 214,659 m^3 f sand' from the Rewa River system, representing only 6 % of the total volume dredged from Rewa River (Annual Reports of Department of Mineral Resources, 1986, 1987).

Dredging - Design

The design criteria of the Rewa River channel sections have been based on a design flood return period of one in ten years and a bank full-flood flow for calculations of the channel capacity according to Manning's formulae for pen-channel hydraulic calculations. A uniform bed slope along the longitudinal profile was selected so as to avoid dead storage within the channel or obstruction of the flow. Also the channel sections to be dredged were located and positioned along the cross sections, so as to provide a smooth curving horizontal plane allignment of the channel flow and thus to avoid constructions or sharp bends.

The one in ten year return period was estimated at 7500 m^3 /s (cumecs) with 1000 m^3/sec as the estimate of an over bank flow upstream of Nausori.

Dredging Technology

River dredging is a relatively new technology to Fiji, and is an expensive operation.

Overseas expertise provided through the UNDP has assisted with the training of plant operators, design engineers and project managers. This assistance has been extremely useful; dredging management and operation can now be completely localized. The last "expert" is to leave in March 1989.

At present both dredges are likely to continue operating in the Rewa River until mid-1989 by which time some 6 million cubic metres would have been dredged over 15 km of river length. It must be recognised that dredging is a relatively costly measure applied at the downstream end of the sedimentation problem. Concurrent control and reduction of erosion from within the river catchment is an essential adjunct in the long term national interest.

DREDGE – SPOIL UTILISATION

Private commercial small dredgers presently supply selected materials for road construction works and the manufacture of cement and concrete products.

Dredged river spoils from the Government operations have been largely used within the Navua and Rewa Rivers vicinity for the following purposes:

(a) River bank heightening of Navua for a total length of 8 km.

(b) Providing fill material for 15 km of roading in the Rewa Delta.

(c) Filling and heightening deltaic islands of Selo and Natuanuku for future village sites of Muanaira and Muanaicake, both on the lower Rewa river mouth.

(d) A 2 ha Wainibokasi off-shore reclamation for ultimate fisheries jetty development.

(e) Stabilising fill for heavily eroded bends at Naselai and Vunimono along the Rewa River; Vunibau bank protection works on the Navua River.

(f) Filling narrow side channels to create additional land without reducing main channel flood flow capacity e.g. Natogadravu and Nakalavovula on the Rewa River.

(g) On-shore filling in Navua town for the town's extension and future development.

(h) Making available to commercial licensed dealers to buy from the Government.

The imbalance in volume dredged by government, and that consumed locally by industries, will continue to grow. Formulations of policies to safeguard the interests and livelihood o private sectors on the one hand, and the need by Government to recover some costs from the expensive dredging operations through s les of dredged material on the other, will need to b recognised and addressed.

FUTURE DREDGING TRENDS

Direct Dredging

River dredging is an accepted national programme and, therefore, will continue to be a major river engineering activity aimed a deepening all major rivers in order to mitigate flooding. At the same time a better understanding of u stream salt water transgressions and other environmental impacts will be necessary so that preventative measures can be taken together it the dredging exercise.

Preliminary estimates of areas to be dredged together with the corresponding work volume for the National dredging plan are expected to be as follows:

River	Length (km)	Volume (Million m^3)	Area Protected (km)
Navua	7.0	(0.5 remaining)	7,062
Rewa	18.0	6.0	17,162
Rewa Tributaries	10.0	1.0	
Ba	18.0	4.0	7,502
Nadi	28.0	2.0	7,420
Sigatoka	18.0	2.0	4,622
Penang	7.0	0.5	590
Nasivi	9.0	0.7	167
Labasa	12.0	1.5	1,185
Wainikoro	10.0	1.0	970
Dreketi	13.0	2.0	2,235
Nasorowaqa	10.0	0.5	1,472
Wainunu	9.0	0.5	710
	169.0	22.0	51,097

[MR103 - Technical Secretariat]

With the present dredging capacity, the River Engineering section of the Drainage & Irrigation Division of the Ministry of Primary Industries will complete the task of dredging 20 million cubic metres of spoil over the next 25 to 30 years.

However, as an adjunct to dredging, for agricultural and social purposes, the Government is also actively promoting development of harbour facilities, and is viewing feasibilities of coastal reclamation for industrial development.

The concept of trade free zones, now being implemented, indicates the thrust of government policies and strategies to accelerate commercialisation, in view of the limited land that is available for agricultural development.

The capability, versatility and cost-effectiveness of dredgers as the suitable tool for port development is now recognised by Government, through the witnessing of the performances of the Government-owned cutter suction dredgers over the last six years.

WATERSHED MANAGEMENT

Present dredging efforts has brought forth the recognition that concurrent control and reduction of erosion from within the river catchment is an essential adjunct in the long term national interest.

Watershed Management Study

To this end, the Government has approved a UNDP financed Watershed Management study of the Ba and Rewa Rivers in late 1986. The final report of this project is being awaited, although the draft has been received.

The Watershed Management Study focused on the following:

(a) to conduct surveys and mapping of different soils and land types, with recommendations for erosion control or conservation measures;

(b) to review national organisational structures, in order to ensure greater coordination and efficiency;

(c) to review and make recommendations on existing legislation, as well as on the social and economic impact of dredging;

(d) to collect base hydrological data of both river basins including sediment characteristics; and

(e) to undertake river engineering studies to assess impact of dredging and forward proposals on flood and bank protection measures.

River Improvement Master Plan

In the process of dredging the Navua and Rewa Rivers, the need was also recognised to a dress river bank erosion problems, immediately within dredged sections and eventually over the whole river system. Government subsequently signed an agreement with UNDP in March, 1988 for assistance to provide and implement a master plan on improvements to the Rewa River system. The total project cost is $600, 000 of which about 50 % will be funded by the UNDP as technical assistance.

The immediate objectives of the Plan are "to enable Government to adequately plan, design and implement comprehensive river improvement activities ..... through a fully operational design section, capable of investigating and designing all future river engineering works for major rivers in Fiji and of monitoring, updating and maintaining the implemented schemes".

The River Improvement Master Plan will facilitate an overall inventory of the problems, establish a monitoring and measuring programme on general river data as well as set up a relevant data bank. Data will be used to design improvement works using computer simulation a models.

