

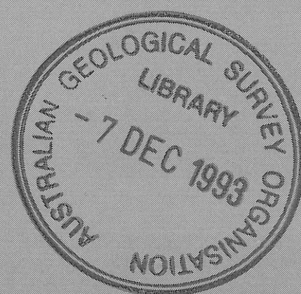
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A REVIEW OF MARINE FACILITIES AT THE UNIVERSITY OF PAPUA NEW GUINEA (UPNG): FINAL REPORT TO THE INTERNATIONAL DEVELOPMENT PROGRAM OF AUSTRALIAN UNIVERSITIES AND COLLEGES (IDP) AND UPNG.

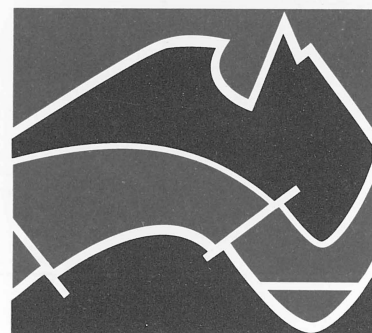
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DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: Hon. Michael Lee, MP

Secretary: Greg Taylor

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Harvey Jacka

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ISSN: 1039-0073

ISBN: 0 642 19883 7

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EXECUTIVE SUMMARY

A visit was made to UPNG during May 1993 to (i) provide lectures in marine geoscience to fourth year students, (ii) review the marine geoscience facilities and (iii) comment upon a curricula and facilities required to support a marine geoscience facility at Tahira Inlet.

Several lectures were presented to fourth year geochemistry students, and these were well received with a distinct interest expressed by the students for marine geoscience. Several texts were purchased and reviewed for their suitability as teaching aids, and left at UPNG.

A visit was made to Motupore Is research station. The station has an infrastructure (accommodation and small boats for easy and rapid access to near shore reefs), that can support teaching and research into shallow water marine systems, but is lacking in modern instrumentation for marine research. An inventory of equipment at both Motupore Is and the Waigani campus was made. Several items were found in various states of disrepair, apparently left by visiting researchers. However, several pieces of equipment could be rehabilitated, probably at minimal cost, and used for marine research and teaching. The MV Scomber is a small, approximately 10 m, vessel which is only suitable for day-trips to near shore marine areas. The vessel is set-up to provide a towing capability for nets and could be modified to tow marine geoscience instruments such as sonar and bathymetric surveying equipment and perhaps some simple high resolution seismic systems. A small davit could be installed for sampling of surface sediments at shallow depths, and this could be adequate for introductory teaching and training purposes, but the vessel is generally unsuitable for extensive seafloor sampling because there is inadequate deck-support to install appropriate winches to provide a vertical lifting capability. The vessel can certainly be utilised by UPNG for near shore training and research, but its modification for certain needs must be reviewed by a shipwright and marine engineer.

Comments have been provided on the core-infrastructure required to support a marine geoscience facility at Tahira Inlet. A core-program includes studies in marine geology (sedimentology and tectonics), marine geochemistry and chemical oceanography (nutrient and carbon cycles in the sea, metal and organic geochemistry in seawater and sediments), and biological and physical oceanography (primary productivity and continental shelf including estuarine circulation processes). An estimate of about 1400 m² of floor space would be required to house basic laboratories and data processing

facilities to support an interdisciplinary program in marine geoscience. There is no provision of office space for scientific staff or technical support staff, nor of building infrastructure (e.g utilities) in this estimate.

INTRODUCTION AND OBJECTIVES

A visit, sponsored by the International Development Plan of Australian Universities (IDP) and the University of Papua New Guinea (UPNG), was made to UPNG between 20 and 31 May 1993.

The objectives of this visit included:

1. To present a series of lectures to UPNG fourth year students in marine geoscience, particularly marine geochemistry and chemical oceanography.
2. To inspect the marine facilities at UPNG, inventory marine equipment at UPNG, and comment upon the feasibility of establishing a marine geoscience research and teaching program at UPNG.

It was quickly realised that some unique marine environments exist in PNG which potentially provide opportunities for marine research and training. These include (i) extensive coral reefs (ii) extensive mangrove forests (iii) extensive seagrass communities and (iv) large and diverse estuarine systems. Collectively these provide a large range of geological/geochemical/biological and oceanographic systems, an understanding of which is important for development and maintenance of renewable marine resources, and monitoring and management of environmental change which often accompanies development of non-renewable resources.

