

**ABSTRACTS OF PAPERS
PRESENTED AT THE STAR* SESSION
1996**

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and
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Editors

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*SCIENCE, TECHNOLOGY AND RESOURCES NETWORK

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FOREWORD

STAR was founded in 1985 as a vehicle to assist the international geoscience community to provide advice to SOPAC on **Science, Technology and Resources** in the SOPAC region particularly during the intervals between SOPAC International Workshops, the fifth of which, devoted to seabed mapping, was held in Noumea and Lifou, New Caledonia in late 1994. The first Chairman of STAR, Dr Charles Helsley, then Director of the Hawaii Institute of Geophysics, guided STAR until 1992 when I took over the helm.

In 1994 STAR was renamed **Science Technology and Resources Network**.

STAR is not merely a technical meeting at which individuals present scientific papers and discuss results and implications. Participants have the additional responsibility to formulate advice to SOPAC about its work program and to highlight technical and scientific issues of particular importance or urgency. This advice is tendered during the Technical Advisory Group (TAG) sessions during the Annual Session, and all STAR participants are invited and urged to participate in this phase of the meeting. To facilitate this, STAR and TAG sessions on related topics have been scheduled sequentially.

One of the great strengths of SOPAC is its ability to mobilise excellent science and bring it to bear so as to address the national needs of SOPAC's island member countries. The long-established working relationship between SOPAC and the international research community is a vital element in this endeavour, which STAR is charged to nurture. This relationship stimulated an order-of-magnitude change in the geoscience database for the SOPAC region during the 1980's. This is summarised in *Marine Geology* v. 98, p. 155-165 (1991).

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 1997 Work Program and its Medium-Term Plan, which all participants should examine, encompass a broad spectrum of geoscience activities. So, new fields have been added to STAR, such as sea-level change and geo-hydrology. Coastal processes and coastal mapping, which have been the focus of several special workshops and training sessions since 1984, have been included. SOPAC's track record demonstrates that this approach to program development is synergetic, forwarding both the national needs of island nations and fundamental research. I commend it to you.

Keith A W Crook
Chairman, STAR

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September, 1996.

STAR Presentations at SOPAC Annual Session, 1996

PROGRAM

Time	Theme	Authors & Speaker	Title
Thursday			
08:30	Opening of STAR	Keith Crook	Chairman's remarks; explanation of working procedures, program, establishment of Working Groups
08:45-09:10		Winterer	Drowned carbonate platforms of the northwest Pacific: testing Darwin's hypothesis for the formation of atolls and barrier reefs
09:10-09:35		Collen & Eagar	Contribution of Foraminifera to sediments, Funafuti, Tuvalu
09:35-10:00		Morel	Modelling water depth and bottom type using remote sensing data in shallow coral reef waters
10:00-10:30	MORNING TEA		
10:30-10:50		Tappin	Coastal erosion on small coral islands: an example from Tonga and its regional relevance
10:50-11:10		Johnson & Talai	1994-96 Rabaul eruption, Papua New Guinea: local effects and regional consequences
11:10-11:30		Johnson	Community vulnerability to the effects of natural hazards: the role of IDNDR, and implications for the SOPAC region
11:30-12:00		Bevis	The future of GPS geodesy and precise navigation in the SOPAC region
12:30-13:30	LUNCH		

Friday			
08:30-08:50		Cruickshank	Waterworld - a 21 st Century reality? A discussion on the future of marine minerals
08:50-09:10		Auzende, Urabe & Scientific Party	Hydrothermal venting in the Manus Basin
09:10-09:30		Exon	Manganese crust and nodule deposits from bathyal depths, south and west of Tasmania
09:30-10:00		von Stackelberg	Environmental studies of a manganese nodule field in the Peru Basin (SE Pacific)
10:00-10:30	MORNING TEA		
10:30-11:50		Hosoi	The results of deep-sea mineral resources survey in Tongan Waters, 1995
11:50-11:10		Hosoi	Japanese Survey, Research and Development and Technology for Deep-sea Mineral Resources
11:10-11:30		Kojima	Review of MMAJ studies on recovery of metals from sea nodules
11:30-12:00		Yamazaki	Distribution characteristic of cobalt-rich manganese deposits for mining design
12:30-13:30	LUNCH		

Saturday			
08:30-09:00		Greene, Yoklavich, O'Connell, Wakefield & Cailliet	Why habitats - should SOPAC become involved
09:00-09:30		Cailliet	The importance of marine habitats in maintaining biodiversity and regional fisheries
09:30-10:00		Verlaan	The importance of accurate bathymetric and seismic surveys in light of edge-of shelf considerations under the 1982 UN Convention on Law of the Sea (LOS Convention)
10:00-10:30	MORNING TEA		
10:30-10:55		Kroenke & Mahoney	Spreading in the Ellice Basin: relation to the 90 Myr eruptive episode on the plateau
10:55-11:20		Tappin, MacLeod & Bloomer	Ocean drilling in the Tonga forearc: subduction geodynamics, arc evolution and deformation processes at non-accretionary convergent margins (ODP Proposal 451)
11:20-11:45		Montgomery	Update on US remote sensing missions in the SOPAC Region (NO ABSTRACT)
11:45-12:00		Murty, Henry & Aung	Tsunamis in the South Pacific Region
12:00-13:30	LUNCH		

(Abstract)		Wright	Morphology and evolution of the remnant Colville and active Kermadec Ridges south of 33 30'S
(Abstract)		Lee	Introduction of KIGAM's activities in Geosciences

Hydrothermal venting in the Manus Basin

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The Manus Basin is one of the intra-arc or back-arc basins aligned along the Australian-Pacific Plate boundary. It is limited by the islands of Manus to the north, New Ireland to the east, New Guinea to the west and New Britain to the south. The whole domain constitutes the Bismarck Plate. Structurally the Manus Basin is bounded by the fossil Manus subduction zone to the north and to the south by the tectonically active system formed by the New Britain Trench and the folded and overthrusting suture of Papua New Guinea. The emerged areas surrounding the Manus Basin constitute an ancient Tertiary volcanic arc, part of the unique arc separating the Australian and Pacific plates at that time and dismembered during the opening of the Manus Basin about 4 Ma ago. Different models have been proposed to explain the Manus Basin creation, from diffuse accretion up to a complex system combining accretion, microplate rotation and stretching passing through simple oceanic spreading.

The aim of the Manusflux cruise of the R/V YOKOSUKA and the submersible Shinkai 6500 (16 October-13 November 1995) was, within the New STARMER French-Japanese joint program, the in situ exploration and sampling of the Manus Ridge segments and active hydrothermal sites previously surveyed by indirect measurements and the exploration of the Manus Spreading Centre (MSC) in order to detect new hydrothermal sites. This multidisciplinary cruise involved geophysicists, geologists, chemists and biologists from France, Japan, Papua New Guinea, Australia and Canada.