DREDGING TECHNOLOGICAL DEVELOPMENT

The state of knowledge about dredging and its applications, and manpower training were all practically nil prior to the purchase of the IHC Beaver 1000 cutter suction dredger M*anabatibati*. Although the Marine Department as previously operating a much smaller cutter suction dredger, it had no impact because of inadequate knowledge.

Since 1982, Dutch expertise has been continuously made available through various UNDP financed projects to train the local tradesmen, engineers and managers in the implementation of dredging projects. The operational aspects are now completely localised; the mechanical section still has the services of an expatriate engjneer, but project management is now localised.

Technological development has also spilled over to the local heavy engineering firms who have supplied or undertaken maintenance repair works on an annual contract basis.

A tough task is still ahead to increase the numbers of properly trained locals, in view of the fact that tertiary educational institutes in Fiji do not cover this engineering discipline. However, given the recognition now achieved on the versatility and cost effectiveness of this power tool, training developments will be sure to follow.

Environmental Impacts

The dredging activity has direct physical impacts and effects on the river environments and the marine culture. As Fiji is blessed with thick stands of mangroves, conflicting interests has arisen over the utilisation of these resources.

The Government has approved and is seeking FAO/UNDP assistance in financing and equipping and environmental impact study of dredging in the Rewa River. Future plans are aimed at securing environmental impact studies first before project implementations.

CONCLUSIONS

To ensure that the river engineering programme is as effective as possible, the following equipments must be accorded high priority:

(a) establishment of data banks;

(b) implementation of recommended land use practices within river catchments in order to minimise erosion;

(c) review of Government organisational structure in order to facilitate cooperation between Ministries; and

(d) training and retaining of local staff, particularly engineers.

LEGISLATION AND LICENSING

[MR103 - Technical Secretariat]

OFFSHORE MINERAL EXPLORATION AND WORKING

STATUTORY CONTROL AND ADMINISTRATION IN FIJI

by

Varani M Rayawa Mineral Resources Department Private Mail Bag, Suva

THE RELEVANT LAWS

In Fiji, both on land and under the sea within the Exclusive Economic Zone of Fiji, all minerals are vested in the State. Those acts of the Laws of Fiji, which have a bearing on mineral prospecting and mining are:

Chapter 146	The Mining Act
Chapter 147	The Quarries Act
Chapter 148	The Petroleum (Exploration & Exploitation) Act
Chapter 149	The Continental Shelf Act.

It is made clear in the Marine Spaces Act (Chapter 158A) that the Continental Shelf Act applies to all offshore areas within the Exclusive Economic Zone.

The administrative control over mineral resources is the responsibility of the Director of Mineral Development in his capacity as Director of Mines. This administration is subject to overall policy control by the Minister responsible for mineral resources, who currently is the Minister for Lands and Mineral Resources.

MINERALS

In dealing with mineral exploration and 'Working it is important to clearly define what a mineral is, in the context of the laws which govern that exploration and working. This is done under the Mining Act where the definition for “minerals" reads:

(a) "precious metals" which shall include gold, silver, platinum, palladium, iridium, osmium, or ores containing them, and any other substances of a similar nature;

(b) "precious stones" which shall include amber, amethyst, beryl, sapphire, turquoise, and all other stones of a similar nature;

(c) "earthy minerals" which shall include asbestos, ball-clay, barytes, bauxite, bentonite, china-clay, fuller's earth, graphite, gypsum, marble, mica, nitrates, phosphates, pipeclay, potash, salt, slate, soda, sulphur, talc and all other substances of similar nature;

(d) "radioactive minerals" which should include minerals either raw or treated (including residues and tailings) which contain by weight at least 0.05 per cent of uranium or thorium or any combination thereof, including but not limited to-

(i) monzanite sand and other ores containing thorium; and

(ii) carnotite, pitchblende and other ores containing uranium;

(e) "coal" which shall include coal in all its varieties and all other substances of a similar nature;

(f) "metalliferous minerals" which shall include aluminium, antimony, arsenic, bismuth, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, tin, tungsten, vanadium, zinc, and all ores containing them, and all other minerals and mineral substances of whatsoever description but excluding only the minerals and :mineral substances included in paragraphs (a), (b), (c), (d) and (e),

but shall not include clay, gravel, sand, stone or other common mineral substances, and for the purpose of avoiding doubt the Minister may from time to time by notice in the Gazette declare any mineral substance to be included in or excluded from this definition;

To date, the Minister has not had occasion to add to or detract from the list of minerals.

NON-MINERALS

It can be seen then, that the laws controlling minerals do not refer to sand, gravel, clays, rocks and stones of a general nature which might be won on a commercial basis for the building and construction industries or for other purposes. Silica sand for glass manufacture, for example, would not be a mineral as defined, unless and until the Minister declares it to be such by notice in the Gazette.

The Quarries Act, administered by the Director of Mines, covers the winning of these "non-minerals" only in so far as health and safety are concerned. The ownership of these non-minerals lies with the holder of the surface rights and that holder may win those non-minerals or grant licences or leases for that purpose, and receive royalty payments for them.

LAND OWNERSHIP

About 80 % of the dry land in Fiji is, owned exclusively by the indigenous Fijian people al'1ld whereas they are able to grant leases over the land, subject to certain controls, they are not permitted under the laws of the countf1y to sell the title of the land. The details of this are found in the Native Lands Act (Chapter 114).

The remaining 20 % or so of the land is largely owned by the State, but some is freehold land. The State-owned land, known as "Crown Land" includes, by definition, "foreshores and soil under the waters of Fiji", and also includes all rivers and soil under the rivers as far upstream as they are navigable by Takia. The rivers are reserved to the State under the Rivers and Streams Act (Chapter 121). Crown Land is administered under the Crown Lands Act (Chapter 132) by the Director of Lands, subject to the overall policy control of the Minister who, in this case also, is the Minister for Lands and Mineral Resources.

A Takia is a traditional Fijian sailing outrigger canoe which has a very shallow draught. The

Freehold land will not be discussed because none of it covers the foreshore or offshore areas.