Facilities for research and teaching of marine geoscience are limited by funding. Two approaches exist for training and research. One approach utilises vessels or facilities of opportunity. For example foreign research vessels have been conducting surveys in the Manus and a Woodlark Basins offshore the north east coast of PNG providing some opportunities for PNG students. Also, the Fly River delta is a one where a major riverine system enters the sea and opportunities potentially exist for PNG students to participate in training with the OK Tedi company or other possible foreign surveys to his river delta. These opportunities should actively be sought out. However, they potentially will always exist and are a valuable source of exposure and training for students in marine geoscience. However, these external opportunities do not contribute in a significant way to the development of a local infrastructure to support marine training and research. Hence, while recognising the potential contribution of these external opportunities to a marine geoscience program, the fact that these opportunities

do not contribute substantially to a local core marine program, they will not be considered further below.

The following text includes:

1. Student contact at UPNG, including (i) a brief description of the content which was presented in lectures, and (ii) a list of marine geoscience texts which were purchased and reviewed as possible teaching aids and reference texts in a marine geoscience curricula.
2. A review of facilities at the Motupore Island Research station, including comments on the MV Scomber.
3. An inventory of equipment located at both Motupore Is and on the POM campus of UPNG that could be used in marine training and research.
4. Comments on the proposed development of marine research and training facilities at Tahira Inlet. Included are recommendations for equipment (both field and laboratory), required to support a core marine research and training capability.

STUDENT CONTACT.

I conducted seven hours of lectures to fourth year students. The content included three major topics.

1. General Oceanography, geochemical cycles and the distributions and compositions of marine sediments, and the formation of particulate organic matter in the sea.
2. The destruction of organic matter in the sea and at the seafloor, early diagenesis and the formation of some seafloor minerals, manganese nodules and marine phosphorites.
3. Light hydrocarbon cycles in the sea, biogenic hydrocarbons, thermogenic hydrocarbons and anthropogenic hydrocarbons; application to seafloor exploration for hydrocarbon accumulations and also application to environmental monitoring in the coastal zone.

Marine geoscience texts.

Select texts on oceanography, and marine Geology were purchased prior to the visit and reviewed re content for marine geoscience, and left at UPNG. These texts included:

- a. Oceanography, by M. G. Gross (Prentice Hall Press)
- b. Introductory Oceanography by G. Thurman (Macmillan Publishing Co)

Both of these texts were suitable for introductory Oceanography and would be ideal as texts for a beginning curricula in oceanography. Both texts covered similar material.

- c. How to build a Habitable Planet, by W. Broecker (LDGO Press).

This is an ideal book for students in earth sciences, not only marine geoscience. The book is in an easy to read style and provides Broecker's unique perspective on geochemical mass balances in the planet.

- d. Tracers in the Sea, by W. Broecker and T.L. Peng. (LDGO Press).

This is an advanced text in chemical oceanography and marine geochemistry and is suitable as a reference work or a text that students with a particular interest in chemical oceanography should have readily available.

- e. Marine Geology by J. Kennett. (Prentice-Hall).

This book covers a very wide variety of material in marine geology and would be suitable as both a text for an advanced course in marine geology and as a reference book.

- f. In addition to the above I purchased several issues of Oceanus, a magazine published by the Woods Hole Oceanographic Institution. During 1992, Oceanus did a special series on the four disciplines of oceanography; Marine Geology and Geophysics, Biological Oceanography, Physical Oceanography and Marine Chemistry. Other back issues that were purchased included:

Deep Sea hot-springs and cold seeps, Vol 27 #3, Fall 1984;
 Ocean Disposal Reconsidered Vol 33 #2, Summer 1990;
 Pacific Century Dead Ahead, Vol 32 #4, 1989/90;
 Mid Ocean Ridges, Vol 34#3, Winter 1991/92;
 Marine Chemistry Vol 35 #1, Spring 1992;
 Physical Oceanography Vol 35 #2 Summer 1992;

Biological Oceanography Vol 35 #3, Fall 1992;
Marine Geology and Geophysics Vol 35 #4 Winter 1992/93.

Recommendation: That IDP continue to support short-term visits to UPNG by marine scientists to foster an interest among students for marine geoscience.

MOTUPORE IS RESEARCH STATION.

A visit was made to the Motupore Island Research Station, and environs (Figures 1 and 2) on Saturday and Sunday 22 and 23 May. There exists a significant infrastructure to support marine activities, with laboratory space, bunk accommodation (probably for 20 people or more), kitchen facilities and running seawater for laboratory work. Four small boats fitted with outboard motors are available for excursions to the outer reef and the environs of Motupore Is and the Bootless Bay area. Current activities include marine biological research by Dr. Mike Huber. Equipment for other marine activities is very limited (see below), but an active marine program has been carried on at sometime in the past.

The fisheries research vessel MV Scomber was inspected. This vessel is approximately 10 m in length, and is of fibreglass construction. The vessel has a small coach-house amidships but no apparent accommodation space for crew or scientific staff, although we could not see below-decks.

