ABSTRACTS OF PAPERS PRESENTED AT THE STAR* SESSION 2005

22nd STAR Session is held in conjunction with the
SOPAC 34th Session (24-30 September 2005)
Hosted by the Government of Samoa at the Kitano Hotel, Apia

John Collen & Lala Bukarau
Editors

SOPAC Miscellaneous Report 603

September 2005

*Science, Technology and Resources Network

SOPAC

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FOREWORD

STAR (SOPAC's Science, Technology and Resources Network) was founded in 1985 in collaboration with IOC. STAR was formed to assist the international geoscience community to provide advice to SOPAC, particularly during the intervals between SOPAC International Workshops. The first Chairman of STAR, Dr Charles Helsley, then Director of the Hawaii Institute of Geophysics, guided STAR until 1992. He was succeeded by Keith Crook from the Hawaii Undersea Research Laboratory. Keith served until the end of 1999 when John Collen from the School of Earth Sciences at Victoria University became Chair.

STAR meetings are not simply technical conferences at which individuals present scientific papers and discuss their results and implications. Participants have the additional responsibility to formulate advice to SOPAC about its Work Programme and to highlight technical and scientific issues of particular importance or urgency to the region. This advice, in the form of reports and recommendations from STAR Working Groups and reports on highlights of STAR technical presentations, is tendered to Council by way of an address in Plenary by the Chair of STAR and during the Governing Council/Technical Advisory Group (GC/TAG) segment of 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 and multi-disciplinary 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 endeavour, 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. During the 1990's it supported the changes in SOPAC's scope and focus that led to the development of the three major work programmes and that are still continuing. Starting this year, Programme Monitoring and Evaluation Groups (PMEGs) comprising TAG scientists, will be meeting with SOPAC Programme Managers and reporting to Council as independent advisers during the joint TAG/Council part of the Annual Session.

In earlier years STAR was primarily concerned with "blue-water" marine geoscience, tectonics and resource exploration and evaluation. However, as national needs and priorities have changed, the scope of STAR has similarly altered, partly reflecting changes in focus of international science but also to ensure that SOPAC's Work Programme and its forward planning are influenced by international science that is both excellent and relevant. The wide scope of the work outlined by the abstracts in this volume is a clear indication that this evolution is continuing. The major theme of this year's STAR meeting, "Disaster Risk Reduction, particularly with respect to natural events in the SOPAC region", has proven very timely given the events of 2005, and the number of presentations devoted to that theme further emphasize the relevance of this meeting to the Pacific.

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September 2005

PROGRAMME FOR 22nd STAR SESSION, 2005

(as @ 14 September 2005)

Time	Theme	Authors & Presenter	Title
Saturday, September 24th Venue: Ocean Terrace, Kitano Hotel			
13:30-14:00	**STAR Opening & Business Meeting** John Collen, Chair, STAR & Cristelle Pratt, Director, SOPAC Venue: _____		
SESSION 1			
14:00-14:20	Tectonics	Kroenke, L.	Victoria Fracture Zone: a failed incipient subduction zone?
14:20-14:40		Kadoshima, K., Arai, S., Wong, H.L. & Tomizawa, N.	Petrology of mafic-ultramafic rocks obtained from the NFFZ: implication for tectonics & hydrothermal activity
14:40-15:00		Taylor, P., Cronin, S.J., Smith, I. & Platz, T.	New evidence for widespread. late Holocene, explosive volcanism along the Tofua Volcanic Arc and its implications on the Kingdom of Tonga in the future
15:00-15:20		Suetsugu, D., Inoue, H., Vuetibau, L. & Mafi, K.	Seismic observations in the South Pacific by international cooperation: on islands and seafloor
15:20-15:50	**REFRESHMENT BREAK**		
15:50-16:10	Tectonics & mid-ocean ridges	Martinez, F. & Taylor, B.	Arc to oceanic seafloor spreading in western Pacific back-arc basins
16:10-16:30		Jeon, D.	KORDI's plan for surveying deep-sea hydrothermal environments
16:30-16:50		Fisher, C.	Ridge 2000 expeditions to the East Lau Spreading Center 2005: life at the vents
16:50-17:10	Disaster Risk Reduction	Taylor, P. & Meija-restrepo, A.	Volcanic Hazards Awareness Program for school children: an example from Niuafo'ou Island, Kingdom of Tonga
17:10-17:30		Mearns, A. & Jones, R.	Disaster risk reduction & disaster management: 'The Pacific Islands Framework for Action 2005-2015' & its international & regional contexts
Saturday, September 24th evening – Icebreaker			
Sunday, September 25th morning – Meetings of Working Groups			
Sunday, September 25th afternoon – Picnic & Volleyball Tournament			
Monday, September 26th SESSION 2, VENUE: Ocean Terrace, Kitano Hotel			
09:00-09:20	Disaster Risk Reduction	Bell, R. & King, A.	Regional Riskscape Model: quantifying & comparing consequences of natural hazards
09:20-09:40		Saunders, W., & Becker, J.	Planning for recovery before an event occurs
09:40-10:00		Biukoto, L.	Information management for disaster risk reduction
10:00-10:20		Rahiman, T. & Pettinga, J.	The source of the Suva tsunami of 14th September 1953, Fiji
10:20-10:50	**REFRESHMENT BREAK**		
10:50-11:10	Disaster Risk Reduction – tsunami, volcanoes & landslides	Bell, R.	Lessons from Boxing Day Tsunami: implications for disaster reduction & detection/warning systems
11:10-11:30		Glassey, P. , Trustrum, N. & Brackley, H.	Tsunami hazard in the Pacific: lessons learnt after the 26 December 2004 Asian tsunami
11:30-11:50		Neméth, K. & Cronin, S.J.	The 1913 phreatomagmatic mafic explosive volcanism in w. Ambryn, Vanuatu & its implications for volcanic hazard
11:50-12:10		Cronin, S.J. & Charley, D.	Combining traditional and scientific views for community disaster education in Vanuatu
12:10-12:30		Rahiman, T. & Bonte, M.	Discoveries at the Namosi Gap, central southeast Viti Levu, Fiji

12:30-14:00	**L U N C H**						
Monday, September 26th							
SESSION 3A Venue: Ocean Terrace, Kitano Hotel				**JOINT SESSION 3B Venue: Stevenson Fale, Kitano Hotel**			
14:00-14:20	Disaster Risk Reduction – landslides, cyclones & community involvement	Buleka, J.	Causes of siltation in Lae, PNG 2004				
14:20-14:40		Naidu, P.	Natural hazards in the tropical SW Pacific: community risk & vulnerability analysis in tropical cyclone prone areas				
14:40-15:00		Ramsay, D., Puka, H. & Jensen, T.	Reducing the impacts of cyclone storm surge inundation on the atolls of Tokelau				
15:00-15:20		Leenders, N.	Disaster risk reduction though hazard and vulnerability mapping: a multi stakeholder approach, Lae, Papua New Guinea				
15:20-15:50	**R E F R E S H M E N T B R E A K**						
15:50-16:10	Disaster Risk Reduction – economic aspects	McKenzie, E.J., Prasad, B.C. & Kaloumaira, A.	The economic impact of natural disasters on development in the Pacific: research report and economic assessment tools	15:50-16:10	Minerals	Cronan, D.S.	Cook Islands manganese nodules revisited
16:10-16:30		Crimp, R., Cronin, S. & Charley, D.	Dental fluorosis attributed to volcanic degassing on Ambrym Volcano, Vanuatu	16:10-16:30		Okamoto, N.	Japan-SOPAC co-operative deepsea mineral resources study programme: the summary of the programme
16:30-16:50	Oceans & Coastal	Drexel, J., Montoya, J., Garton, D. and others	Stable isotope analysis of lagoon food webs: potential for assessing impacts of pearl oyster farming	16:30-16:50		Iizasa, K.	Japan-SOPAC co-operative deepsea mineral resources study programme: exploration for hydrothermal sulphide deposits
16:50-17:10		Kitazawa, K.	Monitoring buoys and ARGO floats [no abstract received]	16:50-17:10		Usui, A.	Japan-SOPAC co-operative deepsea mineral resources study programme: exploration for ferromanganese deposits
17:10-17:30		Grimes, S.	Future Directions for Marine Science, Oceanographic Monitoring & the Pacific Island Global Ocean Observing System (PI-GOOS) in the Pacific	17:10-17:30		Matsumoto, K. and others	Results of environmental survey in South Pacific waters 2000-2005

Tuesday, September 27th

JOINT SESSION 4A Venue: Ocean Terrace, Kitano Hotel				JOINT SESSION 4B Venue: Stevenson Fale, Kitano Hotel			
09:00-09:20	Oceans & Coastal	Callaghan, D.P. and others	Atoll lagoon flushing by forced waves	09:00-09:20	Water	Grover V.I., Mayfield, C., Daley, R.J., Babel, M.S., Kahsai, K. & Ofori-danson, P.K.	Integrated water resources management – its development and water virtual learning centre
09:20-09:40		Kim, S.-P., and others	Bathymetry and morphology of the southeastern lagoon area in Savai'i Island, Samoa	09:20-09:40		Iddings, S. & Davies, S.	*Water Safety Plans: a tool to safeguard drinking water quality in Pacific Island Countries*
09:40-10:00		Chang, S.W. and others	Coastal geological mapping of Savai'i Island, Samoa	09:40-10:00		Fatiaki, M.	A community-based water monitoring toolkit using the H2S paper strip test
10:00-10:20		Pickrill, R.A.	Habitat mapping and national seafloor mapping strategies in Canada	10:00-10:20		Hasan, T.	Pilot wetland in Tagaqe Village, Coral Coast, Fiji
10:20-10:50	**REFRESHMENT BREAK**						
10:50-11:10	Oceans & Coastal	Pohler, S., Lovell, E. & Zann, L.	Aspects of vulnerability of the Suva area (Fiji) to seaborne threats	10:50-11:10	Water	Eti, I.	Hydrology, Samoa
11:10-11:30	Energy & Aggregate	Mario, R. & Fairbairn, P.	Demand side management in the Pacific	11:10-12:30		Water Working Group	Planning meeting for Pacific position paper for 4th World Water Forum
11:30-11:50		Cloin, J.	Coconut oil biofuel – clean and competitive				
11:50-12:10		Tawake, A.	Promotion of sustainable development of aggregate resources in the Kingdom of Tonga: offshore aggregate extraction north of Tongatapu				
12:10-12:30							

Tuesday, September 27th afternoon	Meetings of Working Groups

Wednesday, September 28th 09:00-10:00	**Official Opening of SOPAC Governing Council 34th Session**

ABSTRACT OF PAPERS

ANTON & McKEE

Papua New Guinea Building Construction Seismic Zoning

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Seismic zoning for building construction in Papua New Guinea (PNG) was introduced in 1971 (PNG Statutory Instrument No. 44 of 1971), based on the occurrences of earthquake intensity 8. The seismic zoning was later revised when the PNG National Standards Council and Department of Works, in consultation with various PNG authorities, commissioned engineering consultants Beca, Carter, Hollings and Ferner Ltd to develop a seismic zoning map. The development of the seismic zoning map was reported by Jury, et al. (1982) and PNG National Standards Council (1983). The map is shown in Figure 1.

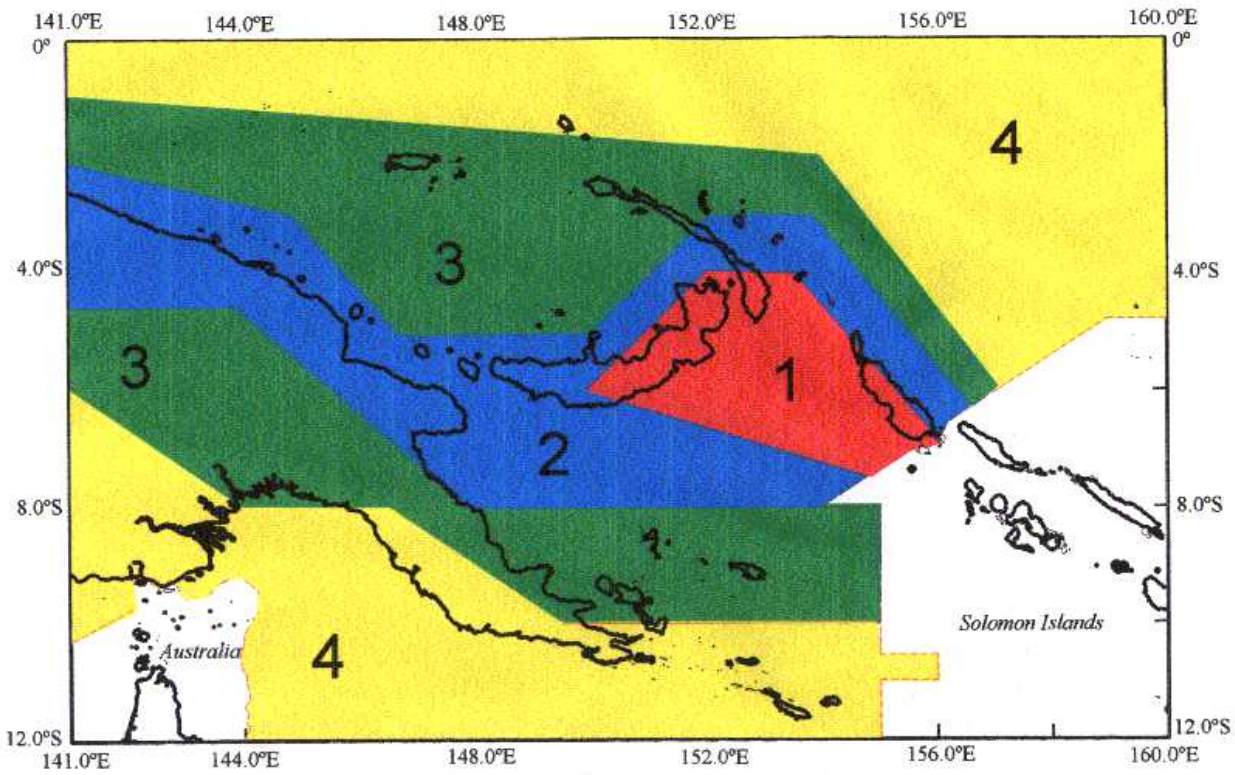

Figure 1. *Seismic Zones for building construction in PNG: zone 1 included accelerations of 0.68 g or greater, zone 2 accelerations of 0.54 g – 0.68 g, zone 3 accelerations of 0.4 g – 0.54 g and zone 4 accelerations less than 0.4 g.*

It has been recognized for some time that this map of seismic zones is in need of revision. Adequate local acceleration attenuation data was not available at the time when the seismic zoning map was developed, which led to use of data from Indonesia and New Zealand in the development of the map. The zoning was also criticized (McCue, 1984) because it does not closely match the seismotectonic framework of Papua New Guinea.

The seismicity of Papua New Guinea has been studied in detail for over 30 years, and is reasonably well understood. The distribution of seismicity in the region is shown in Figure 2. Shallow earthquakes occur either on or near plate boundaries, and also away from the plate boundaries in areas of crustal deformation. Seismic activity is greatest in the area of the northern Solomon Sea, while the area of lowest seismic activity is in the south and southwest of Papua New Guinea.

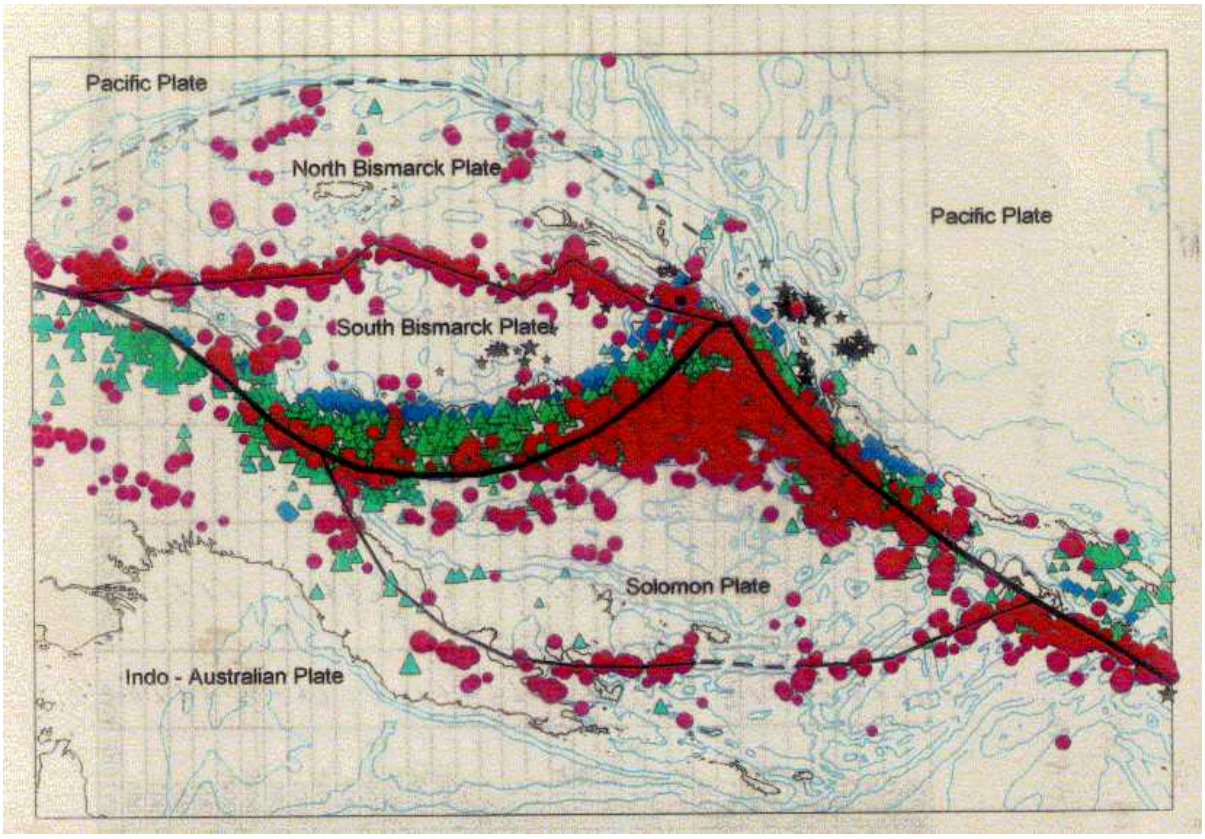

Figure 2. *Papua New Guinea seismicity and tectonic plates. Red circles denote depth range 0-39 km, green triangles denote range 40-99 km, blue diamonds denote range 100-299 km and black stars denote depths greater than 300 km.*

Comparing Figures 1 and 2, the well recognized plate boundaries and seismic zones of the Bismarck and Solomon Seas are not well reflected in the seismic zoning map. The seismic zone of the Papuan Fold Belt which coincides with a broad zone of Pliocene/Quaternary faulting and folding caused by collision of the South Bismarck and India/Australia Plates is also not well reflected in the seismic zoning map. This seismic zone should appear as a separate feature, separated by 200 km from the active northern coast PNG mainland zone. A third main concern is that Seismic Zones 3 and 4 of mainland PNG should be in better agreement with the seismicity and geology of the western part of the Solomon Plate.

A new revision of the PNG seismic zoning is now possible as Port Moresby Geophysical Observatory (PMGO) has a comprehensive earthquake database and a large collection of accelerograms, recorded on medium or soft foundation, some of which have been analysed by the then Bureau of Mineral Resources, Geology and Geophysics (now Geoscience Australia) and others have been analysed by PMGO.

Seismic acceleration attenuation relationships for the entire PNG region should be derived from analysis of the accelerograms and synthesized with the distribution of seismicity and the geology and tectonics of the region to produce a new map (or maps) of seismic zoning. The resultant map (or maps) should correlate closely with the distribution of shallow seismicity. Seismic zoning boundaries should parallel or coincide with seismic zones (and lineaments) and their levels correspond to the density of epicenters. Smoothing processes should continue boundaries across seismic gaps. Additionally, the seismic zoning maps should continue across political boundaries.

References

Jury, R.D., Hollings, J.P., and Fraser, I.A.N., 1982. The development of seismic zones and the evaluation of lateral loadings for earthquake resistant design of buildings in Papua New Guinea. *Bulletin of the New Zealand National Society for Engineering,* 15: 123-140.

McCue, K.F., 1984. Discussion of paper "The development of seismic zones and the evaluation of lateral loadings of earthquake resistant design of buildings in Papua New Guinea, by R.D. Jury, J.P. Hollings and I.A.N. Fraser". *Bulletin of the New Zealand National Society for Earthquake Engineering,* 17: 292-296.

Papua New Guinea National Standards Council, 1983. Code of practice for general structural design and design loadings for buildings, Part 4, Earthquake loadings. Papua New Guinea National Standards Council, Boroko, Papua New Guinea.

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ANTON & McKEE

Tectonic significance of the magnitude 7.8 Wewak Earthquake of 9 September 2002, Papua New Guinea

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The magnitude 7.8 (Ms) "Wewak Earthquake" of 9 September 2002 was one of the largest earthquakes ever recorded from the northwestern part of mainland Papua New Guinea. The earthquake was shallow and its epicenter was located at 3.2°S, 142.9°E, just offshore and about 90 km west-northwest of Wewak. The strong shaking caused serious damage to numerous houses and water tanks, triggered many landslides and created ground cracks. Uplift of as much as 30-40 cm occurred at the "Wewak Islands", Tarawai, Walis, Kerasau, Kairiru and Muschu. A moderate tsunami, having maximum amplitude of 3-4 m, was generated at the same time as, or soon after, the earthquake.

The focal mechanism of the earthquake may have involved both overthrusting and strike-slip movements, but dominantly the former (Figure 1). The wide separation of the hypocentre and the location of the centroid of the moment tensor solution suggests a large rupture surface. This finding is supported by the great extension (about 180 km) of the aftershock distribution field (Figure 2). The predominantly overthrust focal mechanism for the main earthquake and the approximately east-west orientation of the aftershock distribution field are consistent with the main pattern of faulting in the east-west trending coastal mountain ranges.

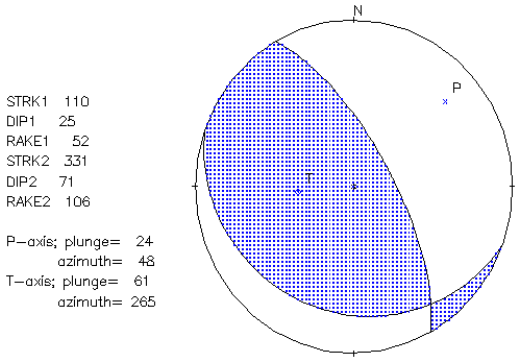

Figure 1. *Focal mechanism solution by Harvard University.*

Two large aftershocks (magnitude 6) about one week after the main earthquake were located at the western end of the aftershock distribution field. Their normal faulting mechanisms and their locations suggest movement on a northeast trending cross-fault system, which terminates the main east-west overthrust (and transcurrent) rupture surface.

The tectonic significance of the September 2002 "Wewak Earthquake" is that it represents a major overthrust movement of the leading edge of the India-Australia Plate, contributing to the long history of uplift of the coastal region of northwestern Papua New Guinea.

ARTACK & LAL

Pacific Regional Maritime Delimitation Boundaries Project

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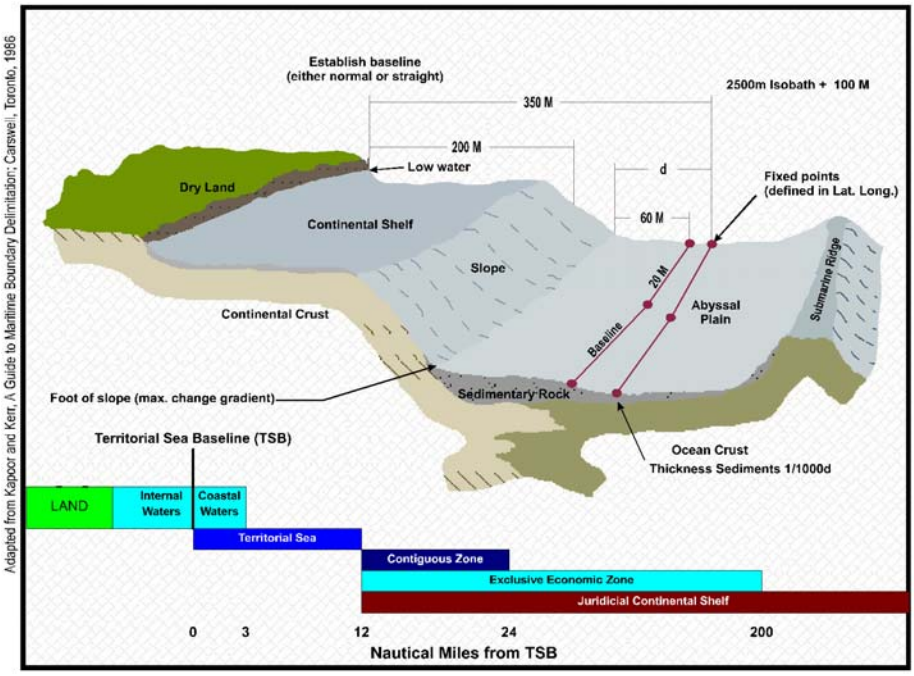
At the 28th Session of SOPAC held in October 1999, the Governing Council endorsed a proposal for the transfer of the Maritime Boundaries Delimitation Project from FFA to SOPAC. Similar endorsement was forthcoming from the Forum Fisheries Committee [FFC] at their 44th Meeting in May 2000, subject to preparation of a joint submission by FFA and SOPAC seeking approval from AusAID [Donor] for the Project and remaining funds to be transferred to SOPAC.

The United Nations Convention on the Law of the Sea 1982 [UNCLOS] is accepted by an overwhelming majority of states, as a body of international law governing the broadest possible agenda of ocean issues. Under customary international law, as reflected in the United Nations Convention on the Law of the Sea 1982 [UNCLOS], each South Pacific Applied Geoscience Commission [SOPAC] member country is entitled to four maritime zones seaward of the territorial sea baselines. These are:



12 nautical mile [NM] territorial sea
Contiguous zone [CZ]
200 NM exclusive economic zone [EEZ]
Continental Shelf

There is a need to determine a boundary between the zones of neighbouring countries where the potential maritime zones overlap. There are a total of 45-shared boundaries between SOPAC/Forum Fisheries Agency [FFA] member countries and neighbouring countries. The settlement of these boundaries helps regional stability and gives certainty to the ownership and management of maritime resources. In particular

settled maritime boundaries provide a firm foundation for bilateral and regional resource management arrangements and for effective surveillance and enforcement.

