

**ABSTRACTS OF PAPERS
PRESENTED AT THE STAR* SESSION
1998**

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Editors

1998

SOPAC Miscellaneous Report 300

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FOREWORD

STAR (SOPAC's Science, Technology and Resources network) was founded in 1985 in collaboration with IOC. The first Chairman of STAR, Dr Charles Helsley, then Director of the Hawaii Institute of Geophysics, guided STAR until 1992 when Keith Crook took over the helm. STAR was formed as a vehicle to assist the international geoscience community to provide advice to SOPAC, particularly during the intervals between SOPAC International Workshops, the most recent of which was the Conference on Marine Benthic Habitats and Their Living Resources: Monitoring, Management and Application to Pacific Island countries, held in Noumea 10-16 November, 1997.

STAR is not merely a technical meeting at which individuals present scientific papers and discuss results and implications. Participants have the additional responsibility to formulate advice to SOPAC about its work program and to highlight technical and scientific issues of particular importance or urgency. This advice, in the form of reports and recommendations from STAR Working Groups, and rapporteurs' reports on highlights of STAR technical presentations, is tendered to Council by way of an address in Plenary by the Chair of STAR, and in the Technical Advisory Group (TAG) sessions during the Annual Session. All STAR participants are invited and urged to participate in this phase of the meeting.

One of the great strengths of SOPAC is its ability to mobilize excellent science and bring it to bear so as to address the national needs of SOPAC's island member countries. The long-established working relationship between SOPAC and the international research community is a vital element in this endeavor, which STAR is charged to nurture. This relationship stimulated an order-of-magnitude change in the geoscience database in the SOPAC region during the 1980's.

In earlier years STAR was primarily concerned with "blue-water" marine geoscience, tectonics and resources. However, as national needs and priorities have changed, the scope of STAR has altered so as to ensure that SOPAC's Work Program and its forward planning are influenced by international science that is both excellent and relevant. As a result of SOPAC's Governing Council examination of the future role and direction of the organisation at the 1996 Annual Session the following were identified as priority focal areas: minerals policy and advice, environmental science and human resources development. SOPAC's 1999 Work Program, which all participants should examine, reflect these priority focal areas and encompass a broad spectrum of geoscience activities. SOPAC's track record demonstrates that this approach to program development is synergistic, forwarding both the national needs of island nations and fundamental research. I commend it to you.

Keith A W Crook
Chair, STAR

Hawaii Undersea Research Laboratory
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September 1998

STAR Presentations at SOPAC Annual Session, 1998
PROGRAM

Time	Theme	Authors & Speaker	Title
Saturday 26th September			
8:30-8:35	OPENING		
	COASTAL	Morris	Applied sedimentology of the Nukubuco reef flat, Laucala Bay, Fiji
		Eagar	Ostracods from Tarawa: their place in the Pacific scheme of things
		Maharaj	Coastal erosion in the atoll islands of the FSM NO ABSTRACT
		Larcombe	Assessment of terrigenous inputs into the coastal zone: a 5-year plan to study Dumbea Bay, Noumea, New Caledonia
		Larcombe & Woolfe	Turbidity and sedimentation as controlling factors on the presence of coral reefs
		McMurtry	Recent history of metals accumulation in the Suva, Fiji coastal zone from ²¹⁰ Pb and fallout ¹³⁷ Cs geochronology
10:35-11:00	MORNING TEA		
	HAZARDS	Cronin	Latest ages of Taveuni volcanism -implications for volcanic hazard
		Crook & Liu	Landforms, sediments, deformation and uplift at the leading edge of a convergent margin: geology of the Lae urban area, Papua New Guinea
		Granger	A spatial data infrastructure for Pacific Data reduction
		Jones	Elements for best practice earthquake risk assessments: the Cairns case study
		Kitazawa	Okushiri Earthquake: an example of seafloor survey after the tsunamigenic earthquake
12:40-14:00	LUNCH		
		Felton	The huloepoe gravel type section, Lanai, Hawaii: sedimentology and stratigraphy and their bearing on the giant wave emplacement hypothesis NO ABSTRACT
		Jones	Probabilistic earthquake hazard assessment for Fiji
		Rynn	Suva earthquake study
		Taylor	A review of some processes occurring along the Tofua Volcanic Arc, Kingdom of Tonga
	TECTONICS	Pelletier	Current tectonics of the Tonga-New Hebrides region
15:30-16:00	AFTERNOON TEA		
16:10-18:00		Working Groups	
18:00-20:00		Working Groups	

Time	Theme	Authors & <u>Speaker</u>	Title
Monday 28th September			
8:30-10:30	TECTONICS	Lonsdale	Recent and planned research on the structure and earthquake activity of the Tonga-Kermadec Subduction zone NO ABSTRACT
	MINERALS	Ollier (presented by James P Terry)	The volcanic geomorphology of Northern Viti Levu
		Pickrill	Offshore exploration for heavy minerals in Sri Lanka
		Yeats & Binns	Hydrothermal activity in the Eastern Manus Basin, PNG: an update
		Kitazawa	Hydrothermal vent fields and vent-associated biological communities in the Manus Basin
		Cronan	Longitudinal Variability in the Composition of Manganese Nodules in the South-west Pacific
10:30-11:00	MORNING TEA		
		Cruickshank	Progress in beach maintenance methods for the State of Hawaii
	WATER	Raj & Terry	The 1997/98 ENSO and Drought in Fiji
		Parakoti & Scott	The calculation and application of drought indices in water resource management
		Falkland & Pelelei	Groundwater Assessment and Development on Lifuka, Kingdom of Tonga
		Heggie	Sediment-water interactions in aquatic environments: implications for water quality and pollution
12:40-14:00	LUNCH		
		Siosi & Scholzel	Water Demand Management and its implication on the Design and Rehabilitation of Water Supply Systems in Auki, Malaita Island, Solomon Island
	OCEANOGRAPHY	Kuroda	Status of TRITON program: Surface meteorology and upper ocean observing moored buoy network
		Steele & Raywaqa	The Interactive Graphical Ocean Database System (IGODS) Implemented in support of coastal ocean monitoring programs in Fiji
	MAPPING	Forestreuter	Remote sensing data for South Pacific Island Countries
		Smith	Developments in Mapping Technology : Benefiting Environmental and Resource Management
15:40-16:10	AFTERNOON TEA		
16:10-16:20		STAR Business Meeting	
16:20-18:00		Working Groups	

Working Group Reports to STAF Chair no later than 09:30 Tuesday 29 September 1998 at the official opening, held at the Forum Secretariat.

(Poster)		Allenbach, M., Bayer, M.	Littoral erosion on east coast of the mainland New Caledonia, South-West Pacific
(Poster)		Auzende, J.M., Symonds, P., Lafoy, Y., Bernardel, G., Van de Beuque, S., Nercessian, A., Exon, N.	FAUST (French-Australian Seismic Transect) Program: deep seismic survey between the New Hebrides Arc and the eastern margin of Australia
(Poster)		Morris, M., Collen, J., Patterson, J.	Calcareous red algae and MgO geochemistry: Nukubuco reef flat, Laucala Bay, Fiji
(Poster)		Ferland, M., Kubota, K.	Surface sediments from the Kadavu Passage, Fiji
(Poster)		Chague-Goff, C., Goff, J.	Coastal palaeo environments: the ebb and flow of catastrophic events
(Abstract Only)		Greene, H.G., Maher, N., Hatcher, G.	Benthic habitat characterization using the Simrad EM 300 swath bathymetry system
(Poster)		Heggie, D., Holdway, D., Fellows, M., Fredericks, D., Longmore, A., Cowdell, R.	Mapping of water and sediment quality parameters for resource and environmental analysis
(Poster)		Kawano, T., Asanauma, I., Matsumoto, K., Kuroda, Y., Lewis, M.	On primary productivity in the western equatorial Pacific and the new research program "Global Carbon Cycle and the related Global Mapping
(Abstract Only)		Keating	Islands, atolls, and seamounts: their structural failures and associated tsunami hazards
(Poster)		Laporte, C., Cluzel, D., Briquieu, L., Picard, C.	Evidence for tertiary cryptic obduction in the North d'Entrecasteaux Ridge (Vanuatu), and its correlation with New Caledonia
(Poster)		Lemennicier, Y., Cluzel, D., Mnot, Ren-Pierre	Geodynamic setting of early miocene granodioritic intrusives and associated epi/ mesothermal gold deposits. Southeast New Caledonia
(Poster)		Maurizot, P., Lafoy, Y.	Field mapping of superficial formations for environmental development and geological hazards mitigation in New Caledonia
(Poster)		Nakano, I., Nakamura, T., Fujimori, H., Yuan, G., Howe, B.	Time series of three dimensional temperature field in the Kurushio extension and study on the decadal scale interaction of the tropics and extratropics using ocean acoustic tomography system
(Poster)		Scholzel, H.	Peri-urban settlement project
(Poster)		Stratford, J.M.C.	Tuffaceous rocks from the Vatukoro Grewacke, Nalawa area, northeastern Viti Levu, Fiji
(Poster)		Stratford, J.M.C.	Recent observations of the Barotu sandstone: with implications for Late Miocene strike-slip basin sedimentation on Viti Levu, Fiji

Littoral erosion on east coast of the mainland New Caledonia, South-West Pacific

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The New Caledonia littoral zone shows several significant examples of fresh erosion attacks. Among threatened sites, some are affected by humans or likely to be so (communication ways, electric and telephone lines, hostelry structures, fishing shelters, etc...). Territorial authorities are nowadays bound to deal with the problem and the littoral sedimentary dynamics and coastal civil engineering have thereby become serious concerns to New Caledonia's economic, technical and political leaders.

Several sites of the west coast have been subject to measures and thorough surveys for years but however very vulnerable the east coast was, it was not studied till last year. Towards mid-May 1997, a survey by Geosciences Laboratory of French University of the Pacific was financed by a group of East coast districts (Ponerihouen, Poindimie, Touho) in the Northern Province, in order to ascertain the situation and to consider decisions to be taken as to littoral arrangement.

The main conclusions of the survey conducted on a shore length of over 60 km show very strong littoral destabilisation by erosion. The reasons of this destabilisation are multiple and narrowly interdependent in genesis of phenomena and facts stated. Should it be difficult to encircle the setting determining factor, the reasons of destabilisation are not very visible and two types of mechanism appear to be generating erosion mechanisms:

Naturally operating mechanisms

Natural mechanisms appear to be strongly related to the climatic environment (s.l.) of the zone and this at different time scales.

There is naturally and essentially the direct impact of tropical depressions. On passing directly on the zone at the end of March 1996, Beticyclone is the most recent swivel of this kind of event but all storms which could touch the region within these last decades have weakened the coast by effect of summation of generated disorders.

After that, there are longer climatic tendencies, which are proved to be unfavourable. It is due to chronic drought periods on New Caledonian Territory. At least three great droughts have harshly affected the east coast between 1951 and 1993. The fourth one related to the last episode of El Nino has just recently come to an end. These drought periods have involved in a throwback in waterways flow which carry along less sedimentary layers to the littoral zone, a deficit in deposits noted by naturalist observation of river mouth systems near eroded areas on east coast. Most of them show a sand deficit on their northern bank and an erosive trend which develops from this point, in perfect accordance with the sedimentary logics of active drifts on this littoral.

Finally, there are much longer tendencies, inadequately quantified by different specialists who carry out surveys on most littorals around the world and who do not always agree among themselves about its signification and about its impact on coastal linear: hothouse effect, rise in atmospheric temperature, marine transgression, etc. Fresh erosion attacks are noted on several littorals in the world which are presumably due to above-referred general environmental changes. New Caledonia does not escape from this overall dynamics in so far as all observations recently carried out on the most part of New Caledonian littoral show a very sharp tendency to fresh erosion attacks on both coasts of the Mainland, even on lagoon islets and Loyalty islands. The generalisation of recent destabilisation observations of coast line leads to consider these general long-term tendencies for explaining the erosion noted.

Anthropic operating mechanisms

East coast linear shows tracks of several awkward, thoughtless anthropic actions which generate serious disorders in matter of littoral erosion. These anthropic actions are:

Uncontrolled sandpits and shore gravels quarrying. Residual matter stock is in several littoral areas under limit which involve in irreversible erosive process at local scale;

Fixing vegetation clearing from top shore dunes and mangroves. Local traditional agricultural techniques (cultures ondenshered land) are all the more disastrous because they attack to aweakened littoral;

Quarrying on littoral \bar{C} platiers \bar{E} of materials essentially provided for realisation of bedrock layers of roads and tracks. This large scale quarrying is an undeniable factor of fragilisation of the coast and the aggravated erosion noted on some littoral segments is punctually and directly related to these practices.

The convergence of anthropic and natural operating mechanisms is shown nowadays on the east coast of the Mainland by a situation which should be considered as serious on erosion field. Basic infrastructures are directly threatened, requiring the setting of coastal civil engineering works. Such arrangements will be soon set on coastal areas mostly affected by erosion, meanwhile a campaign will be conducted for growing public awareness of environment and respect of a fragile and narrow littoral area on which are living most Melanesians of the east coast.

Reference

Allenbach, M. 1997. Erosion of coastal linear. survey on sedimentary dynamics and littoral arrangement. Report of Geosciences Laboratory, French University of the Pacific / Ponerihouen, Poindimie and Touho Municipalities.

FAUST (French-Australian Seismic Transect) Program: Deep seismic survey between the New Hebrides Arc and the eastern margin of Australia.

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For about 20 years, French and Australian scientists have been trying to promote the idea of a long transverse profile between the North Fiji Basin and Australia, and numerous cruises using all kind of methods (bathymetry, seismic surveys, submersible dives, etc.) were carried out in the area and were a significant help to prepare such a project. Since 1993, direct contacts between both French and Australian parties have allowed us to better define the target zone area and to decide the realisation of the joint IFREMER-AGSO FAUST project involving institutions in New Caledonia (IFREMER, ORSTOM, Service des Mines et de l'Energie-SME), France (INSU, IPGP, IFP) and Australian (Australian Geological Survey Organisation- AGSO, Universities).

Rig Seismic 206 deep seismic cruise (21 April-24 May, 1998) of the FAUST (French Australian Seismic Transect) Program was initiated from both French and Australian sides to improve the understanding of the geological framework, the crustal characteristics and the evolution of the basins and ridges located between the Australian eastern margin and the New Hebrides Trench. In total, 4500 km of deep seismic profiles was carried out. The Rig-Seismic was equipped with an array of 32 airguns (3000 cubic inches) with a streamer (256 channels) 4 km-long.

The data acquired during the Rig-Seismic cruise constitute a considerable progress in the knowledge of the crust of the area. They permit evaluation of the crustal thickness above the deep reflectors interpreted as the Mohorovicic discontinuity, and identification of the continental or oceanic nature of the crust. They also give a complete section of the sedimentary infilling of Loyalty, New Caledonia and Tasman Basins. For example, the discovery of deep reflectors in the Loyalty Basin allows us to re-examine the age of the formation of the Loyalty Basin and to consider a late Cretaceous opening instead of the Eocene estimated one.

The seismic profiles of FAUST cruise show that the basement of the Norfolk and Lord Howe Ridges of continental nature are overlain by a succession of pre-Cretaceous sediments crowned by a carbonated platform. The post-Cretaceous cover is commonly eroded and only comprises post-Eocene deposits. This erosion is due to the vertical and tangential tectonic events which affected the whole area during the Paleocene-Eocene and Late Eocene compressive phases and are illustrated within the basins by angular discrepancies. This demonstrates that, during these compressive phases, the deformation was not only concentrated at the Pacific and Australian plate boundaries (subduction trench or obduction front) but might have spread in the early stage of the episode to different zones and especially along the basement of the ridges. The FAUST profiles confirm that the northern margin of the Lord Howe Rise was overthrust during the Late Eocene phase by a series of oceanic basement slices which constitute the Fairway Ridge as has already been shown using conventional seismic methods.

Lastly, the shallow depth of the Mohorovicic discontinuity (between 12 and 15 km) observed on the preliminary processed profiles in the New Caledonia Basin and suggested in the Fairway and Loyalty Basins, confirms the hypothesis of an oceanic nature of the basement of these basins.

The FAUST Rig-Seismic profiles and previous profiles shot by AGSO in 1996 have revealed that a bottom-simulating reflector (BSR) extends over an area of at least 25 000 km² of the Lord Howe Rise and New Caledonia Basin in the Tasman Sea, in water depths of 1500-3600 m (Exon et al., in press). Such BSRs generally are associated with an interface between overlying sediment with methane hydrate (a frozen crystalline mixture of methane and water) and underlying sediment with free methane gas bubbles. The depth of the BSR of 520-600 m below sea bed, as inferred from seismic reflection profiles, is consistent with this interpretation, given the expected thermal gradient for the region. These seismic results constitute the first compelling evidence for methane hydrate deposits in waters off Australia and are of significance for multiple reasons. The Lord Howe Rise gas-hydrate deposit appears to be an immense accumulation of natural gas in an unexpected location that straddles the French-Australian international boundary. In the shorter term the indications of free gas, including a flat spot on a horst, are probably of more interest to the petroleum exploration industry. Forthcoming research cruises will be devoted to mapping the overall dimensions of the deposit and to understanding its origin.