Two tugger-winches on the forward part of the coach-house are apparently used for trawling nets off of the stern. The tugger winches were not in-place during our visit. This vessel has been used for fishing activities and is set-up for towing fore and aft. As such some shallow and high resolution seismic and bathymetric surveys, using sonar, could easily be conducted from MV. Scomber.

However, there are no facilities at present for vertical lifting of any significant capacity. A small mast at the bow of the vessel, approximately 3-4 m in height could be used to swing a boom and light equipment e.g., some water sampling bottles and small sediment sampling grabs, outboard of the vessel, but what capacity this might accommodate I could not evaluate (est 100kg or less). Some capability needs to be installed to deploy equipment outboard of the vessel.

There are no winches or cranes (for vertical lifting), on the vessel, and because of the decking construction, the installation of a winch would probably require reinforcement of the decking. The decking is only thin fibreglass. Beneath the decking are holding

tanks for the fish-catch and trawl lines. This decking would not be suitable for the sustained deployment/recovery of heavy geological sampling equipment.

There are two areas of open deck that are suitable for handling of oceanographic and light seafloor sampling equipment. These areas, one aft of the watch-house and the other forward of the watch-house are each about 3.5 x 2.5 m. A rack could easily be built to hold water sampling bottles (est 20 cm X 100 cm X 70 cm).

The vessel could not deploy/recover a vibrocore of the type currently used by AGSO (3 m frame with approximately 3 m diameter support feet). However, small portable vibrocores are available, without large support frames, that could be deployed from Scomber

Recommendation. That IDP support a visit to UPNG by an AGSO staff member familiar with the engineering and mechanical aspects of small winches and deploying/recovering of seafloor sampling equipment such as small gravity cores and vibrocores. This visit should be conducted in conjunction with a shipwright who could advise on modifications to the Scomber that would be required according to the loads/forces etc exerted by winches that may need to be installed.

INVENTORY OF EQUIPMENT AND MATERIALS AT UPNG.

Listed below is the oceanographic/geological sampling equipment that was located.

Motupore Island Research Station.

1. Self recording current meter, 7/1980 TSK 9604. Tsurumi-Seiki Co. Ltd. 1506 Tsurumi Yokohama Japan. The 50 m (est) of coaxial cable with the 9 pin plug, under the tank stand, belongs to this current meter. There is a battery/AC power pack 100v, 50/60 Hz, 2.9V DC 0.3A, with the current meter.
2. Digital Salinometer Model E-2017, Tsurumi Seiki Number 92969, 100V 50 Hz, mfd 10/1976.
3. Refrigerating coil, Cooldip, by Shandon Southern, USA.
4. Tsurumi Seiki flow meter, stainless steel. The rotor spins and turns geared cogs which count the number of rotations during a given time period.

5. Direct reading current meter, KSK, DCM3. Consists of a white painted streamlined lead weight with tailfin. There is a manual for this device.

6. Three reversing thermometers, Ogawa Seki Co., Tokyo Central POB 1618 Tokyo 03 367 8211, telex J 26271, Answer back Scieosk., thermometer numbers are 4864;4866, 4869., dated 1986. They are each 9-10 inches in length.

7. Depth sonic transducer, est 25 m of electrical cable, No. 2987 Li-Cor.

8. Several microscopes, for marine biology, are stored but these were not recorded. They are used by Dr. Huber.

9. Secchi disk, but without a rope.

10. Viewing box, for use over the side of a small boat.

The salinometer and the two current meters can probably be repaired, but they must be looked at by an electronics technician to evaluate their condition and what parts may be required for repair.

UPNG storage.

Some marine equipment was inspected stored in the Fisheries store, ground floor of the Geology Building.

1. Bathythermographs - two (TS-US) Type 3 No 2780. One BT is stored in a box with smoked glass slides.

2. Four Nansen bottles with two each reversing thermometers. Nansen bottles are Rigosha Brand. There is another water sampling bottle, stainless steel, but I have not seen this type before.

3. Transparent water sampling bottle. I have not seen this type before, but it is either polycarbonate or acrylic with a spring-loaded internal closing mechanism, and maybe the forerunner to the GoFlo bottles. This device probably works.

4. Nauman bottom sampling tube, with a 50 cm barrel which takes a 50 cm 19 mm OD plastic sampling tube. There is a small weight est 3-5 kg for the sampler to penetrate the seafloor.

5. Water Analysis Kit, by Kahlisco, El cajon (San Diego), California, USA 92022. Cat, NO 114WA160, Model DR EL/2. This instrument combines a conductivity meter with a small spectrophotometer. A variety of chemicals, in pre-weighed packets are available for colorimetric analyses. The instrument appears to be 1970's age and the spectrophotometric methods are probably not suitable for seawater analyses, probably for freshwater, rivers and streams.