Two diving sites were selected on the MSC: the first one was on the Vienna Woods site located at 2500 m depth in the axial graben at 3°10'S and 150°17'E on a fault bounding to the SE the neovolcanic ridge. The area of lobate lava and pillows located in the vicinity of Vienna Woods site shows an intense N60° and N120°-140° fissuration. The Vienna Woods hydrothermal site is an important field of active and fossil chimneys about 300 m in diameter. The main explored chimneys, 10-15 m-high on the top of a sulphides mound, expel a 285°-300°C shimmering fluid. The chimneys are made of anhydrite, sulphides, oxides and silica. The associated fauna mainly comprises gastropods, bythograeids, crabs, galatheids, shrimps and cirripeds. These petrological and biological characteristics combined with the temperature and nature of the fluids, are close to those observed on the White Lady site, on the Central Spreading Ridge of the North Fiji Basin, discovered and studied during the earlier STARMER Project.

The second explored area was on the recent axial volcano located in the southern part of the MSC. This volcano named Munkalin (razor-back in Papuan dialect) rises to 1942 m depth. The dive observations show that the volcano has recently been emplaced in a system of conjugate fractures, N45° which is the main trend of the axis, and N120°-140° which are the directions of the Willaumez Fracture Zone. The rocks outcropping are pillows and lava tubes organised in a succession of very recent flows crosscut more recently by scoriated lava flows occupying the top of the volcano. A preliminary analysis of the sampled rocks shows that they are andesitic basalts and not MORB's, such as the rocks sampled on the MSC axial ridge. No active hydrothermal activity was found in this area.

Two zones were selected on the Southeastern Rift: the Pacmanus area to the west and the Desmos area to the east. The Pacmanus site was discovered in 1990 during a deep-towed video-photographs profile. It is located on Pual Ridge which is N65° trending, 1700-2200 m deep linear massif. At its northern tip, Pual Ridge became a double ridge showing a Y-shape. The top of the Pual Ridge is dotted by circular or elongated seamounts a few hundred metres wide, 50 metres high. It is mainly on the NS faults bounding these seamounts that the active hydrothermal vents constituting the Pacmanus site are emplaced. During the 5 dives carried out in this area, 5 active sites have been explored. Two of them are shimmering water (45°C) diffusion zones. The others are sulphide chimneys expelling high temperature black fluids (250°C as maximum temperature and 2.7-3.1 pH). These chimneys are lying on top of sulphide mounds, several tens of metres in diameter. The associated fauna is composed of colonies of gastropods, mussels (bathymodiolus), crabs and fishes. The sampled rocks are dacitic.

The last explored zone was the Desmos area which is a cauldron about 1.5 km in diameter, 300 m deep, slightly elongated in a NS direction and crowned by a discontinuous annular ridge, 200 m high. Hydrothermal deposits and methane, maganese, alumina and pH anomalies have been already reported by US team. The dive data show that the cauldron is cut into a thick layer of lava flow. Its faulted walls cut the lava tubes and are covered with alteration products (oxides, staining, etc.). At the foot of the fault, large talus slopes reach more than 50 m high. On the northwestern flank of the cauldron an active hydrothermal site was observed. It is characterised by low temperature shimmering fluids associated with sulphides, oxides and a poorly developed animal fauna made up of galatheids, mussels and spaghettiworms. In addition one very large part of the site is covered by a continuous layer of white bacteria mats. A very robust site (the Onsen) has been sampled on an EW fault in this area. It is a white smoker, the measured temperature of which is 120°C, the pH around 2 and heavily loaded in H₂S (8 mmol/l).

The Manusflux cruise confirmed the magmatic, tectonic and hydrothermal activity of the two segments, MSC and Southeastern Rift of the Manus Basin spreading system. The MSC shows, along strike, the change of morphology from ridge to the south to graben to the north. The first morphology is linked with a recent magmatic episode meanwhile the second one is related to tectonic stage. The intense hydrothermal activity observed on Vienna Woods site is associated with this stage. The Southeastern Ridge is a more complex system closer to an extension zone than a typical oceanic spreading zone. Active hydrothermal sites are numerous (Pacmanus and Desmos zones) due to the fact that tectonism is predominant against magmatism.

The sampled rocks illustrate the peculiarity of the geodynamic context of the whole area and specially the vicinity of the arc. They are MORB basalts on the north of the MSC, andesitic basalts on the Munkalin volcano and acidic rocks on Southeastern Ridge. The hydrothermal sites cover the whole range from low temperature shimmering waters up to high temperature shimmering or black-smokers. Their content is closely linked with the basic or acidic nature of the outcropping rocks.

The future of GPS geodesy and precise navigation in the SOPAC region

Michael Bevis

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Global Positioning System (GPS) technology has evolved during the last few years into one of the most rapidly growing technologies on Earth. While most commercial users of GPS have exploited its real-time navigational capabilities, and most scientists have focused on more accurate geodetic postioning, the distinctions between these two classes of activity are rapidly breaking down. Networks of continuously-operating (or 'active') geodetic GPS arrays are emerging worldwide and will provide the geodetic infrastructure for a broad spectrum of positioning capabilities, including DGPS Reference Bacons used for precise navigation of ships and planes. It is in the best interests of the region to coordinate such Continuous GPS (or CGPS) networks, in order to encourage the widest possible range of applications. This is the challenge facing SOPAC and the newly constituted STAR Working Group "Geodesy & Precise Navigation".

In this talk I will review the various applications of GPS technology, and describe the activities of various research groups already engaged in construction of CGPS stations in the SOPAC region. Most of these groups are motivated by scientific agendas (monitoring crustal motion, earthquakes and volcanoes, atmospheric water vapour, the ionosphere, etc) while most of their local partners are more concerned with national infrastructure (surveying, precise navigation) etc. Accordingly, considerable thought must be given to patterns of cooperation consistent with both types of agenda, so as to provide maximum benifits to the region, both for science and society.

The importance of marine habitats in maintaining biodiversity and regional fisheries

Gregor M. Cailliet

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Marine habitats are important both to fisheries and to the maintenance of biodiversity. It is well known that many marine fisheries around the world are declining, due both to natural variation and exploitation. Thus, studies aimed at understanding the role of habitats are important for purposes of managing living resources, especially in countries that are attempting to develop sustainable resource use. In some cases, these studies can help establish alternate management tools such as harvest refugia to help replenish certain living resources. Some countries may need assistance in investigating their fishery habitats to develop sustainable resource use. Because human activities have deleteriously affected both terrestrial and marine habitats, there is concern that the diversity of species occupying these habitats will decline, perhaps even making some species extinct.

Considerable pioneering work on marine habitats and their role in hosting many species has been done in the United States. Much experience studying temperate marine habitats with in-situ sampling tools is transferable to tropical areas, and this presentation will provide an overview of current methods used to study habitats and summarize case histories that have been done on both coasts of the United States. In these studies, scientists have identified crucial habitats and resources using such survey tools as remotely-operated vehicles (ROVs), manned submersibles, and acoustics (side-scan sonar, seismic profiling, echo sounders, etc.) and geographic techniques as Global Positioning Systems (GPS), differential GPS, and Geographical Information Systems (GIS) on submarine habitats in shelf, canyon, seamount and ridge, and deep-water benthic areas. These approaches can be used to describe marine habitats and resources adjacent to Pacific Rim nations. We thus propose a SOPAC workshop in 1997 on the use of modern technology to assess both habitats and living resources, with an emphasis on technique transferability.

