ABSTRACTS OF PAPERS

PRESENTED AT THE STAR* SESSION

1999

Keith A.W. Crook & Peter Rodda
Editors

SOPAC Miscellaneous Report 355

*Science, Technology and Resources Network

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FOREWORD

STAR (SOPAC's Science, Technology and Resources network) was founded in1985 in collaboration with IOC. The first Chairman of STAR, Dr Charles Helsley, then Director of the Hawaii Institute of Geophysics, guided STAR until 1992 when Keith Crook took over the helm. STAR was formed as a vehicle to assist the international geoscience community to provide advice to SOPAC, particularly during the intervals between SOPAC International Workshops, the most recent of which was the Conference on Marine Benthic Habitats and Their Living Resources: Monitoring, Management and Application to Pacific Island Countries, held in Nouméa 10-16 November,1997.

STAR is not merely a technical meeting at which individuals present scientific papers and discuss results and implications. Participants have the additional responsibility to formulate advice to SOPAC about its work program and to highlight technical and scientific issues of particular importance or urgency. This advice, in the form of reports and recommendations from STAR Working Groups, and 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 mobilise excellent science and bring it to bear so as to address the national needs of SOPAC's island member countries. The long-established working relationship between SOPAC and the international research community is a vital element in this endeavor, which STAR is charged to nurture. This relationship stimulated an order-of-magnitude change in the geoscience database in the SOPAC region during the 1980's. In the 1990's it has supported changes in SOPAC's scope and focus.

In earlier years STAR was primarily concerned with "blue-water" marine geoscience, tectonics and resources. However, as national needs and priorities have changed, the scope of STAR has altered so as to ensure that SOPAC's Work Program and its forward planning are influenced by international science that is both excellent and relevant. SOPAC's 2000 Work Program, which all participants should examine, encompasses a broad spectrum of geoscience and related activities in three priority focal areas: Resource Development, Environmental Science, and National Capacity Development. SOPAC's track record demonstrates that this approach to program development is synergistic, forwarding both the national needs of island nations and fundamental research. I commend it to you.

Keith A W Crook
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September 1999

REPORT OF STAR

STAR Presentations at SOPAC Annual Session, 1999

PROGRAM

Time	Theme	Authors & Speaker	Title
Saturday 23rd October			
08:30-08:40	**OPENING**		
08:40-9:00	**Tsunami** **Co-chairs:** **Takeshi Matsumoto** **&** **David Tappin**	Matsumoto, T.	Preliminary results of geophysical surveys off Sissano, Papua Niugini
9:00-9:20		Tappin D., Matsumoto, T., Watts, P., Masayama, M., McMurtry, G., Lafoy, Y. & shipboard party	Geological results from offshore surveys of the Papua New Guinea tsunami source region
9:20-9:40		Watts, P., Masayama, M., Tappin, D., Borrero, J., Grilli, S., Synolakis, C.	Simulation of the PNG tsunami and hazard assessment of future tsunamis
9:40-10:00		Tappin, D., Synolakis, C., Watts, P.	Mitigation strategies for Pacific Rim tsunamis
10:00-10:20		Watts, P., Borrero, J., Tappin, D., Grilli, S.	Case studies of Pacific Rim tsunamis generated by underwater landslides and slumps
10:20-10:40		McSaveney, M.	Why the 17th July 1998 tsunami at Sissano Lagoon, PNG, was coseismic and not landslide-triggered
10:40-11:00	**Coffee/Tea Break**		
11:00-11:20 **[Water Working Group Meeting]**		Crook, K.A.W., & Shipboard Scientific Party *SOS-2 CRUISE*	Geomorphic interpretation of subduction processes at the Sissano convergent plate margin: Implications for seismic and tsunami hazard assessment
11:20-11:40	**Mapping**	Irwin, B.	PCGIAP and Pacific Island Nations
11:40-12:00		Baltuck, M.	Opportunities for cooperation with NASA earth science
12:00-12:20		Paylor II, E., Milne, T. & Tapley, I.	PACRIM 2: NASA-JPL AIRSAR mission to the Pacific-Rim region in April-June 2000
12:20-12:40		Crook, K.A.W.	Assessing the potential of AIRSAR for studies of paleoseismology and seismic hazard assessment in Papua New Guinea.
12:40-13:00		Sinclair, M.	The Laser Airborne Depth Sounder (LADS) A Broad Range of Applications
13:00-14:00	**Lunch**		

14:00-14:20	**Mapping**	Ayers, P. & Legoza, S.	GPS-based underwater video mapping and application for coral reef management
14:20-14:40		Smith, R.	Implementation of multibeam surveying capabilities at SOPAC: the process, surveys and results to date
14:40-15:00	**GeoHazards: Disaster Management**	Granger, K. & Shorten, G**.**	A spatial information infrastructure for Pacific Island Disaster Managers
15:00-15:20		Yeo, S.	From Government prevention to community preparedness: shifting the culture for flood damage reduction, Ba, Fiji
	Abstract Only	Veitch, C. & Woolfe, K.	Development of a collaborative Disaster Research Program
15:20-15:40	**GeoHazards: Cities & General**	Buleka, J.	Geological hazards in Papua New Guinea
15:40-16:00	**Coffee/Tea Break**		
16:00-16:20		Shorten, G.	People at risk in Pacific cities
16:20-16:40		Biukoto, L., Swamy, M. & Teakle, G.	Apia – *Pacific Cities* in the Fast Lane
16:40-17:00		Guard, C. & Lander, M.	A scale relating tropical cyclone wind speed to potential damage for the tropical Pacific Ocean region: a *user's manual*
17:00-17:20		Chinain, M.**,** Ung, A., Pauillac,S & Legrand, A-M.	Elevated sea water temperatures increase the ciguatera risk in Tahiti (French Polynesia).
17:20-17:40	**Tectonics**	Lonsdale, P.	Tectonics of Niue Trough and Tonga-Kermadec Trench : results of April 1999 research cruise
17:40-18:00		Fepulea'i, A**.,** Smith, I. & Alloway, B.	Petrology of the Fagaloa Formation, northeast Upolu Island, Western Samoa
18:00-20:00	**STAR Working Groups**		

Time	Theme	Authors & Speaker	Title
Sunday 24th October			
18:00-21:00	**STAR Working Groups**		

Monday 25th October			
08:30-08:50	**Energy**	Conolly, J. B. & Layman, E.B.	The North Efate Geothermal Power Project, Republic of Vanuatu
08:50-09:10	**Minerals**	Petterson, M.G., Coleman, P.J. & Tolia, D.	A Spatial Mineralization Model for Solomon Islands
09:10-09:30		Wong, H.L., Lum, J. & Ricci, G.	Detrital gold survey – Nasivi Delta, Tavua, Fiji
09:30-09:50		Kita, Y. & Sekimoto, M.	An advanced summary of survey results in Japan/SOPAC Joint Deep-Sea Mineral Resources Project and GIS
09:50-10:10		Greenbaum, D. & Coates, J.S.	A mining mineral exploration and mining licence administration system for developing countries
10:10-10:30		McLeod, H. & Niumataiwalu, G.R.L.	Formulation of Fiji's Offshore Mining Policy
10:30-10:40		Petterson, M.G., Wallace, Capt S., & Tolia, D.	Records of Explosive Surseyan Eruptions from Kavachi, Solomon Islands, in 1961, 1970, 1976, 1978, 1991, 1998, and 1999.
10:40-11:00	**Coffee/Tea Break**		
11:00-11:20	Coastal	Lafoy, Y., Smith, R., Labails, C., Young, S., & Juffroy, F.	Post-middle Pleistocene evolution of the New Caledonian southwestern lagoon
11:20-11:40		Merrifield, M. & Kilonsky, B.	An index for ENSO-related sea level changes in the Tropical Pacific
11:40-12:00		Bowden-Kerby, A.	Low-tech coral reef modifications to mitigate sea level rise and climate change
12:00-12:20		Leach, J.H.J. & Flower, C.	The adoption of tourist vessels for coral reef environmental monitoring
12:20-12:40		Maharaj, R.J.	Risk assessment in coastal engineering and management in Pacific SIDS
12:40-13:00		Ramsay, D.	Recent advances in simulating the effectiveness and impact of dredging
	Abstract only	Kirby, R.	New method to permanently reduce maintenance dredging need
13:00-14:00	**Lunch**		

14:00-14:20	**Water**	Allenbach M., Taladoire, G, Lille, D & the ADAGE Group	Decision Support In Environmental Development And Management (ADAGE): the case of Lifou freshwater resources (Loyalty Islands)
14:20-14:40		Falkland, T.	Groundwater quality improvement through the use of infiltration galleries: a case study from the island of Lifuka, Kingdom of Tonga
14:40-15:00		White, I., Falkland, A., Etuati, B., Metai, E. & Metutera, T.	Recharge of fresh groundwater lenses: field study, Tarawa Atoll, Kiribati
15:00-15:20		Terry, J. & Raj, R.	Stream water resources in Fiji and the impact of El Niño
15:20-15:40	**Tsunami**	Prasad, G.	Fiji tsunami warning system and response arrangements
15:40-16:00	**Coffee/Tea Break**		
16:00-16:20	**Volcanic Hazards**	Cronin, S.J.	A new Holcene geologic map, volcanic hazard map and operational support plan for Taveuni, Fiji
16:20-16:40		Johnson, R. W.	Rabaul-Tavui caldera complex, Papua New Guinea: new perspectives since the disastrous 1994 volcanic eruptions
16:40-17:00		Cronin, S.J., Terry, J.P., Ferland, M.A.	Debris avalanche, seismic, tsunami and volcanic hazards of Uluinabukelevu (Mt Washington) Kadavu, Fiji
17:00-17:20		Itikarai, I., Patia, H., Nion, S. & Johnson, R.W.	Volcanic cone collapses in the southwest Pacific: results from the Ulawun Decade Volcano Workshop, Papua New Guinea'
17:20-17:40		Taylor, P.W. & Talia, L.	Volcanism on Savai'i: the risk from future activity
17:40-18:00		Johnson, R.W.	Professional conduct during volcanic crises: recommendations from IAVCEI
18:00-20:00	**STAR Business Meeting**		

	Poster	Atkinson, J.	Recent carbonate sedimentation on a fringing reef flat, near Suva, Fiji
		Cowan, H. & Kozuch, M.	GeoHazards Service – An integrated approach to monitoring and mitigation of risk associated with geological hazards
		Dau, I.	A review of slope stability issues in an expanding Suva, Fiji, and the planning implications of the Global Climate Change Process
		Ferland, M.A., Larcombe, P. & Kubota, K.	Recent Sedimentation in the Kadavu Passage, Fiji
		Greene, G.	Habitats, geohazards and the internet
		Heggie, D., Root, J. & Bierwirth, P.	Remote Sensed Landsat Imagery: application to assessment of environmental resources, natural and anthropogenic impacts.
		Hoibian, T.	Ostracods (Crustacea) populations as environmental tracers: examples from the Thio Estuary – New-Caledonia

		Jaffe, B., Gelfenbaum, G.	Tsunami deposits from the July 17, 1998 Papua New Guinea Event
		Johnston, D., Paton, D., Gough, J., Dowrick, D., Daly, M., Baddon, L., Batistich, T., Wood, I.	Auckland volcanic risk project: gaining a better understanding of the implications of a volcanic eruption at the Auckland Volcanic Field
		Keating, B.	Mega-tsunami Controversy
		Kim, S,P. & Lee, S.R.	Coastal morphology mapping of Southeastern area of the Savai'i Island, Western Samoa
		Kozuch, M., Jensen, S. & Heron, D.	The New Zealand Approach to Integrated Hazard Assessment
		Maharaj, R.J.	Contamination risk assessment of *WWII* armoury/munitions in Iron Bottom Sound, Solomon Islands
		Maharaj, R.J.	Evaluation of aggregate potential in onshore Pohnpei, Federated States of Micronesia (FSM), for engineering applications
		Pelletier, B	The Fiji Fracture Zone and the Futuna Islands **NO ABSTRACT RECEIVED**
		Pickrill, R.A.	Seafloor mapping for integrated ocean management
		Richter, S. & Mrazek, J.	Hydrothermal and volcanic events preserved in sediments from the western flank of the Central NFB Ridge
		Richter, S., Mrazek, J., Frenz, M., Lube, G. & Musolff, A.	Ash layers in Cenozoic sediments from the North Fiji Basin - evidence of volcanic events in the central chain of the New Hebrides Island Arc.
		Saade, E.J., Greene, G. & Meggitt, D.	Defining fisheries habitats by acoustic mapping
		Scott, B.	Dealing with volcano crisis: lessons from Ruapehu and Rabaul
		Spangenberg, T., Mrazek, J.	Earthquakes – sliding – tsunami: investigations at the continental slope, Middle America Trench and Cocos-Plate off Nicaragua, following the tsunami earthquake of 02 September 1992
		Stratford, J.	Changing influences on sedimentary basin development during the breakup of an oceanic island arc system: the Late Miocene to Pliocene record from Viti Levu, Fiji Islands.
		Wessell, P. & Kroenke, L.	Hotspots, Crackspots, and Jerks: Linking intraplate volcanism to plate motions.

Decision Support In Environmental Development And Management (ADAGE): the case of Lifou freshwater resources (Loyalty Islands)

Allenbach M., Taladoire G., Lille D., and The Adage Group

A European consortium with complementary skills - ALCATEL Space Industries (ex AEROSPATIALE Space & Defence), the IRD (ex ORSTOM) French Institute for Development Research, EID (Lisbon, Portugal) and the Common Centre of Research of the European Commission (Ispra, Italy) - have since 1996 been developing an innovative project (EUREKA Project EU 1299) for decision support in environmental development and management (ADAGE).

The ADAGE concept is based on the fact that the scientific expertise does not have a vocation to give the answers to the problems posed by the decision maker, representing the civil society.

The Adage Approach
ADAGE is a targeted approach that supports a manager to take a decision in the domain of the development of the territory, allowing him to visualise and to communicate the impact of the project.

ADAGE adapts itself to the local characteristics (geographical, political, technical, cultural) of the decisional domain.

ADAGE identifies the necessary resources while giving the priority to the one of which disposes the decision-maker already.

ADAGE constructs an interface between scientific knowledge and the needs of society, by an adapted translation of scientific speech to political speech. This translation leans on a double audit :

- audit of knowledge and expertise;
- audit of the decision structure.

ADAGE organises the emergence of information from knowledge in a hierarchical concept wanted by the decision-maker.

ADAGE allows a spatial interrogation of the expertise, notion more easily assimilated in the context of decision.

ADAGE allows the integration of contradictory exits criteria of scientific knowledge or social culture, that are the foundation of the reality and existence of the decisional system.

Regional Application
The ADAGE approach is actually used in New Caledonia in LIFOU (Loyalty Islands) to improve decision-making on exploitation of the freshwater resource. The neo-caledonians actor of this program are :

- the Loyalty islands Province;
- the Lifou Free-town;
- the LATICAL (Caledonian Laboratory of IRD (ex ORSTOM) French Institute for Development Research);
- the UNIVERSITY of NEW-CALEDONIA;
- the A2EP Company (Pacific Water and Environment Agency).

The aim of this ADAGE application (the first operational site of the ADAGE project) is to simulate the behaviour of the freshwater lens, the exclusive drinkable water resource on these islands, towards some principal aggressions (tourism, projects development, demographic evolution...). Of course, this aim depends on the lens and understanding of social behaviour understanding.

At this time the following steps have been realised :

- analysis of behaviour of the Lifou population towards the freshwater resource
- re-reading and analysis of the existing data
- identification and spatialisation of risks
- analysis and understanding of anticipated results
- development of scenarios and their validation by decision-makers

Prototype
An object oriented expert system (G2) is used to integrate the data, to visualise them graphically, and to simulate the interactions between the different objects. Many kinds of data must be integrated in the system in alphanumerical form (counts, statistics, …) or in graphic form (satellite picture, aerial photographs, maps, …). Each element in the system is an object and can have a specific comportment used to generate simulation for each scenario.

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Recent carbonate sedimentation on a fringing reef flat, near Suva, Fiji

Jane Atkinson

Sediments on the Namuka Reef Flat, near Suva, Fiji, are dominantly carbonate originating from reef organisms, with a minor amount of terrigenous components that are derived from land and limited to the nearshore. The sediments are mostly poorly to very poorly sorted and range from boulder to silt-sized. This study involved detailed analyses of the granule and finer sediments, of these most samples contain dominantly sand-sized sediments. Very little silt was present over the reef flat, typically less than 1%, however; there were a few exceptions, most notable of which was the lagoon which contained up to 15% silt.

There is a strong zonation of sedimentary facies, which are oriented sub-parallel to the windward reef crest. The area closest to the crest zone is probably the source for most of the coral fragments, which are the dominant component (49%) of the reef-flat sediment. Other components of the gravel and finer sediment are derived from various parts of the reef depending on the species. They are calcareous algae (22%), molluscs (16%) and foraminifera (9%).

A continuous tidal circulation keeps most of the reef free of silt-sized sediment, with the exception of the enclosed Muaivuso Lagoon which acts as a trap for silt-sized sediment. The reef flat is influenced by waves during the dry season when the Trade Winds blow. At this time coarser sediment may be entrained and moved across the reef flat. During the wet season the reef flat is typically calm, although cyclones and tropical storms can develop. In 1953 a tsunami struck the Suva region and threw metre-sized blocks of limestone up onto the reef flat, and some of these blocks have been moved shorewards by subsequent cyclones. On a far smaller but no less important scale, numerous species of bioeroders are constantly breaking the sediment down from within and without. They vary from blue-green algae to echinoderms and parrot fish.

Geochemical studies of bulk sediment samples showed that MgO increases from 2.62% in the northwestern part of the reef to 3.60% in the eastern reef. Exceptions occurred for the Mangrove Facies where MgO increased to 5.36%. Trace element studies showed that the reef was overall free of those elements associated with the river and Suva Harbour sediments. However, exceptions occur in the sediments closest to the villages of Muaivuso and Waianake. Here, and particularly so for the area close to Muaivuso village, sediments were enriched in lead and arsenic as well as other trace elements that were associated with sediments from Suva Harbour and the rivers.

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GPS-based underwater video mapping and application for coral reef management

Paul Ayers & Sarah Legoza

An Underwater Video Mapping System (UVMS) was developed to examine underwater ecosystems and record their location using Differentially Corrected Global Positioning System (DGPS). UVMS incorporates a Splash Cam underwater camera, a Sony Digital Video Camera, a VMS 200 (Video Mapping System 200), and a Trimble AgGPS 132 Receiver. The VMS 200 allows the GPS position to be recorded on each frame of the digital videotape, thus georegistering all recorded images.

This system was tested in Fort Collins, Colorado, on Horsetooth Reservoir on June 3, 1999. Several hours of georeferenced videotapes were acquired to a depth of 144 feet [43.9 m]. At this depth, camera lights were used to obtain usable images. Underwater images of features such as vegetation, rocks, dams, fish habitats and trash were captured and saved as still images. The videotape indexing and image-capturing procedure is conducted in the MapX GIS environment. Exporting to MapInfo or ArcView (also possible in MapInfo), a map was generated illustrating the path of the boat and icons hotlinked to the still images. The hotlink feature allows for the development of an ArcView layer of georeferenced images in a variety of

categories. The georeferenced hotlink image layers could be overlaid on other GIS layers such as aerial photographs or remote sensing data to provide ground-truthing. The GIS layers (and hotlinks) developed by the VMS are also exportable in HTML format and suitable for WebPages insertion.

Water clarity is an issue and the camera needs to be positioned at appropriate depths to obtain usable images. A Canon Digitrol IV depth-control system can be employed to control camera depth. A Trimble lightbar can be employed to obtain parallel swathing for boat navigation.

The UVMS provides the capability of acquiring, storing and databasing georeferenced images of underwater objects. This technology could be useful in mapping and managing coral reefs. Camera images could be used to georegister coral type, health, and population. Sensor data (i.e. temperature, water quality, and depth) can also be monitored and stored on the videotape for analysis.

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Opportunities for cooperation with NASA earth science

Miriam Baltuck

Most large projects which the United States National Aeronautics and Space Administration (NASA) undertakes are pursued in partnership with the international science community. International participation in a flight project may range from membership in a science data-analysis team to contribution of a flight project instrument. Many of NASA's ground- or air-based scientific campaigns are designed and implemented in the field with international partners' crucial participation. The following paragraphs identify five areas we hope will be of particular near-term interest to members of the South Pacific Applied Geoscience Commission (SOPAC).

SOPAC may find interest in the TERRA mission (formerly the Earth Observing System AM-1; launching later this year), which will carry the Moderate Resolution Imaging Spectrometer (MODIS). MODIS is similar to the Advanced Very High Resolution Radiometer, but carries many more channels (31) and will have a greater spatial resolution capability. It will be used to characterize such parameters as cloud distribution, vegetation indices, ocean color, and sea surface temperature. TERRA also will carry the Japanese-provided ASTER, a higher-resolution instrument package (15m) with earth-observing sensors in the Visible-Near InfraRed, ShortWave InfraRed, and Thermal InfraRed. TERRA will be launched toward the end of 1999.

The Shuttle Radar Topography Mission (SRTM) is currently scheduled to fly on a shuttle flight in November 1999. SRTM will acquire synthetic aperture radar (SAR) interferometric data using the C-band SAR instrument which flew on the Shuttle in 1994 during two Shuttle Radar Laboratory (SRL) flights. This instrument will transmit and receive data and another C-band receiving antenna will be deployed from the shuttle on a 60 m boom. Because SAR is relatively impervious to cloud cover, SRTM should be particularly useful in areas where satellite-derived optical-based topographic data have been difficult to acquire. Data will be collected over all land mass between 60° North and 60° South, and will have an absolute horizontal accuracy of 20 m and absolute vertical accuracy of 16 m. SRTM is flown in partnership with Germany, the United States Geological Survey, and the National Imaging and Mapping Agency. Data distribution policy is still under discussion but it is anticipated that a global data set with horizontal postings of 100 m will be releasable, with higher-resolution data requests considered on a case-by-case basis.

In association with the 1994 SRL flights, NASA arranged to fly its multi-polarizing, multiple frequency, interferometric airborne SAR instrument (AIRSAR) over many of the SRL science team study sites. The success of the 1993 airborne campaign to Australia encouraged Australia and NASA to develop a wider reaching airborne campaign which included the participation of ten Pacific Rim countries in 1996. This first PACRIM campaign was planned and implemented with the cooperation of the participating nations, and acquired airborne SAR data for studies in agriculture, coastal management, geology and tectonic processes, interferometry/topography, natural hazards, urban and regional development, forestry and vegetation, and archeology. PACRIM I airborne SAR data was acquired over Australia, Brunei, Cambodia, Malaysia, New Zealand, Papua New Guinea, the Philippines, Taiwan, Thailand, and the United States of America. PACRIM I was followed by numerous workshops hosted by NASA and the participating countries where results were presented and instruction in data processing and analysis provided. As we develop plans for PACRIM II in the March-June 2000 timeframe, we encourage PACRIM I partners and possible new partners in Southeast Asia and the South Pacific to consider participation in this second airborne SAR campaign. Dr Earnest Paylor/NASA will present a detailed companion paper on this subject at this session.

NASA's Solid Earth and Natural Hazards Program uses remote sensing and space geodetic technology to improve our understanding of the structure and dynamics of the solid Earth, and applying this understanding to disaster management. An important element of this program is its international space geodesy cooperation with over 80 organizations around the world. High-resolution geodetic measurements are made using precision Global Positioning System receivers, satellite laser ranging, and very long baseline interferometry to monitor crustal deformation and study its relation to seismic activity. Participating organizations provide data to an archive which is available to all participating organizations.

The Global Learning and Observations to Benefit the Environment (GLOBE) program is an international program designed to include students, teachers and scientists in a science and education program. Primary and high school students of over 70 nations make research-quality environmental measurements and enter them into a global data set via an Internet website. They have access to that data set and can pursue environmental studies using the entire GLOBE data archive. The cost of the instrument package is $US400-600. GLOBE provides an early venue to attract bright students to the environmental sciences and the global scientific community.

For more information about any of the subjects in this paper:

- TERRA can be found on the Earth Science Enterprise link from NASA's website http://www.nasa.gov,
- SRTM's home page is http://www-radar.jpl.nasa.gov/srtm/,
- Information about NASA's Solid Earth and Natural Hazards Program can be found at http://ltpwww.gsfc.nasa.gov/senh/
- GLOBE can be queried at info@GLOBE.gov, and
- PACRIM II participation can be queried with Dr Earnest Paylor (epaylor@hq.nasa.gov).
- Information about the Airborne Synthetic Aperture Radar system (AIRSAR) can be found at: http://airsar.jpl.nasa.gov/.

In addition, Dr. Paylor will present detailed information on a) the results of PACRIM I and early plans for PACRIM II, and b) NASA's Natural Hazards Programs in this 28th SOPAC Session.

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Apia – *Pacific Cities* in the Fast Lane

Litea Biukoto, Monika Swamy, Geraldine Teakle

The implementation of the *Pacific Cities* hazard and risk assessment program in the various participant cities has been promoted by the SOPAC Hazard Assessment Unit more or less uniformly, not biased toward any one city. In practice, however, the project has moved at a different pace in different cities, very much dependent on the level of political, financial and moral support available for the project in each city.
It is perhaps easy to understand that Suva might, by default, become the leader by virtue of the location of SOPAC and the lower field costs needed to implement the program here, but Apia has also moved rapidly up with the front runners in the program. In Apia, the program of work has benefited firstly from the advantage of the experience achieved in earlier city programs, but significantly, has been moved along by a combination of political will within the country, an amount of seed-funding provided by a donor country, and the synergy developed by a small team of young Pacific Island workers with a vision of the final results of the project.

The inclusion of Apia in the Pacific Cities project was requested by the Samoan Foreign Affairs representative to the Governing Council at the 1998 SOPAC Annual Session, but a start on the project was delayed because of work already underway on the original participant cities. New Zealand ODA gave approval for seed-funding to be obtained from their unspent funds for Samoa. In July 1999, contact was made with various Government Departments and other bodies to seek data on Apia, and a counterpart from the Apia Observatory visited Suva in the second week of August to transfer existing information to the digital GIS database.

Field work began a week later in Apia and, by the end of three weeks, the bulk of the Apia Pacific Cities program was completed, including the incorporation of the existing database of roads, physical features and the water reticulation network, a detailed seismic microzonation of the city and the survey of the structure of all buildings in the greater city area, the assembly of the borehole database, production of a coarse digital terrain model, and the flying of aerial photography and survey of control points in preparation for the production of a fine-scale working digital terrain model.

The core team of three young SOPAC graduates from the region, together with the Samoan support team of eight trainees from the Apia Observatory, worked long hours to bring the project to fruition, assisted by timely interventions and support from Foreign Affairs, Observatory staff and others. Unfortunately, the NZODA seed-funding has been spent several times over in the course of the project but nevertheless has acted as a crucial catalyst for the project and has demonstrated the commitment of Samoa to the *Pacific Cities* project.

Even while acknowledging that further funding is still needed to complete the project, it is manifest that the combination of political will, seed-funding and the dedication and motivation of the local team in Samoa have produced an enviable result in a much shorter time-frame than expected. The outcome is a lesson for all that the seemingly unachievable is, in fact, achievable if the will, motivation and necessary support are provided.

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Low-tech coral reef modifications to mitigate sea level rise and climate change

Austin Bowden-Kerby

Climate-change models predict rising sea levels and increasing storm frequencies. Low-lying coastlines and atoll islands are particularly vulnerable to these changes, and erosion is predicted to increase. Reef-derived features such as calcareous sand beaches and atoll islands are ultimately influenced by the health and growth rates of the reefs on which they depend. Rapid carbonate accretion rates are dependent on high coral cover, and are cited as being critical to coral reef survival in an era of rapidly rising sea levels. In past ages, reefs with low accretion rates have not kept up with rapid sea-level rise, and have died out, becoming seamounts, shoals, or drowned atolls.

This presentation explores the potential for using low-tech coral reef modifications to mitigate the predicted effects of climate change. The methods are part of a new project in community-based coal reef management being implemented by the Foundation for the Peoples of the South Pacific International, the “Coral Gardens Initiative”. The climate-change mitigation aspects of the project include: 1. increasing carbonate accretion rates by planting temperature-tolerant corals on reef flats, 2. widening reef flats by planting rapidly growing coral species (staghorn, upward growth per year 20-50 cm) in the sandy back reef to intercept and deposit sand being transported into lagoons, preventing its loss to the depths, 3. planting coral reefs on the lagoon side (behind) atoll islands to build up a reef-flat base on which the islands can migrate, and 4. constructing a series of tide pools on the outer reef flat to baffle the energy of increasing waves, and using the excavated rock material to reinforce the “boulder rampart” on the seaward side of atoll islands.

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Geological hazards in Papua New Guinea

Joe Buleka

Geological hazards have parallel development in Papua New Guinea and this may reflect lack of long-term developmental vision. Development has in fact made many of our leaders lazy and encourages individualistic and short sighted gains.

Lae, an industrial city and the link to the outside world for 60 percent of our rural population, has been the site of many natural and man-made disasters.

Geological hazards such as tsunamis occur regularly in the Huon Peninsula, caused by large shallow earthquakes and submarine landslides.

Geological hazard assessment in Lae, was carried out jointly by CCOP/GSPNG. This report is completed and can be divided into the land-based studies using Remote Sensing (Landsat TM) and the offshore bathymetric mapping. The latter has highlighted Lae as being at low risk due to canyon curvature and many other factors.

Canyons in many parts of PNG are perpendicular to the coastline and may reflect high runoff potential and consistent emergence of the landmass. Large landslide dams have formed at elevations of about 2000 m (asl), and a breach of one such dam rafted two bridges and the debris flood ended in the canyon, but no tsunami was generated .

In wide, linear canyons, waves are transmitted faster than in curved canyons, with little dissipitation of the wave energy. A good example is the Sissano canyon at which a class 1 wave reached 15 m high. The maximum height of the tsunami covered only a small but highly populated area and killed about 2500 people. Earthquake-generated tsunamis often transmit large waves over large areas. This may reflect the possible source and cause of the tsunami. The linear topography of a variable canyon may in part be responsible for the amplification of the wave near the coastline. A laboratory test on tsunamis carried out by Monash University of Melbourne (Australia) shows that a dense material will displace the less dense material and form waves but this was not the case in the Huon Gulf in 1996.

