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Report on the

INSHORE AND NEARSHORE RESOURCES TRAINING WORKSHOP,

Suva, Fiji

13-17 July 1981

VENUE

School of Natural Resources Auditorium, The University of the South Pacific (USP)

SPONSORS

Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC)

Institute of Marine Resources (IMR), University of the South Pacific

United Nations Development Programme (UNDP)

Economic and Social Commission for Asia and the Pacific (ESCAP)

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FOREWORD

This Inshore and Nearshore Resources Training Workshop was held at the School of Natural Resources Auditorium in the University of the South Pacific from 13-17 July 1981.

The Workshop was designed to deal with inshore and nearshore resources and gave special emphasis to their utilization and management. A major aim of the Workshop was to use expert consultants to train South Pacific country participants to assess mineral and living resources and advise on their exploitation and management. The main fields covered were: the mineral and living resources of coasts, beaches and lagoons; and precious corals.

Each session consisted of expert lectures and informal discussions in about equal parts. The latter allowed free discussion of matters of mutual concern. The inshore and nearshore areas are of critical importance in the South Pacific, and the Workshop stimulated discussion and co-operation by people involved in the development, exploitation and management of these ecosystems and mineral resources. There were 80 registered participants at the Workshop, including 30 trainees/experts in the fields of Fisheries and Geology from each of the CCOP/SOPAC Member Countries - Cook Islands, Fiji, Kiribati, Western Samoa, Solomon Islands, Papua New Guinea, Kingdom of Tonga and Vanuatu. Also attending were well-known experts from organizations dealing with the topics covered in this Workshop and staff members and graduate and undergraduate students from the University of the South Pacific.

Two field trips followed the Workshop. The first was an excursion on 18-19 July to the Coral Coast of Viti Levu with 21 participants. On this excursion the fringing reef, the beaches and the Singatoka dunes (Appendix I) were examined. A three day field course on precious corals followed the Workshop from 18-20 July. The programme included SCUBA collection and preparation of black corals. Because of limited ship-space, participation was limited to 11 people. (Details are included in Appendix II).

The general view of the participants was that both Workshop and excursions were very worthwhile in providing an overview of the field of inshore and nearshore resources. It was strongly emphasized that smaller detailed workshops on more limited fields would be very valuable in building on the beginning made here.

ACKNOWLEDGEMENTS

It is difficult to give credit for this workshop without naming everyone in the list of participants, as well as quite a few outside the list. Although the official credits will be kept to a minimum here the organizers of the workshop extend their thanks to all who helped.

Jim Eade of the New Zealand Oceanographic Institute suggested the idea of the workshop and Neville Exon, Uday Raj and Kristina Israel worked as a steering committee to plan its contents, activities and logistics. Howard Plummer and the Fiji Mineral Resources Department provided counsel and general support, and the School of Natural Resources allowed us to make use of their magnificent new auditorium.

Kristina Israel, Snehlata Maraj and Suraghini Sharan served with dedication and efficiency as secretariat to the workshop, and Hazra Haq and Marilyn Goulding ensured the efficient operation of the audio-visual equipment.

Neville Exon, Don Tiffin and Garry Gauss prepared this summary report making extensive use of the abstracts provided by the speakers.

CCOP/SOPAC Technical Secretariat

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COMMENTS ON CCOP/SOPAC

Mr. Arthur Holcombe, UNDP, Suva

The Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC) is a regional grouping of Southwest Pacific countries, whose inaugural meeting was held in Suva in 1972. Since the appointment of a UNDP Marine Geologist and establishment of a Technical Secretariat in 1974, CCOP/SOPAC has been supported by many countries and international organizations. Its offices are at the Mineral Resources Department in Suva.

In January 1979 the UNDP Project "Investigation of Mineral Potential of the South Pacific" was established, and recruiting was commenced to bring the technical staffing up to a new, considerably higher level. By early 1981 the project was fully staffed, with eight scientists and necessary support staff. In recent years CCOP/SOPAC has mounted major marine programmes involving six months of ship time per year.

Following a recent review, the emphasis is slowly changing from deepwater studies, such as the search for manganese nodules, to shallower water studies, such as the search for petroleum, construction materials, and precious corals. The latter two will be discussed in some detail at this Training Workshop. Training has always been an important element of CCOP/SOPAC's work, with trainees working under the direction of Project staff, both aboard ship and in the office.

OFFICIAL OPENING OF THE WORKSHOP

Summary of comments made by
Dr. James Maraj, Vice-Chancellor,
University of the South Pacific, Suva

To be asked to open or close a Workshop such as this is an occupational hazard. The opening address is more rewarding, as there is still a chance to influence the course of the meeting, although it is, to some extent, an exercise in speculation. This is the first such workshop at the USP to give emphasis to non-living resources. Marine resources are very important here, and it is important to develop satisfactory development models for our needs. Models developed for the large land masses of Asia and Africa are not appropriate to the Pacific island countries.

Management is a considerable problem in our countries for several reasons. The first factor in any management scheme, the existence of adequate resources surveys, is being met. The second factor, the development of adequate analysis of the data and useful comment on the results for the State's decision-makers, is not being adequately covered. The third factor, the establishment of a satisfactory legal framework for management, is still missing. Hence we have to rely heavily on policy guidelines coming out of technical reviews by outside advisers.

Under the Colonial Administration territories were open for prospecting and mining, and customary rights were preserved. Legislation did not separate indigenous from foreign operators. The role of the State was seen almost exclusively in regulatory terms. Nowadays the State has become an active participant, especially through partnerships and joint ventures. The question is what changes should we make in legislation?

The State now generally has the title to the land, whereas in earlier times companies sometimes acquired dubious rights from the traditional owners. However, in the Pacific the State has neither the financial resources nor the technical knowledge to conduct large-scale prospecting or mining operations. The absence of strong technocratic groups in our countries limits our ability to exploit our resources. So I appeal to technical experts to please interpret their mission more widely, and to include recommendations on policy guidelines in their final reports.

INSHORE AND NEARSHORE ECOSYSTEMS OF THE SOUTH-WEST PACIFIC

Dr. U. Raj, Institute of Marine Resources, USP, Suva

The Pacific Ocean is characterized by a wide scatter of islands which rise from great depths. Some which do not reach the surface form guyots and seamounts. Thus the oceanic regime of the Pacific consists of deep ocean basins, trenches, steep island slopes, seamounts and a few shallow sea basins. The islands themselves are mainly atolls, elevated reef formations or volcanic but a few can be geologically classified as continental in origin. Except for the larger volcanic and continental islands the majority of the Pacific islands are small and coral-reef dominated systems. The islands are influenced by a variety of climatic factors, such as cyclones, trade winds, doldrums, etc., depending on the latitude and longitude of their boundaries.

The inshore and nearshore regimes are dominated by the following ecosystems: mangrove, mangrove flats and estuaries (only large islands), coastal vegetation, lagoons, patch reefs, barrier reefs, fringing reefs and atoll reef formations, seagrass beds and outer reef slopes (down to deep ocean basins). In a few islands, e.g. Christmas Island, the atoll lagoon has given rise to isolated hypersaline pools which form unique ecosystems on their own.

Individual resources of these diverse ecosystems are just as varied, although as systems they are invaluable on their own. Numerous activities of the inhabitants of the islands striving to utilize these resources have begun to impinge on the ecosystems, either directly or indirectly. The most obviously noticeable effects are on the local fisheries resources. But, dredging of coral sands, exploration of placer deposits, phosphorite exploration, blasting of reefs, shore construction and hotel development, building of causeways, pollution and increased silt loads are all beginning to concern the management and exploitation of inshore and nearshore systems. For example, tropical ecosystems such as coral reefs are so fragile that even agricultural practices inland leading to increased inflow of nutrients and silt can lead to major disasters on reefs. Thus, for sound protection and management of these interdependent systems, a thorough understanding of the numerous interacting components of these ecosystems is essential. It is hoped that this meeting will address itself to the various factors which govern these ecosystems.

A BRIEF REVIEW OF MINERAL RESOURCES OF THE BEACH AND NEARSHORE AREA

Dr. Donald L. Tiffin, CCOP/SOPAC, Suva

The 'nearshore' area is defined geologically as 'the zone extending from the low water mark seaward an indefinite but short distance'. In island arc regions, deep water often occurs nearshore, therefore mineral resources in the nearshore may include minerals from deep water.

Placer Minerals - The accompanying table lists common placer ores found on beaches and in nearshore zones. Placers are detrital materials divided on the basis of their specific gravity into light-heavy minerals with specific gravity ranging between 2.85 and 5.8, and heavy-heavy minerals with specific gravity between 6.0 and 19. The source of most placer minerals is in volcanic, metamorphic or granitic terrains which exist near the deposits. Trace amounts of mineralization which occur in the mother rock are preserved after weathering, breakdown and erosion of the rocks. Placer minerals are therefore resistant to mechanical abrasion and chemical weathering. The heavy mineral erosional by-product is concentrated during transportation and, after being sorted and re-worked perhaps many times, is left as a deposit in river beds or in beach sands, dunes, or other nearshore high energy environment. Because sea level has varied over time, placers may be found not only on present-day beaches, but in raised beach terraces of the past, or submerged fossil beaches or buried river channels of the nearshore area. They do not usually travel far from the mother rock source.

Prices quoted in the table are from Australia for 1980, as given in the Australia Mineral Industry Quarterly, for concentrations shown in brackets:

Aggregates - Although sands and gravels do not bring high prices per ton, they are valuable resources because they are necessary in construction. Sand and gravel aggregate is particularly important in areas where it is scarce because transportation costs are high if it has to be moved very far, and may inflate construction costs considerably. Removal of beach materials may create severe problems of erosion on the beach or land areas, not just at the site of

removal, but also in adjacent areas. The nearshore may provide a less problematical source for such materials, but may cost more to mine.

Phosphates and Phosphorites - These are fairly common, but only rarely are they found in economic grade and quantity. Phosphates occur in guano deposits, leached guano and associated phosphatized lime sand, and in phosphate rock. Phosphate rock forms the highest grade phosphate materials, with up to 40% P_2O_5. Phosphate rock is mined on Ocean and Nauru Islands, and may be found underwater in some lagoon areas. One such deposit was recently discovered in the Tuamotos, French Polynesia.

Phosphorites form in deeper water where ocean upwelling is prevalent. Upwelling brings nutrients to the near surface waters, which then support high biological productivity. The organic matter concentrates phosphorus, which is released into the bottom sediment and pore waters with the death of the organism, resulting in formation of phosphorite. Ridges, seamounts and other topographic highs where upwelling is present are possible sites for occurrence. However, the water depth must be sufficient to inhibit coral growth and sediment deposition must be low. They may not be economical to mine unless in sufficiently shallow water, and of nigh grade and abundance.

Precious Corals - These are also found in areas where water depths range between 20 metres and 400 metres. They may provide a source of income for remote islands because they lend themselves to a home industry. Prices for individual corals range from a few dollars to tens or thousands of dollars per kilo. On a world-wide basis the precious coral industry has an economic impact of hundreds of millions of dollars.

Other mineral resources - Salt, bauxite, metalliferous muds and manganese nodules may be highlighted in later sessions.

Discussion -

The following points were considered during the discussion after the paper:

a) Salt in sand and gravel or coral aggregate does not have to be a problem in concrete. Concrete can be made using salt water. The problem arises because of porosity, and the proper controls must be applied to prevent high porosity when salt is present.

b) The percentage of minerals taken from marine placer deposits varies with the mineral. For example, in Indonesia, ten years ago 20% of the cassiterite mined was taken from the offshore; that has now increased to over 50%. However, of the total tin mined, perhaps only about 10% is from offshore. In sand and gravel, about 20% of England's supply is derived from offshore. However, in general, placer mining is a marginally economic operation. The importance of offshore deposits will probably increase in the future.

c) Placer deposits may be submerged under newer coral growth in lagoons. However, in closed lagoons there is little coral growth, and there may be a possibility of bauxite and phosphate being found in these locations. There would not be sufficient wave energy in enclosed lagoons to form placers.

PLACERS AND AGGREGATES

ORE	MINERAL	SPECIFIC GRAVITY	CHEMICAL COMPOSITION	AUST. $ VALUE/TONNE (concentration)	USES
Rutile	Titanium	4.2	TiO_2	$320 (90%)	Pigment for paints and ceramics, textiles, plastics, etc. A flux for welding, ore of titanium.
Ilmenite	"	4.7	$FeTiO_3$	$ 64 (54%)	Principal ore of titanium; a lightweight, strong metal used in spacecraft, food processing equipment and many others.
Monazite	REE and Thorium	5.0-5.3	(Ce, La) PO_4	$375 (60%)	Products used in colour TV tubes, lighter flints, polishing powders.
Magnetite	Iron	5.2	$(Fe'', Fe_2''')O_4$		Important ore of iron; magnetic.
Zircon	Zirconium	4.7	Zr SiO_4	$ 55 (66%)	Used in ceramics, glass, cements and glazing. Processed into chemicals used in food preservatives, tanning and refractory materials for non-flammable clothing.
Cassiterite	Tin	6.8-7.1	SnO_2	$134 (70%)	Most important ore of tin.
Chromite	Chromium		(Mg, Fe'')-$(Cr, Al, Fe)_2O_4$	$135 (48%)	Principal ore of chromium.
Corundum	Corundum	4.0	Al_2O_3		Abrasive.
Gold	Gold	15-19		$575/oz	Precious metal.
Platinum	Platinum	14-19		$550/oz	Noble metal: used in laboratory materials, electrical apparatus.
Sand & Gravel		3.0			Construction aggregate.
Quartz Sand	Silica	2.65	SiO_2		Glass.
Shells/ Shell sand	Lime		$CaCO_3$	$29.50	Cement.

INVERTEBRATE FISHERIES OF THE NEARSHORE

Dr. Leon P. Zann, Institute of Marine Resources,
USP, Suva

The nearshore region of the South Pacific islands is very important in the subsistence and commercial fisheries and requires careful utilization and management.