New Zealand region bathymetry: a revised compilation

CANZ Group (Charting Around New Zealand)¹

New Zealand Oceanographic Institute, National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand.

The New Zealand Region bathymetry has been revised (3rd Edition) using data compiled from New Zealand Oceanographic Institute (NIWA) archives, MAFFish archives, Hydrographic Office, Royal New Zealand Navy GEBCO soundings, National Geophysical Data Centre (GEODAS) database, South Pacific Applied Geoscience Commission (SOPAC) database, relevant published scientific papers, and recent swath bathymetric surveys funded by IFREMER, NIWA, and consortia of the New Zealand fishing industry.

These data have been compiled and interpolated at 1:1 000 000 to produce both a bathymetric chart with a 250 m contour interval and a terrain model with a 1 km grid resolution, at final scales of 1: 4 000 000. In areas of high data density (swath mapped) contours are digitally generated using GIS software. For all other areas contours have been digitised from hand-drawn interpretations of bathymetric data. Satellite gravity data were used to constrain morphological trends in areas where sounding densities were low, and to resolve conflicts where data from varying sources were contradictory.

Within the region relevant to SOPAC the new data have helped resolve and/or confirm seafloor features including: (i) the marked change in morphology of the Kermadec Ridge and Kermadec Trench, and associated Havre Trough back-arc system north and south of 32°S, (ii) the distribution of isolated seamounts on the Pacific Plate surrounding the Louisville Ridge seamount chain, (iii) the extremely complex morphological configuration of the South Fiji Basin, Three Kings Ridge, Norfolk Basin, and Norfolk Ridge formed by various phases of continental and back-arc rifting and transform faulting.

The data are currently being used to assess and plan programmes for UNCLOS work.

¹CANZ Group comprises: L. Carter, D. Cook, G.A. Foster, R.D. Garlick, N.J. Litchfield, J.S. Mitchell, and I.C. Wright.

Convergence across the New Hebrides subduction zone by GPS

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GPS measurements (10 surveys from 1990 to 1996, and permanent stations from July 1996) are being used to monitor the convergence between the Australian Plate and the North Fiji Basin along 600 km of the New Hebrides Trench, at 5 sites within the New Hebrides archipelago, from Santo to Matthew. Sites on the Australian Plate are in the New Caledonia and Loyalty archipelago, only a hundred of km from the trench. It is shown that the convergence vector strongly varies both in modulus (from <4-14 cm/yr) and direction (from EW to NS) along the New Hebrides Trench. These variations of relative displacements are in noticeable agreement with the seismicity and can be ascribed to the different tectonics setting which take place along the trench.

Contribution of foraminifera to sediments, Funafuti, Tuvalu

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Research School of Earth Sciences, Victoria University of Wellington, Wellington, New Zealand

The larger foraminifera are an important component of reef-flat sediments of many Pacific atolls and may comprise the major part of the motu (atoll island) sediments. Detailed sampling around Fongafale Island, Funafuti, has shown that at least 8 species of larger foraminifera are present. Those most important to sediment formation are; *Amphistegina lessonii*, *A. lobifera*, *Baculogypsina sphaerulata*, *Calcarina spengleri*, *Marginopora vertebralis* and *Sorites marginalis*. *Anomalina rostrata*, *Heterostegina depressa* and other large species occur less commonly. Diverse faunas of smaller foraminiferids, dominated by miliolid species, and ostracods are also present.

In the shallow lagoon (less than about 11 m water depth), foraminifera are generally the dominant component of the sand and gravel, followed in decreasing order of abundance by calcareous algae, coral debris and molluscs. In deeper water, foraminifera are generally replaced by calcareous algae. Close inshore, mechanical abrasion reduces the proportion of calcareous algae greatly and may slightly reduce that of the foraminiferal tests. On land, fresh water preferentially dissolves aragonitic material and removes coral, *Halimeda* and molluscan material. This may increase the proportion of calcitic foraminifera tests to as much as 80% of the subsurface sediment.

On ocean beaches, the sand is composed almost entirely of coral fragments derived from rubble thrown up by tropical cyclone Bebe. However, foraminiferal tests coming from populations of *Amphistegina lobifera* and *Baculogypsina sphaerulata* living on the ocean reef flat are increasing in abundance, and rapid recolonisation of the foraminiferal populations into areas from which they have previously been excluded can be demonstrated.

Despite the surficial dominance of coral debris resulting from the cyclone event, sedimentological data and observations from pits suggest that this was a rare event in the development of Fongafale Island. No features resembling cyclone deposits have been observed in borrow pits, and it appears that much of the accretion of Fongafale occurred by non-catastrophic processes similar to those forming sandbanks today.

Waterworld - a 21st Century reality? A discussion on the future of marine minerals

Michael J Cruickshank

Discoveries made in the last thirty five years indicate that the potential for mineral occurrences in the oceans is as high as for comparable areas of terrestrial lands. On this basis the global mineral resource base has been recently increased by a factor of four of which three quarters is under the sea. The recently enacted Law of the Sea has mandated what is probably the most far reaching e-distribution of natural resources in human history, resulting in a peaceful subdivision of jurisdictions which should significantly affect the world's future mineral markets and balance of economic powers.

Marine minerals resources occur in the continental shelves and in the deep ocean basins as deposits of unconsolidated, consolidated, and fluid materials. The continental shelves are submerged portions of the continents and the minerals there are mostly the same as on land. The seabeds of the ocean basins are host to significant deposits of metal oxides, sulphides and other materials from which many of our terrestrial deposits derive; they too have an economic potential similar to on land. The overlying waters include nearly all known elements in some degree of solution and may represent the most significant source of minerals for sustainable development in the future.

The marine mining industry is undergoing an active phase of exploration and discovery in two major areas. Sands for coastal protection and development, and diamonds for the world's market are being sought in relatively deep waters farther offshore. Metalliferous deposits in the Pacific are the subject of intensive exploration, research and development activity by the governments of Japan, China, and Korea, and private investment development is being sought by the governments of the Cook Islands and the Republic of the Marshall Islands. Island governments support a regional cooperative, the South Pacific Applied Geoscience Commission which is the recipient of much of its funding from newly developed and other countries on the Pacific Rim. The government of India has a significant marine mining program in the Indian Ocean and an intergovernmental body of the governments of Bulgaria, Cuba, Czech Republic, Poland, the Russian Federation and the Slovak Republic has been awarded pioneer investor status by the United Nations in the North Pacific.

Legislation and regulation for seabed minerals is now well established in many states and claims for additional seabeds beyond their EEZs are contemplated by some countries. These additional seabeds are an extension of the Juridical Continental Shelf (JCS) defined under Article 76 of the Law of the Sea Treaty.

