ABSTRACTS

of Papers Presented at the STAR* Session 2000

John Collen & Russell Howorth
Editors

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FOREWORD

STAR (SOPAC's Science, Technology and Resources network) was founded in1985 in collaboration with IOC. The first Chair of STAR, Dr Charles Helsley, then Director of the Hawaii Institute of Geophysics, guided STAR until 1992. He was succeeded by Keith Crook from the Hawaii Undersea Research Laboratory. Keith served until the end of 1999 when John Collen from Victoria University became Chair. 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 ENSO Workshop, held in Nadi, from 19-23 October 1999.

STAR meetings are not simply technical conferences at which individuals present scientific papers and discuss their results and implications. Participants have the additional responsibility to formulate advice to SOPAC about its Work 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 and multidisciplinary science and bring it to bear so as to address the national needs of SOPAC's island member countries. The long-established working relationship between SOPAC and the international research community is a vital element in this endeavour, which STAR is charged to nurture. This relationship stimulated an order-of-magnitude change in the geoscience database in the SOPAC region during the 1980's. During the 1990's it supported the changes in SOPAC's scope and focus which are still continuing.

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 2001 Work Program, which all participants should examine, encompasses a broad spectrum of geoscience and related activities focussed on three areas in particular: Resource Development, Environmental Science, and National Capacity Development. SOPAC's past record demonstrates that this approach to program development is synergistic, advancing both the national needs of island nations and fundamental research.

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September 2000

STAR Presentations at SOPAC Annual Session, 2000

PROGRAM

Time	Theme	Authors & Speaker	Title
Tuesday 27th September			
14:30-14:40	**OPENING**		
14:40-15:00	**Energy**	Mario, R.	Energy audit of the South Pacific Applied Geoscience Commission.
15:00-15:20		Prasad, R, & Gonelevu, A.	Evaluation of an energy conservation project.
15:20-15:40		Mario, R.	Efficiency monitoring of solar hot water systems in the Fiji Islands and the Kingdom of Tonga.
15:40-16:00		Matakiviti, A.	The analysis of the Nabouwalu Hybrid Power System in Fiji.
16:00-16:30	**Coffee/Tea Break**		
16:30-16:50		Fairbairn, P.L.	Overview of the Regional Energy Meeting REM 2000 26-26 September.
16:50-17:10	**Hazards**	Tappin, D., Silver, E.A., Sweet, S., Watts, P. & Matsumoto, T.	Morphologic, Visual and Seismic evidence for slumping in tsunami generation: The 1998 Papua New Guinea event.
17:10-17:30		McMurtry, G. M., Tappin, D., Herrero-Bervera, E. & Kanamatsu, T.	Stratigraphic Investigations of Sediments Offshore of Sissano, Papua New Guinea.
17:30-17:50		Moore, A.L., Imamura, F., Matsutomi, H., Synolakis, C., Takahashi, T. & Koshimura, S.	Report on the damage caused by the 26 November 1999 tsunami in Vanuatu.

Time	Theme	Authors & Speaker	Title
Wednesday 27th September			
09:00-09:20		Crook, K.A.W., Riko, N., Felton, A.E., Louise, M. & Francklin, D	Megaclast emplacement and movement on shore platforms: An index of extreme events at the land-sea interface.
09:20-09:40		Hayne, M., & Chappell, J.	Cyclone frequency during the last 6000 years and implications given a greenhouse induced climate : Curacoa island, North Queensland, Australia.
09:40-10:00		Nott, J.,	Long-term records of coastal hazards provide a more realistic guide to the future.
10:00-10:20		Cronin, S., Bebbington, M. & Diew Lai, C.	Probablistic assessment of volcanic hazards on Taveuni volcano, Fiji Islands.
10:20-10:40	**Coffee/Tea Break**		
10:40-11:00		Taylor, P., Scott, B. & Petterson, M.	Submarine volcanic activity in the Southwest Pacific: Examples from the Kingdom of Tonga and the Solomon Islands.
11:00-11:20		Cronin, S., Petterson, M., & Taylor, P.	Community-government-scientist interactions: A volcanic hazard workshop with a difference on Savo volcano, Solomon Islands.
11:20-11:40		Teakle, G. & Biukoto, L. (Presented by G Shorten)	Building damage assessment, Suva, Fiji Islands.
11:40-12:00		Mearns, A.	Disaster Management – Future direction in the South Pacific.
12:00-13:30	**Lunch Break**		
13:30-13:50	**Environmental**	Burke, E. (Presented by P Dawe)	Wastewater management in Pacific SIDS: Wastewater Guidelines.
13:50-14:10		Hobian, T.	Ostracod (Crustacea) populations as environmental tracers: examples from estuaries and lagoons of New Caledonia.
14:10-14:30	**Technology**	Forstreuter, W.	Developments in remote sensing for Pacific Island Countries.
14:30-14:50		Martin, F.	GIS Open Source Developments.
14:50-15:10		Forstreuter, W.	IT for Forest Labelling and Certification in Fiji Islands.
15:10-15:30	**Coffee/Tea Break**		
15:30-15:50	**Minerals**	Kojima, K.	Japan/SOPAC Deepsea Mineral Resources Programme – Stage 1.
15:50-16:10		Nishikawa, N	Data analysis and digitalization of the cooperative study project on the deep-sea mineral resources in selected offshore areas of the SOPAC region.
16:10-16:30		Overmars, M., Butcher, A., & Lum, J.	Water Resources Assessment and phosphate reserves survey on Banaba Island.
16:30-16:50	**Coastal**	Forstreuter, W.	Mapping of shallow lagoon using Landsat 7 Image Data.

Time	Theme	Authors & Speaker	Title
Thursday 28th September			
09:00-09:20		Wellington, M.	The Laser Airborne Depth Sounder (LADS). A broad range of applications.
09:20-09:40		Allenbach, M & Hoibian T.	Wallis and Futuna, A pluridisciplinary approach to environment and lagoon resources. Presentation and objectives of the geosciences section of the program.
09:40-10:00		Tappin, D.	Reducing Vulnerability: Geoscience in the context of human impact.
10:00-10:20		Collen, J.	Coastal sediments of the tropical Pacific: What do we need to know?
10:20-10:40	**Coffee/Tea Break**		
10:40-11:00	**GOOS**	Pratt, C.	Coastal Workshop Summary.
11:00-11:20		Nakamura, T., Kitazawa, K.	Oceanographic Observation by TRITON Buoys in the Equatorial Pacific.
11:20-11:40		Erb, W.	Proposal for Capacity Building Project related to ARGO drifting float program.
11:40- 12:00		Martin, F.	Metadata standards in GIS/RS
Continuation of STAR Working Groups Meeting, if necessary; any other STAR business; workshop on Tarawa science; workshops on aspects of science for local teachers, etc.			

	Poster Presentations	Eager, S.H.	Freshwater Ostracods from Tarawa: A breach of biosecurity?
		Maurizot, P., Lafoy, Y., Fabre-Martineau, J.	Field mapping of superficial formations in New Caledonia: Geohazards Mitigation.
		Pelletier, B., Regnier, M., Calmant, S., Pillet, R., Cabioch, G., Lagabrielle, Y., Bore, J-M., Caminade, J-P., Lebellegard, P., Ioan, C., Temakon, S.	The Mw 7.5 November 26, 1999. Ambrym-Pentecost (Vanuatu) eathquake: preliminary data on seismicity, associated tsunami and crustal motions.
		Pelletier, B., Cabioch, G., Calmant, S., Lagabrielle, Y., Regnier, M., Pillet, R.	A multidisciplinary study of active tectonics at Futuna, Southwest Pacific.
		Rufin, C	From dynamic processes study to concerted management for a low coralline island. The example of Fongafale, Funafuti Atoll, Tuvalu.
		Tappin, D	Scientific targets at intraoceanic convergent margins drilling objectives in Tonga.

ABSTRACTS OF PAPERS

Energy Audit of the South Pacific Applied Geoscience Commission
Rupeni Mario, Energy Unit, South Pacific Applied Geoscience Commission.

Energy conservation and efficiency programs are an essential component of the economic and environmental development for Pacific Island countries. The ultimate goal of any energy conservation and energy efficiency program is the elimination of energy wastage and the minimisation of electricity bills.

But where are the areas of wastage? They may not always be immediately apparent and they can vary from one building to another and from one location to another.

The role of management in any organisation is of paramount importance to a successful energy conservation and efficiency program.

The energy audit of the SOPAC Secretariat Headquarters originated from the SOPAC Director who stated that *"SOPAC should demonstrate what it preaches at home first"*. This came with the transfer of the energy program to SOPAC in 1998 with one contributing factor being a greater awareness of energy issues.

The approach taken was to establish a demonstration project that could be used to develop a methodology for application in SOPAC member countries. The primary activities and objectives of the energy audit were as follows:

- To carry out an energy audit of the SOPAC Secretariat and document the methodology used; the experience gained; and the results to be used as training/reference material for member countries and other interested parties.
- To increase awareness and appreciation of the SOPAC Secretariat staff and visitors on how their individual/collective efforts on energy conservation and energy efficiency can be beneficial to SOPAC.
- To demonstrate that energy conservation and efficiency is a win-win strategy.

The general perception about energy conservation and efficiency programs is that it is inconvenient and costs money. Not only is one restricted in their use of energy but one has to undergo certain adjustments in working habits to minimise energy consumption. But energy conservation and efficiency are not necessarily about minimising, reducing and changing user habits. It is about rationalising and optimising.

Simple housekeeping measures such as ensuring that lights, fans and air conditioners are switched off when not needed have been identified in most energy audits as the easiest, least destructive and the most cost-effective energy conservation and efficiency measures. It really comes down to an educational process in most cases.

An effective energy conservation and energy efficiency program does not end with the identification of energy and monetary savings potential. Although it may take one to two years to eliminate wastage altogether and practice energy conservation and efficiency habits, it is also important that the program is ongoing.

The paper details the various stages within the energy audit process, discusses the immediate opportunities to minimise electricity consumption and costs and outlines a guideline to monitor the impact of implementing the recommendations of the energy audit.

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Evaluation of an Energy Conservation Project
Prasad, R., and Gonelevu, A., Department of Energy, Suva, Fiji

Energy is becoming an increasingly expensive commodity. It may still represent a small proportion of our total outgoings, but recent increases in energy prices have been above the average rate of inflation and the proportion is likely to be rising.

Energy conservation offers an immediate opportunity to reduce costs and increase profitability. For example, savings in imported petroleum fuels and a reduction in our electricity demand. There is a further potential value in that energy conservation measures fully applied can lead to more energy efficient use of plant and equipment, which in turn can reduce maintenance and replacement costs.

The Fiji Department of Energy's (FDOE) conservation program has the main objective of reducing energy costs and expenditure in the public and private sectors in Fiji through efficient use of energy.

This paper presents energy savings analysis after the upgrading of lighting and air-conditioning systems at the Commissioner Central's Office Building in Nausori, Fiji. The project was funded by SOPAC and commissioned by a company, Sinclair Knight Merz. It was envisaged that after the upgrading works the energy costs per year would be reduced by 40% thus a saving of $2,500 per year. After six month's of monitoring, it was found out that a saving of $1,182.22 had already been made.

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Efficiency Monitoring of Solar Hot Water Systems in the Fiji Islands and the Kingdom of Tonga
Rupeni Mario, Energy Unit, South Pacific Applied Geoscience Commission

Solar water-heating systems are used in the region and are considered to be able to compete on an economic and financial basis with gas and electric water heaters.

However, due to the variable nature of solar radiation and seasonal temperatures their efficiency can vary accordingly.

Hence, the South Pacific Applied Geoscience Commission, through its Energy Unit, became involved with the Fiji Department of Energy and the Tonga Energy Planning Unit in implementation and efficiency monitoring of solar water heaters installed on domestic premises. The primary objective of the project was to substantiate the efficiency values of locally constructed and imported solar water heaters in actual operation.

The sites selected were on the basis of a triangular arrangement so as to give as wide as possible coverage of the region. In the Fiji Islands, there were four monitoring sites, two in Nadi, located at latitudes $17^0 46'$ and longitude $177^0 27'$, and two in Suva, located at latitude $18^0 8'$ and longitude$178^0 26'$. The two monitoring sites in Tonga were in Nuku'alofa, located at latitude $21^0 20'$ and longitude $174^0 55'$. The selected solar water heaters were a Solahart hot water system, imported from Australia, a Beasley solar water heater (locally constructed in the Fiji Islands) and a Tonga Solar System (locally constructed in Tonga). The selection of the solar hot water systems to be monitored was on a set of predetermined parameters that took into account, all the systems were relatively new, and installation was optimum in accordance with the manufacturers specifications.

The project was established following the preparation of an economic template where the cost of providing hot water from solar water heaters is compared with other alternative supplies such as electricity and liquid petroleum gas (LPG). As the installed solar water-heater efficiency is one of the key inputs into the template, it was deemed necessary to have more realistic efficiency figures for the region.

As efficiency values stated by manufacturers are usually for ideal conditions, then these are generally not supported in practice. In addition, simple factors such as the orientation of collector(s), insulation of the hot water storage tank and condition of the solar water heater all contribute to the systems installed efficiency. General installation and the natural environment also affect system performance.

The selected solar water heaters were monitored over a twelve-month period with the automatic data loggers programmed to record quantity of hot water used per household, temperature of water flowing into the system, temperature of the hot water flowing out of the system and irradiance on the collectors.

Project results indicate that the installed efficiency of selected solar water heaters was in the order of 10 – 15% less than their instantaneous collector efficiency. The comparison of locally-constructed solar water heaters to imported solar water heaters show that the imported solar water heaters have a slightly higher efficiency value. The paper also compares and discusses the various models and their manufacture.

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The Analysis of the Nabouwalu Hybrid Power System in Fiji

Anare Matakiviti, Energy Unit, SOPAC

The Nabouwalu Hybrid Power System (NHPS) utilises wind and solar resources to generate electricity for approximately 100 consumers. A diesel generator is also included as a standby system. This paper analyses the performance of the NHPS and three other options, namely solar (PV), wind and stand-alone diesel generator systems, for power generation.

Using manufacturers' performance curves and weather data from various sources, the output from the PV and wind systems was predicted, and compared with the limited operational data (39 days). The measured climatic data was also compared with the long-term average. Analysis of the measured values indicates that both the solar radiation and windspeeds were less than expected and therefore the energy generated by the PV and wind systems should reduce correspondingly but it was found that the energy generated reduced by a greater margin than expected.

In the financial appraisal, two methods were utilised to perform the analysis. The simple payback period analysis used is based on the fuel savings achieved. For the PV and wind systems, the simple payback period has been found to be approximately 27 and 17 years respectively while the NHPS has a payback period of 29 years. Using the life cycle cost analysis (LCCA) method it was found that none of the options are financially viable due to the expenditure (costs) almost always exceeding the benefits gained. It was also found that the life cycle cost of electricity (LCCOE) would be highest ($0.30 per kWh) for a PV system and the NHPS and lowest (FJD$0.18 per kWh) for a wind system. The LCCOE for the diesel system was calculated to be FJD$0.21 per kWh. High capital and replacement costs were found to be the main factors in the determining the LCCOE.

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Overview of the Regional Energy Meeting REM2000 - 20-26 September 2000

Paul L. Fairbairn, Energy Unit, SOPAC

The opportunity was taken to convene a regional energy meeting, REM2000, at Tarawa prior to the SOPAC/STAR Annual Session.

The focus of the REM2000 was to create an opportunity for all stakeholders, PIC representatives, regional organisations, donors and other interested parties to pitch in and deliberate on issues that are pertinent to the energy sector in PICs.

Moreover, the REM2000 will come out clearly at the end of the meeting with resolutions that will guide all stakeholders in their quest for not only improving the energy sector in PICs but more so to make it more affordably sustainable within their individual economies.

The three main issues that were considered and discussed at length during the REM 2000 were:

[a] CSD9 - Regional Energy Position Paper;
[b] Regional Energy Priorities – a matrix being prepared by the CROP - EWG; and
[c] Review of SOPAC/SPC regional framework.