PROSPECTING FOR AND MINING OF MINERALS

Any person wishing to prospect for minerals may do so only when holding a current Prospector's Right. These are granted by the Director of Mines to any person who has authority to work in Fiji such as a work permit or Fiji citizenship. The cost is $25 and the Right is valid for 12 months. The holder of a Prospector's Right may not prospect in certain "closed" areas such as villages, burial grounds and the like, but there are none of these offshore. It is required al o that before entering an area to prospect, the holder of the Right must give written notice to the owner or occupier of the area. Where offshore prospecting is concerned it would be necessary to communicate with one or mote of the Lands Department, the Native Lands Fisheries Commission and the Department of Fisheries (of the Ministry of Primary Industries) in order to determine who held fishing rights over the area and hence to whom to give the written notice. Protection of the fishing environment is of great importance in most of Fiji's offshore areas and it would be necessary for the intending prospector to satisfy the authorities and the Iocal people that their fishing grounds would not be damaged.

If it is desired to obtain exclusive prospecting rights over an area, then it is necessary to obtain a prospecting licence covering the particular area of interest.

A Prospecting Licence may cover up to 400 ha and up to three such licences may be held by one individual. For any area over 1300 ha, a Special Prospecting Licence would be needed and indeed most licences granted are Special Prospecting Licences. Annual fees are charged for these licences amounting to a little less than 30c per hectare and they are granted only subject to certain conditions. For any Special Prospecting Licence there is always a minimum expenditure requirement and this could vary, depending largely on the area under licence, from about $30,000 upwards, per year. The term of such licences is usually one year, but could be up to 5 years.

A bond or banker's undertaking is usually required also. This would be held against the holder's commitments to expenditure and compensation for or reinstatement of damage to the environment.

The size of the deposit or bond might be of the order of 10 % of the committed expenditure. A Bond is refundable soon after the respective licence has been relinquished or surrendered, subject to all commitments having been met satisfactorily.

The actual winning or mining of minerals' would be the subject of a Mining Lease or a Special Mining Lease granted by the Director of Mines with the approval of the Minister. The holder of a Prospecting Licence can expect to be granted a Mining Lease over any part of the Prospecting Licence area, subject to special conditions. These special conditions would again relate largely to protection of natural resource such as fish, reinstatement, compensation and so on. A Mining Lease may be granted for up to 21 years.

In summary then, the stages for mineral prospecting are:

1. A Prospector's Right required for all prospecting anywhere.
2. A Prospecting Licence to give exclusive prospecting rights over a particular area and to give certain entitlement to a consequent Mining Lease.
3. A Mining Lease.

PROSPECTING FOR AND PRODUCING PETROLEUM AND GAS

For the purposes of petroleum exploration, the Exclusive Economic Zone of Fiji has been divided up into blocks measuring 6' of latitude by 6' of longitude. The areas of the blocks vary slightly depending on their latitude, but are about 117 km^2 on average.

Any person may apply to the Ministry for an Oil Exploration Licence. With his application he would be expected to submit a detailed work programme with estimated costs and evidence to show that the applicant had the necessary financial resources as well as the prescribed fees. A bond would have to be lodged also.

An Exploration Licence may cover a maximum of 70 blocks (about 8200 km^2) and is usually granted for a 5-year initial term with the possibility of renewing for a further 3 years over up to half the area, provided that all the terms and conditions of the licence have been fulfilled.

If any petroleum or gas is found then the discovery must be disclosed to the Director by he licence holder. The holder may apply to the Minister for a production licence and this would normally cover 2, 3 or 4 blocks. A production licence would be granted for 21 years if the licence conditions have been observed. Any further renewals after that would be at the discretion of the Minister. As yet there have been no reports of any discovery of oil or gas in Fiji and no production licences have been applied for.

PROSPECTING FOR AND WINNING "NON-MINERALS"

As stated earlier, the minerals which are not included specifically or implied under the definition of minerals, are vested in the owner of the land and in the case of offshore and foreshore areas and navigable rivers (Crown Land), the administrative authority is the Director of Lands. Application for sand and gravel digging licences would have to be to him and he would impose such conditions as deemed fit. The same concern for the protection of fishing grounds and the natural environment would apply as for minerals. As already stated in a previous paper, licences have been granted for the dredging of coral sand for the manufacture of cement in Fiji and for other sand. There are some small operators licensed to dredge sand from-the rivers for use in the building and construction industry. Table 1 gives quantities and values of past production of some "non-minerals".

ROYALTIES

Royalties are payable on minerals produced or exported. For designated minerals and for petroleum and gas the rates for royalty payments are detailed in the Mining and Petroleum Acts. Until this year they were payable to the State, but a decree was published earlier this year which makes provision for the royalties to be paid through the normal collecting agency to the owners of the surface or fishing rights of the areas from which the minerals or petroleum products came. Cabinet may reserve some of the royalty payments for the State however. The royalty rates remain the same.

For "non-minerals" won from Native Land where the Native Lands Trust Board has granted licences on behalf of the owners, the royalties are paid to the NLTB for redistribution after deducting an agent's fee.

Likewise, for non-minerals excavated under licence issued by the Lands Department, the royalties are payable to the Director of Lands for the State.

The rates of royalty charged by Native Lands Trust Board and by Lands Department are of the same general order and have not been !revised for some years. They are based upon volume excavated or produced rather than value of sales.

Table 1. Quantities and values of past production of some "non-minerals".

PRODUCT	1983 Quantity	1983 Value F$x1000	1984 Quantity	1984 Value F$x1000	1985 Quantity	1985 Value F$x1000	1986 Quantity	1986 Value F$x1000	1987 Quantity	1987 Value F$x1000
Quarried stone m^3	154,817	1301	133,900	*725	136,756	1231	94,709	750	66,832	596
River sand and gravel m^3 ¶	405,037	2025	397,855#	1989	298,085	1490	341,786	1709	254,713	1273
Other river sand § (flood prevention scheme (m^3)					1,230,000		1,788,000		1,785,651	
Coral sand for cement (m^3)					74,857		95,235		50,642	62

NOTES:

* Some of the material produced was used by the producer and not sold; this value applies to only 119,260 m^3

¶ This river sand and gravel includes those from dredges, crushing plats and PWD gravel pits.

\# This figure (397,855 m^3) includes about 26,000 m^3 of river sand for cement manufacture but excludes 54,355 m^3 dredged from the Rewa River under the flood prevention scheme.

§ This is sand that is extracted by MPI from the Rewa River under the flood prevention scheme.