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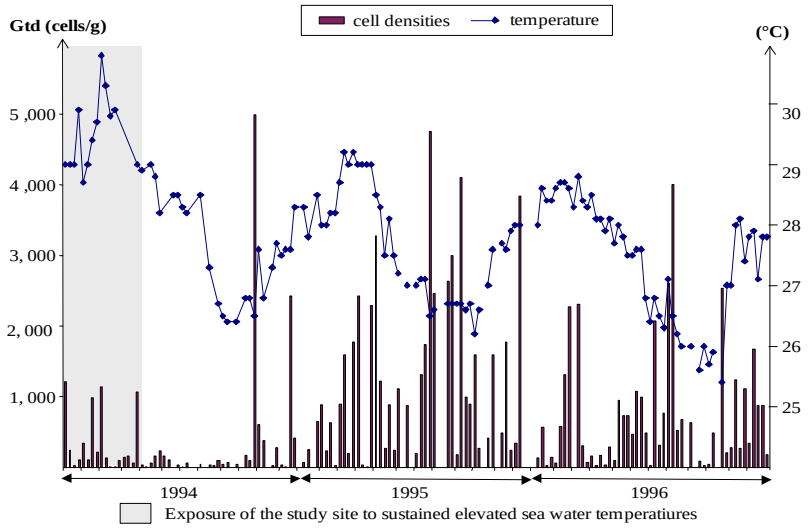
Elevated sea water temperatures increase the ciguatera risk in Tahiti (French Polynesia)

M. Chinain, A. Ung, S. Pauillac and A-M. Legrand

Ciguatera is fish poisoning affecting humans, resulting from the consumption of any of a large variety of tropical reef fish. This intoxication is prevalent in the Caribbean and the Indian Ocean as well as the Pacific regions. In French Polynesia, the primary causative agent of ciguatera is the benthic dinoflagellate *Gambierdiscus* spp., which is the source of two types of marine toxin, maitotoxins (MTXs) and ciguatoxins (CTXs), these latter being regarded as the principal cause of the poisoning. These toxins are known to accumulate through the food chain via the herbivorous fish grazing on coral reefs, and the carnivorous fish that feed on them [1].

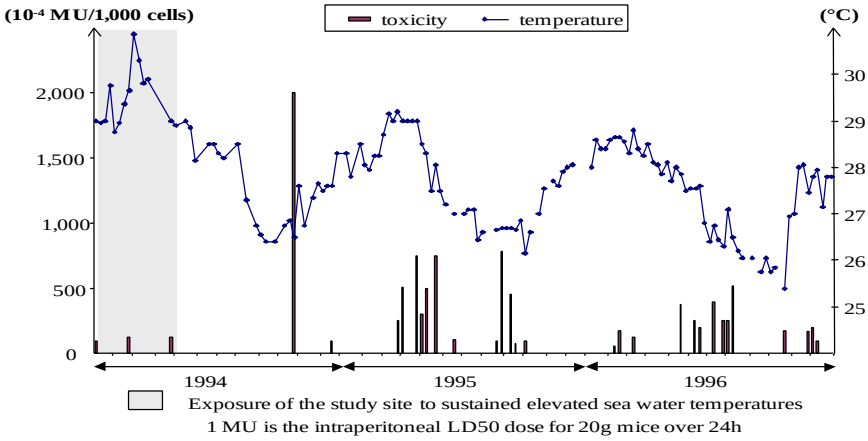
Factors controlling the initiation of ciguatera outbreaks are still poorly understood. However, based on earlier observations, it has been speculated that ciguatera outbreaks can occur in response to reef disturbances, as *Gambierdiscus* cells are generally found in close association with macrophytes that proliferate on dead coral substrates. The study presented here describes the seasonal abundance and toxicity of natural populations of *Gambierdiscus* spp., from 1994 to 1996, in Atimaono barrier reef (Tahiti, French Polynesia) in relation with sea water temperatures. During this period, temperatures monitored weekly were found to range between 25.4 °C and 30.9 °C. In particular, our study site was exposed to sustained elevated temperatures from January through April 1994 (Fig. 1), concomitant with a mass coral-bleaching episode largely documented in Tahiti and Moorea islands [2,3]. Population densities (Gtd) ranged from 2 to 4992 cells/g of algal wet weight - maximum abundance recorded in October 1994 - with most of the peak densities preferentially reported during 1995-1996 (Fig. 1).

Figure 1: 1994-1996 fluctuations of *Gambierdiscus* cell densities, in relation with T(°C) in Tahiti



A total of 37 blooms of *Gambierdiscus* (i.e. Gtd > 1000 cells/g) were also sampled during this 3-years' survey, yielding a total biomass of 238 x 10^6 cells, and their toxicity assessed using the standard mouse bioassay [4]. The striking increase in both peak densities and frequency of *Gambierdiscus* blooms observed in 1995-1996 - 86% of the blooms occurred during this period - also coincided with maximum toxin production (Fig. 2).

Figure 2: Toxicity of blooms of *Gambierdiscus* in Tahiti, from 1994 to 1996



Epidemiological data on ciguatera incidences tend to support the idea that 1995 and 1996 were high-risk years in French Polynesia, as 824, 866 and 924 cases were reported in 1994, 1995 and 1996, respectively [5].

From these data, it is suggested that natural reef disturbances, such as coral bleaching, resulting from unusual elevated sea water temperatures, can increase the risk of ciguatera in a given area by providing "new benthic surfaces" further colonized by various opportunistic species of macroalgae that are ideal hosts for *Gambierdiscus* cells. The occurrence of highly toxic blooms of this dinoflagellate further contributes to maintaining a high toxin reservoir in fishes of this area. Our conclusion is consistent with previous observations that ciguatera outbreaks can occur in response to reef destruction [6,7]. Our data also suggest that the time lag between major reef mortality and an increased risk of ciguatera may be limited to a few months (7 months in our study).

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The North Efate Geothermal Power Project, Republic of Vanuatu

John R. Conolly & Erik B. Layman

An active geothermal system centered in northern Efate island in the Republic of Vanuatu has excellent potential for generation of electrical power. A volcanic heat source for the system is indicated by the geology of Efate, which is composed of Quaternary age rhyolite pumice and basalt, flanked by uplifted limestone terraces. The geothermal system discharges up to 320 liters/sec of thermal waters, mainly at the Takara thermal area on the north coast and at several springs along the Teuma graben, a well-defined, north trending structure which bisects the island. At Takara, a shallow thermal-probe survey (30 cm depth) has identified an extensive, 0.5 km^2 area of hot ground which includes localized “hotspots” with temperatures of 80-100°C. A 3-meter borehole in the same region measured 88°C. Subsurface reservoir temperatures of 160-220°C, sufficient for electrical power generation, are indicated by geochemical analyses of the thermal springs waters (SiO_2 and Na-K-Ca geothermometers).

A regional-scale gravity survey has identified a 170-milligal Bouger gravity positive, centered in the mountainous area 3-4 km south of the Takara hot springs area, near the northern terminus of the Teuma graben. Drilling in volcanic geothermal systems has shown that such features typically result from dense intrusive masses, which often penetrate into the Quaternary volcanic section. The heat source for the Efate geothermal system may be the deeper, still hot portion of the inferred intrusive complex. Areas of low electrical resistivity, defined by Schlumberger surveys, correspond well with the gravity positive. These are

interpreted as areas of clay-rich, argillic alteration of rocks overlying the high-temperature reservoir. A preliminary hydrologic model of the Efate geothermal system suggests that thermal fluids rise up from depth near the northern end of the Teuma graben, and flow laterally ("outflow") northeast towards discharge at the Takara thermal area, and south to the Teuma graben springs.

At present, electric power on Efate island is generated and distributed by UNELCO Vanuatu, Ltd., a French firm under contract with the government. The current power demand on Efate consists of about 2.5 megawatts (MW) of base (or minimum) load and 7.5 MW of peak load. Power is produced by generators which burn imported diesel fuel, resulting in relatively high power prices to consumers. In an effort to initiate geothermal development on Efate and reduce power costs, the government has signed an agreement with the Efate Geothermal Joint Venture (EGJV), a cooperative venture between two firms, Rawson Resources, N.L. and Layman Energy Associates, Inc. Through its agreement with the government, EGJV has obtained rights to a geothermal concession area on Efate and will undertake a feasibility study for development of an initial 2.5-MW geothermal facility to supply base-load power to the island. Installation of a second 2.5-MW unit to accommodate anticipated growth in demand will also be evaluated. A key goal of the study will be to carefully define costs of the proposed geothermal development, and determine if the project can deliver power at lower rates than the current 100% diesel system.

The relatively small size and capital-intensive nature of the project will require that development proceed in the most economical fashion possible. A key aspect of the development plan will be to target the shallow, outflow portions of the Efate geothermal resource for production in order to reduce drilling and road-construction costs. It is anticipated that capital costs for the second unit will be significantly lower than for the initial unit, due to use of existing infrastructure (transmission line, roads, wells, etc.). This should translate into significant reductions in the cost of electricity delivered.

The Efate Geothermal Project can be seen as a model for development of clean, renewable power for other island nations in the Pacific region with geothermal resource potential. Produced geothermal fluids are reinjected underground, and a binary (heat-exchanger type) geothermal plant, if used on Efate, would generate essentially zero air emissions. A "flash" plant, appropriate for resources over 180-200°C, would generate only a small fraction of the greenhouse and sulfur gases emitted by a similar-sized fossil-fired plant.

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GeoHazards Service – An integrated approach to monitoring and mitigation of risk associated with geological hazards

Hugh Cowan & Michael Kozuch

Earthquakes, volcanic eruptions and related geological hazard events around the Pacific Rim during the last decade have shown that the impacts and losses due to these events are rising, as industrial and urban economies are becoming increasingly dependent on the continuity of supply and timely delivery of products and services. Although the physical impacts may be locally severe, greater losses are usually associated with disruption to business and economic life in the days or months that follow.

Mitigation and response planning can reduce the severity of potential impacts through a combination of pre-event hazard and vulnerability assessment, and near-real-time monitoring and reporting of hazard-event information, tailored to specific needs. The GeoHazards Service has been created in pursuit of this aim, to promote a New Zealand society and economy resilient to the impact of geological hazards.

The main economic issues that require complete control by organisations in order to reduce the bottom-line impact of a disaster include: down time, the customer base, cash flow, production and distribution. Communities manage their customer base and cash flow independently of the GeoHazards Service, but the Service can make significant contributions to the management of down time, loss of production and service distribution through:

- almost immediate notification of an event that might adversely affect company operations
- almost immediate notification of an event that might be widely reported and generate alarm, but not adversely affect company operations
- advance warning of volcanic-hazard events and their likely impacts
- identifying the likely failures that will directly affect operational capabilities

- assisting clients to reduce potential losses and disruption through application of state-of-the-art analysis of the hazards and vulnerabilities.

Community partnerships with GeoHazards Service ensure that scientific knowledge and information are correctly matched to mitigate the risks associated with geological hazards. Through this approach the scientific understanding of the hazard potential can be translated more effectively to disaster reduction.

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A new Holcene geologic map, volcanic hazard map and operational support plan for Taveuni, Fiji

Shane J. Cronin

The Holocene geology of Taveuni has been mapped at a scale of 1:50 000 to be used as the basis for a volcanic hazard map of the island. The 436-km^2 island is entirely volcanic in origin, but Holocene eruptive products are mostly confined to its southern half and isolated portions in the north. The basaltic island volcano has a prominent rift zone along its NE-SW axis, which was the zone of greatest volcanic productivity. The volumetrically dominant deposits are lava flows, but large volumes of pyroclastic and volcaniclastic deposits are also present. The dominant eruption styles were Hawaiian and Strombolian, with some hydrovolcanic activity. Thirty-one radiocarbon dates, along with stratigraphic and geomorphic relations, provide an accurate chronology of the 166 identified eruptions on Taveuni during the Holocene (at least 56 since humans were present on the island). All eruptions since 2000 BC were confined to the southern half of Taveuni, but occurred at seemingly random locations along the main southern axis of the island. The monogenetic and apparently random activity is the main challenge to volcanic hazard mapping of the island. The hazard map uses a three-level colour-coding for ground-based volcanic hazards, ranging from high hazard (red), intermediate (yellow) and low (green). The red zone encompasses the central rift area of the southern portion of the island and the potential lava flow pathways that radiate from this. The yellow zone encompasses all secondary lava flow routes in the southern part of the island, as well as the main rift area in the north and the primary potential lava pathways that radiate from it. Tephra-fall hazard zones are delineated into two zones, areas subject to falls >20 cm, and those subject to >10 cm falls. For all the hazard zones, only a very small proportion of each zone will ever be affected by a single eruption. This depends on the vent location (which will not be known until pre-event tremors are detected), and the wind direction (for tephras and gases). Hence the generic map is the basis for long-term development use and pre-event planning, by zeroing in on a section of the map once the location of activity is known. Additional to the geological components of the Taveuni study, a plan for the management of volcanic risk on Taveuni has been developed. This Operational Support Plan outlines the pre-, during- and post-event management strategies required to minimise the loss of life and property on Taveuni. The plan was presented to the Fiji Government in June 1999, and is now undergoing revision to fit within the disaster management framework of the country.

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Debris avalanche, seismic, tsunami and volcanic hazards of Uluinabukelevu (Mt Washington) Kadavu, Fiji

Shane J. Cronin, James P. Terry, Marie A. Ferland

Nabukelevu is an 805-m-high volcanic edifice located at the extreme western end of Kadavu, Fiji. Westward-migrating volcanism in the Kadavu area was related to subduction at the Hunter Fracture Zone (east of Kadavu), but plate convergence at this zone has apparently ceased. Nabukelevu is an acid andesitic stratovolcano, dominantly comprising interlayered lavas and volcaniclastics. Its volcanic products appear to be mainly viscous short lava flows and domes. Lava-dome collapses and blasts were an apparently common theme of activity, as evidenced by abundant and widespread block-and-ash flow deposits with homogeneous magnetic alignment (ie. emplaced above Curie Point temperatures). The youngest volcanic activity produced an apparently unusually pumiceous pyroclastic flow, which travelled mainly to the northeast and west. The larger, western lobe has homogeneous clast magnetic orientations for up to 3.5 km from the supposed vent, and contains charcoal as well as pottery sherds, mixed throughout the undisturbed primary deposit. The final stage of this eruption is thought to be the formation of a large lava dome or coulee on the volcano's summit and upper eastern flanks. The plain pottery sherds incorporated within the pyroclastic flow deposit indicate that this eruption occurred within the last c. 3000 years. However, this may not have been the only momentous geological event to occur during this time. At least four large landslides (or debris avalanches) occurred on the northern, western, southeastern and southern flanks of the

edifice. At least two of these were probably large enough to generate at least local and probably sub-regional tsunamis. Deposits from the debris avalanches in the south and southeast contain charcoal and plain pottery sherds, and the southeast unit also contains bone fragments (human or large animal). We are investigating the possibility that wood fragments and other detritus from the northern debris avalanche are contained within surface sediments within the Suva Basin, that lies between Kadavu and Viti Levu. The four obvious debris avalanches from Nabukelevu may all have occurred at the same time and could possibly be fault controlled and seismically triggered. A previously unmapped fault (possibly active in 1998) cuts through the edifice along a NE-SW strike – parallel to mapped faults further east. An earthquake swarm in 1998 caused small landslides from reactivation of the large debris avalanche scarps, which are all located along the strike of the newly mapped fault. We are awaiting radiocarbon dating results that may help to confine the ages of some of these debris avalanches and the latest volcanism.

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Geomorphic interpretation of subduction processes at the Sissano convergent platemargin: Implications for seismic and tsunami hazard assessment[1]

Keith. A .W. Crook & ShipboardScientific Party SOS-2 CRUISE[1]

Sissano, situated on the north coast of western Papua New Guinea between Aitape and Vanimo (Tappin et al., 1999), lies on the convergent margin between the Australian and Pacific (North Bismarck) plates. Convergence is oblique, along an azimuth trending 070° (Davies, 1998); there is no volcanic arc on the overriding Australian plate. Exposures of granitoids, metadiorite, and well-indurated lithic sandstone of metamorphic and plutonic provenance, sampled in February-March 1999 by ROV Dolphin 3K during R/V *Natsushima* cruise SOS-2 in water depths of 1600-2800 m on the continental slope, indicate that subduction erosion has exposed the metamorphic basement of the Australian plate. The rock types retrieved probably represent outcrops of the Torricelli Intrusive Complex and the Ambunti Metamorphics, and associated cover units, which crop out in the Torricelli Mountains to the south (Norvick & Hutchison, 1980).

The ocean floor of the North Bismarck plate slopes gently towards the base of the continental slope, forming a narrow trench 6-10 km wide with a floor at 4000 m. Ridges and seamounts rising to 2500 m trend ENE and cross the ocean basin floor, locally obstructing the trench. A broad rise with a summit at 2500 m, ENE of Aitape, has obstructed the trench, which is only 2 km wide from Aitape eastwards and has shallowed to 3500 m.

The continental shelf is narrow (<10 km), grading gently and continuously out to a sedimented uniform upper slope with a break at 600 m. Along much but not all of the margin, the middle slope is steep and gullied. Four sectors showing different degrees of dissection are recognized from west to east: Pual (moderately dissected), Serra Hills (undissected), Bliri-Sissano (intensely and finely dissected), and Arope-Aitape (strongly and coarsely dissected).

The steepest parts of the middle slope are north-facing arcuate re-entrants with locally vertical head-walls. There are two large river-mouth-related submarine canyons: the sinuous, deeply entrenched Yalingi Canyon, and the less prominent Pual Canyon. There is no canyon off the Bliri River mouth.

The lower continental slope, deeper than 2000 m, is topographically complex. The section from Sissano westwards displays two distinct ridges interrupted by narrow passes at south-V-ing indentations. South flanks of these ridges are steep, and form the northern margin of semi-circular to semi-elliptical sediment ponds at water depths > 3 km. The inner, more elevated set of ponds is the most extensive.

The lower slope east of Sissano has only a single discontinuous ridge made up of several arcuate segments 15 km long, with steep to vertical south faces. The depressions landward of these features contain little sediment; the largest sediment pond lies west of the Yalingi Canyon and is adjacent to the westernmost arcuate ridge segment northeast of Sissano, the "Pop-up Block" (PUB). Topographic lineaments up to 10 km long, trending 085°-090°, transect the lower slope. They are most common in the slope sector west of Sissano. The base of the continental margin is sharp, and is generally convex towards the trench, with several prominent V-shaped re-entrants. Both these re-entrants, and the lower-slope sediment ponds, resemble features associated with seamount subduction described by Dominguez et al. (1998). However, variations in their conformation and spatial distribution imply a complex history of upper-plate deformation. The south-facing lower slope features west of Sissano are best interpreted as young fault-lined scarps, upthrown on their north sides as a consequence of seamount subduction into the New Guinea trench.

The north-facing arcuate re-entrants are slightly degraded head walls to collapse features that formed in response to subduction of edifices on the lower plate. Some re-entrants are supplied with sediment by canyons and gullies, which are secondary features. There is no spatial association between the re-entrants and the heads of submarine canyons.

The variability in middle-slope dissection is not structurally controlled. It may reflect the relativities of sediment supplied to the shelf and upper slope versus sediment bypassing down canyons to lower-slope and trench depo-centers.

The spatial distribution and orientations of topographic lineaments, V-shaped subduction scars, sediment ponds, arcuate collapse features, and lower-slope ridge segments, strongly suggest tectonic erosion of the continental margin during the course of lower plate subduction. However, the presence of two sets of ridges in basins in the lower slope sector west of Sissano implies a complex history, including phases of tectonic accretion of material off-scraped at the toe of the inner trench wall.

The high incidence of tsunami on this convergent margin **(6 since 1888:** Ripper et al., 1998), the copious sediment supply generated by major seismic events such as the 1935 Torricelli Mountains earthquake (Stanley et al., 1935), and the geomorphic and sedimentologic complexity of the trench and inner trench wall, when combined with the known trajectory and rate of plate convergence, provide an opportunity for reconstructing the long-term history of seismic and tsunami impacts. The data required for this reconstruction are recorded off-shore in submarine sedimentary sequences and geological structures. This record can be accessed by an intensive program of sediment coring, and high-resolution sub-bottom profiling using a variety of techniques.

1: Acknowledgements

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Assessing the potential of AIRSAR for studies of paleoseismology and seismic hazard assessment in Papua New Guinea.

Keith A W Crook

Papua New Guinea is a country of high seismicity, high relief, and high rainfall. Consequently, landslides are both widespread and recurrent, with concomitant stripping of steep slopes and obstruction or rapid aggradation of river channels and alluvial fan surfaces. This is particularly evident in the Finisterre Range and Ramu-Markham Valley, on the NE PNG mainland. The October 1993 - January 1994 Finisterre earthquakes, with epicenters in Madang Province, north of the Ramu River, and the non-seismogenic 1988 Kaiapit rock avalanche in Morobe Province east of the upper Markham Valley, exemplify these surficial processes.

The extent and effects of these landslides were studied by Greenbaum et al. (1995), using Landsat imagery that shows the denudation and aggradation resulting from these earthquakes (33 ³ magnitude 5, and 2 ³ magnitude 7). During the subsequent interval of seismic quiescence, revegetation has commenced on the affected slopes and stream channels on alluvial fans have stabilised.

The methodology proposed for this study envisions using the progressive changes over time in various remotely sensed parameters, derived from areas denuded by landslides or aggraded by catastrophic discharge events, to establish criteria for determining the age of the denudational and aggradational events. Changes in measured parameters are expected to be rapid during the decade following such events, with annual change increments decreasing progressively with time.

To obtain data that will constrain changes occurring over several decades, another area, located in the Torricelli Mountains of West Sepik Province, will be studied using Word War II and post-war airphotos, and Landsat imagery, preferably supplemented by future AIRSAR data. This area, which in rainfall and topography is similar to the NE PNG area (Ward & Lea, 1970), was affected by severe seismicity (probably many events magnitude ³ 5, and a few of magnitude ³ 7) in September-October 1935, producing effects similar to those arising from the Finisterre earthquakes (Stanley et al., 1935). Consequently, provided that older remotely sensed data from this area can be integrated satisfactorily with the more recent NE PNG data, the time series will be increased from 10 to 65 years duration.

The rationale for conducting this study arises from two circumstances, one general and the other particular. In general, records of natural processes occurring in PNG are of short duration, particularly in mountainous areas, and details are anecdotal (e.g. Stanley et al., 1935). Consequently, hazard assessments for particular areas adjoining mountainous regions, such as Lae, PNG's second city, are incompletely constrained.

No magnitude 7 earthquakes have occurred within 50 km of Lae since 1900, and the current estimate of the return period in Lae for a ground acceleration of 0.5 g (about intensity 9) is 230 years (Ripper and Anton, 1995). Geological investigations in Lae (Crook, 1989a, b; Crook & Liu, 1998) provide evidence for episodic co-seismic uplift events in the Lae urban area, with vertical displacements of up to 5 m, but dating of these events is not adequately constrained.

Recent GPS estimations of plate motions in NE PNG (Tregoning et al., 1998,Stevens et al., 1998) show that the South Bismarck and Australian plates are converging, the convergence rate at the longitude of Lae being 50 mm/yr (Tregoning et al., 1998). However, Lae, which lies geologically on the South Bismarck plate, presently has the same motion as the Australian plate (Tregoning et al., 1998, Fig. 7), implying that the plate boundary is "locked' in the vicinity of Lae.

This plate boundary was also locked in the Ramu-Markham Valley between 1974 and 1993, where the 1993 co-seismic plate convergence was up to 20 cm. However, the interseismic shortening rate of ca. 4 mm/yr is much less that the plate convergence rate of 35 mm/yr calculated for this area (Stevens et al., 1998).

Lae has the only container port facility in northern PNG, servicing imports and exports for some 60% of PNG's population. This facility, and many of the buildings in Lae - which have been built to aseismic Australian building code standards - are likely to be at risk in the event of a magnitude ³ 7 earthquake occurring within 50 km of Lae. Thus there are strong societal reasons for seeking new ways to constrain the timing of significant seismic events in the vicinity of Lae, and thereby more closely constrain seismic hazard assessment calculations.

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A review of slope-stability issues in an expanding Suva, Fiji, and the planning implications of the Global Climate Change Process

Ifereimi Dau

Suva, the Fiji Islands' capital city, is rapidly developing into a major cosmopolitan area. With this development there come people and with people comes housing. Housing for Suva's huge workforce is spread over a very wide area. New residential subdivisions are being built in areas that were previously hilly scrubland or lush wetlands. With sophistication in engineering design these areas, previously inaccessible, have been reclaimed for use as housing subdivisions.

In the Fiji Islands, slope instability has always been associated with rainfall. For the areas of southeast Viti Levu, previous studies have identified the relationship between rainfall and landslides. A threshold had been identified above which landslides have occurred in the past. Further studies are now needed to refine this threshold and tie it in to other physical parameters that also influence slope instability.

The lack of a proper building code has had a major impact on slope instability in urban areas. Inadequate or non-existing storm-water or runoff drainage and/or the lack of proper maintenance of such drains are the two major factors that contribute to the slope-instability problems in and around Suva. These two factors occur right across the board from individual house owners, who normally would not be aware of such slope-stability issues, to Government or Statutory Bodies responsible for housing design and construction, who normally should be aware of such issues. The lack of a standard building code has enabled these developments to pass the building inspectors' tests as the lack of uniformity in auditing such structures ensures that shortcomings are not detected until later, often when a slope movement has occurred.

Rainfall in Pacific Island countries is influenced to a large extent by the ENSO events. Global climate change seems to be having an effect on the frequency of El Niño events. This could cause an increase in the probability of more rainfall events and that leads to slope instability. The implications of this is that Fiji authorities will need to put in place planning strategies that will reduce the economic impact of such events in greater Suva's rapidly developing surburbs.

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Groundwater quality improvement through the use of infiltration galleries: a case study from the island of Lifuka, Kingdom of Tonga

Tony Falkland

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

Some islands experience moderate to high levels of salinity in their water supply as a result of local overpumping of groundwater, which occurs in the form of a thin 'freshwater lens' above seawater. An example occurs on the island of Lifuka in the Ha'apai group of the Kingdom of Tonga. Until recently, the public water-supply system for the township of Pangai-Hihifo on Lifuka, which is operated by the Tonga Water Board, relied solely on groundwater pumped from 10 wells. The wells, both dug and drilled, were each pumped at about 0.15 L/s using electrically operated pumps. Since construction of these wells and pump stations in the early 1990s, the water salinity has a risen to a level where the water is non-potable (moderately high salinity, electrical conductivity values of 5000 – 10 000 µS/cm). This rise in salinity has been caused by a combination of factors including siting of wells, design of the extraction system and the pumping rates at the wells. While the pumping rates are relatively small compared with many pumping installations, they are too high in the local area around the well, resulting in upconing of underlying brackish water.

In last year's STAR session a paper by Falkland & Palelei (1998) presented the background to the water-supply investigations, leading to the implementation of pilot project of alternative pumping strategies on Lifuka.

This paper describes the outcome of the pilot project and describes the design, installation and initial performance monitoring of water-supply infiltration galleries. The selection of this technology was based on successful use of it in other islands to either control or improve salinity which was kept at acceptable levels in freshwater lens situations. Examples of successful implementation in the Pacific Ocean are Tarawa in Kiribati, Aitutaki in the Cook Islands (and now Lifuka in Tonga). In the Indian Ocean, galleries have significantly improved the salinity of groundwater supply on Home Island in the Cocos (Keeling) Islands. The reason for the success of galleries is that freshwater is effectively skimmed off the top of freshwater lenses, thus avoiding the upconing of brackish water that can occur under wells.

In late 1998 and early 1999, two infiltration galleries, consisting of long lengths of slotted PVC pipes laid horizontally below the water table, were installed on Lifuka. These were sited in areas where the freshwater lens was known to exist under the village area and on playing fields so that the distance to sanitation facilities was maximised. At each gallery, slotted pipes have been laid below the water table and connected to two pumping wells. One well at each gallery is fitted with a solar pump for day-time pumping and the other is fitted with an electric pump, which is used for night-time pumping. Each gallery has a length of approximately 200 m. Pumping commenced in July 1999. The recommended maximum pumping rate, at least in the initial stages, is 45 000 litres per day, based on estimates of sustainable yield. The electric pump can be manually switched on for longer periods to supplement the solar pump output on cloudy days.

At the gallery pump stations, automatic monitoring systems have been installed to monitor pump flow, water level, water salinity and water temperature. Periodic manual measurements of water level and salinity supplement these data. These monitoring data showing the performance of both solar and electric pumps, including the reduction in salinity, will be presented Data showing the impact of similar pumping at existing wells will also be shown.

The application of this type of groundwater development technology on a wider scale to Lifuka and to other small islands in the Pacific will be discussed.
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Petrology of the Fagaloa formation, northeast Upolu Island, Western Samoa

Aleni Fepulea'i, Ian Smith and Brent Alloway

There are four main islands in Samoa, Savaii, Upolu, Tutuila and Manua, which together with a number of islets, atolls and submerged reef banks and seamounts form a linear feature which rises steeply from the Pacific Ocean floor. The island chain has a total length of about 1000 kilometers from Rose Atoll in the east to Wallis Island on the west and varies between 130 and 220 kilometers in width. The Samoa Islands consist of a western group referred to as Western Samoa and an eastern group called Tutuila and Manua, which is also known as American Samoa.

Bathymetrically the Samoa islands are located at the end of the 7000 – 9000-meters-deep Kermadec-Tonga trench. The Samoa Islands are aligned along a trend of 288°, nearly parallel to the 283° trend of the adjacent Tonga Trench and to the vector of relative plate motion of the Pacific Plate with respect to a fixed Australia Plate.

Kear and Wood (1959) used geomorphologic criteria such as erosion, extent of soil profile and relation to offshore reefs to define the relative ages of lava formation on both Upolu and Savaii. The deeply eroded Fagaloa Formation, of Pliocene to middle Pleistocene age, is flanked and largely buried by late Pleistocene to Recent lava of the post-Fagaloa formation. In this study (1997) the Fagaloa Formation is subdivided into two units which are referred to as the upper Fagaloa and the lower Fagaloa. The K-Ar dates from a previous study in the area also support this subdivision (lower Fagaloa: 2.8 Ma and upper Fagaloa: 1.5 Ma). The upper Fagaloa lavas are olivine tholeiites and those of the lower Fagaloa are alkali olivine basalts.