The characteristics of the main marine ecosystems - reef slope, coral reef, lagoon, mangrove and soft shores - were outlined and their fisheries potential discussed. Distinction was made between the low technology or traditional subsistence fisheries and the high technology commercial fisheries; the necessity to protect the former was stressed.

Plants and invertebrate animals utilized by Pacific Islanders outlined included: algae; mangroves; jellyfish; anemones and coral; annelid and siphunculid worms; snails, bivalves and cephalopod molluscs; shrimps, crayfish and crabs; and the edible sea urchins and beche-de-mer.

Low technology commercial fisheries discussed in detail included: mother-of-pearl (trochus, greensnail and pearl oysters); cultured pearl; the seashell or conchological industry; the Asian tridacnid market and fishery; cultured oysters and mussels; pilot squid fishing; shellfish industries including airfreighted crayfish, local mudcrab, cultured panaeid prawns and deepsea carid shrimp; and the revival of the beche-de-mer industry.

LIVING RESOURCES OF THE OUTER REEF SLOPES OF THE FIJI ISLANDS

Dr. Uday Raj, Institute of Marine Resources, USP,
Suva

Outer reef slopes are being continually surveyed off the Suva Barrier Reef; off Naselai Reef; Bligh water, off Ba Coast; outer reefs off Northern Viti Levu; off Kadavu Island; Makogai; Beqa offshore and the Great Sea Reef area, for fin fish and crustaceans. Other areas to be sampled in the near future include Laucala Island off Taveuni and Vatulele. Fishing gear used include traps, handlines and hydraulic reels.

The following demersal fishes have already been caught and identified.

BONY FISHES

SERRANIDAE (Sea basses)
Epinephelus magniscutes
Ep. cometae
*Ep. horridus
*Ep. medurensis
*Ep. morrhua
*Ep. microdon
Ep. areolatus
Ep. poecilonatus
Ep. dictyophorus
Saloptia powelli
CARANGIDAE (Jades & Pompanos)
Caranx lugubris
Carangoides coeruleopinnates
Seriola rivoliana
TETRAODONTIDAE (Puffer)
Lagocephales sp.
LUTJANIDAE (Snappers)
Aphareus rutilans
**Aprion virescens
Etelis carbunculus
Etelis oculatus
Etelis sp.
**Lutjanus malabaricus
LETHRINIDAE (emperors)
**Lethrinus miniatus
**Lethrinus kallopterus
PENTAPODIDAE
Gnathodentex mossambicus
Gymnocranius robinsoni
CARPROIDAE (boarfishes)
*Antigonia capros
TRIODONTIDAE (3 toothed puffer)
*Triodon bursarius
ALUTERIDAE (File fishes)
1 unidentified sp.
SCOMBRIDAE (mackerel & tunas)
*Gymnosarda unicolor
MORIDAE (morid cods)
2 & 3 unidentified
MULLIDAE (Goat fishes)
Parupenus pleurospilos
BRANCHIOSTEGIDAE (tilefishes)
*Branchiostegus japonicus auratus
HOLOCENTRIDAE (Squirrel fishes)
Ostichthys sp.
NEMIPTERIDAE (Threadfin breams)
Scolopsis inermis

Lutjanus rufolineatus
Lutjanus caeruleovittatus
Tropindinius zonatus
Tropindinius amoneus
Pristipomoides multidens
**Lutjanus sebae

Nemipterus aurifilum
SHARKS
SCYLIORHINDAE (swell sharks)
Cephaloscyllium ventriosum
SQUALIDAE (Spiny dogfish)
Etmopterus sp.
EELS
MURAENIDAE (Moray eels)
Gymnnothorax richardsoni
MURAENESOCIDAE (Pike eels)
Muraenesox cinereus
CONGRIDAE (Conger eels)
Conger japonicus
2 other unidentified sp. of fish and 1 shark 3 eels.

** Shallow water fishes which sometimes intrude into deeper water.

New fishes are constantly being caught and identified. Data collection from these fishes include length; weight; sex; visual gonad condition (gonads are also preserved for closer examination later); stomach contents, if any, are collected; and age determinants such as scales and otoliths are looked at. Otolith analysis has also been carried out.

Catch rates are as follows for the following fishing gear:

Traps:	2.472kg/trap
Hydraulic reels	51.74kg/reel
Hand lines:	1.66kg/line

Average catches per Fishing Day:

Traps:	14.66kg
Hydraulic reels:	103.49kg
Hand lines:	22.113kg

Initial surveys have shown that Aphareus rutilans and Pristipomoides flavipinnis comprise 50% of total catch by weight. Lutjanus caeruleovittatus comprises 30% of total catch by number.

The bottom fishes are believed to aggregate in 2 manners: as a multispecies group or as a single species group, as they are reflected in the catch.

A gear selectivity factor exists for a few of the outer reef fishes:

Lutjanus caeruleovittatus is only caught by traps whereas Aphareus rutilans is only caught by fishing lines.

Apart from finfishes the following shrimps have been recorded from 150f.-400f. depths:

Heterocarpus sibogae (ensifer)	Plesionika longirostris
Heterocarpus gibbosus	Plesionika martia
Heterocarpus laevigatus	Parapandalus serratifrons

These shrimps are caught at an average of 1-2kg/trap/night set. Additionally, the red crab, Geryon sp. and Nautilus pompilius have been taken at these depths.

All finfishes and the crustaceans appear to congregate in large numbers on seamounts or ridges or shallows which arise from landward extensions.

Thus apart from the abundant tuna-like fishes of the outer reef slopes, the demersal finfishes, crustaceans and precious corals form rich living resources of the Pacific islands, as yet unexploited.

FISH POISONING IN THE SOUTH PACIFIC

Professor T. Yasumoto, Japan

More than 12,000 people suffer from food poisoning in the Pacific every year. This poisoning is usually caused by a unicellular alga (Gambierdiscus toxicus) which appears to be stimulated by man's activities on reefs. Laboratory experiments show that soil extracts and phosphate stimulate growth of this dinoflagellate.

It is now apparent that construction work is the cause of the increase in abundance of the toxic dinoflagellate. This happens in two ways. Firstly, soil dropped in the sea covers and kills corals, thus eventually providing a dead coralline surface on which blue-green algae can establish themselves. These blue-green algae attract epiphytic plankton including the toxic dinoflagellate. Secondly, phosphate in soil dumped in the sea makes its way into solution, and fertilizes blue-green algae, which increase in abundance, again encouraging the toxic dinoflagellate. The toxic dinoflagellate is then eaten by fish which are eaten by, and poison, man. The solution to this problem is to stop dumping soil into the sea.

Discussion -

Dr. Withers at Hawaii had worked on a "toxic" organism which was epiphytic on seagrasses, and increased in abundance as they increased. Yasumoto remarked that Withers had misidentified another non-toxic organism as the toxic Gambierdiscus toxicus, so that her studies were irrelevant as far as food-poisoning was concerned.

PRECIOUS CORALS

Richard Grigg, Hawaii Institute of Marine Biology,
Hawaii

and

James V. Eade, New Zealand Oceanographic Institute,
Wellington, New Zealand

The use of precious coral for jewellery and ornamentation dates back thousands of years. Precious corals were only known to occur in the Mediterranean Sea until the beginning of the nineteenth century when they were found off Japan. The industry in the Pacific has outgrown that in the Mediterranean during the last century as discoveries were made in Japan, Taiwan and east to the Emperor seamounts and the Hawaiian chain, and as the Mediterranean became fished out. The industry has remained firmly in the North Pacific, and until 1975 it was not known whether or not Corallium, the most prized of all precious corals, occurred south of the Equator. At present there are about 250 Taiwanese and 100 Japanese vessels working in the precious coral industry in the Pacific.

Definitions

Precious corals are coelenterates and not minerals. They belong to the two subclasses - octocorals and hexacorals. The octocorals have two orders which include precious corals - Coenothecalia (blue corals), and Gorgonacea. Under the Gorgonacea come most of the precious coral families:

Corallium - 7 species
Primoidae - gold coral
Lepidicus - bamboo coral

The hexacorals have two orders which contain precious corals:

Zooanthidea - Hawaiian bamboo coral
Antipatharia - black coral

The value of precious coral depends on its hardness and condition (live, dead, bored) and on its colour. Average 1981 prices, in $US/kg are listed below.

Coral	Common name	Value
Corallium japonicum	Aka, oxblood	$600-4800
C. elatius	Maguy	600-4000
C. elatius	Momo-iro	300-3000
C. nobile	Momo	100-2000
C. konojoi	Shiro, white	100-2000
C. secundum	light pink	75-250
White Corallium		20- 50
Gerardia sp.	gold	100
Primisoa reseda	gold	100
Antipathes dichotoma	black	20- 50

Fraudulent corals are commonly sold to unsuspecting tourists. These include:

1. Black coral soaked in liquid oxygen to resemble golden coral. It has no characteristic shimmer.

2. Plastic "black coral". When scratched it does not give the characteristic rust-brown powder of black coral.

3. White coral dyed to resemble pink coral. The colour match is not good, and scratching can reveal the underlying white material.

Ecology of black coral

Black corals are composed of horny protein and have annual growth rings. They grow above the thermocline in cool water. In Hawaii they are found between 75 and 350 feet. They need a hard substrate, preferably limestone. They prefer to keep out of the light, and often cluster under overhangs. Currents of 1-3 knots are favourable.

Black corals grow at about 6cm/year and can live for up to 100 years. They reproduce both sexually and asexually and the larvae appear to be gregarious. Their mortality rate is about 10% per annum, which equals the recruitment rate. They are killed largely by boring organisms, which weaken the base and cause toppling. The maximum sustained yield is about 4% per annum. Black corals are ubiquitous in the Pacific.

Ecology of pink corals

Pink and gold corals are composed of high magnesian calcite, and their colouring is related to their small organic content. They grow in water depths of 375-400m in Hawaii. In the Far East *Corallium* grows in water depths of 100-300m. Recent work at Midway Island has shown that there are both "shallow" and "deepsea" pink corals found at 400m and 1200m respectively. The preferred substrate is limestone or volcanics. The preferred habitat is a rise, seamount or gently-sloping terrace swept by strong currents and free of sediment. Sediment can smother young corals, and abrade the stalks of older ones, causing toppling. Thus steep slopes where debris is moving downslope are unsuitable for coral growth. Currents of 0.5-3 knots are favourable. The corals grow at about 1cm/year and can live 100 years. Their mortality equals recruitment rate at about 6% per year, and many are killed by boring causing toppling. The maximum sustained yield is about 2% per year.

The corals occur in commercial quantities only in small beds. Food supply and temperature seem to have little effect on their distribution. In the northern hemisphere they come no further south than 22°N. Gold corals are apparently confined to Alaska and Hawaii (completely different varieties).

Harvesting

In Hawaii black coral is harvested by SCUBA divers who go rapidly to the bottom, cut the coral with axe and sledge hammer, and float it to the surface with air bags.

Pink and gold coral are generally recovered by tangle-net dredging using large river boulders. The Taiwanese or Japanese boats have up to 16 lines over the side as they drift with the current. These are handled by mechanical line haulers, and are kept on the bottom for up to an hour at a time.

In Hawaii a submersible is used for controlled harvesting of pink coral.

Processing

Processing is labour intensive and there are about 500 small factories in Taiwan. Simple lapidary methods are used for jewellery, but complex hand-carved figures are made of the best pieces. Such carvings sell in Paris for up to $50,000.

Economic trends and world trade

In 1980 Taiwanese boats landed about 156,000kg, and Japanese boats about 72,000kg of precious coral, the great majority from the newly-discovered Midway beds. The total value of the industry is about $50,000,000 ex-vessel, $65,000,000 wholesale and $130,000,000 retail (excluding gold settings etc.).

At present there is an abundant supply of black coral, so prices are stable. Midway pink coral is also in good supply so prices have dropped a little to an average $75/kg. Prices for deeper pink Momo corals have gone up 30% and the rare oxblood corals by 200%, in the last year. 50% of coral goes to Italy.

Conservation and management

The slow-growing, long-lived precious coral is very vulnerable to over-exploitation. This resource can be managed by limiting takes, or areas, or gear, but a biological basis for guidelines is needed.

The so-called "Beverton-Home model", making use of growth and mortality rates, indicates that maximum sustained yields are 4% and 2% for black and pink corals respectively, and this forms a basis for management.

Corallium distribution in the South Pacific

The systematic search for precious corals, especially Corallium, in the South Pacific began in 1977 when CCOP/SOPAC accepted a programme for its member countries. Since then reconnaissance surveys have been carried out in Papua New Guinea, the Solomon Islands, Vanuatu, Fiji, Tonga, Samoa, the Cook Islands and Kiribati.

CCOP/SOPAC surveys have been designed primarily to find out if Corallium occurs in the region, to map its distribution and abundance, and to locate beds which could be exploited commercially. In designing the survey programmes the first step has been to try and identify those areas where the habitat is suitable for Corallium to occur. In the North Pacific Corallium occurs at 90 to 350 metres, and where the bottom is rocky and swept by strong currents (0.5-3 knots). Commercial sized beds are only found where these conditions occur and the bottom is flat to gently sloping. Possible sites for Corallium beds in the South Pacific were identified from existing information on bathymetry, currents and bottom type.

Surveys have been carried out from small vessels, less than 30m in length, and many vessels in the region are suitable for such survey work. Vessels must be equipped with navigation equipment such as radar and satellite navigators to make accurate navigation possible, accurate echo-sounding equipment capable of sounding to at least 500m, a winch or line-puller for dredging and underwater photography, and sufficient space both inside and on deck to operate this equipment. A typical survey has been carried out as follows:

1. detailed echo-sounding survey to identify dredging sites;

2. three or four dredgings, each lasting 30 to 60 minutes on the best-looking part of each site;

3. underwater photography at the site where the most promising looking dredge sample was collected. At all times precise navigation was carried out.