LOCAL SAVUSAVU GEOLOGY

[MR103 - Technical Secretariat]

THE GENERAL AND COASTAL GEOLOGY

OF SAVUSAVU

by

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SUMMARY

This paper has been compiled for the CCOP/SOPAC - ICOD sponsored workshop on "Nearshore Mineral Resources of the South Pacific Island Nations" convened at Na Koro Resort, Savusavu, Fiji from 29 September 1988 to 12 October 1988 as an introduction to the geology of the area. It essentially provides a summary of the general and coastal geology of the area that may be covered during field excursions and is based on available material.

The Savusavu district is rugged with few large coastal plains. It contains six hotspring localities and strata in the district belong to the Upper Miocene to Pliocene Natewa Volcanic Group. The group largely consists of basalts and basic andesite flows with related sedimentary facies and were deposited in a mainly shallow submarine environment.

Coastal deposits consist of colluvium, beach and terrigenous sand, alluvium and limestone. Raised beach and deltaic deposits occur on some of the coastal plains.

Three main structural trends occur in the area. The trends are followed by the strike of rock formations, faults and dykes.

INTRODUCTION

Savusavu (Figure 1) is located on the central south eastern coast of Vanua Levu, the second largest island in the Fiji Group. Savusavu represents the smaller of the two urban centres on Vanua Levu and is the commercial and government centre for people in the district. Labasa is the larger urban centre and is located on the central northern coast of the island.

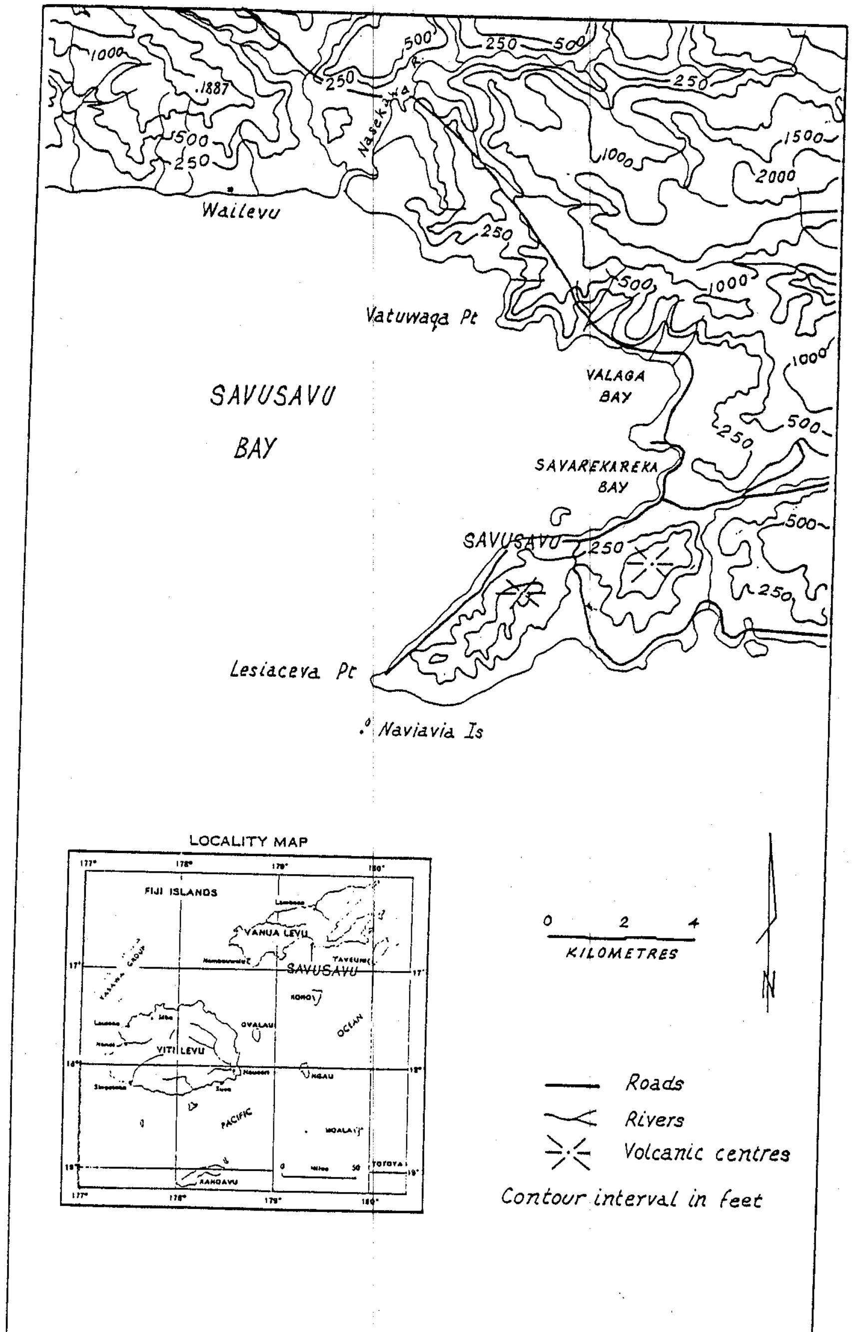

FIGURE 1 : Locality map and topography of Savusavu

Figure 1. Locality map and topography of Savusavu.

Copra continues to be the main produce of Savusavu. Apart from employment within the commercial and government organisation tourism, small scale fishing and market gardening provide alternative sources of income.

The area is rugged, with peaks of more than 230 m occurring within a kilometre of the shoreline. Coastal plains are narrow except within the Valaga and Nasekawa - Wailevu areas. In general, the physiography of the area reflects the volcanism, folding and faulting that has occurred, modified by erosion. The volcanic centres still maintain high relief while Savusavu Bay is inferred to be a downfaulted block.

The area is open to the south east tradewinds and receives rainfall of between 1500 - 5000 mm per year. Along the coastal plains, coconut is the dominant vegetation while the interior is heavily forested. Savusavu is well known for its harbour which provides adequate shelter and anchorage in most conditions, land its hotsprings.

PREVIOUS WORK

In the past, interest in the Savusavu area has mainly been for the hotsprings and harbour. Various early workers visited the area to carry out studies related to these two subjects.

The first comprehensive study of Vanua Levu's geology and hotsprings was undertaken by Guppy (1903). Bartholomew (1959) regionally (1:50,000 scales) mapped western Savusavu Bay, and Healy (1960) studied the Savusavu hotsprings as part of a broad examination of the geothermal resources of Fiji.