Whereas it is business as usual with placer minerals, it seems likely that activities in deep seabed mining will be dominated in the near future by the developing or newly developed countries in the Pacific area under heavily subsidised government assisted programs.

It is concluded that every country with or without a coastline would do well to examine the seabeds and assess the value of these vast new territories which fall under their jurisdiction and for which they are responsible, either as sovereign states or as members, through the United Nations, of the global community.

Like it or not, we are about to become a Waterworld!

Manganese crust and nodule deposits from bathyal depths, south and west of Tasmania

Neville Exon
Australian Geological Survey Organisation

West of Tasmania, and on the South Tasman Rise south to 50 degrees south, rocky outcrops in bathyal water depths are commonly coated in manganese crusts up to 20 cm thick, which is unusually thick compared to those in most parts of the world oceans. Manganese nodules are also common in many

places. Previous work has shown both nodules and crusts to be generally of low grade, and this was confirmed for the bulk of the 43 samples analysed from the early 1995 AGSO Cruise 147. The deposits are dominantly ferruginous vernadite, and are of hydrogenetic origin.

The Tasmanian nodules are sometimes exceptionally large (up to 12 cm in diameter) and are frequently cored by granite or other basement rocks, which is very unusual. They average 12.1 % Mn, 16.1 % Fe, 0.14 % Cu, 0.29 % Ni and 0.20 % Co, the three valuable metals (Cu, Ni and Co) totalling an average of 0.63 %. These values are commercially very uninteresting as compared to those of the deep ocean nodules from the Central Indian Ocean, the Northeast Pacific Ocean, and the Cook Islands EEZ.

The crusts average 16.2 % Mn, 17.2 % Fe, 0.08 % Cu, 0.32 % Ni and 0.34 % Co, the three valuable metals totalling an average of 0.74%, figures that are not of commercial interest. However, six analyses of crusts taken within the lower part of the oxygen-minimum zone (1000-2000 m water depth) average 0.79% cobalt, indicating that these shallow-water crusts may have possible long-term economic potential. Further crust sampling in the oxygen-minimum zone might reveal a valuable long-term resource of cobalt.

Why Habitats -- should SOPAC become involved?

H. Gary Greene¹, Mary M. Yoklavich², Tory O'Connell³, Waldo W. Wakefield⁴, and Gregor Cailliet¹

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⁴*Rutgers Univ, New Brunswick, NJ*

Attention is increasingly being directed at benthic habitats as it becomes apparent that describing them and understanding their role are critical to the preservation, sustainability and management of important economic marine living resources. SOPAC has a major role to play in this process in the South Pacific through the reinterpretation of its coastal and seafloor geological data. By establishing teams of marine geologists/geophysicists and biologists to evaluate available data, considerable progress can be made to define and understand fisheries and other significant habitats that exist within the SOPAC region.

Habitat studies elsewhere in the Pacific are useful models that can be used in the tropical areas. For example, temperate to high latitude studies of benthic habitats along the western margin of the United States (California and Alaska) have contributed significant understanding of rockfish (*Sebastes sp.*) habitats that is useful in resource management. In the Monterey Bay region off central California, side-scan surveys and submersible observations have defined refugias in submarine canyons and along seafloor areas where rock outcrops produce rugged bottom topography. In southeastern Alaska, the recent investigations of the offshore Mount Edgecumbe lava field using AMS 150 (150 kHz) side-scan sonar/bathymetric system and submersible observations have resulted in habitat characterisation that are of such fine resolution to approach definition of specific macro-habitats for the commercially important demersal shelf rockfish assemblage. Distinct volcanic and lithologic morphologies such as cinder cones, lava tubes and lava-sediment contacts attract different species of rockfish and these habitats can be predicted with side-scan sonar imagery. The combination of estimated habitat-specific fish densities and detailed habitat characterisation and quantification through geophysical techniques provides resource managers a unique and critical tool for fisheries management.

Hydrochemical and microbiological studies at hydrothermal emanation sites - a new device to sample the benthic boundary layer

P. Halbach, T. Kuhn, N. Blum

Freie Universitat Berlin, Dept. of Economic and Environmental Geology

With a growing number of discoveries, detailed geochemical and biological studies of submarine hydrothermal areas have increased significantly in recent years. These studies concentrate mainly on

hydrothermal precipitates, hard rocks, sediments and biota from active chimney fields. Another major point of interest are the discharged hydrothermal fluids. However, sampling of vent waters has only been possible by the use of submersibles, and therefore, only a relatively small number of water analyses are available. Furthermore, the sampling concentrates on fluids from active chimneys, but it must be kept in mind that two emanation types of hydrothermal fluid discharge exist:

- (i) a disperse type, which is recognized by effects such as shimmering water and color changes in ocean-floor sediments; and
- (ii) a focused type, which is commonly known to emanate from black and white smokers.

While chemical studies of hydrothermal fluids have concentrated on active chimneys, little is known about the chemistry of fluids from disperse discharge sites. These areas are, however, of particular interest since disperse emanations represent not only quantitatively a major amount of hydrothermal fluid, but play also an important role in the formation process of extensive mineralised zones within the uppermost oceanic lithosphere. For the balancing of chemical fluxes in active hydrothermal areas and microbiological studies the sampling and measurement of dispersely discharged hydrothermal fluids will provide useful information.

Since the currently used water sampling and measurement systems do not allow controlled water sampling directly from hydrothermal emanation sites, we have developed a concept for sampling and monitoring hydrothermal fluids from disperse low-to-medium temperature emanation sites.

The Hydro-Bottom-Station (HBS) consists of five main components:

- instrument cage/frame (Fig. 1),
- adjustable fluid sampling system with PTE-sampling bags,
- multi-functional sensor system (pH, Eh, O₂, CO₂, Temp.),
- on-line data transmission system for co-axial and optical cables, and
- on-line black and white and color camera system.

The components are independently housed to provide flexibility in mounting capabilities for different experimental designs. The data transmission system is designed for the use of an optical cable combined with power transmission to allow on-line real-time two-way data transmission, and to provide the HBS-System with power. If an optical cable is not available, HBS can be operated via a standard 18 mm coaxial cable and two deep-sea batteries for power supply.