Olivine is the most common mineral phase in the Fagaloa lava and it is typically strongly forsteritic, Fo_{90}. Pyroxene is strongly calcic and magnesian. Feldspar shows a wide range of compositions (anorthite to sanidine). Like the Fagaloa Formation, post-Fagaloa lavas contain strongly forsteristic olivine; pyroxene compositions overlap those of the Fagaloa Formation and plagioclase ranges between bytownite and andesine.

Linear trends in major- and trace-element abundance indicate increasing incompatible-element concentration with increasing degrees of silica undersaturation. Inflexion in such linear trends possibly shows either the entry of a new phase during crystal fractionation or loss of a phase during partial melting. The most differentiated lavas of the upper Fagaloa require 20% crystal fractionation or loss of a phase during fractionation of a parental composition.

The progression of volcanic activity in the Samoa chain is long thought to be from east to west, that is opposite to the trend first observed for the Hawaii Island hot spot (Dana, 1849). Savaii was noted earlier in this century for being the largest single outpouring of basalt on any island in the Pacific outside Hawaii. An underwater eruption in 1866 (Friedlander, 1910) to the northwest of Manua group at the eastern end of the chain raised the confusing prospect of a Pacific island chain active at both ends.

Upolu and Savaii are much the largest and most mountainous islands of the Samoan Archipelago. The volcanic cones of Upolu are distributed along the crest of the island and Savaii is in the form of chain over a broad convex plain. The island of Savaii represents the uppermost part, presently exposed above sea level, of Savaii Volcano, a huge pile of volcanic rocks built upon the surrounding deep sea floor from a depth of 4000 m below present sea level. The island presently rises to a height of 1858 meters at Mountain Silisili, making the total height of the volcano nearly 6000 meters.

From the latest studies (1997), lavas generated on Savaii and Upolu represent a continuum of the same magmatic process which created the earliest volcanism in the island. Geochemical data obtained by previous workers also corroborate the forgoing approach. No conspicuous geochemical difference is observed betweem lavas of Upolu and of Savaii with age, which leads us to infer that the whole suite of lavas in western Samoa, both Fagaloa and post-Fagaloa, are petrogenetically related.

The volcanism on northern Upolu can be interpreted as a 3-phase process. Because of its alkaline nature, the lower Fagaloa is inferred to have a deeper origin with respect to its olivine tholeiitic counterpart termed upper Fagaloa Formation. Post-Fagaloa lavas plot in the alkali olivine basalt and olivine tholeiite basalt field suggesting deep and high-level sources respectively for these suites.

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Recent Sedimentation in the Kadavu Passage, Fiji

Marie A. Ferland, Piers Larcombe and Katsuhiko Kubota

Surface sediment samples were collected along two north-south transects (*c.* 50 km long) crossing the 2100-m-deep Kadavu Passage, an elongate basin in Fiji located between the relatively large island of Viti Levu (10 388 km^2) and the smaller island of Kadavu (411 km^2). Fifteen samples were obtained between Suva and the eastern end of Kadavu (1997), and ten samples were collected between the western ends of the Beqa barrier-reef system and Kadavu (1998); both transects include slope and central-basin samples. The objectives of the study are to characterize the recent sediment that is filling this basin, and to identify the microfossils.

Methods include grain-size analyses (pipette analysis and Malvern laser particle sizer), determination of % carbonate in various grain-size fractions, XRD of the mud fraction, and examination of the biogenic material (predominantly foraminifers). In addition, subsamples from short push-cores (10-25 cm long, obtained from a large Van Veen grab) have been analysed to identify temporal changes in composition. Several samples are also being dated by AMS to estimate rates of sediment accumulation in the basin.

All samples are classified as calcareous hemipelagic mud; the terrigenous content varies from 2 to 70%. The proportion and grain size of the relatively minor sand fraction varies depending on location, and gravel-sized material is rare and mostly biogenic. The Suva transect is located to the south of Fiji's largest river, the Rewa. Mean grain size decreases downslope from *c.* 0.075 mm, to 0.035 mm in the central basin, which is 90-95% mud and may reflect direct input from the Rewa. However, some slightly coarser terrigenous sediment in the basin (mean = 0.056 mm) indicates that downslope transport occurs at times. Most of the recent basin sediment is terrigenous (65%), in contrast to the two slopes which are more carbonate-rich, with material contributed both by the reefs and planktonic organisms. The proportion of carbonate on the Suva-slope decreases downslope from 85 to 35% of the total sample, while the Solo/Kadavu slope (much further from terrigenous sources) contains 82-98% carbonate. The relatively minor sand fraction is composed mostly of pteropods and foraminifers, while the very fine sand fraction contains more terrigenous material.

The Beqa-to-Kadavu transect is also dominated by mud (85-90%); the remainder of the sediment is very-fine mixed carbonate and terrigenous sand, with traces of biogenic gravel (<1%). The central-basin samples contain substantially more terrigenous material (56-70%) than the adjacent slopes (28-52%); the composition of the carbonate in the slope samples is a mix of reef detritus and planktonic micro-organisms. Surface samples from the central-basin grabs contain more terrigenous material (70%) than the sediment 15 cm lower down, at the base of the same grabs (56-64% terrigenous). This suggests that either the supply of terrigenous sediment has increased (due to human activity, or changed climatic conditions?), or, that the basin has received less carbonate material. A further possibility is that the slope is affected by downslope processes. At present, the relative contributions of primary and secondary sedimentation processes on the slope are unclear (i.e., settling *vs.* sediment gravity flows). Final interpretation will incorporate AMS dates, from which we will estimate accumulation rates and the timing of compositional changes.

Preliminary attempts to group samples by their grain size using an ENTROPY program produced 3 groups which roughly define (1) the upper-mid slopes and coarser basin samples (i.e., those thought to be influenced by downslope transport), (2) the lower slopes and central basin, and (3) miscellaneous sandy mud samples that are geographically widespread. It was hoped that ENTROPY might allow us to separate the samples into groups based on different sources of sediment to the basin, and/or common groups of sedimentary processes, however this may not be possible due to the dominance of mud in all samples, and hence, generally similar grain sizes. XRD analysis of the mud fraction is ongoing; preliminary results show a

lack of diagnostic minerals in significant abundances to conclusively identify sediment source(s) for the basin. This may be due in part to the similarity of bedrock in the various major river catchments. While the main source of terrigenous sediment is probably the Rewa River, and to a much lesser extent the Navua River, pumice and micaceous sediment indicate that the Kadavu volcanics also contribute. Pteropods are abundant in the slope carbonate fraction, while their absence in the central-basin samples suggests that the aragonite compensation depth may be above 2000 m. Planktonic foraminifers dominate the carbonate fraction of the central basin, however there is also a substantial contribution from agglutinated and other benthic species.

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A spatial information infrastructure for Pacific Island Disaster Managers

Ken Granger & Graham Shorten

There is nothing more certain in the disaster management business than the fact that once a disaster starts to unfold, it is too late to start looking for the information needed to manage it.

An investigation into the information needs of disaster managers in Pacific Island Countries (PICs), and the nature of the information infrastructure needed to ensure the delivery of that information, was conducted by AGSO during 1998-99. The report of that study addresses two key aspects. First, it provides a guide to follow by those engaged in disaster management and research in building their own project, national or regional disaster information collections. It is specifically targeted at the National Disaster Management Officers (NDMO), regional agencies such as the South Pacific Applied Geoscience Commission (SOPAC) and aid donors. Second, it makes some observations on a range of technical and organisational issues, such as data formats, transfer standards and custodianship arrangements, that need to be considered in establishing and operating any modern information infrastructure.

The research undertaken clearly demonstrated that PIC disaster managers recognise and appreciate the need to have appropriate information available to them at all stages of the disaster management process. It was not possible, however, to investigate the reality of information use during an actual disaster situation. None-the-less, a culture of using information certainly exists.

It is also clear that disaster managers throughout the PICs possess a broad range of skills and experience in managing and applying information for decision making in disaster situations. Clear also is the fact that there is a nucleus of technical and professional staff throughout the PICs that have skills, training and experience in the use of geographic information systems (GIS) and the manipulation of spatial information – a major component of disaster management information. The level of collaboration and interaction between these two groups, however, is less certain.

As part of the research, PIC disaster managers were asked to complete a survey that asked them to rate a comprehensive range of topics according to their perceived need for information on those topics. Given the narrow focus of that survey, it is not surprising that the topics identified reflected a strong bias towards disaster response needs, and closely parallel the needs identified in similar surveys of response-oriented emergency workers in Australia. It needs to be recognised, however, that ‘disaster management’ covers a much broader field than those whose primary responsibility is to manage the response phase. The scientists who develop an understanding of the hazard phenomena and operate monitoring and warning systems, for example, require a broad range of information, as do those responsible for designing and implementing mitigation activities and for planning and managing the recovery process. Disaster management, after all, is part of the total community governance process and its information needs fit within the broad needs of that process.

An impression was gained that disaster managers have an expectation that much of the information they need will be provided by other agencies should or when the disaster managers need it. Experience suggests that this is a very hazardous approach to disaster management, unless those agencies who are expected to hold and manage that information see themselves as part of the disaster management process, and are aware of the requirements of disaster managers for their information.

A key first step in establishing an information infrastructure, therefore, is the creation of a clearinghouse mechanism, including an information inventory through which disaster managers can find and arrange access to the information they need to make decisions. There is evidence, for example, that in some PICs,

such as PNG, Vanuatu and Cook Islands, government agencies and/or universities of the former colonial administering nations such as Australia, New Zealand and the United Kingdom, have more complete and detailed inventories (and collections) of information than now exist in the country itself. This is clearly an area that needs much work, however most PIC have access to the technology that can make such a mechanism accessible across the country and across the region.

The creation of an effective information clearinghouse to support disaster management throughout the PICs will inevitably mean the development of technical standards and institutional arrangements. Both of these factors lie well outside the realm of disaster managers. Disaster managers, however, will need to play a role in the development of both, because it is simply not possible to reduce the impact of disasters without appropriate information. That may require using outside experts to influence the process, as suggested by one of the NDMOs, or using the experience of a significant disaster event to convince the 'powers that be' that the outcome would have been more favourable if the country (region, district, etc.) had an appropriate information infrastructure in place. There is also a major role for agencies such as SOPAC and the regional universities to assist in the more technical areas of developing, negotiating and introducing standards – as they already do.

The experience of local governments and small regional groupings of spatial data users in Australia could serve as a useful guide for PICs, SOPAC and aid donors to look at if it is decided that a formally structured information infrastructure is to be developed. That experience may be more appropriate than the higher level experience at state and national level in Australia, New Zealand or the USA, where issues such as metadata standards and clearinghouse directories tend to be rather formalised and heavily dependent on technology and a relatively large and skilled work force.

It is a relatively simple task to describe and define the components of an information infrastructure that would be suitable to support disaster management in PICs. Implementing such a process, however, will not be so simple. It will take time and it will take commitment on the part of all those involved, because there are at least four sources of frustration that will need to be addressed before it can become a reality.

A recurring view was expressed by NDMOs that they had 'heard it all before' at various conferences and workshops, but nothing <u>practical</u> had ever eventuated. They are looking for a worked-through example that they can follow and the resources to do it. That can not be achieved in a workshop; it can only be achieved on the ground in a real-world situation.

The lack of communication reaching both down to, and up from, the village level was also seen as a major source of frustration, and consequently a major hurdle. For a process that is all about information and improving the effectiveness with which it may be disseminated and used, the <u>sharing</u> of information about the process is critical – and that depends on communication.

The third frustration revolves around a stated lack of coordination and cooperation between the people and agencies that should be working together to improve community safety. This was seen as part of the power and political processes that tend to build barriers, rather than bridges.

The fourth key frustration relates to the perceived lack of resources – human, financial and technical. This is probably a universal frustration for all disaster managers. Typically, they are allocated only limited resources because senior policy makers seem to hold the view that a disaster is unlikely to happen during their term in office, so why spend too much money on a disaster management system that does not bring significant votes with it. This may be a simplistic and cynical view, but it seems to correlate well with reality.

These are not technical issues, they are <u>human</u> issues - an information infrastructure is not a physical thing, it is more of an accepted way of doing things. An information infrastructure is a philosophy, not a technology.

Fortunately, frustrations can be overcome, even those as seemingly intractable as the four identified here. There are significant components of an information infrastructure already in place in most PICs, and a number of real-world case studies are either under way or planned that can demonstrate and promote the value of the support an information infrastructure can provide to disaster management. These include programs such as the SOPAC *Pacific Cities* and *Communities at Risk* Projects and SPDRP initiatives such as the Community Vulnerability Analysis process.

These established foundations are very sound indeed, and provide an excellent base on which to build an appropriate and sustainable information infrastructure that can address issues from the village level to the level of the national capital and beyond. There are undoubtedly frustrations and problems that will need to

be addressed along the way, however it is clear that NDMOs are committed to embarking on this journey. It is also clear that they will make a good job of it because they are committed to the task.

The way ahead

The report provides a 'road map' for NDMOs and others to follow in building and managing the information resources they need to manage disasters. Having a map, however, is of little value unless one is both prepared to start the journey and committed to completing it. The commitment appears to be there in PICs, so how best to help NDMOs and others to start the journey?

The following simple pointers are provided as a guide:

- the best place to start is with the information that is already held by disaster managers. Develop an inventory of existing material as the first step so that it is easier to identify where the significant gaps are;
- sketch out an information management plan, as part of the disaster management plan;
- be prepared to take time - it is important to be practical in setting targets, because if they are too ambitious at the outset and subsequently fail, the whole process of developing the information management process could be seriously set back;
- establish priorities using the 80/20 rule - that says that 80% of the answers can be provided by 20% of the information;
- develop partnerships with key data custodians and research agencies and involve as wide a cross-section of stakeholders as possible in the process;
- whilst the ultimate objective may be to employ GIS and other computer decision support tools, it is not necessary to have such technology in place before starting to either use information or to build an information infrastructure. Hard-copy maps, manuals, reports and so on, will always be needed and used, regardless of how many computers are available;
- it is much easier to 'sell' the message of information and information infrastructures if their benefits can be demonstrated in a real-world case study. A worked-through example to demonstrate is far more believable than a 'dummy' or artificial example. It is also human nature to want what the neighbour has, so by being able to demonstrate what one village or town has done, and the advantages that they have gained, tends to stimulate other villages and towns to want the same advantages. Case studies are also very useful for disaster managers to share their experience and to exchange ideas that might be useful in other areas. The work completed by the *Pacific Cities Project* in establishing a broadly based information infrastructure for its case-study cities provides an excellent starting point;
- insist that disaster management research and aid programs involving outside experts contain a strong information management component that can easily be incorporated into national and local systems; and,
- don't be afraid to ask for help – you are not alone.

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Habitats, geohazards and the internet

H. Gary Greene, Norman Maher, Dallas Miggett, Edward Saade and Clive Moody

The recent worldwide explosion of the internet use, and the installation of oceanic fiber-optic telecommunications cables to support future demand for data transfer, has led to the collection of unique marine geophysical data sets in selected areas along the Pacific continental and island margins. The concerns of communication companies and regulatory agencies to install these cables along geologically stable routes and with little impact to the environment is producing data sets that are useful in assessing critical marine benthic habitats, establishing baseline data, and evaluating potential geohazards.

Several planned trans-Pacific cables have proposed landfalls in central California. To evaluate these routes that are located along the tectonically active California margin, extensive detailed geological and geophysical data collection has occurred. These data have not only been useful in the identification of geologically stable routes, but have played a major role in characterizing significant fisheries habitats as well as defining areas of potential geohazards.

The interests and concerns of SOPAC member countries in the sustainability of economically significant fisheries resources, understanding of local and regional geohazards, and participation in the new world economy should benefit from these types of studies. Future expansion of oceanic cable networks in the SOPAC region may not only bolster the economies of island nations and aid in facilitating their offshore businesses in data transfer abilities, but should provide data that are useful in environmental and natural hazards assessment.

We present studies based on the use of sidescan sonar and multibeam bathymetric images, high-resolution seismic-reflection profiles, ROV observations, seafloor sampling and other data that are applicable to the interests of SOPAC. Seafloor images and interpretations are presented in a form that is easily used by managers and policymakers.

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A mining mineral exploration and mining licence administration system for developing countries

David Greenbaum & J Stan Coates

The paper describes the results of a project recently completed under funding from the UK Department for International Development's (DFID) Knowledge & Research (KaR) programme, concerned with the development of a simple, affordable system for administering mineral exploration and mining licences for developing countries. It also outlines a new proposal being submitted to DFID which will seek, in collaboration with the regional organisations SOPAC and SADC, to implement the system regionally within the member countries represented by these bodies. A computerised mining cadastre is essential in a modern survey organisation. The overall purpose of such system is to promote efficient mineral exploration and mining licence management in order to encourage investment in the mining sector. It can: show active licence areas; check for overlap; interrogate lapsed licences; distinguish licences by minerals; and provide hard copy to specification on demand. The system is simple in concept and easy to operate. It is on around (1) a database and (2) a Geographic Information System (GIS). The main factors considered in choosing the software products are: ease of use; wide market acceptance; handling capability; industry-standard PC operable; value for money; and compatibility with existing systems and regional organisations. The systems selected in the initial study were Microsoft Access for the database and either MapInfo or ArcView for the GIS. Customisation of the system requires a detailed analysis of the national legal framework and careful design of the database. One of the largest tasks is capturing all the required data from existing paper maps and records. Once implemented, however, the system is relatively easy to use and maintain. The question of long-term sustainability will be addressed under the new project through ongoing technical support to be provided by the regional geoscience organisations.

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A scale relating tropical cyclone wind speed to potential damage for the tropical Pacific Ocean region: a *user's manual*

Charles 'Chip' Guard & Mark Lander

The authors spent six years adapting the Saffir-Simpson Hurricane Scale to the tropical western Pacific Ocean region. The Saffir-Simpson Hurricane Scale has been used for over two decades to relate hurricane wind speed to potential damage along the Gulf and East coasts of the United States of America. At the recommendation of Mr. Herbert Saffir, the new Scale has been coined the Saffir-Simpson Tropical Cyclone Scale. The authors have given the Scale the acronym STCS with the pronunciation "sticks". The Hurricane Scale was not for use outside the Atlantic basin and had several weaknesses when applied to the tropics. STCS is specifically tailored for the tropics. It considers the building materials and building practices common to tropical areas. Further, it considers infrastructure and vegetation, especially trees, common to the tropics. The Scale specifically addresses the weakening effects of termites, wood rot, salt water and salt air corrosion, and recurrent episodes of strong winds. It also considers the effects of sub-hurricane force winds, which can do considerable damage on less developed islands. Finally, STCS considers the effects of coral reefs on coastal wave action and coastal inundation. The Scale has two tropical storm wind categories and five typhoon (hurricane) wind categories. The *User's Manual* explains some aspects of tropical cyclone wind behavior and the behavior of waves and surf over coral reefs. There are many illustrations of damage to structures, infrastructure and trees. The new Scale has two basic purposes: (1) To help decision makers and the general public better associate a level of damage to warning wind speeds, and (2) To help assess

the maximum wind where wind-measuring equipment is not available or has been rendered inoperable. This Scale should apply to all tropical areas susceptible to tropical cyclone- or monsoon-generated winds.

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Remote Sensed Landsat Imagery: application to assessment of environmental resources, natural and anthropogenic impacts.

D. Heggie, Jonathan Root & Phil Bierwirth

The Urban & Coastal Impacts Project and the Information Management Branch of AGSO (Australian Geological Survey Organisation) are evaluating linkages between sediment facies, biogeochemical processes in sediments, the preservation of benthic habitats and maintenance of ecosystems. These interdisciplinary linkages comprise a concept of 'environmental health'.

Satellite imagery is a rapid, cost-effective means of providing spatial coverage of marine and coastal environments. These data are being used in Australian tropical, sub-tropical and temperate ecosystems to document a series of geomorphological indicators, such as maturity and facies identification for estuaries, coastal lakes or reef lagoons. These indicators will be used to develop a framework for understanding and differentiating between natural processes and anthropogenic impacts in the coastal zone. When integrated with knowledge of the biogeochemical processes occurring in estuarine sediments, e.g. the processes for efficient recycling and preservation of nutrients (nitrogen, phosphorus and carbon) in sediments, a differentiation between healthy and unhealthy coastal environments may be made.

Remotely sensed data can also be used to map distributions of benthic biota such as living coral, algae and coastal seagrasses over wide regions. Plumes of nutrients and sediments that may affect reefs and coastal environments can be detected. The use of multi-temporal images allows for (1) the separate identification of sea-floor and water-column materials and (2) identification of changes to the marine environment as a result of human activities, natural hazards or climate change. Examples are presented here of the remote sensing of reefs and coastal areas. Most of these examples employ the multispectral Landsat TM system and they demonstrate that important information can be extracted by the use of various processing algorithms. In particular, the spectral nature of the benthic substrates can be distorted by the changing optical effects of water depth. An algorithm has been developed at AGSO that determines the substrate hue independent of the effects of water depth. The results can be classified to produce an accurate map of, for example, reef habitats. Other algorithms are used to derive practical environmental information, e.g. suspended sediments, chlorophyll, and sea-surface temperature.

The use of high-volume datasets such as multi-temporal, multi-spectral satellite remote sensing requires a thorough information management strategy to ensure appropriate and simple access to research results for all potential users. AGSO has developed systems for the online delivery of satellite-data processing results, via interactive, web-based image processing systems. The development of robust algorithms in an on-line system allows environmental managers who don't have access to large processing systems, or to appropriate remote sensing expertise, to make good use of research results. An example is shown of a system developed at AGSO that can deliver images of specific areas that highlight specific themes. Other data can be provided with thematic images such as interpretations and localities, to provide an integrated information system for natural resource managers.

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Ostracode (Crustacea) populations as environmental tracers : examples from the Thio Estuary - New-Caledonia.

Hoibian T.

Ostracode populations of the Thio river (located on the east coast of the main island of New-Caledonia), have been recognised in thirteen samples collected along a transect from freshwater to coral-reef islet environments. Different assemblages have been identified, corresponding to the fluvial distributary, the tidal channels, the front estuary slope and the coral reef flat.

The high dynamic conditions of the fluvial channel lead to only four freshwater ostracode species, mainly *Erpetocypris Rom neocaledonica* MEHES, *Stenocypris Rom Darwinula Rom* being found in very few stations, associated with aquatic plants such as *Hydrilla* and *Juncus*.

The microfauna found in the tidal channel is not very abundant and less diversified (2 to 4 species), dominated by *Xestoleberis Rom granulosa* (BRADY) and *Mutilus Rom* associated with *Loxoconchella honoluliensis* BRADY which develop on sandy-mud bottoms with sparse sea-grass. These species indicate a phytal character of this assemblage of the brackish environments of the tidal channels.

Along the delta slope of the estuary, the microfauna is distributed in concentric zones of increasing density and diversity with the deepness and the weakening of dynamic conditions. This assemblage has 8 to 17 species. The dominating species are *Parakrithella pseudodentata* (HANAI), *Alocopocythere reticulata* HARTMANN and *Leptocythere keiji* (HARTMANN).

The low specific diversity met in the estuarine surroundings opposes the very highly diversified assemblage of the coral-reef islet where about thirty species have been met in the same sample. This assemblage is dominated by Bairdiinae as *Neonesidea longisetosa* BRADY and *N. schultzi* HARTMANN, *Paranesidea consobrina* TITTERTON & WHATLEY, *P. fracticorallica* MADDOCKS and *Triebelina sertata* TRIEBEL, associated with strictly phytal species such as *Microxestoleberis Rom*, *Paracytheroma mangrovicola* HARTMANN, *Paradoxostoma Rom*, or peri-phytal taxa mainly belonging to the Loxoconchinae such as *Loxonconcha dampierensis* HARTMANN, *L. heronislandensis* HARTMANN, *Loxoconcha Rom insulaecapricornensis* (HARTMANN) and *Loxocorniculum Rom.*

Discussion

Globally, the distribution of ostracode populations shows an increasing individual density and specific diversity from the inner environments toward the outer coral reef surroundings where this faunal indices are maximum. This evolution might be linked to the decrease toward offshore of the continental influence, mainly turbidity and lateritic sedimentation, which is generally unfavourable to the *biota* of the marine environments and the global development of seaweeds. Even if the species compositions of the ostracode microfaunas appear to be quite similar between the east and west coasts, some differences have been noticed and might signify slight variations of the environments. In comparison with the Néra delta (located on the west coast of New-Caledonia), the microfauna of the inner environment appears to be less abundant and less diversified. About thirty species have been met in the Thio estuary and more than forty five in the Néra delta, in similar environments. The genus *Clithrocytheridea* which was dominating in the euhaline assemblage of the Néra delta has been found here only in subordinate amounts. Some others species of the marine coastal assemblage such as *Venericythere darwini* BRADY and *Venericythere papuensis* BRADY which have been found in the Néra delta are absent in the surroundings of the Thio river. This indicates a less important incoming of the coastal-assemblage species in the tidal channel. This difference might be linked to the heavier rainfall of the east coast and to the lateritic sedimentation which develops in this region.

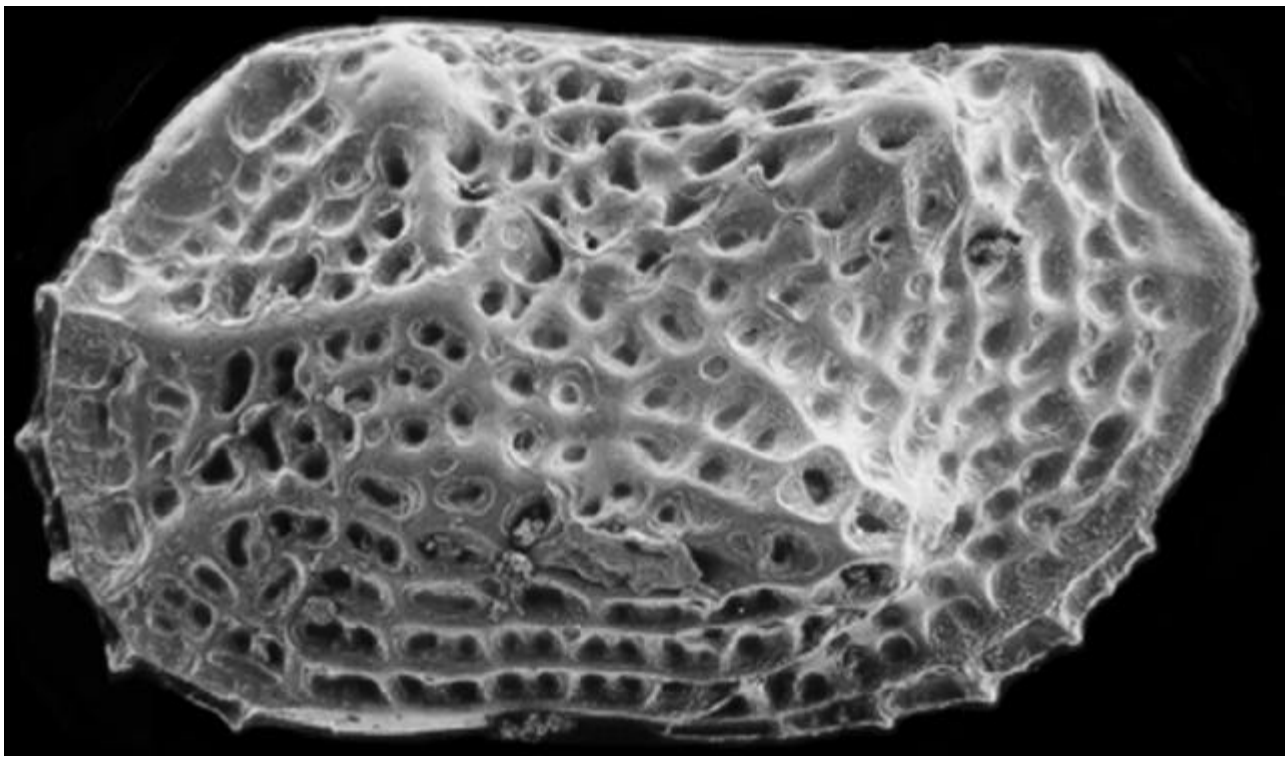

Figure 1. Loxoconcha cf. insulaecapricornensis HARTMANN.

FRENCH ABSTRACT
Les populations d'ostracodes de la riviére de Thio (situé sur la cote Est de la Grande Terre) ont été reconnus au travers d'une trentaine d'échantillons prélevés depuis les milieux fluviatiles, jusqu'aux abords des îlots coralliens du lagon.

Différentes associations ont ainsi été reconnues ; association d'eau douce, des chenaux de marée, marine littorale et récifale :

Les conditions de régime dynamique élevées présentes au niveau du chenal fluviatile font que les ostracodes d'eau douce dont *Herpetocypris cf. neocaledonica* MEHES, *Stenocypris sp.* n'ont été rencontrés qu'à de rares stations, associées à des herbiers de phanérogames aquatiques dont *Hydrilla verticillata* et *Juncus*.

Dans les chenaux de marée, une faune assez peu abondante et peu diversifiée (2 à 5 espèces) dominée par *Xestoleberis cf. granulosa* (BRADY) et *Mutilus sp.* se développe sur les substrats sablo-vaseux non latéritiques, indiquant un caractère phytal de cette association des milieux saumâtres.
Au niveau de l'embouchure, la microfaune s'étage en fonction de la bathymétrie et de la diminution des conditions dynamiques. Cette association des milieux prodeltaïques, plus abondante et plus diversifée (8 à 17 espèces) reste dominée par *Parakrithella pseudodentata* (HANAI), *Alocopocyhere reticulata* HARTMANN et *Leptocythere keiji* (HARTMANN).

La faible diversité spécifique rencontrée dans les milieux internes et littoraux s'oppose à celle des milieux récifaux où le nombre d'espèces rencontré s'élève à plus de 30. La microfaune caractéristique de ces milieux est dominée par les Bairdiinae ; *Neonosidea longisetosa*, BRADY et *N. Schultzi* HARTMANN, *Paranesidea consobrina,* TITTERTON ET WHATLEY *P. fracticorallica* MADDOCKS et *Triebelina sertata* TRIEBEL ainsi les formes phytales ou périphytales principalement *Loxonconcha dampierensis, L. heronislandensis, L. insulaecapricornensis, Microxestoleberis sp* , *paracytheroma mangrovicola, Paradoxostoma*, etc..