Reconnaissance mapping of Vanua Levu was carried out by Rickard (1966), and Woodrow (1976) has regionally mapped the Savusavu Bay eastern area. Various exploration companies have also carried out work in the area, and several exploration licenses presently cover the area.

Continuing interest in Fiji's geothermal resources resulted in a detailed evaluation of the Savusavu hotsprings by Cox (1980, 1981). The potential of the limestone deposits east of the Savusavu Peninsula (at Devodara) for lime manufacture has been assessed by Lum (1982).

Recently, urban development related investigations focusing on the foreshore and nearshore areas of the town and related environments have been undertaken by the Fiji Mineral Resources Department (Whippy, 1985; Vuibau, 1986; Smith 1987a, 1987b) and CCOP/SOPAC (Roy, 1988).

The "HIPAC" team (1986) and the Mineral Resources Department have looked at some of the raised beach deposits (Nalovu, Wailevu) land limestone wave cut notches in the area as part of a study on sea level changes and tectonics in the Middle Pacific.

A review of the Savusavu geothermal Prospect has recently been undertaken by Caldwell (1987) and further work is proposed for 1988.

GENERAL GEOLOGY

Vanua Levu is made up largely of the coalesced erosion products of several volcanic centres; part of this volcanism was submarine in origin. Separate islands formed by volcanoes were united when erosion products filled the intervolcanic basins and the island took on its present shape after intermittent uplift of several thousand feet and considerable erosion.

The Savusavu region is composed of strata belonging to the Middle Miocene to early Pliocene Natewa Volcanic Group (Woodrow, 1i976). The group largely consists of basalts and basic andesite with related sedimentary facies and were deposited in a mainly shallow submarime environment.

The geology of the area is shown in Figure 2. The Natewa Group is represented in the district by the following formations and the descriptions are based on Woodrow (1976).

Savudrodro Basalt

The Savudrodro Basalt is the oldest formation in the area and consists of basalt flows, agglomerates and tuffs extruded from the Savudrodro Volcano. The formation covers the area between Savarekareka and Valaga Bays and is extensive eastwards. Eruption of the formation is believed to have been from east-west fissures in the Savudrodro area.

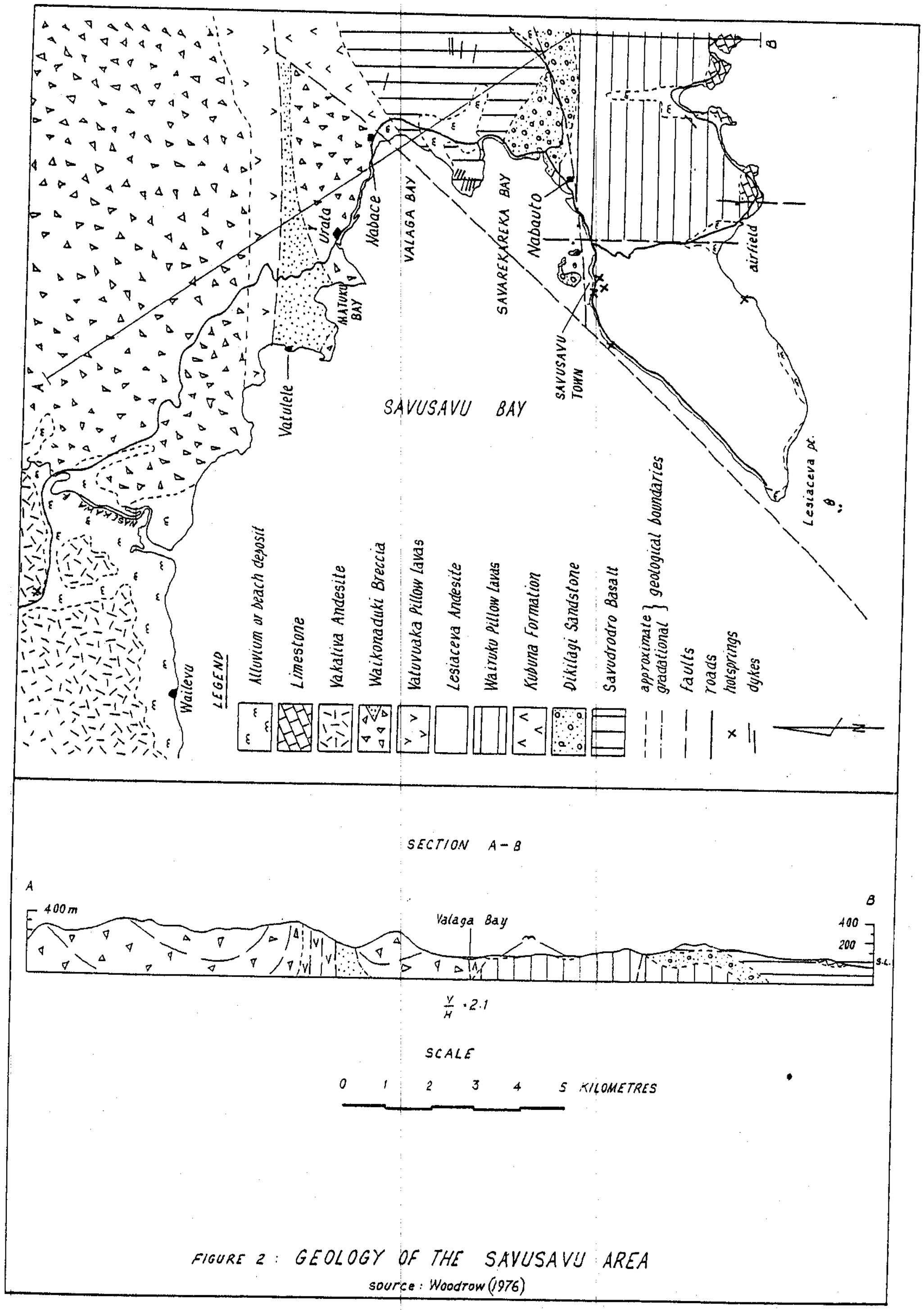

FIGURE 2 : GEOLOGY OF THE SAVUSAVU AREA
source : Woodrow (1976)

Figure 2. Geology of the Savusavu area.