6. Salinity/temperature bridge Type MC5, certified by National Institute of Oceanography (NIO)., mfd by Kent Industries Measurements Ltd, SNO5/705/1407. There are approximately 25 m of cable with a conductivity probe attached.

7. Stainless steel grab - maybe a Smith-Macintyre type. The grab is approximately 15-20 cm on a side. This could easily be deployed by hand in shallow waters, or deployed from Scomber with light wire.

8. Several, approximately 20 calibrated bottles were found for Winkler titrations of dissolved oxygen in seawater.

All of this gear is probably useable, although currently does not probably work and the electronics must be assessed by a technician to advise on repairs etc.

Recommendation. That IDP support a visit by an electronics technician to evaluate the potential rehabilitation of a variety of electronics field-equipment at both Motupore Is and the Waiganii campus.

TAHIRA INLET

New plans have been drawn for the establishment of a marine science facility at Tahira Inlet. The following outlines projected needs to establish a basic core-program in interdisciplinary marine geoscience including; (i) marine geology (ii) marine geochemistry and chemical oceanography and (iii) biological and physical oceanography. These are schematically illustrated in Figure 3, all of which have requirements for (i) field capabilities (ii) laboratory facilities and (iii) data processing needs. The major emphasis is on marine geology and marine geochemistry/chemical oceanography with a lesser emphasis on biological and physical oceanography. Reflecting the interdisciplinary nature of marine science some facilities are common, but others are unique to each discipline. I have indicated throughout where some sharing of facilities can be obtained. I have also based crude estimates of space

requirements on the needs of an assumed scientific staff of three persons for each of the three disciplines shown in Figure 3. The space requirements are estimates only for laboratory, analytical and data processing facilities. These are discussed below and summarised in Table 1. There is no provision here for office space for either scientific or support staff. Space estimates are conservative.

Field capabilities.

An essential requirement for a marine geoscience research and teaching program includes an appropriate vessel for field work. Assuming that the focus of marine geoscience work around PNG would be confined primarily to continental shelf and slope surveys, including estuarine work, an appropriate vessel would need to be available to stay at sea for a period of about 1 month. While this vessel need not necessarily be large, it should include deck space to accommodate the following equipment which would be essential requirements for a comprehensive teaching and research facility in marine geoscience.

Marine geology

- (i) Seismic system; several possibilities exist here, ranging from simple high resolution seismic systems utilising short cables (<1 km) and small water and air guns to large deep crustal seismic capabilities requiring a significant amount of deck-space for seismic cables, compressors and storage of large mechanical pieces. Laboratory space is required for seismic data acquisition.
- (ii) Seafloor sampling equipment. These require a side or stern A-frame to deploy and recover a variety of seafloor sampling devices including; a 5 m gravity core capability to collect consolidated sediments from the shelf and slope, a 3-5 m vibrocoring capability to collect unconsolidated sediments from the continental shelf, a box-core capability to collect undisturbed surface (<50 cm) sediments from shelf and slope sediments, Van Veen type grab to collect surface sediments, and deep sea dredges for collecting rock outcrops on the continental slope.
- (iii) Bathymetric capability including 3 and 12 kHz and side scan sonar (towed) equipment.

Shipboard 'wet' laboratory space would be required for processing, logging and sampling of cores and other seafloor samples.

Marine Geochemistry and chemical oceanography.

All the seafloor sampling tools noted above would be used in a marine geochemistry (sediment geochemistry) program. Equipment required for a chemical oceanography (water column) program includes a water sampling capability. There are two possibilities here. One includes the traditional Rosette sampling capability and Niskin-type seawater sampling bottles, which provide discrete sampling at various water depths, and these are deployed from a traditional hydro-wire. Another capability includes a continuous flowing seawater system similar to that which AGSO has been using as part of its Continental Margins Program. This capability has a sampling depth to about 400 m but provides for a continuous profiling capability of dissolved components in seawater. Laboratory space is required for marine geochemistry and this includes wet space for processing, logging and sampling of core, which could be common with that for marine sedimentology noted above. Dry laboratory space would be required to accommodate analytical equipment for sea-going analyses of seawater and sediments.

Biological and Physical oceanography.

Biological oceanographers need a capability to sample seawater for studies of nutrient dynamics and primary productivity. This capability would be served by the water sampling methods noted above. Biological oceanographers often need also to deploy small nets for plankton sampling. Most of this could be done from a hydro-wire.

The primary need for a core physical oceanography program is for a hydrographic capability including a CTD (Conductivity/temperature/depth) instrument and a water sampling capability. CTD units and Rosette samplers are common integrated oceanographic tools and most basic physical oceanography needs could be met with this capability. Laboratory space is required to house a CTD data acquisition capability.

Land-based facilities including laboratories and basic equipment at Tahira Inlet.