The absence of an agreed maritime boundary, which is both binding at international law, and reflected in domestic legislation, may give rise to difficulties in enforcement. It may lead to a dispute with neighbouring countries over the ownership of resources either in the shorter or the longer term. For example, the absence of established boundaries may give rise to disputes with distant water fishing nations [DWFN].

In order to enhance the above tasks a comprehensive Geographic Information System [GIS] MapInfo database [Pacific Islands Maritime Boundaries Information System – PIRMBIS] is being designed, developed and maintained to validate and store datasets for the 14 countries in the SOPAC region. These include Cook Islands, Fiji, Federated States of Micronesia (FSM), Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea (PNG), Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu.

The Pacific Islands Regional Maritime Boundaries Information System [PIRMBIS] is a geographic information system [GIS], which contains a regional coverage of the maritime limits of Pacific Island coastal States. PIRMBIS is being designed, developed and maintained by SOPAC in consultation with its member countries and Geoscience Australia.

BELL

Lessons from Boxing Day Tsunami: implications for disaster reduction and detection / warning systems

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Up until Boxing Day of 2004, New Zealanders by and large viewed tsunamis as a curiosity – a phenomenon that occasionally reached our shores that provides interesting viewing down at the beach. The wider South Pacific has been no stranger to devastating tsunamis, with the most recent damaging events occurring in the Sissano Lagoon region of PNG on 17 July, 1998 (approx. 2,500 deaths) and on Pentecost Island (Vanuatu) on 26 November, 1999 (6 tsunami-related deaths) with a further earthquake event on 2 January 2002 that impacted Port Vila. Following the recent mega-tsunami that struck several Indian Ocean countries, there has been a flurry of initiatives by different states and groupings of countries to improve tsunami detection and warning systems. The Indian Ocean event also provides an opportunity to learn further lessons about reducing the impact of tsunami risk for coastal states, particularly with the escalating coastal development and population increase that has occurred in the last few decades.

Progress was already underway prior to the landmark Boxing Day event on a number of fronts to improve the awareness of the tsunami risk to coastal communities and the appropriate response/warning systems required. A few examples are:

- Increasing focus on risk (the consequences) of natural hazards (including tsunami) aided by the use of risk-assessment techniques and toolboxes such as the Comprehensive Hazard and Risk Management Programme (CHARM), the SMUG analysis used in New Zealand for prioritising hazard impacts for emergency management, and the new Regional Riskscape Model being developed in New Zealand (separate presentation);
- Major advances in equipment and techniques to image the seafloor, which have resulted in the discovery or much improved definition of offshore faulting, and submarine volcanoes and landslides;
- Application of 3-D tsunami propagation and “dynamic” (rather than “static”) over-land inundation models to assist in quantifying the risk;

- Increasing use of hi-resolution aerial or satellite surveys such as photogrammetry, LIDAR and satellite imagery (e.g., QuickBird or IKONOS) to support modelling and visualisation of tsunami inundation;
- Formation of the Tsunami Working Group for the South Pacific to foster international and intra-regional cooperation that supports tsunami risk reduction activities.

However, much more impetus has been focussed on the Pacific's risk exposure to tsunamis since the Boxing Day event plus there is much we can learn from the calamity suffered by several countries surrounding the Indian Ocean. Some of the lessons that can be gleaned from post-event reconnaissance surveys in Thailand and Sri Lanka (sponsored by Earthquake Commission) are (Bell et al., in prep):

- Saving lives must always be the key objective in managing tsunami risk;
- To achieve this goal, no singular approach will work. Instead it must be a balance of several approaches that transcend the physical sciences, engineering, social sciences, emergency management, education, policy & planning, socio-economic and political sectors in order to achieve resilient coastal communities understanding and managing their hazards including the elusive tsunami threat. These approaches needs to include at least:
    - Robust and timely earthquake and tsunami detection and confirmation systems;
    - Clear and nationally consistent systems for producing and disseminating appropriate warnings, while at the same time minimising false alarms;
    - Clear evacuation and/or refuge systems that are practiced (in part anyway);
    - Improve public knowledge building on the tremendous platform laid by the media coverage of the Boxing Day event – however the knowledge needs to also be institutionalised to retain "corporate memory";
    - Timely response & recovery operations during and after the event;
    - Reduction in the risk (or at least holding the status quo) through strong policy and planning provisions (e.g. managed retreat, set-back zones, but working together with communities and involving the real-estate, insurance, engineering and local/regional government sectors;
    - More encouragement for community-based coastal dune, coral-reef and beach care rather than hardening coastlines — dunes, high beach ridges and coastal vegetation are useful as evidenced in Thailand and Sri Lanka. (It is recognised that developed urban shorelines may need protection works, although sustainability of such works in the long-term with climate-change effects looming will be an increasing issue to grapple with.)
- Infrequent, mega-tsunami can cause total catastrophic damage to timber and masonry buildings at the coast, so not much can be done economically to improve the tsunami-resistance of existing buildings and infrastructure. However, some tsunami proofing may be possible for new developments e.g., more open ground-floor spaces, improved tie-downs to foundations. However, the key objective and priority of effort to prepare for large tsunami events must remain the saving of lives.

Following the Boxing Day event, various Governments are working on developing or bolstering their tsunami detection and warning systems under the umbrella of the International Oceanographic Commission (IOC). The NZ Government are embarking on the development and operation of purpose-built tsunami detection and warning system for New Zealand. This project is being coordinated by Land Information NZ (LINZ) for the sea-level network component in cooperation with the GeoNet system run by GNS on behalf of the NZ Earthquake Commission. Such a system, where seismic and sea level monitoring are combined in near-real time will substantially improve the robustness and timely service than the present ad-hoc system. We are working cooperatively with Australian counterparts to ensure inter-operability between seismic/tsunami detection systems covering the SW Pacific region and how these systems will fit in under the overall Pacific Tsunami Warning System based in Honolulu (Hawaii).

The recent calamity in the Indian Ocean has heightened people's awareness of the hazard and has re-focussed attention again on our own exposure to tsunamis in the Pacific, particularly against the backdrop of continued coastal development and rising numbers of tourists.

References

Bell, R.; Cowan, H.; Dalziell, E.; Evans, N.; O'Leary, M.; Rush, B.; Yule, L. (in prep). The December 26, 2004 Sumatra Earthquake and Indian Ocean Tsunami: Post-Event Survey of Impacts on the Andaman Coast, southern Thailand. Invited paper, *Bulletin of the New Zealand Society for Earthquake Engineering*.

BELL & KING

Regional Riskscape Model: quantifying and comparing consequences of natural hazards

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New Zealanders are exposed to a wide variety of natural hazards and within historic time (last 200 years), have experienced community damage from almost every conceivable natural hazard. The past two years have seen three damaging floods and some sizeable earthquake events e.g., Fiordland, New Zealand in 2003.

The risks need to be managed, but first the phenomena itself must be understood. Much of hazards research has been historically targeted at the latter, but increasingly emergency managers and planners are demanding more quantitative information of the risks associated with different hazards and to be in a position to compare the impacts across the different hazards.

Once the zone of influence of a particular hazard has been ascertained and its recurrence interval established, then the impact of events of various intensity can be calculated by overlaying the hazard exposure for each event over built-environment inventories and people exposed to that event. Then, by reference to the fragility of each inventory or people class to that exposure, the losses, casualties and disruption (i.e. consequences) resulting from these events can be quantified. Conceptually, this process is relatively straight forward, but application to real-world situations with inherent difficulties in obtaining and linking good-quality inventory and demographic datasets and comparing hazards with vastly different recurrence intervals and source mechanisms is problematic, but nevertheless is achievable.

In June 2004, the New Zealand Foundation for Research, Science and Technology (FRST), being the research-funding agency for central government, agreed to provide funding for the development of a Regional Riskscape Model to accomplish the above. The business approach preferred was a joint venture comprising Geological Risk Ltd. (a subsidiary of the Institute of Geological & Nuclear Sciences (GNS)) that focus on geological hazards and the National Institute of Water & Atmospheric Research (NIWA) that focus primarily on weather-related hazards. The main goal of the project is to produce a decision-support tool that converts existing hazard knowledge into likely consequences for a region, such as damage and replacement costs, casualties, disruption and number of people that could be affected. Consequences for each region presented in a common platform across all natural hazards can then form the basis of prudent planning and prioritised risk-mitigation measures that link directly to the severity of the risks. Progress to date will be outlined with examples. Without a good assessment of the overall risk profile (aka riskscape), efforts to manage natural hazards may be futile.

BHIKABHAI

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The Regional Energy Meeting held in Rarotonga, Cook Islands in 2002, the South Pacific Applied Geoscience Commission (SOPAC) accepted the mandate to assist in coordinating initiatives related to the development and implementation of an action plan for women and energy.

In 2003 SOPAC convened the regional workshop on "Gender, Energy and Sustainable Development" in Nadi, Fiji Islands from 4-8 August 2003. One of the key output from the workshop was the establishment of "*Pacific Energy and Gender (PEG) Network*", that initially be hosted by the SOPAC Secretariat.

Further to this in the recent Regional Energy Meeting (REM 2004) held in Madang, Papua New Guinea from November 29 – 3 December 2004, the energy officials recommended as follows: "*We endorse the further development of the Pacific Energy and Gender Network Work Programme through national and regional initiatives".*

PEG has received support from international organisations in various activities. Technical Centre for Agriculture and Rural Cooperation (CTA), Netherlands has provided funds for "Support to Pacific Energy and Gender (PEG) Network to increasing awareness on gender issues in the energy sector in the Pacific ACP Region".

The specific project activity is *increased awareness on gender issues in the energy sector*. It will be attained through the delivery of the following **outputs:** (i) information materials developed and distributed in the region; (ii) articles on gender & energy featured on the Pacific Energy Newsletter (PEN); (iii) PEG website developed, including an on-line interactive contact database; and (iii) documented and shared successful experiences, case studies and examples that include community participation.

Another recent funding was received from ENERGIA (International Network on Energy and Gender) based in Netherlands for "Developing an Annotated Bibliography and Comprehensive Overview of Project Activities for the Pacific Region". This project is currently in the final stages.

The poster presents PEG's ongoing awareness raising activities in the region.

BHIKABHAI

Pacific Islands Energy Policy and Strategic Action Planning (PIEPSAP)

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PIEPSAP project is an outcome of the World Summit on Sustainable Development that was held in Johannesburg in 2000 where two initiatives were launched: the PICs regional energy sector umbrella initiative, Pacific Islands Energy for Sustainable Development (PIESD) and the European Union Energy Initiative for Poverty Eradication for Sustainable Development (EUEI). In 2003 the Danish Government agreed to fund the PIEPSAP project under the EU Energy Initiative.

The PIEPSAP project inception period initiated 15 August 2004, with PIEPSAP Team commencing 1 September 2004. PIEPSAP has progressed well over the past months. Government endorsed/approved work programmes are in place now for Fiji, Marshall Islands, Samoa, Tonga, Tuvalu, Solomon Islands and Cook Islands with work being undertaken on policy development, regulatory frameworks, energy sector strategies and corporate plans. Draft work programmes are under consideration the Federated States of Micronesia, Niue, Papua New Guinea and Kiribati with continued consultation with the partners. PIEPSAP has held national consultations in 12 countries.

PIEPSAP also actively supports biodiesel research through co-funding a Masters programme at USP, subregional workshop on biofuel in Vanuatu and other country initiatives in the area of biodiesel.

The poster presents PIEPSAP ongoing activities in the region and consultations with countries.

BULEKA

Causes of siltation in Lae, Papua New Guinea 2004

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Papua New Guinea is sandwiched between the northeast advancing Australian and the southwesterly advancing Pacific Plates. A number of small plates have developed as a result of lengthy compressional stresses between these two major plates and together these plates have contributed to the formation of present day PNG landform.

The 1993 Finisterre Earthquake has contributed more long- term damage than just killing 109 people. It has in part reloaded 1989 Kaiapit Landslide debris and together have breached a number of Bridges on its way to the sea. The Combined effects from the individual landslides have blocked the fast flowing rivers and formed dams and eroded and affected the Bridge foundations.

Boana Dam triggered by the 1993 Finisterre earthquake and landslides existed unnoticed for 6 years and the saddle was artificially breached only after the local people reported it in 1996. The debris flood from the saddle destroyed two bridges and reshaped the offshore bathymetry offshore of the Busu River in the Huon Gulf.

The 1993 earthquake and landslide debris is still locked in the tributary areas of the Markham River. The 2004 breach of the Markham Bridge is believed the result of increased release of the debris due to intense rainfall. The increased rainfall had the Markham River bed raised by allowing deposition and diverted much of the Water at oblique angle at the left abutment, affecting the foundation of the pier. The sediment eroded at the Markham River Bridge entered the river at about 1 km from the sea and have not densified sufficiently to become part of the Markham Sediment plume load. This sediment is therefore lighter and as a result surfaced and deposited in the quieter part of the harbour.

The Ramu River aggraded soon after the earthquake and this has advanced upstream gradually. The Boku River, a tributary of the Ramu River, rafted her bridge at about the same time and the intense rainfall therefore must be responsible for the flushing of the debris.

SOPAC has helped PNG in the past and the EU EDF8-SOPAC Project and the selection of the Project site is seen as very important, as it incorporates other stakeholder's interests.

CALLAGHAN & others

Atoll lagoon flushing forced by waves

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Water level and current measurements from two virtually enclosed South Pacific atolls, Manihiki and Rakahanga, support a new lagoon flushing mechanism, which is driven by waves and modulated by ocean tide. This is evident because the lagoon water level remains above the ocean at all tidal phases and because the average lagoon water level rises significantly during periods with large waves. Hence, we develop a model by which the lagoons are flushed by wave pumping of ocean water into the lagoon and gravity draining water from the lagoon (figure 1A). That is, the waves on the exposed side push water into the lagoon during most of the tidal cycle while water leaves the lagoon on the protected side for most of the tidal cycle. The wave driven through-flow flushing is more efficient than alternating tidal flushing with respect to water renewal. Improved water quality should therefore be sought through enhancement of the natural wave pumping rather than by blasting deep channels, which would change the system to an alternating tide driven one.

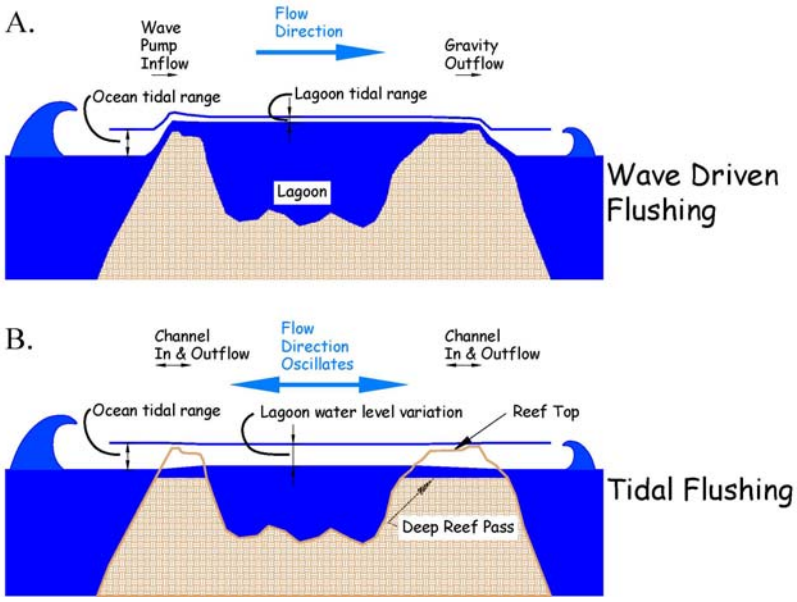

Figure 1: *A. The wave driven lagoon flushing process present at Manihiki and Rakahanga, illustrating the elevated lagoon water surface level and the persistent one-way flow across the atoll. B. The tidal flushing process that occurs when deep and wide channels connecting the ocean and lagoon are present. Tidal flushing typically generates alternating flow patterns in the lagoon with the lagoon water surface variations contained within the ocean tide variations. The alternating flow patterns associated with tidal flushing give less water renewal than the wave driven through flows.*

There are two natural sources of power for flushing atoll lagoons: tides and waves. Their relative importance depends on the topography of the atoll rim as well as on the local wave and tide climates. If the atoll has wide reef passes, which are deep compared with the wave height and the tidal range, the flushing will be generated mainly by the tide and the lagoon water level will oscillate within the range of the ocean tide as shown in figure 1B.

If, on the other hand, the atoll has an almost unbroken rim of living coral growing to a few decimetres above mean sea level (MSL), the flushing will be driven by the waves as shown in figure 1A. That is, the side facing the largest waves will have large amounts of water pushed over the reef rim while water will drain to the ocean on the leeward side. The tide will modulate this process to a degree that depends on A_{tide}/H, i.e., the ratio between the tidal amplitude and the wave height, figure 1A.

The Manihiki and Rakahanga atolls (figure 2) are located in the northern group of the Cook Islands. Both atolls consist of several wide reef flats which are elevated above MSL. Consequently, the lagoons are virtually disconnected from the ocean (Solomon, 1997). This configuration is quite different from the Penrhyn Atoll, also located in the northern group, which has several deep reef passes that allow the ocean tide to drive the lagoon flushing. However, similar to Penrhyn, the lagoon is used to grow black lipped oysters for their black pearls, which is the primary source of income for the Manihiki populace (McKenzie,

2004). The water quality within the lagoon is therefore of great importance to the profitability of this industry. To increase the pearl yield from the lagoon, the number of oysters has increased leading to several episodic large scale oyster deaths from disease directly linked to poor water quality (McKenzie, 2004; Sharma et al., 2001). This reduction in water quality has also increased the number of shells rejecting the seed (nucleus for pearl development) or dying after being seeded. One method to overcome these problems is improving water quality by increasing lagoon flushing. This should however be done in a way which is in harmony with the natural system. This research aims to understand the natural system before proposing methods to enhance the flushing.

This talk demonstrates the mechanism of wave driven lagoon flushing occurring at Manihiki and Rakahanga atolls using observed lagoon dynamics. The processes observed were; inflow driven by waves via the wave pump concept identified by Bruun & Viggoson (1977) and quantified by Nielsen et al. (2001; 1999) and, outflow controlled by critical flow conditions at the leeward reef edge. Combining these two processes with the conservation of water volume, two new models have been formulated which compare well with the field measurements.

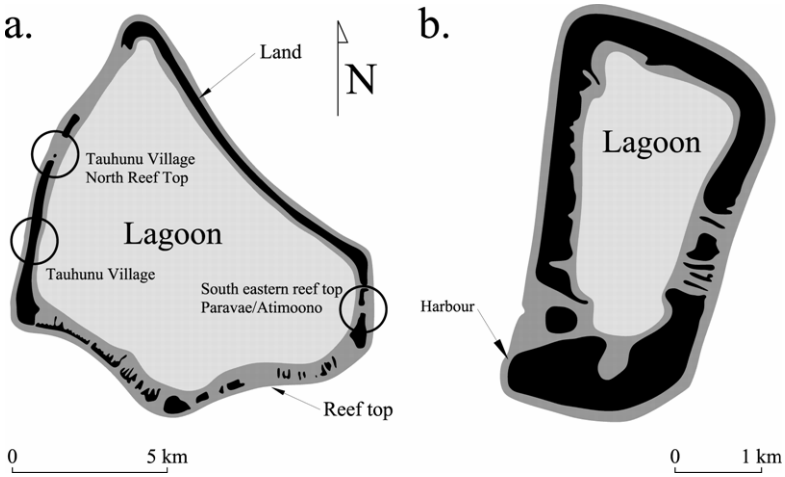

Figure 2: *A. Manihiki and B. Rakahanga atolls of the Cook Island, location in the South Pacific are shown.*

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CHANG & others

Coastal Geological Mapping of Savai'i Island, Samoa

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The coasts of Samoan islands are vulnerable to the sea-level rise and extreme cyclones related to global climate change like the other small islands in the Pacific Ocean. Furthermore the continuing global warming of the ocean temperature triggers coral to shed the algae that nourish it and consequently allows bleaching of coral reefs. Since 1831 there have been tropical cyclones of Class 4-5 about every 14.4 years in the Samoa region. Tropical Cyclones Ofa (2-5 Feb. 1990), Val (6-10 Dec. 1991), and Heta (3-4 Jan. 2004) were Class 5 events. During Class 4-5 tropical cyclones, storm surges of 1.3 m to greater than 5.5 m above high water, promoting serious flooding and erosion of coasts, are generated. Recent mapping of the coastal areas vulnerable to natural coastal hazards, funded by the World Bank, indicated that only 4% of the coastline of Samoa is resilient to coastal hazards.

Coastal mapping can provide decision support data to protect the coastal area and the peoples in the islands. The coastal geological map contains the fundamental data to develop the coastal management system through the monitoring and prediction of coastal disasters, such as coastal erosion, sea cliff landslides, basement subsidence, and intrusion of saline water into ground water aquifers. The coastal geological map also includes basic data on geological resources such as sand & aggregate, corals, etc. and on the anthropogenic features.

On the issues about climate change, Samoa has already completed a number of activities. SOPAC has published a series of the coastal morphological maps for Upolu Island in 1992 through the work done by USGS. The coastal geological mapping around Savai'i Island (task WS 1999.009, SOPAC) was initiated by the request of Samoa, as a part of SOPAC-KIGAM programme. But the mapping and the publication of the coastal morphological maps were not continuously done due to lack of both funds and fundamental data such as aerial or satellite imagery. By the request of the representative of Samoa at the 2003 SOPAC Annual Session, KIGAM decided to continue the coastal geological mapping on Savai'i island and performed the reconnaissance field survey in 2004.

In this year, KIGAM launched a new three-year UNDP project: "Coastal Geological Mapping of Savai'i Island, Samoa". The intended outcomes are the enhanced regional cooperation through bilateral and multilateral cooperation in the science and technology, in line with the MDG 8 (global partnership for development) and the enhanced capacity of Samoan researchers in the field of coastal geology for monitoring and prediction of coastal disasters, such as, erosion, subsidence, and salinitization. The indicative activities are the coastal field survey in Savai'i Island, in cooperation with SOPAC and SMD and the capacity building of Samoan researchers on the coastal geological survey. A field survey of two weeks and a training session of two weeks in each year will be conducted during the project.

As a part of coastal field survey, onshore mapping and offshore sounding were done from 21st July to 4th August (Figure 1). The employment of underwater camera was also tested during the offshore sounding. Aerial orthophotos of 1:5,000 scale along the coastlines of Savai'i Island were provided by the Ministry of Natural Resources, Environment, and Meterology (MNREM), Samoa and used as base maps for onshore mapping. IKONOS imagery on Savai'i Island taken by SOPAC/EDF-8 programme was also provided by SOPAC and used for the offshore sounding.

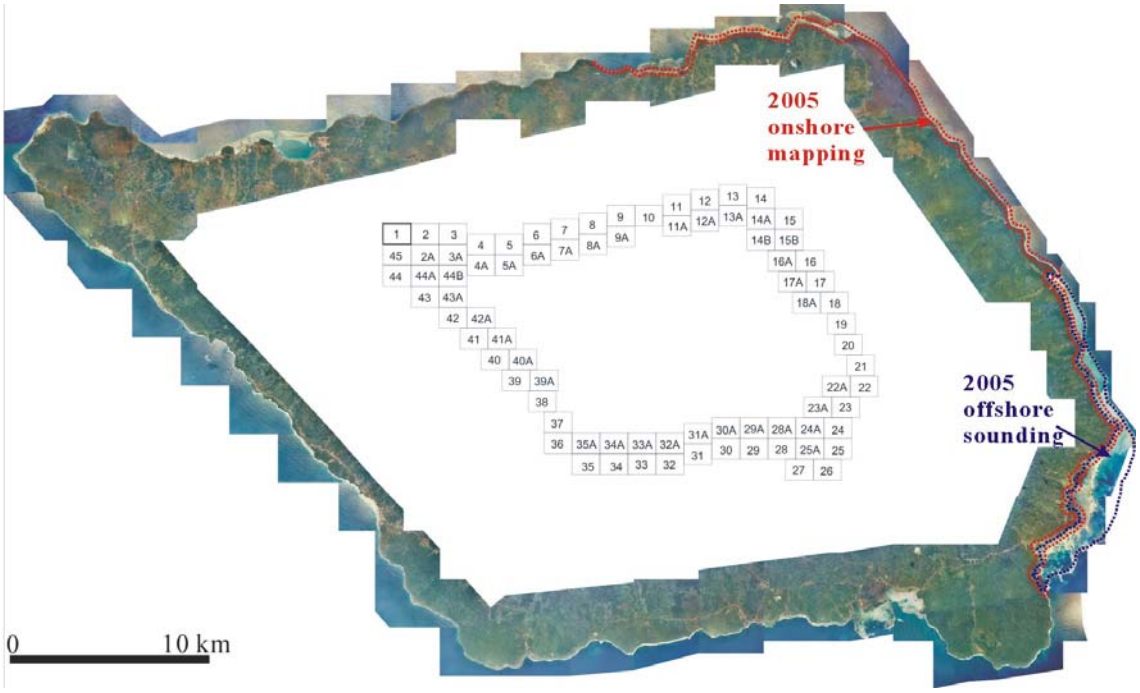

Figure 1: *Mosaic of aerial orthophotos (1:5,000) along the coasts of Savai'i Island showing the areas of onshore mapping and offshore sounding in 2005.*

CLOIN

Coconut Oil Biofuel – Clean and Competitive

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The use of biofuels such as coconut oil to replace diesel fuel has many advantages for Pacific island economies. These include improved balance of payments, support to the local agricultural industry, a decrease in emissions and an option to hedge the price of diesel fuel with an alternative commodity. In addition, biofuels are biodegradable, renewable and do not cause any additional CO_2 in the atmosphere.