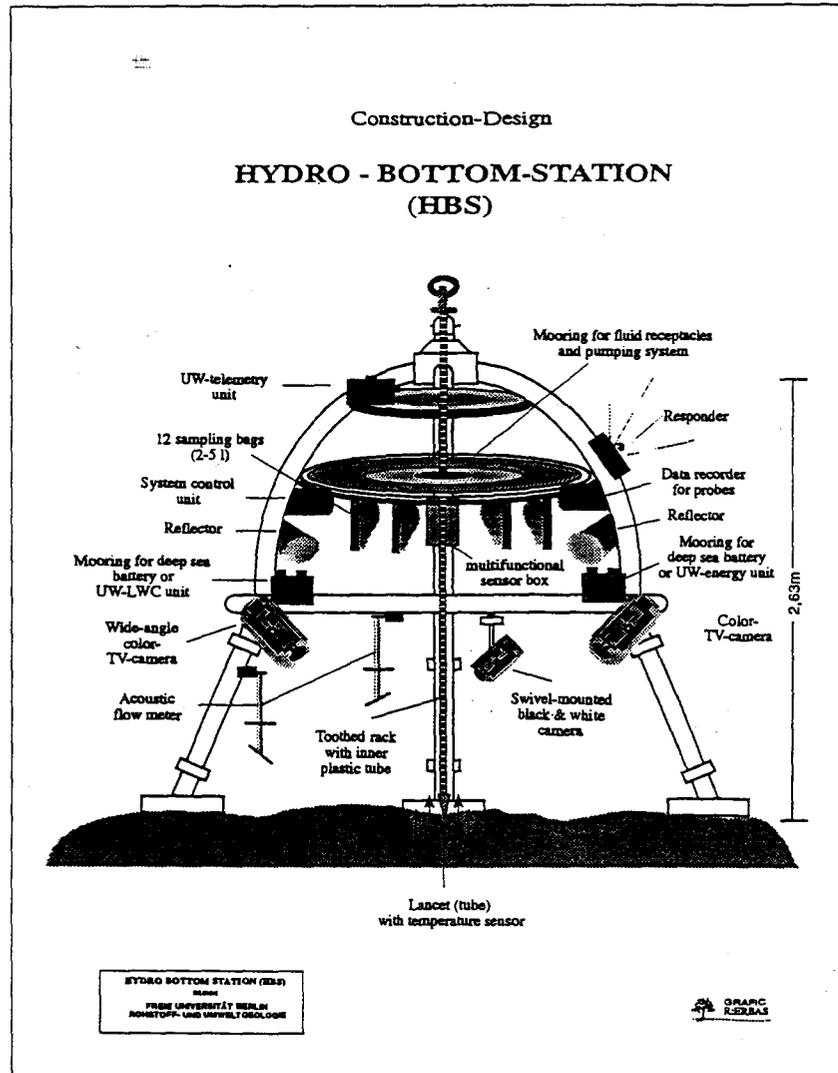


Fig. 1: Sketch of the system configuration

Mineralogy and micro-element chemistry of sulphide precipitates from a recently discovered Central Fiji Ridge hydrothermal site

P. Halbach¹, G. Paul¹, N. Blum¹, J.M. Auzende²

¹Freie Universität Berlin, Dept. of Economic and Environmental Geology

²IFREMER, Noumea

In the northern portion of the 15°N segment of the Central Fiji Ridge three hydrothermal sites were previously known. These are, from south to north, the highly active 'LHOS' Field, the active 'White Lady' Field and the inactive 'Pere-Lachaise' Field.

During the SO 99 cruise a further hydrothermal field was discovered northwest of Pere Lachaise, between 16°58' S and 16°57'S. This so called 'SO 99 Field' is hydrothermally still active, however, in a final, low-temperature stage.

Here we observed two generations of chimneys, which differ in their grade of preservation. The older generation has been physically degraded, just like the chimneys from Pere Lachaise. Its age is estimated between 2000 and 3000 years. The younger generation has an age of about 200 years. One can observe

very well preserved chimneys, with a height of up to 6 m; smoker activity is not recognisable. However, we find those younger chimneys very close to emanations of low temperature hydrothermal fluids, surrounded by young manganese oxide precipitates which sometimes cover these chimneys.

By TV-grab operation we recovered large quantities of massive sulphides from chimney parts in the SO 99 Field. One TV-grab site is in the northwestern part of this field (48 GTV); the sulphide mineralogy mainly consists of marcasite (FeS_2), pyrite (FeS_2), sphalerite (ZnS) and little chalcopyrite (CuFeS_2). Two generations of pyrite are apparent: an older generation which, as well as relicts of chalcopyrite, occurs as inclusions in sphalerite; and a younger generation which replaces sphalerite. Sometimes remobilised chalcopyrite is fissure filling in the younger generation pyrite. Frequently a narrow rim of marcasite surrounds this younger pyrite, or it is fissure filling.

The second TV-grab sample was recovered from the southeastern part of the SO 99 Field (102 GTV). This material has more chalcopyrite than the sample from the northwestern part. However, chalcopyrite mainly occurs together with isocubanite (CuFe_2S_3). The occurrence of isocubanite indicates high temperature conditions of formation ($>450^\circ\text{C}$). With decreasing temperature ($<300^\circ\text{C}$) the solid solution system exsolved, and the two mineral phases precipitated separately. In sample 102 GTV a lot of sphalerite, pyrite and marcasite is present. It is apparent that sphalerite formed at the same time as chalcopyrite. This sphalerite contains a lot of Fe. Marcasite and pyrite coprecipitate, similar as in specimens from the northwestern part.

For reasons of comparison we also got a grab sample from the north of the Pere Lachaise Field (21 GTV). The main difference to the SO 99 field samples is that the material from Pere Lachaise frequently contains chalcopyrite. In outer chimney portions secondary minerals such as covellite (CuS) and bornite (Cu_5FeS_4) replace chalcopyrite. Inclusions of marcasite, pyrite and sphalerite in chalcopyrite are abundant. The sphalerite contains also a lot of Fe (~12%). In outer chimney portions barite (BaSO_4) is voluminous, which is typical for late stage hydrothermalism.

Microchemical examinations of all these samples show that the occurrence of Cd and Zn is positively correlated at higher concentrations. Whereas the presence of Cd indicates the occurrence of sphalerite, a lot of Cd ($>0.5\%$) is typical for wurzite. Abundant Co serves as an index for elevated Fe-contents in mineral phases. High concentrations of Ag (up to 600 ppm) were determined in different Fe-, Cu- (particularly bornite) and Zn-phases, similar to Se.

In general, the formation of mineralisation is governed by different physico-chemical conditions of the solutions (e.g., temperature, pH, Eh, salinity). The occurrence of chalcopyrite together with isocubanite is typical for catathermal conditions. Sphalerite characterises a mesothermal mineral formation, whereas barite marks epithermal formation conditions. Pyrite formed at different temperatures. Marcasite needs an acid environment, and covellite and bornite formed by weathering of chalcopyrite.

The results of deepsea mineral resources survey in Tongan waters, 1995

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The Japan/SOPAC Deep-sea Mineral Resources Survey Program has just commenced its third five-year phase. The agreement for this third phase which includes work in Tonga, Marshall Islands, Federated States of Micronesia and Fiji waters was signed on 7 March 1995, at Suva, Fiji.

The first cruise of the third phase was carried out by the Japanese research vessel Hakurei Maru No. 2 from Guam to Honolulu, 2 July to 8 September 1995. The purpose of the cruise was to assess the potential for resources of submarine hydrothermal ore deposits on the seafloor in the middle to eastern part of the Lau Basin in western Tongan waters. About one and half months were spent in the survey area obtaining data on topography, geology and submarine hydrothermal ore deposits. The area covered was approximately 36,000 square kilometres. The cruise carried out bathymetric and magnetic surveys, sampling and sea-bottom observations. The results of the survey provide initial reconnaissance information on the potential for submarine hydrothermal ore deposits on the seafloor in the Valu Fa Ridge

of the Lau Basin in western Tongan waters. Major benefits were many new data and the production of a complete detailed bathymetric map of the whole survey area which will be useful for natural resources.