As a result of the CCOP/SOPAC surveys Corallium is now known to occur in Solomon Islands, Vanuatu, Fijian, Tongan, Samoan and Cook Islands waters. A summary of results is as follows:

In the Solomon Islands (New Georgia group to Makira Island) Corallium was found in 29 out of 138 dredgings made;

- Santa Cruz islands, in 6 out of 40 dredgings;
- Vanuatu, in 7 out of 74 dredgings;
- Fiji, in 1 out of 16 dredgings;
- Tonga, in 3 out of 55 dredgings
- Samoa, in 6 out of 36 dredgings;
- northern Cook Islands, in 3 out of 26 dredgings;
- southern Cook Islands, in none out of 2 dredgings;
- Gilbert group, Kiribati, in none out of 88 dredgings;
- Phoenix group, Kiribati, in none out of 7 dredgings.

Although no commercial beds have been found, many sites where conditions are suitable for Corallium to occur have been found and surveyed. Suitable sites are more common in the Solomon Islands, Vanuatu and Tonga. Corallium material from the Solomon Islands has been particularly encouraging, and living, commercial sized specimens have been collected. However, all areas have only been surveyed to a reconnaissance level and more work remains to be done.

Future surveys should concentrate on unsurveyed areas in the Cook Islands and Tonga. Also, more detailed surveys should be made in those areas where the reconnaissance results are most

encouraging, especially in the Solomon Islands. Other favourable areas may well also exist but a lack of detailed bathymetric data throughout the region makes it impossible to be sure that all potential sites have been found. Therefore nearshore bathymetric mapping programmes are needed and should be encouraged.

Future development

Collections of precious corals in the tropical South Pacific are generally not encouraging, and perhaps the best beds may eventually be found further south. More effort should be put into finding suitable habitats, which may still exist in the tropical regions.

Should good deposits be found people would have to be trained in diving for black coral, and dredging for pink coral. Tradesmen could be trained overseas. Local industries could be joint ventures but, if the resources were too small for this, it would be best to focus on the local (tourist) market only.

Discussion -

During the discussion, Grigg pointed out that the recent surveys did not provide a conclusive answer to whether there are precious coral beds in the Southwest Pacific. Tiffin suggested that major coral beds might be identified using sidescan sonar. Grigg indicated that although a submersible is the best method of harvesting, its capital cost of more than $1,000,000 makes it out of the question for most Pacific countries.

EXAMPLES OF NEARSHORE MINERAL RESOURCES FROM HAWAII

Dr. J. Frisbee Campbell, Hawaii Institute of Geophysics,
Honolulu, Hawaii

An active research and development programme was undertaken in Hawaii to use the temperature difference between surface and deep water to work as a heat pump to generate electricity. A vast potential exists for energy from the ocean, but the Ocean Thermal Electric Conversion (OTEC) system requires a difference of temperature of 21°C to operate. Greater temperature differences in equatorial regions would increase the efficiency.

A Mini OTEC system was built on a barge and operated at sea to test the concept. The operating efficiency was low, but the test was successful and an excess of electricity was generated.

The next stage was to use a larger ship in order to generate more excess electricity, and to test new heat exchangers and the anti-fouling characteristics of the 2200 foot long pipe which collected the cold water at depth. The larger equipment was capable of generating 1 megawatt of power, but a cost effective system would have to produce 10 to 40 megawatts. Because of large cost overruns and government spending cut-backs, the OTEC experiments were discontinued and the ship is in mothballs in Hawaii.

The system can produce large amounts of power efficiently, but cannot be scaled down for smaller outposts. It requires deep water near to shore and it is difficult to get high tension power lines ashore. In Hawaii it must also compete with other sources of electricity such as wind power and geothermal sources, which may be cheaper and easier to harness.

A second major resource in Hawaii is the aggregate mined for construction. The amount required has increased steadily and now stands at 900,000 tons per year, most of which is supplied by sand ground from consolidated beach dunes or from basalt, at a cost of $13.50 to $21.00 per cubic yard.

A state study in the late 1950's and early 1960's provided a basis for a management programme of the highly valuable beach resources, ensuring multiple use for maximum benefit. The study included land

use, ownership, physical characteristics, areas of erosion and accretion, geology, location of sand beaches, cliffs, etc. This led the state and counties to buy up beach property to ensure public access to beaches. Legislation was also drafted to regulate beach and shoreline usage, which effectively ended beach mining that had existed up to that time. More detailed studies were commenced to locate offshore sand deposits, and eventually resulted in very large quantities being found, but still not large enough to warrant a large dredge operation. A small suction dredge was therefore designed, and was shown to be effective for mining 100,000 cubic yards per year, and competitive with land sources.

Meanwhile new legislation created a conservation zone of the beach and nearshore extending from 400 feet landward of the shoreline to the 3 mile limit offshore. No construction, mining or other use was allowed without a permit, which could ensure proper and stringent precautions were taken. The application of the legislation prevented the use of the nearshore aggregates, which constituted a sizable resource for the state. The law was therefore modified to prevent taking of sand or corals within 1000 feet of the shoreline and in less than 30 feet of water. This also restricted mining, and mining in the offshore in Hawaii has virtually stopped, because of the stringent requirements for environmental impact statements and mining permits. The aggregate industry has now made large investments in onshore equipment which will inhibit offshore development for some time.

Discussion -

It was pointed out in discussion that although the aesthetics of mining may offend some people, the nutrients brought into recirculation may have a beneficial effect on biological productivity and possibly fishing. The removal of sand in the offshore may also expose a hard substrate which could provide a habitat for precious corals.

The responsibilities for management of beaches and nearshore areas are often unclear amongst the various departments and levels of government. These should be defined in any programme of resource management.

FORMATION OF PLACER DEPOSITS, WITH SPECIAL EMPHASIS ON MOZAMBIQUE

Dr. Klaus Duphorn, University of Kiel, Germany

Placer deposits are accumulations of heavy minerals which have been concentrated in favourable environments. They can be found in all except purely biological or chemical deposits. Heavy minerals can be subdivided into "light heavies" (density 2.9-6.8gm/cc), and "heavy heavies" (density greater than 6.8gm/cc). The light heavy minerals of interest in the South Pacific are ilmenite, rutile, zircon, monazite, magnetite and chromite. Heavy heavy minerals of interest are gold and platinum.

Placers are all detrital deposits laid down when current velocities fall. Most are concentrated by streams, on beaches or in dunes, and offshore placers are relic and sometimes reworked deposits of one of these types. Most inshore and nearshore placer deposits are of Quaternary age, so there is a close relationship between placer formation and the global changes of sea level of the last 20,000 years. The rise in sea level has pushed large quantities of placer minerals with it onto the upper parts of the shelves and onto the present-day beaches, and these deposits are widely worked today. However, relic deposits on the continental shelves may soon be more extensively mined, as the onshore deposits are largely worked out. To prospect for such deposits a general knowledge of global environmental changes during the Quaternary, and a detailed knowledge of the regional and local Quaternary history records are pre-requisites.

German placer exploration in Mozambique

The German Bundesanstalt für Geowissenschaften und Rohstoffe (Geological Survey) put a great deal of work into exploration for placer deposits in the Mozambique region in the early 1970s. This commenced with inshore studies based on geological mapping, hand coring and air photo interpretation. The results obtained inshore were of great value for the planning of the offshore survey.

The offshore survey was carried out in a 600km long strip from the Zambezi delta northward, and concentrated on the seabed in water depths of 30-70m. R.V. VALDIVIA was used for 7 months in 1971 and 1973 to carry out bathymetric, reflection seismic and sampling surveys. Altogether some 1750 samples were taken, and the

best placer deposits were shown to lie off the delta.

These disseminated placer deposits originate from a buried early Holocene beach system around 50m below sea level, and have been reworked during the Holocene sea level rise. They contain 50 million tons of ilmenite, 0.9 million tons of rutile and 4 million tons of zircon. The ilmenite itself contains no chrome, unlike most of the East Australian ilmenite deposits, and therefore would be suitable for pigment manufacture (90% of world use).

PLACER GOLD OFF GUADALCANAL

Mr. James V. Eade, New Zealand Oceanographic Institute, Wellington

A nearshore bottom-sediment sampling programme and sub-bottom reflection profiling survey was carried out during November 1975 off the north coast of Guadalcanal. The aim of the project was to investigate the gold content of terrigenous sediment transported from the Gold Ridge area of central Guadalcanal by the Matepono River. A total of 88 samples was collected from the 93 stations occupied including 53 piston cores averaging 1m in length, with a maximum length of 2.27m, and 35 dredge samples. Subsampling of the cores and dredge samples provided 172 samples for analysis, of which 3 contained gold above the detection limit of 0.02 ppm. All are located off the present mouth of the Matepono River or its old mouth to the east. The gold-bearing samples were all -120 mesh size fractions of the total samples and had a maximum gold value of 0.66 ppm (87 ppm for the total sample). Of four beach samples two, which are local black sand concentrates from Tetere and Koli Point, contained 2.28 ppm and 0.4 ppm gold, and the other two were barren.

Echo soundings and sub-bottom reflection profiles were obtained along 140km and 110km respectively. The continental shelf occupies most of the area studied and water depths are commonly 30-66m. The shelf is 2-5km wide, and its outer edge is well defined by a sharp shelf break at a water depth of 55-75m.

A prominent reflector occurs at sub-bottom depths greater than 15m near the beach decreasing to less than 1m offshore. This reflector represents a transgressive horizon on an old land surface where gold may have been concentrated by wave action at the beach during rising sea level. A prominent buried river-channel occurs beneath the transgressive horizon in Tetere Bay. This is an old channel of the Matepono River where concentrations of gold may also occur.

Discussion -

During the discussion Mr. Baekisapa said that in the early 1950's boreholes were put down in the river, but no records are available. Currently an Australian company has applied for exploration rights. Panning is carried out on Gold Ridge itself. Mr. Eade pointed out that lack of mining legislation was hindering the on-land search for gold.

NEARSHORE MAGNETITE AND GOLD PLACERS IN FIJI

Mr.Richard Holmes, Mineral Resources Department, Suva

The geology of the Fiji islands is typified by thick basaltic volcanics and their metamorphic and proximal sedimentary derivatives ranging from Eocene to Pleistocene. Minor magnetite, titanomagnetite and accessory ilmenite and rutile are ubiquitous within the volcanic and volcaniclastic formations. Magnetite is also found in subcommercial quantities as skarns and magmatic disseminated deposits at several locations on Viti Levu and was formerly mined at Tuveriki (Fig. 1).

Former gold mines and prospects originate from magmatic activity with ores occurring in alteration zones, veins, shear zones and as disseminated deposits on Viti Levu and Vanua Levu. Gold is also commonly found as a minor metal associated with former mines and prospects worked for base metals at many other locations than shown on Fig. 1. Gold is now commercially mined only at the Emperor Gold Mine.

The distribution of marine Pliocene and Pleistocene formations on Viti Levu and Vanua Levu demonstrates that there has been uplift on these islands in the order of 1,000 metres postdating the Early Pliocene. This uplift caused rapid erosion of the volcanic rocks which have been the source for nearshore magnetite and gold placers throughout the Pleistocene and Holocene.

The available commercial data demonstrate that the largest Holocene nearshore magnetite placers are unrelated to the former magnetite mine and magnetite prospects on the mainland (Fig. 1, Table 1). At present there is insufficient data to know if the best nearshore gold placer prospects are linked to areas currently containing the highest grades and volumes of gold mineralisation.

Where land and/or barrier reefs shelter the river discharge points from the prevailing South East Trade Winds and waves, then the river catchment area determines their volume, grade and geometry. This applies to the larger Holocene and deltaic magnetite placers at Mba, Rewa, Tavua and Navua (Fig. 1, Table 1). At Sigatoka a 4km breach through the south-facing fringing reef allows the full effect of ocean waves and the South East Trade Winds to impinge on the shoreline (Fig. 1). The result is the deposition of a

marine magnetite placer deposited from longshore drift to the west of the river mouth and an aeolian magnetite placer inshore also to the west of the river mouth (Table 1 also Appendix 1).

Commercial reconnaissance surveys on Holocene seabed and nearshore magnetite and gold placers at Mba, Sigatoka, Tavua, Navua and Rewa have been unaided by geophysics, and the sampling has been too shallow and inextensive to determine the three dimensional geometry of the prospects. Reconnaissance for offshore placer gold has been poorly serviced by unreliable analyses.

Nothing is known about the prospectivity of Fiji's Pleistocene and buried nearshore magnetite and gold placers.

The worldwide availability of much larger and higher grade deposits of iron and titanium than those discovered in Fiji precludes international interest in the exploitation of its nearshore magnetite placer deposits. Whether commercial placer gold deposits exist in nearshore areas around Fiji remains open to question.