During the first half of 2005, a SOPAC-led team carried out a feasibility study for the Samoan Power Utility (EPC) on the use of coconut oil as an alternative fuel. This paper presents the findings of this study that was funded by UNDP-Samoa. The paper elaborates on a successful pilot project that trialled a 10% mixture of coconut oil with 90% diesel in one of the electricity production engines on the island of Savai'i. Furthermore, it was identified that a dedicated coconut oil production plant could be established and run by EPC as a viable operation where the price of diesel is above 0.65 US$/litre. Based on the findings of the feasibility study that included a pilot project trialling blended coconut oil and diesel as an alternative fuel significant potential exists for replication at other power utilities within the Pacific region.

CLOIN

Disaster risk management training for power utility managers

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Building capacity to plan and minimise the impact of extreme events are a continuing challenge for the Power Utility Manager. As a way of assisting towards meeting this challenge the East-West Center in Hawaii organised a two-week training in April 2005 for Power Utility Managers as part of their "Building The Foundation" programme. The objective was to encourage dialogue between power utility managers on disaster risk reduction issues, transfer leadership skills and enhance awareness of best practices on mitigation of and preparedness for natural disasters. Seventeen (17) power utility representatives participated in the programme[1].

The training for Power Utility Managers was just one component of the "Building the Foundation" Programme where, during 2004, Water Utility and National Disaster Management Officers (NDMO) were trained. The training of Communication Utilities is planned for 2006, which will also link with the NDMO and utility training activities.

SOPAC contributed to the programme through actively participating in the training and by presenting the application of the Comprehensive Hazard and Risk Management (CHARM) methodology that has been effectively adopted as a risk management-planning tool within Pacific Island Countries.

Managers identified three major hurdles commonly encountered in preparing a Disaster Risk Management strategy or response plan. These were: 1) Different priorities; 2) Changing Board and/or Management; and 3) Communication/Co-ordination problems between power utilities and the relevant national authorities.

The paper provides an overview of the outcomes of the initial training in April 2005 including a list of the current level of preparedness of the power utilities in the region. In addition, the opportunity is taken to reflect on the progress made by the individual utilities in preparing for disasters at a follow-up workshop in August 2005. The paper wraps up with recommendations on how to improve the disaster preparedness of the power utilities in the region.

CRIMP & others

Dental fluorosis attributed to Volcanic degassing on Ambrym Volcano, Vanuatu

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Volcanic activity of Marum and Benbow craters on Ambrym Island has been semi-continuous for as long as records have been kept in Vanuatu, and acid rains and vegetation damage are regularly reported. However, little attention has been paid to any long-term impacts on human health in the populated areas surrounding the two volcanoes, despite periodic requests for investigation from community health officers. Up to 7369 inhabitants on Ambrym are potentially affected by semi-continuous volcanism, and initial

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studies reveal that chemical constituents, particularly Fluoride (F) may cause the greatest potential health hazard. Fluoride is one of the common constituents of volcanic ash and gas and has been implicated in many cases of human and animal impacts from volcanic eruptions. It has also been an important hazard faced in recent times in New Zealand. On Ambrym, parts of the population live under ash falls and gas plumes at times on a daily or weekly basis. While initial studies have revealed levels of F in drinking waters that are elevated up to 10 times recommended concentrations, medical records and investigations have not been undertaken to establish the impacts on the local population.

The overall aim of this study is to investigate whether this long-term exposure to volcanic degassing leads to chronic health impacts, and, if so, to recommend measures by which these impacts can be mitigated or at least minimised. In humans, F is rapidly digested and excreted, as well as being deposited in bones and teeth. Impacts of F were measured by non-invasive means including most importantly, tooth surface appearance for children with permanent second teeth (graded on a standard Dean's scale system).

It is known that levels of above 1-2 ppm F in drinking waters lead to a chalky mottling, staining, rapid tooth wear and roughening of enamel, with an increasing percentage of the population being affected with increasing F water levels. Ambrym drinking waters contained typically between 3-10 ppm F during January 05, which was consistent with earlier measurements made since 2002. Hence, these levels should be high enough to generate not only high levels of dental fluorosis, but also potentially crippling skeletal fluorosis.

Data will be presented from >260 children surveyed in West Ambrym, showing extraordinarily high rates of dental fluorosis is ubiquitous in this part of the island. This, being the area downwind of trade winds is known to have the greatest impact from acid rains and gas aerosols, particularly during the dry season. Drinking water is considered to be the major culprit and urgent attention should be brought to bear on identifying safe water sources on the island. Deep bores are considered to offer the best potential for safe water supply, although village-level filtration systems could be tried. Ongoing studies will attempt to characterise rates of dietary intake of F and to identify appropriate remediation measures for the next generation of Ambrym children.

CRONAN

Cook Islands Manganese Nodules Revisited

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An exhaustive analysis of manganese nodule variability throughout the SW Pacific has confirmed that Cook Islands manganese nodules are potentially the most economically viable of these deposits in the SOPAC area (Verlaan et al, 2004). They occur in the Penrhyn Basin south of 10 degrees S, where they reach abundances in excess of 30 kg/m^2. However, if they are to be mined in the forseeable future, these nodules must be comparable with the Clarion Clipperton Zone (CCZ) nodules, immediately to the northeast, in terms of metal quantity per unit area. The average Ni+Co content of Cook Islands nodules is about 0.8-1.0%, compared with an average of about 1.2-1.4 % in CCZ nodules. However, for Co alone they are more valuable and where abundances are higher than CCZ nodule abundances, they can be considered to be mineable deposits.

The Cook Islands nodules of economic interest lie on slowly accumulating non-biogenous clays of moderate to high bearing strength. This substrate, however, is relatively thin in places, and will be very disturbed during a mining operation. It is oxidised at and at least just below the sea floor and thus toxic elements in a reduced state will not be released during mining. However, more data are needed on the nature of the deeper substrate. Deep Sea Drilling has never taken place in the Penrhyn Basin, but analysis of piston and gravity cores should provide the requisite information. Because of the unique nature and setting of the Cook Islands nodules, hydraulic and airlift systems proposed for mining in the CCZ may not be applicable to their extraction. A modification of conventional dredging methods might be more appropriate.

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CRONIN & CHARLEY

Combining traditional and scientific views for community disaster education in Vanuatu

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There is commonly a large gulf between the scientific understanding of hazards and the traditional perceptions of local communities. Such mutual incomprehension is often a major stumbling-block to the preparation of community-oriented emergency management plans and education materials. This is no more extreme than in the case of volcanic hazard in the SW Pacific island nation of Vanuatu. Community inputs into developing emergency plans have effectively been ignored, while scientific volcanic hazard advice and warnings have often been ignored or even challenged by local communities.

Vanuatu is almost unique in having people living in a traditional subsistence fashion on, or near, at least six active volcanoes. Over generations, this experience of volcanism has become part of *kastom* (local world-view, belief system, tradition). The *kastom* knowledge base includes definition of areas of hazard, along with protocols, ceremonies, dances and actions to avoid eruption onsets, or to stop activity once it begins.

To try to find a way forward, using both traditional and external scientific views, has been our focus over the last five years of UNESCO-supported research in Vanuatu. Our objectives have been: (1) to understand and document *kastom* approaches to volcanic hazard management; (2) to develop methods for combining *kastom* and outside scientific knowledge in volcanic hazard management strategies, public educational materials and warning systems; and (3) to develop a local design for community emergency management plans that link upward to island-based plans. All of these are oriented toward reducing the impacts of future volcanic disasters in Vanuatu and nations like it.

We developed a set of participatory methods through a series of activities starting from small villages and village groups and moving up to larger community assemblages (e.g., chiefdoms). This was to develop a clear understanding of the local issues and knowledgebase and ensure that effective community consultation was achieved during the development of materials, plans and templates. We concentrated on producing an overall and consistent information/education strategy.

Participatory activities were developed and tested with small groups of men, women, youth, elders and chiefs. These included group-exercises, such as: village timelines/histories, local mapping exercises (resources, dangers), village structures/communications, reviews of past disaster responses, gender-roles in decision making, local warnings signs of disasters (including volcanism) and discussions of oral traditions plus *kastom* knowledge and practice. The choice of communities was often driven by necessity; e.g., the 2003 eruptions of Lopevi that covered neighbouring Paama Island with fine ash, and the destruction of food crops on Ambrym resulting from a huge increase in volcanic gas release since late 2004. Otherwise communities were selected on the basis of being in particularly dangerous areas, areas of past impact, or alternatively in relatively safe areas (hence having a potential role in the hosting of refugees from other places). Most sets of activities were run over 1-2 days, and villages were visited several times. In addition, later activities have concentrated on higher levels in communities, such as areas of chiefly councils, covering between 5-10 villages. These larger workshops involved between 80 and 200 people representing men, women, chiefs, elders, and youth leaders from all main villages in an area.

From the group activities, the building blocks of community emergency plans were developed, including communications structures, warning signals, evacuation preplanning, escape routes and refuge areas. This ensured that the information in the plans was accurate and included specific local factors such as the effects of differing weather patterns on anchorages. Other concerns regarding past and possible evacuations and resettlements were also discussed. I some cases, local chiefs have gone on to negotiate areas of refuge and possible resettlement on neighbouring islands in a highly proactive manner.

Mapping exercises, carried out on every occasion, were also critical for the development of a new generation of hazard maps for Vanuatu volcanoes (see Figure 1). The maps provided not only information on the local perceptions of hazard, but, more importantly, they demonstrated how the people **depicted** hazards on a map: a critical key to designing new hazard map formats that would be most widely understood. Along maps and plans, a volcanic warning system has been introduced, evaluated and modified through exercises in villages and chiefly council areas. This numerical system aims to convey the state of activity of each volcano in a way that avoids technical/geological terms and in a form of *Bislama* (the *lingua franca* of Vanuatu) that is understandable to all communities.

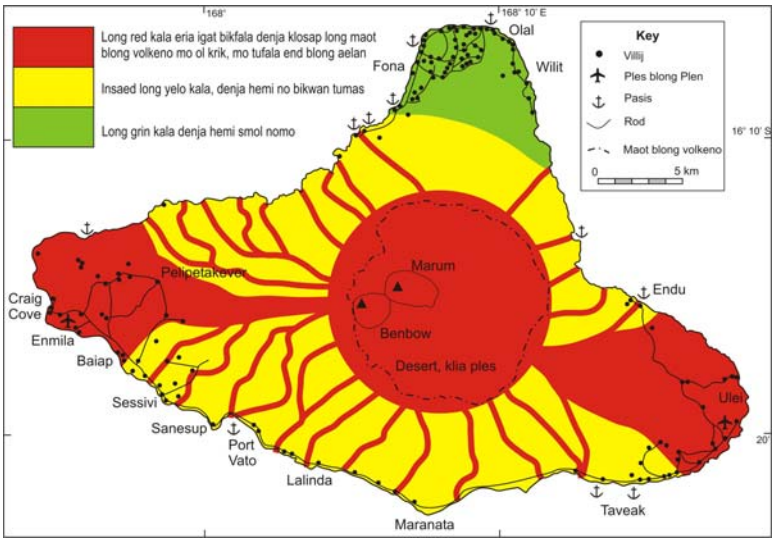

Figure 1: *A hazard map for lava flows and mudflows (in Bislama) on Ambrym Island, developed following community input around the entire island.*

Achieving these first steps has revealed a number of the complexities in Vanuatu community society that must be considered when making further progress. *Kastom* is complex and varies considerably between islands or even within one island. It is also not universally accepted, particularly by the young or the church. However, there are major aspects to *kastom* surrounding volcanoes that can aid local warning of volcanic eruptions (e.g. by behaviour of birds and other animals) and also help to extend the historical record of volcanism for scientific investigations. The activities also revealed that women are strongly underrepresented in any emergency decision-making process and also in any community preparedness actions. They are also poorly informed of hazards both during emergency events and between them. These issues continue to be priorities for future research. Participatory style workshops and activities are excellent avenues for airing, however, they are not likely to generate any long-term improvement or change without good follow-up strategies and targeted educative initiatives.

Whilst the above work is focused on Vanuatu, it has been carried out in the context of an overall strategy applied in other areas of the SW Pacific where similar types of hazard exist, including parallel and previous programmes in Fiji, Samoa and the Solomon Islands. The Vanuatu-derived strategies and methods are hence of much broader application, not only to areas affected by volcanic hazard, but also earthquake, tsunami and other types of natural hazards that are common to this region. Scientists and emergency managers will always face difficulties expressing knowledge of natural hazards to non-specialists. We have shown that this need not be a barrier to communication once a basis of mutual respect is developed between differing world views and backgrounds.

DREXEL & others

Stable isotope analysis of lagoon food webs: potential for assessing impacts of pearl oyster farming

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Atoll lagoons are well suited for farming of filter-feeding bivalves, providing a sheltered environment with higher nutrient supply than the surrounding ocean. In particular, significant farming of the pearl oyster, *Pinctada margaritifera*, has been developed in French Polynesia and the Cook Islands, with recent expansion into the Marshall Islands, Solomon Islands, Fiji and Tonga. Recent cultivated pearl oyster mortality events in the Cook Islands and French Polynesia emphasize the sensitivity of lagoon ecosystems to farming activities. Food web interactions in lagoon ecosystems have not been well studied, and even small environmental disturbances have the potential for negative impacts on both cultured oysters and other native species.

Impacts on lagoon ecosystems from farming activities can be divided into two major sources: natural, resulting from biological processes of the cultured oysters themselves; and anthropogenic, resulting from effluents generated by oyster farms. Distinguishing the contribution of these sources requires sufficient knowledge about the nutrient dynamics of the lagoon ecosystem. This study reports on the feasibility of applying stable isotope analysis of carbon and nitrogen in lagoon food webs for distinguishing natural versus anthropogenic changes associated with the developing pearl farm industry.

Stable isotope ratios of carbon (^{13}C) and nitrogen (^{15}N) have proven useful in studying the flow of energy and mass through food webs, and for quantifying community responses to environmental disturbance. The ratio of stable isotopes of carbon reflects the diet of organisms, and the tissues of predators thus have carbon stable isotope ratios reflecting that of their prey. Metabolic enzymes associated with nitrogen metabolism favor slightly the excretion of the native form (^{14}N) over the stable isotope, ^{15}N. Therefore as nitrogen turnover increases, the ration of ^{15}N:^{14}N also increases. Hence, ^{15}N in the tissues of predators increases approximately 3-4 parts per mil above that of their prey. The stable isotope content of ^{13}C in tissues therefore quantifies the contribution of various prey species to the diet, whereas ^{15}N content reflects the trophic position of that species within the food web. In addition, ^{15}N content serves as an index of eutrophication, being lower in areas where nitrogen is more readily available and is thus turned over less frequently.

Samples representing the food web of Penrhyn Lagoon, Cook Islands, were collected in the spring of 2003 and results reported to STAR in September of that year. Subsequently additional samples were collected from the lagoon at Manihiki, Cook Islands, allowing comparison of these two lagoons. Manihiki Lagoon supports in excess of one million cultured pearl oysters, approximately ten times the number in Penrhyn Lagoon. In addition, several locations were sampled in Manihiki Lagoon near and distant from established pearl farms. For Manihiki Lagoon, the three sample locations were: Paulo, located in the lagoon centre near several oyster farms; Ngake, located on the eastern atoll rim, several kilometres from the nearest pass; and Motutou, located on the edge of the reef flat between ocean and lagoon. The Motutuo sampling location was regarded as a control site, influenced less by the dense pearl farms in the lagoon than the other two sites.

As was observed in Penrhyn Lagoon, Manihiki Lagoon sample stable isotope ratios for carbon distinguished between pelagic (phytoplankton) and benthic (attached algae) sources of primary production. Both species of pearl oysters show similar ^{13}C content in Penrhyn and Manihiki Lagoons, implying that at higher densities oysters in Manihiki Lagoon show no changes in diet sources (i.e. phytoplankton) relative to oysters at lower densities in Penrhyn Lagoon. Other species collected from both lagoons likewise show similar positions

within lagoon food webs: benthic feeders such as *Holothuria* and *Graspus* have ^{13}C content similar to benthic algae, and *Tridacna* occupies a position intermediate between filter and deposit feeders.

Overall, ^{15}N content for samples collected in Penrhyn Lagoon were greater then corresponding samples from Manihiki Lagoon. Within Manihiki Lagoon, specimens collected from Motutuo also had ^{15}N content greater than specimens from Paulo and Ngake. These results imply that eutrophication (nutrient enrichment) has had an overall greater influence within Manihiki Lagoon than Penrhyn Lagoon, and that within Manihiki Lagoon it is greater nearer the oyster farms than distant.

These results are based on small sample sizes collected at single points in time, and should thus be considered preliminary. Comprehensive sampling and investigation of the dynamics of carbon and nitrogen isotopes within these lagoons are required to confirm these initial interpretations of these lagoon food webs. However, these results do illustrate clearly the reliability, feasibility and usefulness of stable isotopes of carbon and nitrogen for identifying and quantifying changes in lagoon ecosystems associated with the pearl farming industry. Given that in the future pearl farming activities will increase in scope and intensity, there is an essential need for increased monitoring of environmental quality in these lagoons in order to protect what is ultimately a sustainable and high-value resource.

EAGAR & SMITH

What you can do with an ostracod shell from Vaiusu Bay, Samoa

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As part of an investigation into the sand and aggregate resources together with the bathymetry, 60 samples were collected by jet probe and from the nearshore surface of Vaiusu Bay (Lat 13 49 S; long 171 46 W) west of Apia, Western Samoa in 1995 by a team headed by one of us (RS). Twelve samples from two traverses were examined microscopically, one from the beach to the fringing reef, the other parallel to the beach. Ten samples contained 1208 ostracods belonging to 12 species. Only four species are considered to be living in the environment in which they were recovered. The subsurface samples did not yield many specimens, perhaps because they may have been winnowed out in the extraction process. The environment may have a reduced salinity compared to the surrounding sea as the Gasegase and Fuluasou Rivers with significant capture areas flow into Vaiusu Bay.

Further material has been examined from around Palolo Deep, Apia. These faunas are quite different in composition to those from Vaiusu Bay. Some samples yielded good faunas with up to 31 species of ostracods. Others samples have small interstitial forms with 12 species. There has only been one other study of material from the reefs of Samoa in 1890 by G S Brady where he recorded some 23 species from Apia and Lufilufi. Another study from offshore samples at depths of 75 m and 176 m, this time by K G McKenzie (1981) for SOPAC, where he listed 9 and 21 species respectively. The latter faunas are deep-water environments and are quite different to those considered here.

All samples have been critically analysed and compared with other faunas from Pacific islands. Previously the Pacific has been regarded as a single large area. With more information available now from these studies, it is now possible to break the region down into smaller units.

Samoa occupies a unique situation with respect to the ostracods. The fauna is different to those of the nearby islands of Tarawa and Funafuti and those further to the east, Tahiti and Easter Island. It has closer ties to Hawaii, New Caledonia and Australia.

EDSALL

Medical geology investigation of indigenous populations of select coral and volcanic islands: a call for SOPAC involvement and support

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Long and short-term exposure to naturally occurring toxic materials affects human health. Excesses or deficiencies in certain trace metals can also affect human health. Spatial and temporal correlations between geology and public health problems in man and animals are the purview of "medical geology."

I am interested in establishing a working relationship with governmental, health and science professionals in order to collect, assess and exchange baseline public health and geologic data on a small number of dissimilar island environments in the South Pacific Ocean.

The ideal human population for a medical geology study would have been born and lived solely on a relatively isolated atoll, reef or volcanic island. This population would: live in more direct contact with the natural environment; eat a more restricted and locally derived diet; not be as mobile; and would only be subjected to chronic contamination by geologic materials due to a lack of industry and other sources of anthropogenic pollution.

The purpose of this presentation is to inform, educate and enlist support among meeting attendees for research directed at better recognizing populations at risk for environmentally-linked public health problems.

FATIAKI

A Community-Based Water Monitoring Toolkit using the H_2S Paper Strip Test

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Live & Learn Environmental Education with the World Health Organization (WHO) Suva office has been developing a Community Water Monitoring Toolkit aimed to increase awareness and action in communities towards developing the important relationship between “healthy water and healthy people”. The kit makes use of the hydrogen sulphide (H_2S) paper strip test, a simple and inexpensive method for checking the presence or absence of potentially harmful bacteria. Live and Learn has piloted the Toolkit in two communities in Fiji with excellent results. The Toolkit activities combined with the use of the H_2S paper strip test as a visual demonstration of contamination have effectively motivated action in these communities to protect and maintain their water supplies.

FISHER & others

Ridge 2000 Expeditions to the East Lau Spreading Center 2005: Life at the vents

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Last year during the STAR sessions Dr F. Martinez (University of Hawaii) and I reported on 2 research cruises funded by our National Science Foundation that mapped the East Lau Spreading Center in high detail, sampled water and rocks along the ridge, and used underwater vehicles to locate and image several active deep sea vents on the sea floor. The second cruise, led by Dr C. Langmuir of Harvard, was underway during the last SOPAC meeting and it was very successful, discovering and taking pictures of 3 new active hydrothermal sites, and making high resolution (~2 meter pixel size) bathymetric maps of each site using the underwater vehicle ABE. During that cruise, Dr Ken Takai from JAMSTEK led a Japanese research expedition that explored several previously know sites on the southern end of the spreading center using the research submersible Shinkai 6500, and also discovered new sites in that area. The American and Japanese expeditions met at sea in Tongan waters to exchange the latest data that each had on the region, some of it only days old. One of the sites subsequently dived on by Dr Takai's group they named the JAC site, referring to the Japanese-American Collaboration, which provided the information necessary for the successful dives at this site. During the Spring of 2005 we conducted three additional cruises using the Remotely Operated Vehicle (ROV) Jason II for detailed imaging and sampling of hydrothermal systems identified during the 2004 cruises, and to explore for other new sites. All three of these cruises were very successful, and we now have all of the information we will need to choose a single site or 'bull's eye" that will be focus of the next round of Ridge 2000 research in this region.

The general plan for the three cruises in 2005 was to begin with a detailed *in situ* exploration and mapping effort of each of the sites discovered in 2004, plus additional sites if any were found. During the first cruise in 2005, led by Dr M. Tivey of Woods Hole Oceanographic Institution, one additional site with rich biological communities was discovered, so a total of 4 new sites with rich communities were studied intensively in 2005. The ROV Jason II used the SM2000 bathymetric mapping instrument to produce maps of each site with a pixel resolution of less than 1 meter. These maps each covered between 400 m and 1 km of the spreading center, depending on the extent of hydrothermal activity at the sites. Also during that first cruise, a high dynamic range 'pixelfly" digital camera was used to create photo-mosaics of selected regions of the sites, that helped to identify specific areas of especially rich biological communities. Together these maps and mosaics were used to plan and localize all of the sampling conducted on the three expeditions. During the first 2005 cruise, the team led by Dr Tivey conducted a detailed water and sulfide sampling programme coupled with limited biological sampling that set the stage for the more focused macrobiological studies that followed. The next cruise led by Dr R. Vrijenhoek from the Monteray Bay Aquarium Research Institute and Dr C.L. Van Dover from William and Mary University, was part of a larger regional sampling survey designed to help understand the relation of the animal communities of the East Lau Basin Spreading center in the context of animals found at other vent sites in the region and around the world. Numerous biological collections were made from sites recently visited by both US and Japanese scientists and the investigators report that several species never found in this area were collected. One unexpected discovery made by Dr Van Dover during this cruise was that the mussels (which are very important members of these communities) in the neighboring Fiji Basin spreading center were heavily infected with a fungal disease, that has not been reported at any other vent site, and fortunately does not appear to be present in the Lau Basin communities.

During the final cruise of the series, our primary focus was a better understanding of the biology of the animals and the relation between their fine scale distribution and the chemistry of the hydrothermal flow they live in. This cruise was completed at the end of June, 2005. Four research teams were part of this expedition: my team from Penn State University and the Station Biologique in Roscoff France; Dr George Luther's team of chemists from the University of Delaware; a team of ecologists from Moss Landing Marine Labs led by Dr Stacy Kim; and a team of physiologists led by Dr James Childress from the Univ. of California in Santa Barbara. Working together we have created detailed chemical/biological maps and

conducted manipulative experiments at the sites that help us understand the environmental conditions that each of the major taxa at the sites prefer or can tolerate. We made quantitative collections of communities of mussels, and of each species of the giant snails to describe the communities of animals that are found along with these major taxa. We also collected a number of the animals alive and studied the metabolism of some of the most important species in high-pressure aquaria and by conducting experiments on tissues isolated from them. Finally, we also discovered several species previously unknown to science in the collections, including what may be the world's smallest species of tubeworm.

Most of the data from the 2005 cruises are still being worked up and analyzed, but I will provide a summary of what we believe will be some of the most exciting findings from this year's work. The US Ridge 2000 Program has a data policy that dictates open sharing of data, and the metadata from all cruises are available in our open database (http://www.marine-geo.org/ridge2000/whats_new.html). In addition, all data collected will be provided to the Kingdom of Tonga along with the software necessary for accessing and visualizing the data. Each of the 2005 cruises included at least one observer from Tonga, and when additional work was done in Fijian waters an observer from Fiji was also included. We are continuing to work with the University of the South Pacific and hope to include either a student or faculty member from USP on our next cruise in early summer of 2006. Unfortunately the University academic year schedule did not allow this in 2005. A new website aimed at the general public was developed during the cruise and is still active: www.venturedeepocean.org.

More information on the plans and scientific dreams for Ridge 2000 research in the Lau Basin is available on our web site (http://www.ridge2000.org), including the Lau Basin Implementation Plan, a variety of background information; Letters of Intent for funded projects and proposals under consideration, and the newest results from ongoing cruises. To join the R2K mailing list, for timetables, data, upcoming meetings and workshops, contacts and other information about the R2K programme, email us at ridge2000@psu.edu, see the R2K website at (http://www.ridge2000.org) or call 814-865-7434.

GLASSEY & others

Tsunami Hazard in the Pacific: Lessons learnt after the 26 December 2004 Asian tsunami

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The 26 December 2004 Asian tsunami caused unprecedented damage and loss of life. Can such a tsunami affect the Pacific Islands, and if so what lessons can we learn from the Asian event? How well is the tsunami hazard throughout the Pacific Islands understood? Recent work in Tonga has demonstrated that the historic record of tsunami is sketchy at best and while there is more evidence for local-source tsunami affecting Tonga and other Pacific Islands, the magnitude/frequency is poorly constrained and sources of such events are poorly understood. Oral tradition with respect to tsunami hazard does not seem to be strong.