Coastal palaeoenvironments: the ebb and flow of catastrophic events

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In New Zealand, coastal hazard plans developed by local government bodies and primary industries are, at best, based upon a 150-yr record of historically documented events. There is a clear need to develop a coastal hazard record (e.g. return periods and inundations) based upon a longer time period. This paper reports about a programme developed by the Institute of Geological and Nuclear Sciences Limited (GNS) that is aimed at producing a high-resolution chronology of environmental changes in the coastal zone over at least the past 6500 years. Environmental changes to be identified (although not necessarily at the same place) include those due to, tsunami, sea-level change, cyclones (storm surges), earthquakes, human impact, ecosystem resilience to change, floods (rivers) and climate change. A suite of key diagnostic criteria or "signatures" will be produced that characterise each type of environmental change found in the sedimentary record. Signatures will include palynological, micro- and macro-paleontological, sedimentological, archaeological and geochemical characteristics. These signatures will be developed from a sedimentary record of known historical events identified in cores using high-resolution geochronological techniques (e.g. ^{137}Cs , ^{210}Pb). Subsequently, these signatures will be used to extend the record back using dated (e.g. ^{14}C , ^{32}Si , OSL) cores taken from selected coastal wetland sites. Data will be directly applicable to coastal hazard planning and will also provide internationally significant outcomes for event recognition or "signatures". Examples of the current "state of play" are given, and the proposed locations for this comprehensive study are given.

Most, but not all, of the individual techniques and methods used are widely practised, although some are unique to GNS. However, the most significant advances are in the:

- i) Comprehensive application of these techniques and methods to a suite of coastal hazards at any one site.
- ii) Ability to construct local, national/island-wide and regional/Pacific-wide databases by the compilation of site-specific work.
- iii) Existence of sufficient expertise within one organisation to carry out the work. With this comes all the advantages of effective time management, cost efficiency, hassle-free data sharing and compilation, a single point-of-contact, and a guaranteed high-quality product from an internationally recognised organisation.

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Longitudinal Variability in the Composition of Manganese Nodules in the South-west Pacific

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Longitudinal variability in SW Pacific nodule composition has not been investigated to anything like the same extent as their latitudinal variability. This is partly because the latter is much greater than the former over any given distance, and can be clearly related to productivity and CCD variations. However, nodules do vary in composition longitudinally across the Pacific and some of the factors controlling this are the same as those that control latitudinal variability.

The main controls on latitudinal variability in nodule composition in the SW Pacific are biological productivity and the depth of the CCD. Manganese, nickel and copper-rich nodules occur at depths near the CCD under the high biological productivity zone, but values of these metals are lower both above and below the CCD under the high productivity zone, and at all depths as productivity declines to the south. By contrast, Co enrichment increases southwards as biological productivity declines and the CCD is raised, such that the highest Co grades in nodules occur on red clay sediments well south of the high productivity zone, especially in Antarctic Bottom Water (AABW) covered areas like the Aitutaki Passage in the Cook Islands EEZ.

Examination of the variability in nodule composition in an east-west direction shows features similar to those found in a north-south direction, but over much greater distances. In the 5° - 10°S latitudinal band, Mn, Ni and Cu decrease longitudinally from highest values in the Line Islands and Cook Islands regions to intermediate to low values in the vicinity of Tokelau and Tuvalu. Over the same distance, some 30° of longitude, Co shows a very slight increase. In the equatorial region between 0° - 5°S , few nodules have been recovered east of 165°W , but those that have generally contain between 0.5-1.0% Ni with above average concentrations of Mn and Cu also. These high values persist to about 175°W , especially between 0° - 2.5°S and then decrease as the Gilbert Islands are approached at 180° . Cobalt shows little systematic east-west variation at all in this latitudinal range. Between 10° - 15°S , there is little systematic longitudinal variability in Mn, Ni, Cu or Co, and the same conclusion applies to the 15° - 20°S latitudinal band.

Knowledge of the main factors affecting latitudinal variability in nodule composition in the SW Pacific, biological productivity and depth to the CCD, allows hypotheses to be erected to account for their longitudinal variability too. However, it cannot be emphasised too strongly that these hypotheses need to be tested both by the analysis of additional data and samples, and by the collection of additional material at sea, before conclusions based on them can be substantiated.

Examination of the isolines of biological productivity in the SW Pacific show an equatorial zone of high productivity thinning towards the west. Thus, at any given latitude between the equator and about 10°S , where productivity decreases to background levels, productivity should decrease in a westerly direction. This could be a factor in accounting for the westerly decline in Mn, Ni and Cu contents of the nodules in the 5° - 10°S latitudinal band. However,

maximum Mn, Ni and Cu only occur in nodules close to the CCD and, as the basins deepen below the CCD towards the west, fewer and fewer nodules will occur close to it. This could be an additional factor in accounting for the decline in Mn, Ni and Cu in a westerly direction between 5°-10°S. The slight westerly increase in Co in this latitudinal range will be due in part to declining amounts of Mn, Ni and Cu diluting its concentration in the nodules, but might also be due to the influence of AABW coming from the south. The greater westerly extension of the Mn, Ni and Cu rich nodules between 0°-5°S than between 5°-10°S could be due to biological productivity being highest in the former latitudes. The lack of systematic E-W variation in Mn, Ni, Cu or Co in the 10°-15°S and 15°-20°S latitudinal bands might be due to those areas falling entirely outside the high productivity zone and thus there being no productivity influences at all, positive or negative, on nodule composition there.

Additional factors affecting nodule composition in an E-W direction in the SW Pacific are changing topographic and sedimentary regimes. Going from 150°W to 180°, one encounters first the Manihiki Plateau and then the island groups of the Phoenix and Samoan Islands, and Tokelau. Here much of the sea floor is elevated above the CCD which will reduce the Mn, Ni and Cu content of any nodule on it, and much of it will be covered by turbidites slumped from the islands and seamounts which will likewise reduce nodule Mn, Ni and Cu concentrations substantially. It is only in the basin areas of slow sedimentation that potentially economic Mn, Ni and Cu rich nodules can be expected to occur.

On the basis of these observations, one can classify areas of the SW Pacific according to their likelihood of hosting potentially economic nodules. As far as Mn, Ni and Cu rich nodules are concerned, the most promising areas are in the north of the region, principally in the central Line Islands, northern Cook Islands and Phoenix Islands EEZs, and the areas in-between. As far as Co rich nodules are concerned, the most promising areas, apart from the central and southern Cook Islands EEZ, are the southern Line Islands EEZ, the western EEZ of French Polynesia and the EEZs of Niue and American Samoa.

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Latest ages of Taveuni volcanism - implications for volcanic hazard

Shane J. Cronin, Vincent E. Neall

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Taveuni is the largest Pleistocene volcano in Fiji but until now there has been very little absolute dating of its past eruptive activity. Volcanism on the island has occurred from at least 150 recognisable vents (with many others buried), located along the central long-axis of the island. Most of these vents were probably monogenetic. We have collected ten new radiocarbon dates from the island, each of which can be related to at least one eruptive episode. The dates of activity range between c. 4800 and 340 years B.P. The new dates, together with dates collected in past soil, pollen, and archaeology studies on the island, indicate that between 1000 and 2000 years B.P. there were at least six eruptions on Taveuni. Since 1000 years B.P. we have 14C evidence for a further three eruptions, the youngest dated at 340 ± 70 years B.P. (Wk6209). Stratigraphic evidence indicates that there were many more eruptions during these periods, and that the dates collected so far show only an absolute minimum eruption recurrence interval.

Most eruptions of Taveuni are "dry" Strombolian and Hawaiian effusions of lavas and scoriaceous tephra. Lava flows typically inundate areas of 3-15² km, whilst the largest eruptions can produce flows of >24 km² in area (c. 250 million m³ in volume). Most eruptions also result in the production of 6-16 million m³ of tephra, covering areas of up to 17 km² with tephra thicknesses exceeding 10 cm. Tephra is commonly blown NW of eruption vents, onto the populated western slopes of Taveuni, with thinner (<1 cm) finer tephra probably covering parts of eastern Vanua Levu. Eruption columns during past tephra eruptions are estimated to have been between 7 and 11 km high, high enough to endanger passing air traffic as well as facilitate widespread dispersal of fine ash. Heavy rainfalls that occurred during or soon after past tephra eruptions sometimes generated lahars. The lahars were channelised on the steeper slopes but sometimes spread widely in flatter coastal areas.

A lesser number of past Taveuni eruptions occurred through bodies of water or saturated sediments, causing a more explosive "wet" or phreatomagmatic style of eruption. Pyroclastic surges generated from these eruptions radiated out for at least 1 km from the vent. These types of eruption are most likely to be located in the nearshore surrounds of Taveuni and in lakes on the island.

Future work on this project will concentrate on 1) obtaining a better estimate of the eruptive frequency on the island over the last 5 000-10 000 years, 2) characterising "most probable" and "worst case" eruption scenarios for Taveuni, 3) assessing temporal and spatial trends in eruptive activity and geochemistry, and finally 4) developing a comprehensive volcanic risk assessment for the island along with volcanic contingency plans.

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Landforms, sediments, deformation and uplift at the leading edge of a convergent margin: geology of the Lae urban area, Papua New Guinea

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Lae, Papua New Guinea's second city, lies on the leading edge of the South Bismarck plate convergent margin, which is over-riding the Australian plate along the Ramu-Markham Collision Zone. Reconstruction of the Holocene deformation and uplift history of the Lae urban area is based on examination of landscape elements, sedimentary facies, and geological structure, supplemented by data from geotechnical and water boreholes, shallow reflection and refraction seismic surveys and resistivity probes.

Lae straddles two structural units of contrasting geomorphic and sedimentologic character, separated by the Bumbu Fault, a normal fault down-thrown to the NE, that has been active during the Holocene. The Mt Lunaman block, west of the Bumbu Fault, which was tilted NE-wards at or before 8000 yrs BP, has been uplifted episodically during the Holocene and probably earlier, at 4.8-8.8 m/ka. This block is bounded on the W by the Dowsett Fault, a steeply NE-dipping thrust, that effectively forms the plate boundary at which the Pleistocene Leron Fm was thrust over contemporary fan delta gravels at 870±110 yrs BP.

The Busu block, east of the Bumbu Fault, is a fan delta, the foreset slope of which terminates offshore at the leading edge of the plate boundary - the Markham Canyon. The subaerial depositional surface of the fan is unmodified tectonically, except at the mountain front and near the Bumbu Fault, but the fan slope (0.5°) is anomalously low, possibly due to back-tilting of the leading edge of the plate boundary. Uplift rates are poorly constrained at <2.3 m/ka.

During the middle and late Holocene, the Bumbu River flowed across the Mt Lunaman block, creating erosional and gravel depositional landforms. However, the most recent uplift ca. 250-300 years ago, which left +5 m shoreline traces on both blocks, cause diversion of the river into its present course along the Bumbu Fault. The villagers at Buko Settlement, on the east bank of the Bumbu at its mouth, retain an oral history of this river avulsion.

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Progress in beach maintenance efforts for the State of Hawai'i

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Beach nourishment is a critical need for beaches throughout the United States and other parts of the world. The supply of sand for beaches in the U.S. is a major component of the MMS mission and the technical developments required in tropical island environments will be a key focus of the proposed research at the MMTC/OBD in close collaboration with the Continental Shelf Division (CSD) and the Arctic Shelf Division (ASD).

Tropical islands having U.S. jurisdiction or responsibilities include the State of Hawai'i, the Commonwealths of Puerto Rico and Northern Mariana Islands, the Federated States of Micronesia, Guam, the Republic of Marshall Islands, Palau, American Samoa, Wake, Johnston, Palmyra, Jarvis, Howland and Baker. The use of coastal sands for commercial purposes in tropical islands has resulted in critical problems of coastal erosion largely because the sand supply, except for the largest islands, is derived entirely from the adjacent coral reefs and their associated life forms. Considerable work is still needed to resolve these problems which include damage or removal of beaches, seawater flooding of agricultural lands and destruction of communities.

Environmentally and commercially sustainable acquisition of sand for beach nourishment or infrastructure development must be preceded by research and development actions which are dependent on each other. These are: (1) an examination of production needs versus available supply; (2) delineation and characterization of source deposits; (3) field sampling and analysis of biological habitats within the deposit; and (4) evaluation of recovery, transportation and placement options. MMTC has had wide experience in each of these areas and the divisions have collaborated in this work on a continuing basis.

The State of Hawaii, through its Department of Land and Natural Resources has formed a Marine and Coastal Zone Management Advisory Group (MACZMAG) with a Sub-Committee on Coastal Erosion. The subcommittee is examining the feasibility of providing a limited one stop permitting process for offshore sand mining and a demonstration project to mine sand from relatively deep water and place it on a selected beach. Some of the many problems to be overcome include a multiplicity of Federal, State and NGO interests, a paucity of data on the deposits and a serious limitation on funds.

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Ostracods from Tarawa: their place in the Pacific scheme of things

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We now have a temporal record, albeit a short one, for the ostracod fauna from South Tarawa. The oldest information is from some exploratory cores taken on the lagoon side of the Dai Nippon causeway prior to its construction, which may go back to approximately 600 yrs BP. This was supplemented by material collected in 1982/3 from the intertidal zone. Further intertidal material was collected in 1995 together with some traverses across the lagoon, and living material was collected in May 1998.

Even though the timespan represented by the samples is relatively short, changes in the fauna can be shown to have taken place. Twenty-six species of ostracod are now known from Tarawa; the same number are known from Tuvalu, but Tahiti, New Caledonia, Onotoa, and the Marshall Islands, have many more. The maximum number of species collected on any one sampling programme seems to be about 18 and, when living species are targeted for sampling, they represent a smaller number than the total number found at that locality. Overall, the numbers of specimens recovered are quite low. Some species are unknown except from the cores; others are known only from the present environment. Do the latter represent recent arrivals?

What are the factors influencing numbers : El Nino? Tidal circulation? Ships' bilgewater? Pollution? Anthropism? For the foraminifera for example, the increased nutrient levels from human waste may tend to lower diversity, increase the numbers and produce deformed specimens. With ostracods, it only lowers the numbers and species diversity.

Endemism in the Pacific islands is not as prolific as was once thought; most species are found throughout the Pacific islands with some species widespread and distributed from Kenya to the Carribean, as far south as New Caledonia and exceptionally to Australia. Taxonomy is important and has been the key to the understanding and comparison of interisland faunas. The re-examination of earlier collections has enabled comparison of faunas to be made. This has caused the focus to change from examining the problem of pockets of isolated faunas to, now, the distribution of circum-equatorial or inter-Pacific island species.

An additional observation was made this year. Two freshwater species have been found living on Tarawa atoll. One species was found in a newly formed pond in an accreting area, the other in a babai pit in an established area. They are not new species to science, but rather well documented species from Asia and the Pacific which have been known for many years. How did they arrive in Tarawa?

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Groundwater Assessment and Development on Lifuka, Kingdom of Tonga

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The groundwater resources of small coral islands, which provide a valuable source of freshwater to island populations, are often very limited. Special attention to water resources assessment and development is required in order to ensure that water supplies are sustainable.

Some islands experience moderate to high levels of salinity in their water supply as a result of local overpumping. An example occurs on the island of Lifuka in the Ha'apai group of the Kingdom of Tonga. At the township of Pangai-Hihifo on Lifuka, the current public water supply system, using groundwater pumped from a series of about 10 wells, is operated by the Tonga Water Board. The wells, both dug and drilled, are each pumped at about 0.15 L/s using electrically operated pumps. Since construction of the wells and pump stations in the early 1990's, the water salinity at these wells has risen to a level where the water is non-potable owing to moderately high salinity (approx. 5 000 - 7 000 $\mu\text{S}/\text{cm}$). This rise in salinity appears to be caused by a combination of factors including siting of wells, design of the extraction system and the pumping rates at the wells. While the pumping rates are relatively small compared with many pumping installations, they appear to be too high in the local area around the well, resulting in upconing of underlying brackish water.

This paper describes:

- recent investigations undertaken to evaluate the groundwater potential on the island of Lifuka so as to provide a water supply with lower salinity than is presently available.
- design of an alternative groundwater extraction system (infiltration galleries) to provide water with lower salinity.

The investigations included:

- salinity monitoring of Tonga Water Board (pumped) wells and private (not pumped) wells to gain a better understanding of the distribution of freshwater areas within the township, and the effect of current pumping on salinity. Salinity monitoring included manual measurements of electrical conductivity (or EC) with a portable meter, and more detailed investigations at selected wells using EC sensors connected to electronic data loggers.

- the trialing of a floating suction point at the solar pump well to see if this method would improve salinity compared with the fixed suction arrangement. This trial conducted in 1997 showed no significant improvement, indicating that the use of floating rather than fixed intakes would not improve the long term water salinity.
- the trialing of a 'mini-infiltration gallery' at a potential site for a larger gallery. This trial installation consisting of approximately 12 m of horizontal slotted PVC pipe below the water table was undertaken in mid 1997. Monitoring indicated that the salinity of the water did not increase under pumping conditions.
- drilling of nine salinity monitoring boreholes to further investigate the thickness of the freshwater lens underlying the township. Useful data are now being gained from these installations and have been used to site potential galleries.
- monitoring of groundwater fluctuations at selected wells and tidal fluctuations (at the wharf) to assess the degree of tidal effect within the groundwater.

The proposed alternative groundwater extraction design is to install infiltration galleries, consisting of long lengths of slotted PVC pipes laid horizontally below the water table. At each gallery, the slotted pipes would be connected to a central pump well. Solar pumps rather than the present electrically operated pumps will be used to save on energy costs. This technology has been successfully used to pump water without causing an increase in salinity on a number of small islands in the Pacific Ocean (e.g. Kiribati, Cook Islands). In the case of one small coral island in the Indian Ocean (Home Island in the Cocos (Keeling) Islands), the salinity levels at former wells were significantly lowered by constructing infiltration galleries. The reason for the success of galleries is that freshwater is effectively skimmed off the top of freshwater lenses, thus avoiding the upconing of brackish water that can occur under wells which are being pumped at the same rate.

The area of Pangai-Hihifo in Lifuka has conditions somewhat similar to those on some of the islands mentioned above and also has reasonably shallow depths to water table (about 3-4 metres in many places). These conditions lend themselves to the use of infiltration galleries as a means of improving the salinity of the water supply.