Discussion
La distribution de ces populations d'ostracodes montre une augmentation croissante de la densité et de la diversité des milieux les plus internes jusqu'au niveau des îlots coralliens où elle est maximale. Cette évolution pourrait être en relation avec l'augmentation globale de l'activité photosynthétique (développement d'herbiers et de phanérogames aquatiques) avec la diminutions des apports continentaux notamment la turbidité et la sédimentation latéritique assez peu favorable au développement de la biota.

PCGIAP and Pacific Island Nations

Bob Irwin

The Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) is a regional body established by the United Nations Regional Cartographic Conference for Asia and the Pacific. PCGIAP was formed in 1995 and membership comprises all 55 nations of the Asia and the Pacific region.

This paper explains PCGIAP's main areas of responsibility:

1. development of a regional spatial data infrastructure; and
2. support for member countries with their national spatial data infrastructures (NSDIs).

PCGIAP currently carries out its activities through three working groups: Geodesy; Fundamental Data; and Development Needs.

The geodesy group is establishing a regional geodetic network and regional horizontal and vertical datums on the International Terrestrial Reference Frame.

The fundamental data group is developing a policy for sharing data, defining the datasets, investigating the establishment of data nodes and carrying out research into spatial data infrastructures. The group works in collaboration with Japan's Global Map initiative.

PCGIAP is encouraging greater participation of the Pacific island nations in the above working group activities.

The Committee established a third group in 1998, the PCGIAP Development Needs Taskforce, with the aim of identifying relevant assistance in NSDI activities. The Taskforce is running workshops and gathering information from PCGIAP member countries from which appropriate development projects can be identified in support of these activities.

Australia's role on the Taskforce is primarily to work with Pacific island PCGIAP members in scoping development needs projects that would attract funding support. In March 1999 Pacific island representatives formed a PCGIAP Pacific Group to address their unique GIS and related needs, and it is proposed that SOPAC be the Pacific Group secretariat.

All 55 member nations of PCGIAP have an important role in contributing to the Asia and the Pacific regional model – the Asia-Pacific Spatial Data Infrastructure (APSDI). The involvement of member countries derives a dual benefit; individual NSDIs will be improved and the APSDI will be enhanced.

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Volcanic cone collapses in the southwest Pacific: results from the Ulawun Decade Volcano Workshop, Papua New Guinea'

I. Itikarai, H. Patia, S. Nion & R.W. Johnson

Volcanoes such as Ulawun in West New Britain Province, Papua New Guinea, are unstable mountains. Large parts of them may collapse from time to time, forming giant rock slides that become dangerous avalanches. Destructive tsunamis may form where these volcanic avalanches enter the ocean. The general problem of collapsing volcanic cones, volcanic activity, tsunamis, and emergency management was discussed at an international IAVCEI Decade Volcano Workshop where Ulawun was taken as a 'case study'. The Workshop made 25 recommendations of local, national, and regional scope.

The Workshop proposed, for example, that identification and adequate monitoring of volcanoes capable of collapsing should be undertaken throughout the southwest Pacific region, and that their structure and underground magma systems should be studied fully. Furthermore, more research is required on the effects of the tsunamis that may result from cone collapses, although these can be predicted already to some extent from computer calculations. A project should be undertaken in West New Britain Province as a matter of urgency to map hazard zones, to identify communities, investment, and infrastructure that are at risk, and to make specific recommendations for risk mitigation. The proposal for a revision of the national Papua New

Guinea Disaster Management Plan was strongly supported. The Workshop also recognised that volcanically vulnerable areas throughout the southwest Pacific region require volcanic emergency-management plans.

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Tsunami Deposits from the July 17, 1998 Papua New Guinea Event

Bruce Jaffe, Guy Gelfenbaum, Michael Nongkas & Hugh Davies

The July 17, 1998 Papua New Guinea tsunami was devastating to coastal villages located near the shoreline. However, after uprooting trees and destroying homes, the retreating tsunami left another more subtle record of its power. The July 17th PNG tsunami left in its wake extensive sand deposits across the coastal plain. These deposits were easily identifiable as sand overlying a dark soil. Even one year after the tsunami, deposits were found preserved and were, for the most part, unmodified. Information from these deposits can be valuable not only for determining characteristics (e.g. wave height, flow strength, number of waves) of the July 17 tsunami but also for improving models of tsunami sedimentation for use in interpreting paleotsunami deposits.

Tsunami sedimentation was discontinuous and not only reflected the flow during the tsunami, but also the grain size of the sediment source. Deposits were found at locations spanning more than 30 km of coast in the region where the tsunami was largest (Waipo to Sissano Village). Detailed transects at three of the locations found coarse to fine sand deposited by the tsunami in sheets that blanketed the underlying soil. Sand sheets ranged in thickness from 1 to 16 cm and extended up to 700 m inland. The sheets thinned with distance from the coast as the tsunami wave height decreased as energy was lost.

Future research on tsunami deposits in Papua New Guinea could help to answer questions about the July 17 tsunami and help to assess recurrence intervals for tsunamis in this region. First, a thorough search for deposits from the July 17 tsunami in areas where the International Tsunami Survey Team (ITST) did not have time to explore could provide information on the spatial distribution of the wave heights that would constrain models of the tsunami. This new information could help discern whether a landslide or earthquake (or both) generated the July 17 tsunami. Second, a systematic program of coring the coastal plain in this region could give information about the frequency and size of tsunamis that have made landfall in the past. This would be accomplished by identifying and dating paleotsunami deposits in cores. Tsunami deposits could hold the key to a better understanding of tsunami hazards in this region of Papua New Guinea.

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Rabaul-Tavui caldera complex, Papua New Guinea: new perspectives since the disastrous 1994 volcanic eruptions

R.W. Johnson on behalf of many staff from the Rabaul Volcanological Observatory (PNG), Australian Geological Survey Organisation (AGSO), Australian National University Research School of Earth Sciences (ANU-RSES), University of Hokkaido (Japan), and University of Wisconsin (USA)

The destructive 1994 eruptions at Rabaul caldera have resulted in further investigation of the magma systems that underlie the populated northeastern tip of New Britain island. These investigations have been funded largely by the Australian Agency for International Development (AusAID) as part of the Papua New Guinea – Australia Volcanological Service Support Project. The investigations have been designed specifically to enhance disaster-management concepts in this high-risk volcanic area, and to provide the Rabaul Volcanological Observatory (RVO) with additional tools so that it can continue its important role as Papua New Guinea's national agency for volcano monitoring and volcanic-hazard management.

New volcanological insights at Rabaul have been provided, mainly through interpretation of data collected during a major, international, seismic tomographic survey, conducted from September 1997 to January 1998 and using both land recording stations and ocean-bottom seismometers. Indispensable support and encouragement was received from village communities and others throughout the Rabaul area. The survey is called RELACS (Rabaul Earthquake Location and Caldera Structure). Its primary aims are to (1) provide RVO with a much improved crustal-velocity model in order to locate caldera earthquakes with a significantly greater degree of confidence, and (2) supply tomographic images of the deep interior of Rabaul volcano so that likely magma reservoirs can be identified and their significance explained by RVO to local communities. Additional insights have been provided from a re-examination of whole-rock geochemical data from Rabaul, especially from the 7000-year-old Raluan Pyroclastics (a rhyolitic ignimbrite overlying thick basaltic scoria)

and rocks dredged from the largely submarine Tavui caldera immediately to the northeast of Rabaul caldera. In addition, new Ar-Ar geochronological results from selected volcanic units at Rabaul volcano are helping to define more closely the timing of major plinian-ignimbrite eruptions in the area.

A picture has emerged of a highly complex, double-caldera structure made up of the immediately adjacent Rabaul and Tavui caldera systems and an intervening line of basalt-andesite stratovolcanoes - the Watom Island to Turanguna (South Daughter) zone. The Rabaul caldera system has been historically active (e.g. in 1878, 1937, and 1994-) and has received a good deal of attention in terms of monitoring and disaster management. Now, however, the submarine Tavui caldera system must be regarded as potentially active. Longer-term disaster-management strategies should also take into account possible disasters that may arise from events at Tavui caldera.

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Professional conduct during volcanic crises: recommendations from IAVCEI

R. (Wally) Johnson on behalf of the Sub-Committee on Crisis Protocols, International Association of Volcanology and Chemistry of the Earth's Interior

Stress during volcanic crises is high, and any friction between scientists can distract seriously from both humanitarian and scientific effort. Friction can arise, for example, if team members do not share all of their data, if differences in scientific interpretation erupt into public controversy, or if one scientist begins work on a prime research topic while a colleague with longer-standing investment is still busy with public safety work. Some problems arise within existing scientific teams; others are brought on by visiting scientists. Friction can also arise between volcanologists and public officials. Two general measures may avert or reduce friction:

(1) National volcanological surveys and other scientific groups that advise civil authorities in times of volcanic crisis should prepare, in advance of crises, a written plan that details crisis-team policies, procedures, leadership and other roles of team members, and other matters pertinent to crisis conduct. A copy of this plan should be given to all current and prospective team members.

(2) Each participant in a crisis team should examine his or her own actions and contribution to the crisis effort. A personal checklist is provided to aid this examination. Questions fall generally into two categories: Are my presence and actions for the public good? Are my words and actions collegial, i.e., courteous, respectful, and fair?

Numerous specific solutions to common crisis problems are also offered. Among these suggestions are:

(a) choose scientific team leaders primarily for their leadership skills;
(b) speak publicly with a single scientific voice, especially when forecasts, warnings, or scientific disagreements are involved;
(c) if you are a would-be visitor, inquire from the primary scientific team whether your help would be welcomed, and, in general, proceed only if the reply is genuinely positive; and
(d) in publications, personnel evaluations, and funding, reward rather than discourage teamwork.

Models are available from the fields of particle physics and human genetics, among others.

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Auckland volcanic risk project: gaining a better understanding of the implications of a volcanic eruption at the Auckland Volcanic Field

David Johnston, Douglas Paton, Janet Gough, David Dowrick, Michele Daly, Lesley Baddon, Tony Batistich, Ian Wood

In order to provide a basis for developing a framework for the comprehensive management of the wide range of risks associated with volcanic hazards, Auckland Regional Council has been working towards a better understanding of the Auckland Volcanic Field and the hazards posed by a potential eruption. The first phase involved developing five eruption scenarios to illustrate what might happen in Auckland should an eruption occur, and a qualitative assessment of the effects of these scenarios on selected infrastructure, population and the environment generally. The second phase involved a more quantitative GIS risk assessment,

including economic and social considerations of the eruption scenarios. The next phase will involve developing a model of volcanic-hazard effects that integrates physical, social and economic data for use in disaster reduction (mitigation) planning and response management within an Integrated Emergency Management system. The poster will present a summary of work completed to date.

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Mega-tsunami Controversy

Barbara H. Keating

Moore and Moore (1984 & 1988) suggested that gravel deposits on the southern slopes of Lanai, Hawaii, were left when a giant landslide occurred on the southern slopes of the Hawaiian Island chain, around 105 ka. The evidence for a mega-tsunami went unchallenged for several years but, as Hawaiian geologists examined the type section and surrounding deposits, many questions have been raised about the validity of the "Giant Wave" hypothesis. Scientists now question the basic tenets of the hypothesis including: the soil stripping to 365 m (soils 40 to 280 cm thick have been documented in the proposed inundation zone); age determinations (rather than a single age around 105 ka, three clusters of ages are found which roughly correspond with the last three highs of sea level); no corals were found in growth position in the type section (but in a gully with 100s of meters of the type section mollusks are found in assemblages consistent with water depths of roughly 70 m. and assemblages and positions which appear to be in-situ); corals in the gravels were thought to be part of a coral reef offshore (instead only individual specimens have been found indicating there was no established reef offshore); the mix of coral-rich and coral-free gravels was thought to represent catastrophic runup and rundown cyles (but the corals, shells and basalt boulders show a conspicuous lack of abrasion and breakage and occur as 13 beds rather than 6 as originally proposed); the highest occurrence of fossils was reported at 325 m elevation (but this outcrop cannot be found, instead veins of caliche are found within basalts at this elevation and the highest fossils observed occur at 190 m); the Hulopoe Gravel unit is described as a wedge-shaped unit on the slopes of the island (but the outcrops instead are discontinuous and largely occur as gully-fillings). A review of the geologic evidence indicates that major revisions to the "Giant Wave" hypothesis are now warranted. Detailed sedimentary records produced by modern and fossil tsunamis on ocean islands would be very valuable in establishing the nature of tsunami impacts on rocky shorelines.

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Coastal morphology mapping of the Southeastern area of Savai'i Island, Western Samoa

Seong-Pil Kim & Sung-Rock Lee

As technical assistance to the South Pacific Applied Geoscience Commission (SOPAC) work program, a twelve-day (July 30 –August 10, 1998) survey project was undertaken along the coastal area of Savai'i Island, Western Samoa. The objectives of the work program were to investigate the morphologic features along the shoreline and to establish fundamental data for coastal zone management. The main focus of the survey project was to check the ground features in the available aerial photographs of the study area and to describe any morphologic symptom coastal erosion. This presentation is a preliminary result to partially fulfill the previously mentioned objectives.

The surveyed area is geographically located between the Saleleloga and the Pu'apu'a villages in the Savai'i Island ($13^{o}34'$S – $13^{o}44'$S) and is the most populated on Savai'i (Ward and Ashcroft, 1998). In February 1990 and in December 1991 this area has experienced severe damage twice, by the cyclones Ofa and Val (Ward and Ashcroft, 1998; Elmqvist et al., 1998), which brought great concern of the Western Samoan government.

Taking accessibility on ground and time available into consideration, the area of interest was confined within backshore to low-tide level and behind the barrier reefs fringing the study area. A 1:100 000 geologic map, 1:20 000 topographic maps (New Zealand Geological Survey, 1958) and aerial photographs of 1:15 000 scale taken in 1990 by the New Zealand Mapping Agent were used. Any morphologic features that indicate coastal erosion were noted as well as man-made structures like sea walls, groins, swimming pools, wharves. Photographs, surface sediments and some rock specimens were also acquired at several locations for further laboratory studies. Along Faga beach (between Cape Tuasivi and Malae village), vertical profiles were measured though roughly to observe the differences of the beach slopes. When it was necessary, a portable global positioning system (GPS) receiver was used for geographic location. The survey results were

compiled into a morphology map, which was submitted to the SOPAC Technical Secretary (Kim and Lee, 1999).

Considering the distribution of morphologic features, the study area can broadly be divided into two zones; the rocky shore zone and the coastal beach zone.

The rocky shore zone is dominantly found in the southeastern area, which extends from the Saleleloga wharf to Cape Tuasivi in Si'ufaga village. The exposed rocks were noted as the Pleistocene Mulifanua volcanics (New Zealand Geological Survey, 1958). The zone extends seaward to gravelly sand/mud intertidal flats of the surrounding lagoon, which could be easily seen at low tide. The flats consist of greyey (white) calcareous mud and black basaltic sand. Near the high-tide level, scattered gravel and boulders of decimeter diameter were easily seen, which were presumably derived from the basement rocks as well as adjacent sea walls. Locally some pocket beaches, sea cliffs, some plantations of coconut and mangrove development were found. Construction of houses, wharves, groins, swimming pools and seawalls by the local people was active in this zone. Several fresh water springs were found in the Foua, Iva, Vaisa'ulu villages.

The coastal beach zone dominates the northeastern area from Cape Tuasivi to Pu'apua village. In this zone, white Holocene Tafagamanu sand beaches consisting of coral sand have developed along the coastline. The aerial photographs taken in 1990 show the whole backshore area across the beach road covered with this sand after cyclone Ofa. Notably lithified sand (beach rock) was exposed at low tide along all beaches. Toward Pu'apu'a village, in the north of the survey area, the size of sand beaches decreased smaller pocket beaches with increasing amounts of black sand of volcanic origin. Tidal creeks and sand spits at river mouths developed near the beaches, which indicate the local current direction. Inland springs, swamps and man-made seawalls were also noted at many locations.

During the survey some indications of erosion were recognized. Of the two zones, the northeastern coastal beach zone apparently showed more erosional features. They might have resulted from processes of either the short term (e.g. the Faga beach) or the long term (e.g. the submerged benchmark at the Cape Tuasivi). The former might have resulted from meteorological impacts such as storms, cyclones, changes of coastal plantation and man-made structures disturbing the local hydraulic conditions. The latter could be caused by sea-level transgressions, erosive patterns of the regional current system, decreasing sediment input and tectonic subsidence, etc.

Although more-detailed studies on the coastal processes of this area should be conducted, the authors recommend that greater efforts from the government-level (intervillage-level) should be considered to protect this populated area from coastal erosion. Constructing seawalls or wharves and reclaiming along the coastal area especially must be carefully pre-designed to assess their influences or advantages and disadvantages so to prevent more severe coastal erosion. At present the majority of activities concerning coastal management seem to be done by the local residents to meet their own private needs.

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New method to permanently reduce maintenance dredging need

R Kirby

I, and a few very expert European colleagues, have developed a "passive" method to overcome the long-standing conflict of interest offered by permanently open harbour basins in siltation-prone areas. The conflict is that in order to permit safe vessel movements the entrance must be wide, but in contrast this maximises sediment input opportunities across the entrance. This is a classical problem in hydraulics.

Water and sediment exchanges arise in the most complex situations (estuaries) due to three main mechanisms.

1. Horizontal mixing (or the "tea cup" effect) due to flow separation across the entrance. Flow separation itself induces a strong sediment-transfer gradient into the basin. The effect is often made worse by the setting up of a large stable primary eddy. Rotation in this eddy may lead to an entrance shoal. This mechanism is the only one present in rivers and may be the major one in the open sea (certainly at sites of low tidal range).

2. Tidal filling. At tidal sites water enters and leaves on every tide, bringing in turbid water on each occasion, which then settles in the relatively tranquil waters of the basin. This is an especially important input mechanism at sites of high tidal range.

3. Vertical densimetric input. In estuaries the salinity gradient will induce a strong inflow of turbid water near the bed, matched by an outflow of less-saline low-turbidity water at the surface. Large sediment inputs result.

European Union-funded Research
In the course of two research contracts funded by the EU we have proved that a device we have invented can reduce sediment input due to all three mechanisms (where all are present).

Our Device
We build a very carefully tailored curved wall or vane around the upstream corner of the basin, coupled with a number of other ancillary devices. We call this a Current Deflecting Wall and it is protected by patents. The purpose is to catch water approaching the basin, and use the flows so created to suppress the entrance wake as well as to kill the eddy. Several other important modifications to the entrance flow regime permit us to minimise water and sediment exchange. Self-evidently the device is simple in principle, has no moving parts, operates automatically all the time water is flowing past the entrance, uses no fossil fuels and will provided a benefit in perpetuity (so long as its integrity is maintained).

Practical Experience
We have 10 years practical experience with our prototype in the world's 10th largest port – Hamburg - and also a second device already part-built there, have other contracts to build these at the largest ports in Europe and have studies underway in the US. At Hamburg the long-term reduction in sediment input rate is 45%. There are two input mechanisms on the Elbe at Hamburg. At sites with three mechanisms there is likely to be a greater reduction. The cost benefit of these installations is high, especially where the mud is contaminated.

SOPAC/STAR
Our largest European ports have taken the risk of evaluating a very radical port maintenance concept, of being able to deepen their approaches and berths whilst actually decreasing maintenance dredging need.

The principle of preventing sediment ingress to basins in this way may be even more applicable to countries in the SOPAC region. Its adoption may, for example, render certain port development schemes economic, which would otherwise be non-viable on grounds of the high maintenance dredging need. By reducing sediment input rates, and by spreading the reduced sediment volume more evenly within a basin, maintenance dredging intervals can be greatly lengthened, again with important economic implications at isolated localities.

Our devices can be constructed using a high proportion of local materials.

The Challenge
There always has to be a snag! It is difficult to give even ballpark figures regarding costs of an installation. Cost is directly related to size of the device, which itself is controlled by water depth and size of basin. More appropriate is to ask SOPAC participants to estimate the cost of a full-water-depth wall and its foundations in their areas. A more pertinent issue is payback time; our first prototype device in Hamburg is 150 m in length and had a payback time of less than 1 year (but it is at the entrance of a large basin).

The snag? Our long experience is that our devices are very sensitive to precise location, and all our existing designs have been carried out using physical scale models, which are expensive.

Even the most sophisticated of mathematical models are insufficient, alone, to design a complete installation. They are, potentially, much cheaper than physical models.

Our challenge, then, is that natural and man-made basins come in all shapes and sizes, with the consequence that every new design must be specifically and delicately tailored to its precise location.

We are aware that our devices are equally well applicable to marinas and small ports as to these huge commercial ports, but it is the economics of design more than the economics of construction which constrain our ability to apply these devices more widely. Specifically, too, our device is environmentally friendly and especially applicable at sensitive locations.

Are there any larger basins in your region with big siltation problems suited to our existing methodologies? Alternatively, can you help our small business entity take the step towards the less-expensive small-basin design technologies? We have a few ideas on how design costs might be brought down.

Finally, a word of caution. Building a “bent wall” may look deceptively simple, and indeed the principle is, but there is an infinite variety of lengths, degrees of curvature, distance off the upstream corner and relation in plan to the other fixed structures, all of which, together with our ancillary devices, influence performance. From experience we have found that, when our less-experienced students have not been sufficiently closely supervised during model testing, an injudiciously placed device can exacerbate rather than alleviate a problem!

Furthermore, it costs just as much to build a non-optimised device as an optimised one!

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An advanced summary of survey results in Japan/SOPAC Joint Deep-Sea Mineral Resources Project and GIS

Yoshiyuki Kita & Maki Sekimoto

At the request of the SOPAC, Metal Mining Agency of Japan (MMAJ) has been conducting a basic exploration project in deep-sea areas in the exclusive economic zones of SOPAC member countries, using the Hakurei-Maru No.2. The project started in 1985 and has been carried out in three phases, each consisting of five years. The fifteen-year project has been carried out in eleven countries and areas since 1985. The purpose of the project is to obtain data on mineral resources such as manganese nodules, cobalt-rich crusts and hydrothermal deposits on the sea floor. Countries and target resources of the project are shown in Table 1.

Table 1. Countries and targets of the project

Phase	Year	Country	Target Resource
1	1985	Cook Islands	manganese nodules
	1986	Cook Islands	manganese nodules
	1987	Kiribati	Co-rich crusts
	1988	Tuvalu	manganese nodules
			Co-rich crusts
	1989	Kiribati	manganese nodules
			Co-rich crusts
2	1990	Cook Islands and Samoa	manganese nodules
			Co-rich crusts
	1991	Kiribati	manganese nodules
			Co-rich crusts
	1992	Papua New Guinea	hydrothermal deposits
	1993	Solomon Islands	hydrothermal deposits
	1994	Vanuatu	hydrothermal deposits
3	1995	Tonga	hydrothermal deposits
	1996	Marshall Islands	Co-rich crusts
	1997	FSM	Co-rich crusts
	1998	Marshall Islands and FSM	Co-rich crusts
	1999	Fiji (in progress)	hydrothermal deposits

Manganese nodules

The surveys for manganese nodules have been conducted in four countries, Cook Islands, Kiribati, Tuvalu and Samoa. Results are summarised in Table 2. The EEZs of Cook Islands are specially defined as promising areas.

Table 2. Survey results for manganese nodules

Country	year	richest grade			abundance
		Co(%)	Ni(%)	Cu(%)	(kg/m^2)
Cook Islands	1986,87,90	1.34	0.98	0.63	10.68
Kiribati	1987,89,91	0.23	0.96	0.96	1.54
Tuvalu	1988	0.2	0.54	0.47	2.74

Cobalt-rich crusts
The surveys for cobalt-rich crusts were conducted in five countries - Tuvalu, Kiribati, Samoa, Marshall Islands and Federate States of Micronesia. Results are summarized in Table 3. The surveys found thick crusts in the EEZs of Marshall Islands, FSM and Kiribati (Line Islands).

Table 3. Survey results for cobalt-rich crusts

Country	year	Thickness (mm)	richest grade	
			Co (%)	Ni (%)
Tuvalu	1988	? 65	0.94	0.29
Kiribati	1989	? 200	1.01	1.58
Samoa	1990	? 13	0.55	0.54
Marshall Islands	1998	? 140	1.55	0.85
Federate State of Micronesia	1998	? 150	0.94	0.45

Hydrothermal deposits
The surveys for hydrothermal deposits on the sea floor have been conducted in five countries - Papua New Guinea, Solomon Islands, Vanuatu, Tonga and Fiji. The surveys found some hydrothermal mineralization in Papua New Guinea, Solomon Islands and Fiji.

JAPAN will be going to a new stage of investigation in the promising sites selected from our survey results, from 2000.

While planning a new project, MMAJ started the compilation of our fifteen years of data with Geographic Information System (GIS). The system is designed to display several types of data such as analyses, acoustic data, etc. Analyses include several kinds of chemical analysis, X-ray diffraction analysis, isotopic dating, etc. Acoustic raw data consist of Multi-beam echo sounder, Narrow-beam echo sounder, Proton magnetometer, Narrow-beam sub-bottom profiler and Multi-frequency exploration system, etc. Microscopic observation data, foraminifera and radiolaria determinations and sea-floor photographs are also stored in the system.

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The New Zealand Approach to Integrated Hazard Assessment

Michael Kozuch, Steve Jensen , David Heron, Jim Cousins

Natural hazards are present in New Zealand on a daily basis. Learning to live with these hazards is essential to our survival. As our cities grow both in size and complexity, their vulnerability increases exponentially. Thus, a clear picture of how these assets are interconnected and interdependent is critical to planners and emergency managers. A core activity in Wellington's management of risk is the development of lifeline projects to prepare for and manage crisis situations that may or may not involve natural hazard events. To meets these needs the Wellington City Council embarked on a hi-tech approach to gear up for their planning requirements. GIS platforms are routinely used to manage their assets and databases. This knowledge base enables staff to plan and analyse, and provide services to the public.

Planning for crisis situations, however, requires additional steps that include cutting-edge scientific input. As part of their strategy the council have contracted GNS to assist in developing an all-hazards approach to risk management for the city. This collaborative project includes earthquake, landslide and tsunami data as well as fire-spread, ground-shaking, damage-ratio, inundation and liquefaction models. The output assessments consist of maps depicting relative distribution of economic and social effects casualties and damage, throughout the city. We are also creating links to direct the users to sources of information for mitigation. An

important aspect of mitigation is providing information/tools that are consistent with the materials and resources at hand.

During the next 6 months we will concentrate on creating a web-based platform for the GIS package. The internet platforms will be designed for a broader audience of users. With internet tools, users will be able to create their own scenario events and maps to rapidly assess the status of an event or design the future of the city for “what-if” events. GIS married with the internet provides the optimal combination to exploit the power of spatial data.

The biggest challenge facing any city or community is to generate accurate digital information. This is often the most tedious and time-consuming step. Once in an electronic form, however, this information can be manipulated or reformatted to meet the changes in the supporting technologies. As new technologies emerge, the backbone of our system will evolve to meet these changes.

To achieve a solid risk-management programme requires a delicate balance of resources, priority setting, and strategic thinking of game plans that carry the community into the future to meet its goals. An important ingredient in this process is to understand the distribution of risk due to natural hazards. Once these parameters are identified, organisations are well on their way to effective risk management and to building communities that are resilient to natural disasters.

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Post-middle Pleistocene evolution of the New Caledonian southwestern lagoon

Yves Lafoy, Robert Smith, Cinthia Labails, Simon Young, Fabien Juffroy,

Swath-bathymetry and seismic-reflection data of the New Caledonia-SOPAC ZoNeCo 7 cruise (11-25 June 1999, aboard R/V Dawa) enabled a detailed interpertation of the post-middle Pleistocene evolution history of the southwestern part of the New Caledonian lagoon located offshore Noumea, between the Dumbea and Boulari passes.

The study area is tectonically controlled by four main trends, as follows:- NW, the general trend of New Caledonia mainland, its western lagoon, and the Signal-Snark and Seche Croissant ridges that both occur between the Noumea peninsula and the reef barrier; N-S ridges are well expressed at the Dumbea and Boulari's northern arm passes; NE, at the Dumbea pass and the northern part of the Signal-Snark and Seche Croissant-Maitre NW trending ridges; an E-W ridge, upstream of the Dumbea pass. The Tenia borehole (Coudray, 1976) enables us to date the seismic unconformities: - seismic reflector 3 is correlated with the -42-m unconformity that characterises the Mindel-Riss inter-glacial uppermost period. The likely age of this unconformity is dated at middle Pleistocene, close to 550 000 years B.P. Reflector 2 is synchronous with the unconformity identified at -23 m. Unidentified by Dugas et al (1980) southeastward to our survey, this unconformity, dated slightly prior to 250 000 years, shows an environmental change from an open lagoon-type to dominate reefal deposits. Reflector 1, contemporary with the late Pleistocene-Holocene unconformity is identified at -11 m and -12 m at Tenia and Amedee boreholes, respectively. Characterised by a tabular morphology, reflector 1 is interpreted to be synchronous with an emersion phase responsible for a coral reef-flat building, 125 000 years ago, near MLWS (Mean low water spring). The synthetic structural map enables an interpretation of the post middle-Pleistocene evolution of the southwestern part of the lagoon located between the Dumbea and Boulari passes: - the Dumbea and the Boulari's northern arm passes are flanked by normal faults that limit paleo-channel migration and asymmetric sedimentary infilling across time. The passes are inherited features with a strong tectonic control. Characterised by a deep acoustic substratum, these passes change upstreamward to submarine paleo-canyons, likely of early Miocene age. They correspond to the immersed extension of the Dumbea and La Coulee river stream beds, to the north and to the south, respectively; from the middle Pleistocene to Recent, stream beds of the dowstream side of the Dumbea river, and the northern arm of the Boulari passs, have both migrated through time, southeastward and westward, respectively. These stream-bed migrations are responsible for the building of sedimentary levees that are associated with the paleo-channels. These post-Holocene sedimentary sequences are, according to the Tenia borehole, sand deposits. The deposits can reach, locally, thicknesses up to 20 m. In-situ samplings are necessary to determine the sedimentological and geotechnical characteristics of these sandy deposits.

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The adoption of tourist vessels for coral reef environmental monitoring

Joseph H.J. Leach and Cathy Flower

The environmental health of coral reefs is important for both economic and environmental reasons. Not only are they the sites of major tourist activity and incredible biodiversity, but they also represent an important commercial and traditional fishery. However, these important ecological sites are under threat from nutrient runoff, overuse and damage by tourist operators, and coral bleaching and increased storm damage due to climate change. In order to understand the extent of these problems, an extensive monitoring program is required. However, coral reefs tend to be concentrated in developing countries. This means that many of the countries that have extensive areas of coral reef do not have the resources for the necessary seagoing operations dedicated to monitoring the environmental health of these areas.