There is uncertainty about how distant-source tsunami will affect Pacific Islands. The relationship between wavelength, bathymetry and island size is not well understood and requires modelling. Distant-source events allow some warning of the approaching tsunami to be given. Local-source tsunamis allow for little warning and the wave dynamics of local-source tsunamis may cause different patterns of damage to islands compared with distal-source events.

Aceh Province and the city of Banda Aceh were devastated by the local-source 26 December 2004, Asian tsunami generated by a magnitude 9.3 earthquake on a subduction-thrust. There have been at least seven tsunamis along the coast of northwest Sumatra in the past 300 years, including one that affected Banda Aced in 1905. Despite this, there was no understanding of what was to follow this earthquake shaking that

was so strong that people could not stand – except perhaps on Simeulue Island close to the epicentre. On this island, anecdotal evidence indicates that only seven people died because they had an oral tradition based around earthquake and tsunami which involved them immediately going to high ground.

Hazard education is essential to ensure that people know to move to away from the coast and to higher ground immediately after strong earthquake shaking or if they witness an unusual recession of the sea to below normal low tide levels. Such recession occurred for a period of at least 5 minutes before the tsunami struck the Andaman coast, and perhaps for 10 minutes before it arrived at Phang-Nga on the Thailand coast. Recession is an important indicator for building public awareness of tsunami threat.

In the Pacific however, there are many islands with little relief and no high ground to escape to. A striking observation in Banda Aceh was the number of mosques that survived the tsunami. This is thought to be because they were well constructed and have an open arched design. Hence, within the Pacific Islands, the use of cyclone shelters designed not only to withstand extreme winds and storm surge, but also significant earthquake shaking could provide effective tsunami shelters. Could public buildings and tourist resorts (often close to the beach) be designed and constructed in a way that they provide tsunami shelters? The mosques quickly became centres of shelter and coordination of relief aid. Another observation from Banda Aceh, and observed elsewhere, was the affect of green belts such as dunes, mangroves and dense coastal trees which significantly reduce the force of impact of the tsunami.

After such an event, it may be days before help arrives. There must be a degree of self-reliance (resilience). It should be noted that very little reconstruction has taken place in Aceh 9 months after the event. Reconstruction may have been hastened by having a recovery plan in place, prior to any event. This would involve appropriate land use planning to take into account such hazards when siting critical facilities for example.

No single measure can provide complete protection from tsunami. There needs to be a balance between detection, warning, response, refuge and long-term planning, and particularly for critical facilities.

GRIMES

Future directions for marine science, oceanographic monitoring and the Pacific Island Global Ocean Observing System (PI-GOOS) in the Pacific

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Marine science, oceanographic and associated climate monitoring has wide-reaching implications for sustainable development, environmental health, improved risk management and mitigation of impacts of natural hazards in the Pacific. Despite this, the region is still developing capacity for ocean sciences and their application to coastal and marine management, and sustainable development planning. Currently, most coastal, marine and risk management efforts are uncoordinated, duplication is common and planning gaps exist, with little access to timely and reliable scientific data (especially oceanographic) to support appropriate decision-making. This is attributed to poor communication links, insufficient human resources and knowledge in the region. Most South Pacific-focused marine and related atmospheric science qualifications, research and industry practice have been conducted elsewhere, especially Australia, USA and Europe. After completion of international research and industry projects, Pacific Island Countries (PICs) often have difficulty acquiring the information that has been taken offshore. At present, there are only four known physical oceanographers within the region, none of whom are Pacific Islanders. This absence of information and local expertise can seriously impair effective and timely management of island resources, activities and development within PICs. As such, there is a critical need to improve knowledge, monitoring, information collection, cataloguing, analysis and dissemination of ocean science products in order to assist and improve research, capacity building, environmental planning, decision-making and self-reliance.

PI-GOOS has been set-up in response this need, and has recently been improved and strengthened. This presentation will outline key milestones in the past year, including development of a specific oceanographic database and website, to assist access and improvement to oceanographic research being carried out within the region, mostly by international scientists, and directly relevant to disaster risk management and improved understanding of the ENSO phenomena and its application to improved management of fisheries and tourism industries.

GROVER & others

Integrated water resources management – its development and water virtual learning centre

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This presentation will give an overview of the main advantages, features, issues and problems involved in producing an integrated water resource management plan (IWRM) is based on the curriculum and content of the courses in the Water Virtual Learning Centre (WVLC). The WVLC is a series of ten full courses given by Distance Learning and is produced by the United Nations University – International Network for Water, Environment and Health (UNU-INWEH) and the United Nations Department of Economics and Social Affairs (UN-DESA). The WVLC curriculum includes full courses on water transfer, the terrestrial ecosystem and the impacts of land use changes, the aquatic ecosystem, aquatic ecosystem health and impact assessment, water use, wastewater, governance and community based approaches and organizational infrastructure and management as well as an introductory course and a practical "hands-on" course where the participants develop an IWRM plan. The entire programme will be delivered by regional partners and will be customized and tailored for each region in close cooperation with local regional partner institutions. The participants will progressively build their own example of an integrated water resource management plan from materials covered in each course and based on data and information from their local region or watershed that they will gather and analyse during each course. They will then integrate this data and information during a final "hands-on" course at the conclusion of the programme. The presentation will demonstrate the WVLC as tool for capacity building in developing countries.

In this presentation, the emphasis is placed on the integration of knowledge that is required to carry out an IWRM plan rather than the detailed knowledge and data that are required. The goal of the presentation will be to give a high level view of the IWRM planning process and to show importance of the interactions between the many interested parties in a typical situation. These interactions range from those between the different scientific disciplines involved to the complex interactions between scientists, planners, engineers, government agencies and the communities and their political structures.

HASAN

Pilot wetland in Tagaqe Village, Coral Coast, Fiji

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Nutrient (nitrate and phosphate) levels potentially damaging to coral reefs have been detected at several sites along the Coral Coast of Viti Levu, Fiji. The elevated nutrient levels are of concern given the importance of the Coral Coast for the local communities and as a tourist destination. A study in August 2004 by two experts from New Zealand and the United States determined that the three main anthropogenic sources of nutrients were village sewage, pig raising and waste from resorts, in that order. Low-cost and low-level technology methods to reduce nutrient pollution on the reefs were suggested and have been since implemented. One of these methods has been the use of wetlands as a post-septic treatment to further purify wastewater and remove nutrients. Results from the pilot wetland in Tagaqe village located in Coral Coast, Fiji show 96% of phosphates and 83% of nitrogen are being removed through the natural processes in the wetland.

IDDINGS & DAVIES

Water Safety Plans: A tool to safeguard drinking water quality in Pacific Island Countries

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Access to safe and adequate supplies of drinking water is fundamental for human health and well-being. The WHO workshop on Drinking Water Quality (DWQ) Standards and Monitoring held in February 2005 in Fiji brought together water service providers and health departments from across the Pacific region and allowed an up to date picture to be drawn of the current situation and needs in terms of drinking water quality in the Pacific Island Countries (PICs). Variations in water resource availability, often inadequate supply and treatment systems, increasing pollution and lack of proper institutional frameworks and resources for water quality monitoring are all issues that affect water quality in PICs. The workshop produced a 'Framework for Action on Drinking Water Quality and Health in Pacific Island Countries' subsequently endorsed by Pacific Island Health Ministers and containing a key message on the need to adopt risk management strategies to safeguard water quality, rather than simply "end-point" monitoring as currently practiced, particularly as most PICs are limited in their ability to carry out comprehensive water quality monitoring. The use of risk management tools such as Water Safety Plans is an effective means to improve drinking water quality in the Pacific region by looking at the whole water supply chain from catchment to consumer.

IIZASA

Japan-SOPAC Co-operative Deep-sea Mineral Resources Study Programme: Exploration for Hydrothermal Sulfide Deposits

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The South Pacific region has been investigated in order to evaluate the potential for the formation of volcanogenic massive sulfide (VMS) deposits during 6 cruises by Hakurei-Maru No. 2 since the Japan-

SOPAC co-operative study programme started 21 years ago. The surveys of VMS deposits were carried out using benthic multi-coring system (BMS), finder-installed deep-tow camera (FDC), finder-installed powered grab (FPG), gravity corer (LC) based on detailed bathymetric information in the tectonically active regions of Manus and Woodlark basins east of Papua New Guinea, the Coriolis trough east of Vanuatu, the Lau basin west of Tonga, and the triple junction and central Hill of the north Fiji basin.

On the basis of these geological results during the 6 cruises, VMS deposits including sings and occurrences of hydrothermal activities were found in areas of Manus and Woodlark basins, triple junction and central Hill of north Fiji Basin, and the Coriolis Trough east of Vanuatu. Among the findings a typical VMS deposit occurs as sulfide mounds constructed by chimneys and rubbles composed mainly of chalcopyrite, pyrite, sphalerite and marcasite around the triple junction of the north Fiji basin, and hydrothermal Fe hydroxide deposits composed mainly of amorphous Fe hydroxide and goethite occurs predominantly at a submarine caldera where exists on a fracture zone across the Coriolis trough east of Vanuatu. The others are hydrothermal Fe hydroxide deposits including some barite, chalcopyrite, tetrahedrite, sphalerite, pyrite, and hydrothermal Mn crust. Some deposits in the Coriolis trough are associated with a hydrothermal biota of shells, snails etc.

The VMS deposits drilled by BMS in the triple junction of the north Fiji basin and hydrothermal Fe and Mn hydroxide deposits recovered with FPG and LC in the Coriolis trough are discussed based on geological and geochemical examinations and field observations by FDC. And the South Pacific region is also potentially rich in sites favored for the formation of VMS deposits.

JEON

KORDI's plan for surveying deep-sea hydrothermal environments

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Good morning ladies and gentlemen! I am honoured to get a chance giving a talk in front of honourable members from SOPAC countries and observers from associate countries. All the participants here except myself seem to know one another probably because the SOPAC annual session is already 34 years old.

It is rather late for Korea to start the hydrothermal vent project after a few trial surveys in the western Pacific since 1992. At that time, it was mainly focused on the regional climate system, but the cruises were carried out twice only and stopped in 1994. Then, the major concern was shifted into geophysical problems during the second phase (from 2000 to 2003). Now, it seems to be the beginning stage of the third phase. For 2005, we received funding of about USD500,000 basically for a test cruise for a long-term research plan, for an exchange programme of personnel among institutions, and for attending this kind of workshop. As a first step, we KORDI members are making implementation planning for the project between 2006 and 2015 (for 10 years), where we expect to receive more than 1 million dollars for 2006 and up for the rest of the period.

Our surveys will be carried out based upon multidisciplinary and interdisciplinary marine scientific research, which means that our survey team is composed of all the aspects of physical, chemical, biological, and geological oceanography as well as deep-sea engineering

For the first 3 years, we are going to detect hydrothermal vents and plumes in the West Spreading Ridge of Papua New Guinea, which may include geophysical mapping, measuring physical and chemical characteristics of seawater and bottom currents, monitoring acoustic and seismic signals by mooring

hydrophones and micro-seismometers. I remembered the report that there was a big disaster by tsunami in July 1998 in Papua New Guinea. As accompanying research, we also plan to set up the tsunami forecasting system of numerical modelling along the coasts of Papua New Guinea, with the direct measurements of seismic signals by moored equipments. For accurate forecasting, we are going to survey precise topography in the coastal region of Papua New Guinea during the first 3 years.

During the second stage (2009-2011), KORDI will focus on monitoring the hydrothermal vent fields - plume processes, seismic and geological setting, biodiversity, mooring current-meters, hydrophones, and seismometers. We will launch a large research vessel of 6,000 tons and an unmanned submersible in 2008. For reducing trials and errors, we need scientific collaboration with French and Japanese scientists, especially for their experience in operating submersibles. As a first step, a scientific proposal of our collaboration submitted to both Korean and Japanese governments would be the better solution to expand the project for a long term. An expert/student exchange programme will be also set up between IFREMER, France and KORDI, Korea.

During the final stage (2012-2015), we will continue to monitor acoustic and seismic signals of water and, at the seafloor, variations of plume dynamics and biodiversity, and the potential periodicity of hydrothermal plumes.

The first discovery of the hydrothermal vent at the Galapagos rift area in the Eastern Pacific, which was less than 30 years ago, became one of the greatest turning points in human history for about 5,000 years. Our present energy and efforts to launch the project into the western Pacific would be hopefully another small foot-print in the research field of deep-sea hydrothermal environments.

However, I do believe that we can never succeed our goal without the help of the SOPAC countries in drawing the whole picture of the hydrothermal environments in the western Pacific region. So, I cordially solicit your concern and criticism about KORDI's new plan for marine scientific research of hydrothermal vent environments during the session. Thank you!

KADOSHIMIA & others

Petrology of mafic-ultramafic rocks obtained from the NFFZ (North Fiji Fracture Zone): Implication for tectonics and hydrothermal activity

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The R/V Hakurei-Maru No.2 cruises conducted sampling rocks in the EEZ off the Republic of the Fiji Islands in 1999 and 2001 in search for hydrothermal sulfide deposits, and we recognized the highest potentiality

for hydrothermal mineralization at the two areas 'Central Hill' and 'ERZ A', in addition to the Triple Junction area, in the NFFZ as (Figure 1).

During the latest cruise at the Central Hill in 2004, we found hydrothermal zones, consisting of bluish green and yellow discolored zone accompanied by organisms, over the top of massif of plutonic rocks. We obtained ultramafic and mafic plutonic rocks by FPG (TV-monitored Power Grab) and dredge.

The ultramafic rocks are bimineralic, being composed mainly of olivine and clinopyroxene with small amount of chromian spinel. The mafic rocks are largely two-pyroxene gabbros (or we may call them as "mafic granulite") suffered from alteration (hydration) to various extents. The ultramafic rocks are commonly heterogeneous in terms of olivine/clinopyroxene ratios (dunite, wehrlite and olivine clinopyroxenite depending on the proportion of olivine to clinopyroxene). Apparent graded bedding can be observed on sawed surface, and clinopyroxene grains tend to grow finer with an increase of olivine amount. Clinopyroxene-rich clots (or irregular-shaped layers) up to one centimeter in thickness are not rare. Gabbroic rocks intruded into the ultramafic rocks as thin sinuous veins, and exhibit melt impregnation textures (formation of amoebic plagioclase). The ultramafic rocks are sometimes foliated, and gabbroic rocks are massive but are sometimes foliated.

Petrographic examination suggests that the ultramafic rocks were derived from parts of a certain type of layered plutonic body. Dunite appears to gradually change, in ascending order, to clinopyroxenite through wehrlite and olivine clinopyroxenite in the layered body. Gabbroic rocks possibly have intrusive relations to the ultramafic rocks. Intrusion and impregnation of the gabbroic melt have added the ultramafic rocks much complicated aspects such as precipitation of plagioclase from the impregnated melt. The impregnated melt may have been hydrous; secondary amphibole was selectively formed around the gabbroic veins. Alternatively, hydrothermal solution has acted selectively around the gabbroic veins, forming secondary hydrous minerals (amphiboles, sericite, and "saussurite" composed of hydrogrossular and zoisite). The wehrlite of the Central Hill, Fiji, is quite different from the wehrlite forming the late intrusion of the Oman ophiolite, which is usually homogeneous in terms of olivine/clinopyroxene ratio (Uesugi, 2004). Some of the dunite samples are very homogeneous in appearance and are free of clinopyroxene. They seem to be different in origin from the dunite that is gradational to wehrlite.

Mineral chemical change is gradual from wehrlite (dunite) to gabbro, indicating that the whole rock suite (dunite to gabbro) may have been a series of cumulates from a magma. The order of crystallization was olivine (chromian spinel), clinopyroxene, orthopyroxene and plagioclase (and magnetite). Gabbroic or felsic veins within the ultramafic rocks were due to invasion of fractionated magma into earlier cumulates.

The dunite-wehrlite-clinopyroxenite-gabbro suite, possibly with layered structure, obtained from the knoll off Fiji is different in lithology from the so-called late intrusive rocks in ophiolites (e.g., the Oman ophiolite), which are massive and homogeneous in appearance. The mineral chemistry is, however, strikingly similar especially in spinel chemistry, which very clearly denies the mid-ocean ridge affinity, and we suggest that the dunite-wehrlite- clinopyroxenite-gabbro suite from Fiji was originated not from the mid-ocean ridge but from an arc as a whole. This is consistent with that dunite-wehrlite-clinopyroxenite series of rocks have not been documented from the ocean floor (e.g., Dick, 1989; Dick and Natland, 1996; Arai and Matsukage, 1996) but have been very commonly found as xenoliths from arcs (e.g., Arai et al., 1998, 2000). We should further examine trace-element characteristics of clinopyroxene by La-ICP-MS in order to specify the tectonic setting of its genesis. This will, also, give us clues to understand the mechanism of hydrothermal activity and potentiality of mineralization associated with ultramafic environment of arc origin in the Fiji.

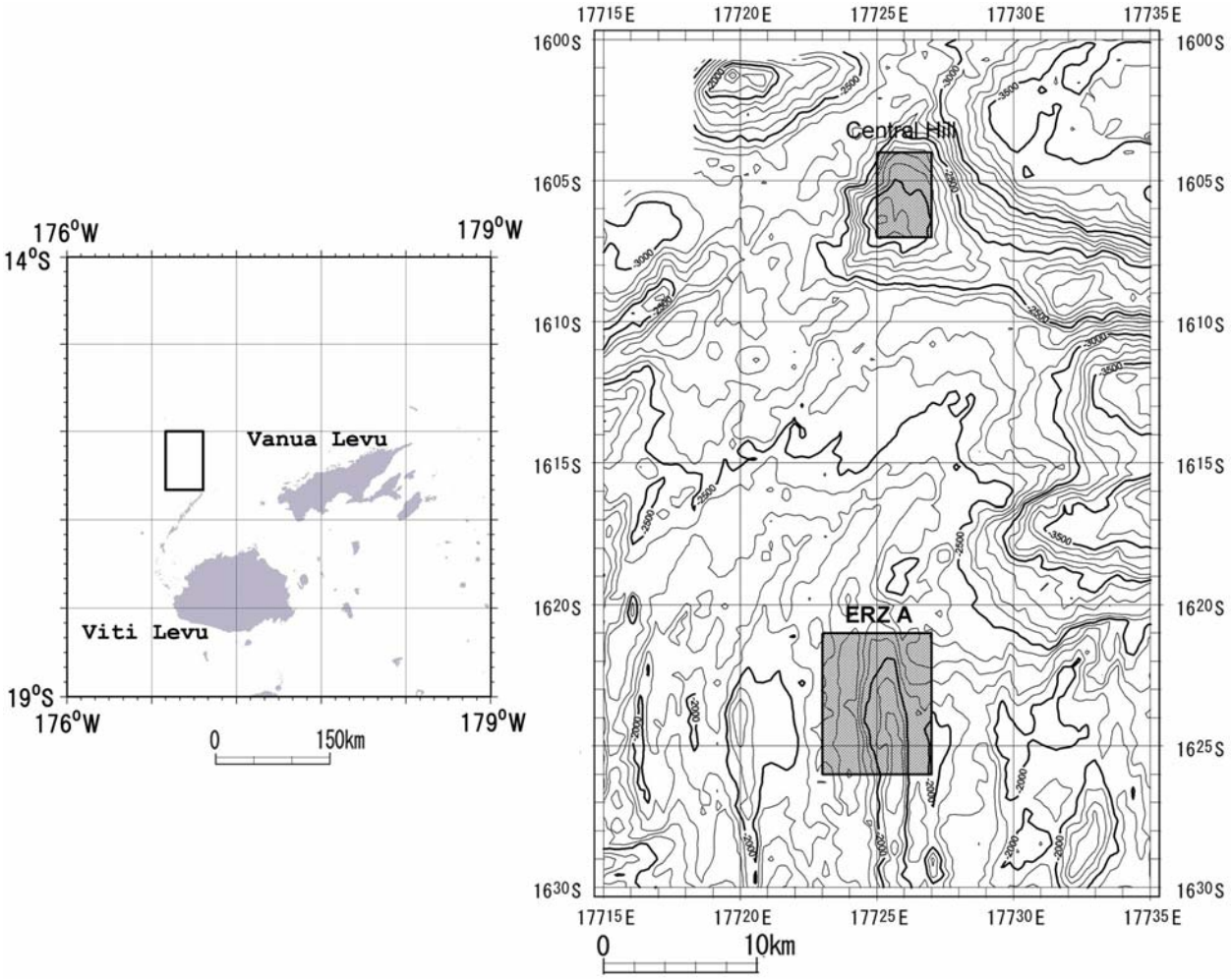

Figure 1: *Location map of survey area.*

KALUWIN & LAL

AusAID South Pacific Sea Level & Climate Monitoring Project Phase III

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There is a major concern that the sea level is rising in the world and as well as in the South Pacific region. Everyday regional countries are taking up issues related to sea level rise. These issues relay that sea level is rising due to the thermal expansions of the seawater or is it the tectonics movement of

the sea floor or is it the contributions from the land ice. All of these contribute to the sustainable development of communities and their very existence, which is threatened by inundation and damage to their fresh water supply.

Therefore the South Pacific Sea Level and Climate Monitoring Project (SPSLCMP) is monitoring sea level change. It is being funded by AusAID, is managed by Australian Marine Science & Technology and is coordinated by the National Tidal Centre Australia and Geoscience Australia. The project is now in its final year of the Phase III of its 20-year project. This project started in October 1992 where by Phase II and I are completed. The regional office of this project is based at the Forum Secretariat Building office in Suva, Fiji Islands. SOPAC has been approached as one of its regional partners in the project, contributing towards technical assistance and also being the regional data archive centre for the project.

This project aims to provide high quality meteorological and sea-level data through an array of latest climate monitoring stations, backed by the precise geodetic survey network in the region to produce data, research and results upon which the South Pacific Countries can make future development plans. A series of high-resolution sea level recording stations has been established in twelve countries of the South Pacific Forum with data transmission via satellites.

The data collected by the project are in various forms and are used by the meteorological department, lands and survey department and by the research scientists. The Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) measures water levels, wind, atmospheric pressure, air and sea temperatures in twelve countries. The method of data collected is through Precise Differential Levelling surveys whereby vertical control stations are established with the survey data also being used by the surveyors for their land and geodetic surveys. The surveyors and the navigators are benefiting from the establishment of the Continuous Global Positioning Systems (CGPS) survey network by this project. Both the SEAFRAME and the CGPS stations are tied together using the precise differential levelling surveys.

The raw CGPS data is distributed and made available to the participating South Pacific Forum countries, and the global scientific community in the international standard Receiver Independent Exchange Format (RINEX).

The data provides benefits to the national infrastructure of the participating countries with opportunities to:

Upgrade their geodetic survey network
Unifying height datum, nationally and regionally
Determine transformation parameters
Cadastral and Engineering Surveys
Digital Elevation Models (using kinematic GPS and geoids)
Coastal Zone Management
Mitigation

The project data and information are produced in various forms of fact sheets, SEAFRAME & CGPS data reports, six-monthly newsletters and tidal calendars

Year 2005 is the final year for the Phase III of the South Pacific Sea Level Climate Monitoring Project. Samoa has participated in the project since 1993 where the SEAFRAME station was established and the Continuous Global Positioning Systems was commissioned in July 2001. The Apia Observatory Office and the Department of Lands & Surveys are the local agencies facilitating the project in Samoa. There have been field survey visits on an 18-month cycle phase for calibration and maintenance of the SEAFRAME stations and the precise differential levelling geodetic surveys to monitor the movement and establish the link between the SEAFRAME and the CGPS station.

Phase IV of the South Pacific Sea Level & Climate Monitoring Project starts in January 2006.

KENNEDY

Island Sediment Budgets – Towards a complete understanding

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Coral reefs are considered to be one of the most vulnerable landform systems in the world. Islands perched precariously on their surface extend only a few metres above sea level and are therefore very vulnerable to a range of coastal hazards such as cyclones, ENSO, or tsunami. On high islands, where the centre of the island can rise hundreds of metres above the sea surface, coastal plains close to high tide level are often the focus of human activity. These areas are just as vulnerable to change as small cays and motus. The vulnerability of these systems is expected to increase due to human-induced climate change.

The unique aspect of these island systems is that the sediments they are composed of are created *in situ* by the biological communities of the reef. Any change or disturbance to these systems may have a direct impact on their ability to produce sediment and hence nourish the associated islands and coastal plains. The loss of those reef communities that directly contribute sediment to the islands causes sediment loss and results in coastal erosion. It is therefore essential to establish the degree of connectivity between the reef and the backing depositional systems of lagoons, islands and coastal plains.

The morphology and sediment characteristics of islands are unique. This means that generalising sediment budgets and predicting how they respond to change is difficult. By using specific examples from the South Western Pacific this paper aims to show how an understanding of the basic sedimentology of a reef system can provide detailed information on the degree of connectivity between areas of sediment production and their final location of accumulation. This information is of critical importance to managers and planners as it can assist in predicting how island systems may respond to future environmental change such as sea-level rise as well as assess contemporary erosion problems.

KIM & others

Bathymetry and morphology of the southeastern lagoon area of Savai'i Island, Samoa

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As a part of coastal geomorphology mapping brief bathymetric survey was performed in the Savai'i Island, Samoa. The main purpose of the survey was to ground-check bathymetric changes discernable in satellite images and aerial photographs. The survey period is from 26th to 29th in July, 2005 and the survey area is a lagoon between the Salelologa to the Pu'apu'a villages, which is located in the southeastern coast of the Savai'i Island. Approximately 80 line-km were surveyed in five- to six-knot speed. The water depth data were acquired using a single channel echo-sounder (Raytheon model DE-719C) at every seconds. Ship's navigation was based on a GPS (Trimble), which normally gives no more than ten-meter position error. Position and depth data logging and processing were performed with the Hypack (v.4.3) hydrographic survey software. Sound speed and transducer draft were measured and input to the software every day before starting a survey.