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Surface sediments from the Kadavu Passage, Fiji

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Surface sediment samples were collected along a north-south transect from Suva to Solo Reef, north of Kadavu (Fiji) in December 1997. The sixteen samples were collected with a very large Van Veen grab (on loan from SOPAC) from the Japanese training vessel *Koyo-Maru*. The size of the grab sampler and the capability of the ship's crew enabled relatively undisturbed samples to be obtained down to a maximum water depth of 2063 m. The first sample site is located just seaward of the Suva barrier reef, and the transect continues down the slope, across the floor of the Kadavu Passage (depth approximately 2060 m), and up the very steep slope to Solo Reef.

Results obtained thus far show that most samples from the Suva slope and the Kadavu Passage contain >80-95% mud, with several exceptions. One sample, collected from just seaward of the barrier reef, is rich in sand- and gravel-sized *Halimeda* plates. Another sample from 1431 m on the Suva slope is composed of heavily iron-stained sandy mud and some terrigenous gravel, that probably represents a slump deposit which originated from much shallower water (hence the coarse grain sizes). This conclusion is supported by the available bathymetry (MRD 817, 1:250 000) which indicates that the slope topography is steep, irregular and channelled. As would be expected, the %clay in the samples increases toward deep water in the central part of the Kadavu Passage. The contribution of terrigenous mud is notable along the entire transect until the base of the Solo slope, where carbonate content increases markedly. Quantitative compositional results for the mud fractions are not yet completed.

The sand fractions of the grab samples (mostly <7% of the total sample) are composed largely of carbonate, which generally includes a wide variety of foraminifers, micro-molluscs, pteropod fragments, and 'other'. Several samples contain fecal pellets and small fragments of organic matter, charcoal or wood. *Halimeda* plates and coral fragments occur only in samples collected nearest the reefs. The samples adjacent to Solo Reef contained almost no terrigenous grains. Detailed analysis of the microfossils is in progress, and will be compared with earlier results obtained during a 1973 NZOI cruise (Lynas, 1973).

At most of the very deep sites, the grab sampler was full and undisturbed, with live organisms observed at the sediment surface despite being winched up over 2000 m. Short cores were obtained at four sites by pushing a piece of PVC pipe down through the top of the grab sampler through the sediment, capping it, twisting the pipe, and then pulling the core upward. A cap was placed on the other end and the cores were frozen onboard the ship. Several of the push cores contain marked stratification with at least 3 to 4 major sedimentary units, based on differences in texture and composition. Sub-samples from layers within two of the cores will be dated by AMS radiocarbon. These results will provide the data to estimate the rate of recent sediment accumulation in this marginal basin, as well as document temporal changes in the composition and source(s) of sediment.

Reference

Lynas, B.D.T. 1973. Preliminary Report on Project CCSP-1/FJ.10: Bathymetry and Bottom Sampling in Kadavu Passage, South and Southwest of Suva, Fiji. *In Proceedings of the Third Annual Session, Apia, Western Samoa*, p. 51-55.

XX

Remote Sensing Data for South Pacific Island Countries

Wolf Forstreuter

The use of image backdrop has increased significantly during the last few years and is due to three main reasons:

Image backdrop enhances vector maps and includes such items as vegetation cover, accessibility of cadastral plots etc. where this is important for power and other utilities.

In rural areas, maps of 1:10 000 scale are missing and can be replaced by rectified images.

Many maps of Pacific Island Countries are outdated and image data can provide necessary updates.

SOPAC provides hardware, software and knowledge to rectify aerial photographs. This is an activity that cannot be performed with the majority of GIS software, as it requires image analysis packages and specific skills. SOPAC proposes the use of digital spaceborne image data because of:

Better spectral resolution,
Lower cost,
Availability in digital format, which avoids the scanning process,
Nearly orthogonal projection, which reduces the effort of image correction.

During the 1960s only the Landsat satellites provided image data for civil use while in the mid 1980s SPOT recorded images as well. In the 1990s, the number of available satellites in space suddenly increased and also the number of agencies selling the image data. By end of this year, a new generation of data will be available. While existing satellite images provided the source for thematic mapping at 1:50 000 scale, the next generation of satellite data will have a spatial resolution of 3 to 4 metres multi-spectral (colour) and 1 metre panchromatic (greyscale). This allows 1:10 000 and 1:5000 mapping and for many applications spaceborne data will replace aerial photographs.

SOPAC provides the link between the data-selling agencies, the software and the hardware provider on one side and the end users on the other side. SOPAC provides help when purchasing and analysing image data. SOPAC informs the member countries about satellite image data available for Pacific Island Countries on its web site. As these countries are outside the footprint of any ground receiving station, on-board tape-recording facilities are necessary. News about Remote Sensing is also distributed through the GIS and Remote Sensing newsletter and the mailing list GIS-PACNet. Finally, SOPAC is always available via e-mail, fax, phone and the PEACESAT communication satellite.

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A spatial data infrastructure for Pacific Disaster Reduction

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At the 6th Regional IDNDR Meeting held in Brisbane in 1997 it was resolved that the primary IDNDR theme on which the South Pacific Region would focus for the remainder of the Decade would be '**Shared Knowledge and Technology Transfer**'. That meeting identified the requirements of the information systems needed to underpin disaster reduction across the Pacific in the following terms:

In order for the (information) system to meet the needs of its user, namely Pacific disaster managers, the fundamental data/information needs must be understood. The following questions will help to create this understanding:

- a) *What are the problems, the system should help to solve?*
- b) *What information does the system need to solve these problems?*
- c) *Where can this information be accessed?*
- d) *In which format should the information be disseminated?*
- e) *To whom should information be disseminated?.*

Some of these questions have been addressed already. Ultimately all elements of the system have to be linked up in order to establish the information infrastructure.

A project to facilitate the development of that information infrastructure is currently in progress, funded largely by the Australian Coordinating Committee for the IDNDR and supported by SOPAC, AGSO and UNOCHA/UNDP. Given the dominant requirement for spatial information to underpin disaster reduction, an emphasis is being given to the creation of an effective spatial data infrastructure (SDI) that will form a key component of that wider information infrastructure.

This project will use experience gained under both the AGSO *Cities Project* and the SOPAC *Pacific Cities Project*, together with input from a workshop to be held in Suva following the SOPAC Council sessions.

A typical SDI has four components, namely:

- an institutional framework which defines the policy and administrative arrangements for building, maintaining, assessing and applying the standards and datasets;
- technical standards which define the technical characteristics of the fundamental datasets;
- fundamental datasets that provide the answers to the key questions which users need answers to; and
- a clearinghouse network by which the fundamental datasets can be identified and made accessible to the users in accordance with policy determined within the institutional framework and to the technical standards agreed.

The project aims to develop and document structures and models for an institutional framework, technical standards, fundamental datasets and a clearinghouse network that are suited to Pacific Island Country (PIC) requirements. It also aims to raise the level of awareness amongst PIC disaster managers of the value of employing spatial information and GIS precision support tools to reduce disaster risk.

The project has a strong focus on institutional strengthening and capacity building in PIC.

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Benthic Habitat Characterization Using the Simrad EM 300 Swath Bathymetry System

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Recently collected Simrad EM 300 30-kHz swath bathymetric data along the central California margin imaged a variety of marine benthic habitats that reveal process-associated features critical to the sustainability of commercial demersal fisheries. Habitat types are based on the classification scheme introduced at both the last SOPAC Annual Session and SOPAC co-sponsored "Marine Benthic Habitat" Conference held in Noumea, New Caledonia, November 1997 (Greene et al., in press). These high-resolution data, collected by the Monterey Bay Aquarium Research Institute (MBARI), are used to characterize mesohabitats ranging from hard rocky plutonic and meta-sedimentary outcrops to fluid-induced mass wasting and carbonate build-ups. These habitats are located in outer continental shelf (distal edge, 90-100 m), upper continental slope (100-300 m) and upper submarine canyon (100-300 m) mega habitats, and attract commercially valuable rockfishes (*Sebastes*, *Scorpaenidae*).

The mega habitats are the result of active tectonism and erosion associated with the oblique convergent (transform) margin along the Pacific and North American plates. Tectonic activity along this margin has created areas of transpression and transtension. In transtensional areas, extensive canyon erosion takes place and in transpressional areas, fluid-induced mass wasting and carbonate cementation occurs. In addition, above-normal sediment input to the region, resulting from unusually high precipitation, an El Nino phenomenon, has accelerated the formation of progradational shelf edges, buried hard-bottom habitats and increased sediment input to canyon heads. All of this exacerbates the ephemeral nature of marine benthic habitats.

These data withstand gridding at 5 to 10 m and consequently image macrohabitats. We were able to resolve in good detail sediment lobes, bedding planes, boulders, pinnacles, fractures, crevices and other macrohabitats. Many of the habitats identified in the data are comparable to marine benthic habitats of the South Pacific. We will present this data set in a manner that will be useful to understanding and characterizing of habitats of intermediate to deep-water fisheries around and adjacent to South Pacific island nations.

Reference

Greene, H.G., Yoklavich, M.M., O'Connell, V., Wakefield, W.W., Starr, R.M., Sullivan, D., McRea, J. and Cailliet, G., (in press). A classification scheme for marine benthic habitats. *Oceanologica Acta*.

XX

Mapping of water and sediment quality parameters for resource and environmental analysis.

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A Continuous Geochemical Tracer analysis system has been developed for underway analyses of (i) petroleum hydrocarbons including saturated (C₁ through C₆) hydrocarbons, (ii) aromatic compounds (BTEX, benzene, toluene and ethylbenzene and xylene), measured by gas chromatography, (iii) dissolved nutrients (ammonia, nitrate and nitrite, phosphate and silicate, (iv) biogenic fluorescence, an indicator of biomass, (v) dissolved oxygen, turbidity, salinity and

temperature and % light transmission. Environmental parameters are mapped and used in GIS formats and in transport modelling to (i) identify inputs and rates of nutrients and toxicants to the coastal zone and (ii) develop wastewater management strategies in support of ecologically sustainable development. Data points can be collected at distances of about 75 m as the vessel is underway.

Produced Formation Water (PFW) Mapping.

Produced Formation Water containing petroleum hydrocarbons is sometimes discharged into the sea from production platforms. These may pose an environmental hazard to aquatic organisms with implications for benthic and pelagic fisheries. Benzene and toluene were found to be the most sensitive tracers of PFW discharged into the sea from a production platform on the North West Shelf Australia, which discharges about 7 ML/d. Mapped distributions of these compounds showed that on spring tides hydrocarbons were dispersed at distances up to about 10 km from the platform. Simple one-dimensional modelling of hydrocarbon distributions estimated half distances of dispersion of about 3-4 km. Benzene and toluene both appeared to be more reactive in the discharge - plume than the saturated hydrocarbons.

Ocean Outfalls and sewage tracers.

The deepwater ocean outfalls, offshore Sydney, discharge about 1500 ML/d of primary treated sewage into the sea at depths about 80 m. Methane was found to be the most sensitive tracer of primary sewage discharge. Methane anomalies were identified at the locations of all three outfalls; methane anomalies were measured in bottom waters (15 m from the seafloor), at mid-depths and also in surface waters (5 m water depth).

A comparison of the abundances of hydrocarbons being discharged from the outfalls (methane dominated) was quite different than those discharged from a harbour and bay (heavier hydrocarbon dominated). These unique and characterisable hydrocarbon mixtures are a unique tool to identify input 'sources' of various hydrocarbons to the coastal zone.

The methane anomalies were found to correlate with ammonia anomalies in seawater; both these tracers tracked the sewage discharge plume about 50 km from the seafloor sites of the ocean outfalls.

Nutrient (nitrogen and phosphorus) discharges from catchments.

Catchments are one important source of nutrients (nitrogen and phosphorus) discharged into estuaries, harbours, coastal lakes and lagoons. Increased loadings into waterways, resulting from man's urban and rural activities, may result in eutrophication of local water bodies. The mapped distributions of nutrients and hydrographic parameters in the Swan-canning estuary of West Australia, identified high levels of nitrate (and silicate) being discharged from the catchment during high flow periods. Ammonia and phosphate in contrast appeared to be delivered to the mid estuary during these times by inputs from the underlying organic rich sediments.

One-dimensional mixing models of estuarine distributions were also used to identify (i) sources of major external (catchment) and internal (sediment recycling) nutrient loads to the estuary, (ii) the locations of major losses of nutrients either from flushing to the ocean or removing from the water column via particle scavenging and accumulation in the underlying sediments, and (iii) the rates of these processes. Most N added from the catchment as nitrate was taken-up by photosynthesis and removed to the seafloor, but returned from the underlying sediment as ammonia. Most N and P remained trapped within the estuary.

Sedimentary mapping of geoscience parameters for resource and environmental investigations

A survey conducted recently in a large open marine bay on the eastern Australian seaboard compiled a variety of parameters measured in the sediments at approximately 70 sites. The mapping of grain-size properties identified sediment facies. Together with a knowledge of the distributions of benthic plants, including seagrass and mangrove distributions, both sediment and biofacies were identified. Several geochemical parameters measured in the sediments (organic carbon, total N, P and biogenic silica) correlated with mud facies, indicating an association between fine-grained particles and biogenic debris in the sediments. These types of data were combined to develop a sedimentary and biogenic framework for sediments which was subsequently used to scale-up site-specific studies of benthic nutrient fluxes to whole-bay estimates. Sediment facies were identified where denitrification was active and maintained a 'healthy' environment. Within riverine sediments, excess P was shown to be released from anoxic sediments.

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Sediment-water interactions in aquatic environments: implications for water quality and pollution

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Increased nutrient (nitrogen and phosphorus) inputs from rural or urban activities enhance the potential for widespread eutrophication (the prolific growth of aquatic plants and decreased water quality) in aquatic waterways. Similarly, increased inputs of toxicants such as heavy metals, petroleum hydrocarbons, pesticides and others, which are particle reactive, result in deteriorating sediment qualities as these toxicants accumulate locally in rivers, estuaries, harbours and lagoons. AGSO, via the Urban & Coastal Impacts Project, has developed the expertise to study nutrient and toxicant dynamics in a variety of aquatic environments in support of ecologically sustainable development. This presentation will focus on techniques and results of studies of sediment-water interactions, specifically the use of benthic chambers.

Benthic chambers measure the net rates at which nutrients (or toxicants) are released from the seafloor into the overlying waters. Benthic chambers are comparatively small instruments, rapidly deployed and recovered, which when placed on the seafloor capture a parcel (approx 10 L) of seawater overlying the sediments. Metabolite concentrations are measured either in-situ or collected automatically and stored in-situ for subsequent lab analyses. Rates of changes of metabolites and tracers in chambers measure net benthic fluxes across the sediment-water interface and, when combined with stoichiometric models of organic carbon degradation, identify key processes controlling N and P concentrations, fluxes and the potential for eutrophication.

Oxygen status of sediments

The major oxidants important in sediments include oxygen (from the overlying waters), nitrate from pore waters or the overlying waters, sedimentary Mn and Fe oxyhydroxides and sulphate. Specific data from benthic chamber deployment, such as the oxygen flux and the metabolic TCO_2 flux, can be used to partition carbon metabolised in the sediments between various key oxidants and thus uniquely describe oxic and anoxic sediments. This partitioning has important implications for how both N and P are recycled through surface sediments and control water quality.

N diagenesis and cycling at the sediment-water interface

When particulate organic material (C,N,P) is incorporated into surficial sediments a variety of reactions result in a release of N from its parent material into various dissolved species. When sediments are oxic (low organic carbon loadings), nitrate accumulates in pore waters of sediments as a result of the nitrification process; under 'moderate' carbon loadings nitrate in pore waters is reduced and N_2 gas is produced which is lost to the atmosphere. Nitrogen in this form is not available for plant growth; this process has been found to be an important control on quality of overlying water. When organic carbon and N loadings are 'high', most N liberated from the sedimentary source material is in ammonia produced during sulphate reduction. This N, when returned to the overlying waters, is biologically available and may provide a positive feedback to external loadings and contribute to potential eutrophication of any aquatic system.

Recent work in Australian sediments suggests that a measure of the denitrification efficiency [the proportion of N liberated from the sediments as N_2 , compared to the proportion of total N liberated (N_2 + ammonia + nitrate + nitrite)] is one key parameter controlling the transition from 'healthy' environments, with oxic sediments, to eutrophic environments with anoxic sediments.

P cycling at the sediment-water interface

Similarly the 'oxygen status' of sediments has an important control on the flux of phosphorus across the sediment-water interface. Studies conducted in open marine environments indicate that in oxic and sub-oxic sediments a significant component (about 50-90%) of P which arrives at the sediment-water interface in particulate matter is probably trapped within the sediments; with the remainder released to the overlying waters. The pore water data and solid phase enrichments of Fe and P in surficial sediments support this trapping mechanism. The net effect of this sedimentary Fe/P coupling is that the oxygen status of sediments and the redox transitions of Fe control the 'gateway' through which P can escape the sediments and be transported to overlying waters.

In contrast, in some rivers and brackish estuarine waters, we observe large fluxes of P from sediments to overlying waters, beyond those predicted from stoichiometric models of organic matter degradation. This 'excess' P we suggest results from catchment inputs of P bound to metal oxyhydroxides. When these oxyhydroxides are reduced within anoxic river and estuarine sediments, P bound to particulates is released in large quantities to the pore waters and subsequently the overlying waters.