One solution is to use satellites. Coral reefs are ideal areas to do satellite seafloor mapping: the water is clear and the areas of interest are relatively shallow. Many studies using this technique have led to a greatly increased capacity to map reef areas and to monitor large-area problems such as nutrient oversupply and increased terrestrial turbidity. This study used a Landsat TM image of part of the Great Barrier Reef in Australia. Moore Reef was chosen as a test site and a depth-compensated, classified image was produced (Figure 1).

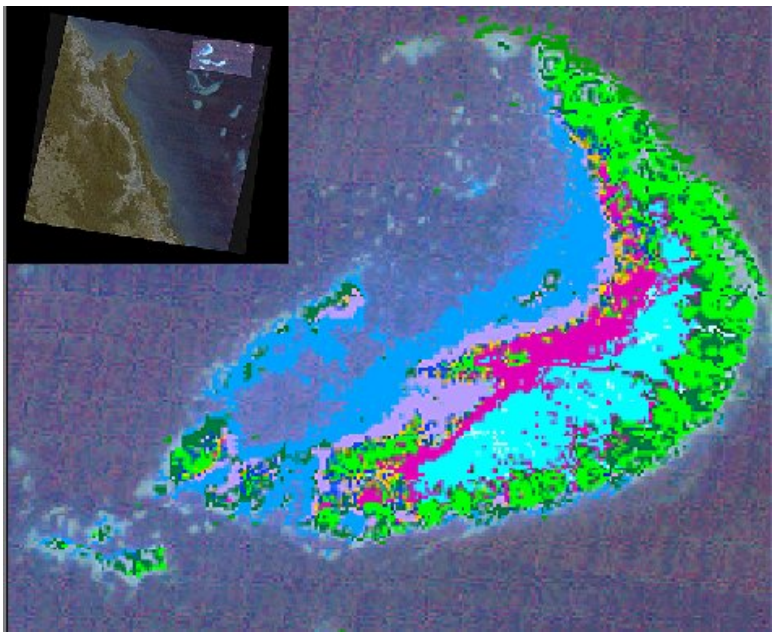

Figure One. Moore Reef. Locality map and classified Landsat TM Image.

However, these images still need to be "ground truthed" to be properly interpreted, and problems of scale mean that some the sever problems facing coral reefs, such as damage by tourists, storm damage, coral bleaching and overfishing, can often not be detected or monitored by satellite observation. The monitoring for all these problems would require imagery at centimetre or better resolution. Studies at this scale are normally carried out using diver quadrates or "manta board" traverses. This solution is slow and requires a heavy expenditure in personnel and boat time. Such studies are beyond the capacity of many smaller countries which, nonetheless, have large areas of reef at risk from tourism and fishing. There is a need for a cheap, rapid method of monitoring coral reefs at a scale fine enough to detect the beginnings of this type of degradation.

The approach used in this test study was to ground truth a satellite image using one of the glass-bottomed tourist vessels, which are commonly used to view reef areas. Since the vessel need not vary from its normal course in order to carry out video transects across heavy-use areas of coral reef, there are no additional boat-time costs, and the use of video will produce objective data without the need for highly trained field personnel. These video data can then be sent to a central location for analysis. The Moore Reef trial has shown that this approach can produce excellent results in a very cost-effective manner. The trial used a

shaded video camera and a portable DGPS unit. A time code was used to co-ordinate the video and DGPS information. This simple system produced imagery detailed enough to see small-scale damage to coral (see Figure Two). It could also distinguish individual organisms, which allowed an estimate of fish numbers and a survey of the distribution of sea cucumber, giant clam, etc.

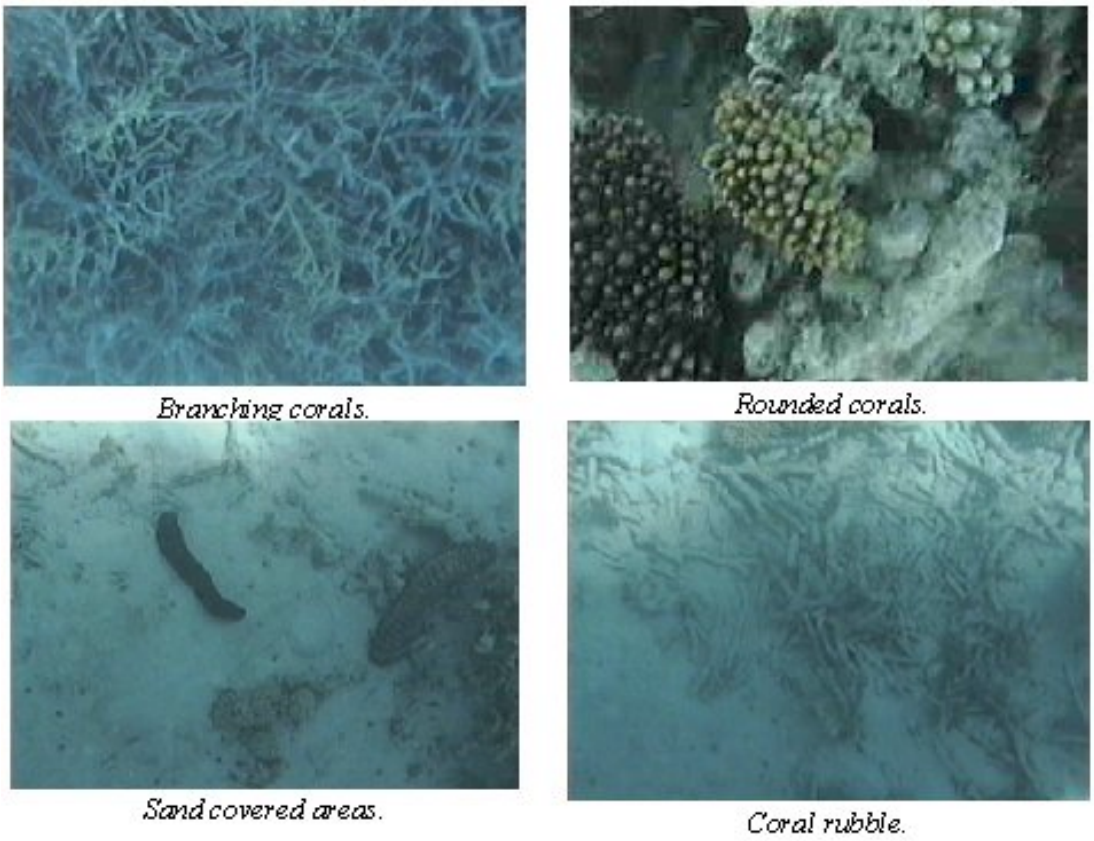

Figure Two. Images of various bottom classifications taken from the video transects over Moore Reef.

The advantages of this approach over conventional environmental survey are: it uses sea-going infrastructure that is already in place; it uses readily available equipment; and it concentrates monitoring on areas where there is strong environmental pressure from tourism. It can act as an early warning system for environmental degradation.

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Tectonics of Niue Trough and Tonga-Kermadec Trench : results of April 1999 research cruise

Peter Lonsdale

Some results are now available from our recent research cruise that used R/V MELVILLE to investigate the geology and geophysics of the Tonga-Kermadec Trench, though geochemical and radiometric analyses of igneous rocks sampled from oceanic crust entering the trench are not yet complete. Multibeam bathymetry and seismic profiling show that extensional faulting of the crust begins 50 km from the trench axis, and rapidly creates rift valleys more than 1 km deep. Active faults extend twice as far to the east between Samoa and Niue, where the oceanic plate buckles and fractures as it negotiates the bend at the northern end of the trench. Machias Scarp is a fresh break, oblique to pre-existing structural lineations, that deforms young strata of the Samoan sediment apron. Further south, the walls of a 40 km-wide rift valley that strikes northwest from Niue are also being rejuvenated and becoming seismically active where they approach within 100 km of the trench axis. The trough itself proves to be an old (Miocene) structure that probably formed when the cluster of large submerged volcanoes around Niue was emplaced, and most of it probably has a low potential for seismic hazard in the next few hundred thousand years.

The eventual fate of Niue, a million years hence, is displayed by Capricorn Guyot, a geologically similar feature that has been carried 250 km closer to the trench. It has just entered the zone of intense extensional faulting, and its 500 m-thick cap of subaerially eroded limestone has been tilted, submerged to depths of

400-1100 m, and dissected by fault scarps that have already grown up to 300 m high. In another 200 000 years the completely dismembered former island will collide with the rocky inner wall of the trench.

As a counterpoint to our study of the destruction of southwest Pacific islands, the preceding MELVILLE leg examined how such islands are born, with detailed survey and sampling of the active submerged volcano at the southeast end of the Samoan hotspot chain (40 km east of Tau). This seamount has a summit (on the rim of a caldera 2 km wide, 350 m deep) that is still 650 m below sealevel, but it should break the surface well before Niue disappears. Initially, it may bring new hazards of its own, including explosive eruptions and tsunamigenic rock slides.

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Risk assessment in coastal engineering and management in Pacific SIDS

Russell J. Maharaj

Large-scale weather phenomena and oceanographic processes continually affect Pacific Small Island Developing States (SIDS). These cause sediment removal, considerable modification of coastal morphology, alteration of shorelines and loss of valuable land. In addition, infrastructure and property damage, loss of lives and loss of investment result from extreme events. In SIDS where financial capital and natural resources may not be easily available, these impacts create genuine concerns and are of paramount importance for developing island economies. Human occupation of narrow coastal fringes on small atoll islands also makes coastal communities more vulnerable to coastal hazards, increasing the specific risks to these communities.

Risks to coastal communities in Pacific SIDS are directly related to natural coastal hazards and human development of coastal fringes. In almost all cases, coastal erosion and land loss is the main hazard responsible for property and infrastructure damage and loss of lives and investments. While these are related to natural phenomena, activities like mining of aggregate (sand, gravel and rock) on beaches, berms, sand banks, reef flats and reef crest areas exacerbate erosion hazards. In many cases, live coral is removed for aggregate supply, causing deterioration in reef communities, decrease in carbonate sediment production, imbalance in the sediment budget, loss of natural shoreline protection and increase in erosion of adjacent land areas.

Much carbonate material mined from reefs is used for engineering constructions. These include pavements, backfill, rubble structures, concrete, mortar, retaining walls, piles and houses. These aggregates are of low unit weight and density, are of low crushing/compressive strength, contain harmful chloride and sulphate ions and are of low abrasive values. These inherent properties render these materials generally of low quality, with an engineering design life much shorter than terrestrial crushed-rock aggregates. In particular, much of this material bonds poorly in concrete, is of low compressive strength, deteriorates in concrete-aggregate admixtures, and is porous and can easily crumble during large-magnitude seismic ground motion. Consequently, there are also construction risks associated with use of these building materials.

In the Federated States of Micronesia (FSM), there are alternatives to nearshore reef aggregate mining. Several of the larger islands are composed of more-competent volcanic, metasomatised and low-grade-regional metamorphic rock assemblages. These include Kosrae, Pohnpei, Chuuk and Yap islands. These islands' rocks are primarily erupted oceanic basalts and differentiated alkalic magma series. They are competent and durable. These rocks are good sources of superior-quality construction aggregate and can replace much of what is normally mined and dredged from coastal reef communities around many of these islands. Field and laboratory studies of rocks from Pohnpei have shown that large reserves of good-quality rock are available. On-land quarrying of this material can also reduce the need to dredge and mine reef environments and therefore, reduce environmental degradation of reef communities, reduce the wave energy entering the nearshore areas, and ultimately, reduce the erosion hazards to coastal communities. Quarried rock can also supply a much better-quality construction aggregate, with a design life and performance far superior to reef carbonates. As a viable source of construction materials, rock from on-land sources can be quarried, crushed to suitable dimensions and transported to many construction sites quickly and at relatively low cost. In addition, there is the potential to supply adjacent islands or nearby countries. Consequently, on-shore quarrying and extraction of aggregates can be a revenue earner, for both the state and national governments.

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Contamination risk assessment of *WWII* armoury/munitions in Iron Bottom Sound, Solomon Islands

Russell J. Maharaj

The Solomon Islands Government (SIG) requested of the South Pacific Applied Geoscience Commission (SOPAC) to conduct a contamination risk-assessment study of *World War II (WW II*) sunken vessels/ships and aircraft in Iron Bottom Sound, Solomon Islands. The study area is defined as the sea area which lies between lines of longitude, 159^0 43' E and 160^0 25'E along latitude of 80 58' S. The area is about 3500 km^2.

The purpose of the study was to collate existing information on the military vessels and aircraft which were destroyed and sunk in Iron Bottom Sound, and assess the possible risk of contamination to the coastal and marine environment in the area. This information will then be used to evaluate the possible environmental impacts of *WW II* military hardware and armour on the natural and human environment, and assist in the developing of optimum management strategies for utilisation of the said areas. Information was collected from published/public information, from maps, atlases, charts, aerial photographs, books and journals held in international libraries and national archives. The main tasks identified for this phase of the project:

- Compile as complete an inventory as possible, of the number of vessels, their location, type/s and probable cargo content, using data from as wide a variety of sources as possible.
- Develop a database, in computerised GIS, using *MapInfo* software, with overlays of vessel location, water depth, oceanographic conditions where available, such as currents and water quality.
- Identify, from preliminary assessment, areas of potential environmental risk.
- Define a follow-up work program, as deemed necessary, for further field investigations of selected areas to assist in developing sustainable planning and management strategies for the coastal and marine areas.

Results of a contamination risk-assessment study in Iron Bottom Sound have shown that 111 Japanese, American and New Zealand naval vessels were destroyed and sunk. These comprise 65 Japanese, 44 American, I Australian and 1 New Zealand vessel. Altogether, 1450 fighter planes (1120 Japanese and 330 American) were destroyed and 15 000-20 000 military personnel were killed in the Sound. Of 52 wrecks with known bathymetric locations, 10 are in water depth of less than 100 m, 8 in 100-500 m; 31 in 500-1000 m and 3 in water greater than 1000 m deep. Calculation of the volume/tonnage (T) of debris which litters the seabed of the Sound indicates a cumulative volume of 446 517 T of metal from the 111 sunken vessels. Of this, 321 822 T is from the Japanese, 115 795 T from the American, with the remaining wrecks from the Australian and New Zealand vessels. The tonnage of military aircraft is unknown.

Investigations show that the shallow-water wrecks are extremely corroded and are heavily colonised by benthic species, including corals, green, red and brown algae and other macro-benthic dwellers. For the deeper wrecks, corrosion does not appear to be as aggressive as for those wrecks in shallow water. This is largely due to less available oxygen in these deeper waters, in some cases down to 1000-1200 m. As a result, these deeper wrecks are more intact than their shallow-water counterparts. The specific cargo contents of the various military vessels which were part of the Guadalcanal Offence, are unknown. For the various armed forces which participated in the Guadalcanal campaign, several types of cargo were common. These include rifle ammunition, bombs, torpedoes, explosives, land and sea mines, naval artillery ammunition, engine and lubricating oils and diesel and other fuel. Much of these cargo contents of the sunken vessels and aircraft was destroyed before and during sinking. Since many aircraft were shot down and ships were bombed or torpedoed, many of these military arsenals were set on fire and partly burnt at sea, before coming to rest in their watery grave. Consequently, much fuel, oil and explosives was destroyed. However, some of this material is still present in many of the wrecks. Divers on many of the shallow wrecks report oil slicks and rifle ammunition on several of them while land-sea mine explosives have also been recovered and destroyed, on the same north coast of Guadalcanal.

The presence of military hardware, munitions and possible fuel and oil from the various vessels represents possible contamination risk to natural communities. Sources of risk and pollutants include the leakage of oils and fuel (DDPHs), and leaching of trace elements and heavy metals from paints, corroded aircraft, ships and munitions. These represent a real source of pollution to the natural environment. To determine if these petroleum hydrocarbons and metals are affecting the biophysical environment requires analysis of water and sediment chemistry, and possibly toxicological tests, depending on the level of petroleum hydrocarbons in the local environment. Since these types of data are not available, further comments cannot be made at this time.

Based on the physical characteristics and the location and possible distribution of *WW II* wrecks in Iron Bottom Sound, further and detailed assessment of environmental effects and contamination risk, especially

specific risk, should incorporate additional environmental variables. These variables will assist in further understanding of wreck distribution and the possible levels of contamination of the coastal and marine environment. Based on bathymetric distribution of some of the wrecks, and the relatively deep ocean in Iron Bottom sound, it is recommended that further studies be concentrated in the shallow nearshore/coastal areas. These areas are the zones of high biological productivity and concentration of marine biota, including reef species. It is also the area the most accessible by people on the surrounding islands and the areas in which human contact is the most frequent. Further studies should include,

- specific location of nearshore wrecks, especially within the 100 m bathymetric contour, for which positions are unknown;
- identification of the aereal distribution of nearshore wrecks by swath or sonar mapping;
- assessment of the nature of ecosystems in the above-mentioned nearshore areas; and
- assessment of the levels of contamination of nearshore water and sediments by various trace and heavy metals and petroleum hydrocarbons (both dissolved and dispersed petroleum hydrocarbons) which may be leaching from nearshore vessels into the surrounding water masses and sediment,

The assessment of water and sediment chemistry parameters should use control stations, from which background/normal concentration of the various chemical parameters can be assessed. This will facilitate a sound approach to environmental management of the nearshore and marine areas and facilitate a rational use of the nearshore resources of the area.

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Evaluation of aggregate potential in onshore Pohnpei, Federated States of Micronesia (FSM), for engineering applications

Russell J. Maharaj

ABSTRACT: Coral reef mining has for many years been the main source of construction aggregate for domestic and industrial purposes in Pohnpei, FSM. However, over the past decade, nearshore aggregate has been depleted, while extraction has resulted in the loss of aquatic marine species and loss of biological productivity and pollution of coastal waters. In addition, dredge sites have been continuously deepened, resulting in significant alteration of nearshore hydrodynamics and propagation of larger waves along shorelines. These have caused significant scouring and erosion of coastal land areas, threatening coastal infrastructure and increasing erosion risks to coastal communities.

To address the aggregate supply in the short and long term, and to curb some of the deleterious effects of mining in the coastal and reef environments, an onshore aggregate study was implemented. The purpose of this study is to:

- Examine the possibilities of mining on-land sites, on the main island in Pohnpei State;
- Assess the aggregate potential of onshore Pohnpei island to determine the suitability of the various lithologies as construction engineering material;
- Identify possible sites for quarrying; and
- Recommend a follow-up programme to further define possible end uses and engineering application of the various materials.

This information will then be used to assist in the development of on-land quarry sites for supply of construction aggregate in Pohnpei and FSM.

Information was collected from published information, field surveys, field geological description of lithologies and testing of selected samples of crushed rock specimens. Rock descriptions are based on standard IUGS nomenclature. Sample collection procedures, test methods and evaluation conform to guidelines of the American Society for Testing Materials (ASTM), and are also in accordance with international guidelines of the International Society for Rock Mechanics (ISRM). Over 40 kg of crushed rock samples (2.5 cm and 4.0 cm) was collected from exposed cliff faces at two quarry sites. Emphasis was placed on collection and examination of the more durable/competent lithologies, which are potentially more suitable for the construction industry. Most of these samples are olivine basalts (basanite series) from Sokehs District.

The basalts are aphyric, dark grey to grey black in freshly cut and crushed samples, and are composed mainly of olivine and augite in a feldspar groundmass. Most outcrop sites consist of columnar basalts, with side dimensions of 25-30 cm. In almost all fresh quarry sites and cut faces, there is very little sign of weathering, generally less than 5%. Crushed samples are very angular, with sharp edges, due to the largely fine texture. No mesoscale discontinuities are visible in mesoscale samples or larger quarried blocks. Some samples contain augite phenocrysts. Titanaugite is also found in many samples. Other minerals include phenocrysts of plagioclase, orthoclase, olivine, magnetite and apatite. Amygdules of plagioclase, anorthoclase, olivine and apatite are present. Due to the mineral assemblage, samples are heavy and of high specific gravity. Dry densities of rock samples measure between 3000 and 3200 kg/m^3. Wet density varies between 3100 and 3376 kg/m^3. Water absorption is 0.19-0.59%, averaging 0.415, while crushed rock samples have specific gravity of greater than 2.90, and can be up to 3.20. Blocks are generally of good integrity, with very few visually observed fractures (less than 5% of the blocks). Quarried blocks also contain very few impurities, less than 10% in fresh quarried faces. This suggests good block durability. Based on block integrity densities, and mineralogy, quarried blocks are more likely to be of high impact/dynamic and compressive strengths and high abrasion resistance.

Based on geological and geotechnical characteristics, on-land areas have excellent potential for quarrying and supply of aggregate of quality superior to coral material for the construction industry in Pohnpei. This includes supply for rip-rap, roads and pavements, concrete and cement works, rubble walls, breakwaters and other hard applications. In addition, overburden can be utilised as backfill for various applications. In addition, excellent cliff faces are available for quarrying, with good exposures of sound columnar basalts.

This project was funded by the *Commonwealth Secretariat* under *the Commonwealth Fund for Technical Co-operation (CFTC).* This work was executed and funded under *SOPAC's Project FM 99.03*.

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Preliminary results of geophysical surveys off Sissano, Papua Niugini

Takeshi Matsumoto

The Sissano Lagoon, northern coast of Papua Niugini suffered from a M7.1 earthquake and its subsequent large-scale tsunami which occurred on July 17, 1998. The epicentral area was surveyed by the Research Vessel KAIREI (owned by JAMSTEC) in January 1999, in order to locate the possible seismic faults and/or underwater landslides as the source of the tsunami, and to study the process which took place off Sissano and the driving force of the event. Precise bathymetric survey by use of SEABEAM2112 and other geophysical surveys (bottom reflectivity, sub-bottom profiling, surface ship gravity and geomagnetic surveys) were carried out and four piston core samples were collected during the nine-day survey.

The study area is characterised by a large amount of fan sediment supplied from Sissano Lagoon. Straight small-scale submarine canyons and valleys are eroding the shelf slope constructed by the fan sediment. Topographic features of arc-shaped slumps caused by landslides are recognised at numerous sites of the study area. Most of them are old, and the most recent is located 25 km north-east of the Sissano Lagoon. Two major topographic depressions on the shelf were located off Sissano Lagoon. The western is a depression about 10 km in width, and the eastern is a meandering deep-sea canyon. A numerical simulation of the propagation of tsunami shows that the height of the recent tsunami was amplified through these two topographic depressions and resulted in the same pattern of the maximum wave height as observed after the event along the coast.

Onboard surface ship gravity measurement was carried out during the whole cruise by use of the Wodenseewerke KSS-31 gravity meter. The study area is classified into three zones sub-parallel to the shoreline: (1) positive aside the shore, (2) negative along the topographic low, (3) positive off-shore. The gravity low corresponds to the topographic depression of assumed deep-sea trenches (Wewak Trench). However the low zone is characterised by the two isolated lows. The minimum free-air anomalies are –100 mgal in the western side and –80 mgal in the eastern side. Other lows located at 2°35'S 141°45'E and 2°45'S 142°00.0'E correspond to the "collapsed" basins edged by circular slope. The boundary between Zone 1 and Zone 2 is characterised by high gradient of free-air anomaly, which corresponds to the steep slope off the coast. Zone 3 is characterised by positive (0-40 mgal) free-air anomaly. The area north of 2°30'S is characterised also by the maximum Bouguer anomaly corresponding to typical oceanic crust.

The geomagnetic anomalies were also observed by proton-precession and 3-D vector magnetometers. The total force anomaly shows that negative anomaly is predominant in the coastal zone and positive anomaly

off the coast. A large-intensity positive and negative pair in the northeastern part of the survey area corresponds to the seamount chains located in this area. These seamounts are considered to be of volcanic origin and are colliding with the plate at the convergence zone off Sissano.

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Formulation of Fiji's Offshore Mining Policy

Helena McLeod & George RL Niumataiwalu

The mining of minerals has remained a terrestrially based activity from its early beginnings. The primary reason for this has been the ease of access and of extraction of minerals that are found on land compared to the marine environment, and the subsequent costs and risks involved. This bias has been reflected in the formulation of legislation and policies worldwide that deal with the extraction of predominantly terrestrial-based minerals. There is now keen interest by some mining companies in investigating the potential of developing marine or offshore-based minerals. This has been fueled by the need to lower mining extraction costs and also to minimise the negative impacts of mining on the community. One such company is Nautilus Minerals Corporation Ltd, who was granted two exploration licences in Papua New Guinea in 1997 to explore for polymetallic massive sulphides (PMS) in the Bismarck Sea. The same company has applied for a similar licence to explore for PMS in the North Fiji Basin. On 22-26 February 1999, a SOPAC-coordinated workshop on Offshore Mineral Policy was conducted in Madang, PNG , and this workshop attempted to review the draft PNG Offshore Mining Policy as a test case, and to derive a policy framework for formulating offshore mining policies in general. The results of this workshop have provided Fiji's Mineral Resources Department with a framework in which to derive its own Offshore Mining Policy, and which is the subject of this paper.

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Why the 17th July 1998 tsunami at Sissano Lagoon, PNG, was coseismic and not landslide-triggered

Mauri McSaveney

Just how the disastrous 17th July 1998 tsunami at Sissano Lagoon, PNG, was generated is a matter of some controversy. There is general acceptance that there was only one tsunami event (of three closely spaced waves), and that it was associated with an earthquake (M_W 7.1), but its size was far in excess of what was expected for an earthquake of this magnitude. Tappin *et al.* This volume report the results of recent marine surveys in the area and suggest that the tsunami was created by a large, sea-floor, earthquake-triggered sediment slump. A numerical model based on such a slump gave a better approximation of the observed tsunami *run-up* than did one based on a high-angle reverse fault. This is not surprising, because it is unlikely that a high-angle reverse fault was involved. Since the magnitude of modeled coseismic displacement must be constrained by the recorded earthquake, but the magnitude of a slump may be a variable, we can expect better apparent fit for slump models even for earthquake-generated tsunami.

In this study, the sea-bed information is interpreted somewhat differently, and in the context of observations of coseismic deformation on land (McSaveney *et al* 1998, Goldsmith *et al.* 1999). Co-seismic sea-floor deformation associated with movement of a low-angle thrust fault is suggested to have caused the unusual tsunami. Even the simplest model of coseismic deformation, neglecting horizontal motion and the focusing effect of curvature of the trace of the fault rupture across the sea floor, creates a significant tsunami. The significant variance between the observed tsunami run-up and run-up determined from fault models indicates clear modeling deficiencies, but not that the basic fault model is wrong. There is need to model the sea-surface uplift due to horizontal motion of the exceptionally steep trench wall, and the effect of curvature of the initial wave form which was concave towards the Sissano coast.

With only one tsunami reported, there is call for only one explanation. Coseismic sea-floor deformation is a necessary and sufficient causative agent. I therefore conclude that the 18th July 1998 PNG earthquake was tsunamigenic and that there is no need for the sediment-slump hypothesis.

Until tsunami modelers introduce as much flexibility into faulting models as is currently used in slumping models there is much danger in using modeling as a tool for determining tsunami genesis. Nonetheless, modeling will continue to be the most valuable tool that we have in the study of tsunami, but it must be tempered with good observations of the effects of tsunami on land.
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An index for ENSO-related sea level changes in the Tropical Pacific

Mark Merrifield & Bernard Kilonsky

Introduction

The El Niño Southern Oscillation (ENSO) accounts for the largest fluctuations in tropical Pacific sea level on interannual time scales. The difference between peak El Niño and La Niña events can exceed 0.5 m in some areas. The consequences of such variation for low-lying island regions are severe, particularly if various climate-change scenarios (e.g., more frequent and energetic ENSO events and/or an enhanced human-induced sea-level rise) are realized.

The assessment of ENSO-related sea-level changes is based primarily on long time series collected from island tide gauges, and more recently on satellite altimeters which provide unprecedented spatial coverage of the entire Pacific Ocean. In particular, the TOPEX/Poseidon altimeter has provided detailed coverage of the 1997-98 El Niño, the subsequent La Niña of 1999, and weaker ENSO events during the early 1990s. In this paper, we present a simple index for estimating interannual changes in sea level associated with ENSO in the tropical Pacific Ocean, using altimeter observations (NASA/GSFC Pathfinder Gridded Sea Surface Height Variations) and the Southern Oscillation Index (SOI) which is a well-known proxy for ENSO variability. The index is applicable to a well-defined region of the tropical Pacific between 15°N and 15°S.

The Sea-Level Index

A description of a sea-level index based on tide-gauge empirical orthogonal functions (EOFs) is given in Merrifield et al. (1999). The method presented here is similar to that of Merrifield et al., except that we use the Southern Oscillation Index (SOI), a more readily available and widely used data product than the tide gauge EOFs. The use of the SOI instead of the EOF modes to specify the index results in slight reductions in explained variance (10%) and timing shifts (1-3 month) in some areas (see Merrifield et al., 1999).

Interannual sea-level fluctuations at each of the altimeter grid points in the tropical Pacific are estimated from the SOI using a least-squares regression. Regions where the regression explains at least 70% of the interannual sea-level variance are pictured in Figure 1. The pattern is similar in shape to well-known descriptions of ENSO. During El Niño events, the classic see-saw pattern is evident, with a fall in sea level over a broad region encompassing the western Pacific warm pool and a commensurate rise in sea level over the cold tongue region of the equatorial eastern Pacific. During the recent 1997-98 El Niño, the rise and fall corresponded to 0.25 m and -0.25 m on either side of the Pacific. The pattern reverses during La Niña conditions such as late 1998, when sea level rose above the mean by approximately 0.15 m in the western Pacific, and fell by a similar amount in the eastern Pacific.

To determine the sea-level change associated with ENSO events at any particular location in Figure 1, the regression value is obtained from the contour map and multiplied by the SOI index. For example, we examine the area near Pohnpei (6°59' N, 158°14' E) in the western Pacific, which has an index value of approximately -7. In Figure 2, it is readily apparent that the index provides a good assessment of all major El Niño and La Niña sea-level variations over the course of the tide-gauge record.