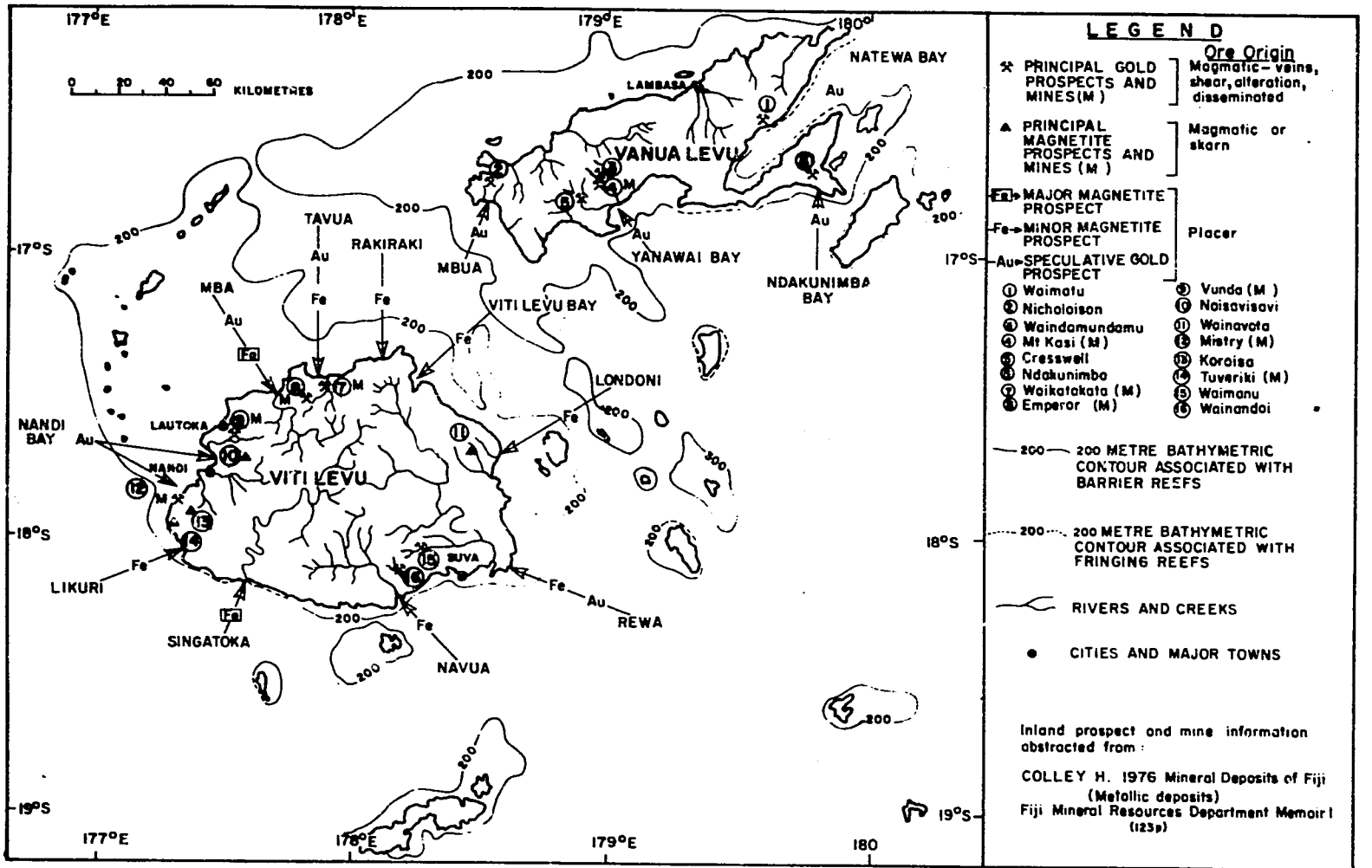

Fig. I Magnetite and Gold, Fiji The relationship of inland prospects and mines to nearshore and offshore placers.

TABLE 1

NEARSHORE MAGNETITE AND GOLD PLACERS IN FIJI REPORTED FROM COMMERCIAL EXPLORATION

Location	Environment	Magnetite		Gold	Comments
		Approx. Recoverable Grade %	Approx. Reserve Million Tonnes		
Mba	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 km^2; East: 4.7 to 6.7, 0.6 km^2 (1)	1.8 to 2.0 (1)	Not reported (1)	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)	0.8 (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, 13 boreholes (1)

Location	Environment	Magnetite		Gold	Comments
		Approx. Recoverable Grade %	Approx. Reserve Million Tonnes		
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 and 0.7	Small and scattered	Not reported	Reconnaissance, 2 boreholes.
Likuri	Estuarine to near-shore shallow marine	0.7 to 0.9	Small and scattered	Not reported	Reconnaissance, 3 boreholes.
Viti Levu Bay	Estuarine to near-shore shallow marine	0.4 to 1.0	Small and scattered	Not reported	Reconnaissance, 3 boreholes.
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)

THE MAGNETITE SANDS OF VANUATU

Dr. Neville Exon, CCOP/SOPAC, Suva

The Vanuatu Geological Survey has studied a number of occurrences of beach sands which are rich in pyroxene and magnetite. The sands are derived from the volcanic hinterlands of the islands which consist largely of basalt and andesite. These volcanic rocks range in age from Miocene on the large western islands of Santo and Malekula to Pliocene on Efate, Plio-Pleistocene and Quaternary on Erromango, and Quaternary on Vanua Lava. The sand is carried by streams to the coast, where it accumulates on and near beaches. The size of the sand bodies depends on the volume of material eroded - a function of age and island size for example. The richness of the bodies, in terms of magnetite percentage, depends on the amount of reworking by wave action, which in turn depends largely on the amount of protection provided by local reefs. Features of the more important deposits are listed below:

Locality	Sand tonnage	% Magnetic fraction	Magnetic tonnage
Santo			
Big Bay	17,600,000	3.5	625,000
West	9,620,000	1.4	136,000
Southwest	2,923,000	14.5	424,000
South	16,034,000	7.1	1,151,000
Malekula	?	8	30,000
Efate	370,000	47	173,000
Erromango	325,000	36	128,000
Pt. Patteson	?	9.5	?

By far the largest sand bodies occur on Santo, and despite the relative poorness in magnetite (% magnetic fraction), these are the largest magnetite deposits in Vanuatu. The magnetite-rich deposits of Efate and Erromango are unfortunately very small. None of the deposits are large enough to be of present-day economic significance.

CCOP/SOPAC is continuing with work started by the Geological Survey on the Port Patteson (Vanua Lava) deposits, with a view to better defining their grade. Follow-up work will be needed to properly determine their size.

AUTHIGENIC MINERALS - PHOSPHORITES, METALLIFEROUS SEDIMENTS AND MANGANESE NODULES

Dr. David Cronan, Imperial College of Science and Technology, London

Authigenic minerals are those which are precipitated from aqueous solution or form by alteration in aqueous solution of pre-existing minerals. Most authigenic minerals on the sea floor are present in minor amounts and are of little or no economic significance. However, three authigenic minerals on the sea floor can be both abundant and of economic value. These are phosphorites, metalliferous sediments and manganese nodules.

Phosphorites are composed mainly of phosphate minerals, whose principal use is as a fertilizer. Their main mineral is carbonate fluorapatite, $Ca_{10}(PO_4\ CO_3)_6\ F_{2-3}$. They range in phosphorus content up to about 14%, and generally contain a host of impurities some of which, such as uranium and the Rare Earth Elements, may be present in sufficient quantities to be extractable as by-products. Phosphorites generally occur in water depths of less than 1000m, on continental shelves, banks, seamounts and on marginal plateaux. They are most abundant on western continental margins, and form in association with upwelling which leads to high biological productivity. They are also locally abundant on oceanic seamounts. Phosphorites are formed as a result of the breakdown of phosphorus-bearing organisms on the sea floor, leading to the liberation of phosphorus to the interstitial waters of the sediments, and its precipitation to give weakly phosphatised muds. These, then become lithified and upgraded, partly as a result of the loss of volatile constituents such as oxygen, carbon and nitrogen. Uplift, erosion, re-deposition and re-phosphatisation of the deposits can occur and lead to further upgrading of their phosphorus content. In the southwestern Pacific, their principal occurrence is on the Chatham Rise off New Zealand, and on seamounts.

Metalliferous sediments are hydrothermal precipitates from submarine volcanic solutions. The main components in them of value are copper and zinc sulphides, and these are generally associated with iron and manganese oxides. Metalliferous sediments are most abundant on the World Mid-Ocean Ridge System, with spectacular examples of sulphide minerals in the Red Sea (which are now undergoing a feasibility study as an ore body) and on the East Pacific Rise

at 21°N. However, they also occur in island arcs, including that in the southwestern Pacific. As yet, sulphide mineralization has not been found on the sea floor in the southwestern Pacific (although ancient marine sulphides have been found on land) but several occurrences of what appear to be hydrothermal oxide sediments have been reported, and further work will probably locate sulphides also. One way in which the sulphide deposits could be found is by utilizing their association with the hydrothermal manganese and iron oxides mentioned above. In the Red Sea, and elsewhere, it has been found that sulphide deposits of limited areal extent are surrounded by a zone of manganese enrichment in the sediments, of much greater areal extent. In the Red Sea, for example, this so-called "manganese dispersion halo" is up to 20km in diameter. Thus, by searching the sea floor for areas of manganese enrichment, and concentrating detailed exploration work in those areas, the chances of finding hydrothermal sulphides are maximised.

Manganese nodules are precipitates of iron and manganese oxides, which can contain up to 3% combined Cu and Ni. It is these elements which are of principal economic value in the deposits. Nodules containing ore grade concentrations of Ni and Cu are most abundant in the northeastern equatorial Pacific and have also been found in the south equatorial Indian Ocean. The main conditions for their occurrence are:

(i) elevated biological productivity in the overlying surface waters;

(ii) a sea floor depth below the lysocline (depth at which $CaCO_3$ exhibits a significant increase in its rate of dissolution), and

(iii) low rates of deposition of associated sediments.

Under these conditions, sinking organisms containing metals such as Ni and Cu can dissolve at the sea floor and liberate their metals to the interstitial waters of the sediments, where they are available for uptake by forming manganese nodules. In the southwestern Pacific, the most likely areas where the above conditions for ore grade nodule formation are likely to be satisfied are in the deep basins of the south equatorial region.

REEF SEDIMENTATION

Dr. Bruce M. Radke, Bureau of Mineral Resources,
Canberra

Reef development is influenced by many factors: biota, substrate, relative sea level, the energy regime, water characteristics and terrigenous sediment influx. With such diverse variables, some of which are partly interdependent, there are numerous permutations in reef geometry and sediment distribution. Consequently, generalisations on sedimentation patterns are made with reservations.

Reef development can be classified into three phases: vertical accretion, transitional and lateral accretion. The phase of development is determined by the level of the reef crest with respect to sea level, and the balance between vertical reef accretion and tectonic uplift or subsidence. Vertical accretion dominates when the reef crest is below sea level. When the reef crest is at sea level, carbonate framework production is transformed to detritus which infills lagoons and irregularities between reef crests (transitional phase) until the reef begins to accrete laterally over its newly formed detrital deposits.

The formation of detrital carbonate deposits involves carbonate production, erosion, transportation and sedimentation of debris.

Carbonate production is by various organisms with carbonate skeletons (coral, coralline algae, foraminifera, etc.) and varies over the reef. Highest production is on the seaward margin; reef front, intertidal algal pavement on the reef crest, and the adjoining coral flat. In these zones production of skeletal material is between 3.5-4.0kg $CaCO_3/m^2/yr$. Seagrass meadows which develop on sandy substrates are also an important producer of sediment as foraminifera and bryozoa grow as epiphytes on the seagrass. When carbonate production is averaged over the whole reef and lagoon areas, it is in the order of 1.5kg $CaCO_3/m^2/yr$ between 24-12° latitude, but most probably drops to as little as 0.5kg $CaCO_3/m^2/yr$ in the equatorial zone.

Using these estimates of carbonate production, reef productivity per linear kilometre of reef margin (at sea level) can be applied to rates of sediment production.

Erosion of framework encrustation in consolidated reefs is by the combined effect of biological and mechanical processes. Estimates of overall erosion of indurated carbonates range from 0.1-0.5 mm/yr. However, the potential of bioerosion by borers in lithified substrates is much higher. Important macroborers include cryptic boring sponges, echinoids, bivalves, gastropods and sipunculids. Microborers are endolithic algae and fungi. Fish and holothurians ingest and transport sediment. Skeletal material that is excavated by boring sponges is removed as silt particles, and the sponges leave large golf-ball sized cavities that render standing coral colonies susceptible to structural failure. This bioerosion, and mechanical abrasion caused by waves, produces detritus of all sizes which is transported by gravity slides, traction and suspension to lower energy areas. These are mainly leeward of production zones. Wave trains from prevailing weather, larger oceanic swell and periodic storms provide energy for erosion and sediment transportation. The deposits resulting from infrequent but catastrophic events are reworked during the intervening longer periods of prevailing weather.

Sediment also filters into the highly porous reef framework and is transported through cavity systems to both lower reef front and leeward lagoons.

Sediment transported across the surface is deposited in lower energy environments away from the reef crest and coral flats: supratidal to intertidal banks of gravel or sand, intertidal sand sheets, subtidal sand wedges, and lagoonal muddy sands or silts. The average origin of detritus for One Tree Reef in central Queensland is given in Table 1. However, relative contributions of skeletal organisms can differ significantly in different reef ecosystems.

Characteristics of deposits

Intertidal gravels	- banks and thin sheets with vertical and lateral grading. These are reworked from the reef flat by high energy events.
Intertidal sands	- sheets with low angle forsets to leeward. Fine to coarse grading and lag deposits. Formed by high energy events with the front prograding towards lagoon.
Subtidal sands	- deltaic banks with coarse to fine vertical grading. Deposition during winds greater than 25km/hr at spring tides or equivalent swell.

Lagoonal sand, silt, mud	- horizontal grading, homogenous vertically because of extensive bioturbation. Sand introduced during strong wind periods. Large proportion of sediment produced in the environment by foraminifera etc. Silts and mud deposited during slackwater periods, especially neap tides.

Surficial cover maps

Assessment of energy zonation and areas of carbonate deposition on reefs can be made from reconnaissance maps of surficial cover. Surficial cover can be classified in a simple ternary system using detritus, pavement and framework encrustation as end members.

Detritus is unconsolidated, reworked material, almost exclusively calcium carbonate, that has been derived by mechanical and bioerosion of skeletal organisms, pavement, and other detritus. This end member is subdivided into sand-dominant and cobble/boulder-dominant fields in a third dimension to the ternary system.

Pavement is an indurated and eroded surface with an absence of surface encrustation by hard-skeleton organisms. This surface commonly exhibits cross-sections of coral heads and detrital deposits.

Framework encrustation encompasses the bound hard skeletons of any sessile organisms in growth position. Most prolific are coral and coralline algae.

Because these components can be rarely separated except by the most detailed mapping, the ternary field is subdivided into zones of increasing entropy (the degree of mixing). In the 60% to 90% entropy zone (Pelto, 1954), 9 fields are readily distinguished by reconnaissance field observations.

These maps show surficial cover facies only, and need to be superimposed on detailed bathymetric maps. A simple but useful bathymetric classification can be applied by differentiating supratidal (above MHWS), intertidal, and subtidal (below (MLWS) zones. This mapping technique is being developed by the Bureau of Mineral Resources for the production of 1:10,000 maps that will contribute to future management of reef areas.

PELTO, C.R., 1954 - Mapping of multicomponent systems. Journal of Geology, 62, 501-511.