Land-based storage facilities, for the sampling and support equipment noted above and its maintenance when not at sea, should include (in part) a shared facility between marine geology, marine geochemistry, chemical oceanography, biological and physical oceanography for ship-board equipment. These include for marine geology storage space for seismic cables, water and air guns, gravity corers, box-corer, Van veen grabs, dredges and vibrocores, water sampling gear, the CTD unit and nets for biological sampling and miscellaneous floats and deployment/recovery aids. A conservative estimate of floor space required to store and maintain these bulky items is about 200 m² with additional equivalent open uncovered storage space.

An electronics and mechanical work-shop are required to maintain sea-going equipment. An estimate of about 70 m² could accommodate an electronics shop and about 100 m² would be needed for a mechanical workshop.

A refrigerated facility is required for the storage of marine samples including sediment cores. Based upon that facility at the Australian Geological Survey (AGSO) in Canberra, approximately 100 m² of floor space can accommodate about 4000 linear metres of sediment cores.

Marine geology including sedimentology and tectonics.

Laboratory space is needed for sedimentology, and this should include wet areas for the layout, logging, processing and sampling of sediment cores, and sinks for wet-sieve analyses of sediments. I estimate approximately 120 m² of floor space to accommodate benches and storage space for sedimentological analyses

In addition an area of comparable size (est 120 m²) would be required to house analytical equipment for sedimentology, and these include (i) settling tube (ii) grain size analyser (iv) ovens and freeze-drier facility for analysis of physical properties of sediments (v) appropriate microscopes for mineralogical analysis (vi) analytical and bench-top balances (vii) floor-standing centrifuge. Laboratories housing analytical/electronics instrumentation should be air-conditioned in a tropical environment.

Data processing requirements include appropriate computers for processing of seismic (probably high resolution data) and mapping displays of processed data. A computer-based data processing capability for marine geology (seismic operations) could exceed those computer processing needs of other sub-disciplines, although physical, chemical and biological oceanographers are increasingly using mapping-tools to contour large oceanographic data sets for the examination of meso-scale oceanographic processes, and a data-processing facility as such would provide a computer-based data processing service to all these disciplines. All research areas should be serviced with PC's linked to a central computer system. Estimated floor space for a computer and data-processing facility is 120 m². This area would have to be air-conditioned.

Marine geochemistry and chemical oceanography.

For programs in marine geochemistry including sediment geochemistry, many of the seafloor sampling tools mentioned above in sedimentology (specifically the gravity, corer, vibrocorer and box-corer), can be shared with marine geochemistry. Many of the sediment processing needs of marine geochemistry and sedimentology are common, hence, an area for sampling, logging and processing of sediments for geochemical analysis is required. This area should be maintained in a clean condition to eliminate the possibility of contamination of samples. This 'wet' area should be approximately 120 m², and at least part of this could be shared with sedimentology above.

A core research and teaching program in marine geochemistry and chemical oceanography should include the following (i) Carbon and nutrient geochemistry including nitrogen, phosphorus and silicon in both sediments and seawater (ii) trace element (metal) geochemistry including heavy metals in seawater and sediments (iii) organic geochemistry including (marine photochemistry, naturally occurring trace organics which may have application in pharmaceuticals, and anthropogenic organic materials which may be toxic to marine organisms.

Geochemical equipment and analyses required to support the above includes (i) nutrient analyses by autoanalyzer or similar continuous analyses methods for large volumes of discrete sample analyses. (ii) light isotope mass spectrometer for analysis of both carbon, hydrogen and nitrogen isotopes in a variety of marine materials and for isotope dilution experiments on carbon, nitrogen cycling processes particularly in coral reef communities. (iii) a variety of gas chromatographs for analyses of a variety of naturally occurring trace and also anthropogenic materials -more sophisticated equipment including GC-MS (gas chromatograph- mass spectrometers) are now being used in most of the leading laboratories (iv) metal analysis facilities such as AAS, ICP or combined ICP-MS.

Specially designed 'clean' laboratory facilities are required for analysis of trace metals and organics, although many studies, research and teaching can be conducted without resorting to these very expensive 'clean' laboratory facilities for analysis of trace organic and metals. Laminar flow 'clean' benches would be required in laboratories. I estimate approximately 180 m² of floor space required to accommodate these basic instrumental facilities above.

All laboratory facilities with instrumentation included must be air-conditioned for these equipment to operate effectively and to prevent deterioration in a tropical environment. Geochemical and sedimentological laboratories require 'clean' water facilities for

processing, preparation and analysis of both seawater and sediment samples for analysis.

Physical and Biological oceanography.

Physical oceanography requires laboratory space for processing computer data. Estimated space approximately 100 m².

Modern biological oceanography often involves sophisticated instrumentation, such as mass spectrometers for isotope studies of nutrient and carbon cycling in the oceans, and some of these needs could be shared with chemical oceanography noted above. However, other equipment such as specialised microscopes would be required. Estimated laboratory space 120 m².