Discussion

This simple method gives a clear indication of which areas of the Pacific are most susceptible to large sea-level variations during ENSO events. Regions of the tropical Pacific that are not highlighted in the index map (Figure 1) either experience weak variations during ENSO or processes other than ENSO are of greater import. The method can be used to hindcast previous ENSO events based on the long SOI record, or to estimate the impact of future ENSOs, particularly in conjunction with different estimates of sea-level rise.

We caution that the index is derived from a relatively short altimeter time series, although longer tide-gauge data sets are consistent with the index estimates. The index map will be updated as the length of the altimeter time series increases.

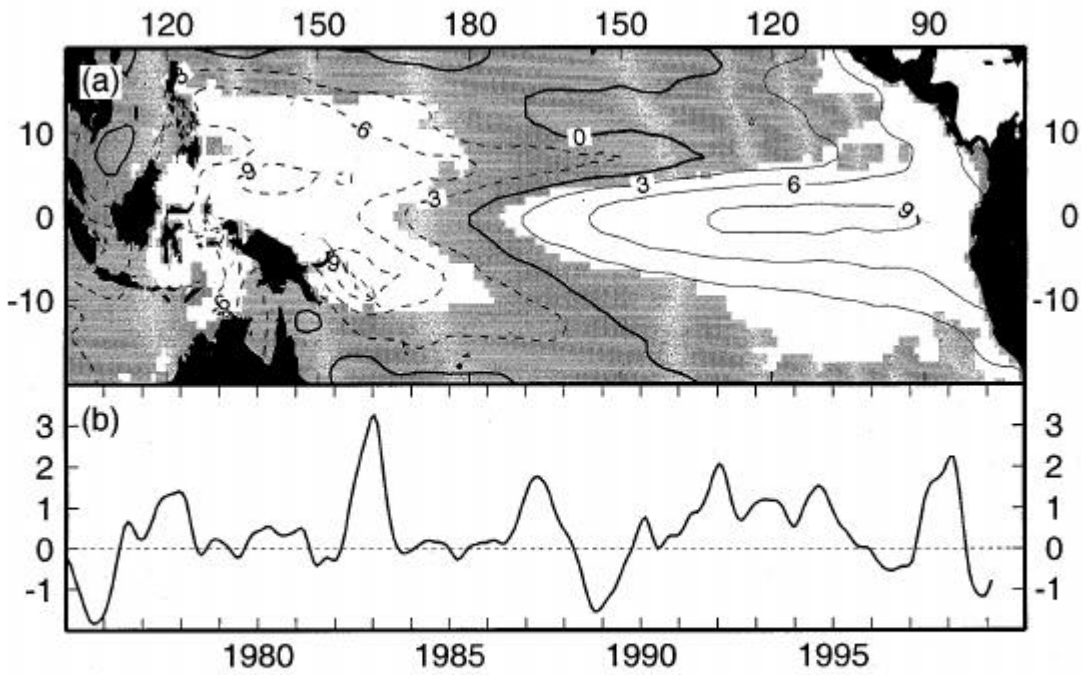

Figure 1. (a) Regression coefficients between the altimeter-measured sea level and the SOI. Units are in cm. The unshaded region corresponds to areas where at least 70% of the variance is accounted for in the regression. (b) The Southern Oscillation Index.

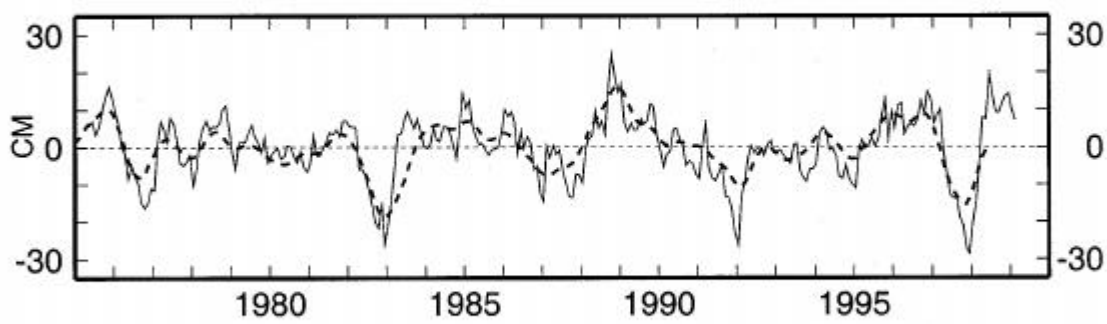

Figure 2. A comparison of the sea-level anomaly recorded at Pohnpei (thin solid line), with the estimate of the ENSO-related sea-level changes obtained from the regression model (thick dashed line).

Reference

Merrifield, M., Kilonsky, B. and Nakahara, S. 1999. Interannual sea level changes in the tropical Pacific associated with ENSO, GRL, in press.

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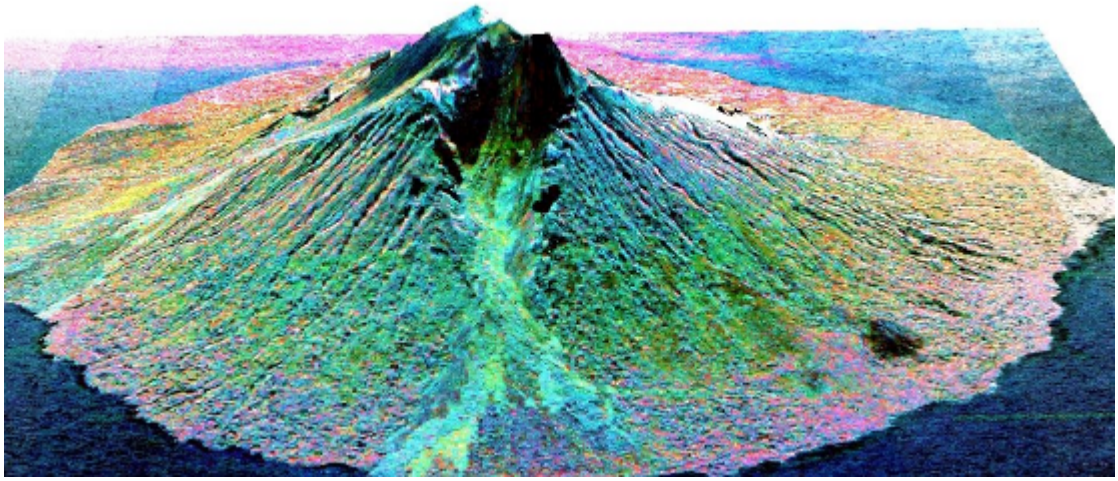
PACRIM 2: NASA-JPL AIRSAR mission to the Pacific-Rim region in April-June 2000

Earnest D. Paylor, Tony Milne, Ian J. Tapley

PACRIM2 is a NASA-sponsored science mission to advance the development of polarimetric and interferometric radar in the Pacific-Rim region including SOPAC member countries. Data will be collected at cost for government-agency, university and private-sector groups using two state-of-the-art instruments, AIRSAR and MASTER.

AIRSAR is a NASA-sponsored airborne synthetic-aperture radar system developed at the Jet Propulsion Laboratory in California. AIRSAR operates in three modes: polarimetric SAR (POLSAR) provides operational-quality polarimetric data in three frequencies; cross-track interferometric SAR (XTI or TOPSAR) allows precision digital elevation information of the earth's surface to be obtained; and along-track interferometric SAR (ATI) can be used to detect the movement of ocean currents and wave patterns.

Some important science and applications benefits of these datasets in tropical environments include: disaster planning and management; forest and crop classification and inventory; deforestation and regrowth inventory; mangrove forest and coastal wetland mapping; identifying the position and extent of flooding below a forest/mangrove canopy; floodplain morphology; distribution and extent of sediments and pollutants within waterways and offshore; geological mapping; examination of topography and drainage networks; generation of large-scale topographic maps; terrain analysis for such applications as watershed management, planning access to remote localities and developing geochemical sampling strategies; archaeology/cultural resource management; and urban inventory and management.



An example image of AIRSAR data: a 3D perspective of three POLSAR bands draped over the TOPSAR elevation data of Manam volcano off the north coast of Papua New Guinea. These data were collected through a volcanic ash cloud in November 1996 when the volcano was erupting. The extent of lava flows, shape of summit crater and changing vegetation patterns extending from the volcano peak to the coastline are clearly visible.

The inclusion of the MODIS/ASTER Airborne Simulator (MASTER) in the PACRIM2 payload will provide for the collection of high-resolution optical datasets in the visible near-infrared, short-wave infrared, mid-infrared and thermal-infrared regions of the electromagnetic spectrum. Thus it will be possible to collect optical, microwave and elevation datasets over the same target, albeit from two flight passes owing to the side-looking nature of AIRSAR and nadir-pointing direction of MASTER.

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SW Pacific Mineralization into the Millenium

M G Petterson

SOPAC are planning to publish a thematic volume dealing with mineralization issues in the SW Pacific as we approach the third millenium. Originally the idea was to publish papers arising from the PET 98 conference in Nadi last year.

The project has now developed, and currently twelve papers have been reviewed and accepted subject to revision (other papers are currently being drafted). These twelve papers deal with a variety of issues such as: the science of metallogenesis, new mineralization and geological models; the results and interpretation of recent geophysical surveys; history of mineral exploration in key areas; the importance of the minerals sector to specific island countries; the impact of the low gold price on the mineral industry; environment - and culture - sensitive mineral development; and policy and economic issues relating to mineral exploitation in the Pacific region.

The editors of the volume are Michael Petterson, Helena Mcleod, and Jackson Lum. We invite workers who are active in the above areas, or in similar appropriate areas, to submit papers for publication in this volume. We believe that the volume will form an invaluable database and guide for future workers in the Pacific region, in the general field of sensitive mineral development which aims to benefit all Pacific people. You can ensure that the quality of this volume is the highest we can achieve by contributing your data and ideas. We look forward to hearing from you.

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A Spatial Mineralization Model for Solomon Islands

M G Petterson, P J Coleman, D Tolia

Recent developments in terrain analysis coupled with a cognizance of the importance of CTC tectonics (composite-transform-convergent tectonic zones) provide a powerful predictive framework for assisting with the location of mineral deposits. A combined application of terrain and CTC modeling has direct relevance to both generic metallogenic modeling on a broad scale and more-localised site-specific problems. Although this paper concentrates on Solomon Islands, the principles discussed are universally applicable to similar geo-tectonic environments, both present and past.

The two fundamental principles of our model are:

- Solomon Islands is a complex collage of terrains which have individual geo-tectonic histories and modes of genesis. The character of the terrain can range from entirely ocean plateau to entirely young arc and to more-hybrid and complex terrains. An understanding of the fundamental nature of each terrain is essential to metallogenetic modeling and mineral exploration.

- The SW Pacific has long been affected by oblique collisional CTC-style tectonics. CTC zones tend to produce a complex collage network of highly fractured crustal blocks bounded by boundary parallel and boundary normal structures, and are dominated by strike-slip and transpressional tectonics. Relative rotational and translational movements between fault blocks provide potential pathways for fluid migration, a variety of dissection profiles and degrees of crustal exhumation, etc. An understanding of this tectonic style is crucial to correlation.

A recognition of the importance of these fundamental principles can lead to fruitful applications to the mineral explorer and tectonic modeler alike. Perhaps the key guideline is the adoption of the principle ‘to each terrain its own strategy’. This paper will suggest that terrain-CTC modeling has ready applications in such fields as: prioritisation of mineral potential for a specific terrain collage; choosing the most appropriate exploration strategy; identifying key structures / mineralization pathways; recognising levels of crustal exhumation; correlation problems; and providing a theoretical basis for mineralization and mineralization-related geological associations (e.g. magmatism and mineralization).

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Records of Explosive Surseyan Eruptions from Kavachi, Solomon Islands, in 1961, 1970, 1976, 1978, 1991, 1998, and 1999.

M G Petterson, Captain S Wallace, D Tolia

Kavachi is a submarine volcano located 30 km south of Vangunu island, and some 30 km north of the South Solomon trench system. Volcanic activity at Kavachi has previously been reported for the period 1950-1982 by Johnson and Tuni (1987) among others. Unfortunately much of the activity has gone unreported due to the geographic isolation of Kavachi. The most relable and regular source of information originates from Solomon Island pilots who daily fly scheduled flights over Kavachi. This paper reports some recent accounts by one Solomon Airlines pilot (Captain Wallace) combined with a photographic record originating from a variety of sources for the eruptions of 1961, 1970, 1976, June 1978, May- ? September 1991, and April-May 1999.

Kavachi is tantalisingly close to forming a permanent volcanic island, with the highest point of the volcano only tens of metres beneath sea surface. During eruptive events the the Kavachi edifice inflates, often forming temporary islands which remain subaerial for periods of weeks to months. The photographic evidence discussed in this paper provides details on three main stages in a typical Kavachi eruptive cycle: 1) submarine-only eruptions; 2) transitional eruptions which include both submarine and subaerial eruptions; and 3) subaerial-dominated eruptions.

The recent April-May 1999 eruptions and the previously unreported 1998 eruptions were almost entirely submarine, with activity concentrated in the very near-surface submarine environment (probably at depths of c. 20 – 1 m). Plumes of ash-laden water, wedge shaped in plan view, extended for several to tens of kilometres down current of Kavachi volcano. The area in the immediate vicinity of Kavachi was a mass of boiling and / or highly convective and turbulent sea water. In the quieter periods only a slight disturbance was visible at the surface, producing a striking network of annular waves centred on Kavachi. Occasional hydrovolcanic plumes rose tens to >100 m into the air and were accompanied by phreatomagmatic steam eruptions.

The 1961, 1970, 1976, and 1978 eruptions evidence activity at an incipient to very immature volcanic-island stage. Submarine activity is similar to that described above from the 1999 eruptions, but is more intense and vigorous, producing ash-laden phreatomagmatic plumes tens of metres wide and circa 100 to several hundreds of metres high. The infant island stage is characterised by highly prolific steam production and the production of steam-rich plumes and clouds around the island. Dark and rapidly quenched basalt was exposed above sea level, with associated phreatomagmatic explosivity resulting in the eruption of both lava and red-hot incandescent, plastic volcanic bombs.

The May - ?September 1991 eruption produced a volcanic island mature by Kavachi standards, measuring up to 1 km wide and tens to >100 m above sea level. The island was tear drop shaped in plan view, which reflected the overall topography of a moderately steep-sided basaltic cone with an associated crater (measuring several tens of metres in diameter), breached on one side, with the geometric asymmetry being produced by a composite blocky aa lava field extending out of the central crater beyond the breached crater lip. Red-hot lava was visible within the crater. Steam eruptions were present, but were much less vigorous than during the incipient island stage. Ash plumes were common.

Note: measurements in this paper are only estimates from photographs and fly-bys, and are only meant to give an indication of scale.

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Seafloor mapping for integrated ocean management

Richard A Pickrill

Growing recognition of the usefulness of marine geoscience data to fisheries habitat mapping has opened up a new rationale for systematic sea-floor geoscience surveys. Multibeam bathymetric mapping, when groundtruthed with high-resolution seismic and sidescan sonar surveys and bottom sampling, provides base maps for benthic-community mapping. Pilot studies on the Scotian Shelf, completed in partnership with the fishing industry, have demonstrated the benefits of this approach to evaluation of Marine Protected Areas, fisheries stock management, fishing efficiency and habitat preservation. Data are archived within Geographical Information Systems, from which interpretive maps of bathymetry, backscatter, geology,

bedforms and benthic habitat can be produced or exported into electronic charts. Commercial demand for digital map products has provided the resources to accelerate mapping programs. This year Canada implemented the “Oceans Act”, which sets forth a framework for the sustainable management of Canada’s oceans. Interdisciplinary hydrographic, geologic and benthic surveys will provide the data base and interpretive maps and reports to support integrated ocean management.

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Fiji tsunami warning system and response arrangements

Gajend Prasad

Fiji’s islands are vulnerable to tsunamis generated anywhere in the Pacific, and it is important that appropriate measures are taken to minimise the effect of tsunami attacks on the coasts of Fiji islands. In case of a tsunami impact on Fiji there could be considerable losses, especially to human life, which to a large extent can be reduced through a comprehensive communications plan. This plan will endeavor to address the issues related to tsunami information/warnings and response requirements.

Eleven tsunamis have been recorded in Fiji, of which three were generated within Fiji waters. The most damaging tsunami was in 1953 following an earthquake near Suva. This tsunami killed 5 people in Suva and Kadavu and flooded parts of Suva City. The tsunami occurred at a peak low tide, and had it occurred at a high tide the damage and casualties may have been more severe.

The tsunami watch and warnings in Fiji will follow very closely the system used by the Pacific Tsunami Warning Center (PTWC). The authority to issue warnings will be vested upon the Director of Meteorology Department, however assessment by a seismologist will be provided when practical. Other key agencies that will play important roles in the dissemination of messages and warnings have also been identified. It is also proposed that sirens be installed in strategic places and used as necessary.

One of the key activities identified for the mitigation of tsunami disaster is public education, and this will be pursued vigorously. Communities will have to be fully prepared to understand the messages and warnings and to take appropriate actions.

One of the major hurdles of providing effective warnings is the short onset times for some of the tsunamis. Tsunamis generated locally will probably have no warning issued before the impact of the tsunami. Under such circumstances the communities will be depended on to take appropriate actions, as they would understand what to do after experiencing a strong earthquake. The biggest hurdle is being able to give warnings for tsunamis generated regionally with onset times of close to one hour. It is here proposed that some type of communication be developed between regional countries for dissemination of information on tsunamis.

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Recent advances in simulating the effectiveness and impact of dredging

Douglas L Ramsay

Sediment release is one of the most important primary environmental effects of dredging and dredged material disposal operations. Increasingly, as part of the environmental impact assessment of a particular dredging activity or development project involving dredging or fill placement, it is necessary to consider the impact of the re-suspension of fine material during the dredging/placement activities. Indeed, the dispersion of fine material arising from the dredging/placement operations is often the major impact associated with a particular development and can comprise:

- a reduction in water translucency and hence in photosynthesis;
- the aesthetically displeasing effects of the turbid appearance of the water;
- the burial of bottom life which cannot withstand this;
- interference with the respiration of fish and other marine life;
- the excessive availability of nutrients; and
- physical and chemical changes in the local environment.

In addition, if the material re-suspended is contaminated, results are:

- the migration of (contaminated) sediment from the dredging area;
- the absorption of toxic substances and by marine organisms which can then be harmful to man if such contaminated seafood is consumed;
- the exchange of contaminants between the sediments (brought into suspension) and the water.

There are three common methods for considering the dispersion of material re-suspended from dredging, each of which involves a different level of analysis:

- a desk analysis involving tidal excursion lengths and residual currents to identify the areas likely to be affected by the sediment plume;
- use of an analytical advection/diffusion model to establish an initial estimate of suspended-sediment concentration increases and potential deposition; and
- Full 2D/3D process modeling of sediment transport.

Although the choice of approach depends on the nature of the study, these approaches are not exclusive of one another, and best practice usually entails an initial appraisal followed by a more in-depth study.

The level of analysis is different for all three approaches, but the quality of the results determinable by each of the approaches is hugely dependent on the quality of knowledge of the initial conditions, in particular, the mass and rates of input of sediment initially introduced into the water column. In most plume dispersion models, this loss of sediment into the water column is described by a “loss rate”. To date such loss rates, where the information is available, have been derived by calculating or estimating the mass rate of discharge through the spillways or screening reject chutes, and assuming that all of this material is entrained into the water column. Unfortunately, this information is usually an overestimate of real “loss rates” as a significant proportion of this material descends rapidly towards the bed. The resulting predictions of suspended-sediment concentrations and deposition from modeling are therefore also over-predictions, and there is a need for more-realistic initial conditions for input into these modeling tools. As understanding of the initial conditions of dredging plumes increases, the reliability of the modeling results will correspondingly increase.

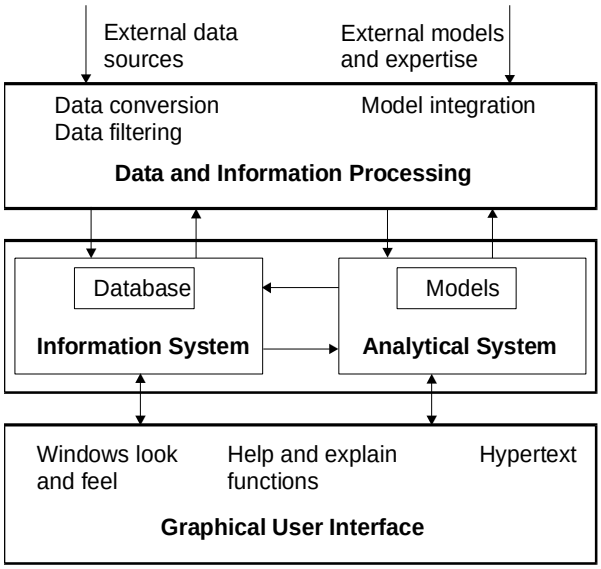
The mechanisms by which sediment is generated from dredging activities are numerous and often complex. Research into this topic has been undertaken since the early 1970s, but there has been little progress in terms of validated predictive techniques. The Dutch dredging industry, through VBKO, has recognised the need to improve this situation and has commissioned new research to develop a calibrated software package which can be used to derive realistic estimates of sediment release during dredging and disposal.

The research has sought to identify all of the mechanisms by which sediment is released during dredging and to develop models that predict the rates of release. Use has been made of previous research efforts in this field, particularly work undertaken by the Corps of Engineers in the USA and by several Netherlands organisations including the Dredging Research Association (CSB). In some cases, predictive models already exist (e.g. overflow losses from trailer dredgers) but, in most, little theoretical work has been done. In all cases, accurate field measurements of losses are not available, although some measurements are available which can be used to derive an initial ‘order-of-magnitude’ calibration.

The software being developed predicts sediment release, and the initial dynamic behaviour of the sediment plumes, in a logical manner and in broad agreement with the sparse field data. Future work will focus on obtaining accurate field measurements of sediment release in order to calibrate and refine the predictive components of the software package. The system comprises four components;

1. a *soil model* which describes the tendency for soil and rock to disaggregate during the dredging process;
2. a suite of *process models* which, in combination with the soil model, describe the rates and locations of sediment release, and the particle size distribution of the released sediment;
3. a *dynamic plume model* which describes the initial behaviour of the sediment suspension; and
4. a *database*.

The *process models* predict the release of sediment for grab, cutter suction, bucket ladder, backhoe and trailer dredgers. These have been selected because they are the most commonly used dredgers but additional types may be added in the future.



Output from the process models is used as input to the *dynamic plume model,* which predicts the initial behaviour of the material released from the dredger during the dynamic phase of dispersion, i.e. up to the point at which further sediment transport is dominated by the processes of advection and settling. The behaviour of the sediment after this point is not covered by the system, as there are several existing proprietary passive sediment-transport models, which can be applied to this stage of plume development.

Figure 1 Conceptual design of the software package**.**

The *database* is used to store details of field measurements of sediment release around working dredgers. The database will be accessible using a range of search routines, and will include facilities to extract and analyse data in a manner which will enable the predictive models to be refined as measurements accumulate.

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Ash layers in Cenozoic sediments from the North Fiji Basin - evidence of volcanic events in the central chain of the New Hebrides Island Arc.

Steffen Richter, Johann Mrazek, Michael Frenz, Gerd Lube & Andreas Musolff

Sedimentological investigations were done in the northeastern, western and northwestern part of the North Fiji Basin (NFB) by Chase (1971), Jezek (1976), Brocher (1985), Riech (1990), Marchig (1990), Eade and Gregory (1993) and McMurtry et al. (1993). They show that the sediment characteristics are very different in different parts of the NFB. The amounts of hydrothermal, volcanic, carbonate and detrital components in the sediments are not known from most areas of the central part of the NFB. Four long undisturbed sediment cores were taken in an E-W profile crossing the central NFB ridge (CNR) in the NFB during two German expeditions (SO 99, SO 134). The outer sample points are situated approximatly 62 km each sides of the rift. One sediment column of max. 830 cm was taken with the piston corer (46 PC) west of the CNR. From the eastern NFB a sediment core with a maximum. length of 605 cm was recovered (48 PC). The stations where cores were recovered are at water depths between 2830 m (76 PC) and 3360 m (99 PC).
The sediment cores were studied in detail with sedimentological, geochemical and stratigraphical methods. One main aim of these investigations was the detection of volcanic components and the determination of their origin. Sediment samples were fractioned by wet sieving in subfractions >63 µm for component analysis with special respect to volcaniclastic particles. The fraction <63 µm was used for grain-size analysis using SediGraph 5100. Furthermore, geochemical

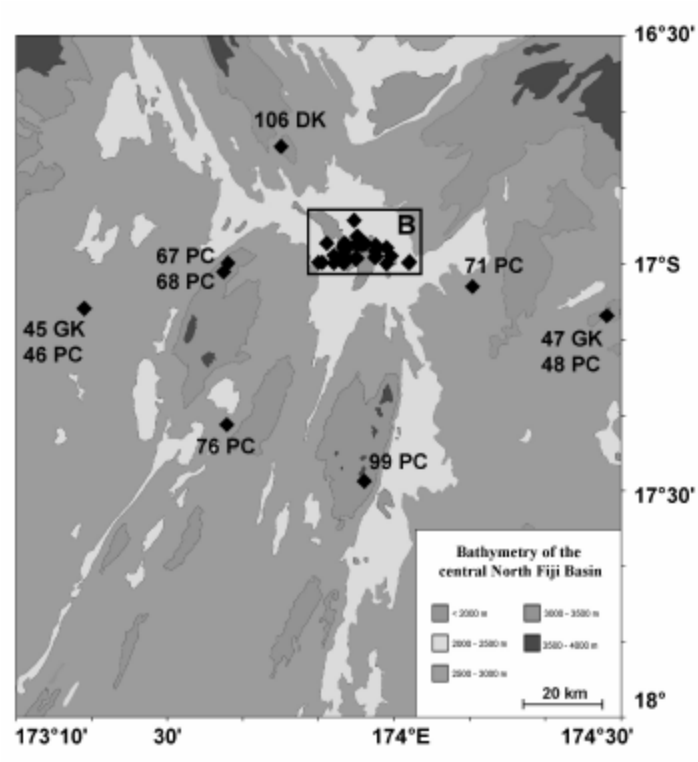

Fig. 1: Bathymetry of the central North Fiji Basin (mod. after Urabe and Auzende 1994).

investigations (ICP-AES, AAS) were carried out. The bulk samples were leached to remove the carbonate and the particle fractions <10 µm were eliminated by the ATTEBERG-method. The pink-coloured *Globigerinoides ruber* were used for a first age determination.

The sediments in the central NFB are dominated by the silt fraction. The average contents in sediments of the western area (76 PC) are 22% (11-34%) sand, 50% (35-69%) silt and 28% (7-29%) clay. The same grain-size contribution was detected in core 99 PC with 20% sand (8-41%), 50% (36-72%) silt and 30% (8-51%) clay. The average contents of silt and sand are increased, caused by selection of tephra-enriched samples. Between two ash layers only one sample was taken. Regular sampling at intervals of 5 cm shows average sand contents of 16.9% in core 46 PC and 9.5% sand in core 48 PC. The average content of carbonate in core 76 PC (41%) is higher than in core 99 PC (36%). Samples from tephra layers are characterized by median values of 8-15 µm in core 99 PC and 5-15 µm in core 76 PC.

Quantitative compositional investigations show that the carbonate-rich samples consist mainly of biogenous components (70- >90%) of ca. 90% planktonic foraminiferas. The 10-20% of volcaniclastic components in the coarse fraction of carbonate-rich sediments represents the background volcaniclastic sedimentation. Usually the coarse fraction of discrete tephra layers consists of 60-90% volcaniclastics. In most of the disseminated ash layers it is diluted to 20-40%. Pumice is the dominant type of glass in core 99 PC except for two ash layers in which dark scoria prevails. Hyaloclasts with contribution of <10% to the coarse fraction are unimportant components. The dominance of pumice occurs mainly in the upper and lower parts of core 76 PC. The content of scoria dominates the middle part of core 76 PC and reach a maximum of 83% in a sediment depth of 325 cm bsf. The average content (n = 76) of SiO_2 is 56.1% (49.7-65.3%). K_2O ranges from 0.97% to 3.13% (av. 1.58%) and Na_2O from 2.45% to 4.35% (av. 3.35%). Mainly basaltic andesites, andesites and dacites occur. Basalts, trachybasalts and trachyandesites are rare. The maximum age in core 46 PC is ca. 520 ka. The youngest bottom sediment occurs in core 48 PC. It shows that the rates of sedimention vary between 1.6 and 4.0 cm/ka in the central part of the NFB.

The main sediment types in the central NFB are silty ashes, calcareous mud, pumice and clayey detritus. A minimum of 16 separate ash layers was found in the investigated cores. It is possible to correlate all of these tephra layers, stratigraphically and geochemically. The ash layers are normally graded by size and also by the content of more-compact scoria at the base. Distance from the source area, estimated from grain size, is between 500 and 1000 km. The metereological data show that easterlies dominate the wind regime between 2-3 and 18-20 km height in the NFB. The differences in the sediment characteristics, the high content of

volcaniclastic material in the western of the central North Fiji Basin and the lower content of ashes in the eastern part imply that the main origin of the ashes is the Vanuatu island arc. The volcanoes on Tongoa or Lopevi are possible sources of the andesitic and dacitic ash layers; the volcanoes Epi and Tanna are responsible for the more basaltic andesites and the volcano Ambrym for the basaltic and basaltic-andesitic tephra particles.

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Hydrothermal and volcanic events preserved in sediments from the western flank of the Central NFB Ridge

Steffen Richter & Johann Mrazek

The North Fiji Basin (NFB) with its hydrothermal activities is a well-investigated complex marginal basin created 12 Ma ago (Auzende and Urabe 1994). It lies at the boundary of the Pacific and the Indo-Australian plates between two subduction zones of opposite polarity: the New-Hebrides trench to the west and the Tonga-Kermadec trench to the east. During two cruises with the German research vessel Sonne in 1995 and 1998, sedimentological samples were collected from the central part of the NFB. Sedimentological and geochemical investigations of this material can be used to reconstruct the sedimentation processes in areas proximal and distal from the active hydrothermal vents in the NFB. Sediment samples were collected from 49 stations (Fig. 1) in and near the Central NFB Ridge (CNR).