Discussion -

In the discussion Dr. Radke indicated that the degree of boring of coralline material varies greatly from one reef to another, so that it would be sensible to check various reefs for suitable construction material for concrete aggregate.

As regards the question of whether one could predict whether unconsolidated rubble suitable for construction purpose might lie below a hard crust, Dr. Radke said it was impossible to estimate the thickness of crust. The crust is often formed by primary cementation when tides are low, and a thin layer of hot water rests on the substrate. This may be originally only a few centimetres thick.

TABLE 1

SEDIMENT COMPONENTS

One Tree Reef
Great Barrier Reef

	Gravel	Coarse Sand	Fine Sand	Silt & Mud
Coral	AAA	AA	AAA	?
Coralline Algae	AA	AAA	AA	?
Pelecypods	AF	AF	AF	?
Gastropods	F	A		?
Foraminifera	A	F	AF	?
Echinoids		F		?
Sponge Spicules			F	?
Gorgonian Spicules			F	?
Ostracods			F	?
Crustacea	F		A	?

A - Abraded
F - Fresh

AAA Dominant
AA Common
A Present

BEACH SYSTEMS AND THEIR MANAGEMENT

Professor Eric C.F. Bird, University of Melbourne

Beaches are resources of value for coastal protection, as a habitat for littoral organisms, as a source of minerals, as a base for nearshore fishing, and as an environment for recreation. Beach sediments, generally sands, but locally gravels, are emplaced by wave processes, and may be derived either from the hinterland by way of rivers, from cliff and shore erosion followed by longshore drifting, or from nearshore reefs or the adjacent sea floor, delivered by shoreward drifting. Beach systems are dynamic in response to nearshore wave and current processes, and show both cyclic alternations of cut-and-fill, and secular changes leading either to net progradation or to a long-term erosional trend. Some beaches are still receiving sediments, but on the world scale most sandy coastlines have been eroding during the past century, the exceptions being those still supplied with sediments from rivers, or by longshore and onshore drifting.

Management of beach systems requires basic knowledge of these cyclic trends, of sources of sediment supply (if any) and regimes of sediment removal (onshore as dunes or into inlets and estuaries; alongside; or out to the sea floor). Quarrying of beach materials may lead to, or accelerate, coastal erosion except where natural replenishment is sufficient to maintain the sediment volume. Anti-erosion works such as sea walls and boulder dumps are often followed by beach depletion. With erosion prevalent on sandy coastlines it is generally good policy to conserve beach sediments, or augment them by dumping sand (dredged from offshore or brought from hinterland quarries) on the shore. Such artificial beach nourishment is expensive, but may be justified in resort areas.

In the South Pacific region, most beaches are partly or wholly derived from adjacent reefs, and consist mainly of coral fragments, coralline algae, and other debris of reef organisms that were washed from the reef surface and accumulated on the backshore. Locally, beaches are fluvially nourished, or include material eroded from adjacent cliffs and rocky outcrops. In many cases, beach erosion is in progress, indicating a deficit in sediment supply, with losses mainly to the sea floor offshore. Quarrying of sand and gravel is therefore likely to lead to accelerated erosion of the backshore, damaging property and land resources behind the beach. On beaches with an

abundant and continuing natural sediment supply this risk is diminished, but sand and gravel requirements in the South Pacific region should be met by dredging offshore sources when possible, or by quarrying emerged beach and reef formations in the hinterland. Assessments of the beach erosion hazard, and of the possibilities of quarrying hinterland and offshore deposits, are urgently required in this region.

Discussion -

During the discussion, Dr. Bird indicated that the cost of replenishment of sand on a moderate-sized beach could be hundreds of thousands of dollars, and this might be necessary every few years. Replacement of natural fine sand by coarser material could slow down the rate of erosion.

Mr. Tongilava raised the example of a locality on the coastline on the lee side of Nuku'alofa, where the coast was receding slowly, but had an adequate beach until a seawall was built. Despite little wave action, the beach had scoured away from the foot of the wall. Dr. Bird responded by saying that the limited wave action, plus current action, must have caused the original coastal recession and the recent scouring.

COASTAL EROSION - EXAMPLES FROM HAWAII

Dr. J. Frisbee Campbell, Hawaii Institute of Geophysics, Hawaii

The viewpoint of a geologist regarding the coastal area is different from that of an engineer. While the engineering solution to coastal erosion is to build a wall or some other form of protection, the geologist seeks the cause and attempts to find a natural solution. Engineering solutions often do not survive over a long time, so an attempt to understand the cause will usually lead to better solutions or a better form of protection. Three examples of management problems involving erosion serve to show how this knowledge can lead to a better and often cheaper solution.

The first example is Ala Moana Beach along which a navigational channel had been dredged inside the reef. Wave energy was mainly expended on the reef, but winter storms provided sufficient energy to reach the beach and cause slow localized erosion into the dredged channel. Beach loss is accumulative and serious in the long term, so the solution was to periodically dredge sand from outside the reef before the cumulative loss became serious and the beach needed improvement. This would only have to take place every few years and offered a cheap solution on a yearly basis.

The second management problem is at Waimea Beach where a study indicated considerable loss over a period of several years. An adjacent offshore study showed that the cause of the problem was not human interference with beach processes, but a relative rise in sea level. This was not only immersing the beach, but also allowing natural long shore patterns of sand movement to be diverted seaward away from it, so that beach nourishment was reduced. Most erosion was occurring during storms with high surf, but no significant man-made structures were endangered. The final management solution was to move a minor building back from its beach front location and to do nothing to the beach itself.

The third coastal management example is at Kailua Bay where home owners complained that beach erosion was occurring which threatened their houses. Studies of photographs over historic time provided evidence that the beach had a natural cycle of emergence and submergence over a period of many years. Development took

place during a period of maximum emergence, and homes were allowed to be built on areas subject to submergence during the transgressive part of the cycle. The new homes were now endangered as the beach retreated. One long term solution is to remove the endangered homes, but the matter is under litigation and has yet to be decided.

ENVIRONMENTAL IMPACT OF SAND DREDGING

Mr. Gilberto Cintron, Department of Natural Resources,
Puerto Rico

Island shelves contain various extractable resources. Of these, surface unconsolidated sediments, which may be readily dredged, can augment the limited land-based sources of aggregate used for construction. Traditionally sand has been obtained from beaches, sand dunes and river mouth deposits. Removal of sand from these areas invariably results in increased coastal erosion and loss of highly valuable beach-front property.

To avoid this problem it is imperative to tap only those sand deposits which are at least partially renewable, and which are not providing shelter to inshore systems. After it has been determined that a sand deposit is renewable, the impact of its extraction on nearby ecosystems must be evaluated.

Coral reefs and seagrass beds are the most productive biological systems in tropical shallow waters. Both need adequate light. Corals, although animals, contain microscopic algae in their tissues which assist in the process of calcification and growth.

Turbidity caused by dredging increases turbidity and reduces light penetration and the amount of energy available for photosynthesis, causing severe stress. Suspended sediments also interfere with the feeding activity of polyps. Corals may rid themselves of small amounts of sediments by ciliary motion and exudation of mucus. Sediment particles are trapped by the mucus and transported to the edge of the colony by ciliary motion. This drains energy and reduces the amount of energy available for growth and reproduction. Another problem is that coral larvae do not settle over sediment-covered substrates, so that regeneration of a sedimented reef may be prevented. In general, the best reef development occurs where sedimentation rates are less than 5.0mg/cm^2/day, suspended sediments are less than 1.0mg/L and the extinction coefficient is less than 0.17 or the turbidity is between 0.3 and 1.0 F.T.U.

Sea grasses are also highly productive (8-16g dry organic matter/m^2/day) and have standing crops in the order of 2kg/m^2. They also require high levels of illumination and are affected by high turbidity levels.

These two systems give high yields of fin-fish. In Fiji the maximum yield from coral reefs is estimated to be 4.4 tons/km^2/yr. Bare sands have yields of only one-tenth as much. These fish are important protein sources for island inhabitants. Degradation of seagrass and coral reefs by poorly planned and executed dredging can decrease these yields.

The type of dredging method also influences the degree of impact of a dredging operation. Basically there are two types of dredges - mechanical and hydraulic. Mechanical dredges are of the dragline, clamshell or bucket type. They are basically excavating machines. This type of dredge is limited to shallow waters and small projects, and causes a great deal of disturbance and turbidity.

Hydraulic dredges have greater volume and depth capability. One type, the hopper dredge, is self-contained and may dredge while underway. This dredge can haul its own cargo to port. It can dredge in water depths greater than 30m. Using this dredge causes turbid plumes, since a water-sediment slurry is pumped aboard, the coarse material is retained, and the fines and sea water are allowed to drain overboard. However, dredging impacts are minimized by dredging in deep water and the hopper dredge system is best suited for this.

It should be noted that sands of good quality may be obtained from port development projects.

A regional survey of the characteristics of surface sediments is needed to locate suitable fine aggregates. This survey must include coring and seismic profiling to determine the magnitude of the resource. An inventory of vulnerable marine ecosystems must also be prepared, since a knowledge of these systems is needed for coastal zone planning activities.

Studies of nearshore oceanography must be encouraged. These data are needed to predict the dispersion patterns of pollutants discharged into the marine nearshore environment, including the fate of turbidity plumes caused by dredging.

Regulations must be enacted to prohibit the removal of sands from beaches, river mouths and dune fields.

Finally it is necessary to consider environmental problems in the selection of the sand stockpiling areas ashore.

Discussion -

In the discussion Dr. Cintron indicated that in Puerto Rico dredging permits are not time-limited, but can be stopped if major environmental problems arise. A royalty is paid on the volume taken. The company produces an environmental impact statement before a permit is granted, and this can be independently checked by the Department of Natural Resources.

Dr. Cintron also remarked that the tailing edge of an island might provide shallow water deposits which can be safely used. He mentioned that siltation is often more of a problem to deep water than surface corals, because waves sweep the surface corals clean. One solution to dredging in sensitive areas can be to strictly control the taking of sediment to periods when currents will sweep the resulting sediment plumes into deep water.

RESOURCES MANAGEMENT

Dr. Arthur Dahl, South Pacific Commission, Noumea

Management refers to actions that are directed toward some end, which requires the definition of goals or policies. Resources are something with a use or potential use, and in the coastal zone include the uses of the coastal water itself, the uses of the bottom and bottom materials, and the living resources. Resource uses are multiple and interacting, and may be mutually exclusive.

Different management approaches are required for renewable and non-renewable resources. For non-renewable resources, management means efficient and economic extraction until exhaustion, while minimizing the economic, social and environmental impacts both before and after resource depletion. For renewable resources, management should aim to achieve sustainable yield.

A general criterion for successful management is to use a resource with minimal negative effects on other resources, and ultimately to achieve the balanced use of all resources for maximum multiple benefits.

The first element needed for sound resource management is information on the resource and its interaction with other resources. Even where scientific or traditional information exists, it is frequently not used. This information should be compiled through comprehensive planning to enable the best choice of resource uses. Development projects can then be defined and subjected to economic analysis, and environmental social impact studies, in order to achieve the most probable nett benefit. Both plans and projects should be monitored to ensure that the defined goals are being met and to identify unexpected impacts.

Inshore and nearshore resources and the whole coastal zone require an integrated management approach which may require the coordination or restructuring of the responsible government departments. Much effective resource management can also be done at the local or village level.

Inshore resources such as coral reefs and reef fisheries form a complex, largely closed system which is difficult to manage. There is

natural variability in the system depending on the stage of reef development, population fluctuations and extreme events such as storms. If the system is pushed beyond its limits, it is easily degraded, and is slow and difficult to re-establish. The rapid technological changes in inshore resource utilization in the tropical Pacific have created new management needs for which answers must still be found.

CONCRETE AND CONCRETE AGGREGATES IN THE SOUTH PACIFIC

Dr. J. Feike de Bock,
New Zealand Concrete Research Institute

Directors of Public Works in the Pacific Islands are usually concerned at the lack of good quality aggregates available for the building and construction industry. These aggregates are derived either from coral or coral limestone of varying quality on the low islands or from volcanic rocks on the high islands where use may also be made of coral deposits.

Contractors need to know the quality of aggregates and their behaviour in the production of concrete products if the best and safest use of aggregate is to be achieved. At present little is known about the physical properties of aggregates from the region.

In Suva and Nadi one gets the impression that Fiji is a modern developed country. The streets, especially full of shops filled with tax free cameras and electronic goods make it easy to get a totally wrong idea. Fiji is a developing country with a badly trained labour force and lack of infra-structure. This is expressed in the quality of building, especially in concrete.

Apart from assessment of the existing resources of concrete aggregate, future projects should be aimed at development of aggregates on the smaller islands where coral is the only material available. The project should, at least in the first phase, concentrate on centres of population. Here the economic results can be quick and optimal.

During discussion with representatives of Standard Concrete Industries Ltd., Fiji Technical Institute, Public Works Department, Fiji Industries Ltd. and local contractors it appeared that there exists a lack in basic knowledge on concrete construction technology. There is no supervision at building sites, and no controlled testing of the concrete or aggregate used. This is a hurricane and earthquake prone region proven to be in an extremely dangerous location, and highest concrete strength and construction standards must be achieved.

Coral deposits can be successfully used as concrete aggregates for everything from small buildings to vast concrete edifices. However, guidelines and specifications for the use of coral aggregate have to be determined, supplied and followed. Coral concrete can then develop a strength very close to that using crushed rock.

Training courses should be organized, testing facilities improved, control and acceptance testing should become standard practice. This will result in better control of mix design which is then based on improved knowledge of behaviour of aggregates and concrete and will result in safe and more durable structures.

Several examples of poor concrete design, mixing and pouring procedures were noted. When proper procedures and tests are not used, the concrete will be highly variable and loss in strength of as much as 50% may result. The importance of a number of characteristics of concrete materials and tests were defined including sieve analysis, fineness modulus, particle shape, cone test, surface texture, crushing resistance, absorption, cleanness, voids, density and others. Training of technicians and supervisors, so that proper testing would be carried out, was stressed. Good testing will ensure adequate strength, and save money.