The preparation of and agreement to a regional energy position paper during the meeting established the immediate priorities and longer-term concerns of the region. The paper in its agreed format will be submitted to the United Nations for inclusion in the CSD9 (Ninth Commission on Sustainable Development) meeting in April 2001.

Other specific details of the REM2000 Meeting will be provided to STAR and in a Summary Record prepared for the meeting.

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Morphologic, visual and seismic evidence for slumping in tsunami generation: The 1998 Papua New Guinea event

D. R. Tappin, E. A. Silver, S. Sweet, P. Watts, T. Matsumoto

Discrimination between tsunami generation mechanisms such as coseismic displacement and sediment slumping can be made using appropriate morphologic and observational evidence. The source mechanism of the Papua New Guinea tsunami of July 17, 1998 has been determined using a multibeam reconnaissance survey, followed by visual seafloor observation by Remotely Operated Vehicle and Submersible, together with seismic data acquisition.

These provide a database by which slumping through rotational faulting is demonstrated. In particular, seismic reflection data document that the slump involved about 10 cubic kilometres of material and moved laterally as much as a kilometre. Modelling shows that this mass is capable of generating the locally-observed tsunami runup.

Additionally, the visual observations provide evidence of many recent seabed movements, although the age of such movements cannot be dated.

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Stratigraphic Investigations of Sediments Offshore of Sissano, Papua New Guinea.

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The stratigraphy and geochronology of a suite of four 7+ to 8+ m long piston cores and twelve <30-cm long submersible push cores collected offshore of Sissano Lagoon, PNG are being studied by a variety of geophysical and geochemical methods. These cores were collected during joint JAMSTEC-SOPAC-sponsored cruises to the area of the July 1998 tsunami using the JAMSTEC R/V Kairei followed by the JAMSTEC R/V Natsushima with the Shinkai 2000 manned submersible. The goals of this study are to determine the nature, sedimentation rates and ages of the sediments within the offshore area affected by the July 1998 earthquake and subsequent tectonic events that led to the devastating tsunami. Further aims are to help constrain models of tsunami generation in the area and to date the occurrence of any past events preserved in the sedimentary record offshore.

Our approach includes detailed magnetostratigraphy using a 2-G scanning cryogenic magnetometer at SOEST. Two of the long piston cores (KR99-PC1 and PC2) were subsampled and run at 5-cm intervals and two others (KR99-PC3 and PC4) were continuously scanned at 1-cm intervals down the entire core's length. Sediment porosity and density were also determined down these cores at 5-cm intervals. Our current radiochemical dating approach uses down-core profiling of excess or unsupported activities of ^{210}Pb and ^{230}Th that decay with half-lives of 22.2 and 75 200 years, respectively. These activities as well as those of ^{226}Ra, ^{232}Th and ^{238}U are being determined by gamma-ray spectrometry using high-purity Ge detectors at SOEST.

The piston cores comprise cohesive olive-green hemipelagic clays with scattered, coarser-grained lithic turbidites (PC-1, PC-3), a visually homogeneous green clay (PC-2), and a heavily turbidite-rich core (PC-4). The submersible push cores are mainly olive-green hemipelagic clay with those collected on two dives within cold seep areas composed of a mixture of green hemipelagic clay and black, fine-grained sulphides (pyrite?). Preliminary dating results present an interesting paradox. The magnetostratigraphy suggests at least three of the four piston cores record either: (a) the Brunhes-Matuyama polarity boundary; (b) the top of an excursion of the Earth's magnetic field within the Brunhes Chron; or (c) the consistent magnetic signature of a regional tectonic event at core depths ranging from 200 to 360 cm. However, the short (<26 cm length) push cores and the topmost 0-25 cm portions of the piston cores display excess ^{210}Pb profiles, indicating ages of less than 150 years near the surface. The 785 ka age of the Brunhes-Matuyama boundary yields average sedimentation rates of 0.25 to 0.50 cm/kyr to these sediment depths, whereas the ^{210}Pb profiles yield rates of 0.1 to 0.2 cm/yr that are 3 orders of magnitude higher. Extrapolated piston core bottom ages could therefore range anywhere from 4 ka to >3 Ma. The ^{230}Th profiling currently underway should delineate which of the two dating interpretations is correct. Radiocarbon (^{14}C; half-life = 5,700 yrs) dating of the organic fraction of these sediments may be necessary to resolve the chronostratigraphy.

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Report on the damage caused by the 26 November 1999 tsunami in Vanuatu

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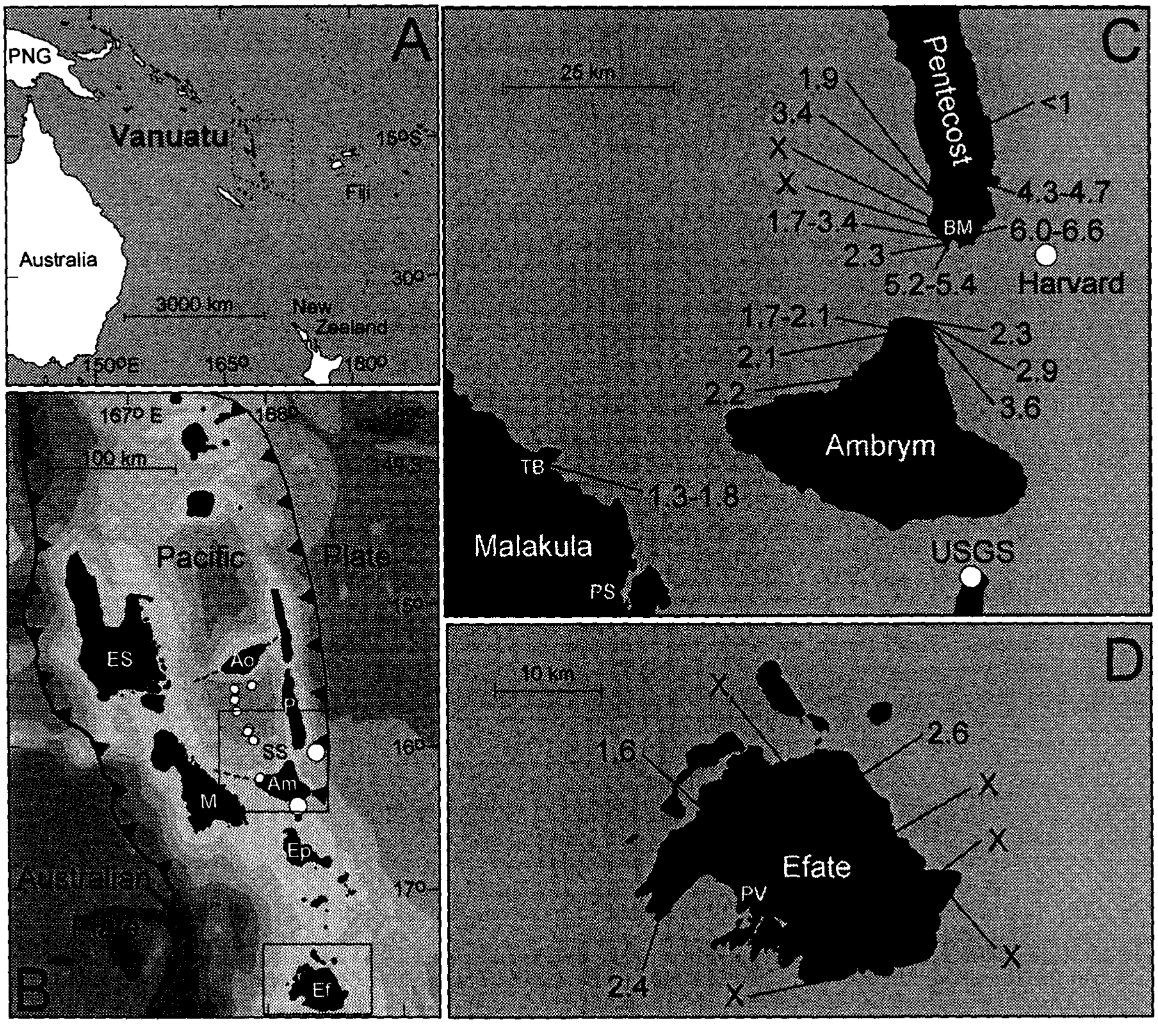
An earthquake estimated between moment magnitude 7.1 and 7.5 occurred off the coast of Vanuatu on 26 November 1999 at 13:21 UTC. The earthquake generated a damaging tsunami that struck the coast of Vanuatu, where it reached as high as 6.6 meters above sea level and destroyed the village of Baie Martelli, where a sand sheet was deposited.

The tsunami reached a maximum of 6.6 meters above sea level, with damage limited to Baie Martelli, at the southern tip of Pentecost Island (see figure). The east coast of Pentecost and Ambrym, which face the tsunami source, shows runup heights as great as 4.7 m, decreasing with distance from the earthquake. On the east coast of Malakula, which faces the tsunami source through the Selwyn Strait, runup heights were no more than 1.8 m. Especially large waves observed by eyewitnesses in small bays such as Baie Martelli imply that the tsunami's energy was focused, or was augmented by nearby submarine landslides, in those areas. No tsunami runup was noted on Espiritu Santo or northern Pentecost, despite the concentration of earthquake damage in northern Pentecost. Though far removed from the tsunami source, the coast of Efate showed runups of up to 2.6 m. The tide gauge at Port Vila, on the south coast of Efate, showed a tsunami wave height of only 40 cm.

Witnesses reported that destruction at Baie Martelli was caused by three waves, led by a receding wave. The first and smallest wave arrived within about 10 minutes of the earthquake. It was followed by two larger waves arriving about 15 minutes apart. The buildings of Baie Martelli were mostly woven grass walls with corrugated metal roofs, and were totally destroyed. The few concrete structures in the village remained standing, but were very badly damaged. Perhaps the strongest building in town was the church—it survived the tsunami, which dug 1.5 m deep scours at the leading corners of the building. The wave did not itself exceed the height of the church (~4.5 m), but water impounded in front of the church surged over the rooftop, collapsing the roof and flooding the interior.

The tsunami also covered Baie Martelli with sand. The sand forms a layer 5-15 cm thick in most areas the tsunami reached. Its likely sources are the shore face, which village residents state was eroded by the wave, and some pits dug into the coastline by the tsunami. The pits are between one and two meters deep that extend about five meters into the shoreline. Just landward of these pits, the deposit is relatively thick, about 15 cm. This band is generally about 20 meters wide in the areas studied
landward of this is a band of no deposition about 20 meters wide. Landward of the bare zone the layer shows two fining upward sequences, which probably represent two pulses of sedimentation. This stratigraphy becomes less distinct landward, until only one pulse can be recognised in outcrop at the most landward parts of the deposit.



Maps of the Vanuatu earthquake and tsunami. A. Location of Vanuatu in the southern Pacific Ocean. B. Tectonic and bathymetric map of northern and central Vanuatu. Large circles are the Harvard (northern) and USGS (southern) epicenters for the earthquake, smaller circles are aftershocks from the NEIC catalogue larger than M=4.5. Bathymetric contour interval is 1000 m. Ambrym is labeled "Am", Aoba "Ao", Efate "Ef", Epi "Ep", Espiritu Santo "ES", Malakula "M", Pentecost "P", and the Selwyn Strait "SS". C. Runup in meters for locations surveyed on Pentecost, Malakula, and Ambrym. Where more than one measurement was taken at a single site, a range of heights is shown: sites where signs of runup were not found are marked "X". BM marks the location of Baie Martelli, PS Port Sandwich, and TB Tisman Bay. D. Runup in meters on Efate. Sites where signs of runup were not found are marked "X". PV marks the location of Port Vila.

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Megaclast emplacement and movement on shore platforms: An index of extreme events at the land-sea interface.

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Extreme events are an important feature of environmental change and landscape evolution, because the energy expended is likely to leave a physical record. Being located at the land-sea interface, shorelines are particularly important repositories of such records, which include the emplacement and movement of megaclasts on rocky shoreline platforms.

Two distinct kinds of extreme events are known to be responsible for megaclast emplacement and movement: giant storm waves, from nearby or distant storms; and tsunami, of local or trans-oceanic origin. Although megaclast-derived criteria for distinguishing between these two emplacement mechanisms have yet to be established, understanding the physical and hydrodynamic differences between tsunami and storm waves may provide the needed insights.

Both storm and tsunami wave emplacement mechanisms of megaclasts onto shorelines are important from the perspective of natural disaster preparedness. However, for assessing the consequences of environmental change, the record of storm wave effects is particularly important and needs to be distinguished from tsunami wave effects. This task is just beginning.

Here we describe evidence from a shoreline terrace near Sunset Beach, O'ahu, Hawai'i, for the emplacement and movement of megaclasts up to 90 tonnes by storm waves and by tsunami between 1927 and 1996; and for emplacement on the rock platform at Ben Buckler, north of Bondi, NSW, of the 235 tonne megaclast "Mermaids Rock" by a storm wave in 1912. These observations, tied to known events, provide valuable qualitative constraints on the physics of the entrainment processes. For example, the orientation and packing of megaclasts is of equal importance or even outweighs the size of the megaclasts as an indicator of wave power at the shoreline. Quantitative investigations of these processes are now under way.

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Cyclone frequency during the last 6000 years and implications given a greenhouse induced climate: Curacoa Island, North Queensland, Australia.

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Cyclonic storm ridges form when high energy waves and cyclonic storm surge combine to scour nearshore reefs transporting coral shingle shoreward and depositing it into ridges above the reach of normal tidal levels. By using radiocarbon ages of corals from storm ridges an age of organism death is provided, in most instances this represents the time of cyclonic occurrence. Ages from a number of cyclonic deposited ridges along a beach ridge plain can then be statistically evaluated in order to estimate cyclonic frequency.

A sequence of cyclonic storm ridges occur at Curacoa Island (18^{o} 40' S; 146^{o} 33'E) which lies immediately north of Great Palm Island, 28 km offshore from Lucinda on the Queensland coast. There ridges are used to assess the frequency of past cyclones and assist long-term climatic prediction.

At the north-west corner of Curacoa Island a curved composite boulder spit and shingle ridge platform rises to 3.5 m above highest astronomical tide (HAT). On its southern side, the boulder spit cradles a series of storm-beach ridges with crests up to 3 m above HAT built of coarse lithic gravel and coral shingle detritus supplied by a narrow fringing coral reef. The shingle ridges nested in the lee of the boulder spit are protected from normal heavy seas and swell driven by prevailing winds but are likely to be influenced by exceptional seas generated by tropical cyclones.

Two transects across the shingle ridges were surveyed and levelled to mean sea level. Stratigraphy along both transects was investigated via a series of hand-dug pits and trenches dug with an excavator. Twenty-two (22) individual storm deposits were identified using stratigraphic markers indicative of buried ground surfaces. Palaeo-ground surfaces were evidenced by changes in sediment size, composition, imbrication and the occurrence of midden deposits as well as lenses of pumice pebbles that also provide evidence that seas occasionally overtopped the shingles ridges. Each storm deposit is interpreted as the product of a single cyclone. The number of identified storm deposits is almost certainly fewer than the actual number due to limited trenching along transects however, the methods used to identify storm deposits are considered consistent.

Each storm deposit was sampled for radiocarbon dating. In total, 68 reservoir-corrected conventional radiocarbon ages were calculated. Radiocarbon ages increase steadily through the sequence from very recent to about 6000 yr b.p. Ages of 19 storm deposits were determined from multiple dates (from 2 to 8 samples each) and three storm deposits have one date each. Consistency is good within each set of multiple dates although some sets contain one or two dates (11 in total) that are older than the rest which are considered to have been reworked from older storm deposits when their younger host was emplaced.

Because the radiocarbon time scale is not linear, radiocarbon ages need to be converted to calibrated ages in order to assess whether the frequency of ridge building events has varied. Calibration was done with the OxCal II program (Bronk Ramsey, 1994). A routine within OxCal combines radiocarbon ages, tests whether dates within a given set are statistically equivalent and calculates the calibrated age for the set. This routine was used to exclude outlier dates and to derive calibrated ages for storm deposits.