The characteristic lava of the formation consists of a grey rock with phenocysts of augite and in most rocks, zeolite amygdales. The groundmass is aphahitic. Other lavas, found mainly as dykes, are pale grey with smaller augite phenocysts and lacking in amygdales.

Pyrite mineralisation within microdiorite associated with the formation occur inland.

Prospecting companies have unsuccessfully investigated the area for economic mineralisation.

Dikilagi Sandstone

The formation is a volcanic sandstone and it abruptly overlies the Savudrodro Basalt in the south. It forms the area between Nabauto and Savarekareka Bay and is extensive eastwards.

The Dikilagi Sandstone is similar to sandstone units interbedded with the Wairuku Pillow Lavas with coarse sandstones predominant. Bedding within the formation is well developed in most areas.

Wairuku Pillow Lavas

The formation overlies the Dikilagi Sandstone and forms the extreme eastern end of the Savusavu Peninsula. It has a faulted contact with the Lesiaceva Andesite, the formation which comprises the Savusavu Peninsula. The relative ages of the formations are not known.

The Wairuku Pillow Lavas consist basically of interbedded andesite pillow lavas and volcanic sandstones. The alternating units of lava and sandstones are rarely less than 3 m thick and generally much more.

Lesiaceva Andesite

The formation is composed of interbedded hypersthene andesite flows and breccias with minor sandstones.

The flows are generally less than 10m in thickness and the typical lava is dark grey in colour with small phenocysts mostly of feldspar in fine-grained groundmass. Weathering is often strongly developed in outcrop.

The breccias are mostly unbedded and formed of the same material as the massive flows.

Clasts up to 0.3 m occur. The sandstones are fine-grained and mainly composed of volcanically derived rock and crystal fragments.

Kubuna Formation

The formation overlies the Savudrodro Basalt in the north and is separated from the adjacent Waikonaduki Breccia by a steep fault. It consists of basalt and andesite flows, breccias and sandstones. The bulk of the formation is composed of breccia. The formation essentially contains two lava types:

(a) Black basalt with mostly pyroxene phenocrysts and olivine in some specimens;

(b) Lava characterised by abundant crystals of hornblende.

Waikonaduki Breccia

The formation covers the area at the head of Savusavu Bay with the northwest boundary described by the Nasekawa River.

Basically, the formation consists of polymict breccia interbedded with sandstones. The sandstone content increases southwards forming the core of a gently syncline above the breccia in the Vatulele - Matuku Bay area. A few lava flows occur within the formation.

Clasts within the breccia consist of hypersthene and hornplende andesites and a variety of other lava types and vary in size up to 5 m across.

Vatuvuaka Pillow Lava

In the Savusavu district, a thin east-west trending strip of the formation occurs between two areas of Waikonaduki Breccia towards the head of the Bay. The southern boundary of the formation is a fault with the south side relatively downthrown.

Essentially, the formation consists of interbedded sandstones and basic andesite pillow lavas with minor breccia. The sandstones are of the volcanolithic type, well bedded and have a blue-green colour on freshly exposed surfaces.

Vakativa Andesite

The formation is present west of the Nasekawa River and is mapped as basalt flows and breccia by Bartholomew (1959). It is inferred to be downfaulted against or to overlie the Waikonaduki Breccia.

The Vakativa Andesite consists of andesite flows and breccia of unknown relative proportions. It also contains pillow lavas and conglomerates in some localities. The characteristic lava type is porphyritic with fieldspar phenocrysts set in a black fine-grained groundmass.

Limestone

Limestone deposits occur as headlands along the coast east of the airport. The deposits are believed to represent patch reef limestones formed originally on pre-existing topographic highs composed of basement rocks. The limestones overlie neighbouring rocks.

At Devodara, Lum (1982) reports that the' limestone is bioclastic in nature and consists predominantly of coral, molluscan, foraminiferal and algal detritus.' Woodrow (1976) reported the presence of colonial corals up to a metre across at Namali. Emerged notches are well developed within some of the limestone deposits.

Intrusive Rocks

The intrusive rocks of the district are composed of similar material to the formation they cut and restricted to dykes. The dykes are mostly of dark fine grained basalt or basic andesite. Common dyke directions over the region vary between 090° and 180'.

STRUCTURE

Three main structural trends are dominant in the district and these are apparent in the shape of Savusavu Bay and Peninsula and also in the strike of the formations.

The main trends are: northeast - southwest (followed by, the faults along the southeast shores of Savusavu Bay); east-west (followed by the dominant strikes of the formations in the district); and northwest - southeast (followed by smaller faults within the peninsula and the strike of some dykes).

Savusavu Bay is inferred to be a downfaulted block with faults occurring along the northern and eastern edges and faulting is believed to have given the Savusavu Peninsula its basic outline. Faulting is also believed to be one of the controlling factors in the location of hotsprings along the northern and southern coasts of the Savusavu Peninsula.

COASTAL GEOLOGY

The coastal and nearshore geology of 'the area has been studied by Roy (1988) for CCOP/SOP AC whilst the Mineral Resources Department has carried out surveys of the Savusavu town foreshore and adjacent nearshore areas. These studies were undertaken to provide basic geological data for development planning purposes and the following summary is based on them. The coastal geology of the area is presented in Figure 3 and the foreshore geology of the town area in Figure 4.

The coast of the district is composed of limestone, calcareous and terrigenous sand, colluvium and alluvium.

Due to the close proximity of steep beachrock slopes to the coastline, coastal plains are not extensive, with the main ones occurring in the Nasekawa - Wailevu and Valaga Bay areas. In these areas, the plains are shown to be composed of alluvium by Woodrow (1976). The plains have a narrow zone of beach sand along the coast.