Recommendation: The Australian Geological Survey Organisation is currently designing a new building to include laboratory space and ship support facilities. AGSO staff could provide advice and input into the design of a marine facility in PNG. The AGSO contact is Ken Heighway telephone 06295 7774, fax 06 239 7385.

Acknowledgments

I thank Gil Warne of IDP for co-ordinating the visit, Prof. Hugh Davies, Connie-Lou Davies and the staff at the Waigani campus and Motupore Island for their support and assistance during a very interesting and enjoyable visit.

Table 1. Basic equipment and space to support core programs in marine geoscience.

1. Common storage facility for sea-going equipment and ship support.

This is required to store and maintain equipment when not in use at sea for items such as; gravity corer, vibrocorer, box-corer, dredges, Van Veen (type) sediment grabs, bathymetric and other sonar equipment, seismic acquisition capabilities, including cables and guns, seawater sampling capability either a CTD unit with Rosette-sampler and Niskin-type sampling bottles (this could be shared with the physical and biological oceanographers), or a continuous profiling capability similar to that used by the Australian Geological Survey Organisation, a variety of nets used by biological oceanographers and other miscellaneous deployment/recovery gear.

Estimated approximately 200 m² of undercover storage space at Tahira Inlet to accommodate and maintain seagoing equipment when not being utilised on the ship. An equivalent amount of uncovered storage space for miscellaneous sea-going gear.

Estimated 70 m² for an electronics work shop.

Estimated 120 m² for a mechanical work shop.

Estimated 100 m² of floor space for refrigerated storage of seafloor samples.

2. Marine geology (sedimentology and tectonics)

Sample 'wet' processing laboratory, estimated space approximately 120 m²

Instrumental lab. space primarily for sedimentology estimated at approximately 120 m² to include: grains size analyser, settling tube, freeze drier/ovens, mineralogical microscopes (other microscopes), floor mounted centrifuge, analytical and other balances.

3. Marine geochemistry and chemical oceanography.

Approximately 120 m² of laboratory space would be required for processing of sediment and seawater samples for analysis and some of this could be shared with the sedimentology laboratory noted above.

Instrumental lab. space estimated at 180 m² to accommodate; water analysers such as an autoanalyzer, ion-exchange chromatograph (or similar instrumentation), gas chromatographs and other analysers for organic materials, metals analysis capability such as AAS, ICP-Ms, and mass spectrometers for light isotope analyses. 'Clean' facilities would be required for analysis of some 'trace' materials in seawater and sediments. A high quality water supply must be available.

4. Biological and physical oceanography.

Estimated 100 m² for a physical oceanographic data processing laboratory.

Estimated approximately 120 m² for a biological oceanographic instrumental laboratory.