Care in stockpiling of aggregate and cement is important in areas of high humidity where moisture content may vary from day to day. This variable moisture content must be considered in determining the correct proportions of cement, water and aggregate.

Sound concrete is made with the right materials by people to whom it is an honour to produce a good piece of workmanship.

Discussion -

Questions concerned quality control in concrete construction which, in Fiji at least, appears to be absent, and with ways of protecting reinforcing steel in concrete containing salt from marine aggregates. It is highly desirable to establish a project which would include testing of coral aggregates and other concrete materials in the various regions. Training of the work force in good concrete procedures must follow, as well as the setting up of proper procedures for testing and supervision of concrete construction mixes and materials. The speaker offered to be of assistance in this if people wished to contact him.

SEA BED INVESTIGATION TECHNIQUES

Dr. G.A. Gauss, CCOP/SOPAC, Suva

Dr. Gauss reviewed the principal modern techniques for investigating the sea bed in nearshore areas either for mineral exploration or engineering purposes. He drew the attention of the meeting to the comprehensive range of equipment now held at the office of the CCOP/SOPAC Technical Secretariat in Suva and available for use on member country projects. The major items of equipment are as follows:

Radio positioning system (Del Norte Trisponder)

Deep and shallow water echo sounders (Raytheon)

Graphic Recorders

Sidescan Sonar (Klein)

Reflection Profiling equipment (sparker, boomer, pinger and air gun)

Marine Magnetometer (Barringer)

Sampling Equipment (Shipek and van Veen grabs, gravity corer, sediment and rock dredges)

Diving Equipment (SCUBA, Nikonos Mk IV diver held camera)

4.6m inflatable dinghy (Avon)

The importance of a sea surface positioning system accurate enough for the purposes of the sea bed survey was emphasized. The traditional optical methods, utilizing theodolite bearings taken from shore or double sextant angles taken on the survey vessel between shore beacons of known position, were commended as inexpensive, accurate methods highly suitable for survey areas within about 10kms of the coast. Further offshore an electronic positioning system will generally be required, consisting of two or more stations on land and a display unit on board the survey vessel. The Trisponder system owned by the Technical Secretariat is a radio line-of-sight system with a maximum possible range of 80km and a theoretical positioning

accuracy of ± 3m. Other systems are available, and ranges of many hundreds of kilometres can be achieved, but the accuracy of the position given is generally inversely proportional to the distance offshore. Actual techniques of sea bed investigation may be either direct or remote. The former include inspection, sampling and photography by diving, and sampling by various types of grabs and corers. The latter include a number of geophysical techniques and, because of the existence of the water medium, these indirect methods assume a much greater importance than they do on land.

Amongst the geophysical techniques, those depending on the transmission, reflection and recording of sound in the water are perhaps the most useful. These include echo sounding, side scan sonar and sub-bottom reflection profiling techniques.

In echo sounding a high frequency sound pulse is transmitted from the survey vessel vertically down to the sea bed, and the returning reflected pulse is picked up and the round trip time is measured. Knowing the velocity of sound in sea water an accurate water depth can be calculated. Water depths are generally displayed graphically on a moving paper trace as a sea bed profile along the track of the survey vessel. For inshore bathymetric surveys the echo sounder must be calibrated by bar check daily, to compensate for variation in the speed of sound in water, and tidal reduction must be applied to depth values recorded to bring them to a standard datum.

The sidescan sonar operates on the same principal as the echo sounder and utilizes sound of similar frequency. The towed sonar fish transmits a sound beam to both sides of the surface vessel's track. This beam is fan-shaped in the plane at right angles to the track, and is very narrow in the plane parallel to the track. The transmitted sound irradiates the sea bed on either side of the fish, and reflected signals are picked up by the same fish, amplified and recorded on a graphic recorder. Strong signals are generally returned from topographically prominent features and from hard materials, whereas weak signals are returned from depressions and soft materials, with the result that the graphic record resembles a distorted "acoustic photograph" of the sea floor. The sidescan sonar has a very high definition. Rock outcrops and sediment covered areas can be clearly mapped and features such as wrecks, pipelines and sand ripples can be easily resolved. The technique is extremely useful for both geological and engineering studies of the sea bed surface.

Sub-bottom reflection profiling is, in principal, similar to echo sounding but lower frequency sound is transmitted at higher energy, generally from a towed acoustic transducer. Returning reflected signals may either be picked up by the same transducer or more

generally, are picked up by a towed hydrophone. Low frequency sound will be both reflected and transmitted downwards at the sea bed, and the transmitted sound will in turn be reflected at boundaries of materials of differing acoustic properties. Such boundaries generally correspond to geological boundaries with the result that the reflected signals, when amplified and printed on a graphic recorder, produce a vertical profile along the vessels track which can be interpreted as a geological cross section. The technique can provide invaluable sub-bottom geological data but, for thickness measurements from the profile, the velocity of sound in the sub-bottom strata must be known or assumed, and for detailed correlation with geological material sea bed sampling and coring is necessary.

Another marine geophysical technique widely used for inshore studies is magnetometry. A towed proton precession magnetometer sensor allows measurement of the earth's magnetic field to be made to an accuracy of better than 1 gamma at rate of once per second or more. Magnetometer records can be used to investigate the regional sea bed geology, and also for small scale geological investigation where formations of contrasting magnetic properties are involved, e.g. the location of volcanic outcrops in sedimentary formation. Magnetometers are also extensively used in the location of ferrous objects on the sea bed such as shipwrecks and pipelines.

Although the direct techniques of geological investigation are not as dominant in the marine environment as they are on land, they are still essential since no remote technique can itself reveal the presence of economic minerals or allow the detailed soil or rock properties to be evaluated.

Diving is a useful technique of sea bed investigation in the CCOP/SOPAC area, since waters are generally clear and water temperatures are comfortable. However, the technique is limited to depths of less than 40m to be safe. Only the sea bed surface can be directly studied and sampled, although short cores can be obtained by divers, and sediment probing to several tens of metres can be undertaken.

Sea bed surface sampling by a variety of grab samplers lowered from a boat is generally a satisfactory method of obtaining surface samples up to several litres in volume. Gravity corers can obtain cores of up to perhaps 10m in soft silts and muds, but corer penetration is reduced to perhaps one metre in coarse sands, and may be zero in gravelly or shelly deposits which are extremely difficult sediments to core successfully. A vibrocorer, either electrically,

pneumatically or hydraulically operated, can obtain cores of up to perhaps 10m in coarse unconsolidated sediments. However, for deeper coring in any type of sediment, and for coring in cemented formations, it is generally necessary to use conventional land coring techniques operated from a pontoon or drill ship. Such operations are highly specialized and very expensive.

Discussion -

Mr. Holmes asked what were the major gaps in the sea bed investigation capabilities of the Technical Secretariat.

Dr. Gauss replied that the Secretariat was weakest in the field of sea bed coring. The limitations of the gravity corer had been pointed out and as much of the CCOP/SOPAC work was involved with investigation of sands and gravels, either for placer minerals or aggregates, this limitation is a significant one. The Technical Secretariat now has funds hopefully sufficient for the purchase of a vibrocorer, acquisition of which would improve our sampling capabilities in these materials. However, it is considered that deep sea bed coring will always be outside our capabilities and will have to be undertaken by specialized operators probably from the private sector. This, however, will usually constitute the last stage of a sea bed site investigation.

INSTRUMENTATION FOR NEARSHORE ENVIRONMENTAL STUDIES

Mr. Wendell Gayman, CCOP/SOPAC, Suva

There are a substantial number of dynamic, static, physical, and chemical characteristics of the environment which should be or might be measured during the course of a variety of field projects. In many cases it may be desirable to obtain data on these characteristics 24 hours a day, continuously throughout a fortnightly or monthly tidal cycle. Also, it may be necessary to acquire data representative of all seasons. In addition to collecting information during normal or average conditions, it may be desirable to collect data during abnormal conditions such as those which would be produced by the nearby passage of a cyclone.

The various instruments available for measuring dynamic environmental characteristics include anemometers (for determination of wind velocities), wave recorders, tide gauges, and current meters. All or most of the instruments designed for recording environmental characteristics are of electronic design. Unfortunately, most electronic instruments designed for oceanographic use are fairly expensive to purchase and operate. For this reason, one may wish to select one or more of several crude and or inexpensive methods to obtain data on the dynamic characteristics of the environment. Such methods may include the manual reading of tide staffs, determining wave characteristics with a hand compass, stop watch, and horizon levelling techniques, and studying currents by tracking drogues or timing the movements of wood chips. These appropriate technology methods may require more labour than the more sophisticated electronic methods, or they may produce less accurate results.

Many environmental field studies require the measurement of the horizontal and vertical distribution of various physical and chemical properties such as temperature, salinity, turbidity, pH, and the concentrations of dissolved oxygen and other chemical constituents. There are two methods for determining vertical gradients of the various static properties. A water sampler can be used to collect water sampes from one or more depths at any selected station. Subsequently, in the survey vessel or in an onshore field laboratory, the water sample collected may be analyzed for the properties of interest. A more sophisticated method utilizes electronic sensors lowered into the sea to make in situ measurements of the

water characteristics. This permits the determination of a continuous vertical profile of any given constituent in the sea.

Electronic instruments recording on magnetic tape are usually used for the long term collection of environmental data from a single surface or subsurface location. These instruments are very expensive. Also, they are frequently subject to failure and it is often impossible to determine whether they are operating correctly, until long after one has departed from the field site.

Because of the large number of parameters of interest, and the high cost of oceanographic instrumentation, the environmental field investigation often must:

1) make use of existing data, which may be available from distant areas in the same region, and

2) make various assumptions with regard to the environment which will eliminate the need for the collection of certain types of data, or will shorten the necessary period of collection.

The CCOP/SOPAC office has the following items of equipment available:

1) One NBA DNC-3 current meter which includes a sensor, 150m of cable, and surface indicator. The indicator shows depth, current speed, current direction, temperature, and conductivity (which can easily be converted to salinity).

2) One Partech water quality meter consisting of an underwater sensor, 150m of cable, and a surface indicator. The instrument is designed to measure depth, temperature, conductivity, dissolved oxygen, turbidity and pH.

3) Two 2-litre water sampling bottles with messengers.

4) A number of smaller items used for calibration and water sampling analyses are also held in stock.

SESSION ON COASTAL MANAGEMENT IN CCOP/SOPAC MEMBER COUNTRIES

This session was planned by Dr. Eric Bird to elicit information of use to planners in the region. Representatives of each member country were asked to prepare and present answers to the following four questions:

1. Which agencies or organizations decide the use of coastal and nearshore resources in your area?

2. What is the pattern of ownership, leasing and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

3. What are the major changes (natural or caused by man) in progress on your coasts?

4. What are the key problems of coastal management to be solved in your area?

Mr. A. Utanga, Department of Survey and Physical Planning, Cook Islands

Question 1: Which agencies or organizations decide the use of coastal and nearshore resources in your area?

Answer:

The Conservation Act administered in the Ministry of Internal Affairs was passed a few years ago (1975?), and empowers the Minister to counsel land owners, owners of historical building and owners of historical traditional monuments, on ways and means of preserving these monuments (and/or trees) for the benefit and enjoyment of the community. These powers are delegated to conservation officials, who have no real powers to enforce control on land use and development.

A land use act was passed in 1969 which gives powers to a land use board to regulate and control land utilization and sub-divisions. Again the act only sets up the board and the machinery for administration, but does not specify its powers and the way to administer good land use practices.

Clearly what is needed is a code of ordinances for town planning and use, and a better and more effective Conservation Act or regulations.

The combination of these two pieces of legislation will be sufficient to control and regulate use and control of beaches, sand and aggregate mining from beaches and lagoon areas, and the preservation of a green belt along the sea front to stop erosion and/or damage to properties inland. These should include development of properties along banks of streams etc.

In our northern group islands, island councils have their own island council ordinances which empower them to regulate the harvesting of pearl-shells, trocus and other shells, and species of fishes, crayfish, turtles and sea birds.

Question 2: What is the pattern of ownership, leasing and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

Answer:

Land Boundaries are bounded by the Mean High Water Mark and therefore land owners rights go down to this MHWM. The government theoretically owns the land below this MHWM out to the 3 or 12 miles territorial waters.

In some islands e.g. Aitutaki, traditional fishing rights of the land owners continue to the lagoon and reef fronting their property, for the collection of certain species of fishes, crabs, seaweed, etc.

There is an ineffective Land Use Act (as mentioned above) which is supposed to help manage and control property development so that beaches and the natural green belt are protected and or improved.

Therefore land owners can, at present, mine and sell their sand and aggregate off their beach fronts. However, any land owner can apply to the land court through injunctions to stop his neighbour from mining or building a construction on his beach, from which the action of natural elements will result in adverse effects on the land owners own land further along the beach. This avenue has been successfully used in previous cases of adverse mining practices of beaches.

Question 3: What are the major changes (natural or caused by man) in progress on your coasts?

Answer:

Physically uncontrolled sand and aggregate mining had damaged and depleted beaches on the main island of Rarotonga. This problem is negligible in the other islands of the group, where construction is not as intensive. The effect of this mining caused erosion further along the beach, creating banks and silting up the lagoons and harbour areas. Pollution of the lagoon in some areas of Rarotonga, Aitutaki, Atin and Mangaia islands from runoff of agriculture chemicals, and factory effluent (Rarotonga) discharges are causing real problems and concern. It is considered that these pollutants may be causing the disappearance of certain species of seaweeds, fishes and other marine life.

Question 4: What are the key problems of coastal management to be solved in your area?

Answer:

Control and regulation (Management). There is an urgent need to update the two pieces of legislation to give them more power to

control and regulate land development, which will give impetus to management of beaches and nearshore resources. Our Minister of Justice and Lands, who is also the Minister of Internal Affairs and Conservation, has come out in print that he is looking seriously to giving the Conservation Act more power. It is hoped that this will give priority to the town planning codes, in ordinances and other suitable legislation to regulate development of properties and thereby help management of beaches, etc.

Mrs. Padman Lal, Fisheries Department,
Suva

Question 1: Which agencies or organizations decide the use of coastal and nearshore resources in your area?