Japanese Survey, Research and Development and Technology for Deepsea Mineral Resources

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In the early 1970's, a deep-sea mineral resources development was adapted as one of the metal mining policy in Japan. The Metal Mining Agency of Japan (MMAJ) has started the survey of manganese nodules at the request of the Ministry of International Trade and Industry (MITI) in 1975. MMAJ has also started the survey for hydrothermal deposits and cobalt rich manganese crusts, and deep-sea mineral survey in SOPAC region also as a co-operative survey in the mid 80's. MMAJ has started development of advanced equipment for high accurate and efficient survey. The Agency of Industrial Science and Technology (AIST), MITI, started R&D of manganese nodules mining system in 1981 and will conduct ocean mining test in 1997. MMAJ started the R&D on metallurgical processing of manganese nodules and the environmental study for manganese nodules mining in 1989. In the meantime the National Institute for resources and Environment (NIRE) and the Geological Survey of Japan (GSJ) play important roles in the scientific and fundamental research of deep-sea mineral resources development.

1994-96 Rabaul eruption, Papua New Guinea: local effects and regional consequences

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The near-simultaneous eruptions of high-silica andesite magma from the intra-caldera volcanoes Tavorvur and Vulcan in September 1994 caused extensive damage to Rabaul town and nearby villages but, fortunately, relatively little loss of life. In addition, major disruption was caused to what had been established social patterns throughout the northeastern Gazelle Peninsula of the island of New Britain. Both eruptions appear to have been rather typical of previous, intra-caldera, Holocene eruptions at the Rabaul volcanic complex, and were of a much smaller scale than those of past ignimbrite-producing events that accompanied formation of the calderas at Rabaul (the most recent about 1390 yr B.P.). The 1994 eruptions took place 23 years after two tectonic earthquakes marked the start of a period of caldera unrest (earthquake swarms and ground uplift) at Rabaul, and nine years after the end of a major seismo-deformational crisis (1983-85) that, at the time, had been expected to lead imminently to an eruption. The crisis probably represented the final 'charging' of the volcanic system beneath Rabaul, which eventually was released nine years later. Only 27 hours of warning in the form of two caldera earthquakes of maximum ML 5.1, and followed by intense earthquake swarms, preceded the volcanic outbreak at Tavorvur at 6.07 a.m. on 19 September 1994. Volcanic activity is continuing at Tavorvur although intermittently and at a relatively low level, and conforming (so far) to the overall character of events that took place in the previous period of eruptive activity at Rabaul in 1937 (Vulcan and Tavorvur) and 1941-43 (Tavorvur).

Restoration and re-organisation of the Rabaul area are taking place through the Papua New Guinea Government's Gazelle Restoration Authority, supported by international development-assistance funding. This includes an enhancement of the Papua New Guinea Volcanological Service (based at the Rabaul Volcanological Observatory, RVO) by means of a major project being funded by the Australian Agency for International Development (AusAID) and managed by the Australian Geological Survey Organisation (AGSO). The aim of the project is to strengthen the volcanological service mainly through provision of:

- (i) new volcano-monitoring equipment (seismometry, GPS ground deformation, electronic tilt) on five high-risk volcanoes, in order to improve the forecasting of eruptions and early warnings to vulnerable communities;
- (ii) an increased knowledge base of Papua New Guinea volcanoes, through training, data compilation, and public-awareness campaigns; and
- (iii) a volcanic-hazard information system that will permit improved hazard mapping, visualisation, and community awareness.

The five high-risk volcanoes being targeted by the AusAID/AGSO/RVO project are Rabaul, Ulawun, Karkar, Manam, and Lamington. Ulawun is one of 15 volcanoes world-wide which have been endorsed by the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) for further study through the IAVCEI Decade Volcano Project. Rabaul is the highest risk volcano in Papua New Guinea and particular attention is being directed towards a greater understanding of its deep interior and magmatic 'plumbing' system. Plans are in progress, therefore, to undertake a major seismic tomographic study at Rabaul in mid-1997. This is known as the RELACS (Rabaul Earthquake And Caldera Structure) work program and is aimed at mapping the sub-caldera magma bodies and improving the seismic-velocity model used by RVO for earthquake location at Rabaul.

The 1994 Rabaul eruption was the most destructive volcanic eruption in the SOPAC region so far this century, as measured in terms of monetary loss (about 300 million PNG kina). It serves to focus attention not only on the need for enhancement of the Papua New Guinea Volcanological Service, but also on the volcanic vulnerability of other SOPAC countries. The 'island-arc' countries of SOPAC (Papua New Guinea, Solomon Islands, Vanuatu, Fiji, Tonga, and New Zealand) are the most vulnerable as they contain active and potentially active, explosive-type volcanoes characterised by volatile-rich and viscous magmas, that are related to the complex array of arc-trench systems in the region. Western Samoa has ocean-island (hot spot) volcanoes, and Australia has low-risk, passive-margin and hot-spot volcanoes. Explosive eruptions at island-arc volcanoes in the SOPAC region can have local, regional, and even global consequences. Furthermore, all large volcanoes near the sea have the capacity for major, gravitational (debris-avalanche) collapses that may generate destructive tsunamis of regional extent.

Each SOPAC country is responsible for its own volcano-monitoring and hazard-mapping efforts, and for early warnings of impending activity to communities on or near active volcanoes in their individual countries. How well prepared is each SOPAC country? What are the volcanological needs of each country? Have 'at-risk' populations been identified and are they aware of volcanic hazards they face? Are there ways in which SOPAC countries can collaborate in establishing a network of volcanological activities of mutual benefit? Does the SOPAC Secretariat have a role to play as a regional agency? Are there other agencies that can assist? These questions are being addressed currently by both the SOPAC Secretariat and IAVCEI. A proposal has been made to hold a joint SOPAC/IAVCEI volcanological workshop in Vanuatu at the end of February 1997, in order to provide answers to the questions that, based on country needs, may result in a regional approach to volcano monitoring, volcanic-hazard identification, public awareness, and mitigation efforts. Volcanological expertise will be provided to the workshop largely through the World Organisation of Volcano Observatories (WOVO) which is a Commission of IAVCEI (the WOVO Leader is J.-L. Cheminee of France, and the Secretary is M. Calvache of Colombia). Interest in the workshop proposal will be sought from SOPAC-country representatives during the course of the 25th SOPAC Annual Session.