Transport across the sediment-water interface

An internal tracer 'spike' added to the chamber measures chamber volume. The rate of loss of the tracer from the chamber-waters, combined with the increase in naturally occurring tracers, such as Rn , (which is derived from the underlying sediments), is used to determine rates of transport across the sediment-water interface. Results to date indicate that solutes are transferred by diffusion, mostly in anoxic sediments. However, and generally within oxic and suboxic sediments, solutes appear to be transported by bioirrigation. Bioirrigation generally describes processes such as benthic burrowing activities by infauna which pump overlying waters into the sediments, effecting a more rapid exchange of solutes between sediments and overlying waters, 'ventilating' the sediments and enhancing the oxic/suboxic degradation of organic carbon.

This presentation is made with the approval of the Executive Director of AGSO, Dr. Neil Williams.

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Elements for best practice earthquake risk assessments: the Cairns case study

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The risks from natural hazards that face Cairns, a community of some 120 000 people, are becoming amongst the best understood for any Australian city, through the comprehensive databases, information systems and risk assessment

methods developed by AGSO's *Cities Project*, its collaborators, and participants in the *Tropical Cyclone Coastal Impacts Program*.

Cairns is the first comprehensive pilot study for the AGSO *Cities Project*, and geohazard risk assessments have been made for earthquakes, landslides and storm surge inundation. Results from the earthquake risk study of Cairns are presented here.

Community risk from earthquakes arises from a complex interaction between the hazard event and the vulnerable physical, cultural and societal aspects of the community. We model this risk using largely GIS-based decision support tools.

An assessment of the regional earthquake hazard for Cairns is contained in the maps of Australian Standard 1170 Part 4:Earthquake Loads.

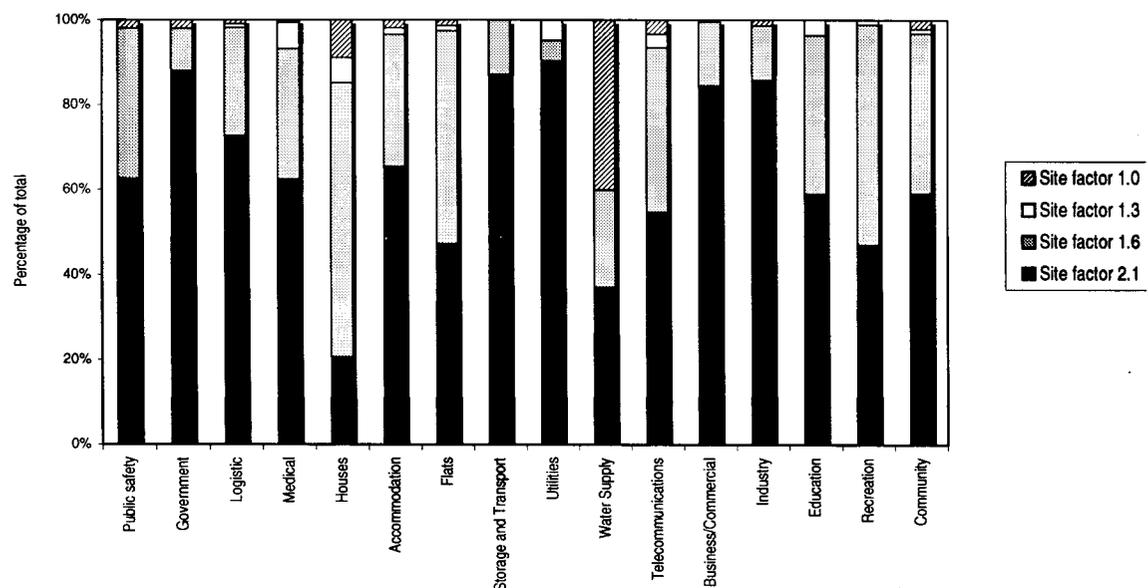
However, localised earthquake hazard can vary considerably across a city, primarily because of site geology, and this effect has been responsible for the concentration of major damage in many earthquakes. Urban earthquake hazard maps (microzonation maps) were prepared for Cairns using geological maps, geotechnical data from borehole logs, and micro tremor data from recordings of 'background' ground noise. Amplification factors, dependent on the period of vibration and on the level of input ground motion, were assigned to the various zones of differing hazard in Cairns.

The risk to the Cairns community from damage to buildings was assessed using a comprehensive geo-coded building dataset. This dataset describes all buildings in Cairns (more than 35 000) and contains information on earthquake vulnerability attributes such as building usage, age, wall cladding type, number of storeys, and degree of vertical and plan asymmetry. Vulnerability models were constructed using mean damage ratio curves and the building dataset.

The hazard and vulnerability data were compiled in MapInfo, Arc/Info and ArcView GIS environments, and a large number of collateral datasets including drainage, geological maps, road centrelines, cadastral database, and digital elevation model were also used in the analysis. A range of risk scenarios were prepared for more (and less) extreme hazard phenomena.

Our analysis shows that 87% of all buildings in Cairns are built on ground with either of the two most hazardous site classifications. The figure shows how building usage is distributed across zones of all four hazard site factors. This remarkable distribution increases earthquake risk in Cairns in at least two ways. The first is that direct losses may be relatively high from any future damaging earthquake. The second is that the community's ability to respond to, and recover from, a strong earthquake may be impaired because of damage to medical, public safety, logistic, life line and government facilities.

Direct loss estimates were made for residential buildings in Cairns. Provisional results show that for earthquake shaking with an input peak ground acceleration of 0.1 g, the losses to housing stock in Cairns may lie between 5% and 16%.



Probabilistic earthquake hazard assessment for Fiji

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Probabilistic earthquake hazard maps were prepared for the Fiji Islands. Damage has been caused by Fiji earthquakes around 1850, in 1884, 1902, 1919, 1932 (twice), 1953 and 1979. No previous assessment had produced a comprehensive description of the earthquake hazard in Fiji and the present study was initiated in 1990 when the author was attached to the Mineral Resources Department, Fiji. Collection and analysis of data continued at MRD until 1992 and the study was completed at the Australian Geological Survey Organisation in 1993-1997.

The aim of the study was to produce probabilistic earthquake hazard maps which can be used in the National Building Code for Fiji, for design of special structures, for planning, for emergency management and for risk management. Few, if any, similar studies have been undertaken in the seismically active Southwest Pacific.

A catalogue of about 3200 shallow earthquakes occurring from around 1850 to 1990 in an area extending to 200 km from all populated islands, and featuring about 2250 earthquakes located by the Fiji Seismographic Network (FSN), was used in the study. Magnitudes of all earthquakes were converted to moment magnitude M_w and the largest known earthquake had a magnitude of M_w 7.1. Macroseismic data from 16 shallow earthquakes were analysed to produce a relation for the attenuation of Modified Mercalli Intensity in Fiji.

The probabilistic methodology introduced by Cornell (1968) was used. The procedures to calculate earthquake hazard for Fiji paralleled closely the procedures used to prepare the Zone Factor map in NZS 4203:1992; Part 4 Earthquake Provisions. The primary reason for following the New Zealand procedures is that the Structural Provisions for Earthquake Loads in the draft National Building Code for Fiji (Section B1.2 (b); Pacific Building Standards Project, 1990) refer to NZS 4203: Part 4.

All parts of the study area were considered sufficiently seismically active to justify their inclusion in a source zone, and seismicity parameters describing nine earthquake source zones were defined. The Modified Katayama relation for the attenuation of strong ground shaking developed for New Zealand was used in the absence of instrumentally recorded data from Fiji. The good agreement between the attenuation of Modified Mercalli Intensity in Fiji and in New Zealand provided confidence that the Modified Katayama attenuation is equally appropriate for Fiji and New Zealand.

Probabilistic earthquake hazard maps were prepared for return periods of 50, 150, 450 and 1000 years. The hazard was represented by values of acceleration for elastic, 5% damped, horizontal response spectra at period $T = 0.2$ seconds for Katayama ground condition Type 3.

The earthquake hazard in Fiji is estimated to range from moderately low to very high. The hazard estimated for Rotuma is comparable to moderate continental intraplate values. The estimates for most of Viti Levu are comparable to moderate values in New Zealand. Spectral acceleration values in the map for a 450-year return period lie between 0.5 g and 0.7 g for a large area of Fiji: almost all of Viti Levu including Suva, western Vanua Levu, the Lomaiviti Group, and the Lau Group from Vanua Balavu to Nayau. The estimated hazard is significantly higher in the northern Yasawa Group and western Kadavu where spectral accelerations of around 1.0 g were calculated for a 450-year return period. The spectral accelerations calculated for eastern Cakaudrove (Taveuni, Udu and Rabi) and Cikobia range from about 1.2 g to 1.5 g and are higher than the maximum spectral acceleration of 1.2 g specified for New Zealand in NZS 4203:1992.

The earthquake hazard map for a 450-year return period is recommended as a basis for the Zone Factor map to replace the Preliminary Earthquake Risk Map in the draft 1990 National Building Code for Fiji. Simultaneous with adopting the new Zone Factor map, Section B1.2 (b) of the National Building Code should be amended to refer to NZS 4203:1992. Failure to make this amendment could result in the misapplication of the Zone Factor in loading calculations with a consequent over specification of lateral strength requirements of approximately 50%.

The proposed Zone Factor map for Fiji is similar, in broad terms, to the Preliminary Earthquake Risk Map in the 1990 draft National Building Code for Fiji, although there are some significant differences. The hazard estimated for western Viti Levu, including Nadi, Lautoka, Ba and Tavua, is similar to estimates in the 1990 map. Estimated hazard at Kadavu, Labasa and the Yasawa Group also is similar to that in the 1990 map. The new hazard estimates for the Lomaiviti Group and southern and eastern Viti Levu including Suva are about 25% lower than the estimates in the 1990 map. Hazard estimates for the Lau Group are lower than previously estimated except for Vanua Balavu where the estimate is little changed. The estimate of hazard for Rotuma is lower by a factor of about three compared to the value in the 1990 map. In eastern Vanua Levu, Taveuni, Rabi and Cikobia the new estimates of hazard range from zero to 40% higher than the estimates in the 1990 map.

The Fiji Seismographic Network in its first 10 years of operation has proven extremely valuable in defining the seismicity of Fiji. Its continued operation will lead to improved estimates of seismic hazard in Fiji, especially in Viti Levu and western Vanua Levu.

Local strong-motion data are required to define the attenuation of strong shaking and ultimately to produce uniform hazard response spectra to describe the earthquake hazard. An increase in the number of fixed, free-field digital instruments in the Southwest Pacific, and the deployment of similar instruments to record aftershocks in the epicentral areas of strong earthquakes, is essential to provide such data.

This national hazard assessment does not take into account the different ground conditions which may exist in urban areas and at critical facilities. The site-specific hazard may be strongly dependent on local ground conditions, and the hazard assessments of this study should be augmented by detailed urban zonation studies and site-dependent risk studies for lifelines and important infrastructure where appropriate.

XX

On primary productivity in the western equatorial Pacific and the new research program "Global Carbon Cycle and the related Global Mapping"

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Global warming is one of the most serious problem for us. To know the carbon cycle is the key to understand the mechanism of global warming. As for the ocean, phytoplankton plays an important role in the carbon cycle through its ability to fix carbon (primary production). From this aspect, the equatorial Pacific is an important area because of its distinguishing characteristics. It occupies a large region of the world's ocean and the warmest water of the planet exists there. The western equatorial Pacific contains a so-called warm water pool. Nitrate is depleted there and primary production is small. In the central and eastern equatorial Pacific, vertical flux of nutrients is enhanced due to quasi-stationary upwelling caused by equatorial divergence, and consequently chlorophyll *a* concentration and primary production rate increases along the equator. However, primary production and biomass are not as high as what one would expect that the flux of nutrients could support. This is called high nutrient/low-chlorophyll situation. Since this east-to-west asymmetry is affected by ENSO events, there is a significant variability in physical characters on seasonal and inter-annual scales with effects on geochemistry, as well potentially with the similar scale of variability.

JAMSTEC has made scientific cruises in the western equatorial Pacific since 1994 to study a bio-optical variability in this region. In Nov. to Dec. 1994 and Dec. 1995 to Jan. 1996, bio-optical cruises were carried out along the equator by R/V KAIYO in a joint research program of JAMSTEC, Meteorological Research Institute, Japan and Dalhousie University, Canada. Simulated in-situ incubations were carried out using ¹³C and ¹⁵N as tracers along the equator from 145 E to 165 W. In 1994, the warm pool was enhanced to the east and all the stations seemed to be in the same water mass. Nitrate concentration at the surface was almost undetectable. The layer of chlorophyll maximum was observed at around 80 m depth. Primary productivity was less than 0.2 mgC/m³/hr and integrated daily primary productivity was estimated to be about 0.1 gC/m²/day. In 1995, the equatorial upwelling was observed to the east of the 180°. Nitrate concentration on the surface was more than 2 M and chlorophyll maximum was at 50 m depth in this region. Integrated daily primary productivity increased by a factor of five in the warm pool region, for the upwelling region, it increased approximately tenfold. Since integrated pigment biomass over the euphotic zone and new production did not vary significantly in the warm pool region, the increased primary production was regenerated production due to the increase of an assimilation index (biomass-normalized primary production), while it was due to enhanced pigment biomass and the increase of an assimilation index in the upwelling region. Contraction of the warm pool and westward extension of the nutrient-rich cold tongue were among the mechanisms responsible.

As research programs become more global, the application of satellite data to compute primary production has become important. In 1997, SeaWiFS, which provides the ocean color data, was launched. A lot of algorithms to estimate primary productivity from the ocean color data have been proposed. However, few data exist on primary production in the western equatorial Pacific and hence the region's productivity cannot be evaluated, particularly with respect to El Nino. In order to improve our understanding of the carbon cycle in the western equatorial Pacific, JAMSTEC will join the comprehensive program named "Global Carbon Cycle and the related Global Mapping". This research program is coordinated by Science and Technology Agency of Japan and started in 1998. In this program, we will measure not only primary productivity but also related optical, chemical and physical parameters. We also receive ocean color data from the satellite at the same time to contribute to the validation of the algorithms. We will moor sediment traps and take deep-sea sediment samples by multiple-corer to estimate so-called "export production". To combine these data to the TRITON data, the "carbon cycle" of this area can be studied from the various aspects. The first cruise of this program will be conducted by R/V MIRAI in December 1998. The accumulated data from this project such as moored sediment traps, ship observation, TRITON data and so on will provide the fundamental knowledge to south Pacific countries on the El Nino impacts on biogeochemical phenomena as well as physical phenomena. We really appreciate and hope for further support from adjacent countries with security and maintenance of sediment trap moorings and TRITON array.

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Islands, atolls, and seamounts: their structural failures and associated tsunami hazards

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Studies of the submarine slopes of islands, atolls and seamounts made possible by the introduction of sidescan sonar mapping systems have provided us insight into their stability. Islands, atolls and seamounts have proven to be unstable edifices, prone to structural failures. Contributing factors include: unstable foundations, submarine/subaerial transitional zones of high porosity and low physical strength, thermal alteration, seismic activity, dike injection causing edifice

spreading, accumulations of cumulates near the core of the volcano which induce volcanic spreading, oversteepening of flanks, surface loading and climate effects, fault activity, repeated subsidence or uplift, changing sea level, karst and cave features producing mega-porosity and low physical strength, endo-upwelling and excess edifice pore pressure, tectonic seismicity and deformation (e.g. earthquakes on fracture zones, etc.), hurricanes, man-made triggers (including construction and nuclear blasts), extended landsliding on adjacent slopes, and unbuttressed flanks.

Any one of these elements, or a combination, can trigger a submarine landslide that results in a local tsunami. Moore and Moore (1984) proposed that a local tsunami associated with the collapse of a portion of the western flank of Hawaii around 105 ka left evidence of runup to 375 m on Lanai, Hawaii. [This giant run-up is now being seriously questioned by many workers.] Lipman et al. (1988) and Normark et al. (1993) suggest that giant landslides take place around Hawaii every 25-100 ka. Much work is needed to better constrain the frequency for giant landslides. Small fault movements, of only a few meters, have generated the largest earthquakes observed on the island of Hawaii, produced millions of dollars of damage and loss of life and have a frequency of 35 yr. (Dudley and Lee, 1988).

Landslides which have triggered tsunamis within restricted bays and fjords have produced the largest runup (524 m). Krakatoa Volcano produced a runup of 40 m, and killed 36 000 people. The 1998 Aitape Tsunami produced waves 6-9 m high and killed roughly 3000 people. The 1992 Flores tsunami had runup of 4-26 m, and killed over 2000 people. The 1907 eruption in Savaii produced local tsunami waves 3-4 m high. The 1933 collapse of part of the flank of Mt. Unzen (Japan) into the sea generated a tsunami 9 m high that killed 14 500. The 1896 Meiji Sanriku Tsunami killed 27 000 people in Japan. The 1993 Hikkaiso Nasei-Oki Tsunami was associated with runup heights of 32 m and 1.2 billion US dollars of damage. Chilean tsunamis have produced damaging local as well as long-ranging tsunami waves that reached the Hawaiian, Samoan and Cook Islands. Submarine landslides in the Atlantic have caused tsunamis which struck Newfoundland, Scotland and Norway.

No island group is immune from tsunamis. Both locally generated and remotely triggered tsunamis will continue to strike islands in the future. Geologic studies directed at discovering sand deposits within intertidal muds and peats of low-lying coastal zones and marshes, and dating the sands, have been successfully used to estimate tsunami frequency. Scientists estimate tsunamis along the Japan Sea to have a reoccurrence interval of 250-400 yr. Work is now underway on deposits in the Canary Islands to determine if the islands have experienced giant waves like those inferred on Lanai. Within the SOPAC region we urgently need well defined records of dated tsunami deposits so that a better understanding can be developed of the statistical re-occurrence rate for this region. Better bathymetry is also needed in the source area of the Aitape earthquake and tsunami to map the offshore and determine how such large tsunami waves were generated from this earthquake.