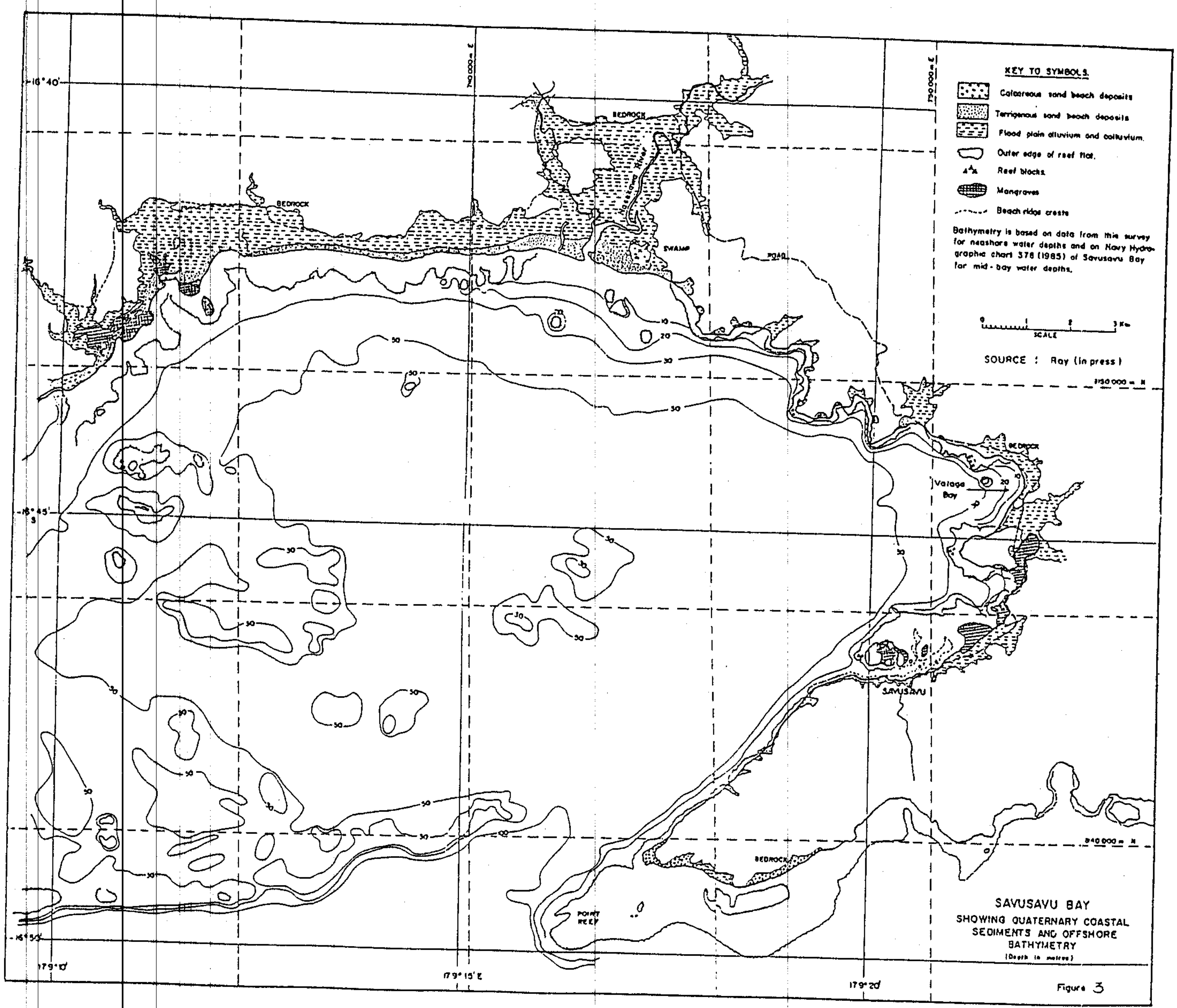

Figure 3. Quartenary coastal sediments and offshore bathymetry.

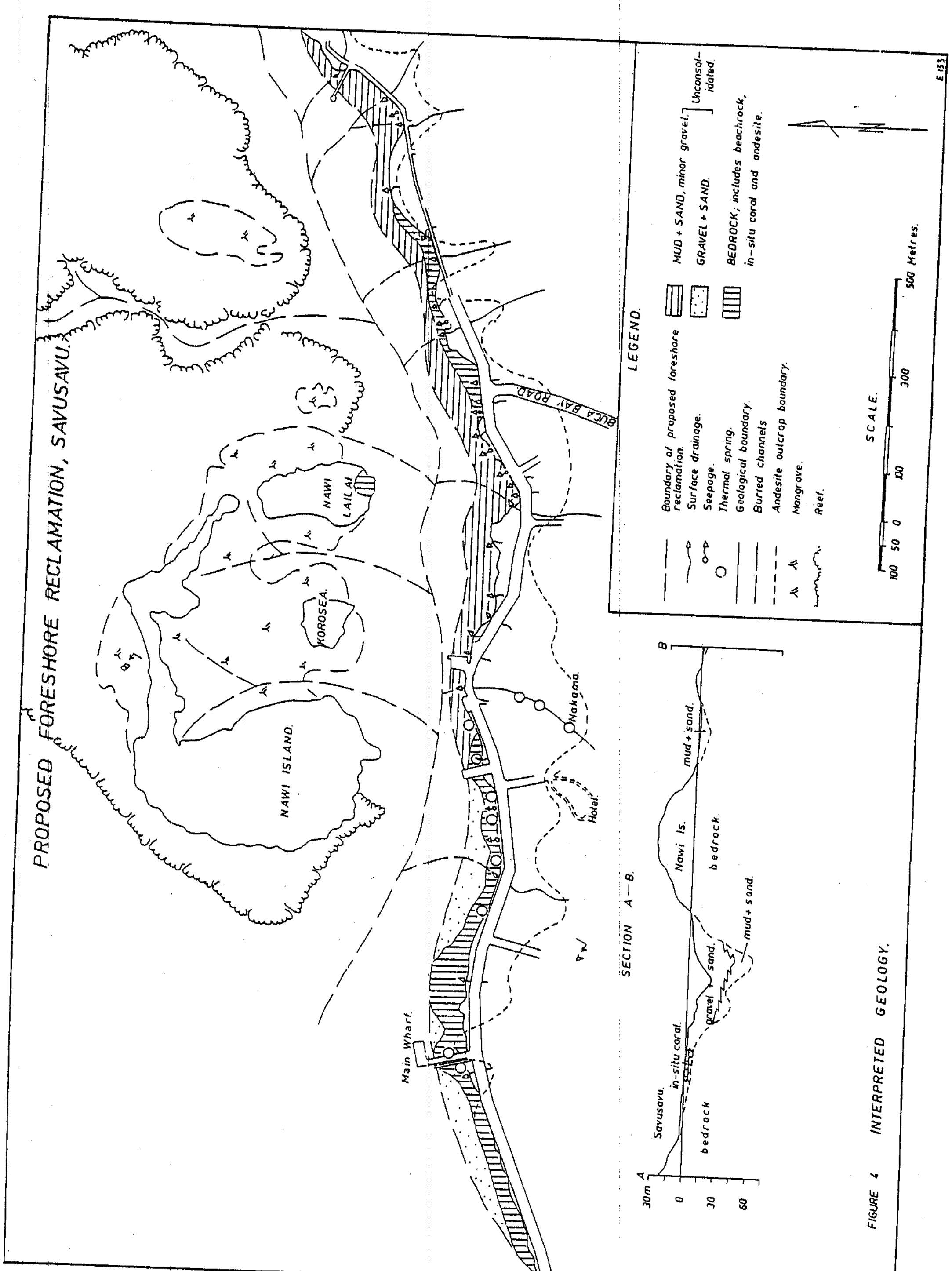

Figure 4. Interpreted geology of the Savusavu foreshore.