Based on remote-sensing images, ground-check data and predicted tide level the overall bathymetric character of the study area could be explained. In the reef flat the water depth is less than a meter, whereas more than fifteen meters in the blue holes and reef breaks. The southern part of the study area (from Salelelоga to Tuasivi) has higher values in water depth and more irregularities in topography than the northern counterpart (from Tuasivi to Salelelоga). Hence, the former shows a shoreward-deepening trend, whereas monotonous and uniform water depth is maintained in the latter. It is noteworthy that, in the Safua village, slight bathymetric depressions in the river mouths and distinct changes in color and composition of surface sediments are recognizable, which are presumably due to river run-off during high precipitation period.

Owing to the survey result it is expected that the overall reef bathymetry and morphology could quantitatively be described and input into a coastal geomorphology map as an additional information layer for future detailed survey (e.g. a multi-beam survey).

KITAZAWA

Monitoring buoys and ARGO floats

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NO ABSTRACT RECEIVED

KROENKE

Victoria Fracture Zone: A Failed Incipient Subduction Zone?

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Lying east of the Ratak - Gilbert Chain, the NNW striking Victoria Fracture Zone separates ENE trending M series magnetic anomaly lineations that are roughly 10 My older to the west than those to the east of the fracture zone. Sea floor topography is somewhat unusual for a fracture zone. At its northern end, the zone is marked by a deep broad trough, flanked on its eastern side by a high broad ridge and an adjoining deep wide basin. Southward, these features become increasingly suppressed, before finally completely disappearing at the far southern end of the fracture zone, even though the magnetic lineation offset continues to be preserved. The northern end of the fracture zone seems to be structurally deformed, with the trough curving eastward and the broad ridge, east of the trough, appearing to be uplifted, with a steeply dipping western face and a more gently dipping eastern slope. The ridge is also broadest at its northern end. Another unusual facet of this feature is the depth of the ocean floor on either side of the fracture zone, with the sea floor considerably shallower on the older western side then the younger eastern side. These structures, which seem to be overprinted on the original seafloor fabric, are suggestive of focused sub regional rotation that may have produced local convergence antecedent, perhaps, to the development of a subduction zone. Indeed, volcanic ridges, often oblique to spreading fabric and with radiometric ages frequently in the 80-90 Ma range, which commonly occur around this region, suggest the development of surrounding extensional stress and may indicate the origin time for the structure.

Early failure of subduction zone development may have been caused by collision with the anomalously shallow seafloor, i.e. with thickened lithosphere, adjoining the Ratak – Gilbert Seamount chain west of the Victoria Fracture Zone.

LAFOY and others

The ZoNéCo 11 deep seismic and wide-angle seismic survey: contribution to the petroleum potential of Western New Caledonia's EEZ

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Since 1993, French scientists have been studying the Southwest Pacific region, particularly the area located between the Lord Howe Rise and New Caledonia. The geodynamic history of the Southwest Pacific region has been dominated, since Cretaceous times, by the dismembering of Gondwanaland (Crawford *et al.,* 2002). From *ca.* 120 to 52 Ma, an extensional episode led to fragmentation of continental crust to form three subparallel marginal basins: from west to east, the Tasman Sea, the New Caledonia Basin and the Loyalty Basin; and two aseismic microcontinental ribbons, the Lord Howe Rise and the New Caledonia–Norfolk Ridge.

Petroleum potential of New Caledonia

The potential for finding commercial petroleum reserves in New Caledonia and its offshore area is considered good as:

1) Onland, Senonian coals (and coaly shales) were identified as source rocks (Vially et Mascle, 1994). In 2000, the Cadart-1 well confirmed the existence of an active petroleum system (France, 2000) with significant gas shows but no commercial accumulation.

2) Offshore, the thick sedimentary basins and the high geothermal flux values are compatible with the generation of hydrocarbons. The petroleum potential of the deep submarine basins located west of New Caledonia has been recently appraised within the framework of two main programmes:

   i) ZoNéCo, that aims at assessing the resources (non-living, living) of New Caledonia's EEZ;

   ii) FAUST (French Australian Seismic Transect) that aimed at improving the understanding of the geological framework and the evolution of the area between Australia and New Caledonia.

The main results of these two programmes, together with the work carried out by the French Institute for Petroleum (IFP) (Vially & Bénard, 2001), showed that the northern parts of the New Caledonia and Fairway basins, both located west of New Caledonia mainland could be considered as a frontier exploration zone for conventional hydrocarbon recovery.

- The NW-SE trending Northern New-Caledonia Basin is underlain by a basement that shows large tilted-blocks filled by deposits up to 8 km-thick (Lafoy *et al.,* 1998, 2005). The sedimentary infilling is sufficient to generate liquid and gaseous hydrocarbons.

- The NW-SE trending Northern Fairway Basin shows an average sedimentary infilling of 3 km, compatible with production of liquid and gaseous hydrocarbons (Vially *et al.*, 2003), and underlying diapirs (sedimentary and volcanic intrusions) rooted within Cretaceous series. This part of the basin appears to be the major target for conventional exploration with thick sedimentary layers and tilted-blocks traps.

However, to better assess the petroleum potential of the Fairway and New Caledonia basins, the unknown nature of their basement needed to be unveiled with the help of a deep seismic reflexion and refraction survey, the ZoNéCo 11 campaign (Lafoy *et al.,* 2004).

The ZoNéCo 11 deep seismic survey

The ZoNéCo 11 deep seismic survey (8 Sept. - 5 Oct., 2004 aboard Ifremer's R/V L'Atalante), the programme's sixth geophysical cruise, aimed at improving the understanding of the geological framework, crustal characteristics, and evolution of the submarine basin and ridge system located west of New Caledonia's mainland. The ZoNéCo 11 survey involved scientists from both New Caledonia and France, and acquired 2500 km of deep seismic reflexion and 600 km of wide-angle seismic data. All shots from the 8000 cubic inch airgun array were recorded by a 4.5 km (360 channels) digital streamer and 15 OBS (Ocean Bottom Seismometers).

On board interpretation of the seismic reflection data and preliminary modelling of wide-angle data (Lafoy *et al.,* 2004) confirm the continental nature of the Lord Howe Rise and the Norfolk Ridge, corroborating Shor *et al.* (1971). For the first time, the ZoNéCo 11 wide-angle seismic and magnetic data reveal the continental-type seismic velocities and crustal thicknesses of the Fairway Ridge and Basin system, and the oceanic origin of the New Caledonia Basin N-S Central segment that likely opened during the Upper Cretaceous Magnetic Quiet period (anomalies M0 to 34, i.e. 114-83 Ma) (Lafoy *et al.,* 2005).

Impact on Petroleum potential

The discovery of the thinned-continental origin of both the Fairway Basin and the Northern New Caledonia Basin has a direct impact in terms of petroleum potential, allowing evolutional analogies between the Western Offshore New Caledonia basins and both Australia and New Zealand.

- The thinned-continental Fairway Basin, filled by 3 km-thick deposits, is interpreted as part of the Gondwana block, made of the Lord Howe Rise and the thinned-continental Fairway Basin and Ridge. Moreover, geophysical interpretations enable us to extend the Fairway Basin down to the Taranaki Basin, New Zealand's only petroleum-producing basin. Estimated recoverable reserves total 5 trillion cubic feet (TCF) gas and 300 million barrels (MMB) oil/condensate. Consequently, the Southern New Caledonia Basin ends further north than previously thought, within the Reinga Basin, northwest of Zealand's North Island.
- The Northern New Caledonia Basin, with a complex type of crust could be interpreted as a thinned continental basement, part of the Norfolk Block comprising the thinned-continental West Caledonia Basin (west of New Caledonia) and the Norfolk Ridge. In this hypothesis, the petroleum system described onshore (Cadart-1 well, France, 2000) can be extrapolated offshore, with Cretaceous tilted-blocks, filled by deposits up to 8 km-thick, as structural traps.
- The oceanic nature of the N-S trending Central New Caledonia Basin's basement does not show any hydrocarbon prospects.

Conclusions – Prospective

The preliminary results of the ZoNéCo 11 deep seismic survey are of key importance in terms of assessing the petroleum potential of New Caledonia's Western EEZ. A complementary petroleum synthesis is currently being carried out within the framework of a national development plan for New Caledonia's mineral resources. According to the preliminary results of this synthesis, the Western New-Caledonia deep offshore

basins appear to have a likely long-term petroleum potential and consequently could be considered as frontier basins for the 21st century's hydrocarbon exploration.

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LEENDERS

Disaster Risk Reduction through hazard and vulnerability mapping: a multi stakeholder approach, Lae, Papua New Guinea

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The coastal city of Lae is the second largest, and arguable, the most hazardous in PNG. The "Pacific Cities" extension for Lae is intended to benefit the communities in and around Lae with respect to the several hazards that have the potential to turn into disasters because of the high vulnerability in the area.

The population of Lae has risen continuously, from 16,500 in 1966 to more than 120,000 according to the 2000 census. Future growth is forecasted to be 4% annually. Illegal settlements are not included and have

an enormous expected population of over 50,000 in the very hazardous areas. The collapse of the Umi Bridge (over the Markham River) for 5 weeks in 1994 cost the Coffee Board an estimated loss of US$40 million for coffee only. The total economic loss of import/exports and for the coastal trade is not known.

Planning processes in developing areas fail to include hazard mitigation. In addition, increasing illegal settlements are often located in disaster-prone areas. At times when hazards are about to turn into disasters it is to late for response organisations to start looking for information of the areas involved or even to find out who is responsible for the different types of response. Baseline data is scarce and hazard/vulnerability maps unavailable to those who can and should deal with it. Planners should assess natural hazards as they prepare or review projects (from the location of new schools through to large local or foreign investments) and should encourage stakeholders in avoiding or, at the very least, mitigating against potential damage from hazards such as floods, earthquakes, landslides, chemical spills and other catastrophic events. Adequate advance planning can minimize damage from these events and, when development is proposed in known hazardous areas, proper investigations can be suggested. It is anticipated that familiarizing planners with an approach for incorporating natural hazard management into development planning and giving planners the data, the tools and the training to assist them can improve the planning process in Lae and thereby reduce the impact of hazards.

Disaster Management Centres (National or Provincial) are involved in Awareness, Preparedness and Response programmes and therefore rely on data made available by several Government bodies and the private industry. Again, these data need to be available prior to any programme as listed above and especially in an actual Disaster Response there is an immediate need for information to be able to make sound decisions on the problem at hand.

Hazards

Development planners, business managers and disaster workers do not need to be hazards specialists, but ought to understand the main features of the hazards and their possible impacts in the communities they are responsible for. To facilitate this requires the development of Hazard and Vulnerability products on:

Coastal planning
- Planning in other hazard prone areas (flood, earthquake, landslide etc.)
- Disaster Management purposes, National and Provincial level
- Public awareness material (access for all, through the internet and other means)

Main hazards identified:

Tsunami	:	Possible inundation mapping (and modelling if funds permit)
Floods	:	Inundation area mapping for events having a 5 or 10, 25 and 50 year return period
Earthquake	:	Microzonation mapping, based on exiting research
Coastal erosion	:	Susceptible area mapping
Landslides	:	Susceptible area mapping
Wharf siltation	:	Extensive hydrodynamic river and coastal modelling will be required but may fall outside the scope and funding of this project

An intensive vulnerability assessment focussing on Housing, Infrastructure, Land use and the Environment needs to be carried out and the data from this exercise will be used to address the hazards mentioned above. Town planning and Disaster and Risk management professionals require analysis of the hazards and mapping of the outcome in a GIS with training provided for the end-users.

Benefits

The main benefits of Multiple Hazard/Vulnerability Mapping are the clear overview on the different hazards and vulnerabilities facing a community. This provides a useful tool to identify areas of special needs or interest. It also reduces time and effort of surveying each area several times to be able to identify the different vulnerabilities to hazards.

An excellent tool for awareness raising has been successfully employed in Fiji where a school designed and made a 3 dimensional model based on similar data to that required in this project for all to see and relate to dangerous areas in our neighbourhoods.

The Provincial Government of Morobe has already indicated a very strong interest to maintain the proposed database and to supply other stakeholders with the data in soft or hardcopy.

MARIO

Demand Side Management in the Pacific

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DSM is of high importance and presents a unique challenge. Improving the efficiency of energy utilisation leads to a reduction in energy consumption per unit product or activity. In the past the Pacific has been relatively poor at adopting practices and designs that promote energy efficiency. This stems from a lack of policy, a lack of information and education, and reluctance among consumers and energy suppliers such as power utilities to make the necessary up-front investments. It has been well demonstrated and recognised that more efficient energy systems will contribute to cost reduction, reduce fossil fuel imports, reduce demand, improve local environments and reduce greenhouse gas emissions. Energy efficiency and conservation in the Pacific have not been considered seriously as the region strives towards ensuring a reliable energy supply.

Demonstration projects currently being implemented through the Fiji Electricity Authority and Electric Power Corporation in Samoa will demonstrate the benefits that can be gained through energy efficiency and conservation projects in small island countries.

MARIO

Rural Development and Poverty Alleviation in the Pacific Islands. The role of biomass – issues, risks, strategies and options

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The Pacific region is distinguished by its geography and environment as well as its unique cultures and social traditions. Its islands are widely dispersed over a large geographical area [6% of the Earth's surface and 30% of the Earth's EEZ[2]] and differ significantly in size, population, resource endowments and development constraints, but nevertheless share a number of development challenges.

Poverty is not commonly associated with Pacific Island societies, and many in the region have resisted the idea that poverty exists. Participatory studies undertaken by the ADB[3] in a number of Pacific island countries state that poverty (or hardship) is an inadequate level of sustainable human development, manifested by: a lack of access to basic services; lack of opportunity to participate fully in the socio-economic life of the community; and lack of adequate resources (including cash) to meet the basic needs

[2] Exclusive Economic Zone
[3] Asian Development Bank (Abbott and Pollard in press)

of the household, and/or customary obligations to the extended family, village community and/or the church.

In this context, Pacific rural development programmes have been structured to address these components. The role of biomass in Pacific rural communities is also notable with an average of about 42%[4] of households using biomass (wood, charcoal, crop residues and dung) as the primary source of domestic energy for cooking and heating. The Pacific Islands Energy Policy also makes reference to the development of sustainable energy options (including biomass) with a dedicated chapter on Rural Areas and Remote Islands.

The biomass resource in the Pacific is believed to be in abundance, especially in countries like Papua New Guinea, Fiji Islands, Samoa and Solomon Islands. On the other hand, there are issues such as the lack of reliable data; guiding plans and policies; and the absence of trained and experienced nationals that pertain to sustainable management of biomass energy resources in the Pacific region.

In response, SOPAC implemented a biomass resource assessment project in six Pacific island countries with a capacity building component and the development of a way forward. The initiative concluded with the formulation of a Technical Cooperation Programme Project Proposal on *Technical Assistance for the Development of Regional and National Biomass Energy Programmes for the Island Nations of the Pacific Region* and submitted to the United Nations Food & Agriculture Organisation for funding.

Recently, SOPAC further diversified its biomass programme with a feasibility study [CocoGen Project] on the use of coconut oil as fuel for electricity generation on the island of Savaii in Samoa. The study also looked into strategies and options of reviving the coconut oil production industry in Samoa through enabling activities for coconut plantation farmers.

Biomass related activities in the Pacific also continued at the national level with electricity generation using bagasse and wood chips in the Fiji Islands; and the use of coconut oil as fuel for land transport in the Marshall Islands and Vanuatu.

This paper intends to showcase the role of biomass by highlighting the challenges, risks, strategies and options the Pacific region has taken in its efforts to develop sustainably and alleviate poverty.

MARIO

Small Islands, Big Challenges. Minimising risks through strategic energy planning

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Energy as an integral component of everyday living necessitates strategic planning. Pacific energy issues within the context of sustainable development in the Pacific region involve many complex, cross-sectoral and interdependent factors requiring a professional approach and coordination. The region is confronted with four-dimensional problem matrices that involve technical, financial, economic and social aspects. These are challenged largely because of the range of varying demographics between countries and markets that prove difficult to serve, and the lack of significant economies of scale.

The understanding of how well any system can cope with the challenges requires more than just stakeholder consultation. There is the need for an in-depth holistic approach to energy planning.

[4] Millennium Development Goals Pacific Report Goal 7 Indicator 29.

The paper will attempt to use the Comprehensive, Hazards and Risk Management (CHARM) approach to demonstrate the integration of risk management into energy planning.

MARTINEZ & TAYLOR

Arc-to-oceanic seafloor spreading in western Pacific back-Arc basins

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Several back-arc basins in the western Pacific share a common, but until now, poorly examined form of seafloor spreading that differs markedly from that which forms most of the crust in the Worlds oceans. In the Mariana Trough, Manus Basin and Lau Basin spreading segments form crust from mantle sources which span end-member arc and oceanic mantle types, with major effects on crustal accretion, in a process we term “arc-to-oceanic” seafloor spreading. The spreading segments in these basins are situated at varying distances from the arc volcanic front. At one end-member, the spreading axes are located at or very near the tectonic position of the arc volcanic front and accrete thick crust which is geochemically arc-like; the spreading axes are magmatically robust and have “fast-spreading” morphologies. At the other end-member, the spreading axes are located far from the arc volcanic front, form typical mid-ocean ridge basalt (MORB)-like crust and have morphologies consistent with mid-ocean ridge spreading. At intermediate distances, the spreading axes surprisingly produce thinner than normal crust with geochemical characteristics intermediate between arc and oceanic sources. Although these back-arc basins are geographically small relative to the oceanic basins we will discuss how their spreading characteristics have important implications for global tectonic processes, addressing the following topics:

1) Back-arc mantle wedge processes perturb the usual tight coupling of magma production with spreading rate that typifies oceanic spreading centers allowing alternate effects of these controlling variables on ridge tectonics and hydrothermal activity to be examined.

2) The arc-to-oceanic spreading process is a spatial analog for the temporal evolution of back-arc magmatism. Back-arc basins form by splitting the arc massif and accretion of new crust. Thus, back-arc spreading is initially proximal to the volcanic front and with time migrates away. The active processes spatially distributed along the southern Mariana Trough are therefore analogs for temporal evolution of back-arc magmatism. It is possible that the thick crust formed proximal to the arc can be misidentified as rifted arc crust with important implications for understanding the tectonic evolution of back-arc basins.

3) Seafloor spreading at arc-proximal back-arc ridges is a poorly examined mode of crustal production with important implications for continental crustal formation and growth. Crust produced at these spreading centers from highly hydrated mantle can be andesitic to rhyolitic in composition and is produced at high volumetric rates. Such crust is thick and buoyant and may be amenable to emplacement at continental margins when these systems suture in tectonic collisions.

4) Arc-proximal spreading may be a key to understanding ophiolites. Ophiolites are crustal emplacements formed by seafloor spreading but often with strong supra-subduction zone chemical characteristics. An outstanding problem has been that typically they have no arc volcanic edifices evident although expected in this setting. This has lead to the suggestion that ophiolites form in forearcs at subduction initiation, a process for which there are no known modern analogs. The southern Mariana Tough today is actively forming crust by seafloor spreading with strong arc geochemical signatures, but without nearby large arc volcanoes because the spreading system there has effectively replaced the arc volcanic front.

MATSUMOTO & others

Results of environmental survey in South Pacific waters 2000-2005

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It is expected that deep-sea-bed mineral deposits are future targets of development of mining industry since high quality mineral resources abound in these areas. However, various organisms of scientific value and their genetic resources that are considered significant in future industries should be recognized first before making steps for any artificial human activities. It is therefore necessary to evaluate or simulate the magnitude of impacts resulting from deep-sea mining in order to keep a balanced relationship between the development of resources and environmental protection. On this ground, the JOGMEC conducted a basic environmental research together with the investigation of mineralization in the deep-sea-bed areas within the Exclusive Economic Zone of participating nations in the SOPAC. The surveys were divided into two main subjects with the objectives of understanding: 1) the water quality and abundance of bacterioplankton; and 2) the sediment properties and composition of benthic organisms. The subjects included in the survey at seven areas in the years 2000-2005 are shown in the table below. The presentation will focus on the comparison of the common subjects, regarding their sediment properties and the composition of benthic organisms, among the seven areas surveyed. Despite of the difficulties encountered in the collection of samples in the Fiji area for quantitative analysis, it was rewarding to be able to obtain previously lacking information on the composition of meiobenthic communities. Moreover, the observation of tubeworms and *Calyptogena* in the area that indicated the presence of a hydrothermal activity were considered as significant results. The information gathered will be important comparison data for environmental monitoring with mining in future.

Subjects included in the environmental survey in each area

Survey areas	Year	Properties of Sediment and Benthic Organisms								Water quality and Bacterioplankton		
		Water content	Specific gravity	Total organic carbon	Total nitrogen	Sediment bacteria	Meio-benthos	Macro-benthos	Mega-benthos	Water temperature	Salinity	Bacterio-plankton
Cook	2000	○	○	○	○			○	○			
Fiji	2001			○	○	○	○			○	○	○
Marshall	2002			○	○		○	○				
Kiribati	2003	○	○	○	○		○	○				
Niue	2003	○	○	○	○		○	○				
Fiji	2004	○	○	○	○	○	○		○	○	○	○
Micronesia	2005	○	○	○	○	○	○	○		○	○	○

McKENZIE & others

The economic impact of natural disasters on development in the Pacific: Research report and economic assessment tools

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Natural disasters cause direct damage, such as loss of life and damage to housing, and can also lead to indirect losses such as falls in agricultural production and tourism revenue. There are often environmental,

psychological and social impacts, which are less easily quantifiable, but important. Existing data on the impact of disasters in the Pacific are weak, presenting an incomplete and often inaccurate account of their effects. This makes it difficult to plan effective post-disaster rehabilitation and reconstruction strategies. It also creates problems in presenting to policy makers and donors the serious consequences of natural hazards and the imperative for Disaster Risk Management measures. Improving assessments of disaster impacts and mitigation measures should therefore be a high priority for the region.

In response, the University of the South Pacific (USP) and the South Pacific Applied Geoscience Commission (SOPAC) jointly conducted research into the economic impact of natural disasters on development in the Pacific. The report was published in two volumes: Volume 1 contains the research report with findings from the four case study countries (Fiji, Vanuatu, Niue and Tuvalu); and Volume 2 contains the economic assessment tools, which comprise of a set of 'Guidelines for Estimating the Economic Impact of Natural Disasters on Development in the Pacific' and a 'Toolkit for Assessing the Costs and Benefits of Disaster Risk Management Measures in the Pacific'.

The simple, standardised guidelines can help decision-makers to estimate the impacts of future natural disasters comprehensively, including direct physical damage, subsequent indirect economic losses, environmental impacts and macroeconomic effects. The guidelines can be used to assess natural disaster impacts at the national and sectoral level – in social sectors, such as health and education, infrastructural sectors, such as transport and energy, and productive sectors, such as tourism and agriculture.

The cost benefit analysis toolkit outlines economic techniques that can be used to assess the costs and benefits of Disaster Risk Management measures, and thereby choose the most effective option from a range of alternatives.

Both the economic impact assessment guidelines and the cost benefit analysis toolkit are illustrated with examples and data gathered from the experiences of Fiji, Vanuatu, Niue and Tuvalu. The adoption of these guidelines and tools can improve the quality of data on the impacts of natural disasters in the Pacific region, and the relative effectiveness of Disaster Risk Management measures. It is hoped that through this a greater focus on mitigation and preparedness can be achieved, lessening the devastating impacts of disasters for future generations.

MEARNS & JONES

Disaster risk reduction and disaster management: 'The Pacific Islands Framework For Action 2005 – 2015' and its international and regional contexts

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The final draft of *An Investment for Sustainable Development in Pacific Island Countries: Disaster Risk Reduction and Disaster Management: Building the Resilience of Nations and Communities to Disasters: A Framework for Action 2005 – 2015* is being presented to the SOPAC Governing Council at its 34th Meeting following these Network sessions. Subject to Council's approval, the Framework will subsequently be put before Forum leaders for their consideration and endorsement.

The development of this draft was agreed in early June this year at the 12th Pacific Regional Disaster Management Meeting in Madang, Papua New Guinea, attended by SOPAC island member national disaster managers and other representatives from Pacific island nations, Australia and New Zealand. This meeting followed two years of regional preparation for the Second World Conference on Disaster Reduction held in Kobe January 2005.

The Second World Conference on Disaster Reduction had a successful outcome in that the unique vulnerability of the small island developing states was appropriately reflected in the resulting *Hyogo Framework for Action 2005-2015*. Fifty-two (52) participants representing thirteen (13) members of the Forum attended the Kobe Conference, including two delegations led by their Heads of Government.

Building on the outcomes of Second World Conference and since January 2005, SOPAC has coordinated the development and finalisation of the draft *Pacific Framework for Action 2005-2015* which supports the unique environment of the region and reflects the principles agreed in Kobe.

This paper sets out the international and regional contexts within which the Framework has evolved, describes the process undertaken in developing the draft Framework to its final form and offers an overview of the Framework itself.

NAIDU

Natural hazards in the tropical southwestern Pacific: community risk and vulnerability analysis in tropical cyclone prone areas

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The island communities of the tropical Southwest Pacific region are threatened by a variety of natural hazards. The hazards include tropical cyclones, storm tide, floods, earthquakes and tsunami. Based on the literature reviewed, vulnerability of the communities to impacts of these hazards varies greatly, but may be linked directly with income, education and local as well as national preparedness.

The focus of this research will be on the 'vulnerability' component. This research differs considerably from such conventional treatments of disasters and arises from an alternative approach that has emerged in the last twenty years. It focuses on certain aspects of social vulnerability and its role in contributing to the risk from Tropical Cyclones in selected communities in the Cook Islands. In particular, the study introduces a unique method of measuring the vulnerability of individuals within a household in order to contribute to the development of comprehensive natural hazard risk assessments. The research undertaken has been driven by two needs: firstly, to develop a custom-made methodology of quantifying social vulnerability that can be used in all the Pacific Island countries. Secondly this research has been influenced by a need to integrate social issues with hazard model development in order to investigate the greater risk to communities and thus be able to understand the root causes of vulnerability.