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Status of TRITON program: Surface meteorology and upper ocean observing moored buoy network

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JAMSTEC is developing a surface moored-buoy network named TRITON (TRIangle Trans-Ocean buoy Network) for observing oceanic and atmospheric variabilities in the Pacific Ocean and its adjacent seas, in cooperation with other interested Japanese and foreign agencies and institutions. The principal scientific objective is to understand actual ocean circulation and heat/salt transports with emphasis on ENSO, Asian monsoon and decadal-scale variabilities that influence climate change in the Pacific and its adjacent seas. In the first phase, the buoy network will be established mainly in the western tropical Pacific between 8S and 8N in conjunction with TAO-ATLAS buoys which are presently maintained by Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration of USA. Subsurface ADCP current meter buoys will be continually deployed along the equator in a program of the Tropical Ocean Climate Study in conjunction with the surface buoy array. After establishing the network in the western tropical Pacific, two of buoys will be deployed in the Indian Ocean.

JAMSTEC has deployed four TRITON buoys at 8N, 5N, 2N and 0, 156E by R/V Mirai in March 1998, intended for a year-long mooring. The TRITON system worked well for the first three months. However, we had to recover the four TRITON buoys due to technological problems.

We firstly went and recovered the TRITON #1 buoy at 8N which had stopped data transmission since June 6. When we checked the recovered mooring parts, we found severe corrosion on the shackles and chain just below the surface buoy connecting a wire cable. We recovered the other three TRITON buoys because we expected the same corrosion, although those buoys have been sending fine data. We will check them and take some countermeasure to solve these problems.

Future deployment plan:

- (1) JAMSTEC will construct 14 TRITON buoys in FY1998 improving them against the technological problems.
- (2) JAMSTEC will deploy again the four TRITON buoys at 8N,5N,2N,0, 156E in the February-March 1999 Mirai cruise. It is under consideration that the buoys at 2S, 5S along 156E and 5N, 2N, 0 along 147E will be deployed in the same cruise of March 1999 or in the October-November 1999 Mirai cruise. The other sites along 138E will be filled in the end of FY1999 the total 10-13 buoys will be deployed.

To ensure the security and maintenance of the buoys, and promote data utilization, we need cooperation with south Pacific countries and related associations. Through the first four deployments and subsequent recovery, the Federated States of Micronesia generously supported the TRITON program by issuing clearance, alerting fishing communities, and so on. We really appreciate such cooperation and hope for further support from adjacent countries when the TRITON array is expanded.

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Evidence for Tertiary cryptic obduction in the North d'Entrecasteaux Ridge (Vanuatu), and its correlation with New Caledonia.

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The d'Entrecasteaux Zone (DEZ) is an arcuate complex of submarine topographic highs that extends from the northern end of the Norfolk/New Caledonia Ridge to the New Hebrides trench, where it collides with the Western Belt islands Santo and Malekula. The DEZ comprises from North to South: 1. the North d'Entrecasteaux Ridge, an elongated and faulted submarine ridge elevated 2000 to 4000 m above the seafloor; 2. the d'Entrecasteaux Basin, at ca. 1600 mbsl; and 3. the South d'Entrecasteaux seamount Chain (SDC), which includes the Bougainville Guyot and the Sabine Bank, an Eocene volcanic arc that may be extended southwards into the Loyalty Ridge. The DEZ bounds the North Loyalty Basin (pre-Middle Eocene) to the South and the West Santo Basin to the North. The DEZ may be interpreted as an ancient south-dipping subduction zone where the SDC represents the associated volcanic arc, and the NDR the fore-arc area. The horst-and-basin structure of the NDR and its elevation relative to West Santo basin are still questioned. Considering the ongoing subduction/collision of the DEZ and New Hebrides Arc (NHA, Vanuatu), the peculiar magmatic features found in the NHA are of major interest for the knowledge of NDR.

The Australian plate that bears the DEZ is currently subducted eastwards below the NHA. Heterogeneity of the subducting plate results in complex compositional variation of the lavas that erupt in the Quaternary Central Chain volcanoes of the NHA. Geochemical and isotopic variations have been investigated in both space and time, and a clear correlation appears between the subduction of DEZ and a prominent anomaly centered around Aoba Island. In front of the collision zone, the volcanic rocks abruptly change from arc-tholeiite to calc-alkaline basalt compositions. The isotopic features (Sr, Nd, Pb) of the Quaternary volcanic rocks imply contribution of four source-components: a "normal" MORB-type mantle, an "enriched" DUPAL-type mantle, subducted Tertiary to Recent sediment, and an "old" (>500 Ma) continental crust-type component. The latter component is strictly restricted to the collision zone; therefore, as subduction of the SDC oceanic arc cannot account alone for the geochemical and isotopic features of the erupted lavas, a continent-type crust may be suspected to exist in the NDR. In order to better constrain the origin of these various components, new investigations have been carried out on rocks that have been dredged and drilled on the NDR during GEORSTOM III cruise and ODP Leg 134, site 828. Accordingly, the rocks sampled on the NDR are Middle Eocene polygenetic scree breccia composed of tholeiitic basalts that display BABB, P-MORB and N-MORB affinities. This locally derived breccia represents a natural sampling of the NDR probably due to synsedimentary faulting and horst/graben formation. They accumulated well after the crystallisation period of these otherwise ocean-floor rocks originally erupted in a marginal basin. According to fission-track data, ocean floor was formed before the Paleocene-Eocene boundary. There is no way for these rocks to represent the source of a continent-type contamination; therefore, it may be suspected that a hidden slice of "old" continental crust may exist below the uplifted basalts of the NDR.

Considering the NDR as an extension of the Norfolk/New Caledonia Ridge, we suggest that the Eocene subduction/obduction structure found on the main island (Grande Terre) of New Caledonia may be extended northward into the NDR. Consequently, the NDR basalt may represent a lateral equivalent of the oceanic crust of the supra-subduction Loyalty Basin. The Poya mafic allochthon of New Caledonia has been tectonically underplated below the oceanic lithosphere of the Loyalty Basin (the Ophiolitic Nappe) during the Late Eocene obduction. This terrane represents remnants of a subducted basin which was originally an integral part of the Loyalty marginal basin before the onset of the Eocene subduction, and therefore is representative of the ocean floor that existed prior to the Eocene subduction/obduction process. This Campanian to upper Paleocene oceanic crust displays magmatic affinities that vary continuously between P-MORB and BABB end-members. Therefore it may be considered that the NDR, Loyalty Basin and Poya Terrane belong to the same Late Cretaceous to Eocene marginal basin which almost completely disappeared in the arcuate east and south-dipping subduction zone that generated the SDC/Loyalty arc and North Loyalty back-arc basin. Consequently, the NDR bears no direct genetic relationship with the SDC as postulated earlier. The subduction blocking by the Norfolk/ New Caledonia continental ridge resulted in the upper Eocene obduction in New Caledonia; in the same way, although less spectacular, the uplift of NDR may be due to the subduction (or underplating) of a continental slice which thereafter locally contaminated the New Hebrides Quaternary volcanic arc magmatism during subduction of the Australian plate lying to the west.

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Assessment of terrigenous inputs into the coastal zone: a 5-year plan to study Dumbea Bay, Noumea, New Caledonia

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Understanding the inputs and mobility of sediments in tropical coastal embayments is of importance because of the increasingly recognised role of such areas in coastal ecology. Establishing the nature of modern coastal processes and their geological context are vital to accurately assess impacts of human activities. A collaborative research program has been developed encompassing researchers from the School of Earth Sciences and Department of Physics, James Cook University (JCU), Australia, with workers from the ECOTROPE project, ORSTOM, New Caledonia, to assess the oceanographic, sedimentary and Holocene geological characteristics of Dumbea Bay, Noumea. In Dumbea Bay, particular issues include land-use change in the catchment and the presence of a large nickel processing plant and other industrial use at the bay margins.

Existing data on water chemistry derive from vertical profiles from a Seabird CTD equipped with irradiance, turbidity and fluorimetry sensors and from discrete subsurface samples analysed for inorganic and organic dissolved nutrients and particulate organic composition (C, N and P). Analyses to date clearly demonstrate the presence of a significant increase in nutrients, chlorophyll *a* and mainly suspended load when approaching the inshore part of the Bay. Acoustic classification of the sea bed (sediment types and large habitat types) is currently underway using 'RoxAnn'.

In early 1999, a total of 200-300 grab samples will be taken from Dumbea Bay, and additional samples will be collected from the Dumbea River and its floodplain, mangrove swamps and beaches. We propose a 4-6 week deployment of instruments to measure meteorological data, waves, tides, currents and turbidity, to characterise sediment transport regimes in selected environments (eg. fringing reef, rocky shore, muddy shore, mangrove swamp, central embayment). CTD casts will also be made to investigate vertical mixing.

In 2000, an intensive 3.5-kHz seismic survey with associated vibrocoring program will occur to document the sedimentary fill of the bay and its relationships with the geology of the main lagoon to seaward. Future development of the project is likely to include collection of short drillcores from fringing reefs in the bay, from sites where we already have data on sedimentary processes, and the development of detailed oceanographic models of the bay.

The study requires a breadth of expertise and equipment not generally available in any single institution. The integration of university and institutional researchers and facilities is mutually beneficial, and will leading to training of research students, journal publications, and results directly applicable to improved coastal management.

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Turbidity and sedimentation as controlling factors on the presence of coral reefs

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As elsewhere, on the modern GBR shelf, the primary factors which affect the growth of coral reefs include sea-level, temperature, currents and wind & storm patterns. Secondary factors include sedimentation, water quality, and direct and indirect biological interaction. For the GBR, terrigenous sediments are largely confined to the inner-shelf (0-20 m depth), so that only those reefs which fringe the mainland or inner-shelf granitic islands are potentially affected by terrigenous sediments. A significant unknown is the nature of the interaction between the sediments and corals, either in terms of modern sedimentary processes, or shelf evolution over the mid and late Holocene.

Recent data from the inner shelf of the central Great Barrier Reef show that oceanographic controls are crucial to the locations of reef growth, mainly in their implications for the nature of sedimentation. With this background, we model the potential interactions of terrigenous sediments and coral reefs by plotting net sediment accumulation versus the net rate of reef growth (Figure 1) to delineate a series of fields within which coral reefs:

- are influenced by different sedimentary factors;
- are subject to varying mechanisms of turbidity generation; and
- may have resulting differences in their external geometry and internal growth pattern.

In some circumstances this model is quantifiable. It can also be used for illustrating change through time and space, leading to first-order prediction of sedimentary succession.

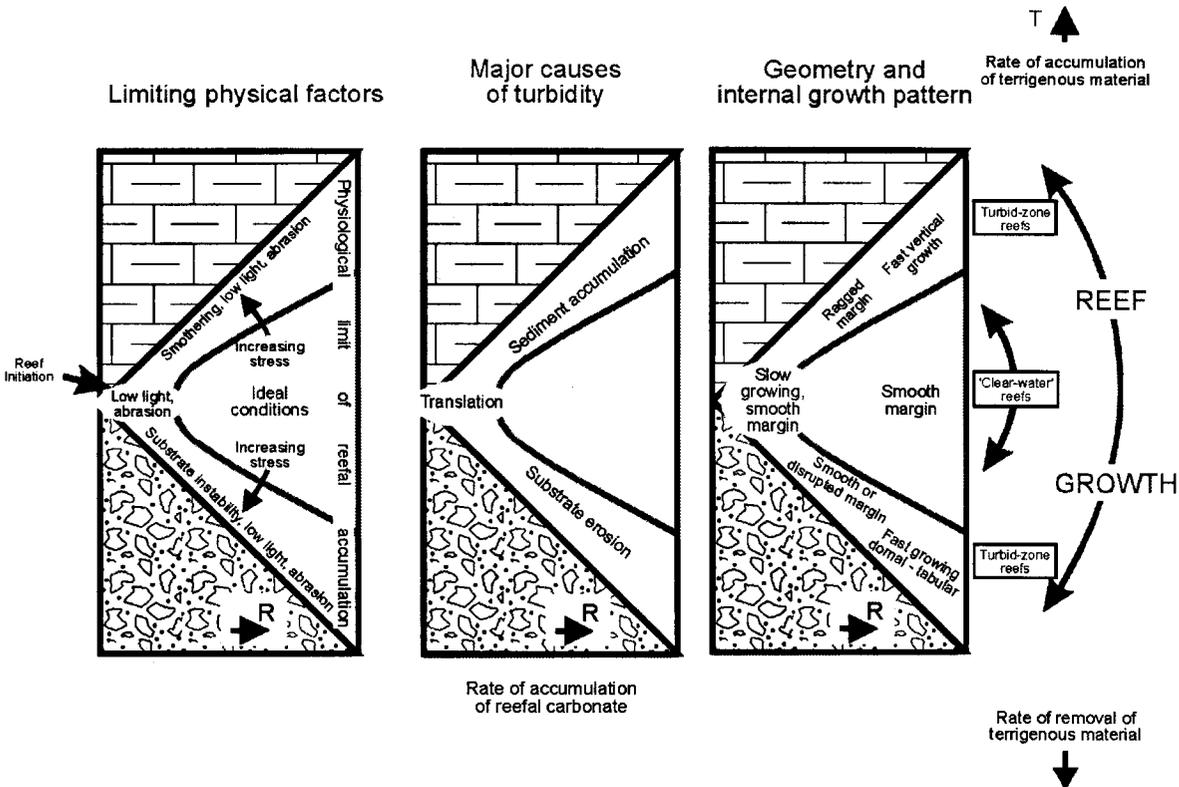


Figure 1. Conceptual fields and controlling factors on coral reefs, which are restricted to the central right portion of the diagram. (From Woolfe & Larcombe, Terrigenous sedimentation and coral reef growth: a conceptual framework. Marine Geology, in press).

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Geodynamic setting of Early Miocene granodioritic intrusives and associated epi/mesothermal gold deposits. Southeast New Caledonia.

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A few kilometre-scale granodioritic intrusives are exposed in the South-East of New Caledonia island where they display small-scale Sb, W, Mo and Au mineralization. The scope of this paper is to attempt a correlation of this plutonic episode with the overall Tertiary tectonic features of New Caledonia.

The occurrence of a large ultramafic sheet covering one third of the island is the most prominent geologic feature of New Caledonia. Obduction occurred in the Late Eocene-Early Oligocene as a consequence of subduction blocking when the Norfolk/New Caledonia "continental" ridge subducted north-north-eastward below the Loyalty arc. This event was preceded by tectonic underplating of oceanic crust and olistostrome accumulation in the fore-arc region. Thereafter, the obducted suboceanic lithosphere of the Loyalty fore-arc basin underwent dramatic weathering and lateritisation that resulted in the accumulation of nickel ore. During the post-obduction period, the convergence of Pacific and Australian plates continued and before the onset of the New Hebrides arc, the lithosphere in excess was subducted in an unknown location. A possible location for post-obduction lithosphere resorption is located along the west coast of New Caledonia where a prominent negative gravity anomaly has been known for a long time to exist. Indeed Tertiary (post-Eocene ?) sediments accumulated in a trench 500 km long offshore SW New Caledonia where sediment thickness may be estimated at 5-7 kilometres. This unusually thick sedimentary pile has been effected by duplexing and normal faulting and resulted in an accretionary prism 25-30 kilometres wide. Below the accretionary complex, an abandoned slab has been detected by seismic tomography at a depth of ca. 70 km below the west coast of the island. Therefore, short-lived NE dipping subduction is suspected to have existed below the west coast of New Caledonia; however, no related magmatic activity has been reported yet.

Upper Tertiary granodioritic intrusives have been known for a long time to exist in New Caledonia and they have been classically interpreted as a product of post-obduction crustal melting; however, this interpretation does not account for the geochemical features of this plutonic rocks and we propose here a new interpretation in terms of subduction-related plutonism.

Granodioritic plutons are typically 0.5 to 2 km wide and crop out on both coasts of the island. The two major occurrences are located on the west coast 12 km to the NE of Noumea, near St Louis (St Louis massif), and on the East coast at 55 km to the North of Noumea, near Borindi (Koum massif, from the name an ancient tribal village). Both are composed of several stocks and sub-volcanic dykes emplaced across the lower boundary of the Ophiolitic (ultramafic) Nappe. The intrusive bodies crosscut both autochthonous and allochthonous terranes and typically display contact metamorphism, and thus clearly post-date obduction. Indeed, cooling ages of c.a. 20 Ma (K-Ar) have been obtained on both granodiorites. Plutons are located along steeply dipping faults that crosscut the basal thrust and along which both normal and transcurrent motion occurred. Intrusive bodies display no preferred mineral orientation or ductile deformation; however, decametre to hectometre-thick subvolcanic dykes are likely to be magma-filled tension cracks. Therefore, magma ascent has most likely been controlled by fault location, while the final emplacement of plutons probably resulted from the rheologic contrast that existed between peridotite and sedimentary basement rocks.

Polymetallic Cu, W, Mo, As, Au mineralisation appears closely related to post-magmatic quartz veins and silica-enriched crushed zones located within both granodiorite and hydrothermally altered surrounding rocks (peridotite and/or sediment). The current deposit is probably due to the tectonic remobilization of a Au-Mo or ophyry-type ore.

The St Louis intrusive is composed of relatively homogeneous hornblende-biotite granodiorite containing numerous hypovolcanic dykes and comagmatic enclaves. Microgranodiorite dikes display the same composition as the host-rock; while mesocratic hornblende-rich enclaves likely represent remobilized early hornblende cumulates. The Koum intrusives appear more heterogeneous, and display contrasting hornblende-biotite granodiorite and biotite tonalite; it also contains hypovolcanic dykes and comagmatic enclaves.