Answer:

a) Fishing resources - utilization of these for subsistence is determined by the mataqali chiefs. For commercial exploitation the Fisheries Division issues licences. Before licence is issued approval of the mataqali owners is needed. This applies to fishing within coastal waters.

b) Physical resources - utilization of these belong to the Ministry of Lands and Mineral Resources. Before any dredging, mining and foreshore reclamation is permitted, the possible impact on the fishery resource has to be estimated. This is only from the point of view of recompensation to the mataqali owners for the loss in fishing resources or fishing rights. This is usually rather subjective and the final decision is usually upon the arbitrator.

Question 2: What is the pattern of ownership, leasing and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

Answer:

Land below HWM (spring tide) belongs to the Crown. The concept of ownership is similar to that in the British Law. However, the right to use belongs to the mataqali chief. This right seems to be for fishing only, however this is not clear. Each mataqali owner(s) has customary fishing rights over the water mass extending from high water mark to the seaward side of the reef system. Beyond this point the resource belongs to the Crown (i.e. Government of Fiji). The sea bed and minerals are also in the ownership of the Crown.

Question 3: What are the major changes (natural or caused by man) in progress on your coasts?

Answer:

The major changes could be summarized as follows:

a) Coastal development for industrial, agricultural, residential pur-

poses, tourism etc. This involves foreshore, including mangrove, reclamation.

b) Dredging/sand mining/channel construction.

c) Erosion, siltation.

d) Coastal pollution - (i) sewage
(ii) industrial pollutants.

e) Increased pressure on fisheries resources, particularly coastal fishery.

Question 4: What are the key problems of coastal management to be solved in your area?

Answer:

a) Lack of defined overall policy regarding management of coastal resources. Management has been, due to necessity, piecemeal and guided by one's own legal jurisdiction. The various government activities need to be coordinated and environmental objectives and policies defined.

b) Need for more specific information on baseline data and processes.

Dr. G.W. Groves, Atoll Research Unit of the
Institute of Marine Resources,
USP, Kiribati

Question 1: Which agencies or organizations decide the use of coastal and nearshore resources in your area?

and Question 2: What is the pattern of ownership, leasing and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

Answer:

As far as I know there have as yet been no important restrictions made on use of coastal or nearshore resources. Each land owner is free to use as he wishes the land above a certain datum (perhaps MHHW). He is free also to take material below this datum adjacent to his land. In colonial times the Crown held the right to take material from anywhere below this datum, but did not usually exercise this right indiscriminately. As far as I know Government still holds this right. Exploitation of resources in the sea, other than the removal of construction material, has not yet been restricted (except for the Economic Zone Offshore). Individuals are free to build fish traps (maa) on the reef flat anywhere. Such traps are privately owned, in much the same way as land, and can be transferred to another owner like land. The owner of a fish trap controls the fish that it catches. Kiribati must be the most unregulated place on earth insofar as coastal resources are concerned. So far this freedom has not led to important conflicts, but it is believed that some restriction may be needed in the near future. The local island councils have the power to make such restrictions in areas of their jurisdiction, and the House of Assembly has such power throughout the country.

Question 3: What are the major changes (natural or caused by man) in progress on your coasts?

Answer:

There are numerous regions of natural accretion and erosion, the latter being quite troublesome in some places. As for man-made changes, the taking of material for construction (causeways, roads, buildings, airfields, other fills) is important. Such material is scarce and expensive, and its removal usually causes unwanted effects. The other main man-made changes are the causeways themselves. These

are built in order to connect motus (islands). They obstruct (completely or partially) the flow of seawater, and alter the sedimentation-erosion regime. Their effect on fish populations is feared to be deleterious and large. Other man-made changes include excavations for boat slips, harbours, the construction and back-filling of sea walls to increase dry-land area, etc.

Question 4: What are the key problems of coastal management to be solved in your area?

Answer:

How much bait fish (such as tarabuti) can be taken for commercial fishing without interfering with direct use as subsistence food.

How to design causeways, and whether their advantages outweigh their deleterious effects.

There are few other serious conflicts, probably because there is such little commercial use of the coastal region, and the population is still so sparse.

Mr. R. B. Moaina, Geological Survey,
Papua New Guinea

Question 1: Which agencies or organizations decide the use of coastal and nearshore resources in your area?

Answer:

1) National Government through its responsible departments.
   e.g. - primary industry department - deals with all fisheries matters.
   Works and supply department or transport and civil aviation - deals with all construction matters.

2) Local people through their various community and provincial governments.

Question 2: What is the pattern of ownership, leasing and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

Answer:

Main owners are: 1) national government (crown/land)
2) local people (traditional land)
3) companies (to a lesser extent)

Access to traditionally owned coastline and intertidal zones is usually restricted.

Question 3: What are the major changes (natural or caused by man) in progress on your coasts?

Answer:

MAN	NATURAL
Waste dumping from mines (copper)	Erosion by wave motion
Dredging (in port development)	Mangrove growth
Sand and gravel removal	Sedimentation problems at mouth of major rivers.
Road construction	

Question 4: What are the key problems of coastal management to be solved in your area?

Answer:

Illegal fishing on traditional fishing ground (including reefs) by foreigners.
Environmental studies and control measures on the effect of waste dumping (from copper mines) and port developments.

Mr. M. Baekisapa, Geology Division,
Ministry of Natural Resources, Solomon Islands

Question 1: Which agencies or organizations decide the use of coastal and nearshore resources in your area?

Answer:

CPO

Baitfish (Fisheries Division

Marine Div.) Port development
PWD) Coastal industrialisation

Central Planning Office, part of the PM's Office formulates and co-ordinates their execution in consultation with the above Divisions.

Question 2: What is the pattern of ownership, leasing, and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

Answer:

Patterns of ownership of beaches and intertidal zones fall under three broad categories:

(i) Traditional owners (clans/tribe) can also claim reefs
(ii) Government - down to high water mark
(iii) Commercial companies - mainly beaches where they have plantations.

Question 3: What are the major changes (natural or caused by man) in progress on your coasts?

Answer:

(i) Removal of sand and aggregate for constructional purposes
(ii) Port development e.g. Honiara and Noro
(iii) Effluent outfalls
(iv) Industrial outfalls: oil palm factory and cannery factory
(v) Use of H-twisted concrete on the western part of Honiara wharf (in Japan - very similar)
(vi) Erosion
(vii) Creation of sanctuaries for turtles e.g. Northwestern Santa Isabel.

Question 4: What are the key problems of coastal management to be solved in your area?

Answer:

(i) Traditional ownership - stumbling block to development
(ii) Lack of qualified personnel to plan and co-ordinate development
(iii) Coastal erosion

Mr. S.L. Tongilava, Ministry of Lands, Surveys and Natural Resources, Tonga

Question 1: Which agencies or organizations decide the use of coastal and nearshore resources in your area?

Answer:

Ministry of Lands, Surveys and Natural Resources are responsible to Cabinet.

Question 2: What is the pattern of ownership, leasing and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

Answer:

Ministry of Lands, Surveys and Natural Resources.

The Government controls all offshore areas and all land extending inward to 50 feet above the high water mark.

Question 3: What are the major changes (natural or caused by man) in progress on your coasts?

Answer:

Depletion of beach sand due to removal (permit system controlled by Ministry of Lands) for construction purposes (housing, roading, etc, etc). Also natural erosion on leeward and low-lying areas. Seawall protection on shoreline.

Question 4: What are the key problems of coastal management to be solved in your area?

Answer:

The important objective of coastal area management in Tonga is protecting the coastal area environment and habitat from human disturbance and also from the natural elements; and at the same time re-landscaping the sand mining pits, and safe-guarding against erosion, etc.

The problem is mainly the beach sand deposits on the main island of Tongatapu which has now come to the stage where the issuing of

sand permits for removal for all construction purposes must now be stopped. The main island of Tongatapu (except for the windward side) is practically flat, and hence the beach sand habitat acts as a buffer zone against the onslaught of the sea and wind. Studies and inventories by CCOP/SOPAC and the staff of the Ministry of Lands have shown that sand extraction has reached saturation point.

Studies and surveys for alternative sand deposits have found an offshore deposit about 7km north of Nuku'alofa, but this is a fertile fishing ground. There is also the so-called sand flat (intertidal area) on the western side of Nuku'alofa, and samples have been sent to New Zealand for analysis. The PROBLEM is "What will be the environmental damage to marine life and to sedimentation patterns from mining?" According to Dr. Cintron both sites seem to have the same ecosystem, that is, the nearshore sand is covered with seagrass etc, so the outlook in both cases seems to be the same. However, I believe that, since the sites are in different localities, the local systems are almost certainly different, and the impact of dredging will be also different.

Mr. W. Harrison, Vanuatu Geological Survey,
Vanuatu

Question 1: Which agencies or organizations decide the use of coastal and nearshore resources in your area?

Answer:

There are no such organizations dealing with coastlines at the moment.
Nearshore - Vanuatu Government recently set up an organization where local fishermen are trained in modern methods of fishing, and the Minister concerned encouraged local fishermen to make full use of our productive seafood resources.

Question 2: What is the pattern of ownership, leasing and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

Answer:

Custom owner - people who need sand for constructions have to pay a certain amount of money for a truck load. Even people fishing on the reefs have to get permission from the landowner.

Question 3: What are the major changes (natural or caused by man) in progress on your coasts?

Answer:

Changes are not all caused by men. The Vila lagoon has been dug up and the mangroves destroyed. An area in the lagoon which was once used by local people to collect shellfish is no longer productive.

Question 4: What are the key problems of coastal management to be solved in your area?

Answer:

1) Unnecessary changes of nature by man
2) Good control of the removal of sand from the beaches, to prevent their destruction.

Mr. A. Philipp, Fisheries Department,
Western Samoa

Question 1: Which agencies or organizations decide the use of coastal and nearshore resources in your area?

Answer:

(a) Minerals: Ministry of Agriculture and Apia Observatory.
(b) Fisheries: Ministry of Economic Affairs and Fisheries.

Question 2: What is the pattern of ownership, leasing and access to the coastline and the intertidal zone (including reef and mangrove areas as well as beaches)?

Answer:

Legislation decrees that all tidal land obtained by legal purchase and/or lease and registered with Lands and Survey Department during the German Regime (1900-1914) is to be recognized. German legislation defined the boundary between dry land and tidal land as the edge of the land covered by sea water at low water mark. New Zealand legislation, operative from 1920 to 1961, and Western Samoa Government legislation defines this boundary as "high water mark".

Two types of land ownership exist in Samoa:

(i) Privately-owned land legally purchased prior to 1900, when the German Government passed legislation that Samoan land could not be sold, was recognized as a legal purchase and not affected by the 1900 German legislation. Legally purchased land included German Government plantations and land purchased by private people. This land now recognized as legal is:

German Government plantations (now Samoan Government plantations and under Western Samoa Trust Estates) comprises about 13% of all land in Western Samoa. Privately owned land comprises about 5% of all land in Western Samoa.

(ii) Samoan-owned land which comprises 82% of all land in Western Samoa.

This land comes under the Samoa land tenure which invests the ownership with the "Matai" (Head of the family). Samoan-owned land cannot be sold but can be leased for "certain purposes" for up to 20 years only. "Certain purposes" do not include for a "homestead".

Mangrove and beach areas would come under "Privately owned" or "Government owned" or "Samoan owned" but the boundary of the three is controlled by Answer 2 provisions where a sea boundary exists.

Coastline and reef areas would come under Answers 1 (a) or 1 (b) as the land covered by sea water at low water mark.

Question 3: What are the major changes (natural or caused by man) in progress on your coasts?

Answer:

(1) Destruction (in a few areas only) of mangrove swamps. Filling-in these areas for buildings.

(2) Heavy agriculture inland causing rivers to dry up, thus affecting the area of outflow to the sea.

(3) Use of sand for building purposes.

Question 4: What are the key problems of coastal management to be solved in your area?

Answer:

The main problems are (1), (2) and (3) above. The use of gelignite and Derris weed killer for killing fish also damages the reef.

CLOSING COMMENTS BY PARTICIPANTS

Mr. W. Harrison, Vanuatu

The Workshop had been of benefit to the Vanuatu participants, and they hoped to make use of the knowledge they had gained.

Mr. S. Tongilava, Tonga

The sponsors were thanked for providing a useful Workshop. Mr. Tongilava had been associated with CCOP/SOPAC for 10 years and outlined its history which started with the discovery of an oil seep in Tonga. In 1976, the search for precious corals, sand and construction materials was added to CCOP/SOPAC's charter. The project came to full strength in 1980. So far no major mineral deposits had been found, and it was time to take stock before deciding on the thrust of future work.

Dr. F. Campbell, University of Hawaii

Dr. Campbell asked whether Tongilava was suggesting that CCOP/SOPAC should concentrate on smaller projects such as precious coral and construction materials. He pointed out that CCOP/SOPAC's original emphasis had been on big projects, such as manganese nodules. The necessary work had been done in many such cases, and had downgraded some of these prospects.

Mr. S. Tongilava, Tonga

It was important that CCOP/SOPAC Member Country representatives should think hard about future programme before the Tenth Session meeting in Vila, later this year. It appeared that a marine biologist was needed to aid the project, and perhaps marine biologists could be borrowed from USP as required.

Mr. R. Holmes, Fiji

The Workshop was worthwhile. We now need more concrete information about what makes a deposit viable. It is important that legislation be established to both encourage and control legislation.

Mr. A. Philipp, Western Samoa

Mr. Philipp thanked the organizers for a useful Workshop. He then asked for clarification as to whether it was worthwhile attempting to establish a black coral industry in Samoa, where raw material was abundant.

Dr. R. Grigg, University of Hawaii

It is difficult to profitably export raw black coral as there is a glut on the market. However, there is a demand for jewellery and carvings and these could be made and sold locally (e.g. to tourists). Such a cottage industry is successful in Fiji, and also in Palau. The potential size of such an industry depends on many factors, including the training of sufficient skilled divers and lapidary workers. Dr. Gauss commented that some black coral jewellery is made and sold in Tonga.