Disaster vulnerability is socially constructed, i.e., it arises out of the social and economic circumstances of everyday living (Morrow, 1999). As population and infrastructure increases, social conditions fluctuate and the relationship between humans and their environment becomes more complex. All of these factors, and more, contribute to the wider picture of risk, including risk from natural hazards. While natural hazards will continue to occur, their ability to become a disaster or merely a manageable event depend on many factors, including the frequency, magnitude of the hazard, the vulnerability of communities, the built environment, risk management and government systems. Protecting the most vulnerable requires knowing why they are vulnerable so that the conditions that put them at high risk can be changed. Thus one is interested not in the vulnerable groups per say but in the conditions that bring about their vulnerability to disasters and their capacity to recover.

The vulnerability studies of communities is based on an understanding that total risk is the outcome of the interaction between a hazard phenomenon, the elements at risk in the community and the vulnerability of those elements. Vulnerability is defined in the literature in terms of the capacity of individuals and social groups to respond to, that is, to cope with, recover from or adapt to, any external stress placed on their livelihoods and well being (Kelly and Adger, 2000). The vulnerability approach does not deny the significance of natural hazards as trigger events, but puts the main emphasis on the various ways in which

social systems operate to increase the likelihood of disasters by making people vulnerable. Vulnerability can be considered as an overarching concept, a focal point that can be aimed at improving the capacity of people to respond to stress. The general aim of this research is to develop a standardized vulnerability model based on a case study of coastal communities on one of the islands of the Cook Islands in the context of risk from exposure to extreme wind associated with tropical cyclones.

Preliminary results from the case study in the Cook Islands will be presented. This survey will be largely conducted through household-level surveys and interviews with key informants. It is anticipated that there will be enough evidence from the Cook Islands case study survey to better articulate that is a strong link between vulnerability to disasters and such characteristics as socio-economic class, gender, age, education, livelihood, employment etc. The survey will examine the individual, community and societal attributes, characteristics and structures of the resident population and determine how household residents within the community, individually and collectively, perceive and mitigate the risk of tropical cyclones. The ultimate goal for the community will be to be in a position to deliver effective mitigation strategies that would contribute to the development of sustainable safe communities, which is in line with the Kobe and Madang outcomes.

Therefore the social vulnerability analysis together with a hazard assessment will give complete overview of the risks and vulnerability existing within the communities.

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NÉMETH & CRONIN

The 1913 phreatomagmatic mafic explosive volcanism in western Ambrym, Vanuatu and its implications for volcanic hazard

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Magma-water interactions drive highly-explosive "phreatomagmatic" volcanism in many island volcanoes of the SW Pacific, as was demonstrated by historic eruptions on Ambrym, Vanuatu. At the western edge of the island, a phreatomagmatic volcanic field developed during a 1913 eruption near the main airfield of Craig Cove. The eruption destroyed several villages, filled-in a former harbour and demolished a hospital, leading to many fatalities. This event formed at least seven phreatomagmatic volcanoes, which completely covered an area of at least 25 km^2. Near-continuous cliff sections along the western coast of Ambrym expose up to 15 m thick successions of phreatomagmatic tephra units of one of the northernmost vents of the 1913 volcanoes. The succession can be subdivided into 4 major stratigraphic units, which aid the interpretation of volcanic processes and consequent hazards. PH1 forms a basal succession of lapilli and ash beds composed of weakly to moderately bedded, poorly sorted, cross-bedded to dune-bedded tephra up to 10 m in thickness. This succession contains coral fragments, indicating that the fragmentation level of magma-water interaction must have been in coral sand and gravel near a syn-eruptive shoreline. This succession is dominated by proximal base-surge beds with interbedded explosion-breccia horizons associated with more vigorous vent-clearing phases of the eruption. PH1 forms a lensoid 3D-geometry,

resembling a tephra ring that is mantled by a metre thick scoriaceous fall deposit assigned (mapped as MF1). MF1 is a clast-supported unit, containing flat to angular lapilli and blocks, which are highly vesicular with irregularly-shaped vesicles. This suggests magmatic (or "dry"), degassing-driven fragmentation of the uprising melt. The unit could be subdivided into at least 5 (dm-thick) coarse bed sets each overlapped by (cm-thick) finely laminated fine ash. The fall-beds are non-graded, moderately sorted with weak stratification. This unit is overlain by a succession of tephra (PH2) up to 10 metres in thickness. PH2 is subdivided into 3 major sub-units each recognised by a basal coarse accidental lithic breccia-bearing ash to lapilli horizon. The accidental lithic fragments are predominantly coherent lava rocks from pre-eruptive mafic lava units as well as indurated older phreatomagmatic lapilli tuff fragments. These dm-to-meter thick accidental lithic rich beds are overlain by a m-thick succession of cross-bedded to dune-bedded ash and lapilli beds, which implies an overall sequence of high-to-low particle concentration base surges to deposit these units. A well-defined tephra ring forms the MF2 fall unit that is similar, but greater in thickness to the lower MF1. Abundant coral fragments and scoriaceous lapilli are the main constituents of this unit. In the distal sections, the base surge dominated succession of PH2 is replaced by a reworked succession of dm-thick beds of fine ash, interpreted to have formed from syn-volcanic reworking of fine ash by debris flows and/or hyperconcentrated mass flows.

The studied succession is a good example that demonstrates pyroclastic density current transportation and deposition during a gradual loss of eruption energy, as well as input of fall material into the passing base-surge currents. Though the base surge currents are interpreted to be low temperature, their destruction potential was huge, because of their high particle-concentration in proximal areas. In addition, their deposits were rapidly and easily mobilised in to violent mud flows that affected adjacent low-lying areas (not already devastated by the base-surges of the eruptions). These events probably also triggered local tsunamis, through the shallow submarine explosions and collapses of growing near-shore and off-shore tuff cones. In addition, huge quantities of fine ash were likely generated, leading to major downwind impacts on crops and water supplies. This style of eruption represent the most likely explosive volcanic hazard on the majority of volcanic islands of the SW Pacific, and these types of deposits are also exposed (albeit not in such pristine state) on Holocene volcanoes of Fiji, Samoa, Solomon Islands, Tonga and throughout Vanuatu.

OKAMOTO

Japan-SOPAC Co-operative Deep-sea Mineral Resources Study Programme: The summary of the programme

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The Government of Japan and SOPAC have been jointly conducting surveys of deep ocean mineral resources in the EEZs of SOPAC member countries since 1985. The various research and government institutions that have been closely involved in this long-standing programme include; the Japan International Cooperation Agency (JICA); the JOGMEC (the former Metal Mining Agency of Japan: MMAJ) and relevant ministries of the participating Pacific Island governments.

The long-term commitment to the investigation of the deep-sea mineral resources in the Pacific Ocean Region has provided invaluable results and improved scientific understanding of the deep-sea mineral resources occurrences within the EEZs of the selected island countries.

The first stage of the project comprised three, five year phases, with surveys conducted within the EEZ' s of SOPAC eleven member countries, being the Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. Primary objectives of the first stage were to assess the marine mineral potential of these eleven countries.

The second stage of the programme commenced in the year 2000, involved surveys within the EEZ,s of Cook Islands, Fiji, Marshall Islands, Kiribati, Niue and Micronesia to evaluate deep-sea mineral resources as well as acquire environmental baseline data for use in environmental assessments in the event of future marine mining activities.

The twenty-one year long marine mineral research initiative has used the Japanese Research Vessel Hakurei Maru No. 2. It is owned and operated by JOGMEC and is designed specifically for deep-sea mineral resources prospecting.

The programme will be completed in March 2006 (2005 Japanese fiscal year) and final cruise was just carried out in May 2005. The overall project, since its inception in 1985, has obtained excellent results and has identified numerous sites with potential marine mineral resources of manganese nodules, cobalt-rich manganese crusts and polymetallic massive sulphides. The deep-sea mineral resources contain valuable resources contain valuable metals such as nickel, copper, cobalt, zinc, lead, silver, gold and other minerals. The survey cruises have identified numerous sites with potential marine mineral resources; manganese nodules in the Cook waters; cobalt-rich manganese nodules in the Marshall, FSM and Kiribati and hydrothermal deposits in Fiji.

Findings indicate greater abundance of deep-ocean mineral resources than similar resources found on land. Anticipated manganese, nickel and cobalt resources of manganese nodules on the seabed are estimated to be over hundred-fold greater than on-land resources. If this is indeed the case, it follows that deep-sea mineral resources within the pacific Islands region may hold an important opportunity to the future sustainable economic development of some pacific Island States.

To date, the Japanese Government has spent approximately FJD 120 million on this twenty-one-year joint programme.

PICKRILL

Habitat mapping and national seafloor mapping strategies in Canada

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As the twentieth century drew to a close Canadian ocean management policy and the supporting marine science within the federal government was entering an exciting new era. Competition for declining offshore resources, fishery collapse, and mounting public pressure for improved management, led the federal government to enact Canada's Ocean Act. This visionary legislation lays the framework for precautionary, sustainable management of our offshore lands; encapsulating the principles of conservation and ecosystem based management, and laying the foundation for systematic habitat mapping.

Management of offshore lands has been constrained by a lack of high quality information on marine ecosystems. However, converging technologies of GPS and multibeam mapping demonstrated the benefits of the new seafloor mapping technology, and led to the development of a proposal for a national programme to map Canada's offshore lands. SeaMap, an interdepartmental initiative would establish standards and set national priorities for seafloor mapping. The programme is yet to be funded. But, the SeaMap proposal demonstrated a need and many of the underlining principals are guiding seafloor mapping and research directions within Natural Resources Canada and the Department of fisheries and Oceans over the ensuing years.

In 2002 research in NRCan was reorganised to improve alignment with government priorities; the resulting Geoscience for Ocean Management Program (GOM, www.gom.nrcan.gc.ca) acknowledged the role that seafloor mapping can contribute to habitat mapping and environmental stewardship. With one of the

largest offshore territories, a relatively small population base, and a severe marine environment, Canada faces challenges to implement integrated and sustainable management of our offshore lands. Through a series of stakeholder workshops priority areas of national importance have been identified, while a habitat mapping strategy has been developed to optimise programme outputs.

Three systematic approaches to habitat mapping have been developed:

1. High-resolution regional mapping of seabed geology and habitats, based on acoustic surveys and groundtruthing (e.g. fishing banks);
2. Targeted high-resolution mapping of seabed features of value for conservation and fishery, and impacted marine habitats (e.g. sponge reefs, dump sites); and
3. Broad-scale habitat mapping based on deterministic modeling of geological and oceanographic controls on benthic fauna (e.g. shelf-wide mapping) and extrapolation of local models to regional applications (e.g. Beaufort Sea habitat mapping).

The model applied in a particular project is defined by geographical extent, ability to collect new data, environmental constraints, the time frame and stakeholder needs, yet always building toward a national framework.

POHLER & others

Sedimentology and oceanography of a tropical lagoon – case study in the Bay of Islands, Suva, Fiji

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Lagoons are common features on today's coastlines due to the marine transgression following the last glacial period. Coastal lagoons are important natural resources particularly with respect to fisheries. The productivity of a lagoon is predetermined by regional environmental factors, which must be understood to manage and possibly enhance productivity.

A study of Nubulekaleka Bay was undertaken from March – May 2005 in order to characterize the lagoon in terms of hydrodynamic regime, oxygen levels, marine geology, biology and shore line morphology. This base line study will facilitate future monitoring of the lagoon in order to better understand the relationship between lagoonal physics and biology.

Nubulekaleka Bay is a small inner bay (approximately 0.15 km^2) forming part of the larger Draunibota Bay. The bay lies on the leeward side (north west) of the main Suva peninsula. Overland along the Suva to Nadi highway (Queen's road) it lies just outside of the Lami township. More commonly know as the 'Bay of Islands', Nubulekaleka Bay nestles behind a number of small barrier islands (Vuo Island, Labiko Island and Vatutaya Rock). This protection provided by the surrounding landforms is further complemented by the Suva Harbour fringing reef system and indirectly by the Suva offshore barrier reef. This series of restrictions classifies Nubulekaleka Bay as a coastal lagoon as defined by Miller *et al.* (1990). A coastal lagoon is "a class of estuary with a restricted connection to the ocean such that wind forcing is more important than astronomical tidal forcing." In addition, the authors note that many lagoons are characterized by topographical axes being oriented parallel and perpendicular to the coast line.

The fact that hydrodynamic processes are important to coastal fisheries is known by all biologists however, the extent of control that physical forcing has over all biological processes in coastal environments is not well understood nor well documented. The study of Nubulekaleka Bay shows that particularly foraminifera and ostracod distributions are controlled by salinity, oxygen levels, water depth and substrate types.

Different ratios of ostracods and forams and different faunal compositions can be observed. Ostracods are the dominant faunal component in the lowest oxygen settings (Stn 1 at now demolished Fisheries Jetty), whereas the highest diversity and specimen counts were measured at the Trade Winds Pontoon (Stn 5). Both locations have the highest faecal coliform bacterial counts in the bay suggesting (a) proximity to the source of pollution and (b) poor flushing of the lagoon. The latter is also seen by the pronounced stratification of the water column in the lagoon and the current measurements at Stns. 1 and 5 which showed hardly any water movement both, at incoming and outgoing tides. The principal conclusion of the Nubulekaleka Bay current investigations is that the bay waters are subject to a very low energy current regime. When present, the most significant current driving mechanism is provided by local winds, which therefore influences the current direction (surface and subsurface). In the absence of wind, there is very little noticeable current movement with the exception of the delayed discharge (relative to predicted tidal peaks) of the culvert controlled inland catchment 'lake' northeast of the Tradewinds Hotel. The bay geometry is characterised by its shallow flanks and a natural deep channel between the Islands of Labiko and Vuo. The surrounding shallow waters damp current flows while the channel provides a natural discharge point for water in the bay.

The salinity measurements taken in the bay indicate that a freshwater lens is sitting on top of more saline seawater. Typically lagoon waters are homogenous due to vertical mixing (wind and waves). The stratified local waters therefore support the low energy current regime measurements and indicate very little flushing. The turbidity depths further reinforce the idea of stratification as the recorded secchi depths corresponded with the thickness of the upper freshwater lens. Radke (2005) suggests that in some coastal waterways a turbidity maximum occurs at interface between the intruding freshwater and the local seawater as a result of trapped and flocculated sediment. Both the salinity and turbidity measurements can be expected to fluctuate with the local and regional weather conditions. The presence of the freshwater lens indicates a contribution to the local current regime by freshwater inflow. The most brackish water is found in the shallow near shore region where the highest numbers of ostracods can be found in sediment samples. Their tolerance for low salinity is well documented. Stns 3 and 7 contain the lowest ostracod numbers and are located closest to the wide passage into Draunibota Bay with more normal salinity.

The study of marine sediments in the lagoon shows that the modal grain size of the bottom sediments near the Fisheries Jetty in Nubulekaleka Bay ranged between mud (5 phi) and gravel (– 2 phi). The mean grain size in the samples ranged from 4.52 phi (mud) to – 1.73 phi (gravel). Sorting of sediments in the bay varied between very well sorted to very poorly sorted. The skewness ranged between strongly negatively skewed to strongly positively skewed. The kurtosis for the bottom sediments in the bay ranged between being very platykurtic to very leptokurtic. It was observed that nearshore sites contain finer sediments that are well sorted which implies that there is low energy and no influx of coarse clastics on nearshore sites. Coarse grained and poorly sorted carbonate materials recovered from sites offshore can be explained by the fact that there were corals and other carbonate-producing life forms (e.g., *Halimeda*) in the bay in the recent past which are now dead perhaps because of the effects of pollution in the area. The other possibility is that the shallow submerged barriers around Nubulekaleka Bay are remnants of extinct Holocene reefs that existed around 4,000 years ago when sea level was higher (Nunn, 1992). Foraminifera retrieved from the carbonate rubble fractions found in the offshore sites are all badly abraded and obviously long dead. Faunas include large benthic reef dwellers such as *Calcarina, Marginopora* and *Amphistegina.* Dissolved oxygen in the Nabulekaleka Lagoon increases with depth for the first meter, and then gradually decreases through the rest of the water body. The station with high DO level is spatially coincident with the warmest median water temperatures. Photosynthesis by phytoplankton produces DO in the photic zone and this process can lead to oxygen concentrations that exceed its solubility by 10 to 20%. (supersaturation) in some surface water or water just below the surface layer. Dissolved oxygen concentrations reach their highest concentrations in the late afternoon when this research was conducted. This may be the most probable explanation of the slight increase in DO concentration in the first meter of depth. Another explanation could be that there was a slight change in temperature and salinity. Both factors combined could account for higher oxygen solubility in the upper meter of the lagoonal water column (Karleskint, 1998). A steady decrease in DO level was noted throughout the rest of the water column. This trend suggests that the depth and concentration of the oxygen maximum in the photic zone depend on the depth of maximum primary productivity and the depth and intensity of wind mixing that brings water to the surface.

In the sediment samples numerous small gastropods were found belonging to the families **Cerithidae (**shallow water dwellers that live in large colonies feeding on mud detritus and decayed algae)**, Bullidae**

(sand or rubble dweller that feed on green algae) **Nassaridae (**usually intertidal mud dwellers, scavengers), **Turitellidae (**sandy mud snails found off coastal shores), **Buccinidae** (prey on bivalves and scavenge on the bottom of intertidal zones and lagoons, **Trochidae** (feed on seaweeds but many eat bryozoans and sponges), **Naticidae (**carnivorous sand dwellers). Other common remains are from sponges (spicules in the fine fraction), and echinoderms. Plankton samples were collected from 4 different sites once at night and once during the day. There was a lot of zooplankton in all the samples The samples collected near the pontoon had a significantly high number of copepods. The least number of copepods were found right next to the old fisheries jetty. Chaetognatha was in abundance near the jetty and in the outside waters near the moored fishing boats. It was significantly low in the passage between the two islands. Euphausid numbers were similar on all sites; however, it was higher than the crab larvae count at all sites. The highest number of crab larvae was near the pontoon and the least near the jetty. The number of jellyfish in all the night samples were fairly similar with the highest counted near the pontoon.

Gill net fishing at various locations in the bay produced 18 different species of fish and two species of crabs. The main components of the catch were mangrove (mud) crabs and and two species of mullet (*kanace*). A littoral survey produced numerous algae, bivalves and arthropods (crabs and shrimps). The data collected show that Nabulekaleka Lagoon is an exceptionally complex body of water. Sedimentation is mixed in terms of grain size, grain composition (clastic and carbonate sediments are present) and age. The water column is stratified and influenced by oceanic and fresh water influx. Biological components are diverse and highly variable within the lagoon. Foraminifera and ostracods are the most useful tools to assess the relationship between biological and physical factors within the lagoon. The results lead to the conclusion that data collection in this type of lagoon has to be extensive spacially and conducted over a range of different conditions in order to assess the governing factors that control lagoonal productivity. Management issues will be difficult to resolve.

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RAHIMAN & BONTE

Discoveries at the Namosi Gap, central southeast Viti Levu, Fiji

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During field work within the framework of the SOPAC/EU Project 'Reducing Vulnerability' and a PhD thesis at University of Canterbury on Seismic Hazards of SE Viti Levu, a new layer in the geology of the Navua catchment in SE Viti Levu has been discovered: Quaternary Lake Deposits. These finely interbedded, partly organic lake deposits (Figure 1) were deposited behind a huge landslide in the Namosi Gorge, which occurred several tens of thousands of years ago. This landslide caused the damming of a 100-150 sq km lake and the separation of the Navua and Waidina river systems.

The Namosi Gorge is a peculiar geomorphological feature in central south eastern Viti Levu, Fiji. It presently forms a wind gap between the Navua and Waidina river catchments and is known commonly as the Namosi Gap. It has been speculated in previous studies [e.g.Terry *et al.* 2002; Band 2003] that a palaeo Navua-Waidina river once flowed through the Namosi Gorge. Disruption of flow of this palaeo river is thought to have occurred at the Namosi Gorge, which led to southward flow of the Navua river from Namuamua and which left Namosi Gorge dry. Small, unconnected occurrences of lacustrine sediments were first noted in the area by Band (1966) and Rodda (1976).

The basement rocks in the area are poorly stratified volcanoclastics of the Namosi Andesite. The Namosi gorge itself is filled for nearly all of its length by landslide debris, which formed a dam of an estimated 100 m thickness. The debris is littered with tree logs and individual boulders reaching the size of a house. Aerial photos reveal a number of distinct and very large landslide head scarps along ridges at the northern end of the Namosi Gorge, which are the most likely source areas of the deposits in the valley floor. East of the gorge, exposures along the Wainikoroluva riverbank reveal the basement rocks overlain by the landslide deposit. This deposit is composed entirely of coarse and angular andesitic material locally derived from the adjacent surrounding ridges. This deposit is overlain by a 20-m thick layer of lake sediments, which in turn is overlain by fluvial sediments. These fluvial sediments are approx. 50 m above present river level. The occurrence of lake sediments has been confirmed for seven kilometres west of the Namosi Gorge and has been found in the upper Navua River area (Figure 2).

The geological history of the area as interpreted from the currently mapped geomorphology and stratigraphy is consistent with an exceptional landsliding event in the Namosi Gorge which ponded the paleo drainage west of the Namosi Gorge for a number of thousands of years. The inferred landslide dam embankment is a cross ridge on valley floor of the Namosi Gorge. This cross-valley ridge forms the highest point along the Namosi Gorge valley (~200 m AMSL). The lake sediments and overlaying fluvial gravels form a distinct terrace level at 120 to 140 m AMSL across the Navua river catchment. The terrace can be clearly seen on aerial photos of the upper Navua catchment and is suggestive of a drowned topography with isolated peaks of the Late Miocene Navua Mudstone surrounded by the flat terrace ground composed of the younger gravels.

This discovery may well be the most important in Fiji's geology over the last fews decades. The lake sediments cover parts of three 1:50 000 geological maps sheets. If the sediments are entirely Quaternary, then it provides a significant data bank of the poorly known Quaternary geological history of Fiji. But beside revealing parts of the geologic history and the development of the Navua catchment there are several more wide spread implications:

Firstly, continuous series of laminated Quaternary lake sediments, which are rare in the humid tropics, are very useful for several avenues of palaeo-climatologic and palaeo-environmental research. This deposit has the potential to provide an invaluable record of Quaternary climate changes in the region, which in turn will help to understand current climatic changes.

Secondly, the amount of aggregation under natural, pre-human conditions establishes a valuable benchmark for comparison with current increased erosion and aggregation rates due to human activities like deforestation, land use changes and road construction.

Thirdly, the Namosi Gap occurs within a zone of seismicity passing through SE Viti Levu. The large 1953 Suva earthquake caused numerous rock falls and landsliding in the upper Waidina area and one temporary landslide dam in the upper Navua river. The paleo Navua–Waidina river disruption may have similarly been caused by a seismo-tectonic event. There is a well known Fijian legend from the Namosi/Navua area which talks about an earthquake and a flash flood [Anonymous & Rodda 1995], which would have happened after breaching of a temporary landslide dam. Studies of the processes that lead to the disruption of the proto Navua-Waidina river may add to the poorly understood seismo-tectonic history of south eastern Viti Levu and hence increase our knowledge of recurrence intervals of large earthquakes.

Fourthly, the size and associated processes of this extreme landslide event, which created the third largest catchment in Viti Levu, should let us reconsider the risk for downstream communities. The Navua delta with its growing township is known for its agriculture potential and part of a resettlement programme of the Ministry of Agriculture. Landslide damned lake outburst floods are known worldwide for its destructive potential and long outrun distances. The narrow Navua gorge is prone to blockage by major landsliding

from the extremely steep side slopes. According to the Flood Legend and a reported event from the 1830s such an event might have happened twice already in the past [Anonymous & Rodda 1995].

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Figure 1: *Fine layered lake sediments – palaeo-climate and palaeo-environmental record (note hammer scale).*

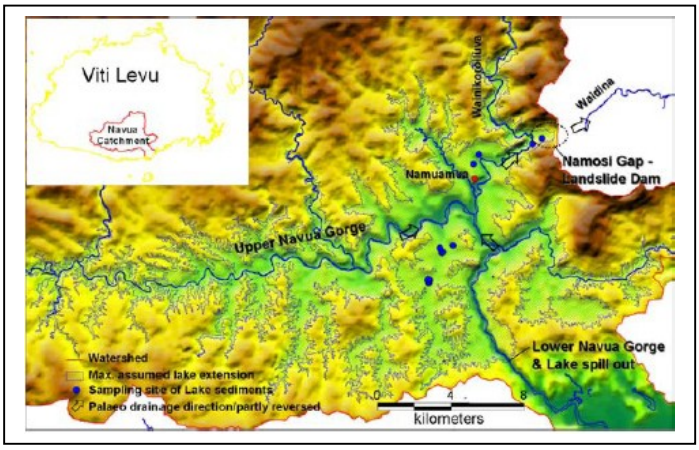

Figure 2: *Map showing the maximum extension of the lake, blue spots show sites where lake sediments have been mapped, arrows indicate the palaeo-drainage.*

RAHIMAN & PETTINGA

Morphotectonic features of the seismically active offshore region of SE Viti Levu, Fiji

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The city of Suva (pop. ~150,000) in the SE coast of Viti Levu is vulnerable to the effects of potential offshore earthquakes and associated seismic hazards. Recently acquired SeaBat multibeam bathymetry and high resolution seismic reflection data reveals for the first time the physiography of the marginal slope of SE Viti Levu in unprecedented detail. The marginal slope is divided into morphological domains, which is primarily influenced by the underlying geology and structure, and sedimentation from terrestrial sources. The Eastern slope, an area between 178.2 and 178.4 E longitude and 18.2 and 18.4 S latitude, has had added influence from active tectonic processes and seismicity. The surface of this slope is scarred by linear submarine canyons, which are the surface expressions of faulted grabens. These submarine canyons are their onshore extensions as fault valleys and structural lineaments collectively define continuous onshore/offshore fault zones. These fault zones form a complex network of faults, through which mesh style coseismic faulting is responsible for the diffused pattern of observed seismicity. The submarine canyons are relict features from the Late Miocene/Early Pliocene that have developed primarily by downslope erosional processes. They have experienced several episodes of re-incision and infilling events,

the latest occurring during the late Pleistocene period of lowered sea level and subsequent marine transgression. Presently, headward erosion of the canyons into the marginal shelf are occurring by basinward sliding of masses at the canyon heads. The stability state of slopes are reduced by long term rapid sedimentation, slope oversteepening and undercutting by canyon currents. Submarine landslides at the canyon heads are initiated primarily by periodic short-term stresses generated by earthquakes, which have induced destructive local tsunamis in the past. The canyons heads, all of which are within 5 km of the coast, are potential tsunami source areas that pose as a substantial threat to the coast.