The alluvium is believed to represent did beach and deltaic sediments deposited as valley fills during periods of higher sea levels (see Rodda and Whippy, 1987; Whippy and Rodda, 1987). The sediments have weathered in-situ to form material similar to floodplain deposits. At the Wailevu coastal plain, relict coral and re-worked blocks are exposed in natural springs and wells. Roy (1988) suggests that infilling of the valleys occurred about 10,000 - 4,000 years B. P. during postglacial transgression.

Within the south and southeastern parts of the peninsula and southern coastline, calcareous sand deposits are common. Along the Savusavu Bay side of the peninsula and the town area backed by steep bedrock slopes, the coast is composed dominantly of colluvium.

Limestone deposits occur along parts of the coast east of the airport. In areas emerged notches about 2 m above present sea level have been developed. Dating of emerged corals by the "HIPAC" team (1986) suggests 'that the notches were formed about 3790 + /- 170 years B.P. Woodrow (1976) reports that the emerged notches corresponds in height with the level surface of raised marine sediments and indicates the sea level previous to the recent negative shift of the strand line which has been recorded throughout the pacific.

HOTSPRINGS

The Savusavu geothermal area is one of the most active in Fiji. It contains six hotspring localities (Figure 2) with hotsprings occurring on both the northern and southern shores of the Savusavu Peninsula and within 20 m of sea level.

Several of the hotsprings are boiling and the coolest has a temperature of 35°C. The Nakama springs (within the township) are commonly used for cooking steamed puddings, fruits and vegetables. Geyser-like discharge with water spouting to a height of 12 to 18 m is reported by Guppy to have occurred at the Nakama springs for a period of two to three months in 1878. Violent discharges were also reported in Savusavu Bay in 1961.

Also in 1961, small experimental plants for producing salt, by the evaporating seawater with surface geothermal heat, were tested near the Nakama springs. Although they produced a satisfactory salt of 97 % NaCl, the experiments were abandoned.

Cox (1981) proposed a shallow intrusive heat source for the hotsprings with thermal waters rising towards the coastline along the Ghyben-Herzberg lens -_ its presence being suggested by the presence of hotsprings at or near the coastline. Hotsprings, with 'higher temperatures and water chemistry suggesting direct migration to the surface, are indicated as being recharged by flows along faults and fracture zones.

Caldwell (1987), however, proposed a deeper heat source, likely to be residual heat associated with old volcanism or heat associated with renewed volcanic activity. He suggested that the hydrology of the system is dominated by the convective transport of hotwater rather than by salinity differences.

REFERENCES

BATHOLOMEW, R. W. 1959: *Geology* of Savusavu Bay west, Vanua Levu. *Bulletin, Geological Survey of Fiji, 5.*

CALDWELL, T.G. 1987: A review of the Savusavu and Labasa geothermal projects, Vanua Levu Fiji. *Contract Report, NZ Department of Scientific and Industrial Research, 38*.

COX, M.E. 1980: Preliminary geothermal investigations in the Savusavu area, Vanua Levu. *Geothermal Report, Mineral Resources Department of Fiji, 1.*

COX, M.E 1981: Geothermal investigations in the Savusavu area. G*eothermal Report, Mineral Resources Department of Fiji,* 5.

Guppy, H.B. 1903: Observations of a naturalist in the Pacific between 1896 and 1899. Volume 1, Vanua Levu, Fiji. Macmillan, London.

HEALY, J. '1960: The hotsprings and geothermal resources of Fiji. Bulletin*, NZ Department Scientific and Industrial Research, 136.*

HIPAC TEAM (ed. A. Sugimura) 1986: Sea-level changes and tectonics in the middle Pacific. Report of the HIPAC Project in 1984 and 1985 (second research) Department of Earth Sciences, Faculty of Science, Kobe University, Nada (Japan).

LUM, .A. 1982: Assessment of the Devodara limestone for a line pilot plant proposal. *Report, Mineral Resources Department of Fiji, 47*.

RICKARD, M.J. 1966: Reconnaissance geology of Vanua Levu. *Memoir, Geological Survey of Fiji,*

RODD ,P.; WHIPPY, F. 1987: Measurement of elevation of emerged Holocene corals at Raralevu Point, Nasavusavu. *Fiji Mineral Resources Department Note BP 1/66*.

ROY, P.S. 1988: Coastal and nearshore geology of Savusavu Bay, Vanua Levu Fiji. *CCOP/SOPAC Tecni'cal Report 60.*

SMITH R. 1987a: Seismic survey, Savusavu foreshore; Vanua Levu. *Fiji Mineral Resources Department Note BP 35/6*.

SMITH, R. 1987b: Seismic survey, Valaga Bay, Savusavu Bay. *Fiji Mineral Resources Department* N*ote B'P* 35/7.

VUIBAU , T.K, 1986: A shallow seismic study of Savarekareka Bay. Fiji *Mineral Resources Department Note 8P 26/6*.

WHIPPY , F. 1985: Proposed foreshore reclamation Savusavu: preliminary investigation. *Fiji Mi'neral Resources Department Note BP* 39/8 ..

WHIPPY , F.; RODDA, P. 1987: Measurement of elevation of old beach, deposits at Nalovu, Wailevu. *Fiji Mineral Resources Department Note BP 39/22*

WOODROW, P.J. 1976: Geology of Southwestern Vanua Levu. *Bulletin Mineral Resources Division, Fiji, 4*.