This abstract will focus on two sediment profiles from the rift flanks. The N-S profile at the western rift flanks in water depths between 2013 and 2402 m is represented by 10 cores at distances of 2.6 to 3.5 km from the spreading axis. A second N-S profile cuts the eastern rift flank at distances between 3.5 and 4.6 km from the spreading axis (water depths 2030-2374 m). The thickness of sediments is different on both flanks at the same distances from the rift axis. On the western flank, a maximum column of 96 cm (core 110 GC) occurs in profile 1. In contrast, on the eastern flank in profile 2 only a maximum sediment cover of 31 cm was found.

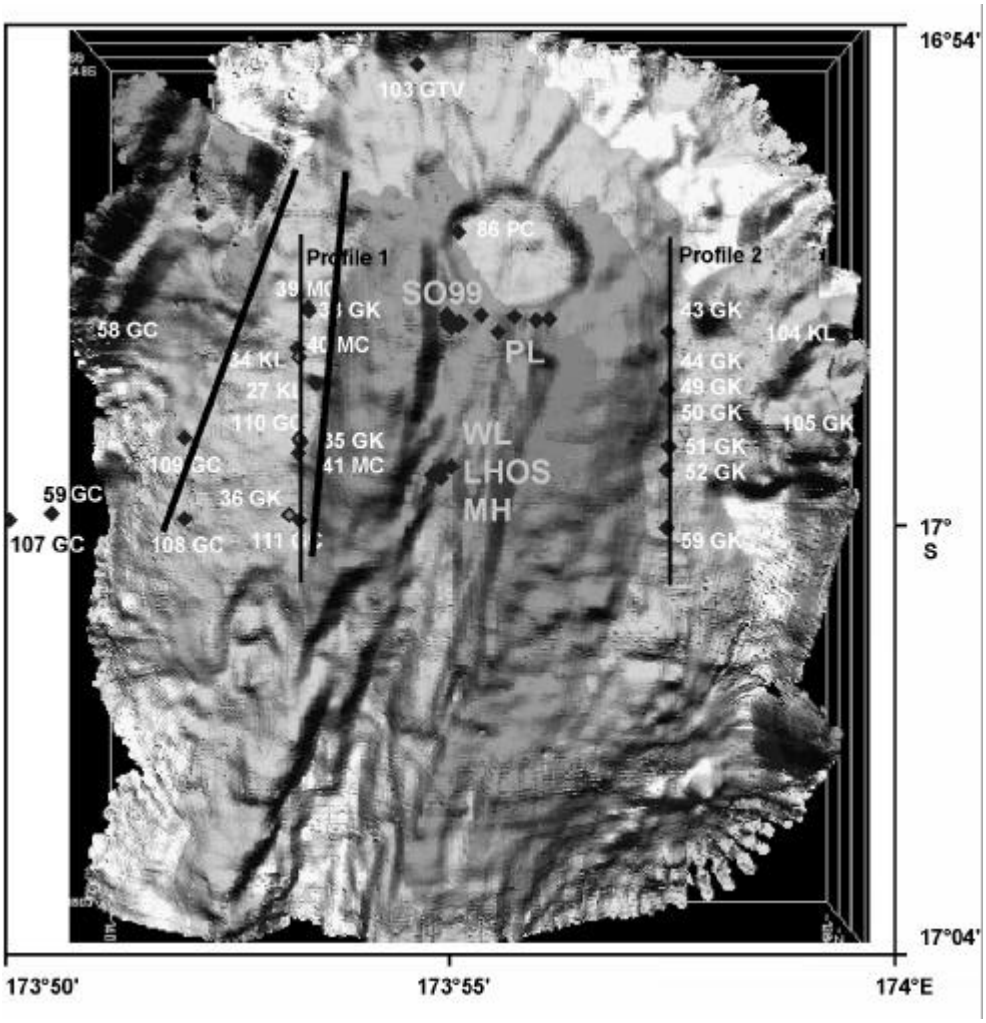

Fig. 1: Morphology of the northern N15-segment and sample stations of cruises SO 99 and SO 134 with areas of active hydrothermal vents (WL = White Lady, MH = Musselhill, LHOS = long-term Hydrothermalism Observation System), fossil vent fields in the graben ('SO99', Père Lachaise') and a fossil volcanic and hydrothermal area on the western flank.

No sediment layers from the eastern and western flank (other than the surface layer) can be correlated. A discrete eolian silty ash layer with a thickness of 3 to 5 cm and with dacitic composition occurs at the surface on both rift flanks. This surface tephra was proved in all sediment cores of the central NFB over an area more than 3000 km^2 by Richter and Mrazek (1999). Nevertheless, the sediment cores within profile 1 can be compared as can those within profile 2. Only fine sandy calcareous muds with carbonate contents up to 50% were found below the surface tephra layer on the eastern flank of the CNR. The sand fraction consists of disseminated eolian, felsic and submarine, basaltic pyroclastic particles, pumice lapilli, micro manganese crusts, foraminifera, pteropods and ostracodes. On the western flank of the CNR a carbonate-rich silt (Fig. 2) occurs below the surface ash layer. A hydrothermal brown to olive-coloured, clayey silt 2 (see Fig. 2) without carbonate is present below this silt. Below this hydrothermal silt, a discrete black, sandy tephra layer with basaltic pyroclasts is conspicuous. This submarine sandy tephra was found at three positions on profile 1 (34 KL, 110 GC, 36 GK & 111 GC). A sandy carbonate-rich sediment with a high content of pteropods follows underneath this submarine ash layer. Below this is a silty carbonate mud with a more-or-less high content of disseminated silty ash particles. A dull yellowish brown and a grayish olive clayey hydrothermal silt 1 was found under this carbonate mud. A sharp border separates this clay from an underlying gray to dark grayish-yellow carbonate-rich silt with a high amount of sandy and silty ash particles. The main grain size in sediments on the western rift flank ranges from clay to sand. On the eastern flank the content of clay and silt in the sediments is very low. Here the sandy fraction, mainly represented by foraminifera and basaltic pyroclasts, dominates. The occurence of two hydrothermal and submarine volcanic events on the western flank of CNR and their absence in the east can also be proved by geochemical investigations (Fig. 3). The eolian dacitic fallout tephras are characterized by SiO_2 content more than 60%, and the contents of total alkali range between 6 and 7%. The hydrothermal clayey silt 2 has up to 16% Fe_2O_3 and high contents of Cu (max. 270 ppm), Hg (max. 680 ppb) and Zn (max. 330 ppm). The discrete basaltic ash layer with

48.4% SiO_2, 1.6% TiO_2, 10.6% CaO, 255 ppm V and 112 ppm Zr is very significant. An early clayey silt 1 at the western flank also has high contents of Fe_2O_3 (13%), Cu (220 ppm), Hg (240 ppm) and Zn (200 ppm). At the eastern flank, hydrothermal indicator elements don't have high concentrations. This implies that only at the western flank were there two submarine volcanic events with following hydrothermal activities. Thus,

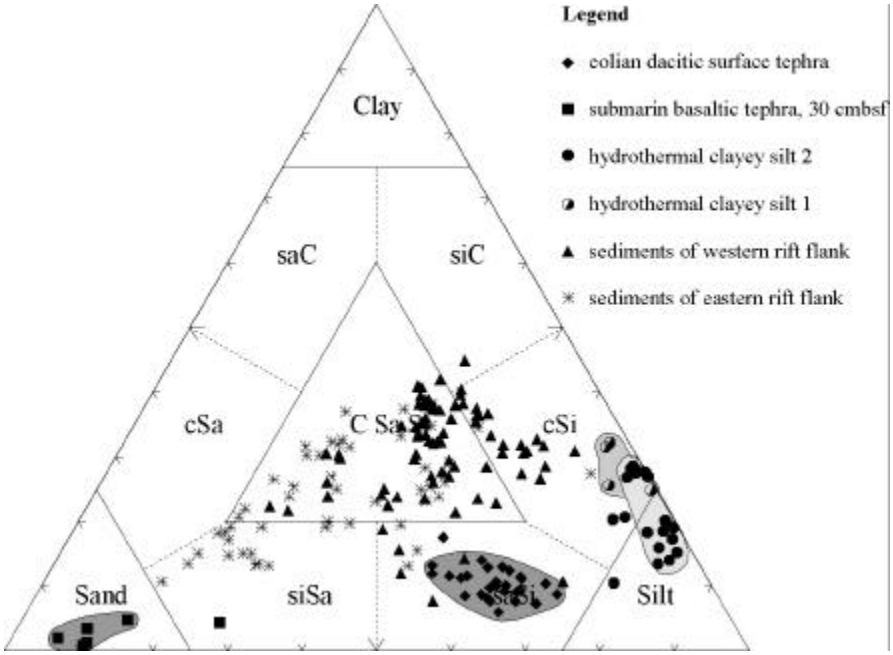

Fig. 2: Classification of sediments from the rift-flank sediments of the CNR in the NFB (n = 178).

magmatic and tectonic conditions are not stable in this area. These phenomena can only be discussed giving consideration to tectonic features of this area. The junction between the N15-Segment and the southern N5-Segment (18°S) shows a V-shaped geometry, which suggests a spreading-direction adjustment with northward propagation (Ruellan et al. 1994). An overlapping spreading ridge lies opposite the propagating rift segment. The western arm of the N15 spreading axis jumps backwards to the northeast, caused by the too-large and unstable offset between the two overlapping ridges. The magnetic pattern suggests that the N15 arm of the overlap has jumped northeastwards three times, with an average velocity of 5.8 cm/a since anomaly J chron. The bathymetry of the investigated area (Fig. 1) shows a ridge 12 km wide and 500 m high, with an axial graben 2 km wide and 100 m deep. It resembles intermediate- and fast-spreading systems such as the East Pacific Rise (Tanahashi et al. 1994). The western boundary of the graben shows a structure concave towards the east. The seafloor mainly has wide NE-SW structures but also some N-trending lineaments. Profile 1 lies north of a little N-S lineament and in the eastern part of a NNE-SSW-oriented depression. The two submarine volcanic and hydrothermal events allow us to suppose a fossil rift system in this depression. It is possible that a former rift axis jumped eastwards to the recent rift axis like what is observed at 18°S, mentioned above. Another interpretation is that a now-extinct hydrothermal system on the western flank were probably produced during an episode of high seafloor extension, as on the Juan de Fuca Ridge flank. The activity or non-activity of those hydrothermal systems would have been controlled by rates of extension of the rift system.

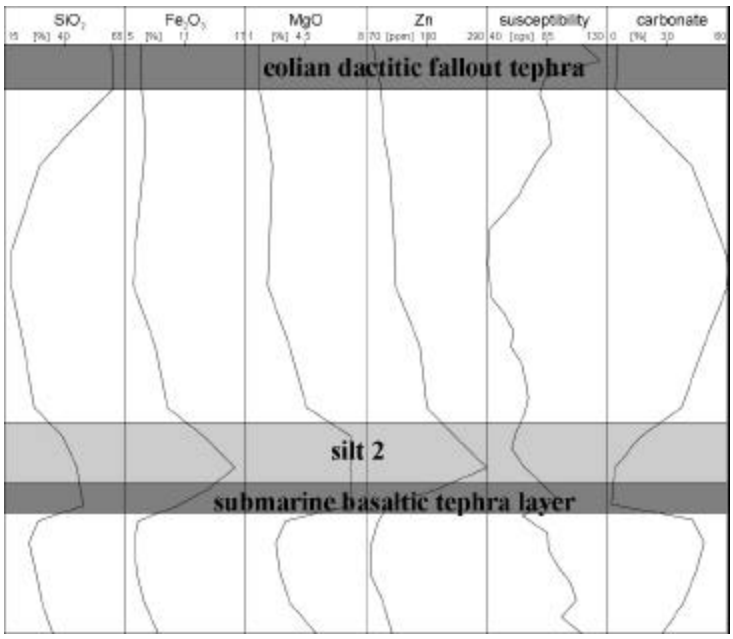

Fig. 3: Geochemical profiles (bulk samples) of core 36 GK (0-36 cm bsf) from the western flank of CNR with second submarine volcanic and hydrothermal events and the eolian surface ash layer.

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Defining fisheries habitats by acoustic mapping

Edward J. Saade, Gary Greene & Dallas Meggitt

Recent developments in high-resolution acoustic sonar systems have provided an integrated systems approach to mapping seafloor features to aid in the understanding of fisheries habitats. The process begins with high-frequency side scan sonar imagery collected, processed using TRITON ISIS software and mapped to support mosaic generation of the seafloor morphology. The mosaic is generated using DELPH MAP software after all sonar data collected with integrated DGPS surface navigation and USBL underwater tracking of the towfish position. The mosaic functions as the base map for determining areas of interest and highest importance. These features include areas of hard bottom, rocky outcrops with significant relief, extensive ridges, zones of textural variations, and other related characteristics. The designated areas are then mapped with a high-frequency multibeam echosounder, typically >200 kHz, to ensure the highest possible resolution and smallest individual beam-pattern footprint. Multiple swaths are collected across the feature to provide 100% coverage and a minimum of 10% overlap. Using ROVs to deploy the multibeam, this methodology can be used to 2500 m water depths. The multibeam data are collected using WinFROG Multibeam software, then cleaned, processed and displayed in CARIS-HIPS software and output in CAD format. The two data sets can be overlain in various formats for analysis and GIS support. The final product aids in defining the fisheries habitat of interest and becomes the baseline for future analysis and studies.

Our prototype evaluation is in Estero Bay, along the central California coast, where we collected multibeam soundings and sidescan sonar images. These data are used to characterize significant rockfish habitats that are useful for evaluating and managing a declining regional fishery. Of particular significance is imaging of a

fault scarp interface and bedrock pinnacles that tend to attract fish. The methodologies and technologies used in this study are readily adaptable to the investigation of fisheries associated with reefs and other tropical environments that are of concern to SOPAC member countries. In addition, the procedures outlined in the poster can be used to define and evaluate coastal, nearshore and deep-water geohazards.

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Dealing with volcano crisis: lessons from Ruapehu and Rabaul

BJ Scott , M Kozuch

On 18 September 1995 a major episode of phreatomagmatic eruptive activity commenced from Crater Lake, Mt Ruapehu. Large explosions expelled the crater lake, producing lahars through skifields and an eruption plume over 10 km high. New Zealand's newly introduced volcano alert system received its first significant test. The system worked, but we also learnt some important lessons that may be of value to other nations with potential volcano problems.

In November 1994 the NZ Ministry of Civil Defence introduced a new annexe entitled 'Volcanic Impacts' into the National Civil Defence Plan. This was based on a five-level volcanic alert system that encompassed both reawakening volcanic centres and historically frequently active volcanoes. Minor eruptive activity at Ruapehu volcano from December 1994 to April 1995 highlighted several interpretation problems with this alert system, and a revised alert system (Table 1) was enacted in August 1995, fortunately before significant eruptive activity commenced.

The revised Volcanic Alert system is based on 6 levels and has two separate schemes that clearly differentiate between frequently active volcanoes like Ruapehu and White Island and reawakening activity at a dormant volcanic centre like Taupo or Auckland. This revised system worked well during the 1995 and 1996 eruption episodes, by producing a uniform platform for central and local government to focus their response upon. It has also provided a platform for critical industries/services and the public to react to.

A comparable volcanic alert system was also used very successfully during the 1994 eruptions of Rabaul volcano in Papua New Guinea. These two examples show that volcano alert systems are a useful part of hazard-management systems and should be adopted in all areas with potential volcanic hazards. There is also potential for these to be aligned with other warning systems like those for tropical storms, hence reducing the possibility of confusion during their use.

Scientific Alert Levels

Frequently Active Cone Volcanoes

Reawakening Volcan

White Island, Tongairo, Ngauruhoe, Ruapehu		SCIENTIFIC ALERT LEVEL	Kermadecs, Northland, A Okataina, Taupo, Taranak
Scientific Interpretation	**Phenomena Observed**		**Phenomena Observed**
Usual dormant, inter-eruption or quiescent state.	Typical background surface activity; seismicity, deformation and heat flow at low levels	**0**	Typical background surface activity; seismicity, deformation and heat flow a low levels
Minor phreatic activity	Departure from typical background surface activity.	**1**	Apparent seismic, geodetic thermal or other unrest indicators.
Significant change in level or style of ongoing eruptive activity.	Increase from low level of eruptive activity, accompanied by changes to monitored indicators.	**2**	Increase in seismicity, deformation, heat flow and/ other unrest indicators.
Significant local eruption in progress.	Increased vigour of ongoing activity and monitored indicators.	**3**	Commencement of minor eruptions at reawakening vent(s). Relatively high and increasing trends shown by unrest indicators.
Hazardous local eruption in progress.	Significant change to ongoing activity and monitoring indicators.	**4**	Establishment of magmatic activity at reawakening vents(s), with acceleration unrest indicators.
Hazardous large volcanic eruption in progress.	Destruction within the Permanent Danger (red) Zone. Significant risk over wider areas.	**5**	Destruction within the Permanent Danger (red) Zone. Significant risk over wider areas.

People at risk in Pacific cities

Graham Shorten

The *Pacific Cities* project was started on a limited budget in 1996 as a long-term, strategic program to produce a total hazard and risk assessment of major Pacific conurbations. It is now approaching maturity in some of those cities where it is possible to predict how and where the health and livelihood of people are at placed at risk from a variety of hazards.

In the most advanced city in the program, Suva, for example, the structure of every building has been individually assessed to determine how it will respond during earthquake, cyclone or flood, and the census results for individual enumeration areas of around 100 households have been tied to this information. In the down-town commercial and industrial area, a more detailed and specific survey again has determined how many people occupy each floor of every individual high-rise building, both during and after working hours. A digital terrain model and orthophoto of the city enables the determination of the height above mean sea level of the floor level of every building. Accordingly, the amount of damage that might occur and the number of people affected in any flooding event such as a storm surge can be readily calculated, and appropriate planning and rescue efforts can be set in place.

The location of community centres and medical facilities to deal with such emergencies, and the locations of open spaces or school buildings to which evacuees can be directed, as well as the state of the evacuation routes to those centres, are all available for planning purposes.

In five cities (Suva, Port Vila, Honiara, Nuku'alofa and Apia), the project has produced seismic microzonations which predict in detail how various classes of building will respond. Given an earthquake of a certain intensity, buildings of a given structure and situated in an appropriate zone can be expected to respond in a manner which might, in the worst case, result in partial or total collapse. By coupling the information available for the structure and occupancy of high-rise buildings, it is possible to predict scenarios encompassing the numbers and locations of people trapped or injured in any particular building. Rescue efforts in the recent Turkey earthquake of August 1999 were severely hampered by the absence of such details on the numbers trapped in collapsed buildings.

The methodologies for determining the level of risk for inhabitants of Pacific cities have been developed, and the speed with which they can be implemented, given appropriate support, has been demonstrated. The most pressing need now is to advance all the current participant cities to the same level, and then to fully implement an ongoing and sustainable project within each of the countries involved. For this to occur, dedicated funding and support is required from donors and countries alike.

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The Laser Airborne Depth Sounder (LADS)
A Broad Range of Applications

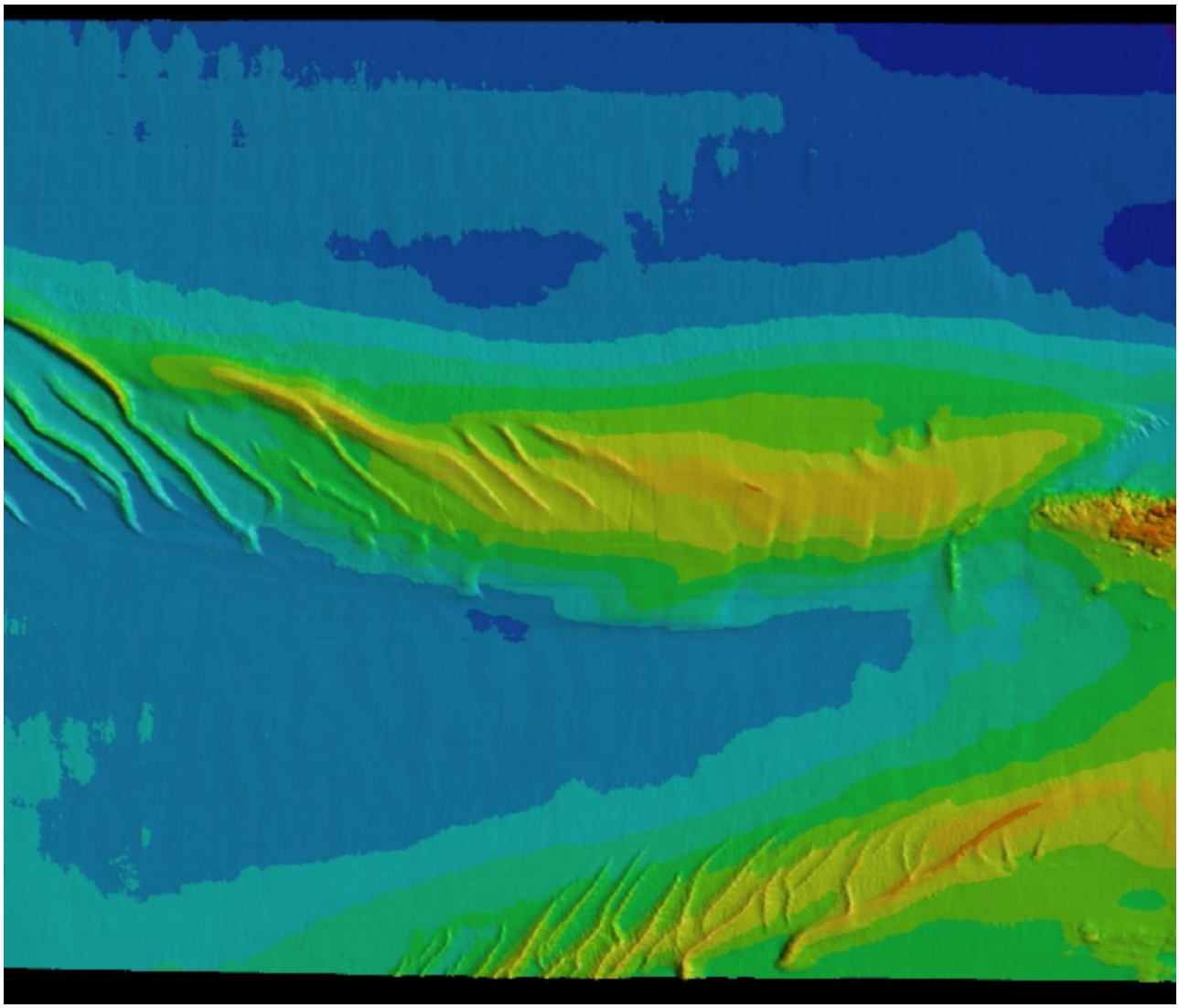
Commander Mark Sinclair RAN (Ret)

Hydrographic survey using airborne laser systems has increased the quality and efficiency of shallow-water surveys for a broad range of applications.

The RAN (Royal Australian Navy) LADS system commenced survey operations in 1993, and since that time has surveyed more than 60 000 square kilometres of Australia's poorly charted and complex continental shelf, at an average rate of over 10 000 square kilometres per annum. It has been proven to be a fast, accurate and cost-effective bathymetric survey tool for hydrographic survey for nautical chart production.

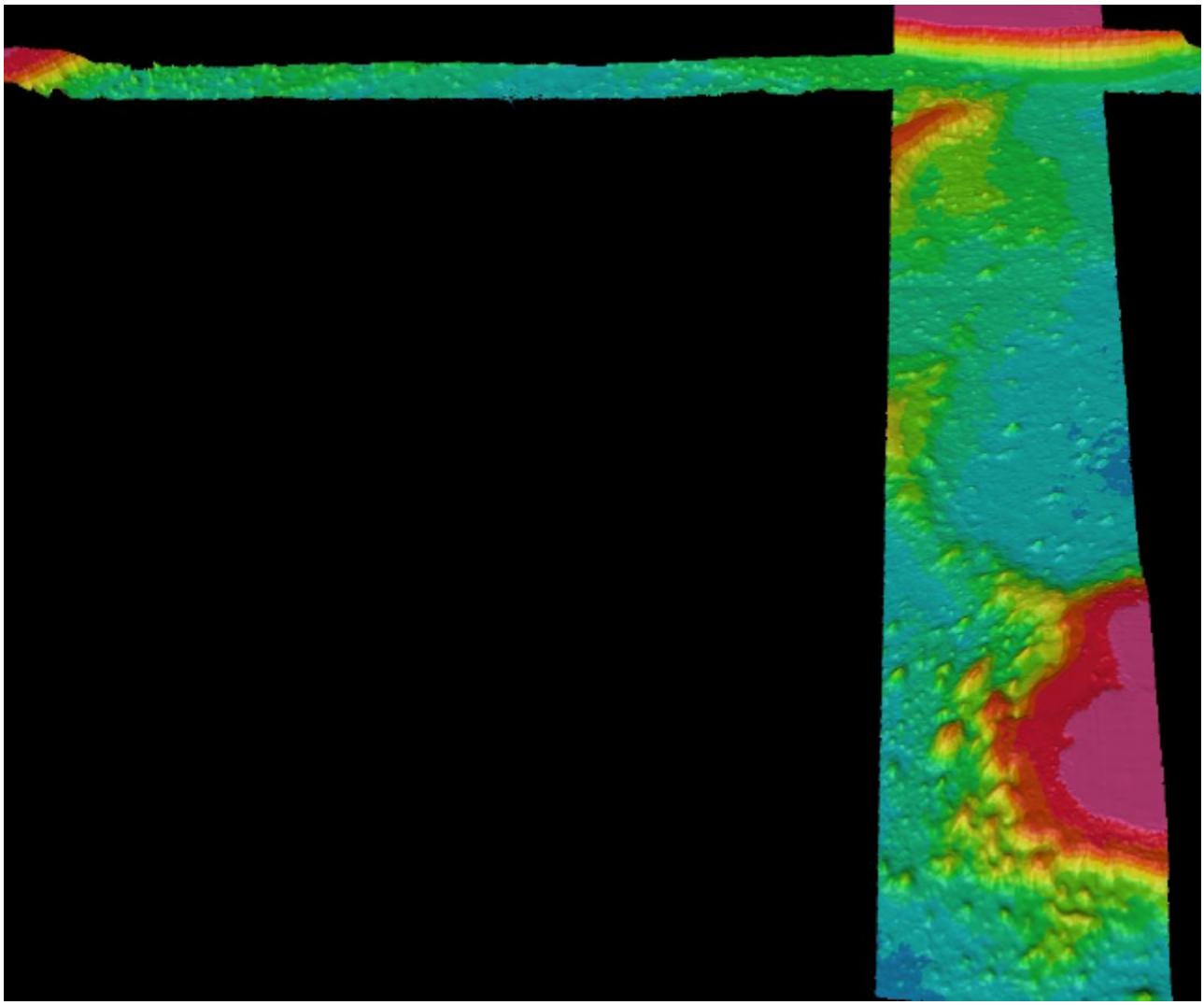
In 1998, the LADS Mk II system also entered operational service. This system incorporates significant technical upgrades to meet government and industry needs in terms of greater speed, increased depth capability, improved accuracy to IHO Order 1, higher data density and greater flexibility with the capacity to work in a wider range of environments. The LADS Mk II system has conducted a number of commercial hydrographic surveys for nautical charting, EEZ delimitation and mapping, marine resource management and oil and gas exploration. These surveys have been conducted in a wide range of conditions such as in the Norwegian Sea and the Skaggerak, the Timor Sea, Great Southern Ocean and the Australian Antarctic Territory.

The survey planning and data-processing requirements for LADS surveys have evolved as a result of the huge RAN LADS output and the differing requirements and survey standards of LADS Mk II contract survey customers. These challenges have required continued improvements in survey planning, data collection, data processing, data validation procedures, quality control, data output formats and data visualisation.



LADS data can be used for many applications

LADS is an ideal system to rapidly and accurately survey poorly charted coastal areas where numerous hazards exist.



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Implementation of multibeam surveying capabilities at SOPAC: the process, surveys and results to date

Robert Smith

In March of this year SOPAC took delivery of a RESON 8101 multibeam profiling system. The 8101 is a 240 kHz system with a 150-degree swath coverage and has a maximum range of 300 m. Following sea trials and training in Suva, five surveys have been completed in Fiji, Vanuatu and New Caledonia. Program areas covered include sand resources, disaster-related issues, hazards and infrastructure development, thus illustrating the diversity of applications for multibeam surveys. The portability and ease of mobilization of the system on vessels when opportunities arise unexpectedly is impressive. In two recent surveys, single-channel seismic profiling has been run simultaneously with the multibeam system, also illustrating the value of combined data sets in the context of evaluating the environment.

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Earthquakes – sliding – tsunami: investigations at the continental slope, Middle America Trench and Cocos-Plate off Nicaragua, following the tsunami earthquake of 02 September 1992

Spangenberg, T. & Mrazek, J.

Scientific background, aims and working tasks
On 2 September 1992 an earthquake of magnitude 7.5 occurred in front of the Pacific coast of Nicaragua. From numerical simulations, based on the earthquake source parameters, Tsunami heights up to 2 m were expected. In nature the tsunami heights reached up to 10.0 m above sea level at El Transito. The geophysical data can´t explain this difference at all, that's why gravitational mass movements are proposed. Therefore one of the main tasks of the PACOMAR 3 (Pacific Continental Margins) research project is to analyse the sediment bedding conditions as well as detailed bathymetric mapping to get information about possible gravitational mass movements. The aim of the analysis is to reconstruct the spatial and temporal conditions before and after the significant and strong tsunamigenic earthqakuake. This should lead to an estimation of gravitational mass movement effect on the generation of the tsunami.

Sampling position
During the SO 107 research cruise in April 1996, detailed bathymetric mapping of the working area off Nicaragua was the first task. After processing of the map, the sampling positions were fixed in relation to the landslide scars. The coring positions can be combined to one profile at 1000 m water depth and a profile at 2000 m water depth above the scars, as well as a profile in approximately 4000 m water depth beneath the scars. The sediment fill of the Middle America Trench and the sediment cover of the Cocos-Plate were sampled with ever one core. The stations at the upper part of the continental slope were sampled by box corers and the other stations by piston corers (see Poster for sampling positions and morphological features of investigation area).

Analysing methods
Altogether 50 m of hemipelagic and pelagic sediments was sampled. The analyses were concentrated on investigations of sedimentological, physical and geochemical properties. All the cores were first examined by X-ray radiography to get information about sedimentary structures and bedding conditions to determine sampling positions. After that the following analyses were executed during the last 2½ years: - granulometric analysis, grain-size distribution, physical properties (e.g. water content, bulk density, grain density, dry density, porosity, shear strength and magnetic susceptibility; also
- loss on Ignition (at 550° C and 1000° C);
- total carbon, total organic carbon, total inorganic carbon, carbonate;
- 14C-AMS age-determination measurements (14 samples);
- X-ray diffraction analysis;
- depth determination using associations of benthic foraminifera (mostly by Dr. Kreisel); and
- modeling of slope stability.