Mr. H. Plummer, Fiji

A handbook of precious coral is needed, telling us how to look, exactly what to look for, and details of marketing.

Mr. A. Utanga, Cook Islands

Mr. Utanga thanked the organizers for an interesting Workshop. The paper on coral concrete was very significant, and should be published and widely distributed. It was clear that more inshore bathymetry was needed to help find precious coral; in the Cook Islands only around Rarotonga was there an adequate bathymetric map for such work.

Dr. Cronan's suggestion, that Imperial College should re-evaluate existing manganese nodule material in the region, was welcomed.

Dr. G. Groves, Kiribati

Dr. Groves thanked the organizers of the Workshop, and stated that he personally had learnt a lot from it. He endorsed the idea put by Mr. Plummer (Fiji) earlier in the Workshop, that a "precious coral handbook" should be prepared. He believed the

handbook series could also include "concrete" and perhaps "fish poisoning" and "erosion and sedimentation on atolls".

Mr. J. Lum, Fiji

Mr. Lum asked the question "Where do we go from here?" He then suggested that smaller, more-detailed workshops on limited subjects would be most worthwhile. Mr. Matos supported this idea and hoped that additional UNDP funding might be available to carry it out. Dr. Radke (Australia) suggested that in such workshops member country representatives could bring data and problems to a panel of experts for discussion and advice.

CLOSURE OF WORKSHOP

Dr. U. Raj, Institute of Marine Resources, USP, Suva

The problems of inshore and nearshore management are complex, and more study is needed to resolve most of them. Guidelines for such studies have been touched upon at this Workshop. Experts present at the workshop would be happy to continue to advise member country participants on their various problems in the future.

The workshop has demonstrated that one cannot look at individual resources in isolation - one has to consider fisheries, geology, management and overall environment at the same time. Although we have not resolved all the outstanding problems at this workshop we have made some progress, and small multidisciplinary projects which have developed during the workshop will help to provide some answers.

The training element of the workshop has been covered by the country representatives listening, commenting, and discussing their problems with the experts. Further training workshops, now that everyone has an overview of the field of nearshore and inshore resources, should be smaller and more specific. This would allow more detailed consideration of problems, and more participation by country representatives.

I wish to thank the School of Natural Sciences for providing the venue, the financial sponsors for their contributions, CCOP/SOPAC and the Fiji Mineral Resources Department for their practical assistance, the experts for their talks, and everyone for their active participation in this very successful workshop.

APPENDIX I

FIELD INFORMATION ON THE SINGATOKA IRON SANDS

Mr. Jackson Lum, Mineral Resources Department, Suva

INTRODUCTION

The sand deposits in Singatoka are the only significant onshore iron-sand deposits in Fiji (Fig. 1). Detailed prospecting of these sands was completed in the early 1970s. It was reported that the reserves are not sufficient to warrant any economic development, but the feasibility of this operation would be improved if additional economically exploitable magnetite deposits were located offshore.

DESCRIPTION OF THE DEPOSITS

Dimensions

The dunes extend westward for about 5km along the south coast of Viti Levu from the mouth of the Singatoka River, and they cover an area of about 2.63km^2. The dunes have an average height of 20m and a maximum height of 60m. The total volume of sand is in excess of 45 million tonnes. Bedrock is exposed towards the western end of the dunes and consists of marls and limestone of the Thuvu Group.

Composition

The deposits appear to consist mainly of eluvial sand, overlying beach sands. The characteristics of the two types of the material are summarized in Table 1.

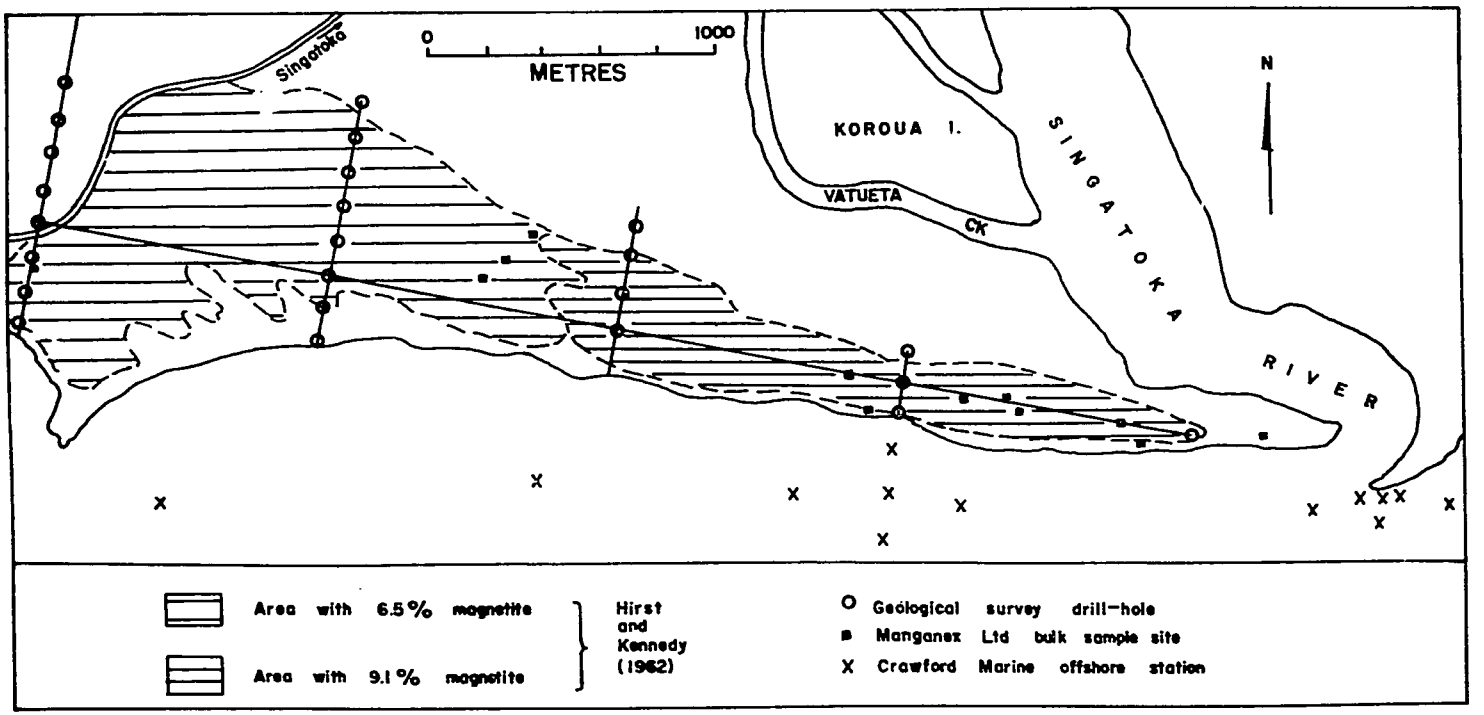

Figure 1 - Singatoka sand dunes (after Hirst and Kennedy 1962)

TABLE 1

Comparison of Eluvial and Beach Sands

	Eluvial Sands	Beach Sands
Grain size	Most of the grains are smaller than 0.5mm and approximately half of them are smaller than 0.25mm. The latter half includes silt and clay.	Almost half the grains are coarser than 0.5mm. The proportion of material smaller than 0.25mm is low.
Estimated Mineral Composition	Quartz 40% Feldspar 15% Pyroxene 28% Basic fragments 10½% Magnetite 6½% Accessory amounts of ilmenite, hematite, rutile, zircon and topaz have been reported.	35% 30% 15% 18½% 1½%
Shape and angularity	Grains are equidimensional except for the pyroxene which tends to be elongate. Most of the sand is angular to subangular.	The smaller grains resemble eluvial grains but the larger ones are subrounded or rounded.

(after Hirst and Kennedy).

Origin

The sand forming the dunes was transported by the Singatoka River from an extensive inland area, probably from the Wainimala Group, the Mba Group and the Tholo Plutonic Suite. The sand was transported by the Singatoka River, discharged at its mouth, and then washed ashore by the heavy swells and longshore currents prevailing in the area due to the lack of protective reefs. The dunes were later formed by the prevailing Southeast Tradewinds. Crude dune bedding with slip faces on the northern side is visible in certain areas. Eluvial action has concentrated the magnetite to several times its previous value as compared to the beach sands.

Distribution of Magnetic Minerals

The map of the Singatoka sand dunes illustrates the distribution of magnetic minerals in the deposit. In the eastern dunes, although a sharp decline in magnetic minerals becomes apparent as sea level is approached, an area of 135 acres has an average of 9.1% magnetic minerals to a depth of approximately 7m. Drilling results

indicate 5½m tonnes of sand would yield 500,000 tonnes of magnetic minerals. In the west an area of 330 acres, comprising 16½m tonnes to a depth of approximately 10m, contains some 1.1m tonnes of magnetic minerals (6½%).

Gold

A gold study was undertaken together with the magnetite study. No gold was found in any of the samples tested (only a little pyrite). However, this is not the case for all iron sand deposits in Fiji. In other iron sand deltaic, beach and submarine deposits e.g. at Mba, Laucala Bay and Momi Bay, gold has been identified following commercial surveys.

Reference

Hirst, J.A. and Kennedy, E.M. 1962: Singatoka iron sands. Econ. Inv. Geol. Surv. Fiji 1.

APPENDIX II

PRECIOUS CORAL PROGRAMME

Dr. Leon Zann, Institute of Marine Resources,
USP, Suva

18-20 July 1981

Objectives: To instruct and demonstrate aspects of the biology, identification, distribution, harvesting techniques and fisheries management of the precious corals to the inshore and nearshore resources workshop trainees.

Sponsor: International Seagrants Programme

Consultant: Dr. R. Grigg, University of Hawaii

Co-ordinator: Dr. L.P. Zann, University of the South Pacific

Participants: Sixty registered participants and about twenty local visitors attended Dr. Grigg's session on precious corals on 15 July.

Workshop: 15 July

The lecture and discussions encompassed aspects of the history of the industry; identified the relevant corals distribution; ecology, fisheries; value; gemmological manufacture; marketing etc. Particular emphasis was placed on conservation and management.

The presentation, including slides, cine film, hand specimens and jewellery, aroused great interest and was among the most entertaining and stimulating of the programme. Considerable discussion was generated among the participants and trainees.

Field Programme: Because of limited ship-space, participation was limited to 12 trainees. Diving participation was limited to those with approved certification. Unfortunately few trainees were SCUBA divers, but several non-divers attended and benefited greatly from the surface activities.

Participants

* Dr. R. Grigg, University of Hawaii. Consultant
* Dr. L. Zann, University of the South Pacific. Programme Co-ordinator.

Mr. Joachim, Solomon Islands rep. Fisheries Officer
Mr. Baleivanualala, Fiji rep. Mineral Resources Department
Mr. K. Kaltongga, Vanuatu rep. USP undergraduate
Ms L. Bolton, USP., A.R.U., Kiribati
Mr. J. Uan, Kiribati, USP undergraduate
Mr. R. Thorpe, New Zealand. USP undergraduate

USP R.V. NAUTILUS crew = 3
registered, but did not attend = 2
* certificated SCUBA divers

Programme

Because of bad weather the intended programme and the order of the day was modified.

Day 1: 18 July Participants collected by bus at 8 a.m., and driven to Fisherman's Lodge outside Suva where they were taken by outboard to NAUTILUS in Namuka 9 a.m. The NAUTILUS proceeded to Torch Passage for an echo-sounder examination and then to Naqara Passage off Vunindoi.

Dr. Grigg had a brief bottom inspection by "bounce dive" and collected several species of gorgonians but noted the area was unsuitable because of poor water movement for Antipathes.

The NAUTILUS then proceeded to the entrance of Daveta Namuku where greater water movement was anticipated.

Five participants SCUBA dived at the entrance (to 25m) and Dr. Grigg continued to 35m where he collected several small antipatharians and semi-valuable gorgonians.

At 1330 hrs NAUTILUS moved to Namuka for lunch after which all participants dived at the shallow reef edge.

At 1630 hrs participants were returned to Fisherman's Lodge for the return to Suva.

Day 2: 19 July

At 0600 hrs NAUTILUS left Namuka in calm seas for Deuba. Participants were collected by minibus at 0900 hrs and were taken to Pacific Harbour at 1100 hrs.

NAUTILUS left for Beqa Island at 1200 hrs when rain squalls cleared.

Dr. Grigg bounce-dived to 35m at Pratt Reefs off Beqa for inspection and collected several species of Antipathes.

NAUTILUS then conducted an echo-sound bottom search off N.W. Beqa for suitable sites.

At 1430 hrs diving trainees dived on a coral patch-reef off Vaqa Bay and collected a range of Antipathes spp. of commercial size.

NAUTILUS returned participants to Pacific Harbour at 1630 and minibus transported them to Suva

Day 3: 20 July

At 0700 participants were collected by bus from Suva Lodgings and transported to Pacific Harbour.

NAUTILUS departed for Beqa at 0830.

0930-1030 hrs bottom echo-sound search for suitable Antipathes habitats. 1030 hrs Dr. Grigg bounce-dived to 45m to inspect bottom off Pearl Rock.

At 1130 hrs all trainees dived at Nanuku Passage off Storm Cay. Experienced SCUBA divers proceeded to 35m and 45m (Dr. Grigg) to collect Antipathes.

NAUTILUS returned trainees to Pacific Harbour at 1300.

Trainees proceeded by road to Suva. NAUTILUS proceeded by sea to Laucala Bay.

Summary

The field workshop was most successful. Regional participation might have been greater, particularly from those islands which have previously expressed interest in precious corals (e.g. Cook, Tonga).

Due to bad weather there was no tangle dredging for Corallium in deep water but methods were discussed and several areas of potential for future work were identified.

Trainees were instructed in underwater collection techniques and non-certified participants were given brief instruction on SCUBA and encouraged to undergo formal training in the future. Two trainees expressed their interest in undertaking a SCUBA course.

A range of specimens were collected. Several identified by Dr. Grigg and others were taken by him to Hawaii for identification. These will be returned to the IMR reference and teaching collection.

APPENDIX III

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