Community vulnerability to the effects of natural hazards: the role of IDNDR, and implications for the SOPAC region

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An attempt was made recently to map natural-hazard potential in the Southwest Pacific region at a scale of 1:10 million (CPMP, 1995; Johnson et al., 1995). The exercise was successful primarily in its failure - that is to say, a clear recognition emerged that sufficient systematic information on a range of natural hazards could not be obtained readily in order to represent the hazard potential as accurately as would have been

wished. In addition, little of the available spatial data on natural hazards was digitised. This recognition led to the identification of a concern: how can communities, including their support infrastructures, cope with increasing vulnerability to natural hazards if we, as scientists, cannot map and quantify the threat and identify and measure the vulnerability of communities at risk? This question emerged also in the context of the UN-initiated International Decade for Natural Disaster Reduction (IDNDR).

IDNDR has had mixed success. Its failures to date relate to the enormity of the problems of disaster reduction and to the absence of sufficient funding needed to support priority projects at the international level. Its successes have been patchy and dependent largely on the efforts of individual countries - and of UN agencies such as DHA in the SOPAC region - picking up the challenges at country level. Indeed, the initial concept of the Decade to some extent may have been flawed. Its key strategic body is a Science and Technology Committee, implying an expectation that science and technology will provide the required solutions to disaster reduction, which is doubtful. Furthermore, the very term 'Natural Disaster' in the IDNDR title is dubious because disasters are not 'natural'. Rather, they are the outcome of communities being unprepared for the effects of natural hazards - in other words, disasters do not take place in resilient communities that are impacted by natural hazards. However, there are signs that these early assumptions about the nature of IDNDR are disappearing.

There is an emerging emphasis in the late 1990s on community vulnerability as a major issue that needs to be tackled in a holistic and integrated way. The issue has emerged particularly in the recognition of the rise in the number and size of megacities, their sustainability, and the burgeoning levels of loss that will have to be borne (not just by re-insurance companies) in the event of major catastrophes, whether from environmental or natural causes. Vulnerability is now on the emergency-management agenda in Australia. Reducing vulnerability is one of the main goals of the Australian IDNDR Coordination Committee, as stated in its new strategic plan being issued this year. Mapping vulnerability to the effects of natural hazards has started as a result of innovative work in cities such as Cairns and Mackay in Queensland partly in the context of the Tropical Cyclone Coastal Impact Project (TCCIP). In addition, the Australian Geological Survey Organisation (AGSO) this year has initiated a new activity, known as the 'Cities project', but more precisely and formally in AGSO as the *Geohazard vulnerability of urban communities* project. Its principal aims are to:

- (i) map hazard potential in relation to city structure and networks;
- (ii) digitise spatial and attribute data in Geographical Information Systems (GIS) for analytical purposes; and
- (iii) provide Local Government in urban areas with GIS-based decision-support systems for public-safety and emergency-management planning.

A more specific focus that is emerging within the framework of community vulnerability research is 'lifeline' vulnerability - namely, the resilience of networks such as roads, water and power supplies, telephone lines, and sewerage systems to the impact of natural hazards. The best known study of lifeline vulnerability in the SOPAC region was undertaken in Wellington, New Zealand, in relation to earthquake hazard (Centre for Advanced Engineering, 1991). This concept is being developed further in Australia by groups such as the one being coordinated by the Australian Emergency Management Institute. In addition, one of two special themes identified for special attention by the Australian IDNDR Coordination Committee is *Lifelines 2000* (the other is *Education 2000*) which is directed at assessing community-lifeline vulnerability to the effects of both natural and technological hazards.

These issues will be of interest to SOPAC given its recently acquired responsibilities for disaster-management coordination in the region. The increased vulnerability of communities particularly in the coastal areas of the region are of notable concern and could be addressed in the light of the data management and analysis techniques being developed elsewhere. A useful starting point for consideration is the 'custodianship' model of information management. This involves cooperating agencies (in, say, the SOPAC region) forming a network around a central 'hub' which is administered by a lead agency. An agreed infrastructure of standards, conventions, security arrangements, and other agreements guarantees compatibility, effectiveness, and interagency collaboration (Granger & Johnson 1995).

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Review of MMAJ studies on recovery of metals from sea nodules

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People have regarded sea nodules as an increasingly important source of valuable metals, including nickel, cobalt, copper, and manganese. From both technical and economical points of view, it is necessary for exploitation of sea nodules to develop a suitable metallurgical processing technique. It is difficult to recover nickel, copper, and cobalt contained in sea nodules by any usual process, for such metals are present as oxides and oxyhydroxides of the manganese and iron phases. Moreover, a French institute (IFREMER-GEMONOD) estimated that the cost of processing would account for more than half of the total cost of exploitation.

Since 1989 Metal Mining Agency of Japan (MMAJ) has performed studies on the recovery of iron, manganese, copper, cobalt, and nickel from sea nodules under the umbrella of the Ministry of International Trade and Industry's Development of Deep Ocean Minerals Program. After investigating existing processes and comparing their respective performance with the same sea nodules, MMAJ developed a smelting and chlorine leaching process. The process is the combination of pyrometallurgical and hydrometallurgical treatments, and enabled the efficient recovery of manganese, nickel, copper and cobalt.

Rifting of the Ontong Java Plateau's eastern salient and seafloor spreading in the Ellice Basin: relation to the 90 Myr eruptive episode on the plateau

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The Ontong Java Plateau (OJP) provides some insight into the debate on the temporal relationship between oceanic plateau emplacement and plate-boundary reorganization or plate-motion changes. The OJP consists of two parts, the high plateau and the eastern lobe or salient. Two episodes of plateau volcanism have been documented, one at ~121 Myr and one at ~90 Myr. Although the relative timing of plate-motion change and the ~121 Myr emplacement event is not yet clear, recent satellite-derived gravity data reveal features which suggest that post-emplacement rifting and spreading occurred within the OJP's eastern salient (Stewart Basin) as well as intra-ocean-basin rifting and spreading farther east in the adjoining Ellice Basin. In particular, the northern and southern margins of the Stewart Basin resemble conjugate ridges, with slight gravity lows on their southern and northern flanks, respectively, similar to those found at known rifted margins. A similar rift-margin-like fabric extends west to east across the adjacent Ellice Basin. Aligned roughly orthogonal to this fabric are structures resembling those of fracture zones and of the Puka Puka Ridge west of the East Pacific Rise. Magnetic anomaly lineations trending

roughly east-west also are reported to be present in the Ellice Basin (D. Handschumacher, pers. comm.) but have not yet been identified (i.e., their age is unknown). However, a ^{40}Ar - ^{39}Ar age of 82.6 ± 1.2 Myr has been obtained for a sample of MORB dredged from the eastern end of the Ellice Basin. This age suggests that rifting of the eastern salient and initiation of seafloor spreading in the Ellice Basin (i.e., plate-boundary reorganisation) followed rather closely the $\sim 90 \pm 4$ Myr eruptive episode on the OJP, during which most of the eastern salient may have been emplaced.