RAHIMAN & PETTINGA

The source of the Suva tsunami of 14th September 1953, Fiji

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On the 14th of September 1953, at 12.26 pm local time, Suva City and the surrounding areas of southeastern Viti Levu, the main island of Fiji, were shaken by a magnitude M_s 6.75 earthquake. Within a few minutes of the end of the main shock, the southeastern coast of Viti Levu was struck by a tsunami that killed 5 people and caused significant damages to nearshore structures, especially around Suva City. New evidence from high-resolution multibeam bathymetric data from southeastern Viti Levu shows that submarine landslides at the heads of submarine canyons between Suva and Beqa are the most likely sources of this tsunami.

One of the submarine landslide source areas of the tsunami can be clearly constrained by eyewitness reports and the multibeam data. People in Suva within sight of the entrance of the Suva Passage, the main entrance to the Suva Harbour, and, remarkably, an inter-island boat captain, on a southwest approach to the Suva Passage entrance at this time, witnessed the formation of the tsunami wave in this source area (Fiji Times 1953a, b). The most accurate location of this source area is provided by Brother Hilary of St Felix College in the Fiji Geological Survey, Suva earthquake questionnaire (1953). He provided a sketch map of the location of the initial area of upheaval of the sea, at the western end of the Suva passage entrance (Figure 1). Previously this disturbance has been attributed to the collision of two submarine slides from opposite sides of the Suva Passage (Houtz 1962). However, using recently acquired high-resolution multibeam bathymetric data, Rahiman & Pettinga (in prep.) have implicated a submarine landslide at the northwestern end of the Suva Canyon head as the source of this upheaval.

The submarine landslide at the northwestern end of the Suva Canyon head is recognised on the multi beam bathymetry data from a well-defined head wall scar (Figure 2). It is 1.8 km wide at the headwall scarp, which is inclined at 25^o to 32^o. The landslide has incised as much as 70 m relative to the undisturbed seabed surface. The top of the failure surface has a rotational scar. This is followed downslope by a narrow planar body and a more channelised progression, 500 m wide, until it enters the Suva Canyon 1.7 km from the head scarp. The overall slide has a thickness/length ratio of 5.3%. The volume of this landslide, taken approximately as the volume of the scar, is approximately 60×10^6 m^3.

The characteristic near-field tsunami wave amplitude in the submarine landslide source region can be calculated using predictive tsunami amplitude equations and input parameters based on the geometry of the submarine landslide. The calculated near field tsunami amplitude value for the northwestern Suva Canyon head landslide, using empirical equations of McAdoo & Watts (2004), is 17 m. This compares reasonably well with the initial tsunami wave height that was observed at the entrance of the Suva Passage (10 to 15 m) during the 1953 earthquake (Houtz 1962). This confirms without doubt that the source of the tsunami at the entrance of the Suva Passage was a submarine slope failure that is now represented by the scar in the northwestern part of the head of the Suva Canyon.

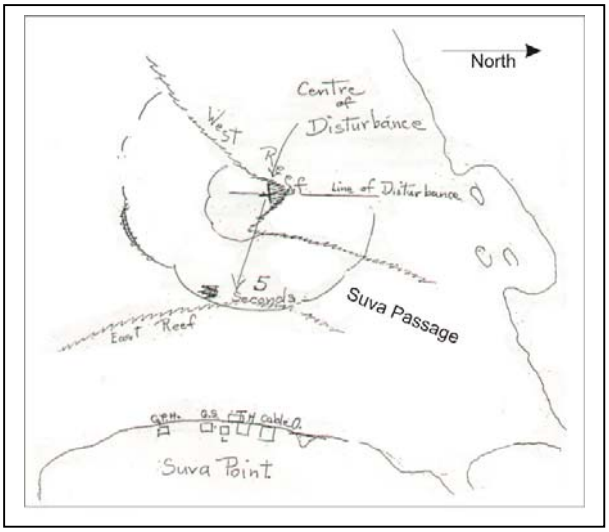

Figure 1: *Sketch location of tsunami source area (Brother Hilary, Fiji Geological Survey, Suva earthquake questionnaire 1953).*

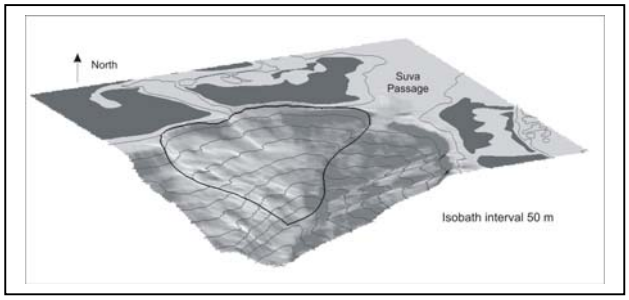

Figure 2: *3D bathymetric image of the landslide tsunami source at the NW end of the Suva Canyon head.*

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RAMSAY and others

Reducing the impacts of cyclone storm surge inundation on the atolls of Tokelau

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On 25 February 2005 Tropical Cyclone *Percy* affected the atolls of Tokelau. The cyclone sustained winds of 178 to 249 km/hr and resulted in widespread damage, particularly on Fakaofo and Nukunonu. On Nukunonu the storm surge and large waves resulted in overwashing of many parts of the inhabited motu. Inundation was also an issue on parts of Atafu and Fakaofo.

In the aftermath of Cyclone *Percy*, the United Nations Development Programme (UNDP) in Samoa commissioned a project to provide technical support to the Government and people of Tokelau. The project

(known as the Tokelau Seawall Project) looked to identify and prioritise ways of reducing the risk of loss of life, damage to infrastructure, property and the environment arising from inundation due to cyclone storm surge and other coastal hazards. On all atolls the initial expectation was that this would be achieving by the continued construction of seawall structures around each inhabited motu.

On each atoll a number of community meetings were held with the Council of Elders (*Taupulega*), Women's Group (*Fatupaepae*), and the working or married men (*Aumaga* or *Taulelea* respectively). These meetings were used to identify the concerns and underlying issues causing or exacerbating cyclone related risks on each atoll. They were also used to identify the important natural processes, using examples on each atoll, to be borne in mind when considering appropriate risk mitigation options and future development projects. The meetings also considered how these risks could be managed and reduced with the emphasis on considering a range of short and long-term options and activities (not just seawalls). These included:

Ensuring protection of the natural coastal defences (reef, reef flat, beach and coastal margin) and identifying existing human impacts that reduce the effectiveness of these natural defences.

Land management planning including both future development and potential for long-term movement of key infrastructural or other buildings from high-risk areas.

Enhancing natural defences including re-vegetating coastal buffer zones and enhancing natural storm banks behind the beach to reduce the potential for overtopping waves inundating further inland.

Structural solutions such as seawalls, building design and localised inundation barriers.

The aim was to develop a way forward for each atoll identifying a range of both short term and longer term objectives and activities for achieving effective mitigation over the long term from the risks associated with cyclone related inundation and other coastal hazards including consideration of the potential effects of future climate change on extreme weather or climate variability phenomena and through accelerated sea-level rise.

RATUYAWA & others

The floating island of Nakelikoso, Fiji – Nuisance or marvel of nature?

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The floating island at Nakelikoso, Vanua Levu, was investigated to determine (a) how it formed in relation to the underlying geology, (b) the causes of its buoyancy, (c) the flora on the island and (d) the role of the floating island in the ecology of lakes and wetlands.

The occurrence of floating islands on lakes is relatively common and seen worldwide. Interest in them has arisen recently due to their variable impacts on adjacent ecosystems and communities. Some floating islands are 'homes' to endemic and rare plants and animals while others have mythological ties to the lake side residents and consequently are considered marvels of nature. In other places their existence is not appreciated and they are regarded as weedy and swampy nuisances. Floating islands can accumulate along shorelines, blocking out access points, interfering with recreational fishing and navigation and shading out and displacing desirable vegetation. Their occurrence leads to low oxygen levels in the water and consequently poor fisheries. Unmanaged floating islands also play a role in succession from open waters to marshes to swamps.

Hence the question arose whether Nakelikoso is a desired or undesired island and what factors make it so?

A visit to the island was undertaken in March 2005 and salinity, temperature and level of dissolved oxygen (DO) of the surrounding lake were measured, samples of flora were gathered on the island and identified in the lab. Surrounding environmental setting was studied in the literature and on site.

The floating island of Nakelikoso is located near the village of Nubu in Vanua Levu. Its Fijian name is "Waqa Qele"– 'Waqa 'meaning ship/boat and 'Qele' meaning soil. The area surrounding the floating island is composed of low rolling hills through which several small rivers pass. Sugar cane farms occupy large stretches of the land.

The bedrock underlying the farmland is composed of coralline limestones with a maximum thickness of 110 feet. With reference to the given geology and geomorphology of the area surrounding this lake, the most probable cause for its formation is that groundwater has dissolved great volumes of the limestone forming the lake basin. There were initially 3 islands, 2 have 'docked' at the lake shore leaving only one floating. The lake must have a high sediment content in which gases build up to the extent that they lift patches of decomposing fibrous material to the surface. These patches then coalesce along shorelines or emergent vegetation and are colonized by wetland and even upland plant. The area surrounding the lake is swampy suggesting that the lake has decreased in size through terrestrification.

Floating islands are comprised of aquatic and sometimes upland plants; herbaceous as well as woody plants, and most importantly, they are characterized by suspended masses of organic deposits like peat and mud from a few inches to a few feet thick. Various theories exist regarding their formation. The island of Nakelikoso probably floats due to a combination of factors: (a) decomposing vegetation releases gases which become suspended in the soil and make it buoyant. (b) The flora on the island are mostly hollow plants such as *Eleocharis ochrostachys* and *Pandanus* sp. and (c) many of the shrubs and herbs have creeping rhizomes and spreading runners that interwine with each other and hold the soil together.

Flora found on the island consists of common (but not exclusive) wetland plants such as *Ludwigia octovalvis* and *Dichanthium annulatum,* endemic ferns (*Davallia fejeensis* and *Nephrolepis biserrata*, one of the most prominent species found on the island-20%); recently introduced plants (*Clidermia hirta*, an invasive weed, *Desmodium triflorum* and *Pycreus polystachyos*) and vegetation used by locals for various purposes such as *Eleocharis ochrostachys,* and *Pandanus* species. *E. ochrostachys* is a prominent plant on the island (50%) which is used to weave fine mats that are expensive Fijian/Tongan treasure and costumes.

The most important aspect of lake hydrology is the low oxygen level. Even low DO tolerant eels and tilapia may not survive in this lake.

Floating islands can be both, a marvel or a nuisance. In Georgia's Okeefenokee (Land of Trembling Earth) National Park, floating islands are home to hundreds of species of plants and animals and thus a prime tourist attraction that was placed under protection. It may also have had some mythological implications to the Native Indians. It is nowhere near lake-side residents and regarded as a marvel of nature.

In Florida, the occurrence of floating islands is near lake-side residential areas with access points for boats (jetties, boat ramps). Moreover, fishing is a popular form of recreation in this region thus the low in DO level contributed by the occurrence of floating islands is unwelcome. Here the occurrence of floating islands (or tussocks) is regarded as a nuisance because it interferes with all of the above.

In Fiji, the floating island in Nubu is far from a residential area (village is situated ~700 m from the island), it has no apparent outlet to rivers and ocean, the people are not reliant on fresh water fish as a food source and they have a long history of mythological ties to the island. In addition, they use vegetation from the island as a natural resource and it has also become a tourist attraction and source of income. Thus to the Fijian community at Nubu the occurrence of a floating island is a marvel and pride to them.

SAUNDERS & BECKER

Planning for recovery before an event occurs

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This paper focuses on how communities can plan for land-use recovery before a natural hazard event occurs.

Recovery from a disaster is most effective where planning for recovery takes a holistic approach, and is integrated with risk reduction, readiness and response.

The ideal way to ensure that communities will sustainably recover from future disasters is to prepare a comprehensive recovery plan, which incorporates the principles of sustainability in every decision about reconstruction and redevelopment. The combination of such a plan, coupled with a common-sense approach during recovery, will help make a community more sustainable than it was before, as tasks such as housing repairs and road restoration can become opportunities for improvement.

Plans can be made for land use changes both before an event occurs, and after an event has taken place. Recovery planning should also consider the diversity of community needs.

Planning for recovery can be linked to the Comprehensive Hazard And Risk Management (CHARM) process, which enhances the sustainability of national development planning processes and encourages a more coordinated and integrated regional approach to risk reduction.

Currently, GNS are formulating a methodology for recovery planning in NZ, which once developed and tested, could be modified for the Pacific Island community.

SAUNDERS & others

Planning guidelines for development of land on or near active faults and landslides in New Zealand

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There are many international examples where property damage and loss of life have occurred as a result of fault rupture or land sliding occurring in areas where buildings have been constructed across known active faults and landslide areas.

Non-technical guidelines, formulated specifically to meet planners' needs for hazard mitigation and planning, are few and far between. In New Zealand, the Ministry for the Environment along with the Institute of Geological & Nuclear Sciences and other relevant organisations have prepared the Active Fault Guidelines (*Planning for Development of Land on or Close to Active Faults*) to provide assistance to planners on how to mitigate against fault rupture. In addition we are also in the process of formulating planners' guidelines for landslides.

This poster outlines the risk-based approach taken by the Guidelines for managing active fault and landslide hazard. In planning for hazards such as these it is important to recognise and incorporate a

variety of factors including the nature of the hazard, likelihood of occurrence, type of structure being proposed, and the different methods needed to mitigate hazards in Greenfield areas as opposed to already developed areas.

SHAH & others

Trace metals in Scleractinian corals of Nukubuco Reef, Suva, Fiji Islands

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The Suva lagoon has been studied for contamination levels with regards to trace metals (or nutrients) using marine biota, water and sediments. This study focused on trace metal analysis in *scleractinian* (hard or reef-building) corals of Nukubuco reef (18°10'S, 178°28'E). Nukubuco reef, a barrier reef, lies approximately 5km off the coast of Suva peninsula. Nukubuco reef continuously experiences freshwater input from rivers (Rewa, Vunidawa, Samabula and Vatuwaqa) and sewage effluent from Kinoya Sewage Treatment Plant (discharge occurs through an 800m outfall pipe). *Pocillopora damicornis* and *Acropora formosa* were sampled from three different sites on the reef flat and analysed for trace metals (Cd, Cu, Pb, Fe and Zn) using Atomic Absorption Spectroscopy (AAS).

Zn was in greater concentration at all sites when compared to the other trace metals analysed. High levels of zinc can be attributed to the use of sacrificial anodes on boats, which get deposited in the marine environment during anchorage, antifouling paints used on marine vessels and through suspended sediments transported by rivers. The other trace metals are in moderate concentrations present. Likely inputs into the marine environment could be from sewage discharge, industrial effluents, agricultural discharge from coastal areas and upwelling of sediments. Upon analysis, it was found that the zooxanthallae of the corals accumulated greater concentrations of the metals when compared to the tissue and skeleton. When under stress, zooxanthallae of the corals are expelled, so if greater concentrations of metals were accumulated then coral bleaching would occur.

SHARMA & others

Benthic Foraminiferan Species in Laucala Bay, their Distribution and Contribution towards Sedimentation

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Foraminifera (forams for short) are single-celled organisms (protozoans) that form shells (tests) of calcium carbonate which, when the animals die, form calcareous sand. Living benthic and fossil foraminifera species can aid in understanding temporal and spatial variability, and more importantly, the implications of positive and negative anthropogenic impacts on the environment (Eade, 1988).

The aim of this study was to identify and determine the different benthic foraminifera species within Laucala Bay, as well as identify the locations where these species are present. Broad patterns of distribution of foraminifera within the Bay were established. The percent contribution of foraminifera towards sand aggregation was also analysed.

Sediment samples of about 1 kg dry weight were collected from 13 sites within the Bay. The samples were washed in dilute bleach and left overnight to soak. Each sediment sample was then washed with water over a 63μm sieve to remove all the clay and mud components. The samples were then dried in the oven at 60-80°C and subsequently sieved in a series of sieves ranging from 2mm, 1mm, 500μm, 250μm, 125μm, and 63μm. The different species of foraminifera present in each sample were picked under a binocular microscope until no new species could be found.

The abundance of foraminifera compared to other components was determined by examining 100 grains of the original, unsieved sediment and counting the number of foraminifera in the sample. There were five replicates (i.e. 500 grains) to get an average percentage.

A total of 68 different species from 43 different genera were identified from the 13 sites sampled.

Table 1: Species of foraminifera found in Laucala Bay

Haddonia (?) sp.	*Miliolinella labiosa*	*Ammonia* (?) sp.
Sahulia kerimbaensis	*Miliolinella* cf. *M. hybrida*	*Helenina* sp.
Sahulia cf. S. conica	*Triloculina terquemiana*	*Pegidia lacunata*
Textularia foliacea foliacea	*Triloculina affinis*	*Lobatula lobatula*
Textularia (?) *rugulosa*	*Pseudomassilina reticulata*	*Tetromphalus bulloides*
Textularia agglutinans	*Pseodotriloculina* (?) *granulocostata*	*Rosalina bradyi*
Textularia sp. A	*Pitella haigi*	*Siphogenrina raphana*
Textularia sp. B	*Pseudohauerina involuta*	*Loxostomina limbata*
Siphoniferoides siphoniferus	*Monalysidium acicularis*	*Rectobolivina raphana*
Septotextularia rugosa	*Peneroplis planatus*	*Planorbulinella elatensis*
Siphogenerina sp.	*Peneroplis pertuses*	*Planogypsina acervalis*
Clavulina cf. *C. multicamerata*	*Marginopora vertebralis*	*Acervulina mahabeti*
Spiroloculina angulata	*Borelis schlumbergeri*	*Elphidium striatopunctatum*
Spiroloculina attenuata	*Orbulina universa*	*Elphidium craticulatum*
Spiroloculina foveolata	*Orbulina* (?) sp.	*Elphidium advenum*
Spiroloculina antillarum	*Amphistegina lobifera*	*Elphidium* cf. *E. alvarezianum*
Hauerina circinata	*Amphistegina radiata*	*Elphidium* (?) sp.
Siphonaperta pittensis	*Calcarina hispida*	*Epistomaroides punctulatus*
Quinqueloculina parkei	*Baculogypsina sphaerulata*	*Haynesina germanica*
Quinqueloculina bicarinata	*Neorotalia calcar*	*Evolvocassidulina belfordi*
Quinqueloculina philippinenis	*Milletiana millettii*	*Operculina ammonoides*
Quinqueloculina eburnea	*Cymbaloporella tabellaeformis*	*Miniacina* sp.
Quinqueloculina sp. A	*Ammonia convexa*	

Table 2: The number of different species and the percent abundance of foraminifera at each site in the study area:

Site	Location	Description	No. of Different Species Present	% Abundance
1	Nukubuco Reef	1/2 way to reef margin in microatoll zone	35	7%
2	Nukubuco Reef	Northwest tip	34	7%
3	Makuluva Island	Eastern side	44	10%
4	Makuluva Island	Northern side	34	13%
5	Makuluva Island	Southern side – toward open ocean	46	20%
6	Makuluva Island	Western side	41	12%
7	Fish Patch	Due south from Nasese Tidal flat	44	9%
8	Nasese Tidal Platform	Outer edge of platform	5	2%

9	Suva Harbour	Centre of lagoon	15	5%
10	Nukulau Island	Northwestern edge – near jetty	40	8%
11	Laucala Island	Off the northern edge	18	3%
12	Vatuwaqa River	Estuary	6	3%
13	Laucala Bay	Centre of lagoon	16	5%

The graph for the number of different species found at each of the 13 sites within the study area shows that the most number of different species, 46, and the greatest percent abundance for forams was found at Site 5, southern side of Makuluva Island towards the open ocean. A total of 44 different species were found at both Site 3, eastern side of Makuluva Island, and Site 7, the "Fish patch", south from the Nasese Tidal Flat.

Site 6, the western side Makuluva Island, recorded a total of 41 different species while Site 10, at the northwestern edge of Nukulau Island, showed 40 species. Site 1, the microatoll zone in the Nukubuco Reef, Site 2, northwest tip of the Nukubuco Reef, and Site 4, northern edge of Makuluva Island showed 35, 34, 34 species respectively.

The samples at Site 9, centre of Suva Harbour, Site 11, off Laucala Island and Site 13, centre of Laucala Bay consisted of 15, 18 and 16 different species respectively. The lowest number of species, 5 and 6, were found at Site 8, Nasese Tidal Flat and Site 12, Vatuwaqa River estuary.

The greatest abundance, that is, the highest number of foraminifera in 100 grains of sand was at the southern side of Makuluva Island, which faced the open ocean. The other sites around Makuluva Island also had relatively higher percent abundance than the other sites. The sites around Nukubuco had 7% abundance while the centre of Suva Harbour, Laucala Bay, Vatuwaqa River estuary, Nasese Tidal Platform and the site off Laucala Island had the lowest percent abundance.

Generally, it was seen that the sites around Makuluva Island, Nukulau Island and the "Fish Patch" showed quite a high diversity of species, while the sites on the Nukubuco Reef and on the northern edge of Makuluva Island showed slightly less number of species. The sites in the middle of Suva Harbour and Laucala Bay as well as off the Laucala Island showed a considerably less number of species. However, the least number of species were to be found on the Nasese Tidal Flat and in the Vatuwaqa River estuary.

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SUETSUGU & others

Seismic observation in the South Pacific by international cooperation: On islands and seafloor

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(1) Broadband seismic observation on seafloor: Polynesia BBOBS array

Broadband ocean bottom seismic observation has been successfully conducted in the French Polynesian seafloor from 2003 to 2005 to image mantle structure beneath the South Pacific Superswell. Seismic structure beneath the French Polynesian region has remained far from well explored in spite of its significances in mantle dynamics. The region is characterized by; a topographic high by more than 500 meters; concentration of hotspot chains (Society, Cook-Austral, Marquesas, Pitcairn, and Arago) of which volcanic rocks have isotope characteristics suggesting deep mantle origin; a broad low velocity anomaly in the lower mantle revealed by seismic tomography. These observations suggest the presence of a whole-mantle scale upwelling beneath the region, which is called 'superplume'. However, the seismic structure has been only poorly resolved so far and the origin depths of hotspots have not been determined mainly because of sparse seismic stations in the region. Much more stations with uniform coverage are necessary for better resolution in seismic tomography.

To overcome the difficulty in seismic imaging, we operated the Polynesia BBOBS array, in which 10 broadband ocean bottom seismographs (called BBOBS hereafter) were deployed in French Polynesia. The BBOBS has been developed by Earthquake Research Institute of the University of Tokyo, since 1990s. The BBOBS is a self pop-up type ocean bottom seismograph with a broadband sensor (Guralp CMG-3T) that can record ground motions at periods from 0.02 to 360 seconds. It runs as long as 400 days and suitable for long-term observation for natural earthquakes. The project was conducted as a Japan-France cooperative project. The participating institutions are: Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Earthquake Research Institute of the University of Tokyo (ERI), Institut de Physique du Globe du Paris (IPGP), Commissariat à l'Energie Atomique (CEA), Université de Polynésie Française (UPF), Université Montpelier II, and Université Louis Pasteur. The last three universities have operated temporary broadband seismic stations on oceanic islands of French Polynesia by the PLUME project since 2001 [*Barruol et al.*, 2002]. Figure 1 shows the station distribution of the Polynesia BBOBS array as well as the 10 temporary PLUME and the 3 permanent CEA stations. The 10 BBOBS locations (FP1-FP8; S1; S2) were selected to supplement the existing stations on oceanic islands so that the overall station distribution should be as uniform as possible (Figure 1). The observation period of the BBOBS project is overlapped with that of the temporary PLUME observation for nearly two years. Preliminary results will be presented in my talk.

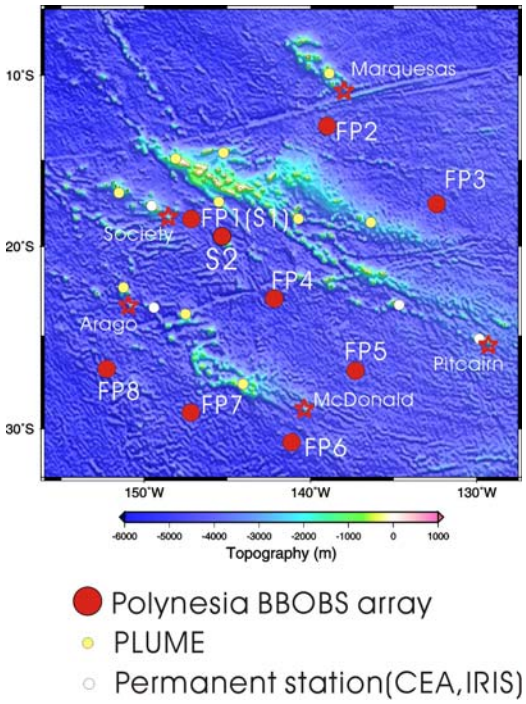

Figure 1: *The BBOBS stations (red circle) on a bathymetric map. The PLUME stations (yellow circle) and the permanent broadband stations by CEA and IRIS (open white circle) are also shown. Red stars denote hotspots in the French Polynesian region.*

(2) Seismic observation on islands: Tonga-Fiji case

Capability for earthquake monitoring has been improved in Fiji and Tonga for last few years. National seismic networks have been deployed in 2003 by JICA cooperation programmes and operated since then. The networks are composed of three and five VSAT stations in Fiji and Tonga, respectively, including broadband and short-period seismometers, digital data acquisition, and analysis system. Waveform data

are transmitted from remote stations to data centres via VSAT on real time basis. For monitoring earthquakes with high accuracy over the Fiji-Tonga region, which is covered mostly by ocean, more island stations, covering the region uniformly, are required. Restoration and integration of pre-existing seismic stations to the new network is an efficient way to improve the station distribution. Rapid exchange of seismic data between the two countries is important to locate earthquakes near the border accurately. Technical trainings are also useful for maintenance and stable operation of the networks. The MRD of Fiji have proposed a project to JICA to upgrade the existing networks for better monitoring capability. Seismologists of NIED and JAMSTEC are ready to support the project as experts.