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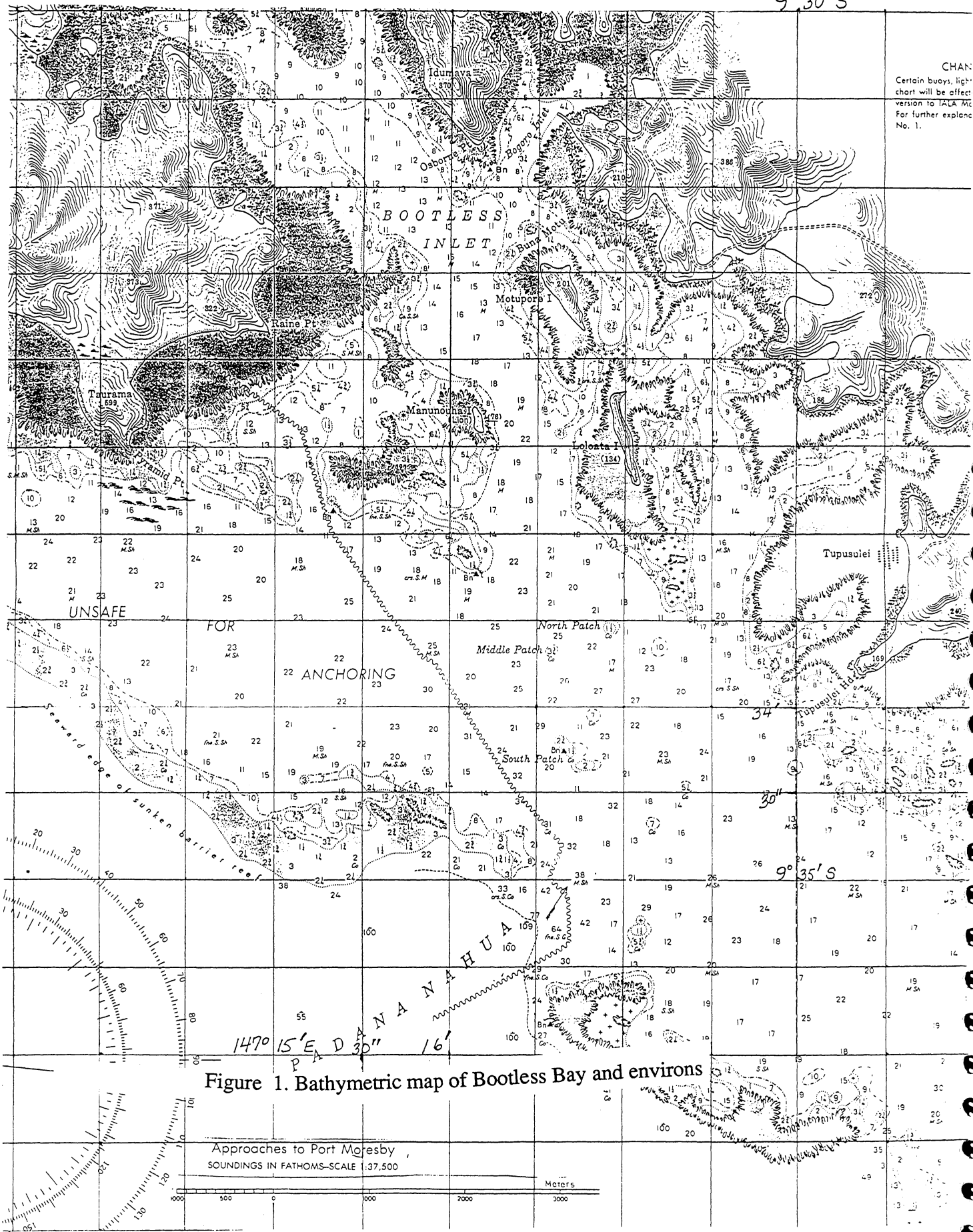
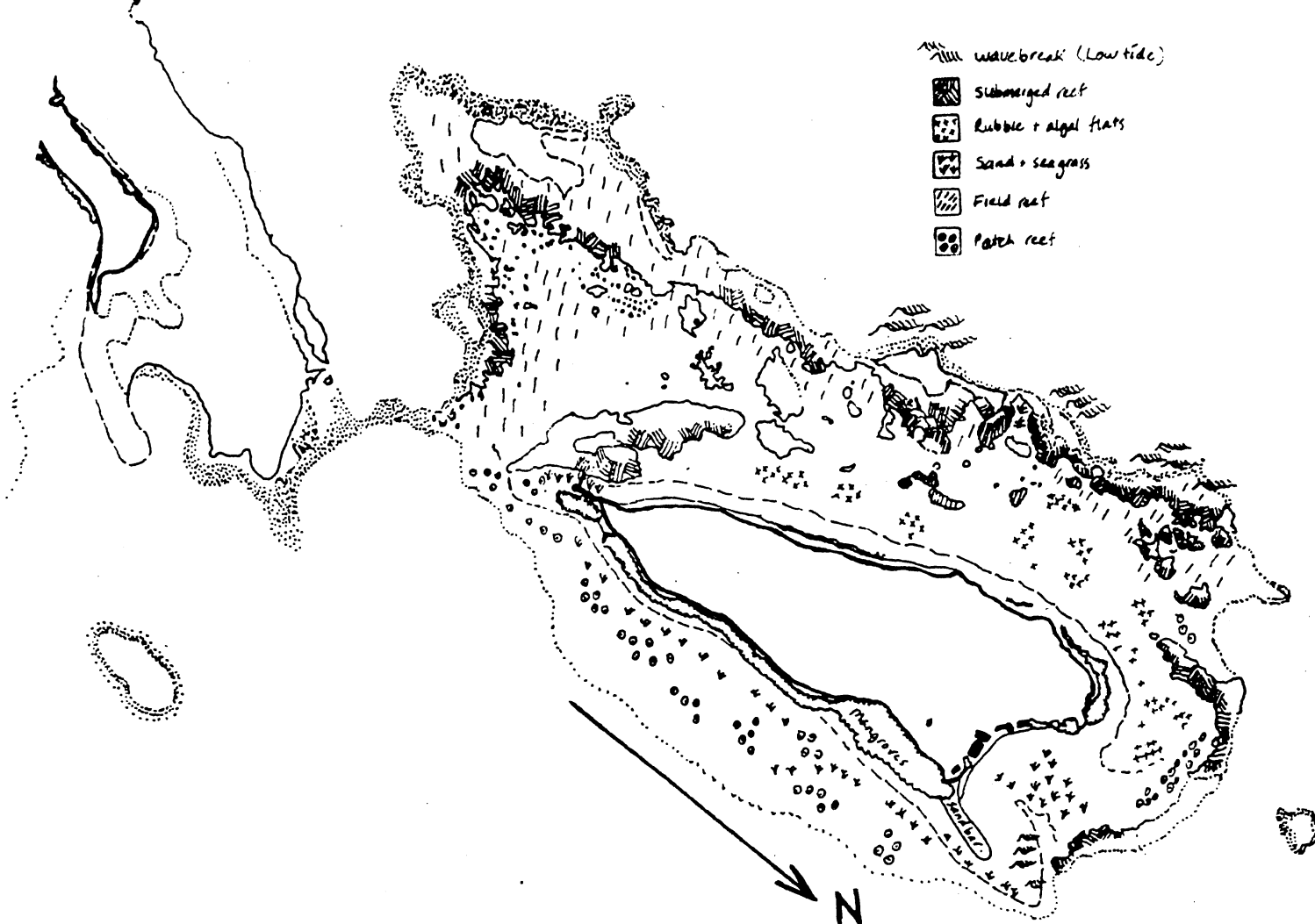