Statistical analysis of the evidence shows that the rate of progradation and the frequency of storm deposit accretion have not changed in the last 6500 years. This suggests that cyclone frequency also has not varied.

The balance of available evidence suggests that greenhouse gas emissions are producing climate change (Houghton et al. 1996). Under the scenario of a greenhouse-warmed world-sea surface temperatures (SST's) could be expected to rise. As SST's greater than 26°C favour cyclogenesis (Gray, 1968), the significance of the cyclonic record must be gauged against palaeoclimatic evidence of SST's as well as modelled responses. Although evidence is sparse, determinations from high-resolution isotopic trace elements from ancient corals provide sound estimates. Results from north Queensland indicate SST's between about 4-6000 years ago are about 1°C warmer than today reducing to about 0.5°C warmer towards the equator (Gagan, 1998 and *Pers. Comm.*). Evidence from the eastern Pacific about 2050 years ago also show SST's 1°C degree warmer than today (Woodroffe and Gagan, 2000). A critical review of cyclogenesis under doubled CO_2 climatic conditions (Henderson-Sellers et al. 1998), indicates no change in the area of global location or frequency of tropical cyclone development and only a slight rise of maximum potential intensity values even if mean SST's were to rise by 2°C.

The record established at Curacoa Island shows no significant variation of cyclonic frequency over the last 6500 years. These results support the general findings of modelled cyclogenesis under greenhouse conditions. SST variations during the last 6500 years appear to have had no effect upon cyclonic frequency as determined in this study. This may however be due to there being other parameters essential for cyclogenesis; alternatively, radiocarbon dating of cyclonic storm ridge development may not be sufficiently sensitive to detect changes in cyclogenesis. However, in so far as the limits of the data allow, there is no evidence to show that putative mid-Holocene higher temperatures had any effect upon cyclonicity.

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Long-term records of coastal hazards provide a more realistic guide to the future.

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Historical records of tropical cyclones and tsunami are frequently too short to be reliable guides of future impacts by these hazards. Longer-term records, often in the form of geomorphic evidence, allow the determination of quasi-periodicities of coastal hazards and allow recognition of potential future hazards even when they have not occurred during historical times.

Along the shores of tropical Australia for example, significant marine inundations, quite possibly tsunami, have occurred twice during the last millennium suggesting that this region is prone to this hazard despite its absence since European settlement. Tropical cyclones occur at much higher frequencies here but there has been an absence of extreme intensity cyclones (category 5) along the Australian east coast during the 20th

century. This has led to a lack of awareness of these events resulting in urban expansion into areas that were regularly inundated by storm surge during the 18th and 19th centuries. It is highly likely that similar situations exist elsewhere throughout the Pacific region.

This presentation focuses on examples of these long-term records from the Australian region. The techniques required to derive them are also outlined.

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Probabilistic assessment of volcanic hazards on Taveuni volcano, Fiji.

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Up to now efforts in mapping and estimating hazards on Pacific Island volcanoes have been largely qualitative and based on simple interpretation of past volcanic histories. This has been the result of both insufficient eruption age data and the non-application of statistical methods for analysing eruption records. For Taveuni volcano Cronin (1999) and Cronin and Neall (2000; and in prep) have built up a large database of radiocarbon-based eruption age data, concentrating on the Holocene. Around 101 eruption episode onsets were identified on the island during the Holocene. We use this age data along with the location of eruption events to develop a probabilistic assessment of both temporal and spatio-temporal eruption recurrence on the island (Cronin et al. in review).

Taveuni is a 437 km^2 oceanic intraplate volcano located in north-eastern Fiji and has been subaerially active since c. 780 ka. Alkali basalt magmas were erupted through monogentic vents at constantly shifting locations along a SW-striking rift zone. Population on the island stands at c. 14 500 (in 1997), and is rapidly growing due to migration driven by the islands fertile soils and freehold land. Hence quantification of volcanic hazard, in both spatial and temporal terms, is of great importance to disaster management and development agencies.

Unlike previous probabilistic assessments of hazards in volcanic fields in other parts of the world (mostly the USA), the activity on Taveuni is both more recent, and on a lesser spatial scale. However, like all geological studies, imprecision in age determinations remains the largest hindrance to statistical analysis. In this study we propose a first attempt at dealing with the imprecision and inaccuracy inherent in volcanic eruption age data obtained via radiocarbon dating.

Our results indicate that volcanic activity on Taveuni has a tendency to occur in episodes separated by intervals of around 800 years. If this tendency is strong, the present hazard may be considerably greater than otherwise supposed. Within episodes, intervals between eruptions are in the order of 57 years.

We also confirm an apparent tendency for the volcanic activity to migrate southwards along the Taveuni rift axis towards the most densely settled area, and also the widest axial vent zone. Geologically this may demonstrate an opening of the rift zone to the south and a higher possibility of future volcanism off the southern coast of Taveuni. This tendency also indicates that the risk from volcanic activity in southern Taveuni is again higher than might otherwise be supposed.

We describe a function to predict the probability of eruptive activity on Taveuni (Fig. 1), from which we can estimate probabilities of renewed activity (the reciprocal of the value read from Fig. 1), for differing time horizons. For example, of interest to disaster managers and the general public, the probability of an event in the next 10 years is 0.15, while for developers of a hospital on the island are facing a probability of 0.56 for renewed activity within the 50-year planned hospital lifespan. Note that site-specific estimates of probability will be lower than the field-wide value.

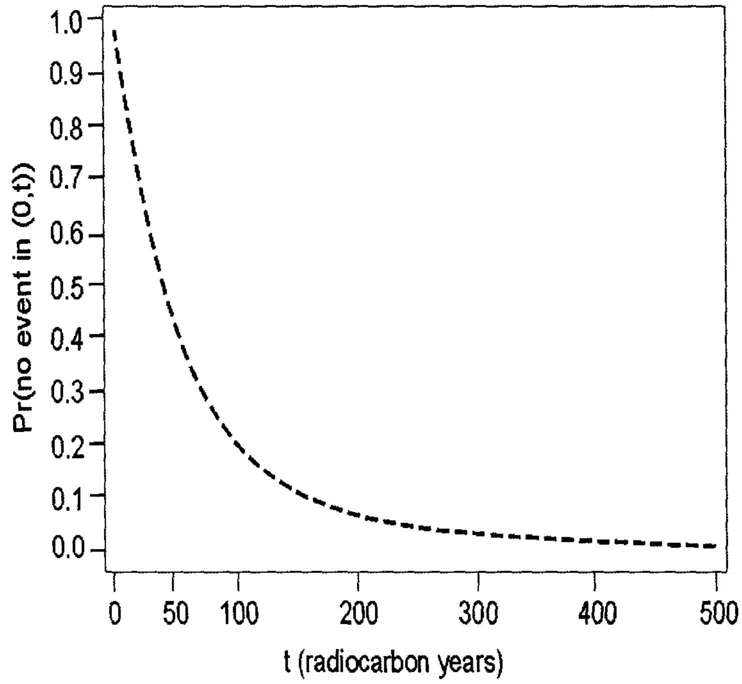

Figure 1. Hazard enhancement with elapsed time from Cronin et al., in review.

The spatio-temporal results indicate that the southern quarter of the rift zone has the highest intensity of eruptions, up to 0.0009 events per km along the rift per year. The next highest intensity, in the central island area (up-slope from the new hospital development) has an intensity of up to 0.00055 events/km of rift/year. By contrast the northern third of Taveuni has very low intensities (< 0.00015 events/km of rift/year). An analysis of eruption transitions reveals that activity is highly unlikely in northern Taveuni under the present field behaviour. This data can be used to revise the hazard map prepared by Cronin (1999).

The quantitative results we derive can be utilised directly within economic and socio-economic loss estimations during the planning stages of new infrastructure, business and subdivision developments at various locations on the island. Having quantitative probabilistic hazard and risk data also helps to reinforce education programs and advocacy of disaster mitigation measures in various areas (eg. Cronin and Kaloumaira, 2000). The methods we develop and demonstrate can be applied to solve other risk-assessment problems for many hazards that have a spatial and temporal dimension.

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Submarine Volcanic Activity in the Southwest Pacific: Examples from the Kingdom of Tonga and the Solomon Islands.

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Due to the oceanic island arc setting of the majority of the active volcanic centres in the Southwest Pacific, submarine eruptions may be the dominant volcanic process in the region. During the past five years there have been at least three periods of submarine volcanic activity reported.

An eruption during June 1995 at *Metis Shoal* in Tonga produced an island that is still present above sea level today. Other periods of activity were reported during June 1991, May – July 1979 and December 1967 – January 1968. A number of eruptions have also been reported during the mid to late 19th century. Islands were also formed during these periods of activity (Scott, 1995). In January 1999, a period of explosive submarine activity occurred at "*Submarine Volcano III*" in Tonga. A small island composed of pyroclastic material was reported, however, it was quickly eroded by the ocean swell (Taylor, 1999). This eruption was small in volcanological terms, but it caused considerable concern because of its close proximity to the main island of Tongatapu. Periods of activity at this volcano have also been reported in 1911, 1923 and 1970. During May 2000, an Australian research vessel observed a new phase of submarine activity at *Kavachi* in the Solomon Islands. Perhaps the most frequently active volcano in the SW Pacific, activity at *Kavachi* was first reported in 1942 and since then at least 23 periods of activity have been reported, many forming islands or near surface shoals (Johnson & Tuni, 1987; Petterson et.al, 1999). Although all three volcanoes have undergone numerous and sometimes long periods of activity since being first observed by Europeans, due to their relative remoteness many periods of particularly submarine activity, may have gone unreported.

During the reported periods of submarine and subaerial activity at *Metis Shoal*, *Submarine Volcano III* and *Kavachi*, a range of volcanic hazards have been reported including explosions, ballistic ejecta, tephra, lava domes, vog (volcanic fog), laze (lava haze) and island/shoal formation. Although not reported during recent activity, volcanic edifice collapse, tsunamis and pumice rafts may also occur. All of these hazards may have long-lasting effects on a large region around the volcano. Where small magnitude eruptions occur, the effects of the hazards may be restricted to within several kilometres of the vent. Where larger magnitude eruptions occur, the hazards may affect passing ships or the communities on the surrounding islands. A generalised volcanic hazard map for submarine volcanoes has been developed (Fig. 1). The map defines three zones of relative risk around the volcano and highlights the hazards that are likely to occur in the zones. This map will be a valuable tool for NDMOs and other government officials in the planning to reduce the effects of volcanic hazards.

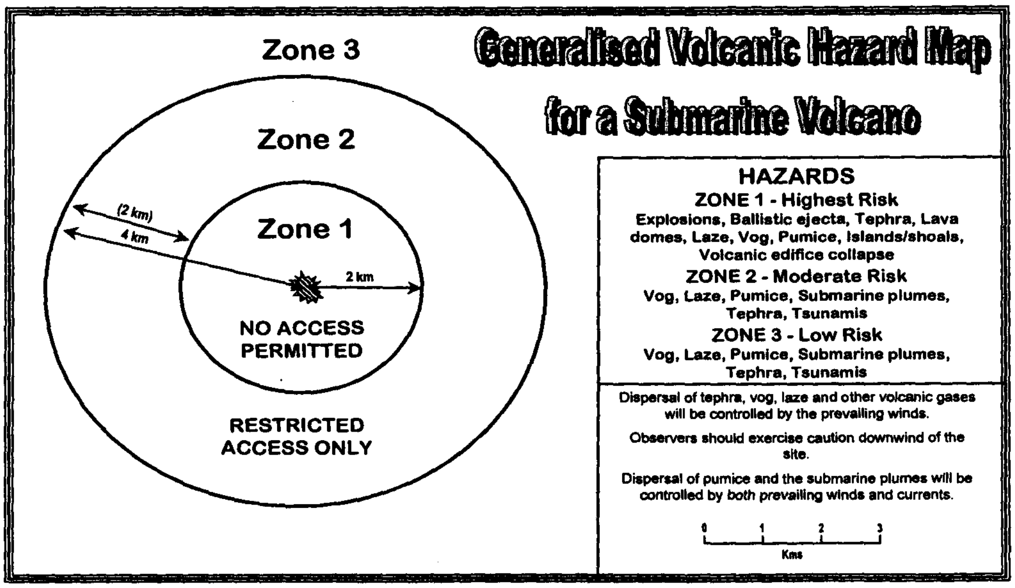

Fig. 1: Generalised hazard map for a submarine volcanic centre

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Community-government-scientist interactions: A volcanic hazard workshop with a difference on Savo volcano, Solomon Islands

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Savo island represents only the top 500 m of a 1500 m high stratovolcano, rising from Iron Bottom Sound north-west of Honiara in the Solomon Islands. That it poses immense hazard to life is well known by its c. 3000 inhabitants, who have oral traditions recording at least three past events (which may correspond to some of the historically recorded events), including one that apparently caused 1007 deaths (Toba, 1993). Geological studies by the Solomon Islands Water and Mineral Division, led to a preliminary classification and map of the hazards on the island (Petterson et al., 1997; Petterson et al. in press).

Pressure from local citizens led the Member of Parliament for Savo to attempt to have the island declared a permanent volcanic disaster area by parliament in mid 1999. Following this the three authors travelled to Honiara in November 1999 to run a 6-day workshop on the volcanic hazards, operational support planning and awareness programs for Savo volcano (Cronin et al., 2000). Randall Biliki (NDMO), Donn Tolia, Thomas Toba and others of the Water and Mineral Resources Division were instrumental in organising and leading parts of the activities and Angelika Planitz of SOPAC DMU joined us for the latter part of the workshop. This activity was facilitated and supported by SOPAC, with funding from the Australian International Decade for Natural Disaster Reduction Committee, Solomon Islands Ministries of Energy, Water and Mineral Resources, and Home Affairs.

With 34 participants comprising local chiefs, teachers, local-government officers, and representatives of six government departments, we had a variety of backgrounds, perspectives and agendas to contend with. Techniques used during the workshop were developed from experiences of similar workshops run in Fiji (Cronin and Kaloumaira, 2000) and Samoa (Taylor et al., 1999), and included a mixture of technical presentations, workgroup activities, and discussion sessions. In Honiara the participants were given a grounding in volcanic hazards and the geologic aspects of Savo, followed by workgroup and discussion activities on: vulnerable element inventories, development plans and potential impacts, vulnerability reduction, operational support planning, eruption scenarios, monitoring systems and awareness programs. For different exercises, differing composition subgroups were formed to obtain opinions from specific groups as well as to encourage opinion sharing and interaction between people of different backgrounds and perspectives.

Following this all participants travelled to Savo to carry out two main activities:

1) A field trip and mapping transect. We led the group up one of the main valley conduits for block-and-ash flows and lahars from dacitic dome extrusion and explosion events in recent past eruptions. We described attributes of the deposits and explained how these were used to assess hazards. Groups of participants prepared transect descriptions of geology and vulnerable elements for the area to derive their own hazard and risk assessments.

2) Village visits: participants were split into three groups to visit different areas of the island where people had assembled from neighbouring villages. At each site the workshop participants spearheaded working groups and discussion groups with the villagers. The main exercise was where separate groups of women and men mapped the vulnerable elements, major geographic features and hazards of their sector of the island. Discussion groups focused on: safe areas (for evacuation points), evacuation routes, traditional warning signals, village evacuations and other types of hazards in the area (eg. coastal erosion). Once presentations of the local maps were made, the visiting group explained the similarities and differences of a scientifically-derived map of the area, and how the two sets of information could be combined.

One of the main outcomes of the workshop was a volcanic hazard map derived for the whole island (Fig. 1), based on the scientific interpretation and the local data. Other outputs included: outline structures of operational support plans and awareness plans, dialogue and communication structures established between central/provincial government and village chiefs, monitoring plans and discussions on resettlement options. The workshop highlighted the importance of using scientific inputs within a realistic framework of traditional knowledge and practice, and demonstrated methods by which science can be used to influence policy at a national and provincial level and preparedness at a community level.