Preliminary geochemical data imply slightly potassic calc-alkaline affinities for the St Louis granodiorite. Trace-element ratios are typical of volcanic-arc-related magmatism. It seems to have crystallised from a single batch of magma with no evidence for fractionation during its fast emplacement and cooling. Intrusive rocks from the Koum massif appear more potassic and differentiated than those from St Louis and display more complex features possibly due to magmatic melange and/or crust assimilation.

These geochemical features are consistent with a subduction-related origin for these plutonic intrusives. Magmatic production may be related to the tectonic features found along the West coast of New Caledonia, especially remnants of an east-dipping subducted oceanic slab. The weak magma production associated with this slab may be explained by the short-lived subduction or/and by the vicinity to the trench, which do not allow enough water production to induce large melting of the overlying mantle wedge.

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Field mapping of superficial formations for environmental development and geological hazards mitigation in New Caledonia

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Of the natural hazards that affect the Southwest Pacific region and thus New Caledonia, tropical cyclones are the most frequent and have the most damaging effects. Excess rainfall often triggers slope failures and landslides. Cyclone Anne in 1988 initiated a big "debris flow" in a suburb of Noumea. There was no human death but the damage costs reached 200 million Pacific Francs (about 2 million US\$).

The geological history of New Caledonia is dominated by the ophiolite nappe thrust during the late Eocene over the autochthonous substratum that mainly consists of volcanic rock bars cropping out within sedimentary units. The tectonic contact between the perched ophiolites and the substratum occurs below an impermeable serpentinite sole. The ultrabasic formations underwent isostatic movements with associated faulting and intense tropical weathering responsible for nickel mineralisation, both processes contributing to the weakening of the ultrabasic massif, whose vegetation often suffers from bushfires.

The knowledge of superficial formations is of first importance in terms of land management, environmental development and geological hazard mitigation. Consequently, New Caledonia, jointly with the B.R.G.M. (Bureau de Recherches Géologiques et Minières), has started a pluriannual programme that aims at both mapping the superficial formations and assessing the slope instability hazards within sensitive areas selected by decision makers.

Oral and historical knowledge together with interpretation of satellite imagery and aerial photography were completed by field mapping (scale 1:25 000, with sensitive areas detailed at 1:10 000) of superficial deposits. These new field data are converted into a Geographical Information System (GIS) format and classified into a superficial-formation database to generate thematic and decision-making maps.

Within the ultrabasic massif, hazards increase with the degree of weathering which is mainly developed along the fracturation network. Within the massif, slope represents the most aggravating factor responsible for the following observed hazards, ranked by increasing disorder degree: scars, rockfalls/collapse, lavaka (hydraulic erosion), landslides, and debris flows. Another aggravating factor that occurs within the ultrabasic formations, locally weakened by human

intervention (old-fashioned mining exploitation), is the drainage pattern that can favour transport of erosional products from the massif during or after high rainfalls. From upstream to downstream, torrential overflows along the slope, and alluvial fans, debris jams and flooding at the slope break, can occur.

Within the substratum, localised rockfalls, superficial landslides and erosion have been mapped.

The highly weathered, perched ultrabasic massif, still affected by vertical movements and characterised by a decollement level (serpentinite sole) at its base, represents an unstable geomorphological unit ("*strong downfall potential energy*"). Within this unit, the combination of aggravating factors such as steep slopes, a well-developed drainage pattern, and human intervention (mining, road construction), strongly increases the probability of slope failures at the slope break near the contact with the autochthonous substratum.

Field mapping of superficial formations is of primary importance to both mitigate geological hazards and monitor urban development near sensitive areas such as the foot of the ultrabasic massif characterised by steep slopes locally cut by valleys.

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Recent history of metals accumulation in the Suva, Fiji coastal zone from ²¹⁰Pb and fallout ¹³⁷Cs geochronology

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To investigate the recent, <150-year history of sedimentation and metals accumulation in the Suva (Fiji Islands) coastal zone, we used ²¹⁰Pb geochronology and fallout ¹³⁷Cs penetration depths to date six cores taken from four sites around the Suva Peninsula: two in Suva Harbour (Tamavua River mouth and offshore Grand Pacific Hotel sites) and two in Laucala Harbour (Vunidawa and Vatuwaqa sites). The recovered cores range in length from 27 to 66 cm and largely comprise silty clays with colors ranging from greenish black to reddish brown. The environmental activities of ⁴⁰K, ¹³⁷Cs, ²¹⁰Pb, ²²⁶Ra, ²³⁸U and ²³²Th were determined from down-core subsamples by gamma spectrometry using high-purity Ge detectors with computer spectral data acquisition and analysis at SOEST. Average, porosity-corrected sedimentation rates range from about 0.5 cm/yr at most sites to >1.0 cm/yr at the Tamavua River mouth. The sedimentation rates determined by ²¹⁰Pb geochronology and fallout ¹³⁷Cs penetration depths are in general agreement and are comparable with sedimentation rates found by our previous work in coastal estuaries and embayments in Hawaii.

For total-metals analysis, splits of the sediment subsamples were completely dissolved and solutions analyzed by flame and flameless AAS and by ICP-AES at LANL. The sediments were surveyed for their contents of Ag, Al, Au, As, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Pt, Si, Sn, Ti and Zn. Most samples were below the analytical detection limit of 0.1 ppm Au, 1 ppm Pt, and 3 ppm Mo. Concentrations of Fe and Mn display inverse depth profiles in many of the cores that likely reflect reduction-oxidation control on their relative solubilities. The Ti, Cr, Co and Ni profiles generally co-vary and follow those of Fe and Al, whereas the Si and Ca concentration profiles reflect some organic contribution to the predominately aluminosilicate clay matrix of these sediments. Depth profiles reveal increasing concentrations of Pb, Zn, Cu, and Cd from about 1940 to the 1996 collection date in all cores, attributable mostly to Pb-based gasoline additives and to marine antifoulants and general industrial sources. In the slowest-accumulating GPH and Vatuwaqa cores there is also an increase in concentration of these metals toward the core's base, suggesting another source (mining/smelting activities?) for these metals in the earlier part of the 1900s. The Sn, As and Hg profiles display a more complex accumulation history with several subsurface concentration peaks. In general, these metals show high values in the topmost samples, suggesting their continued use in marine antifoulants and industry. For most samples, Ag is below the analytical detection limit of 0.05 ppm; however, the Tamavua River mouth cores show increasing Ag concentrations toward the 1996 collection date that best correlate with the Cu profiles.

Further analyses of these sediments are planned and will include comparative metal accumulation rates, multivariate factor analysis, and determination of the clay mineralogy and the organic and inorganic carbon and sulfur contents.

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Applied sedimentology of the Nukubuco reef flat, Laucala Bay, Fiji

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Sediments currently being dredged from the back-reef area of Nukubuco Reef, Laucala Bay, consist of generally poorly sorted coarse sands and gravels. The carbonate clasts originate mainly from coral debris (45 %), with lesser amounts of

red algal (20 %), molluscan (15 %; bivalves and gastropods) and foraminiferal (11 %; mainly *Marginopora vertebralis*, some *Amphistegina* spp.) material. Also present in lesser amounts are clasts derived from calcareous green algae (*Halimeda*), crustaceans, bryozoans, echinoderms and ostracods. Samples are of calcium carbonate with generally 2-3 % MgO. The main clast types have the following average MgO contents: coral 0.2 %, molluscs 0.5 %, *Marginopora* 5.6 % and calcareous red algae 7.6 %. The other common foraminiferan, *Amphistegina*, averages 1.42 % MgO. High (greater than about 3 %) values of MgO in the sediment may pose a problem to cement production because of their weakening effect on concrete. MgO in the sediments is coming partly from *Marginopora* (5.6 %) but largely from calcareous red algae (7.6 %). Sand-sized clasts of calcareous red algae are difficult to identify in sediment samples, and much of the algae is in fact present as encrustations on coral clasts. However, analyses of the sediment composition together with the MgO content of bulk samples and individual clasts enabled quantification of the amount of red algal material present.

Experiments have shown that, at least at laboratory scale, excess MgO can be removed in at least two ways. There is a slight preference for higher MgO levels in the larger size fractions, and MgO content can thus be lowered by removing the coarser fractions. To consistently lower the MgO content, it was found necessary to remove all fractions coarser than 1.0 mm; however, the reduction in MgO was variable and the loss of sample was significant at 25-50 %. Alternatively, tumbling the coarser fractions in water preferentially and rapidly removes the outer, algae-encrusted layers. This consistently lowers the MgO levels by about 0.6 %, with the loss of only about 5 % of the sample. The Mg-enriched lime produced as waste has potential value as fertiliser, but it is not yet known how well these experiments would scale up to commercial levels.

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Calcareous red algae and MgO geochemistry: Nukubuco reef flat, Laucala Bay, Fiji

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Sediments from the Nukubuco back-reef area have been studied by Morris et al. (1998; this volume). Initial optical examination of samples showed that the sediments are composed mainly of material derived from coral (65%), molluscs (15%) and foraminifera (11%). Both gastropod and bivalve material is present and the main foraminifera are *Marginopora vertebralis* with some *Amphistegina lessonii* and *A. lobifera*. Clasts formed from calcareous green algae (*Halimeda*), crustaceans, bryozoans, echinoderms and ostracods are also present in lesser amounts.

Bulk XRF analyses of the sediments showed MgO values to range from 2.23 to 3.50 % (average 2.86 %). High (greater than about 3 %) values cause problems in cement production because of the weakening effect on concrete of expansion during hydration of periclase to magnesium hydroxide. As the proportion of MgO in the main components (corals and molluscs) is low (averaging 0.2 % and 0.5 % respectively), the MgO must be derived from *Marginopora vertebralis* (MgO content of 5.6 %), echinoids (MgO 3 %) and calcareous red algae (MgO 7.6%). There is insufficient *Marginopora* and echinoid material, and so red algae must be the most important magnesium contributor.

Calcareous red algal material, although difficult to recognise optically in sediment samples, forms a relatively small proportion of the sand-sized clasts. However, microprobe analyses, scanning electron microscopy and other examinations show that most algal material is present as encrustations on the outer surfaces of coral fragments. For this reason, red algae is probably underestimated in compositional analyses, as the underlying coral framework is much more obvious. Further, misleading results are obtained if the geochemistry of encrusted coral clasts is determined by bulk analysis. The detailed geochemical studies reported here show that 20 % of the sediment is red algae.

Microprobe and scanning electron microscope studies have shown that the algal encrustation is part of complex series of encrusting and microboring events, which are illustrated here. Intense microboring by endolithic organisms such as cyanobacteria, fungi and algae initially affected the outer coral skeleton, with some of the openings becoming infilled with low-magnesium calcite. Calcareous red algae then grew over this surface and were attacked by boring and microboring organisms. Coral is able to resist red algal growth, and so the main encrustation occurs after death of the coral. The abundance of clasts encrusted with red algae may be related to stress events such as severe storms and *Acanthaster* (crown-of-thorns starfish) infestations.

These geochemical studies have commercial implications as, for example, the position of the high-magnesium red algal encrustations and their weakening by intense microboring explain why selective abrasion of the clasts can readily lower the MgO content to levels suitable for cement production.

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Time series of three dimensional temperature field in the Kuroshio Extension and Study on the decadal scale interaction of the Tropics and Extratropics using Ocean Acoustic Tomography System

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JAMSTEC has developed the ocean acoustic tomography system equipped with real-time data telemetry as a new ocean observation system. The tomographic observation experiment for about 3 months was conducted from July, 1997 through September in the Kuroshio Extension region in order to confirm the performance of this system. In this experiment, the system demonstrated that is able to observe the time series of the three-dimensional water-temperature distribution in the sea area of the diameter about 1000 km in a semi-real time.

Also, it was confirmed that the Kuroshio Extension flows along the boundary between the warm water of Kuroshio system and the cold water of the Oyashio system in the observation sea area and the stationary meander exists at the seamount. Furthermore, it was confirmed that the warm water of the Kuroshio system moves northward gradually from July through August and is pushed down to the south by the extending cold water of the Oyashio system in September. This is considered to be corresponding to seasonal change of the upper layer toward the fall from the summer.

In this year, JAMSTEC and APL will carry out another such observation experiment that inspects the hypothesis of Gu and Philandar (1997) that explains the long-term fluctuation seen in El Nino. This substantial observation experiment that uses the ocean acoustic tomography system and satellites will be conducted for two years in the Central Tropical Pacific to detect the existence of the subtropical cell predicted by the hypothesis.

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The volcanic geomorphology of Northern Viti Levu

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Analysis of radial, centripetal and gutter drainage in the volcanic region of northern Viti Levu, Fiji, enabled the delineation of several distinct volcanoes, despite the early Pliocene age and considerable later erosion. Three main shields with calderas, and several smaller volcanoes are mapped. The results are consistent with some other geological and geophysical facts, but do not support the idea that these volcanoes were dominantly submarine eruptions.

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The calculation and application of drought indices in water resource management

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Introduction

Drought is an unusual hazard as, by its very nature, its onset is gradual. Without a quantitative measure of drought severity, water resource managers may be caught in a situation where they appear unprepared and ill-informed. The routine calculation of an appropriate drought index could provide a valuable tool for monitoring and reacting to drought events.

Drought can be defined in many ways; in terms of plant water requirements, fire hazard, catchment yield, groundwater resources, etc., and each requires a different basis on which to calculate a drought index. The Standardised Precipitation Index (SPI) developed by McKee et al. (1993) quantifies precipitation deficits over different time scales. These time scales reflect the impact of drought on the availability of different water resources; soil moisture conditions could be expected to relate to an SPI calculated on a relatively short scale, whereas streamflow and groundwater conditions reflect longer time scales. The SPI was designed to quantify the precipitation deficit for multiple time scales - soil moisture and runoff are not considered.

Drought Index calculations for Rarotonga

A variation of the SPI was calculated by Ricci and Scott (1998) using 69 years of monthly rainfall data from Rarotonga Airfield (Figure 1). The index for each analysed time scale reached a record low during the drought of 1982-83 and this reached an 'Extreme Drought' condition for the 6 and 12 month time scales. Figure 1 shows the significance of time scale when assessing drought impacts: as the time scale increases, droughts of a given severity occur less frequently and are more persistent.

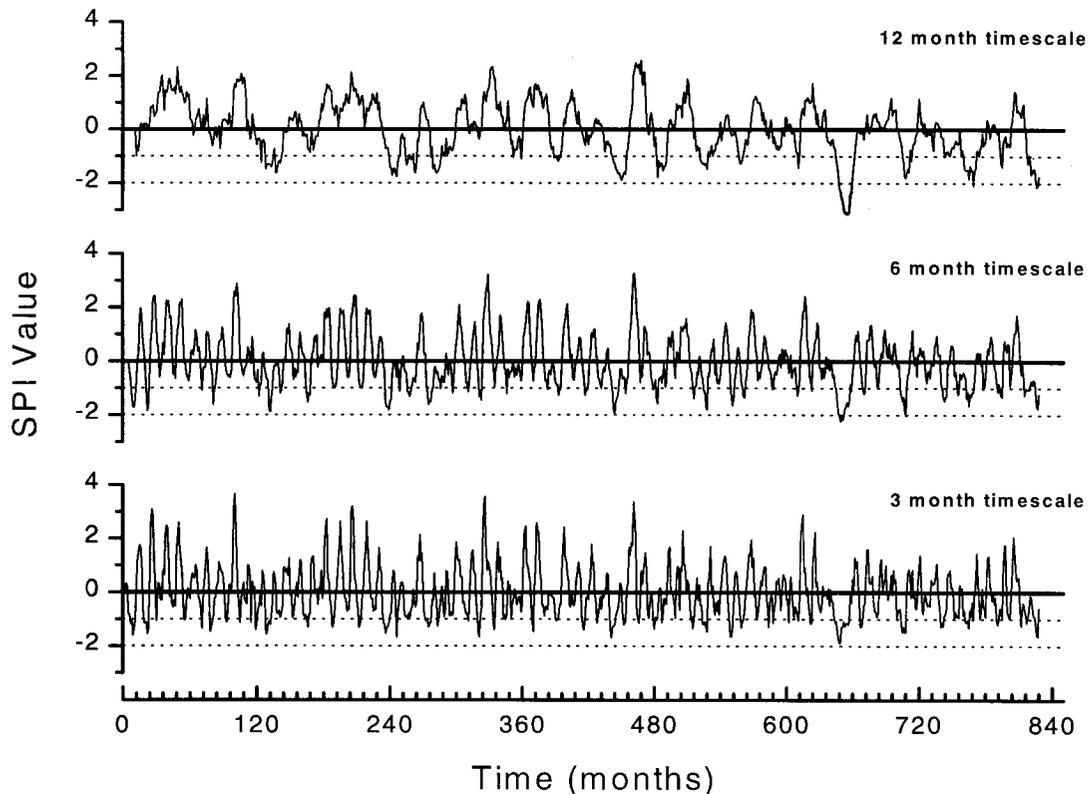


Figure 1: Standardised Precipitation Index for three alternative time scales

In the context of Rarotonga's water supply management, a drought index should, ideally, be simple to calculate, reflect the appropriate time scale for surface catchment yields and use long-term rainfall records which reflect rainfall patterns over the water supply catchments. Some of these requirements can not be achieved with the available data. Until further data are available and the necessary studies undertaken, it should be possible to use the long-term rainfall from Rarotonga Airfield to provide a measure of drought.

A simple weighted sum of recent monthly rainfall totals has been proposed as a simpler alternative to the SPI. Using a ten month window the index closely matches the behaviour of the SPI for a 6-month timescale. This Weighted Sum Drought Index is plotted in Figure 2. Periods when the index fell below 600 (approximately equivalent to the SPI Moderate Drought rating) are marked. The 1982 drought stands out as the most severe for the 69 years of record.