Figure 1. Bathymetric map of Bootless Bay and environs

A) MOTUPORE AND ENVIRONS

19.



B) BOOTLESS BAY (GENERAL)



Figure 2. Motupore Is indicating geological environment

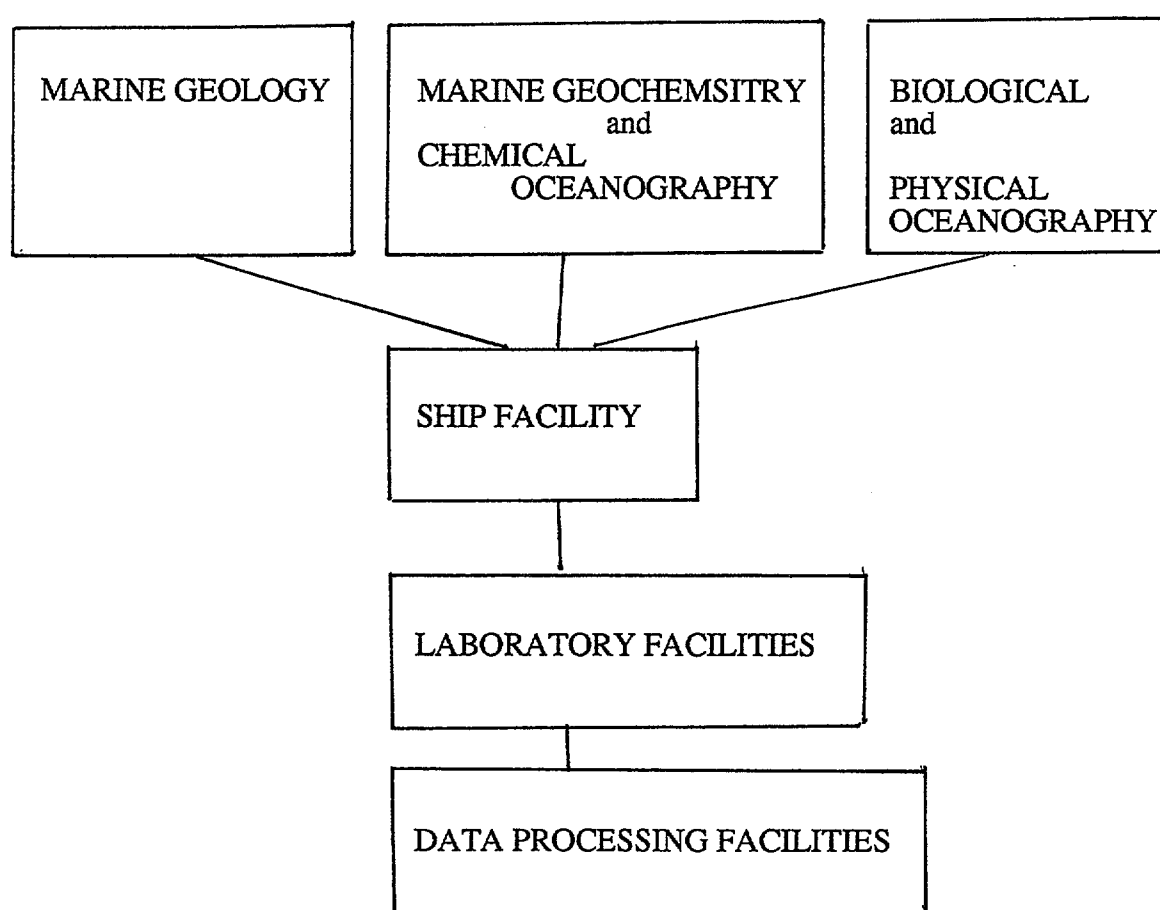


Figure 3. Schematic of interdisciplinary marine geoscience program