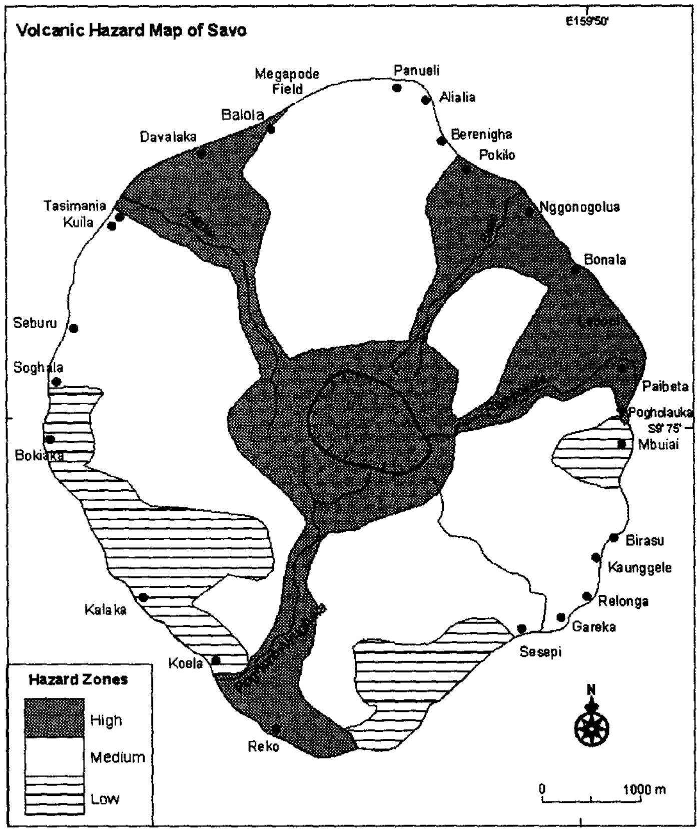

Figure 1. Hazard map for the ground-based hazards on Savo (excluding tephra falls).

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Building Damage Assessment – Suva, Fiji Islands

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An investigation of the degree of damage sustained by buildings in Suva, Fiji, following riots and civil unrest on 19th May 2000 provides an opportunity for response planning and formulation of mitigation activities. The purpose of this study is to provide response agencies with a rapid damage assessment methodology and analysis technique to assist decision making and response coordination immediately after the impact of a hazard or disaster. The ultimate goal is to save lives and livelihoods and reduce vulnerability of Pacific communities.

The data collected from a rapid building damage assessment survey undertaken by SOPAC's Hazard Assessment Unit is stored on a Geographic Information System (GIS) database. The data includes information regarding the degree of damage or a damage score (represented by flags coloured green, orange and red for increasing levels of damage); a digital photograph; and comments on damage specific to each building where necessary. The damage score assigned represents the degree of structural and surficial damage that is detected visually, and does not include contents damage and losses or damage to businesses. The study looks at the use of this damage assessment data in a GIS platform, especially when integrated with the Suva building assets database that was developed in previous years. A damage assessment methodology adapted from other studies is used to analyze the damage data collected. The adapted methodology quantifies total damage in terms of house equivalents [HE], or number of houses totally destroyed. Damage quantification required that replacement ratios (RR's) for representative building types were calculated and central damage values (CDV's), that are transferred from the damage scores, are assigned to each damaged building. A CDV quantitatively represents the degree of damage sustained by a building on a scale of 0.01 to 1.0, where 0.01 represents negligible damage and 1 represents condemnation or complete collapse. Total damage is then expressed in terms of a universal damage index (DI).

The study found that collecting data through a rapid building damage assessment survey is quick, easy and simple and can be done in less than a day in an area the size of Suva central business district. Data entry into the pre-existing Suva building assets database was also quick and simple, although it did require some previous knowledge regarding the GIS software, the database structure and digital photograph displaying techniques. The study found that the quantified total sustained damage was almost 11 HE's which is equivalent to two million Fiji dollars. The study acknowledged that the calculated value is a lot less than a reported value of greater than thirty million Fiji dollars but that the value is justifiable when looking at visual structural damage and surficial damage alone. Evidence suggests that with input from other agencies, such as the insurance industry and the police, the new damage data and the GIS Suva building assets database can be further refined and made available for multi-agency response efforts in future hazard and disaster events.

The importance of the damage index (DI) is that it allows a comparison of the relative total damage between this event and historic or future disasters from other natural or human-induced causes, in any location. The damage index calculated for the Suva riots was 3.4, which in essence implies that the total damage sustained was relatively low. Since further research and calculations are required to calculate DI's for events in Suva (for example the Suva 1953 earthquake), the damage index for the Suva riot event is compared with damage indices from Australian events. The study found that universal representation of damage in past and present events could provide unprecedented advantages in determining damage that may be sustained in future hazard events through event scenario analysis and utilisation of a GIS database. This in turn would aid decision making, and provide a baseline for hazard mitigation activities and disaster response planning. The former has been recommended as an urgent task to be undertaken by SOPAC or any other regional agency capable, together with other agencies to achieve the latter.

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Disaster Management – Future Direction in the South Pacific
Alan Mearns, Disaster Management Unit, SOPAC.

The establishment of a regional disaster management unit (DMU) at SOPAC provides an opportunity to develop and coordinate the implementation of regional and in-country comprehensive disaster management programs that can achieve sustainable outcomes such as in-country capacity building and community resilience to hazard impacts.

From a global perspective the focus of disaster management has shifted from the conventional model of response and recovery to a more holistic approach, wherein the process of hazard identification and mitigation, community preparedness, integrated response efforts and recovery are planned for and undertaken within a risk management context.

There now exists, within the Pacific region, a knowledge base and institutional arrangements sufficient upon which to commence developing in-country programs and regional collaboration, that will see country capacity developed and risk and disaster management mainstreamed as a core business activity of governments.

The SOPAC DMU has as its main goal the strengthening of national disaster management programming capacities through the integration of risk management practices within economic strategies of countries. The purpose of that goal is to reduce the compound risks of natural, technological and environmental hazards.

To achieve its goal the DMU has a three-year planning framework, which includes the following initiatives:

1. To establish a sustainable capacity to design, implement, manage and evaluate national disaster and risk management programs.
2. To enhance national programming efforts through the provision of timely technical and resource support.
3. To foster a more proactive interface between country statements of economic strategies and risk management practices.

A key element of this approach will be a regional advocacy program aimed at promoting the benefits of having risk management practises integrated into the day-to-day development strategies of governments.

Underpinning this advocacy program will be a number of initiatives designed to strengthen the skills of senior government policy makers and national disaster management staff. Capacity building at government and national disaster management office level will lead to a more effective interface with local government, NGOs and the community to reduce the current levels of community vulnerability.

In changing the focus in the South Pacific from disaster management to risk management there are many lessons to be learnt from South East Asia, which is the most disaster-prone region in the world. While natural hazards in Asia remain a major problem the increasing levels of technological or man-made hazards has required a change of thinking in terms of the adoption of an all-hazards approach to planning and preparedness and the inclusion of risk management strategies to development planning.

Lessons from South East Asia

An example of pro-active disaster planning can be found in Lao PDR, where the Government has developed and is currently implementing a new disaster risk management policy and plan. Lao PDR has a long history of natural disasters, particularly floods and droughts and there is also the threat of agricultural pestilence, health epidemics, fires, landslides, unexploded ordinance and emerging technological hazards.

The Government of Lao recognised these risks and hazards as having the potential to cause major setbacks in the process of socio-economic development, both locally and nationally. Such setbacks will result in both direct and indirect losses of lives and economic assets and the indirect costs associated with the diversion of valuable resources to meet short-term relief and rehabilitation needs. A more pro-active approach to disaster and risk management was therefore considered to be essential for both economic as well as humanitarian reasons.

In adopting this approach the government of Lao recognised that the effective management of a wide range of hazards and risks would require the combined expertise and resources of the Lao government, NGOs, private organisations, the community and international donors. The overall aim of disaster risk management in Lao is to establish and maintain the optimum system for dealing with a range of disasters, which is achievable within the constraints of the available resources.

This model is one that could equally apply to many countries within the South Pacific.

In future the direction of the DMU strategies will be to enhance the adoption of a risk management approach to disaster management within the region.

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Wastewater Management in Pacific SIDS: Wastewater Guidelines

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Wastewater discharges are the major cause of pollution to freshwater and coastal marine resources throughout Pacific Small Island Development States (SIDS). Often in urban areas untreated wastewater is discharged directly into coastal waters, rivers and groundwater aquifers. Inhabitants of atolls and coastal villages are polluting their shallow groundwater water supplies with their own wastewater discharges. Many existing wastewater treatment systems do not work properly and/or are not operated or maintained properly due to lack of trained personnel and adequate finance. All these discharges adversely affect the health of the people through drinking and bathing in contaminated water and from eating seafood taken from polluted coastal areas.

In the Pacific, sewage disposal may be regarded as the single most significant source of water (fresh and sea) pollution across the region. The battle against pollution can be controlled through integrated efforts from governments, communities and individuals. This paper highlights existing wastewater guidelines that should assist in reducing pollution problems, but only if they are fully supported by all stakeholders. However workshops and other training tools, built around the existing guidelines, are required to better manage the disposal of wastewater within the Pacific Region.

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Ostracod (Crustacea) Populations as Environmental Tracers : Examples from Estuaries and Lagoons of New Caledonia.

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The distribution of Neocaledonian ostracods species has been studied along different transects from rivers and estuaries to coastal and lagoonal environments of the east and west coasts of New Caledonia.

Comparison of the distribution of ostracod species has improved the accuracy of definition of the ecological ranges of some species and allowed the distinction of different assemblages: freshwater, estuarine, inner euhaline and outer marine.

Freshwater populations of rivers and swamps are dominated by such typical and ubiquitous genera as *Cyprinotus*, *Cypridopsis*, *Stenocypris*, *Erpetocypris* and *Darwinula.* These populations live mainly in sheltered habitats of aquatic meadows of *Juncus maritima* and *Hydrilla verticillata.* Intersticial species such as *Darwinula* sp., which are exposed to frequent destruction of their habitats by hurricanes and floods; have developed a peculiar ecological strategy which consists of an internal breeding of juveniles. This adaptation allows rapid repopulation of the habitat by the surviving specimens after the flood (Lethiers, 1998).

Except for typical freshwater species, most other species seem to have a marine origin and have conquered the brackish environments in proportion to their physiological tolerance to stresses such as salinity, turbidity, low oxygen ratios and temperature variations in relation to the exposure to sun (ie. on intertidal flats).

Upper estuarine environments such as tidal channels are characterised by a low density and low diversity assemblage of *Callistocythere* sp. and *Xestoleberis granulosa* (BRADY), sometimes associated with *Mutilus packardi* (BRADY). This assemblage is found in sparse aquatic meadows dominated by *Halophyla* cf. *ovalis.* The species of this assemblage often have poorly calcified shells, which might relate to the lack of calcium in the continental waters. In estuarine environments, calcium is brought into the estuaries by seawater during the tidal cycle.

An assemblage dominated by *Cyprideis* cf. *australiensis* HARTMANN, in abundant and quite monospecific populations, characterizes salty shallow-water ponds and mangrove swamps with a wide salinity range.

The assemblage found in euhaline environments of tidal channels is very similar to the coastal marine assemblage of marine bays. However, the population structures of these both associations vary: the inner euhaline assemblage is dominated by few species such as *Clithrocytheridea spinulosa* (BRADY) or *Clithrocytheridea atjehensis* KINGMA, while the marine association is characterised by higher diversity. Domination of the assemblage by one species is less important than in the estuarine environment and may vary from one sample to another.

In marine bays and in the lagoon, the microfauna is distributed in concentric zones of increasing density and diversity with the deepness and the weakening of the dynamic conditions.

This observation has met exceptions around fringing reef flats and islets where the abundance of specimens and taxa of the family Bairdioidea induce an increase of the species diversity and of the individual abundances.

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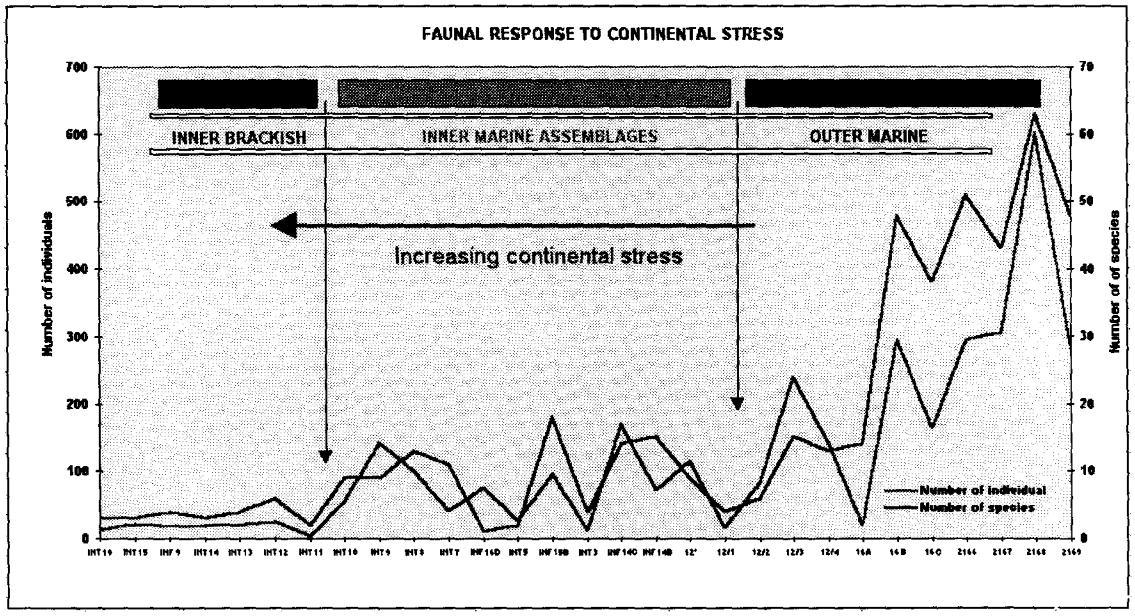
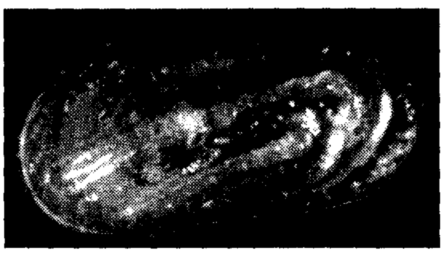
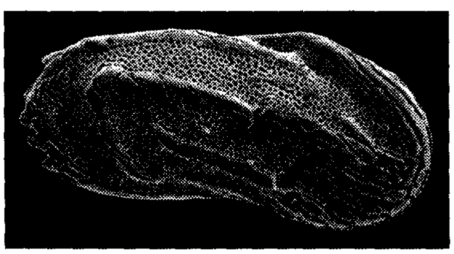


Ostracod shell variability observed in the marine sediments may relate to the hydrochemical conditions of the environment; specimens moulting in precipitating conditions being more heavily calcified and smoother than specimens moulting in dissolving conditions. This variability may also be controlled by genetic factors (Eagar, 1999).



(?) *Australimoosella* sp.A (APOSTOLESCU)
smooth specimen



(?) *Australimoosella sp.A* (APOSTOLESCU)
ornamented speciman

Conclusions: Quantitative as well as qualitative analysis of the Neocaledonian microfauna along continent to ocean transects from various estuaries and bays lets us define with better accuracy the ecological range of the ostracod species and distinguish different assemblages. More than 130 species have been identified which indicates a high level of biodiversity. The gradients observed in the microfauna composition and the increase of individual abundance and of species diversity appear to be linked to the decrease of such continental influences as low salinity, turbidity and laterite sedimentation. All of these observations constitute an important database which brings a better understanding of the distribution of the regional microfauna and could be applied to the interpretation of the sedimentary records of the past (Quaternary to Cenozoic).