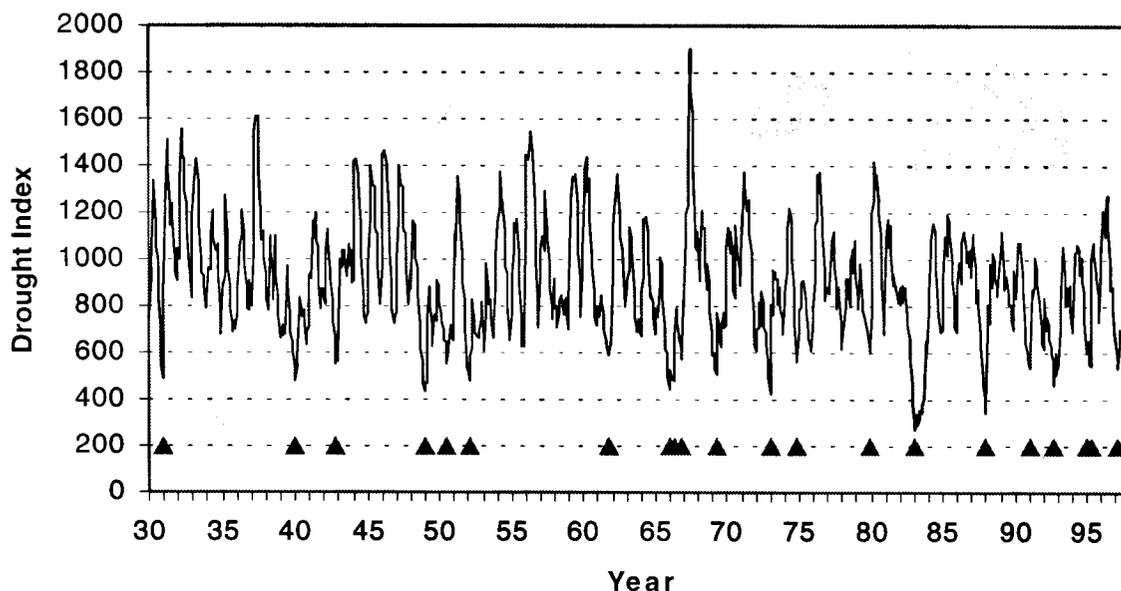


Figure 2: Weighted Sum Drought Index for 1929 to 1997

Drought management strategies

The ability to quantify the severity of a drought makes it feasible to consider a number of management responses. The drought index could be used to provide some objective measurement of the severity of a drought with the following possible responses in mind:

- Initially, the use of public information to increase public and political awareness of the nature of Rarotonga's water supply and to promote conservation efforts;
- Control of irrigation watering from the reticulated supply during droughts of specified intensity and duration; and
- Bans on specified classes of water use during severe or extreme droughts.

Apart from the public information option, these measures would require further analysis and public consultation. A starting point in the development of these strategies could be for the Cook Islands' Meteorological Service to report on drought condition using the Weighted Sum Drought Index or an appropriate alternative measure.

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Current tectonics of the Tonga-New Hebrides region

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A present-day tectonic sketch of the Tonga-New Hebrides region is proposed combining bathymetry, satellite-derived gravity, magnetic, seismicity and geodetic data. Focal mechanisms and a large amount of bathymetric data collected during the last decade in the Lau and North Fiji back-arc basins indicate a deformation distributed on numerous spreading ridges rather than a diffuse and shear-dominated deformation. Data also indicate a large variation of consumption rate along the Tonga and New Hebrides arcs and large variations of opening rate along the Lau and North Fiji basins' spreading centers. Geometry and rate of spreading in the Lau and North Fiji back-arc basins and segmentation of the Tonga and New Hebrides arcs are closely related and significantly influenced by the subduction of aseismic ridges, namely the Louisville, Samoa, D'Entrecasteaux and Loyalty ridges. Slower convergence, arc-transverse strike-slip faulting, thrusting at the rear of arcs, and slow or no back-arc spreading occur where subducting aseismic ridges enter the trenches. Rapid subduction correlates with fast back-arc opening and sometimes requires parallel spreading ridges in the back-arc domain for it to be accommodated.

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A first geological map of Makira, Solomon Islands: stratigraphy, structure and tectonic implications

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Makira is readily sub divisible into the Makira Basement Complex (MBC) and the unconformably overlying Makira Cover Sequence (MCS). Currently available Ar-Ar whole-rock radiometric age data indicates a Cretaceous-Oligocene age (c. 98 Ma - 34 Ma) for the Makira Basement Complex. The Harigha Sandstone Group, a unit within the Makira Cover Sequence, has yielded Mid Miocene to Early Pliocene foraminiferal ages.

The Makira Basement Complex (MBC) forms the great bulk of the volume of Makira (probably c. 90%), of which basaltic lithologies comprise >65%, and locally almost 100% of the sequence. The MBC comprises a basalt dominated stratigraphy (herein termed the Wairahiti Volcanic Group or WVG) with interbedded sedimentary limestones, cherts, sandstones, and basaltic breccias (herein termed the Waihaoru Sedimentary Group or WSG). The WVG is composed of a sequence of basalt, dolerite and gabbro sheets and dykes with local ultramafic sills and intrusions. A total thickness is difficult to estimate as there are few regional stratigraphic units which can be used for correlation purposes; however geological cross-sections suggest a minimum thickness of 2 km. The Waihaoru Sedimentary Group rocks have a wedge - or lens-like morphology, with a local maximum thickness region which quickly pinches out along strike. Individual beds can attain considerable thickness locally (tens to >100 m). Monolithic basaltic breccias are particularly

common within the WSG in the north of Makira. There are no diagnostic stratigraphical units within the basement which crop out on a regional basis, making cross-island correlation very difficult.

The Makira Cover Sequence comprises two main rock groups and an uppermost Quaternary-Recent sequence of alluvium, raised reef, beach, and mangrove swamp deposits. The Upper Miocene to Lower Pliocene Harigha Sandstone Group (HSG) comprises a varied sequence of weak to moderately cemented, poorly to moderately sorted, soft, and sometimes chalk-like, calcareous sandstones and siltstones with occasional interlayer basaltic sheets. The HSG is at least 100 m thick. The Kahua Breccia Group (KBG) comprises monolithic basalt breccias and bi-lithic basalt-limestone breccias which locally grade into coarse, poorly sorted sandstones and interlayer basalt sheets. The KBG is at least 100 - 200 m thick.

Dacite dykes cut the basement at a number of localities. The dykes are several metres to tens of metres thick, fine to medium grained and leucocratic, with phenocrysts to microphenocrysts of hornblende, pyroxene, and feldspar (plagioclase and alkali feldspar) set in a fine-grained felsic groundmass. Flow textures and accessory zircon crystals are common. The relationship of the dacite dykes to the cover sequence is uncertain. Many dykes strike NNE, parallel to the predominant extensional fault trend. The dacite dykes are evidence for a period of arc formation on Makira: corroboratory evidence is provided by earlier workers, who document possible arc-derived epiclastic sediments which crop out in the Arosi peninsula, in western Makira. The intermediate-acid volcanic and volcanoclastic rocks compose the Makira Arc Group, which is post Oligocene (? Miocene-Pliocene) in age.

Compressive folding, extensional faulting, and unconformity structures are all present on Makira. The island is divisible into a number of fault blocks of varying size with NNE-SSW and east-west extensional fault structures separating discrete fault blocks. The density of faulting is greatest in the central, southern and eastern part of the island: western Makira appears to be the least affected by faulting, and contains the largest individual fault blocks by area. Faults are visible on all scales: from island-wide structures to outcrop and smaller scales. Within an individual fault block there is a consistency to the structure: for example within western Makira it is possible to trace individual fold axes and lithological units for 10-15 km along strike. Between many fault blocks, particularly in central Makira, there is often an abrupt 90° change in strike trend from ESE to NNE indicating that there has been significant fault-block rotation. Fold trends are predominantly east to ESE with localised NNE trends, except within local fault blocks as described above. Fold geometry is essentially open and gentle: the degree of shortening is limited. The faulting and folding pattern of Makira can be most easily explained by the highly oblique collision between the Australian and Pacific plates (e.g. Petterson et al, 1997) which induces a predominant transpressive stress regime with resulting north-south compression and east-west sinistral shear. The interplay between the two dominant stresses (i.e. simple shear versus compression) appears to be highly complex with one dominating over the other at certain times and both acting simultaneously at other times. There have been at least two periods of transpression and uplift, separated by a period of localised extension and localised basin formation dated at Mid Miocene to Early Pliocene.

The unconformity between the cover and basement sequences has some intriguing characteristics. Structural cross-sections suggest that the cover sequence has formed within small extensional pull-apart basins, with bounding listric, extensional, growth faults, and which received sediment from rivers draining the surrounding uplifted highlands of Makira. Basalt magma was extruded within these small basins. Despite apparent fault control on the basin margins, the cover sequence exhibits a highly irregular surface contact relationship with the cover sequence, suggesting that the youngest sediments overlapped the edge of the basin and were deposited irregularly on top of the basement. Some fold structures cut straight across the unconformity, suggesting that at least some folding has occurred in the relatively recent past.

Makira appears to be most uplifted towards the south where the highest ridges are located. The major watershed of Makira (which trends east) is located only some 5-10 km north of the southern coast and separates relatively long north-flowing rivers from relatively short south-flowing rivers. The present drainage pattern reflects relatively recent uplift and tilting to the north in response to Makira's present forearc position. This uplift has stripped Makira of the bulk of its deep-sea pelagic and arc rocks. The gross uplift and northward tilting of Makira has a close analogue with Guadalcanal which exhibits a very similar structural style.

The geochronological age structure of the Makiran basement is uncertain as there is poor stratigraphical control across the island. Theoretically the oldest rocks should be exposed in the most uplifted, southern part of the island (this is the case in Guadalcanal for example where there is better geological control). There is some support for this theoretical notion from unpublished preliminary Ar-Ar dating results which have yielded plateau ages of c. 90 Ma from basalt samples taken from the Matangarighi river (SE Makira); c. 55-67 Ma from basalt samples taken from the upper Wairahito river (central-east Makira); and c. 33-35 Ma from basalt samples taken from northern Makira.

It is possible to subdivide Makiran basalt samples on the basis of varying Zr/Nb ratios and Nb concentrations. The bulk of Makiran basalt samples are compositionally most similar to Ontong Java plateau basalts, but a significant number of samples are more akin to 'normal' ocean floor basalts (e.g. Makira 'MORB') or alkaline ocean-island basalts.

A geo-tectonic model of Makira is proposed in which the Makiran basement represents the episodic accretion of oceanic basalts and sediments from the Cretaceous to the Oligocene from a range of oceanic environments. This composite basaltic terrain underwent compression and uplift during post-Oligocene / pre-Mid Miocene times culminating in the formation of an island block. The uplifted island underwent extension / gravitational collapse and erosion which produced a series of local submarine basins into which were deposited basaltic and limestone clastic sediments. An arc

developed on Makira, probably after 8 Ma. Since Late Pliocene times Makira has been subject to intense fore-arc transpression.

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Offshore exploration for heavy minerals in Sri Lanka

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The United Nations Revolving Fund for Natural Resource Exploration (UNRFNRE), in partnership with the Sri Lanka government, committed to an exploration survey for economic concentrations of heavy minerals of the Beruwala area, offshore southwest Sri Lanka. A two-phase program was implemented, Phase 1 to determine the extent of heavy minerals sands containing monazite, ilmenite, rutile and zircon. The second phase, yet to be completed will determine more precisely the quantities and grades of the economic minerals.

The Phase 1 offshore survey was carried out by GSC (Atlantic) utilizing high resolution seismic reflection, sidescan sonar and echo sounder systems. Eleven hundred line kilometers were collected simultaneously over more than 450 km² of the inner continental shelf between approximately 10 and 50 m water depth. Sixty eight surface sediment samples were collected to assist in the interpretation of the geophysical data.

The sediment cover is typically thin (<1 m), thickest sediment accumulations (>14 m) are found in infilled river channels and interconnected basins cut into the seafloor bedrock during periods of lowered sealevel. Eleven potential resource areas were defined, with dredgable sediment at least 2m thick. Gamma ray spectrometry reveals concentrations of monazite in the surface sediments of 0.01% to 1.09%. Conservative total resource estimate is 400 million cubic meters of sediment. These results confirm a high potential for economic quantities of heavy minerals but are insufficient to determine tonnages and grades reliable enough for development decisions.

In Phase 2, a follow up sampling program with vibro-coring or recirculating drilling and full mineralogical and geochemical analyses are recommended to determine the grain size and heavy mineral content of the 11 potential resource areas. The actual resource economics need to be re-evaluated, along with a potential use of the offshore sediments as industrial aggregate, to improve the resource economics.

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The 1997/98 ENSO and Drought in Fiji

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There is considerable intra- and inter-seasonal variation in rainfall over Fiji and the Pacific region. This variation is related to a complex interplay of oceanic and atmospheric influences, and much effort has been directed to research and development to improve understanding of oceanic climates throughout the vast Pacific.

The phenomenon of El Niño Southern Oscillation, a pronounced 'see-saw' of atmospheric pressure differential between Darwin and Tahiti, has been vigorously studied from the early 1980s and found to be linked to extreme weather conditions in the region. Under normal conditions, sea surface temperatures in the western Pacific are 3 to 8°C warmer than elsewhere, whereas a strong El Niño event causes warming in the otherwise cooler eastern Pacific.

During El Niño years, rainfall decreases in the southwest Pacific, but increases dramatically in the normally dry areas along the equator. Therefore, Fiji experiences below average rainfall while islands farther north such as Kiribati receive good rainfalls. Over most of Fiji, rainfall was 20 to 50% below average in September 1997, and deficiencies continued until the end of the wet season in April 1998. This created drought conditions and severe water shortage in many parts of the country.

The current drought has serious economic and social implications, for Fiji Government has already expended substantial resources on emergency water supplies, food rations and the rehabilitation of crops in drought-affected areas. Fiji's sugar industry will suffer heavily through insufficient cane supplies, reduced crushing and major losses in export earnings. Loss of employment on cane farms, in sugar milling and in support industries, coupled with lack of food-crop production, will cause substantial social hardship.

The most difficult period resulting from the drought is likely to be in late 1998, with continued economic hardship in the agricultural sector throughout next year.

Peri-Urban Settlement Project for Suva, Port Vila, Nuku'alofa and Honiara : a regional approach to enhance living conditions in peri-urban settlements

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Growing peri-urban settlements in urban centres is a problem of increasing importance to Pacific Island Countries. Fast and widely growing settlements often lack the necessary infrastructure to provide tolerable living conditions for their inhabitants. Additionally peri-urban settlements are more vulnerable to natural and man-made disasters because of their location in areas less valuable for normal city developments.

Building upon already existing infrastructure data for 4 Pacific Cities collected by SOPAC's "Pacific Cities Project", the "Electricity Utility Project" and a recently undertaken study on "Water Pricing Under Consideration Of Low Income And Poor Households" the project aims to identify problems, solution strategies and to implement them following a participatory approach involving all stakeholders such as settlement inhabitants, NGO's, Utilities, technicians and politicians into the project.

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Water Demand Management and its implication on the Design and Rehabilitation of Water Supply Systems in Auki, Malaita Island, Solomon Island

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The Solomon Islands, with a total land area of 29 785 km² and current estimated population of about 400 000, has 6 major settlements where SIWA is responsible for the water supply and sewer system.

Increasing water demand due to fast growing population (3.5 % p.a.) and rising per-capita consumption results in demand exceeding the current capacity of water supply headworks in all major settlements. This leaves SIWA with the choice to either upgrade the headworks or to influence consumer demand patterns in order to reduce water demand.

The problem SIWA faces is that on one hand, as an autonomous business entity it relies on revenues collected from its consumers (usually consumption dependant) to cover its overall costs, an ever-decreasing demand could jeopardize the entire undertaking. On the other hand, simply meeting the increasing demand would require enormous new investments in infrastructure and the exploitation of more remote and more expensive water resources, together with an increased pressure to recover the investments. This optimisation problem has not yet been resolved by SIWA.

The Auki upgrading

In conjunction with SOPAC Water Resource Unit, SIWA plans to undertake its first major upgrading of a water supply system under a government funding scheme.

Having considered all the facts, SIWA favours a combined strategy using water demand management tools and rehabilitating water supply systems. This involves focussing on unaccounted-for water¹ and consumer information on the demand side, while undertaking carefully targeted development of new water resources. The rehabilitation of the Auki Water Supply System, which SIWA is undertaking with technical assistance from SOPAC Water Resource Unit, will be used as an example for the application of that strategy. Currently the population of Auki is suffering from severe water shortages with water for only ten hours per day, due to a high consumption and a high rate of unaccounted-for water, together with undersized pumps and high water losses at the intake. The current revenue/cost relation is 1/30 per average month (SI\$ 1000 of revenues to SI\$ 30 000 costs (only Operation and Maintenance costs). It is hoped that this strategy will gradually transform the Auki Water Supply operation into a reliable and economically viable service.

The upgrading of the Auki water supply system includes the re-construction of the spring intake to enable the sustainable abstraction of 12 L/s from the spring, the installation of new pumps, rising mains and probably a new storage tank to provide approximately 215 liters per capita per day with a 24 hours a day service.

More technical details will be included when current work on the feasibility study will be finalised.

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Developments in Mapping Technology : Benefiting Environmental and Resource Management

Lee Smith

The latest developments in Mapping technology are greatly assisting in both environmental and resource management.

¹ Note that considering unaccounted-for water as part of the demand is commonly accepted though economically nonsense.