TAYLOR & MAIJA-RESTREPO

Volcano hazards awareness programme for school children: an example from Niuafo'ou Island, Kingdom of Tonga

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Niuafo'ou is Tonga's remotest island, being located some 450 km north of the main island of Tongatapu at latitude 15.60°S, longitude 175.63°W and is home to about 800 Niuafo'ouans who live in 8 villages located on the eastern and northern flanks of the island. Niuafo'ou is the most active volcano in the Kingdom and its history has been dominated by periods of both lava-producing (effusive) and ash-producing (explosive) activity. Since the early-1800s, at least 10 periods of activity have reported. Although the majority of these eruptions have only resulted in damage to dwellings and crops, during the 1853 eruption at least 25 Niuafo'ouans may have perished. Although, the most recent eruption, which occurred (September 1946), was a relatively minor event it resulted in the forced evacuation of the entire population of the island, with resettlement not being allowed by the Tongan Government until 1958. Since the 1946 eruption, the volcano has remained dormant, except for an earthquake swarm and possible small eruption within the caldera on 21-22 March 1985. As evidenced by the numerous periods of activity and the development of a number of new hot springs, Niuafo'ou must therefore be treated as a potentially dangerous volcano.

A volcanic hazard assessment was completed during the mid-1990s and as part of this assessment, a Volcanic Hazard Map and a Volcano Operational Support Plan were developed. The residents of Niuafo'ou further developed the map and plan during a national-level workshop in late-May 1999 and then during an island-level workshop in early-June 1999. The participants of the island-level workshop recommended that a series of Village Response Plans should be developed. These were prepared during 2001. It was also recommended that awareness materials should be developed.

A series of educational awareness materials have been developed in conjunction with the Tongan National Disaster Management Office and the Ministry of Education. They include a student/teacher resource booklet and a series of four posters. The booklet, in full colour, covers general information of volcanoes, volcanic hazards and their effects and highlight aspects that relate specifically to Niuafo'ou. A number of students activities have also been developed to highlight many of the important aspects. The posters, in a full colour large A2 format, further emphasise volcanic hazards in general terms and aspects specific to Niuafo'ou. The resource materials were initially developed in a draft format and taken to Niuafo'ou and further developed in consultation with the teachers and selected students from the schools during a series of workshops. Following finalisation of the draft booklets and posters, quantities were printed in final form and presented to the schools on Niuafo'ou for inclusion into the school curriculum. The main aim of these resource materials is to develop the awareness of volcanic hazards and their effects of the younger population on Niuafo'ou.

In the near future a series of workshops will be conducted in villages on Niuafo'ou to further develop the level of awareness of the older population of Niuafo'ouans and to facilitate the further development and implementation of the Village Response Plans developed during 2001.

TAYLOR & others

New evidence for widespread, late Holocene, explosive volcanism along the Tofua Volcanic Arc and its implications on the Kingdom of Tonga in the future

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The active Tonga-Kermadec oceanic arc extends for 2500 km northward of New Zealand. Volcanism along this chain relates to the westward subduction of the Pacific plate beneath the Australian Plate at a rate that increases northward up to 24 cm/yr in north Tonga. Due to the small landmass along this arc, little is known about subaerial explosive volcanism and related hazards, especially in the 720 km^2 Tongan archipelago. We have developed a new record of post 6 ka B.P. explosive volcanism from the Tofua Volcanic Arc (TVA) through a programme of coring swamps on the populated islands (tot: 100 000 inhabitants) east of the volcanic front, and downwind for high-altitude winds. The low, flat, coralline islands that comprise the eastern islands often contain uplifted lagoons, that are now swamps and lakes which preserve tephra layers well, in comparison to the surrounding tropical soils. Geochemical studies of tephra layers which is in progress will allow correlation to source volcanoes, and radiocarbon dating of inter-bedded peat and lake sediments have enabled the development of a new eruption chronology.

From these data we find that inhabited parts of Tonga were impacted by explosive eruptions on up to eight occasions since c. 6500 yrs B.P. Some events deposited fine lapilli beds >20 cm thick within the lake or swamp sites. A number of centres have also produced a greater proportion of differentiated (dacitic) products than previously thought. Evidence of major eruptions and tephra falls also come from legends in the area, implying these events may have had a greater influence on the agriculture and lifestyle of ancestral Tongans than previously considered.

With the most recent of these events having ages of less than 500 yrs B.P., i.e. well within the time of human occupation, indicates that the volcanoes still present a real hazard to the Kingdom of Tonga. The volcanoes of the TVA continue to be active, although most of the recent historic events have been small in magnitude, large magnitude events can still be expected. Hazards that may occur during such events will include widespread tephra fall, pyroclastic flows, locally destructive tsunamis and range of other volcanic hazards, all of which may have a devastating effect on the population of the Kingdom.

TAWAKE

Promotion of sustainable development of aggregate resources in the Kingdom of Tonga: offshore aggregate extraction north of Tongatapu

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Since 1986, SOPAC has carried out at least five separate aggregate assessments in the lagoon north of Tongatapu Island, Tonga. In the 1989 aggregate survey, an offshore area called Basin A (Figure 1) that occurs to the north of Nuku'alofa was identified for dredging. The area contains suitable sand and gravel materials with an estimated resource of 2.4 million m^3. An environmental impact assessment study of Basin A was conducted in 1996 that recommended aggregate extraction by dredging, provided that relevant

guidelines are adhered to for the protection of marine environment and the long-term stability of coastal zones.

Aggregate dredging in the Tongatapu Lagoon started in October 2004 by the Tonga Ports Authority (TPA) dredge system. The TPA dredging has since been mostly concentrated in an area north of Atata Island (Figure 1). In July 2004 a second company, Vete Holdings Limited (VHL), commenced sand dredging to the east of the lagoon, at a site near Fukave Islet (Figure 1). Neither area was surveyed before the commencement of the dredging operations and as such the aggregate resource volume, quality and the potential environmental impacts of extraction was/is not known.

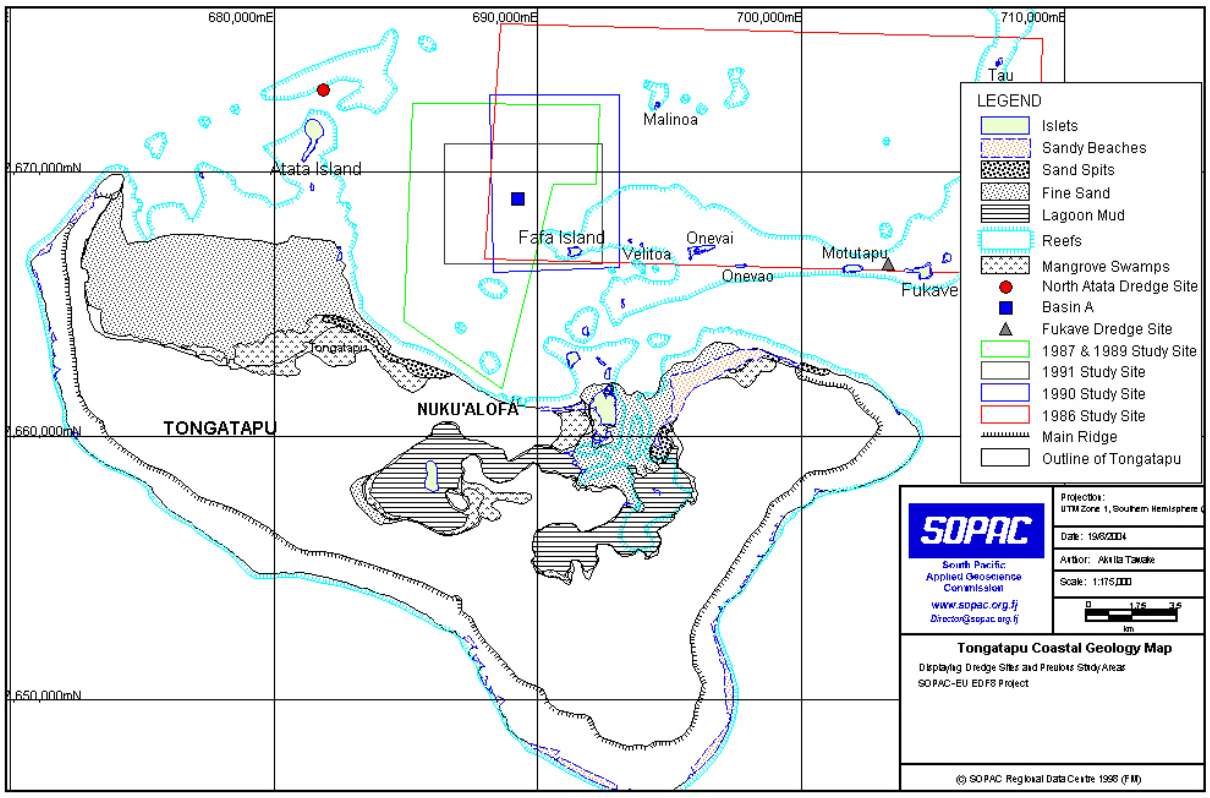

Figure 1: *Coastal geology map of Tongatapu and survey sites.*

At the request of the government through the Ministry of Lands, Survey and Natural Resources (MLSNR), the SOPAC-EU Project has developed a set of Guidelines for Offshore Aggregates Extraction and Monitoring Procedures to guide key-actors such as relevant government authorities, environment conservation groups and dredge operators in the development and management of the dredging operation in Tonga. The guidelines are also designed to highlight the direct and indirect effects of aggregate extraction on the surrounding ecosystems and to provide information to assist in preventing environmental damage. An environmental monitoring plan (EMP) is designed to ensure that adverse effects are detected at the earliest opportunity and appropriate mitigating measures are applied. This EMP is to be coordinated and implemented by a multi-disciplinary team.

In assisting the government of Tonga, the Project has devised and implemented a strategy that would address definite and potential dredging-related problems. This strategy includes the following:

- Review of historical aggregate assessment data and reports,
- Conduct a two-staged stakeholder consultation process,
- Dredge site visit and observation,
- Collection and analysis of sand samples,
- Carry out Environmental Impact Assessment (EIA) of the dredge sites,

- Compile and complete three technical reports on the Proposed Guidelines, Dredging and Action Plan, and the EIA study,
- Hold a 2-days workshop to highlight the findings of the surveys and the recommendations in these three reports. As envisaged, participants have discussed ways in which the recommendations can be implemented and to emphasize areas where key-stakeholders can work together to achieve environmentally friendly dredging operations and to ensure a viable aggregate dredging industry in Tonga.

This paper presents the model for the promotion of sustainable development of aggregate resources in Tongatapu by means of source assessment, EIA, licensing and development, stakeholder consultation and collaboration, documentation of the survey findings and integrated management of dredging operations and extraction sites. Results of sand sample analysis will be discussed in order to highlight the quality of materials that occur in each dredge site.

In addition, the major components of the guidelines will be discussed with more emphasis on the development of the resource and environment management of the dredging operations. With all the relevant information made available, the MLSNR and other key-stakeholders in Tonga are now posed with the challenge of setting a platform for action.

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Tawake & others

Causes of beach erosion at Tagaqe and Votua Villages on the Coral Coast, Sigatoka, Fiji Islands

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A beach assessment was carried out in the villages of Tagaqe and Votua on the Coral Coast near Sigatoka to determine some of the causes of beach erosion in response to questions raised by the village community as to why their shoreline had been continuously receding over their lifetime.

Methods of beach assessment involved village interviews, literature review, aerial photo analysis, beach profiling study, nearshore current and wave study, and sedimentology.

Results of literature survey and the village interviews were related to the results of the aerial photo analysis. From this assessment, the extent of erosion at both sites was calculated and correlated to information collected from the community and literature survey. According to Nunn (1998), there has been significant evidence for tectonic uplift along the Coral Coast. Emerged micro atolls and low level emerged reefs can be seen showing 0.88m of uplift in the last 10 000 years (Nunn, 1998). SEAFRAME results from GPS surveys suggest an uplift of 0.2 mm per year for Fiji, consistent with the observations from the Coral Coast. Further evidence of erosion can be seen in results of aerial photo analyses where both, Tagaqe and

Votua villages have receded by 40m (or more) in at least one place along their shorefront. This amounts to a loss of approximately 400 to 600square meters of land in front of their village in the period of 1967 to 1994, 27 years.

Beach profiling of six transects at each village site were conducted from April 2004 to April 2005 to cover a one year period. Beach profile results confirm that erosion rates are slow and occur more in some areas of the beach than others.

Current studies were carried out for the nearshore areas of Tagaqe and Votua villages using drogues and oranges. Drogue studies revealed that current circulation in the nearshore area was consistently towards the channel area regardless of the change in tides during the day. A general current pattern towards the channel was seen and oranges that were placed at different positions in the nearshore area at high, incoming and outgoing tides, were always swept towards the channel instead of getting washed up ashore.

Sediment samples were taken along every extended transect from the bench marks on the beach to towards the reef crest for a size/composition analysis to describe the kinds of the sediment transport rates that exist in the nearshore areas. Additional samples were taken from the channel area to determine whether the channel really is a sink for sediments being transported from the beach to the sea. Preliminary results show that more than half of the channel sediment is terrigenous and consequently derived from the beach where it accumulated after transport by rivers to the sea. Wave characteristics are currently being observed to determine the wave energy.

In conclusion, beach erosion is a long-term process influenced greatly by the natural coastal processes that occur everyday in the nearshore environment. The uniqueness of the current circulation in the nearshore area towards the channel is the dominating process responsible for the loss of sediments from the beach.

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USUI

Japan-SOPAC Co-operative Deep-sea Mineral Resources Study Programme: exploration for ferromanganese deposits

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The earlier reconnaissance survey before 1990 suggested that the central-south Pacific ferromanganese crusts are of the greatest abundance and highest cobalt-grade. According to the Japanese geological study during 1985-2004 in some selected south Pacific country EEZs, we characterized the distribution patterns in smaller scales and their geological parameters of the deposits in further details within some prime areas. The comparative surveys using multi-beam swath mapping, towed camera observation, and bottom sampling by dredge and drill machine gave us more realistic images of the configuration, chemical and mineralogical characters of the deposits in further details. The small- to regional-scale variations of the nature and ore grade of the deposits are most closely related to the geological history of the substrate which has formed over the past 50 million years or more. We herein report the part of our results of exploration and analysis for the cobalt-rich ferromanganese crusts in the Marshall Islands area and cobalt-rich manganese nodules in the Cook Islands area.

The maximum abundance is about 100 kg/m^2 for the crusts in the Marshall Islands area, but the thickness (for abundance) is often variable controlled by the geological and oceanographic history of the seamounts. Our preliminary data of depth-compositional profiles within single specimens also demonstrated a wide

range and significant variations in cobalt and nickel contents as high as regional variations. The Cook Islands nodules are noted as high cobalt content up to 0.5 wt. %, as the maximum 50 kg/m^2 abundance, and as large extension over a 100 km range over the flat sedimentary basins most probably promoted by Antarctic bottom water.

The SOPAC/JICA project is believed to be a nice example of exploration of Co-rich ferromanganese crusts and nodules for near-future feasibility study. However, we recommend that more comparative studies in geology, oceanography, and biology are needed before commercial mining in the zones.

LATE ABSTRACT

POHLER & others

Aspects of vulnerability of the Suva area (Fiji) to sea-borne threats

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Much of Suva (Viti Levu, Fiji) is located close to the sea shore and as such constantly exposed to sea-borne threats that is, wave attacks with different levels of energy which pose a danger to coastal properties, inhabitants and environments. While some events are low frequency, high impact events (e.g., cyclones, tsunami) others are higher frequency and lower impact such as tropical depressions and flooding. Finally much of undesired shore line alteration is due to chronic erosion caused by daily wave attack and tidal variations. The resilience to such events is to a large degree predetermined by local natural factors such as presence of a barrier or fringing reef, water depth in the foreshore and offshore area, shore morphology, drainage patterns etc, and by human interference with these features. This paper attempts to highlight some of the potential problems and threats that have emerged in the Suva area.

Suva city is located on a promontory (Suva Peninsula) projecting into the Pacific Ocean on the southeast coast of Viti Levu with Walu Bay and Suva Harbour on the west and Laucala Bay on the east. Lami township lies on a narrow coastal plain about 5 km W of Suva. Most of the peninsula is hilly with deep valleys and cliffs of soft marl formed by erosion due to high rainfall and faulting, respectively. The initially narrow coastal plain was extensively widened by shoreline reclamation. Most of the land along the water side of Victoria Parade has been reclaimed, from the Grand Pacific Hotel to Walu Bay industrial area. There were two small hills where the FINTEL building and the Library now stand and a much higher hill backing the Albert Park. These hills provided the fill for the land that was reclaimed. An additional landfill borders the Bowling club (Q.E.D. Park) which is noteworthy because it is not armored by a seawall and is eroding (http://www.fijifvb.gov.fj/activity/listing/suva.htm). Further to the west Walu Bay is bordered by the Muaivuso Village and fringing reef complex. Laucala Bay to the east is bordered by the Rewa Delta and adjacent river terraces composed of alluvial deposits. These areas are largely unaltered with dense mangrove cover along the shore line. Before Europeans arrived to build the city dense jungle reached down from the hills right to the waters edge and the Suva shoreline was protected by mangroves. Today's shoreline is barren of mangroves except for a few patches that are left in front of the seawall that protects the Princess Road.

The Rewa River brings in large sediment loads following high rainfall some of which remains in suspension even in the marine environment. This has a negative effect on the Suva Barrier reef particularly close to the passages where corals are damaged by siltation and eutrophication. Increased fine-grained sediments can also be detected on the ocean-facing reef slope in the top 5 cm of the sediment column. This suggests that suspended sediment content in the river water has increased probably due to soil erosion caused by agricultural development in the Rewa catchment.

The Suva Peninsula is formed by Pliocene sediments (Suva Marl, Veisari Sandstone and Lami Limestone) overlain by a thin veneer of topsoil. Suva has at least three lines of natural and man-made defenses against sea-borne threats. 1. the Suva Barrier Reef, 2. the tidal prism, 3. a protected (armored) shoreline. Due to its coastal location it is threatened by various types of ocean currents, waves and heights. The most influential are: fair-weather waves, storm waves, earth quake generated waves and overall sea level rise.

Fair-weather waves are largely generated by the prevalent southeast tradewind and loose much of their energy at the barrier reef. However, Laucala Bay is quite wide and deep, so the residual waves do not loose much more energy crossing the deep lagoon. Waves break again at the limit of the tidal prism,

particularly on the SE side of the peninsula where mega ripples at the edge of the tidal flat show that relatively high energy waves are still reaching the shore line. Wash-over at USP's lower campus and Suva Point is fairly common at higher than normal wind speeds, particularly when the wind direction is from SW. A riprap embankment was placed at the tip of Suva peninsula to protect the road however, the boulders are seen to be redistributed across the tidal flat indicating that their size is too small too stay in place under storm conditions. There is a lack of erosion adjacent to this location where mangrove stands have survived. A noteworthy effort of the Department of Environment was to replant mangroves at the eastern side of said stand. The little trees are struggling to survive because the prevalent wind direction causes garbage and natural debris to collect there and smothering them.

Most of the peninsula is protected by a massive seawall however, undercutting and cracking of the wall can be observed in many places and maintenance is required. The wall is sitting on top of bedrock in most places (Suva Marl) which aids in stability. In addition some intertidal reefs (made by endemic sandbuilder worms) and mussels have build up at the base in many places protecting the wall by dissipitating wave energy. The reclamation of the land at the expense of the width of the tidal prism has resulted in increased energy of incoming waves which don't cross a wide shallow plane anymore but arrive with less diminished force at the vertical seawall where they are reflected back. This reflected energy is responsible for the erosion of the shore line seen in front of the seawall. Climate models predict that increased sea surface temperatures and sea level rise will impart more energy to the marine system resulting in higher energy waves and increasing numbers of storms. Hence there will be a need for a better protected shoreline which can resist these higher energy conditions (C. Griffiths, pers. comm., 2005).

As an island nation Fiji, surrounded by ocean, is particularly vulnerable to tsunamis but thanks to its tropical location most of Fiji's coastline is protected by coral reefs where tsunamis lose most of their energy at the reef barrier which forms a natural break water. The reef boulders on the Suva Barrier reef flat are testimony to tsunamis striking the Suva coast. According to the records of MRD at least 11 tsunamis have struck Fiji, of which three were generated within Fijian waters. The best documented and most damaging tsunami in recent history was in 1953 with 5 casualties in Suva and Kadavu. The wave was estimated to be 2 m high in Suva and flooded parts of Suva City. Fortunately it occurred at low tide otherwise damage would have been more severe. The tsunami resulted from a massive underwater slumping of sediments caused by an earthquake with an epicenter located 15 km offshore SE from Suva. Return period for such an earthquake has been estimated to be 1 in 200 years. However, another small tsunami was generated in 1975 by a moderate earthquake in Kadavu Passage, and again the tsunami resulted from an underwater landslide. (http://www.mrd.gov.fj/gfiji/geology/educate/tsunami.html). Recent investigations of the bathymetry of Suva Harbour by SOPAC suggest the presence of a fault scarp to the west of the Suva passage which causes a very steep morphology prone to slumping. Hence this region is most vulnerable to even a small earthquake. There are plans underway to reclaim the Lami foreshore opposite the Suva Passage for industrial and residential development. This area must be regarded as a most precarious site for human inhabitation and the development should be discouraged in favour of a more elevated site such as the reclaimed Lami Dump.

The lack of sheltering mangroves all along the out jutting shoreline must also be regarded as a problem because the trees provide a very effective barrier not only against high energy waves but also against the chronic erosion problem that exists along the exposed shoreline and that incurs continuous costs and maintenance. In addition the mangroves shelter many fish larvae and juvenile hawksbill turtles which are needed to replenish taxa that are important for the health of the barrier reef that is in danger of being overcome by algal growth.

Sea level rise

Results from the SEAFRAME project administered through SOPAC in the South Pacific indicate that the net sea level trend in Fiji is +3.1 mm per year. The data have accumulated over less than a century and must be regarded as preliminary. However, based on this prediction, a 3 cm s.l. rise will affect Suva over 10 years and 30 cm in 100 years. Obviously the most important structure for the protection of Suva, the barrier reef must be able to keep up with this rise. Barrier reefs fronting the Suva Peninsula act as a buffer to reduce the effects of ocean waves and currents on Laucala Bay estuary, Rewa Delta and wetlands and Suva shoreline.

The Suva Barrier Reef has reached its limit of upward growth and at low tide the reef crest is exposed. Suva's barrier island Makuluva is actively eroding, and the reef flats are on the erosional side of the sediment budget. Recent surveys show that the reef is more affected by algal growth now than it was 15-20 years ago. The most likely culprits for this development are eutrophication and overfishing (Naqasima-Sobey, pers. comm., 2005). The most productive part of the reef is the reef front and the reef crest which was severely affected by a bleaching event in 2000. However, the height of the reef barrier is to some (unknown) degree controlled by coralline red algae. Their sensitivity to climate events and eutrophication is not well known nor is their significance and composition at the algal-built front of the Suva Barrier reef. It was found in other tropical reefs (e.g., Moorea and Cozumel) that reef building red algae such as *Porolithon pachydermum*, (Reef Cement) stabilize reefs by cementing sand, rubble and living organisms together thus fixing the substrate. At Cozumel, *Porolithon* is the principal component of a majority of reefs, cementing and binding all other materials together, providing for growth and control of the reef margin.

Enhanced growth of coralline algae near sewage outlets suggests that they may be strongly nutrient limited in the open ocean (Chisholm, 2003). Growth rate for *Lithophyllum incrustans* (an encrusting temperate water alga) is reported to be slow, (around 2-7 mm per annum) and some colonies were found to be up to 30 years old. They appear to have a low sensitivity to turbidity and increased temperatures but bleaching was observed when light intensity increased (http://www.marlin.ac.uk/species/Adult_senexp_Lithophyllumincrustans.htm). Very little is known about the growth rate of tropical reef building red algae due to logistical problems with research in this high energy zone.

If the barrier islands and reefs cannot keep up with sea level rise, the system of sheltered wetlands and coast line along Suva Peninsula and Laucala Bay will be increasingly exposed to the force and effects of open marine processes such as wave action, salinity intrusion, storm surge, tidal currents, and sediment transport that combine to accelerate coastal erosion and wetland deterioration. The role and status of the principal reef builders and stabilizers needs to be investigated in view of a predicted 3 mm/ annum sea level rise to protect the Suva Shoreline.

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EXTRA-LATE ABSTRACT

ROEMMICH

The Argo Project: Progress and Plans in the Region

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The international Argo Project (http://www.argo.ucsd.edu) provides measurements of temperature, salinity, and ocean current in the upper 1-2 km of the global oceans using autonomous profiling floats. The fundamental elements of the coupled climate system are heat and freshwater, and Argo data reveals the ocean's role in the heat and freshwater balance on global scales for the first time. As of September 2005, there are more than 2000 Argo floats spread over all oceans building toward the planned 3000 float array to be completed in 2007. All Argo data are freely available to anyone via the internet within about 24 hours of collection. Argo is a central component of the Global Ocean Observing System (GOOS), which has a wide variety of research and operational applications. More than ten operational centers (including ECMWF, NCEP, UK Met, and BoM) already use Argo data in ocean and climate models and forecasts (http://www.argo.ucsd.edu/FrUse_by_Operational.html).

In the Pacific Ocean, with about 1000 Argo floats at present, Argo has already produced many scientific findings related to global warming, water mass formation, and interannual variability of water properties and ocean circulation. Over the past 10 years, the maximum in global warming has ocurred at 40-degrees S, where the oceans have warmed at a rate of 4 Watts-per-square-meter (Willis *et al*, 2004). This signal is due to interaction between a changing wind field and the circulation of the South Pacific gyre (Roemmich *et al*, 2005), and may contain a long-term anthropogenic trend origin as well as natural decadal variability. Another region with strong decadal ocean warming was centered near the Solomons, extending east across the dateline.

The strong collaborative role played by SOPAC and its member nations in GOOS and Argo is gratefully acknowledged. Argo will continue to provide its plans for float deployment (http://www.argo.ucsd.edu/FrDeploy.html) and to participate in identifying and developing applications of ocean observations of interest to SOPAC members, such as the SEREAD education initiative.

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