EAGAR S., 1999 : Intraspecific variation in the shell ornamentation of benthic Ostracoda (Crustacea) from Kiribati, Pacific Ocean. Oceanologica Acta - vol 22 - n° 6.
LETHIERS F., 1998 : Evolution de la biosphère et événements géologiques. GORDON AND BREACH SCIENCES COMPUTER. 321 pages.

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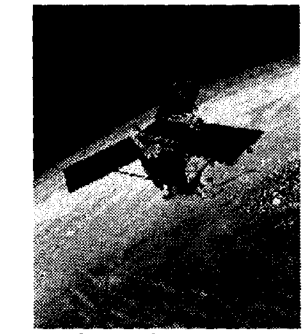
Developments in Remote Sensing for Pacific Island Countries
Wolf Forstreuter, Remote Sensing Specialist, SOPAC Secretariat, Suva, Fiji Islands.

This paper highlights the new satellite image data available for Pacific Island Countries and identifies the additional services that SOPAC will provide the member countries. The higher quality, lower price and faster delivery of spaceborne image data provides exciting new opportunities for Pacific Island Countries where new aerial photographs are still too expensive and require time-consuming planning and post processing. New applications are increasing and new techniques are being developed.

New Satellite Image Data
There are several satellites either planned for launch or recently launched providing new image data. Two satellites of relevance to the region are described.

Landsat 7 now records images in 8 spectral bands and has sufficient onboard storage capacity to update image data of Pacific Island Countries on a routine basis. The dramatic fall in price to USD 600 for 185 x 170 km image coverage that is usable for mapping at 1:50 000 scale provides opportunities for new applications.


IKONOS in space

IKONOS, the first of a new generation of remote sensing satellites, provides 1m panchromatic and 4m multispectral spatial resolution images for thematic mapping at 1:10 000 scale. Two more satellites will be launched during this year with two more during the first quarter of 2001. The user currently pays USD 34 per sq Km for a minimum order of USD 2000. However, the competition of additional satellites will further reduce this price.

Application of Spaceborne Remote Sensing Data
These developments allow more frequent mapping and delivery of images in a more useful format than aerial photographs. The higher quality, lower price and faster delivery of satellite image data provides new opportunities for developing applications such as:

1. Utilities able to produce image backdrop for areas where 1:10 000 maps do not exist:

- power utilities require image data for planning of new circuits and monitoring of their assets such as lines and transformers. The up-to-date vegetation cover provides important information for such mapping.
- water and telecommunication utilities have similar demands for image backdrop as well as for monitoring watersheds.

2. Forestry and environment sectors undertaking vegetation mapping having access to more up to date image data necessary for:

    - forest certification for forest products entering the US or European market must be labelled stating the origin of the product is from a sustainable managed forest.
    - water utilities who have a major responsibility for forest management in the watersheds.
    - carbon binding projects that will provide income for Pacific Island Countries when fallow land is reforested.
    - highlighting drought effects of El Niño.

3. Shallow-water mapping required for:

    - monitoring of coastal erosion including post-cyclone mapping
    - monitoring the impact of aggregate extraction

- hydrodynamic modelling that visualises water flow in lagoon areas and bays for environmental purposes,
- reducing the risk of ship accidents,
- identification of shallow marine habitats

Development of SOPAC Services

SOPAC continually monitors new developments and provides member countries with this information. SOPAC provides recommendations on the type and range of images to meet the needs of all sectors, as well as assistance in analysis of data where member countries do not yet have this expertise.

SOPAC obtains information from image data selling companies and organisations and from the International Society for Photogrammetry Remote Sensing where SOPAC is the regional member. SOPAC then disseminates the following information to member countries:

- availability and cost of satellite image data, which can be recorded from the region,
- suitability for various sectors with cost benefits
- new techniques to enhance and analyse image data,
- new developments for image analysis software,
- recent applications of remotely-sensed image data.

SOPAC has links to the following image data selling companies and organisations that also include future satellites:

- EROS Data Center (USA) for Landsat 7 images and Terra products
- SPOT Image (Australia) for SPOT images
- SpaceImagine EOSAT (USA) for IKONOS image products
- NRSA (India) for IRS-1B and IRS-1D images
- EarthWatch Incorporated (USA) for QuickBird image products
- Orbimage (USA) for OrbView-3 and OrbView-4 image products
- RADARSAT (Canada) for radar images
- NASA (Australia) for PAC RIM products

In addition to direct response, SOPAC uses workshops, the Regional GIS and Remote Sensing newsletter, SOPAC's web site and the e-mail list GIS-PacNet to transfer the information.

During the past year, several tasks were carried out for member countries where remote-sensing data was employed. These included assistance to forestry, shallow-water mapping and power utilities projects. SOPAC also supports the University of the South Pacific in the field of Remote Sensing. As a next step SOPAC will assist member countries in conducting their own image data enhancement and backdrop production as well as image analysis.

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GIS Open Source Developments
Franck Martin, Information Technology Unit, SOPAC.

The international scientific community is frequently used to assist in the development and testing of software released in the public domain for the benefit of researchers. Software such as GMT, a map printing tool, from the University of Hawaii, MB-SYSTEMS; a swath bathymetry tool from the University of San Diego; and GRASS; a raster GIS, from various US universities are examples of software being used by SOPAC.

Linux is a newly-emerging operating system which is based on the proven and reliable Unix operating system. The difference between the two is that Linux is virtually free and applications are developed under the GNU GPL (GNU General Public Licence) which allow people to provide code and binaries free of charge.

The computer industry is shifting towards Linux. Already several scientific applications have been re-compiled under Linux. Various applications have been redesigned to use the latest technology available on Linux: Gnome, the graphical user interface; and CORBA, the object model.

SOPAC has also initiated such a project in GIS using the resources of the open-source community: FMaps. The project is freely hosted and managed from sourceforge web site: http://fmaps.sourceforge.net/. This application uses a real client server approach with the usage of metadata cataloguing information.

The following summarises the main specifications of FMaps:

Database:
The database engine is <http://www.postgres.org/> PostgreSQL. PostgreSQL is an opensource SQL server. A user-defined type has been created to follow more closely the opengis specifications. A SQL server provides multi-user secure access to data over networks, this is a unique advantage over proprietary developed database files.

Metadata:
FMaps will follow the GIS/RS metadata guidelines of the <http://www.fgdc.org/> FGDC or the <http://www.anzlic.gov.au/> ANZLIC. The ANZLIC standard is simpler than the FGDC standard. However an ISO standard for GIS/RS metadata is in preparation and will be adopted as soon as it is available.

Data:
The <http://www.opengis.org/> opengis consortium has released a set of guidelines for databases and GIS/RS applications to store and manage GIS/RS data. These guidelines will be followed as much as possible, but total compliance will be difficult to achieve.

The data should include native 3D objects and Time information. It will allow drawing native 3D maps important for mining, water resources, and also drawing timed series map important for geophysicists, statisticians and other professionals requiring detailed mapping information.

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IT for Forest Labelling and Certification in Fiji Islands
Wolf Forstreuter, Remote Sensing Specialist, SOPAC Secretariat, Suva, Fiji Islands

Introduction
To add value to forest products in Fiji, the final commodity has to enter a market, which demands high quality and is willing to pay a corresponding price. Such markets are in Europe and USA, however, they require that the product comes out of a sustainable managed forest. This again requires that a) forest areas in Fiji are certified as a forest area with sustainable management and b) that the end product was produced out of timber coming from exactly this area. The ITTO (International Tropical Timber Organisation) financed a project to establish a transparent chain of custody allowing at the harbour to identify timber coming out of a certified forest. Fiji's Forestry Department contracted SOPAC to carry out the project based on its IT and GIS experience.

The Barcode Stickers
A transparent chain of custody requires that the Forestry Department is able to monitor timber from the point of origin where the timber is felled in the forest, the scaling that took place, the processing up to the point where the timber is leaving the country. To identify each piece of timber for later tracing stem and stump are marked with plastic barcodes directly after the felling. During the scaling process at the landing each timber is cut to log length and every log gets a plastic barcode. These barcodes are then recorded again when the log gets onto a truck, arrives at the sawmill and finally when it is entering the mill gate. The sawn timber pile gets a new number when the timber is supposed to go into a product, which will be exported later. The barcode tags have a unique number for all stumps, stems and logs labelled in Fiji, reflected in the barcode. After three years, the plastic tags will be supplied with a new colour and the numbering can repeat old numbers. To monitor the location of logs a central data storage and a non-central data input is essential.

Log tagging in Fiji's natural rain forest.

The Network

The Forestry Department uses a wide-area network that links computers located at the divisional offices throughout Fiji. The system allows the divisional offices to connect to a central database that contains information necessary for recording and tracking the flow of timber from point of origin, through processing to point of export.

For such a system to be operational and sustainable in Fiji the following specifications were required:

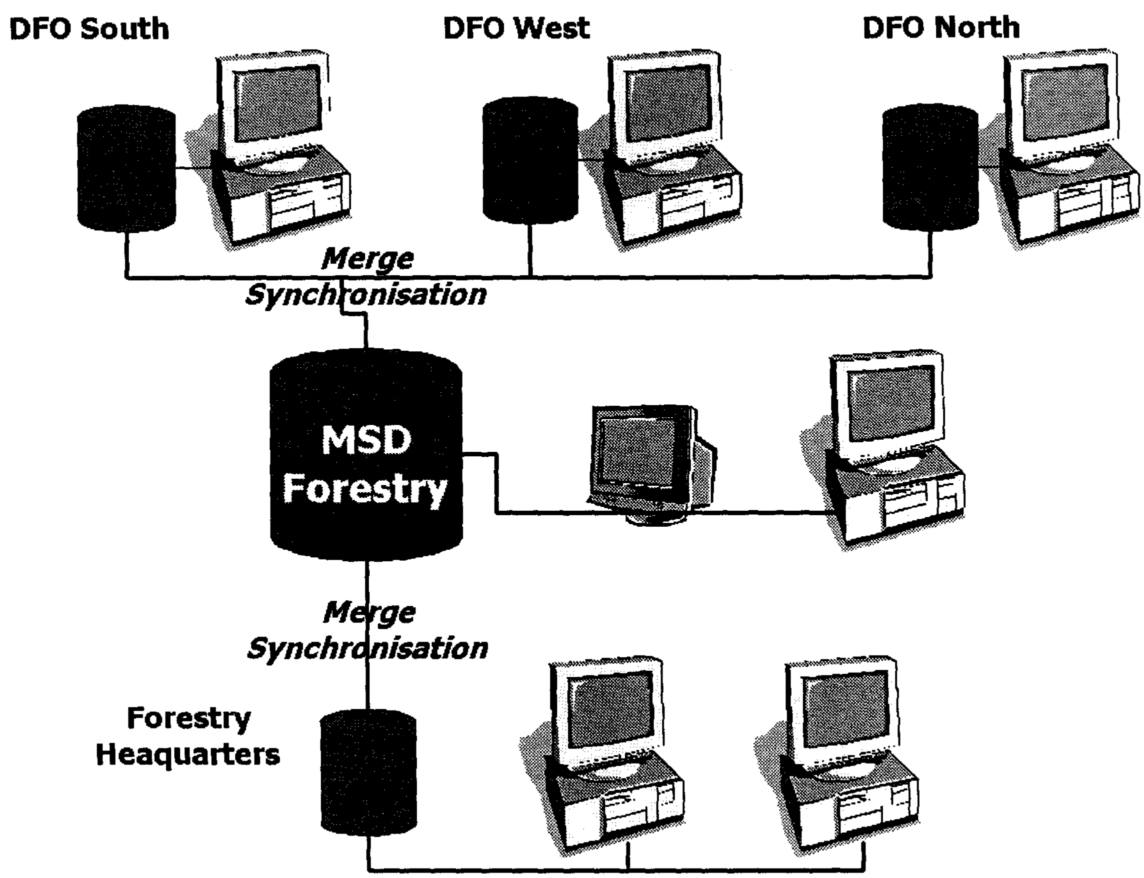
- PC-based hardware that can be maintained by local suppliers
- Recognised standard software that can be developed and maintained by the Forestry Department
- User-friendly interface for data entry by Forestry staff.
- Robust central database system that provides synchronisation with the divisional offices.

Microsoft SQL Server was selected as the database software providing synchronisation between the tables stored at the central server and the tables stored on the PCs at and Forestry headquarters. Telephone lines provide the link between the PCs and the central server and allow the tables to be synchronised daily.

The user-friendly interface has been developed in Microsoft Access that is a component of the Microsoft Office 97 Professional product. The Microsoft Access interface and tables are linked to SQL

Server at each client that allow for synchronisation with the central SQL Server database.

The wide-area network of the log monitoring system.



At the Forestry Headquarters the up-to-date situation can be displayed in spatial environment. The officer linking the Department with customers calling from other countries can display the amount of standing timber per district and will be able to display the amount which is available in timber yards of the different sawmills all over Fiji. This will improve the service provided to customers. In addition, this now allows tracing every timber, waiting in the harbour for the shipping, back to the point of origin.

Conclusion and Recommendation
Fiji's forest situation is stable because the forests are managed in a sustainable manner. Three forest areas have been identified for certification by an internationally recognised organisation. Following certification, timber quality labelling can be implemented that will result in timber products from Fiji being recognised by customers world-wide. Reaching this stage, more value adding of timber products in Fiji would be the consequence, which would create employment in addition to financial benefits for Fiji. This is not limited to timber, bamboo and other renewable forest resources could be added, if a market and production line is established. Such a system is scalable and transferable to other Pacific islands that have comparable timber resources.

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Japan/SOPAC Deepsea Mineral Resources Program – Stage I
Kazuhiro Kojima, Offshore Minerals Geologist, SOPAC

In response to a request by SOPAC, the Government of Japan initiated the Deepsea Minerals Program in 1985 as a five-year cooperative study project between Japan and SOPAC. The program has been extended twice and completed in March 2000. The purpose of the program was to assess the potential of deep-sea mineral resources including manganese nodules, cobalt-rich manganese crusts and submarine massive sulphide deposits within the Exclusive Economic Zone (EEZ) of SOPAC member countries.

The target minerals of the program were manganese nodules, cobalt-rich manganese crusts and hydrothermal deposits. Prospecting for manganese nodules was conducted in the EEZ's of Cook Islands, Kiribati, Tuvalu and Samoa. The EEZ's of Kiribati, Tuvalu, Samoa, Marshall Islands and FSM were survey areas for cobalt-rich manganese crusts. Prospecting for hydrothermal mineralisation was carried out in the EEZ's of PNG, Solomon Islands, Vanuatu, Tonga and Fiji.

Table 1. Survey area and target resources of the Programme

Phase	Year	Country	Survey Area	Target Resource
	1985	Cook Islands	North Penrhyn Basin	Manganese Nodules
	1986	Cook Islands	South Penrhyn Basin	Manganese Nodules
I	1987	Kiribati	Phoenix Islands Group	Nodules and Crusts
	1988	Tuvalu	Ellice Islands and Ellice Basin	Nodules and Crusts
	1989	Kiribati	Southern Line Islands	Nodules and Crusts
	1990	Cook Islands and Samoa	Southern Cook Islands Samoan Islands	Manganese Nodules Nodules and Crusts
II	1991	Kiribati	Gilbert Islands Group	Nodules and Crusts
	1992	Papua New Guinea	Manus Basin	Hydrothermal Deposits
	1993	Solomon Islands	Woodlark Basin	Hydrothermal Deposits
	1994	Vanuatu	Coriolis Trough	Hydrothermal Deposits
	1995	Tonga	Tonga Rides and East Lau Basin	Hydrothermal Deposits
III	1996	Marshall Islands	Northern part	Cobalt-rich Crusts
	1997	FSM	Whole area	Cobalt-rich Crusts
	1998	Marshall Islands and FSM	Southern part Whole area	Cobalt-rich Crusts
	1999	Fiji	North Fiji Basin	Hydrothermal Deposits

Based on the survey results, the resource potentials are summarised as follows.