Technology developments include the latest in aerial camera systems, airborne satellite GPS positioning, high-precision and high-resolution image scanning, digital orthophoto mapping and GIS data acquisition. These technologies are providing up-to-date, comprehensive and cost-effective data for mapping natural resources and monitoring development impacts as well as planning and managing our environment.

The latest high-resolution aerial camera systems, with forward motion compensation, are providing sharper and higher-quality imagery. This allows photographs to be taken from higher altitudes, thus reducing the number of photographs and runs for photomapping cover of an area. A change in flying height by 25% can produce significant savings of the order of 50% in project flying and processing costs.

Precision airborne GPSs such as SKYMAP (linked to aerial photography) are significantly reducing the costs of providing ground control for mapping projects. Differential airborne GPS positioning accuracies of ± 0.3 metres are being achieved for the photo centres after aerial triangulation adjustment. This has resulted in minimisation of survey ground control as well as providing improvements in mapping quality control. A further advantage of airborne GPS, is the improved capacity to cost-effectively map complex areas such as offshore reefs and remote areas (such as dense forests).

There has been a major advance in mapping through scanning technology. This has permitted aerial photos to be converted to digital images for viewing on PCs or for computer mapping. Soft copy photogrammetry now permits the digital photo images to be processed and orthophotomaps (corrected photo images) to be produced as hard-copy colour maps or on CD-ROM. Orthophotomaps provide a clear, easily interpreted and cost-effective mapping base. The fact that they can be loaded into a geographic information system (GIS) is a major advantage. This provides the base layer to which other levels of information can be referenced.

Scanning technology ranges from low-cost, moderate-resolution "desktop scanners" through to high-precision and higher-resolution scanners. The significant advantage of the high-resolution scanner is that we can obtain high-quality enlargements. This means we can view images at high magnifications while maintaining image sharpness and quality. It means we can also fly at higher altitudes and save in aerial photography costs.

Digital technology has greatly increased the range of products. These include scanned photos (on CD-ROM), digital orthophotomaps (on CD-ROM or hardcopy) and digital terrain models.

The ability to load this information into a GIS and combine it with other data sets is assisting fields such as coastal monitoring, environmental planning, resource management and hazard assessment.

The latest developments in mapping technology are providing cost-effective and valuable data for scientists and technologists involved in managing our environment and resources.

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The Interactive Graphical Ocean Database System (IGODS) implemented in support of coastal ocean monitoring programs in Fiji

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Increasing population pressure on the coastal ocean, concern about environmental consequences of resource development, and the need for baseline data sets have prompted the initiation of coastal ocean monitoring programs in Laucala Bay, and along the coast between Suva and Navua.

Monitoring surveys are accomplished using a Sea-Bird, Inc. CTD which includes a real-time dissolved-oxygen sensor. Typically, during each survey 20 or more vertical profiles are completed. At each profiling site, discrete measures of temperature, salinity, depth and dissolved oxygen are logged every 0.5 seconds at depths from the surface down as deep as 300 m. As a result, large amounts of data are recorded on to the internal memory of the CTD unit during each survey.

In July of 1998, members of the Mineral Resources Department and SOPAC staff participated in a workshop to provide training in the use of the Interactive Graphical Ocean Database System. This software tool is specifically designed to enable efficient assembly, analysis and archiving of data from groups of vertical CTD profiles.

The IGOADS program helps guide studies at all levels. Design of new monitoring programs is enhanced by the appreciation for spatial and temporal scales of sampling that are considered when a study template or "INC" file is prepared. Issues such as number of stations, geographic distribution of stations, resolution of coverage in 3 dimensions, and inclusion of samples near significant source points are normally addressed during the template development stage. The program uses a GIS interface and includes navigational support programs with GPS inputs to assist in fieldwork by locating the sampling locations defined in the template file. Data quality is supported by the data import functions, which automate removal of equilibration and up-cast data, and provide direct review of downcast data for each parameter with assistance to flag and identify outlier points. Archiving is simple with a single final data file containing all data for a survey. Analysis of the survey results is direct from inside the IGOADS program.

Outputs from the program include summary statistics, vertical profiles of each sampled parameter overlaid and separated into an approximation of the spatial distribution of the original sampling locations, 3D views of transects and constant depth planes, and 3D animations.

Results from two monitoring programs begun in 1998 are analyzed using 2D and 3D views and animation. The existing monitoring programs include an offshore, Suva to Navua survey, which includes 20 sampling sites distributed along 40 kilometers of coast, and a survey of Laucala Bay, adjacent to Suva. In addition, two previously completed special studies have been analyzed using IGODS; a survey of Savusavu Bay that includes over 200 CTD profiles, looking for signs of geothermal activity, and a study of the water column structure in Majuro lagoon immediately before and after a cyclone.

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Tuffaceous rocks from the Vatukoro Greywacke, Nalawa area, northeastern Viti Levu, Fiji.

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Exposure of the Vatukoro Greywacke in the Nalawa area is characterised by individual beds of coarse to fine grey sandstone and interbedded mudstone, usually less than 3 m thick. Strata up to 40 cm thick containing 25 to 50 % angular mafic crystals occur within this well-bedded sequence. These are typically massive and darker in colour than surrounding grey rocks, with most of the mafic detritus consisting of pyroxene and hornblende crystals larger than surrounding sand-sized grains. Mafic crystals are also concentrated (up to 20 %) at the base of individual flow units in some massive grey sandstones. The angular, crystalline character of most of these detrital mafic grains indicates minimal sedimentary transport, and it is assumed that these crystals were re-deposited soon after their appearance from a submarine eruptive column.

White to pale yellow tuffaceous rocks occur with the dark crystal-rich tuffaceous sandstones. These rocks typically have a coarse basal layer with white angular feldspar fragments and flakes of detrital biotite oriented parallel to bedding, and overlain by a cream to pale brown tuffaceous mudstone. The basal portions of these beds are often heavily bioturbated. The presence of tuffaceous mudstones and crystal-rich sandstones indicates that at times, a significant component of the Vatukoro Greywacke was derived directly from adjacent active volcanic sources.

New exposures along the Kings Road also reveal a poorly bedded sequence of crystalline and juvenile volcanic lithic detritus at least 25 m thick overlying the well-bedded Vatukoro Greywacke. These two units are unconformable, with fragments of mudstone from the Vatukoro sequence incorporated into the overlying tuffaceous unit at the contact. While similar poorly bedded tuffaceous rock has been reported from the Vatukoro Greywacke close to the Tavua Caldera in central Viti Levu (Rodda 1976) this is the first record from the Nalawa area. Although the stratigraphic and temporal relationships between the Vatukoro Greywacke and the tuffaceous unit are as yet uncertain, the presence of this unit indicates increased Ba Group volcanic activity in this area.

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Recent observations of the Barotu Sandstone: with implications for Late Miocene strike-slip basin sedimentation on Viti Levu, Fiji.

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Late Miocene (post-Tuva Group) sedimentation on Viti Levu (Rodda 1994) is dominated by numerous small, geographically isolated basins. In southern and southeastern Viti Levu several areas of the upper Medrausucu Group have a Late Miocene to Early Pliocene succession. Elsewhere the basins are restricted to the Late Miocene, and include rocks of the Navosa Sedimentary Group in the southwest, the Nadi Sedimentary Group in the west, and the Ra Sedimentary Group in the northeast of Viti Levu. While there may be some tectonic significance to the apparent absence of Early Pliocene sedimentary rocks in the Nadi, Navosa and Ra groups, the onset of widespread volcanism across northern Viti Levu at this time (Koroimavua Volcanic Group and Ba Volcanic Group) makes it difficult to compare the Early Pliocene histories of these basins with those of the Medrausucu Group.

Recent work on the Nadi and Navosa groups indicates that they were deposited in strike-slip basins (Hathway & Colley 1994). The stratigraphy of these two basins is broadly similar, both having a coarse basal unit (Lidilidi Breccia in Nadi group, and the Vunamaoli Conglomerate in the Navosa group) overlain by a finer unit (Natawa Mudstone in Nadi group, and the Tamanua Formation and undifferentiated sedimentary rocks of the Navosa group). This stratigraphic succession is typical of strike-slip basins. A similar sequence is observed in the Ra group with an area of outcrop in the south of Ra Province dominated by the basal Wailoa Conglomerate, and the northern outcrops dominated by the overlying Barotu Sandstone. The general similarity between the stratigraphy of the Ra group, and that of the Nadi and Navosa groups, indicates that this Group may also have formed in a similar strike-slip basin setting.

New exposures of the Barotu Sandstone along the Kings Road show many features of rocks deposited in strike-slip or oblique-slip basins. These include rapid lateral facies changes, intraformational breccias and the presence of rocks deposited by high-density mass flows. The sequence is also extensively deformed, with numerous, often tight folds and associated faults observed, some of which may be syn-depositional. Among Late Miocene rocks exposed on Viti Levu, only the Nadi, Navosa and Ra groups are mapped as showing extensive folding, implying an overall similarity in their tectonic regime. The NE-SW spatial distribution of the Nadi and Navosa groups and probably the Ra group is most likely related to the sinistral shear regime thought to have been predominant over much of Viti Levu at this time (Hathway 1993; Hathway & Colley 1994).

The stratigraphy and composition of the Ra Sedimentary Group is currently being investigated to determine if these rocks formed a depositional and tectonic environment similar to the Nadi and Navosa Sedimentary Groups.

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A review of some processes occurring along the Tofua Volcanic Arc, Kingdom of Tonga

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The Tofua Volcanic Arc (TVA) is an active island arc in the SW Pacific where a varied range of volcanic processes is occurring. Periods of activity reported during the last two centuries have included both subaerial and submarine eruptions. Several eruptions have resulted in the formation of islands. This paper will outline some of the preliminary results of work that has been undertaken by the author over the last three years, and will discuss recent submarine activity that has in some cases been hitherto unreported. It will also review several instances of probable volcanic edifice collapse that may have occurred during the recent past, particularly that which may have occurred at *Hunga Tonga* and *Hunga Ha'apai* and on *Late*.

Eruptions reported at *Metis Shoal* have commonly formed volcanic islands that have persisted for only weeks or a few months after the cessation of activity. The island formed during the 1995 eruption is, however, still present with mild fumarolic activity occurring. Because of *Metis Shoal's* remoteness, periods of activity that have been entirely submarine in character may have gone unobserved and hence unreported. One such period of activity was occurring during June 1991 when aerial photographs were taken. Pumice rafts were reported in the region of Fiji prior to and after this time, originating from an unknown source.

The 1973 submarine eruption in the region of *Curacoa Reef* produced extensive pumice rafts which moved to the NW. This eruption was anomalous in that activity was reported at several localities that were some distance apart. Seismicity followed by submarine activity was reported near *Curacoa Reef*. Further reports, however, located activity 35 km to the NW of *Curacoa Reef*. At the time, the location of one of the reports was assumed to be in error. Recent surveys of this region of the TVA have identified a major volcanic structure at a location of the presumed anomalous report. From an analysis of data now available, it is possible to suggest that eruptions may have been occurring at the two sites.

The morphology of several volcanic centres along the TVA suggests that edifice collapse, on varying scales, may have occurred during the recent past. *Hunga Tonga* and *Hunga Ha'apai* are the remnants of a once much larger volcanic structure. From the orientation of the islands and the location of the recently active vents, a large-magnitude collapse event has occurred to produce a large submarine caldera. The date of the event is, at this stage, unknown. Historical records or oral traditions do not make reference to this event, suggesting that it may have occurred prior to the colonisation of the region.

Evidence to suggest that edifice collapse has occurred on *Late* was collected during recent fieldwork. The summit crater of *Late* is breached to the South. An extensive fan-shaped pyroclastic deposit crops out on the flanks of the cone below the breach. Reports of this type of activity on *Late* are unknown. An analysis of the relationships of the recent products suggests that a collapse event of this type may have taken place following the emplacement of a series of lava flows on the upper flanks of the cone, possibly during the 1854 eruption.

The implications of the occurrence of these types of volcanic event are considerable. Pumice rafts produced during submarine eruptions are known to have disrupted shipping and affected the coastal regions of a number of neighbouring countries. The loss of life or large-scale damage as a result of this type of activity is unknown and probably unlikely. Edifice collapse, however, has the potential to cause considerable damage and loss of life within the Kingdom of Tonga and in neighbouring countries, particularly when tsunamis are generated during the events. Thus, processes such as these need to be considered when developing hazard management plans within both Tonga and its near neighbours.

Hydrothermal activity in the Eastern Manus Basin, PNG: an update

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The PACMANUS-IV Cruise of RV *Franklin* in October 1997 (a collaboration between CSIRO, University of Toronto, and Geological Survey of PNG) undertook further detailed surveys and sampling of the PACMANUS and SuSu Knolls hydrothermal sites discovered in 1991 and 1996 respectively. Other previously untested volcanic edifices in the Eastern Manus Basin were also examined, resulting in two new hydrothermal discoveries, and several echosounding surveys were conducted to establish links between major basin and onshore fault structures. The EMB now contains eight known hydrothermal sites. These are, from west to east, Marmin Knolls, Northwest Pual Ridge, PACMANUS, Northeast Pual Ridge, Yuam Ridge, DESMOS Caldera, SuSu Knolls and Nimab Volcano. The host volcanics range from picritic basalt to rhyodacite.

At PACMANUS, further camera tows and dredges were conducted across the Cu-Au-rich Roman Ruins chimney field, actively forming Pb-Zn-rich chimneys were found in a southwestern extension of the main site, and two subsidiary volcanic eruptive centres to the east and northeast were tested with negative results. At the diffusely venting Snowcap field of altered dacite, a 1 m x 1 m square funnel with temperature sensor and an attached Niskin bottle (termed VUNL) was deployed to the seafloor to sample low-temperature hydrothermal fluids. Despite some teething problems with the prototype (including a shark attack on the transducer used to acoustically release the Niskin), the exercise was a technical success and three seawater-diluted fluids with anomalously high Fe, Al and Mn contents were recovered.

At SuSu Knolls, camera tows and dredge or grab deployments expanded the Cu-Au-rich Suzette chimney field and established the presence of pyritic chimneys or mounds on both North Su and South Su, the two high-standing cones of very porphyritic dacite. The 1050-1150 m particulate plume from venting at North Su is intense and rapidly evolving. Between November 1996 and October 1997, it had shifted direction from southeast to easterly while now travelling more than 20 km, and the maximum transmission anomaly had increased from 30% to 40%. A deeper plume (1300-1600 m) encountered in 1996 and apparently derived from South Su had practically vanished.

Of the two new sites, Nimab is a large volcano in the easternmost EMB, built on mildly deformed ?Pleistocene sediments, with basal porphyritic andesites passing upward into porphyritic dacite. A dredge on the 1300 m crestal region recovered altered porphyritic dacite plus Fe-oxide crusts and green-yellow clays, while a camera tow recorded hydrothermal crusts and possible weakly active mounds. Fragments of sulfide-bearing altered dacite were sampled during an accidental camera collision with a mound. No particulate plume has been traced to Nimab.

Marmin Knolls is an area of numerous mafic cones in the western part of the EMB, all composed of olivine-rich basalt flows and fragmental deposits. At one knoll sampled in 1997, dredged lavas are thickly coated with Mn oxides, and hemipelagic ooze from the vicinity is anomalously enriched in transition elements. A sample of porous baritic chimney with Mn-encrusted wall was also collected, with disseminated sulfides (dominant pyrite with traces of sphalerite, chalcopyrite and galena) and containing 7 ppm Au and 117 ppm Ag.

The 1500 sq km EMB is comparable in size with significant mineral provinces on land. We expect to continue investigations aimed at understanding factors that govern the location, size and grade of mineralisation in this modern environment, and at transferring this knowledge to land-based mineral-exploration strategies. Planned future work in the EMB for 1999 and beyond includes:

- Deployment of an improved VUNL instrument to sample diffusely venting fluids at PACMANUS and Susu Knolls.
- Drilling at PACMANUS and Susu Knolls, using the Australian PROD seafloor drill. A proposal for deeper drilling at PACMANUS is also being considered by the Ocean Drilling Program
- Deploying an Australian miniature ROV to map and sample deposits and high-temperature vent fluids at SuSu Knolls and other mineralised sites.

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LATE ABSTRACT – POSTER

Collaborative research action on the influence of anthropogenic inputs on lagoon environments.

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Economic development in the tropical zone corresponds with extensive modifications of the coastal environment. Pacific island states with limited resources and limited land are particularly sensitive to the conflict between their short term needs for economic development and long term concern about environmental conservation. The ECOTROPE programme is a recent joint ORSTOM (L'Institut Français de Recherche Scientifique pour le Développement en Coopération), USP (The University of the South Pacific) and SOPAC (South Pacific Applied Geoscience Commission) scientific action looking at the influence of terrigenous and anthropogenic inputs on the lagoons of Suva (Fiji) and Nouméa (New Caledonia).

We are seeking answers to the following scientific questions:

- 1) What are the origin, nature and amount of terrigenous and anthropogenic agents entering the lagoon ?
- 2) How are those agents transported and modified in the coastal zone ?
- 3) How do terrigenous-anthropogenic inputs modify pelagic and sedimentary environments?
- 4) How do shifts in environmental conditions modify living communities (pelagic, benthic, and fish) ?

This paper presents the various aspects of environmental sciences we are currently covering. Beyond diagnosis, research is also strongly directed toward predictive approaches mainly relying on modeling in different fields (hydrodynamic, particle transport, geochemistry).

The final aim of this program is to provide useful applications for decision-makers who have to deal with sustainable development. The ECOTROPE program is aimed at defining some of the scientific basis necessary to reach environmental diagnosis and edict efficient rules regarding sustainable management of the coastal zone. In the present context we believe that cooperative research is a major challenge that has to be accomplished for gathering significant and efficient scientific forces around the Pacific Island States.