Discussion and interpretation of results
The sediments of the upper continental slope cores can be generally classified as mud. Sedimentary structures other than bioturbation can not be identified. The sedimentation rate at this part of the continental slope can be estimated at 3-4 cm/1000 years. The calculated slope stability shows that an earthquake of magnitude <3 will be enough to initiate mass relocations. The investigation area off Nicaragua has a great natural seismicity with an earthquake occurrence (M <3) nearly every week. That´s why it´s possible to say that the sediment bedding conditions are very unstable. The long sediment cores (up to 13,5 m) beneath the slide scars have different features. Sediments of the core 34 KL were relocated by one great catastrophic debris flow event. The movement initiation was probably by an earthquake, supported by processes of conversion of gas hydrates and/or pore-water gases. From the comparison of older bathymetric data of the area (rare and of bad quality as well as post resolution), this remarkable slide scar can be connected with the September 1992 earthquake. The other cores at the lower continental slope show typical turbidity features, e.g. parallel lamination, gradational bedding and fining-upward sequences. Many mass-movement events have built up a large accumulation complex at the base of the continental slope (see Fig.). From the sedimentary structural features it´s not possible to reconstruct the number of events. It´s remarkable that the core 39 KL has fewer turbiditic features and more sediments which can represent normal hemipelagic sedimentation. The sediments of the MAT are clayey in the upper part und silty in the lower part. In evaluation of all analysed parameters, it seems clear that the upper part is relocated from continental slope and the lower part represents pelagic sediments from the Cocos-Plate. A second main effect of this work is the first identification of structural-geological features in the subduction area. They will have an effect on a new understanding of the subduction process off Nicaragua. In the Figures (see Poster) the influence of seamounts for the sediment layering and (proposed) for the subduction and seismicity is to be seen. A new fault zone, situated westerly of the ragged seamount on the Cocos-Plate was also investigated for the first

time. This structure may be the reason why the earthquake did not have such a strong influence on the easterly parts of the continental slope. As a short conclusion, it can be said that the 1992 Nicaraguan earthquake caused large gravitational mass movements (>17 km^3 mass volume). They should have had an influence on the generation and wave height of the tsunami, but from this investigations it´s not possible to calculate the intensity of influence.

Acknowledgement:
Thanks for the Sponsorship of the Federal Ministry for Science and Technology (BMBF, 03 G 0107 B).

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Changing influences on sedimentary basin development during the breakup of an oceanic island arc system: the Late Miocene to Pliocene record from Viti Levu, Fiji Islands.

James M. C. Stratford

The Fiji Platform provides an excellent record of the contrasting influences of tectonic, volcanic and eustatic processes on the development of the stratigraphic record during the break-up of an oceanic island arc. Late Miocene (post Tuva Group) sedimentation on Viti Levu commenced at around 7.5-7 Ma, following a major deformation event that affected all previously formed units. Four major areas of Late Miocene to Early Pliocene sedimentary basin development are presently recognised on Viti Levu. The major influence on sedimentation at this time was initially tectonic, and associated with the rotation of the Fiji Platform in response to continued breakup of the Vityaz arc and opening of the North Fiji Basin. Basins formed at this time continued to be centres of sedimentation for the next 1½-3 Ma.

Volcanism began to play an increasingly important role in basin filling from around 6.5 Ma, with intra-basinal volcanism recorded in a number of areas. Volcanic activity eventually dominated the stratigraphic record across the north of the island from about 5.6 Ma. This resulted in a reduction in the volume of clastic basinal sediments, and an increase in rocks derived directly from the volcanic edifices. By the beginning of the Pliocene, sedimentation in the north had effectively been halted, or reduced to smaller inter-volcanic basins, by the increasing volcanic activity. Basinal sedimentation continued in areas further from the locus of volcanism (southern Viti Levu). It is in these sequences that the effects of eustatic change, such as the global event across the Miocene-Pliocene boundary, are most easily recognised.

After about 3.5 Ma, retreat of the Fiji Platform away from the Vityaz arc significantly reduced the direct influence of volcanism on basin development. From this time, uplift associated with retreat became the major influence on basin evolution. Uplift of what became Viti Levu severely curtailed sedimentation in the remaining active basins, and resulted in the very poor Late Pliocene sedimentary record presently observed across Viti Levu. Offshore sedimentation would have been quite significant at this time. Sedimentation on Viti Levu during the Quaternary was relatively restricted and would have been mostly influenced by eustatic events.

The early (post-Tuva) basin development on Viti Levu is dominated by tectonism, with volcanic activity gradually becoming dominant. Major global eustatic changes at this time are only easily seen in areas away from the immediate influence of volcanism. As the platform moved away from the active plate margin into an intra-plate position, tectonic (uplift) and finally eustatic changes became the dominant influence on sedimentation on Viti Levu.

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Geological results from offshore surveys of the Papua New Guinea tsunami source region

David Tappin, Takeshi Matsumoto, Philip Watts, Masafumi Masayama, Gary McMurtry, Yves Lafoy & shipboard party

To further elucidate the source of the devastating tsunami that struck the north coast of Papua New Guinea in July 1998, two offshore surveys took place in early 1999. The surveys were carried out by vessels of the Japan Marine Science and Technology Center (JAMSTEC) in collaboration with the South Pacific Applied Geoscience Commission (SOPAC) and Papua New Guinea (PNG). They reveal a complex, tectonically active convergent margin offshore of northern PNG. The inner trench wall is actively subsiding, as evidenced by oversteepened slopes and numerous faults with sharp scarp faces, that displace both superficial sediment and basement. Deeply incised submarine canyons suggest that sedimentation rates are low. Sediment cores reveal homogeneous biogenic mud that is normally consolidated and highly cohesive. The

cohesive sediment fails retrogressively along rotational shears, with the shear planes nucleating along faults. Offshore of the Sissano lagoon there is an arcuate amphitheatre that has been formed by submarine slumping. It is this feature that has been identified as the probable source of the 1998 PNG tsunami. Within the amphitheatre, seabed imaging by a Remotely Operated Vehicle indicates recent seabed movement in the form of fissures, brecciated sediment and fresh deposits of rock talus. Major reverse faulting was not observed.

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Mitigation strategies for Pacific Rim tsunamis

David Tappin, Costas Synolakis, Philip Watts

Two weeks after the 1998 PNG tsunami, an International Tsunami Survey Team visited PNG. On the basis of their examination of the devastated area, the team provided suggestions for future tsunami hazard mitigation that included:

1) the building of memorials at the sites of previous tsunamis to discourage future habitation;
2) keeping community facilities 400-800 metres from shore;
3) organizing evacuation drills on anniversaries of events;
4) establishing vertical evacuation routes;
5) the education of residents about ground motion, sea withdrawal and their likely associations and consequences;
6) the advice that tree groves can protect coastal communities; and
7) the advice that most coastal debris becomes projectiles during a tsunami.

However, it is recognised that these suggestions contain at least three problems:

1) resettlement of coastal populations is not always feasible or desirable;
2) some coastal populations choose to reside along vulnerable coastlines despite a history of tsunami attack; and
3) there is a wide distribution of tsunami vulnerability, and the rewards from mitigation efforts accrue foremost along the most vulnerable stretches of coastline.

It is concluded therefore that future tsunami-hazard mitigation strategies will benefit most from an evaluation of tsunami exposure, probability, and vulnerability.

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Volcanism on Savai'i: the risk from future activity

Paul W Taylor & Lameko Talia

The island Savai'i is the largest and westernmost of the Samoan archipelago and is the home for 50 000 Samoans living in villages located around the coast. Savai'i is a mature volcanic environment, but exhibits the features of recent "monogenetic" volcanism. Geological studies conducted on Savai'i suggest that volcanism has been occurring more or less continuously since at least Pliocene times. It was suggested that two volcanic episodes have occurred during the development of Savai'i. The initial episode, the "shield-building phase", produced the basal lava shield during Pliocene to early Pleistocene times. Following a period of relative quiescence during the early to mid-Pleistocene the "post-erosional phase" has produced a sequence of lavas and pyroclastics that overlie the marked erosional boundary. This phase of volcanism has continued during recent times. The most recent eruption occurred during 1905-11 and resulted in the destruction of large areas of arable land and a number of villages located along the northeast coast.

A volcanic hazard assessment conducted by the authors has concluded that activity is likely to continue. Future eruptions will be effusive (lava forming), explosive (tephra forming) or a combination of both. Because of the lack of comprehensive chronological data for eruptions prior to the mid-1700s, it is difficult to forecast when future eruptions will occur. Furthermore, because of the "monogenetic" nature of the volcanism it is also difficult to forecast where future vents will form.

A preliminary volcanic-hazards map has been constructed using the spatial density of prehistoric and recent vents. The hazard zones shown thus define the relative probability of a vent erupting in that zone. However, because of the possibility that a vent may erupt anywhere on Savai'i, the entire island must be considered

vulnerable to the hazards associated with future activity. The likely hazards include: lava flows, pyroclastic flows/surges, lahars, tephra falls, volcanic gases, ballistic ejecta, lightning and volcanic edifice collapse.

The products that compose large volcanic islands such as Savai'i are inherently unstable. A number of volcanoes in the Pacific region may have experienced large-scale collapses. Collapse may or may not relate to eruptive activity, and commonly occurs along major zones of structural weakness, eg. along major fault zones. Events such as earthquakes or the intrusion of magma into the edifice can act as triggers to collapse. Large-magnitude collapses above and below sea level are capable of generating regionally destructive tsunamis. On Savai'i, the *Ologogo Fault System* is a major zone of potential weakness on the northwest slopes, where movement on a large scale could occur. Although movements along the system have not been reported during recent times, it should still be treated as a site of potential slope failure. Such an event will have effects that reach far from Savai'i itself.

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Stream water resources in Fiji and the impact of El Niño

James P. Terry & Rishi Raj

Over the last twenty years, Fiji has experienced severe seasonal rainfall failure on five occasions – 1978, 1983, 1987, 1992 and 1998. Each of these years corresponds to strong El Niño events, as measured by persistent negative values of the Southern Oscillation Index. The 1998 drought was the harshest to afflict Fiji since rainfall records began some 100 years ago, and has therefore been described as a 1-in-100-year event.

The flow behaviour of streams is a useful indicator of drought in Fiji, with several advantages over rainfall figures:

1. stream flow reflects (antecedent) precipitation over an entire drainage basin, integrated by the physiographic, geologic and hydrometeorological features of the region;
2. streams indicate actual surface water availability since they are the principal water resource;
3. during prolonged dry spells, streams are fed by sub-surface flow, and thus show the extent of soil moisture deficit and depletion of the water table.

This talk describes hydrological investigations of Nakauvadra and Teidamu Creeks, which drain two small catchments (38 and 56 km^2) in the leeward north and west of Fiji's main island, Viti Levu. It is seen that El Niños cause very low stream baseflows during the dry season, manifesting acute surface and groundwater shortages. Some years have heavy rainfalls from tropical cyclones in the wet season prior to full El Niño conditions, but this moisture is lost from the terrestrial system as rapid runoff, and does not compensate for rainfall failure in later months. In the future, droughts in Fiji may be better understood, and more effectively managed, if stream hydrological response to a developing El Niño is considered in addition to climatic variables and patterns.

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Development of a collaborative Disaster Research Program

Craig Veitch & Ken Woolfe

Preamble

This paper outlines a proposed disaster research program in North Queensland, which may also be applicable in other areas of the SW Pacific. The proposed program will use assessment of natural processes, together with data on health and well-being collected from individuals involved in the same event in order to assess short- and medium-term needs.

A feature of the program will be the development of a team that could be deployed at short notice to the disaster site, so as to collect data as soon as possible after the event. The team will include members with specific expertise and knowledge about the particular natural process involved (e.g. cyclone, earthquake, flooding), others with an understanding of disaster-related health issues, and still others with interviewing/surveying skills to collect first-hand accounts of the event's progress, as well as information about community resources, particularly those destroyed in the event.

Program Plan
The program has been established with internal funds provided by the North Queensland Clinical School and the School of Earth Sciences (JCU). The first tasks will be to develop data-collection plans and methods, a pilot study and extensive literature review of natural hazards and disaster study programs around the world. The principal investigators will develop a study plan and method to pilot test during a 'local' disaster caused by natural processes. The Plan, following the broad form outlined above, will include data collection kits and methods appropriate to each type of natural process and cultural group.

Aim
The aim of the program is to integrate research and feedback on the natural processes leading to the disaster and the immediate, medium- and long-term impacts of these on the health and well-being of people in the disaster region.

Outcomes/Benefits
The collection of process- and health-related data will provide a better understanding of the links between cause and effect in communities in regions prone to catastrophic natural events.

A secondary benefit will be to assist relief agencies to provide the most appropriate resources and support, particularly in the medium and long term, as well as providing (immediately collected) information that may be important in post-disaster inquiries.

The paper focuses on the issues of developing an interdisciplinary collaborative program, particularly the need for and development of mutually consistent terminology, and the need to break through disciplinary boundaries.

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Simulation of the PNG tsunami and hazard assessment of future tsunamis

Philip Watts, Masafumi Masayama, David Tappin, Jose Borrero , Stephan Grilli, Costas Synolakis

Soon after the 1998 PNG tsunami, researchers postulated that it may have been generated by a submarine mass movement. During offshore surveys, a candidate event was in fact located. New bathymetric data have enabled numerical simulations to reproduce the observed longshore distribution of runup, but not the measured tsunami amplitude. A novel simulation technique reproduces all gross features of the PNG tsunami by:
1) considering the local geology and soil mechanics;
2) estimating the slump dimensions;
3) calculating the center of mass motion;
4) simulating tsunami generation with full fluid dynamics; and
5) propagating tsunami waves with a depth-averaged inundation code.

This technique reproduces the correct tsunami amplitude. We will examine the effect of source location on wave focusing in front of Sissano Lagoon by moving the source by 10 km in either direction. Applying this procedure to different potential slump locations suggests wave focusing in places other than in front of Sissano Lagoon. Given the apparent frequency of tsunamis in the Sissano area, identifying vulnerable sections of coastline can help mitigate the impact of future events.

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Case studies of Pacific Rim tsunamis generated by underwater landslides and slumps

Philip Watts, Jose Borrero, David Tappin, Stephan Grilli

Suva, Fiji; Kalapana, Hawaii; Flores, Indonesia; Nicaragua; Mindoro, Philippines; Kamchatka, Russia; Sissano, Papua New Guinea. These places all share a common legacy: exceptionally large tsunamis have struck soon after some form of mass failure. We will begin by examining the dependence of these tsunami events on mass failure. We will then estimate the frequency of these tsunamis across the Pacific Basin. We will also provide a probability distribution of tsunami amplitudes from mass-failure events. The amplitude of tsunamis generated by mass failure can be many times greater than those generated by coseismic displacement, the common manner in which tsunamis are generated. These also tend to be local tsunamis that strike a shoreline soon after a triggering event such as an earthquake. This work will show that the size and period of tsunamis generated by different mass-failure scenarios can in fact be predicted. When

combined with knowledge of the regional geography, these predictions provide cost-effective tsunami hazard-assessment opportunities.

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Hotspots, crackspots, and jerks: linking intraplate volcanism to plate motions.

Paul Wessell & Loren W. Kroenke

Ever since Morgan (1971) first formulated the hotspot hypothesis, the most common interpretation of intraplate volcanism has been that most of it is hotspot related, caused by the ascent of deep mantle plumes. This interpretation, however, has not been without its skeptics. For example, Sykes (1978), while accepting a hotspot origin for seamount chains that appear to have a simple space-time migration pattern, such as the Hawaiian-Emperor chain, considered many hotspots to be merely passive features that owed their existence to a favorable orientation of the stress tensor to preexisting zones of weakness on the seafloor.

Recent studies have cast further doubt on a singular origin for all intraplate volcanism. Winterer and Sandwell (1987), for example, suggested that the cross-grain ridges in the Central Pacific were the result of the formation of tensional cracks in the Pacific plate. Sandwell et al. (1995) added the Pukapuka Ridges to this category of intraplate volcanism, concluding that diffuse extension was responsible for the formation of both ridge systems. Wessel et al. (1996), noting that these ridges have radiometric ages that correspond well to documented changes in Pacific and Indo/Australia plate motions, suggested they formed in response to intermittent plate-boundary stresses. Anderson (1995) even argued that deep mantle plumes are an unnecessary explanation of hotspot activity.

Although it now seems apparent that the bulk of some volcanic chains such as the Hawaii and Louisville chains originated over stationary or fixed hotspots, it is not so apparent that all other chains have the same origin. In fact, if the new plate motion model (WK97) proposed by Wessel and Kroenke (1997) is correct, then much of Central Pacific volcanism may not have a hotspot origin at all. Indeed, differential motion vectors, i.e., the difference between the absolute plate motion vectors before and after the change in plate motion (used here as a proxy for instantaneous stress at the time of the change), appear to be aligned roughly perpendicular to intraplate volcanic ridges of the same age.

We suggest that most, if not all, intraplate volcanism may involve one of two end members: volcanism that is (1) initiated by plumes (hotspots) or (2) caused by decompressional melting of the upper mantle along tensional cracks in the overlying lithosphere (crackspots) formed during rapid changes in plate motions (jerks), or even some form of mixing between them (a jerk occurring during a time of low volcanic flux, permitting the surfacing along a crack of some of the limited accumulation of hotspot magma). Both end members also could be contaminated by MORB if located near a spreading ridge. Hotspots that appear to be relatively fixed and long lived such as Hawaii, Louisville, Caroline, Cobb and, perhaps, Bowie are considered to have a plume origin. Others, like much of Central Pacific volcanism, may have a tensional crack origin. Some, such as the Foundation Seamounts, may be transitional between hotspot and crackspot volcanism.

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Recharge of fresh groundwater lenses: field study, Tarawa Atoll, Kiribati

I. White, A. Falkland, B. Etuati, E. Metai, T. Metutera

Freshwater is limited in small, low, coral islands, where shallow groundwater lenses are the principal source of potable water in dry periods. Sustainable extraction from freshwater lenses is governed by the fraction of rainfall recharging the groundwater. Recharge is difficult to estimate accurately because the amount of rainfall intercepted by tropical vegetation, and losses by evapotranspiration from the soil and from shallow groundwater have not been measured on low coral atolls. This UNESCO-SOPAC-initiated study aimed to quantify these recharge and loss processes. Bonriki island, Tarawa Atoll, Republic of Kiribati, was chosen for the study. The Bonriki groundwater reserve supplies water to about 30 000 residents in South Tarawa, over one third of the population of Kiribati.

Novel features of this work were the measurement of throughfall and stemflow, the estimation of interception losses of coconut palms, and the direct measurement of both transpiration by coconut palms and changes in the soil water store in the top 0.7 m of the profile. These were coupled with measurements of the climatic

drivers of evapotranspiration, the watertable height and the thickness of the freshwater lens. To estimate potential evapotranspiration, windspeed, air temperature and humidity, atmospheric pressure, solar radiation, soil moisture to 0.7 m, groundwater elevation and sap flow velocity in coconut palms were recorded at 15-minute intervals for the duration of the study. Salinity-monitoring boreholes were used to estimate the freshwater lens thickness. Analyses of groundwater chemistry were also conducted and profiles of the heavy isotopes ^{2}H and ^{18}O were measured.

It was found that throughfall varies dramatically beneath the coconut palms both spatially and temporally. Close to the crown of coconut palms, throughfall is, on average, 68% of daily precipitation. During heavy rains, the palm crowns concentrate throughfall up to 2.7 times incident rainfall on the palm and, in straight palms, stemflow of 31% of the daily precipitation. On average, the interception store of the crown is 5 mm and fronds have a 0.7-mm store. Interception losses by the crown of coconut palms is, on average, 1% of daily precipitation. Since the Bonriki reserve has only 20% palm coverage, the average interception losses are as low as 7% of rainfall.

The mean daily potential evapotranspiration rate was 3.9 mm/d. Coconut palms were found to transpire about 4 mm/d, close to potential evaporation, independent of soilwater and driven by solar radiation. For the estimated 20% palm coverage, this amounts to 0.8 mm/d losses and seems to be supplied directly from the fresh groundwater. This rate is comparable with the extraction due to pumping of 1.4 mm/d.

Soil moisture monitoring showed very rapid responses to rainfall and drainage, and revealed that soil evaporation took place from the top 0.5 m of the profile. Soil moisture probes at 0.7 m depth identified recharge events during intense rains which were confirmed with watertable height measurements. Water tables show rapid responses to rainfalls in excess of 50 mm/d. Isolated rainfall events of less than 20 mm/d did not recharge the freshwater lens in dry periods, and the non-drainable daily soil-water store to 1.0 m was estimated to be 130 mm.
Estimates from the soil probes showed that soil evaporation decreased as the square root of time following rainfall. Estimates of soil evaporation from rainfall which did not cause recharge yielded soil and interception losses of 1.7 mm/d. These estimates together with the interception and coconut palm losses provide estimates of the mean daily total evaporative losses of about 2.5 mm/d, which is about 2/3 of potential evapotranspiration.

Watertables showed tidally forced fluctuations, independent of position and with a mean tidal efficiency of 5%. It was found from the watertable response that the maximum drawdown due to groundwater pumping from infiltration galleries was less than 20 mm. This is 1/5 the diurnal tidally forced watertable fluctuation of approximately 100 mm. A simple analysis of watertable elevation at the centre of the freshwater lens suggests a mean annual recharge rate of 860 mm/y. A chloride tracer technique finds an average annual recharge of about 690 mm/a. Heavy-water isotope ^{2}H and ^{18}O concentrations in the upper freshwater portion of the freshwater lens were close to the tropical meteoric line, revealing no significant direct evaporation losses from groundwater. Salinity-monitoring boreholes showed that the maximum thickness of the freshwater lens decreased by 1.0 m during the study. This is equivalent to average losses of 2.4 mm /d. Taking into account extraction, this shows groundwater losses of 1.0 mm/d, close to what was found for the coconut palm groundwater use.

Based on these results, a simple daily water-balance model (see Figure) was constructed which estimated interception, soil evaporation and groundwater transpiration losses and changes in soil moisture storage. During the study period, estimated total evapotranspiration losses were 2/3 of potential evaporation, suggesting that equilibrium evaporation may be a more appropriate upper bound for small, low islands. Recharge of the freshwater lens was estimated to be 102 mm, only 17% of the total rainfall of 603 mm, and only occurred after intense rainfalls in excess of 50 mm/d at the end of the study period. The model can be used to estimate mean annual recharge rates and the effects of management strategies.

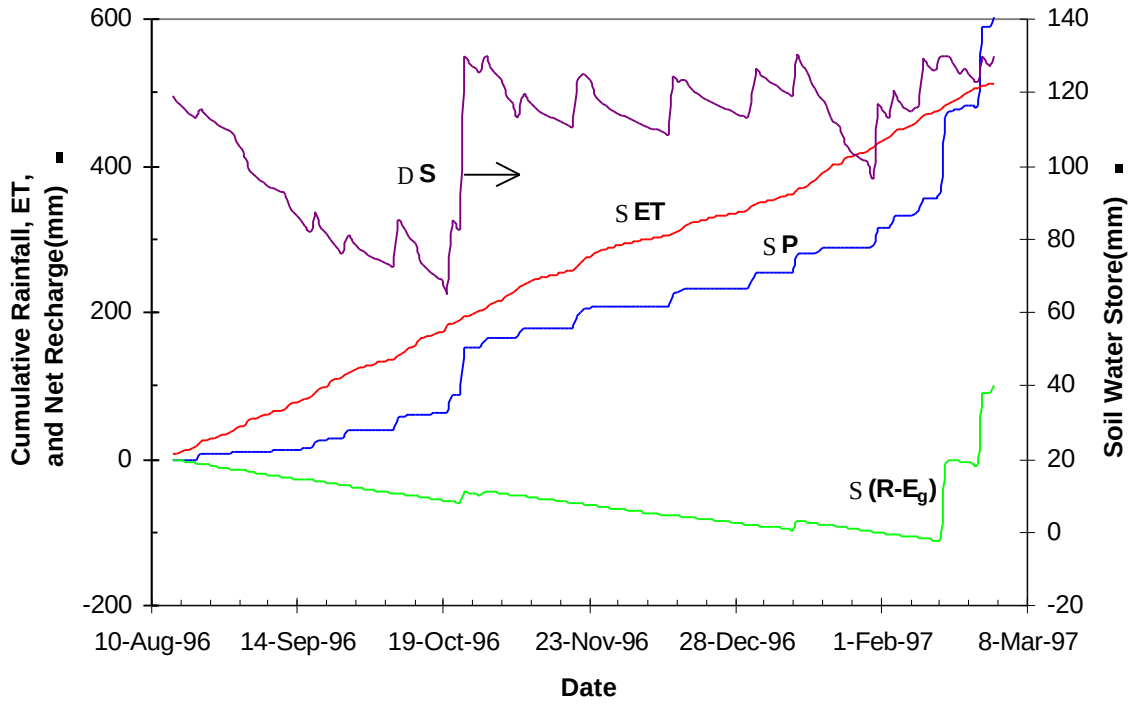

Figure: Daily water-balance components (excluding groundwater pumping) for the study period showing measured cumulative rainfall, ΣP, change in the soil water store to 1 m, ΔS, evapotranspiration losses, ΣET ($=\Sigma[E_i + E_s + E_g]$), and net recharge, $\Sigma(R-E_g)$.

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Detrital gold survey – Nasivi Delta, Tavua, Fiji

H.L. Wong, Jackson Lum & Giovanni Ricci

The primary objective of the Detrital Gold Resources Survey was to assess the placer gold potential in the sediments of the Nasivi Delta, particularly the gravel beds, with a view to drilling later in the year. The Nasivi Delta is the repository of sediments deposited by the Nasivi River system that drains the Tavua Basin, host to the Emperor gold mine. An EM Survey and resistivity depth profiles were conducted in the Nasivi basin. A total of five lines were run in an east-west direction for the EM survey and twenty-one resistivity depth profiles were surveyed. Five holes were also augered to locate gravel beds where gold was expected to concentrate, and also to help define the lithological boundaries between different resistivity layers. The survey shows that a combination of the two geophysical methods can be successfully used to define the different lithological boundaries based on conductivity or resistivity of the substrate. In this area, in most of the resistivity depth profiles four units of varying thickness and resistivity (conductivity) are calculated using the RINVERT forward-modeling method. The areas of low conductivity (sand/gravel) are the prospective areas for gold accumulation and are chosen as the target areas. Seven such target areas have been identified from the survey. The extent of the target areas can be further defined by more-detailed geophysical work and also by drilling. Plans to drill the seven target areas using a portable drill should be considered by MRD and SOPAC for later in the year.

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From Government prevention to community preparedness: shifting the culture for flood damage reduction, Ba, Fiji

Stephen W. Yeo

Flooding in January 1999 caused direct damages of at least $25 million to the commercial and industrial sectors of Ba and Nadi Towns on Viti Levu, Fiji. Indirect losses were also substantial – preliminary results

from a survey of Ba's proprietors indicate that an average (median) 14 days production/ trade was lost during the clean-up and re-stocking phases. At Ba, the 1999 event was the third large flood in the space of six years. There, the three floods left a combined direct damage bill of at least $27 million (nett present value) to the commercial and industrial sectors.

Recent emphasis for addressing the flooding problem has been on Government preventative strategies, usually through various engineering techniques. The most visible strategy at Ba has been the Government's dredging operation, which began after the 1993 flood. A recent study by JICA (1998) recommended the construction of artificial levees along the river-banks at Ba Town, and the construction of a large diversion channel to remove the threat of flooding from Nadi Town. Several members of the Ba community have petitioned for a greater investment in structural measures – whether by further dredging, dam construction, diversion of a creek that flows through the town, or the construction of culverts beneath the elevated approaches of a bridge.

Although each of these options has some merit, it is unlikely that floods will be entirely prevented by any of them. For example, the dredging operation is designed to alleviate inundation only for events more frequent than the 1-in-10-year event, but is expected to have minor effect on rarer events like the 1997 and 1999 floods, which followed intense rain (>400 mm/day for some sites) and (in 1997) a significant storm surge. A more subtle limitation of these approaches is that they provide no incentive for self-mitigation of risk. A survey of proprietors after the 1997 flood suggested that the dredging operation had actually been a disincentive for the emergency protection of property, causing unexpectedly high losses (Yeo, 1997).

An alternative approach is advocated in the Ba Town Flood Preparedness Project – a six-month project that began in July 1999 under the auspices of the Australian Youth Ambassadors for Development Program, following four years of doctoral research on flooding at Ba (Yeo, 1998). The project aims to enhance the capacity of the Ba community to anticipate and cope with flood hazards, with emphasis on the commercial and industrial sectors. A key output is the formulation of a proposal for appropriate flood warning systems, which is complemented by an operational support plan. Community flood awareness and education materials are being developed, and a workshop for business proprietors is scheduled. Based on interviews and observations, it is estimated that about $16 million of the $27 million damages from the 1990s Ba floods (or 60%) could be considered *avoidable*. This suggests that a better-prepared community and an improved warning system could result in substantial savings.

A vital aspect of the project is its community focus, not just in working for the benefit of the community, but by involving the community in developing strategies for preparedness. That is not to say that the Government is not or should not be involved in flood preparedness. First, the Fiji Meteorological Service and the Public Works Department (Hydrology) could do much to improve flood forecasting. Second, the Fiji Police Force's infrastructure could be used for real-time rainfall and water-level monitoring and for the dissemination of warnings on a local basis. Another area of Government responsibility is in the review and implementation of land-use and floor-level regulations. The Government also has an important role in planning and implementing public awareness activities.

But a focus only on the various roles of Government ignores the substantial capabilities and resources contained within the community. Particularly where catchment response time is short, experience has shown that it is essential to develop a local flood-warning system. A strong community involvement in system design and operation (perhaps by using residential wardens as key contacts for the dissemination of flood warnings) tends to generate local ownership and better results during emergencies (Keys, 1999). In collaborating with the community and in fostering community initiatives, the Ba Town Flood Preparedness Project entails a shift of emphasis that should result in tangible benefits when next the Ba River floods.

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