Manganese Nodules
The survey has found two promising areas for future exploitation of the resource in the EEZs of Cook Islands: One is the area between 10°S and 11°S, which extends 6200 km^2 and has the average abundance of 21 kg/m^2. The other is the area between 15°S and 16°30'S, which extends 12000 km^2 and has the average abundance of 25 kg/m^2. In the EEZs of Kiribati and Tuvalu, distribution of manganese nodule is sparse and discontinuous in general. The EEZ of Samoa shows no potential for manganese nodule.

Cobalt-rich Manganese Crust
The survey so far found that thick crusts were well developed in the western part of Marshall Islands' EEZ and at some seamounts within the EEZs of FSM and Kiribati (Line Islands). Taking metal contents and areas of crust coverage into consideration, a couple of seamounts at Marshall Islands could be the most promising for future crust exploitation.

Hydrothermal Deposits
Though the research so far could not find any significant hydrothermal mineralisation but one mineralised zone in the Solomon Islands' EEZ, many hydrothermal communities and hydrothermal precipitates, which suggest possible presence of hydrothermal deposits, were found in all the surveyed EEZ's. The survey was focused on virgin areas rather than the areas around known deposits, and that could be a reason why only one mineralised zone was found.

The research programme revealed that SOPAC countries have huge potential of deep-sea mineral resources. For example, the cobalt resource in manganese nodules in the surveyed area is estimated to be 67.6 x 10^6 metric tons, approximately equivalent to the current word consumption of 2400 years.

The Stage II of the programme has commenced this year focusing on detailed ore prospecting in the promising areas found through the Stage I and environmental baseline survey for future **marine** mining activity.

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Data Analysis and Digitalization of the Cooperative Study Project on the Deep Sea Mineral Resources in Selected Offshore Areas of the SOPAC Region.
Nishikawa Nobuyasu, Metal Mining Agency of Japan

Introduction
At the request of SOPAC, the 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 projects started in 1985 consists of three phase surveys, each five years in duration. The fifteen year project has been carried out in eleven countries and areas since 1985. The purpose of the project is to obtain a basic data on mineral resources such as manganese nodules, cobalt rich crusts and hydrothermal deposits on the sea floor.

Japan-SOPAC GIS
In order to display and analyze the digitalized data of the results of "the Cooperative Study Project on the Deep Sea Mineral Resources", MMAJ built the data base system which is called "Japan-SOPAC GIS". This system is designed to link the data to the existing GIS software such as ArcView and MapInfo. Annual reports (1985-1999) also are stored in it.

Resource Potential Assessment
Using this system, MMAJ estimated reserves, metal grades and metal resources for manganese nodules and Cobalt-Rich Crusts based on the data acquired through this project.

(1) Manganese Nodules

With respect to the abundance of manganese nodule reserves, the characteristics of each group of sea area is summarized as follows;

Tuvalu(1988)-Kiribati(1991):
The abundance is generally high in the southern part and low in the northern part. Stations with abundance better than 19 • /• are distributed sporadically in the southern part.

The total reserves are estimated at 46 518x10^6 tons

Kiribati(1987):
The abundance is generally high in the southeastern part and low in the northwestern part. Stations with abundance better than 19 • /• are outlined in the southern part, not in the northern part.

The total reserves are estimated at 12 324x10^6 tons.

Cook Islands(1985,1986,1990)-Kiribati(1989):
The abundance is high in the central part, moderately high in the southern part and low in the northern part. Significant areas with abundance higher than 19 • /• are outlined in the central part. Some stations with such abundance are also distributed in the southern part. However, no station with such high abundance is located in the northern part.

The total reserves are estimated at 135 530x10^6 tons.

(2) Cobalt-rich Crusts

The surveys for cobalt-rich crusts were carried out in five countries:Tuvalu, Kiribati, Samoa, the Marshall Islands and the Federate State of Micronesia.

As a result, the crust reserves of the 54 estimated sea-mounts are characterized as follows;

- Sea-mounts with crust reserves of more than 15 million tons totaled 15 and account for 28 %. Most of them have an average thickness of more than 30 mm.
- Sea-mounts with large crust reserves are distributed mostly in the territorial waters of the Republic of the Marshall Islands and in its vicinity.

Also, the average metal grades and the estimated metal resources are characterized as follows;

- Co tends to be high in sea-mounts in the sea areas of the Phoenix Islands of Kiribati (1987) and the Marshall Islands (1996).
- Ni is relatively high in sea-mounts in the sea areas of the Phoenix Islands (1987) and the southern Line Islands 1989) of Kiribati.
- Cu concentrations are associated with sea-mounts in sea areas of the southern Line Islands of Kiribati (1989) and the Marshall Islands(1996) in general.

Conclusion
From 2000, Japan started a new stage project in the promising sites (Cook Islands, Marshall Islands , and Fiji, etc) selected from these survey results.

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Water Resources Assessment and Phosphate Reserves Survey on BANABA Island
Marc Overmars, Water Resources Unit, SOPAC.
Andrew Butcher, Human Resources Unit, SOPAC.
Jackson Lum, Mineral Resources Unit, SOPAC.

Water resources assessment
Water has always been a major constraint in the development of Banaba. There are no rivers or surface water areas on Banaba and rainwater rapidly drains through the fissured limestone.

During the mining period (1900-1979) a comprehensive water supply system served a total population of around 8000 people compound of mining labourers, administrative personnel as well as local Banabans. An extensive system of roof catchments was maintained with connections via galvanised pipes to storage tanks. In addition ballast water shipped in empty ore ships was pumped into enormous reservoirs and distributed to individual houses by tank trucks and to the industrial area by pipes. Since the mining has ceased the ships are not able to deliver water anymore with the moorings having disappeared and large ships not being able to cross the dangerous reef in front of the harbour in Ooma.

The current population of around 400 Banabans is now relies on rainwater, which is collected via roof catchments on individual houses, the hospital, the church and various other buildings. In addition three desalination units were installed to deliver water during the El-Niño related drought in 1997/1998. Water still left in three BPC reservoirs since 1979 was delivered to individual houses during this emergency situation.

Within the coral limestone there are series of caves, locally known as Bangabanga, some which are known to contain water. Drought periods during the Second World War led the Japanese military to pump water from pools in the caves. There is little information available on the extent of other caves, their location and the amount of water stored within them.

For many years the possibility to exploit the groundwater lens on Banaba has been suggested in order to overcome long periods of drought. However, it has never been thoroughly investigated and this mission will be a first step towards understanding the hydrogeology of Banaba.

To address the fresh water problem on Banaba three sources were investigated during our mission: a groundwater survey including geophysical detection methods; a roof catchment survey assessing potential and existing catchments and storage facilities and the use of desalination units.

Phosphate reserves
Mining of phosphate began on Banaba in 1900 and ended in 1979 with a brief interruption in production during the Second World War. Some 21 million tonnes of phosphate has reportedly been extracted from the island. There are unsubstantiated claims that economic tonnages of up to 3 million tonnes of minable phosphate material are present on the island. Pre-feasibility studies showed that there could well be some 2 million tonnes of phosphate rock available with 1 million tonnes of unmined areas and 1 million tonnes in earlier workings. Unmined areas include roads, buildings etc covering some 10 percent of the total land area of 595 hectares. Earlier workings include areas of partial mining and low-grade areas that were not mined previously. Additional secondary phosphate may also exist at lower depths that are yet to be tested.

The purpose of this study was to locate the presence of phosphate in unmined areas and to investigate the potential of secondary and buried phosphate on the island through a program of drilling and augering complemented with an electrical resistivity survey.

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Mapping of Shallow Lagoon Using Landsat 7 Image Data
Wolf Forstreuter, Remote sensing Specialist, SOPAC Secretariat, Suva, Fiji Islands.

Introduction
SOPAC employs two systems to map under water morphology: a) the multi beam mapper and b) the side scan. These instruments produce data for digital terrain models (DTM) at 1:10,000 scale and depths up to 300m. The effectiveness of the systems are limited in very shallow lagoons and costly where large coverage is required. Here, Landsat images can complement the former methods because of low cost and the ability to provide shallow area bathymetry at 1:50 000 scale.

Mapping can be carried out in two ways a) producing an image-map, which replaces colours indicating seawater on an existing map with the content of a satellite image and b) converting the satellite image to contour lines showing the sea bed morphology.

The Image-Map
For the target area Christmas Islands, Kiribati a map was available at 1:50 000 scale, which was produced from aerial photographs recorded 1957/1958. This map was scanned at 180 bpi to produce a three-layer image, then the different parts were geocoded and finally they were stitched together to from one image of the map. The next step performed a maximum likelihood image classification converting the three-layer image of the map into a single layer. Every pixel then had the information of the class represented by the colour of the map. By this, all pixels representing seawater could be addressed. This allowed combining the three-layer image of the map with the geocoded satellite image. The program replaced all pixels indicated as seawater by the corresponding pixels of the satellite image. The result is the image-map providing detailed information of the sea bottom where the original map is only showing homogeneous blue and keeping all additional information of the map such as land-cover types, grid lines and island names.

A small portion of the Image-Map, which shows the satellite images for all areas indicated as seawater on the map and map features for all other areas of the original map.

Zooming in before (left picture) and after the filtering process (right picture). The salt and pepper effect is removed because all clusters smaller than 6 pixels are converted and joined with the largest cluster of the neighbourhood. [ERDAS Imagine]

On the left, polygons representing the area shown in the figure above; on the right, polygons converted into a thematic map. [MapInfo]

Producing Contour Lines in Vector Format

The production of contour lines only requires the blue band of the satellite image, which was selected out of the 8 available bands. Knowing that the Christmas Islands lagoon had no sediments in the water and the sea bottom was equally sandy. The intensity of reflection of light is reduced exponentially to water depth. Then a density slicing process took this into account and converted the blue layer (up to 256 values) into 7 classes showing the water depths. The result was then filtered to reduce the number of very small areas. All clumps of pixels equal to or less than 5 were converted and combined with the largest class of the neighbourhood. A raster to vector conversion transformed this filtered raster layer into polygons which were imported to a vector GIS. The resulting contour map matched spot heights recorded from the same area during a recent survey. This allowed a calibration of the classes from the density slicing process of the satellite image.

Conclusion and Recommendation

The techniques of mapping shallow-water areas using satellite image data is a low-cost method for producing an image-map and creating contour lines. Both methods are easy to follow and do not require complicated software or mathematical formulae. Every step was carried out at SOPAC and could be applied to many shallow lagoonal areas that are hazardous to navigate within the Pacific. This would allow the multibeam mapping system to focus on navigable areas at scales from as detailed as 1:1000 for infrastructure development in the nearshore to scales of 1:10 000 or 1:5000 and where detail below 10 m depth is required.

SOPAC has experience in adopting satellite imagery to complement the swath mapper and can provide information over large areas for enhancing navigation and resource monitoring and management.

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

Mark Wellington, Manager, Business Development, Tenix LADS Corporation

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

The Royal Australian Navy (RAN) LADS system commenced survey operations in 1993, and since that time has surveyed almost 70 000 square kilometres of Australia's poorly charted and complex continental shelf, at an average rate of over 10 000 square kilometres per annum. The RAN LADS has been proven to be a fast, accurate and cost-effective bathymetric survey tool for hydrographic survey for nautical chart production.

In addition, the RAN LADS system has been used extensively around Australia to accurately survey territorial sea baseline turning points in remote and inhospitable areas. An example of this is around Ashmore Reef, off the north-west coast of Australia, where LADS surveyed the baseline turning points in order to negotiate the boundary of Australia's EEZ.

In 1998, the LADS Mk II system 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 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, Skaggerak, Baltic Sea, Timor Sea, Great Southern Ocean and Australian Antarctic Territory. In addition, in July 1998 LADS Mk II surveyed the territorial sea baseline turning points on the north east coast of Lizard Island, off the north east coast of Australia.

Figure 1: LADS Mk I and LADS Mk II in Darwin

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.

Figure 2: Sandwaves in New Zealand

This paper will outline some recent surveys conducted by the LADS systems, discuss the range of applications for which LADS and LADS data is used, and explore the data processing and quality control processes that have been developed.

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Wallis and Futuna. A pluridisciplinary approach to environment and lagoon resources - Presentation and objectives of the Geosciences Section of the program University of New Caledonia / Territory of Wallis and Futuna Islands

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The respect for environment and controlled management of development and littoral and lagoon resources are objectives clearly expressed by the administrative and customary authorities of the territory of Wallis and Futuna Islands.

Nowadays, several scientific and technical components play a part in order to refine the knowledge of the natural environment of both islands. Among the teams involved in this vast job, the University of New Caledonia has undertaken a series of expertises and scientific missions since 1999, in the fields of geological and biological oceanography, on request of the Environment and Civil Engineering Services of Wallis and Futuna Islands. Two laboratories of the University of New Caledonia are involved in a multidisciplinary calling research program: the Laboratory of Marine Environment and Living Resources Study and the Laboratory of Geosciences.

Achievements in the field of geoscience are as follows:

- An expertise of the coast of Wallis and Futuna, concerning coastal civil engineering developments and Protection against erosion;
- A geophysics mission with continuous seismic sounding, intended to characterize the superficial sedimentary cover of the lagoon of Wallis and to assess its potential concerning marine aggregates.

The geosciences section of the program (present and future) focuses on two complementary approaches:
- Analysis of the sedimentary dynamics of the lagoon and littoral hydrodynamic environment;
- Applications to civil engineering and environment problems.

Basically, the program to be carried out during the next months in Wallis and Futuna will involve:
- The detailed sedimentological cartography of the sea bed and inmost depths of the lagoon of Wallis;
- The sedimentological and geochemical characterization of the superficial sedimentation of the lagoon of Wallis;
- The acquisition of a series of currentological and « swellographic » measures with a view to the modeling of the littoral and lagoon hydrodynamism ;
- The controlling of the littoral geomorphological evolution of the coasts of Wallis and Futuna Islands.

As far as the applications are concerned, fight against erosion, endangered sites development, the building of founding facilities such as pontoons, quays, marinas, in accordance with the environment of the littoral sites are main priorities in the future. The multi-disciplinary approach to the sites proposed by the University of New Caledonia aims to provide to the decision-makers and the technicians in charge of these projects, the scientific database that is essential to make decisions and works design. The realization of these goals could ensure a better respect for the environment, maximize technical efficiency and present decision-making backed by rigorous scientific data.

As an example of this multi-disciplinary approach of the problems, we will quote the study in progress, aiming to assess the potential concerning marine aggregates of the lagoon of Wallis. The principle of the study has been defined on the basis of a preliminary report intended to take stock of the situation of the coast of Wallis and Futuna Islands. This report concluded on relatively balanced concerning Futuna, and on a strong destabilization of the beaches of Wallis. The reasons for this destabilization are classic and have been described in other places of the Pacific. There are two types of erosion origins. They are:

- Natural. The transgressive erosive trend due to the rise of the average seas level, with a reduction of beaches governed by the rhythm of storms and cyclones;

- Anthropic. Erosion caused are due to human mistakes concerning the management of the littoral environment: inadequate protection works, aggregates borrowing, destruction and anthropization of the dune offshore bars. Development has engendered a change in traditional building practices and a noticeable rise in littoral developments. The aggregates needs have increased, emphasizing the pressure on beach sand borrowings. At the same time, we have noticed an increase in the number of buildings on the littoral dune, and towards the coastline, without any preliminary analysis of their negative impact on the littoral.

With the progressive deterioration of the natural environment, an environmental awareness has appeared and an examination has been requested in order to take stock of the present situation and to propose corrective actions. Among the conceivable solutions to reduce the pressure on beach sand borrowings, the principle of reconnaissance of the potential in marine aggregates has been decided. In September 1999, a mission carried out by a mixed team of biologists and geologists from the University of New Caledonia has recognized the position of potential target areas. The geophysics mission that was carried out in June 2000 (reflection seismic survey) has permitted to draw a map of the superficial inmost depths of the three target areas: Halalo, Mata'Utu and Vailala. Data processing is in the final stage of realization. During the interpretation stage, the areas that have been listed as interesting as far as resources are concerned will be the subject of a biological and ecological analysis by the L.E.R.V.E.M. in November 2000. This analysis will provide the information necessary for the impact study preliminary to any exploitation if it turns out to be desirable in the eyes of the decision-makers compared with other open possibilities.

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Reducing vulnerability: geoscience in the context of human impact
Dave Tappin, British Geological Survey, Nottingham, United Kingdom

When most of us consider the role of geoscience in reducing vulnerability, especially in the context of climate change or sea-level rise, we almost certainly consider the high-profile and hard-core scientific issues of the global context of how and why these changes are happening. Oft asked questions are: Why is sea level rising (or falling)? Is global temperature rising? What is happening to the ozone layer? Most importantly: What is happening to me? And, in the instance of the Pacific Ocean Island communities: What is happening to my island?

Man's contribution to changes in our environment is particularly acute at present. It is increasingly recognised or believed (depending on your viewpoint) that the burning of fossil fuels or release of aerosols into the atmosphere is resulting in global temperature rise and increasing exposure to harmful ultraviolet radiation as the ozone layer thins and develops holes. In this context, the Pacific communities are on the receiving end. They are not primary producers of combustible fuel, nor manufacturing giants. But their location in the planets largest ocean means that they are very vulnerable to rising sealevels. Changes in sealevel are the result of complicated interactions of a large number of variables that affect the coastal zone, coastal dynamics, changes in the level of the land and changes in the ocean surface.

The objective of this contribution is to focus on the how man locally influences his environment and how consideration of man's impact might ameliorate harmful impacts.

The coastal zone is not only home to large numbers of people but is their source of food as well as building materials.

One of the major problems faced by the small islands and atolls of the western Pacific, such as Cook Islands, Kiribati, Marshall Islands, Tonga, Tuvalu and Samoa, is a continuing source of fine-grade construction material, i.e. sand and gravel. For sustainable economic development to continue, alternative supplies must be found and used. At present most fine-grained aggregate is extracted from the beaches. As the beach sand is increasingly removed the beaches are destroyed and the sand source is exhausted. Local studies from Tonga indicate that the active beach, used for fine aggregate, has a lifespan (at present rates of usage) of the order of years rather than decades. The effects of beach degradation impact upon coastal protection. Thus the coastal hinterland becomes more prone to erosion, inundation during cyclones, tsunamis as well as to rising sea level.

These aspects of man's impact on the coastal zone are discussed with reference to case examples.

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Coastal sediments of the tropical Pacific: What do we need to know?
John Collen, School of Earth Sciences, Victoria University of Wellington, Wellington, New Zealand

Coastal and nearshore sediments are important to all tropical Pacific nations as a resource for habitation, tourism and construction materials. As these sediments are immediately affected by environmental change and human activities, understanding of the sediment dynamics and budgets is vital to predicting the responses of the sediment systems to future changes and to managing the coastal and nearshore environment.

Our knowledge of many of the processes involved varies, with some now quite well understood but others requiring much more attention. The starting points are the sediment compositions, with the relative proportions of the most important components (coral, calcareous red algae, *Halimeda*, foraminifera, volcanogenic clasts) known from some areas. Determining these are not straightforward and have require a combination of sedimentological and geochemical techniques.

Many of the sediments are biogenic carbonates; so knowledge of the biology of a range of organisms, and particularly the rate of biogenic carbonate precipitation, is important. Growth rates and carbonate production are quite well known for some organisms for some areas (e.g. coral average 1200 $g/m^{-2}/y^{-1}$) but less well for others (*Halimeda* 13-2000 $g/m^{-2}/y^{-1}$, foraminifera 40-5000 $g/m^{-2}/y^{-1}$). Many studies have concentrated on the productivity or organisms per unit area (usually areas favourable to growth or to scientific study) but total productivity across the entire sedimentary system is more important. Species distribution is also important, and current research suggests that total productivity varies across the region.

Mechanical erosion and bioerosion processes and rates determine how much of the carbonate produced gets into the sediment system. There are few reliable studies of this and the relative importance of normal and catastrophic events needs to be assessed. Depositional processes, including transport directions and mechanisms, beach abrasion and burial diagenesis, also need further study. It is important to determine the "normal" residence time of each type of clast in each part of system. For example, if the residence time of a foraminiferan clast on a beach is 20 years and if foraminifera contribute 60 % of the sediment (as is common), then loss of the living foraminiferan community on the reef terrace will lead to the loss of up to 30 % of the beach per decade through attrition alone.

It is likely that many of these parameters will vary significantly across the region and thus understanding of the sediment budget at a single location will not meet all requirements. However, until the "normal" processes are understood, the reactions of the systems to global climate and other change will not be predictable.

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PacificGOOS Coastal Workshop Summary
Cristelle Pratt, Ocean Unit, SOPAC.

As part of Global Ocean Observing Systems [GOOS] Capacity Building Program for 2000, SOPAC and IOC convened the PacificGOOS Coastal Workshop, in Samoa on 16 and 17 August 2000. Due to the importance of marine and coastal sectors within the Pacific Region, the main focus of the workshop was to develop potential pilot project initiatives under the Coastal Module of GOOS. Workshop participants identified four possible pilot projects to address issues of water quality, coral reef health, mariculture development and coastal sediment dynamics in coastal waters within the region.

The general benefits of establishing CoastalGOOS activities, through improved monitoring and forecasting of the state of the coastal and ocean environment, the weather and climate, include the ability to:

- Detect and forecast the effects of climate change on coastal ecosystems and their human inhabitants
- Protect and restore healthy coastal ecosystems
- Manage living resources for sustainable use
- Forecast and mitigate the effects of natural hazards
- Protect public health
- Enable safer, more efficient marine operations

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Oceanographic Observation by TRITON Buoys in the Equatorial Pacific
NAKAMURA Toru and KITAZAWA Kazuhiro, Japan Marine Science and Technology Center (JAMSTEC)

In order to understand occurrence mechanism of El Niño phenomena, the Japan Marine Science and Technology Center (JAMSTEC) is actively engaged in long-term oceanographic observation with a moored surface-buoy network in the equatorial Pacific since 1998. The network is named the Triangle Trans-Ocean Buoy Network (TRITON) and deployed in the western part of the equatorial Pacific where TAO-ATLAS buoys were placed by NOAA-PMEL.

The principle scientific objective of TRITON is to investigate variations of ocean circulation, and heat and salt transports with emphasis on ENSO, the Asian monsoon, and decadal scale variability that influences climate change in the Pacific and its adjacent seas. TRITON buoys have been deployed in the western Equatorial Pacific at four sites along 156°E in 1998, and ten sites along 156°E, 147°E and 138°E in 1999. TAO-ATLAS buoys replaced with TRITON buoys in this region, and integrated TAO-TRITON buoy data are now used for basin scale ENSO monitoring. Preliminary results of inter-comparison between TRITON and ATLAS buoys that were closely deployed for several months demonstrated good accordance in observed data and adequacy for continuous data collection after replacement.

Both ATLAS and TRITON buoys aim to obtain oceanographic and meteorological data on a continuous basis. An ATLAS buoy consists of a set of basic meteorological instruments, e.g., an anemometer, an anemoscope, a thermometer and a hygrometer, and eleven sea temperature sensors at different depths. In addition to ATLAS buoy installments, a TRITON buoy is equipped with a barometer, a rain gauge and a pyrheliometer for meteorological measurement, twelve sea temperature sensors and salinity sensors at different depths, and an ADCM current meter at the depth of 10 meters. TRITON buoys help to measure heat and freshwater flows at sea-surface and salinity distribution along depth down to 750 m. Observation intervals are every an hour for ATLAS and ten minutes for TRITON, and data are transmitted via satellite to each data center once a day for ATLAS and every hour for TRITON.

A 20°C isothermal line representing a sea-surface thermocline is the indicator of reserved heat in the seawater whilst the depth of the isothermal line suggests degree of warm seawater concentration near the surface. According to recent analysis of such depth of 20°C isothermal lines and anomaly depth with observation dates, the line on the equator showed the remarkably deep value of 210 m in the western Pacific in the period of March-April 2000. The El Niño event of 1997/1998 that is considered as the largest in the history recorded in the isothermal line with 10 m deeper than the average depth of 180 m in the March-April period of 1996. However, the current results revealed that the isothermal line reached 30 m deeper than the average, and the 20°C isothermal lines indicated the similar depths in both north and south sides of the equator. The fact expresses that water mass with higher thermal potential than that of 1996 exist in a wider area. In other words, the TRITON buoy observation suggests that circumstance for appearance of the next El Niño would be settled after the ending of the last El Niño in May 1998 and the succession of La Nina about two years period.

Another remarkable fact is the change of surface salinity and temperature measured by TRITON buoys along 156°E from February 1999 to February 2000. The temperature warmer than 29°C appeared after August 1999 until around January 2000 in the Northern Hemisphere (at the sites of 2°N, 5°N and 8°N). This high surface temperature accompanied with relatively lower salinity, and the water mass variation shows strong negative correlation between SST and SSS. On the contrary, high surface temperature appeared after September 1999 in the Southern Hemisphere (at the sites of 2°S and 5°S), but did not always accompany low salinity. This feature should be investigated with more quantitative analysis taking into account the effects of local heat flux and salinity.

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Proposal for Capacity Building Project related to Argo drifting float program.

William Erb, IOC Perth Regional Programme Office.

Abstract: The Argo Project proposes deployment of approximately 3000 drifting floats over the world's oceans. The floats will provide salinity and temperature profiles from the surface down to 2000 meters depth. This data will support scientists and operational oceanography and will be used by modellers of climate for prediction and forecasting of seasonal and annual variations of climate, and others. There will be many applications for the data, some related to agriculture, marine living resources and coastal area management. Capacity building should be an important component of Argo, as a mechanism for demonstrating the utility of the data and for educating students about the importance of ocean monitoring.

An Argo float will be identified by any number of countries in the South Pacific. Depending on the number of floats deployed in the region individual schools may adopt their own floats. The float will be tracked by using the Internet; thus Internet access is required. On a periodic basis scientists will provide scientific and technical information about the causes for the floats movement and give insight about ocean currents, heat exchange, the southern oscillation, environmental issue, etc. The process should generate discussions about global observing systems, climate change, sea-level rise, global warming and so on.

Interest in the project has been expressed by several parties including the International Ocean Institute, the IOI node at the University of the South Pacific, the UNESCO Apia Office, NIWA in New Zealand, the IOC Perth Regional Programme Office, NOAA and the Argo Science Team Chair.

The project can begin when Argo floats are deployed in the South Pacific. The floats should have a four-year life. This will allow school children to track the progress of a float for the duration of its life.

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Metadata standards in GIS/RS

Franck Martin, Network & Database Developer, Information Technology Unit, SOPAC.

Collecting data for Geographic Information Systems (GIS) and Remote Sensing(RS) systems is an important part of the work of experts in the Pacific Region. It is especially true for oceanographic data. However it is more important to correctly reference this data, and to be able to ensure data quality. This data about data, or metadata is the vital part for data exchange. Where the data was collected, who is responsible of the data, what is the quality of the data, are all questions that metadata standards try to address.

There are currently two main metadata standards used in the Region – the ANZLIC metadata standard and the FGDC Metadata standard. The ANZLIC standard is simpler than the FGDC, and is quite sufficient for most applications. Both standard provides means to extend the standard to add some information. Peculiar to a particular field like oceanography. The MEDI standard used by the IODE/GOOS is based on ANZLIC with some oceanographic extensions.

SOPAC, has developed an application based on the ANZLIC standard that allows to store MapInfo data (which is the Pacific standard for GIS application) into a metadata database system. This initiative is called WAGIS. WAGIS stands for Wide Area GIS, because WAGIS does not only store MapInfo Data, and Metadata, it also allows the exchange of this information with other WAGIS servers via automatic E-mail. For the moment WAGIS push information towards subscribers, SOPAC will shortly add the capability of metadata merging inside WAGIS servers.

WAGIS is freely available, and is released under the GNU Public License (GPL) as per SOPAC data policy. However, a new metadata standard is being approved. This is ISO 15046-15. This standard can be as simple as ANZLIC or as complete as FGDC. We will see how ISO15046-15 fits the requirement for Oceanographic data.

WAGIS will be converted to support ISO15046-15 as soon as the standard is adopted.

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POSTER

Freshwater Ostracods from Tarawa: A breach of biosecurity?

Stephen Eagar, School of Earth Sciences, Victoria University of Wellington, New Zealand

Ostracods are small (typically 0.8 – 1.2 mm long) crustaceans that are found in many aquatic environments. There are many species living in the marine and fresh water environment in Kiribati. There are few freshwater ponds on South Tarawa of which two contain ostracods from two species, with one species in each pond. All ostracods are oviparous. Most young freshwater species form a desiccation resistant cyst in adverse conditions for survival. They can survive up to 50 years.

There are three significant points to the presence of freshwater ostracods on Tarawa : (i) how did they get there? (ii) when did they arrive? and if they can get there, (iii) what other biota have been introduced? Kiribati is an isolated place surrounded by ocean, and hence the introduction of freshwater ostracods naturally poses a problem. Furthermore, it has only been emergent for 2500 years BP, 2-3 metres above sea level and was not split off from another continent at any stage.

Well-established methods for transporting ostracod eggs have been documented. The mechanisms for moving them over long distances is many and varies from high altitude winds, mud on birds legs and even in the alimentary canals of birds. The opportunities to introduce ostracods to Tarawa on tools or machinery imported for construction purposes either in the historic (gun emplacements, bunkers during WW2) or in the recent past (airport runway, foreign embassies) is many and varied. More recently, used vans and cars have been imported from Japan.

There are abundant Cyprinotus Cingulenis (preiously found in Sri Lanka, Hawaii and the Sandwich Islands in a pond at the lagoon side of the Nippon Causeway likely Betio to Bairiki that was consructed in 1986-1988. The pond contains an accretion of car tyres and other rubbish indicating that Cyrinotus Cingulenis may have arrived with the imported tyres.

The pond at Ambo is a babai pit and contains *Limnocythere notodonta* (previously recorded from Java) in lesser numbers. It appears to be an older pond in an established residential area. No explanation is offered for the occurrence of the ostracods here.

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POSTER

Field Mapping of Superficial Formations in New Caledonia: Geohazards Mitigation

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Of the natural hazards that affect the Southwest Pacific region and thus New Caledonia, tropical cyclones are the most frequent and have the most damaging effects. Excess rainfall often triggers slope failures and landslides.

In 1988 in New Caledonia, cyclone Anne initiated a big "debris flow" in the suburb of Noumea, within the Mont Dore district. There were no human deaths but the damage costs reached 200 million Pacific Francs (about 1.8 million US$).

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

The knowledge of superficial formations is of utmost importance in terms of geological hazards mitigation, resources (nickel and alternative resources such as the PGE), land management and environmental development.

Consequently, the Service of Mines and Energu of New Caledonia, jointly with the B.R.G.M. (Bureau de Recherches Géologiques et Minières), has started since 1997 a pluriannual programme that aims at both mapping the superficial formations and assessing the geohazards within sensitive areas selected by decision makers.

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

The highly weathered and fractured, perched ultrabasic massif that overlies the decollement level of the serpentinite sole is still affected by vertical movements. It represents an unstable geomorphological unit within which the combination of aggravating factors such as steep slopes, a well-developed drainage pattern and human intervention (mining, road construction) strongly increases the probability of landslides, debris flows and slope failures. These geohazards mainly occur at the slope break near the contact with the autochthonous volcaniclastic substratum.

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POSTER

The Mw 7.5 November 26, 1999, Ambrym-Pentecost (Vanuatu) earthquake: preliminary data on seismicity, associated tsunami and crustal motions.

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Introduction

On November 26, 1999, at 13h21 GMT, the central part of Vanuatu, and specially the islands of Ambrym and Pentecost, experienced a large earthquake of magnitude Ms 7.5, followed by a tsunami, that killed 10 people, caused significant damage to buildings and structures (churches, schools, markets, water tanks) and triggered numerous land slides.

This large destructive event occurred in the southern end of the back-arc compressive belt of the central part of the Vanuatu subduction zone, whose the structure is heavily perturbed by the subduction of the d'Entrecasteaux ridge.

GPS data indicate a comparatively slow convergence rate at the plate boundary for the central segment of Vanuatu arc (4-5 cm/year at Santo-Malekula while it is up to 10 cm/year at Vate. This implies a convergence rate along the back-arc thrust zone similar to that along the trench, and possibly the existence of an intra-arc right-lateral strike-slip fault zone which connects the fore-arc and back-arc.

We report here the first data recorded by our local seismic and geodetic networks together with field observations collected on Pentecost and Ambrym in December 1999.

Seismicity

The main shock was located between Ambrym and Epi islands by USGS (16.43°S, 168.23°E, 33 km) and to the northeast of Ambrym by Harvard (CMTS location at 16.02°S, 168.33°E, 20 kn). It was located by the IRD network in Vanuatu (8 stations) at the northern tip of Ambrym island (16.11°S, 168.13°E, 18.75 km, the closest station on Ambrym is only 25 km away). The islands most severely damaged by the seismic sequence are Ambrym (eastern and northeastern part of) and Pentecost (the whole southern part) where intensity has been felt up to 7 or 8 on the Mercalli scale. Sixty aftershocks, 6 of which with magnitude between 5 and 6, were locally recorded in the next 9 hours after the main shock. The epicenters spread in a north south trending strip pattern, 100 km long by 25 km wide, from the south of Ambrym (16.5°S) up to the northern part of Pentecost (15.5°S) where the largest aftershock (Ms 5.9 at 22h03) occurred. The size of this aftershock zone is compatible with the seismic moment found by Harvard for the main shock, allowing already an identification of the rupture zone.

The focal mechanism solution published by Harvard indicates a thrust motion. Considering the tectonics of central Vanuatu and the previous shallow seismicity, the plan striking N191° and gently dipping to the west (28°) is interpreted to be the fault plan. This event is the largest recorded earthquake that occurred along the 350 km-long back-arc thrust zone stretching from 13.20°S to 16.40°S. A large thrust earthquake (Mw 6.5) took place on August 22, 1999 in the same area between the Pentecost and Maewo Islands, and earlier that year, a small seismic sequence (Ms 6, 5.4 and 5, from February 14 to 26) also occurred, right north of the aftershock zone of the November 26 earthquake. The intense seismic activity along the back-arc zone is quite comparable with what is observed in the fore-arc domain (Santo-Malekula) where large earthquakes were expected and occurred. Together with the results of the geodetical surveys carried out these past years, it confirms that the back-arc thrust zone is a major fault system in the tectonics of the central part of the Vanuatu arc.

Tsunami

The worst hit area by the tsunami was the Martelli bay at the southern tip of Pentecost island. Eyewitnesses indicate a withdrawal of the sea (200 m) then a sucession of three waves. Water penetrated almost 1 km in the bay and the inundation height was 6-7 m. Along the southwest coast of Pentecost the water height was 1-2 m. In the eastern Ambrym, the wave height is estimated at 3-4 m along the northern coast and 1-2 m along the southern coast. An inundation of 7-8 m, likley due to site effects as in the Martelli bay, occurred at the mouth of the river south of Pamal at the eastern tip of Ambrym.

The tsunami was also documented on the coast of Epi (1-2 m) and the east coast of Malekula (50 tons ship sunk). It was recorded in the tidal gauge of Efate at a distance of 160 km, where several sea level oscillations began at 14h00 GMT, half an hour after the main shock (maximum amplitude of 1.2 m with positive of 0.5 m at 2.30 pm).

Due to fact that the event occurred at mid night, the arrival time of the tsumani and its relationship with the main shock reported by the few eyewitnesses are confused. On Efate, the arrival of the wave train is significantly delayed with respect to the origin time of main shock, suggesting that the source was a seismic-triggered submarine landslide rather than seafloor deformation, as was the case with the Papua New Guinea destructive tsunami. Multibeam mapping of the area by the R/V L'Atalante in March 2000 revealed some landslides southeast of Ambrym and in the channel between Ambrym and Pentecost. These data will greatly help to model the tsunami and to address the problem of its source (works in progress).

Coseismic displacements
Evidence of significant coseismic vertical motion have been observed on the easternmost part of Ambrym. Dead coral heads on a reef flat near Ulei indicate at least 50 cm of uplift. Also a white fringe resulting from the dessication of red algae developed along the rocky coast. The uplift decreases rapidly westward from 1-1.2 m to be nil 3 km west of the eastern tip of the island. Further West, lack of evidence of uplift or evidence of subsidence have been observed on both northern and southern coasts. The high gradient of vertical motion indicates that the rupture zone is shallow under the eastern part of the island.

The GPS local network in the central Vanuatu islands (around 20 sites) has been re-occupied. The closest site of the epicenter, at West Ambrym, has been reobserved in the week following the quake. Coseismic displacement at this site is 35 cm eastward and 5 cm northward, vertical motion being small enough to be ignored.

Vertical and horizontal coseismic displacements observed in Ambrym can be explained by a large slip motion (4.5 m) along a shallow (0-15 km) west-dipping thrust fault plane striking N-S and emerging east of Ambrym and Pentecost islands. Both the size of the aftershocks zone and the first-motion depth of the main shock, determined with the local network, are in accordance with this preliminary interpretation of the ruptured area. However a precise model for the source of this destructive event will be obtained after a body wave form analysis of the main shock and the study of the complete aftershocks sequence and the coseismic displacements at the GPS sites of the whole central Vanuatu archipelago (work in progress).

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POSTER

A multidisciplinary study of active tectonics at Futuna, Southwest Pacific.

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Futuna archipelago (Futuna and Alofi Islands) is located along the northern border of the Fiji Fracture Zone, a segment of the Pacific-Australia plate boundary and one of the major transform faults of the world. The archipelago is subjected to shallow earthquakes and subsequent landslide and tsumani. The last major event (Ms 6.5 March 12, 1993) killed 3 people and caused severe damages on Futuna island. Since 1998 we have conducted a multidisciplinary approach on seismic hazard at Futuna, combining both on land (seismological, geodetic and geological studies) and offshore (regional multibeam mapping) investigations.

Four seismological stations have been installed in 1999 and a GPS array of 8 sites is being observed yearly since 1997. First results of this program include:

(1) measurement of coseismic uplifts (from 0 to 50 cm) related to the March 12, 1993 event by analysing morphology of living coral microatolls;

(2) relocation of this event just south of Futuna island (5 km depth) by fitting dislocation model to observed uplifts;

(3) record of seismic sequence (September 1999) also located south of Futuna;

(4) determination of a reduced (still within the error bars) inter-seismic deformation of the islands derived from the GPS series;

(5) identification of the main tectonic structures offshore from multibeam survey, and of a scar indicative of submarine landslide south of the region which underwent a local tsunami and the maximum uplift in March 1993.

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POSTER

From dynamic processes study to concerted management for a low coralline island. The example of Fongafale, Funafuti Atoll, Tuvalu

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In the context of a likely acceleration in rise in the global sea level and consequent impacts, physical geography may help local communities exposed to these hazards by developing tools for prevention and management.

These tools could make the target population less vulnerable to sea-level rise and ameliorate the impact of natural calamities.

The present study, using Fongafale Island as an example, aims at a re-evaluation of the management of low-coralline islands. Fongafale has erosion problems, initially of a natural origin but later combined with or accentuated by human actions due to excessive coastal development. Funafuti was a strategic location during World War II and the facilities developed at that time have had and still have direct consequences on the behaviour and evolution of sediment deposits and the evolution of the shoreline. The different origins of the coastal disturbance have affected not only the island morphology but also the life of inhabitants, as living space on the atoll has been significantly reduced. The rapid growth of population has made it necessary to find a solution urgently.

This low island is thus an ideal site for a general and geographical review that takes into account the environmental conditions.

In order to understand the environmental problems to which Fongafale is exposed, an evaluation of the lagoon coast will be made based on aerial pictures and new data. It is indeed essential to draw lessons from the past in order to adapt to the present problems facing these shorelines.

Finally, solutions to the management problems such island states are facing will be offered. To do this, the use of applied geography and concerted management between the various participants seems essential.

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POSTER

Scientific Targets at Intraoceanic Convergent Margins Drilling Objectives in Tonga.

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Intraoceanic convergent margins are ideal locations for understanding the transfer of mass and heat to and from the earth's interior. Simple and limited numbers of components allow better discrimination of fluid flows, geochemical inputs and magmatic fluxes as well as rates of crustal erosion by subduction processes than may be obtained along more complex systems. However, many of the present models used are based upon the Izu-Bonin Mariana (IBM) system in the northwest Pacific and although the results of drilling there have led to model definition, confirmatory experiments in other areas are required to assess whether the IBM system is truly globally representative.

Previous phases of ODP drilling have addressed many of the fundamental recycling processes that take place at intraoceanic convergent margins such as chemical and structural evolution and back-arc basin processes. However, there are still outstanding problems. It is the purpose of this poster to identify these problems to stimulate discussion and the formulation of proposals for consideration during the next phase of drilling after 2003. It is also evident that these outstanding problems may be fruitfully investigated along the Tonga convergent margin system. Three main individual scientific themes (although all are inter-related) that are considered here as priorities are those of:

- Island arc initiation
- Rates and mechanisms of subduction erosion, and the
- Origin of ophiolites

Island arc initiation

Evidence from the IBM system shows that magmatism appears to evolve from an early, a really extensive and voluminous phase to a later, more focused phase, when volcanic output is reduced and loci of volcanism emerge. In Tonga, preliminary investigations support this model, suggesting a major magmatic event right across the Western Pacific in the mid Eocene (40 ± 5Ma).

Characteristic of both the IBM and Tonga systems is the presence of boninites, which prove that, in contrast to the later phases of arc evolution, early arc magmatism involved a rapid and, possibly catastrophic, high degree of melting of very hot mantle under unusually high fluid fluxes. However, we do not fully understand:

- the relationships between magmatism and the plate tectonic cycle,
- the type of magmatism of the early arc event compared to that taking place later, when sources and tectonic environments may be very different, nor
- whether all convergent margin systems evolve in a similar fashion.

All of these questions require investigation if we are to more fully understand magmatism at convergent margins and its broader implications for mantle differentiation and the plate tectonic cycle, both of which impact upon heat and material fluxes of the Earth. Initial arc formation may also relate to the origin of Supra-subduction Zone Ophiolites (see below).

Rates of subduction erosion

Mechanisms, by which crustal material is returned to the mantle have been proposed and are considered to operate over a number of timescales, generally described as 'steady state' and 'catastrophic'. However, the actual rates of recycling are not well known. For example comparison of spreading rates in the Atlantic with consumption rates along the convergent margins of the western Pacific indicates that subduction erosion in the latter area may be far in excess of that thought. Much of the evidence from the northern Pacific is in the form of exposed basement rock. More sophisticated techniques used in Tonga utilise subsidence curves and tilt rates. The evidence from Tonga suggests that there may be three mechanisms: early arc subsidence taking place after arc initiation, steady state during 'normal convergence and catastrophic through collision with asperities on the downgoing plate. Subsidence along the length of the arc is confirmed by seismic imaging although there is an along arc change caused by variations in structure of the downgoing plate and the arc massif itself. The object of the drilling experiment is to identify rates of subsidence along the forearc and from this deduce rates of erosion. This type of data may be utlised in understanding both mechanisms and rates of crystal recycling.

Testing the ophiolite model with deep drilling

The sheeted dikes in ophiolites and the abundant structural evidence for synmagmatic normal faulting provide compelling arguments for their formation by seafloor spreading. Hence, ophiolites are typically assumed to reflect the structure and stratigraphy of oceanic crust formed at mid ocean ridges.
However, it has been known for a number of years that the majority of the large, relatively intact Tethyan ophiolites such as the Troodos Massif in Cyprus differ in significant respects from the mafic crust formed at mid-oceanic spreading centers. In particular, systematics of the geochemistry of the magmas that formed these ophiolites clearly requires that the parental melts were generated above a subduction zone.

Appropriate modern analogues for supra-subduction zone ophiolites have been difficult to find, especially as their subsurface characteristics are only accessible through drilling. Backarc basins have provided the most appealing analogue, but these ophiolites rarely have an associated remnant or active arc, nor are they covered by volcaniclastic sediments shed from those arcs, as is the case for most crust formed in a backarc basin. Efforts by the DSDP and ODP at the convergent margins of the western Pacific have identified clear alternatives.

We now know that a range of processesincluding rifting, sea-floor spreading, under-, intra- and over-platingcontribute to lithospheric growth in zones of tectonic plate convergence. Major supra-subduction zone extension and formation of new lithosphere probably accompany the nascent stages of arc growth over an area thousands of km in length and several hundred km in width. Confirmation of the equivalence of the supra-subduction environment with a major type of ophiolite (which represent a significant fraction of the continental lithosphere) is of major interest to a wide geoscience audience. One possible location for a deep drilling program to test this ophiolite model is in the Tonga forearc.

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POSTER

Seabed imaging, sediment coring and visualisation of the area offshore of Papua New Guinea – a case study of the July 1998 tsunami – and its importance in predicting tsunami events.
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The data now acquired from offshore of northern Papua New Guinea allows alternative models of tsunami generation to be evaluated and assessed as well as the construction of more realistic simulations.

The morphological and geological evidence now acquired by a combination of multibeam bathymetry, seismic and sediment piston coring, together with remote and direct visual observation by Remotely Operated Vehicle and Manned Submersible supports a slump generated tsunami event of July 1998. Fault mechanisms are discounted on the basis of an absence of reverse movement and limited fault length. The regional tectonic context of tsunami generation is a convergent margin along which subsidence on the inner trench slope is taking place. The subsidence is along mainly linear normal faults together with slumping in cohesive sediments that results in the formation of arcuate, amphitheatre-shaped depressions. It was in one of these, just offshore of the Sissano Lagoon (the area that experienced the maximum devastation) that the source slump is believed to be located (Tappin et al., 1999; Tappin et al., in press; Tappin et al. submitted).

The area offshore of Sissano Lagoon is sediment starved. Sedimentation is controlled by onshore drainage patterns that divert major rivers eastward thus constraining sediment pathways to the offshore. The sediment deposited is mainly fine (clay-grade) grained, and is soft and weakly consolidated in bathymetric lows and stiff and highly cohesive on slopes. Fine-grained cohesive sediment comprises the slumped area and is most prone to deformation.

Recent seabed movement is evidenced by the steep seabed morphology, fresh rock falls, talus slope deposits, steep fault headwalls and fissuring. Extensive cold water venting, with associated chemosynthetic communities (some very obviously recently displaced) indicates sediment dewatering either through slumping and/or near-seabed faulting. Limited transpressional faulting at the base of the slump amphitheatre is suggested by a prominent upraised seabed feature. The morphology of the fissures observed in the cohesive sediment indicates the slump to have moved as a mass, along rotational faults.

The offshore surveys demonstrate the critical importance of bathymetric, seismic and sediment data, as well as visual observation, in assessing tsunami generation mechanisms. Together with the evidence from onland investigation, survivor's accounts, seismology and historical reports, general predictions about tsunami vulnerability of northern PNG have been made.

The experience of PNG is undoubtedly applicable to other areas where there is a tsunami threat such as Japan and the west coast of the Americas', the Mediterranean and the Sea of Marmara. Of most importance is the construction of geological paradigms in which tsunamis may form, particularly the controls on the creation of large magnitude events. These paradigms are essential to the construction of realistic mathematical simulation of tsunami wave height and wave height distribution.

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