Petroleum potential of New Caledonia: main results of recent field work studies

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The Norfolk Ridge that links the southern end of New Caledonia to the northwestern tip of New Zealand, was overthrust at the end of the Eocene by the Loyalty Basin oceanic lithosphere (Paris, 1981). Both New Caledonia and New Zealand are part of a continental crust fragment that drifted away from Gondwana when it started breaking up. The Taranaki Basin, that lies along the western side of the North Island, is at the southern end of the rift that extends northward into the New Caledonia Basin. Recently, a mature oily residue was found in a rock sample dredged by Orstom on the Norfolk Ridge. The rock is a Late Cretaceous black shale (Herzer, 1996), similar in age with petroleum source rocks in the producing Taranaki Basin.

The potential for finding commercial reserves of hydrocarbons in New Caledonia is considered good for a number of reasons:

- oil seeps associated with Cretaceous and Eocene rocks have been found in a number of places on the island (the West Coast basins);
- 2 wells (Gouaro-1 and Gouaro-2) drilled in 1954-55 on the most prospective structure, the Gouaro Anticline (160 km northwest of Nouméa), had numerous shows of oil and gas;
- potential producing horizons represented are Triassic, Jurassic, Cretaceous and Eocene;
- potential reservoirs could be intra-Senonian sandstones and/or fractured Eocene flysch;
- seals could be the Eocene flysch;
- geochemical (SREPNC, 1954; AMOCO, 1982-83) and radiometric (PLAINS RESOURCES and NEW CALEDONIA ENERGY, 1993) surveys indicate hydrocarbons to be present.

Recent field work studies: main results

In 1993, the Institut Français du Pétrole (IFP) sampled all levels appearing to have any petroleum potential in the West Coast basins. The study identified the Senonian coals as the main potential source rocks in New Caledonia (Vially and Mascle, 1994). The authors concluded that *"It is certain however that the total volume of coal and carbonaceous shale has been sufficient to generate significant quantities of hydrocarbon, notably in gaseous form"*. Vially and Mascle (1994) agree with Gonord (1977) on the generalised allochthony of the basalt nappe and the peridotites. Consequently:

- (i) the Paleogene basalts in the Bourail Basin are part of a large overthrust sheet of basalts and ultrabasics from the northeast;
- (ii) the Gouaro Anticline is thus a nappe anticline in the midst of which the Eocene flysch reappears as a tectonic window in a relative autochthonous position.

The allochthonous nature of the basalt nappe has direct consequences on the petroleum potential of the West Coast, as well as on the potential of the Western Lagoon: the geographic extension of the coal basins might be much greater than what is suggested by the outcrops.

More recently, geological mapping (December, 1994; February and March, 1995) of the Gouaro Anticline (Blake, 1995) supports the autochthonous model of Paris (1981) who concluded that the Paleogene basalts formed in situ in the deep trench and forearc basins on the West Coast. According to Blake (1995), the Bourail Basin is a Cretaceous basin limited by normal faults, subjected to extensive rifting volcanism, and inverted during the Eocene compressive phase.

To evaluate the subsurface structure of the Gouaro Anticline that covers both onshore and shallow offshore areas (Blake, 1995), a multichannel seismic survey was requested by New Caledonia Energy SARL (NCESA) that holds the PRA 436 petroleum exploration. Victoria Petroleum N.L., operator of the permit, engaged Velseis Pty Ltd to conduct the survey in 1995.

After interpretation of the seismic lines, Blake (1996) concludes that the most probable reservoirs beneath the Gouaro structure are:

- (i) the sandy unit at the base of the flysch;
- (ii) the fractured Paleocene limestone/chert sequence.

The Middle to Late Eocene flysch contains shales and argillaceous siltstones which are capable of providing a good seal for entrapped hydrocarbons. The seismic data supports the autochthonous model of Paris (1981), the Gouaro structure appearing as a breached anticline, buried by the Eocene flysch deposited and then eroded in the central core of the anticline.

On the basis of the seismic interpretation, Blake (1996) proposes a test well for the Gouaro Anticline. The prognosed total depth of 1600 m should allow a full test of the hypothetical gas cap with an oil leg scenario for either the base flysch sand reservoir or the fractured chert reservoir.

Conclusions

The Gouaro structure is regarded as mainly prospective for gas but with additional potential for oil. The Late Cretaceous coals generated oil as well as gas. The Bourail Basin to the north would have provided a potential drainage area into the prospect. The timing and folding of the Gouaro structure and the Bourail Basin coincided with the "Alpine Orogeny". Generation and expulsion of hydrocarbons would have occurred during the Late Eocene to Oligocene, and any valid structural trap formed during the "Alpine Orogeny" should have filled with hydrocarbons. The presence in the Late Eocene, and maintenance until now, of a dominantly compressive regime, should have kept hydrocarbons sealed in their traps.

On the basis of the seismic interpretation, the proposed test well for the Gouaro Anticline allow a full test of the prognosed basal flysch sand and fractured Paleocene chert reservoirs.

However, new multichannel seismic data are needed, especially offshore. The "Lagoon prospects" remains an entirely unknown area. The thickness of the sedimentary series in the basins offshore, and the relative high geothermal flux values are compatible with the formation of hydrocarbons. Although potential source rocks remain unknown, the discovery of the Late Cretaceous black shale dredged on the Norfolk Ridge should boost the petroleum interest of New Caledonia and its offshore dependences that still remain underexplored.

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Introduction of KIGAM's activities in geosciences

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KIGAM, since established as the Geological Survey of Korea in 1918, is a unique research institution in Korea, which is dedicated to the understanding of extensive research and development in the fields of earth science. KIGAM aims firstly to design, develop and advance relevant technologies for the exploration, exploitation and utilisation of mineral resources and fossil fuels, and thereby to contribute to development of the national economy, and secondly to understand the history and structure of the Earth. It's research and development activities also include exploration for offshore mineral resources and petroleum potentials, utilisation of rare metals, synthesis of new materials and development of processing technology. The emphasis is currently placed on environmental issues such as geological hazards, remediation of contaminated soil and water, etc.

The organisation of KIGAM is comprised of eight research divisions, one technological information division and one administrative division. Prime objectives of each research division is follows.

- Geology Division: geological mapping, engineering geology, stratigraphy and onshore basin analysis.
- Environmental Geology Division: evaluation of geothermal resources, hydrogeological mapping, characterisation of geotechnical properties and waste disposal sites, image processing (GIS).
- Economic Geology Division: geological investigation, exploration and evaluation of domestic and overseas mineral resources, study of mineral synthesis.
- Resources Exploration Division: regional geophysical and geochemical survey, seismic data processing, environmental geochemistry and geochronology.
- Petroleum and Marine Resources Division: petroleum geology and engineering, data acquisition and processing, marine geological mapping, deep-sea mineral resources exploration, ocean drilling program (ODP), operation of research vessels.
- Resources Development Division: mining technology and rock engineering, utilisation of underground space, mine safety engineering, deep-sea mining technology.
- Mineral Utilisation and Development Division: mineral treatment and metallurgical processing, manufacture of advanced and novel materials, resources recycling techniques, processing of manganese nodules.
- Chemical Analysis Division: routine analysis service, development of new analytical techniques and apparatus, manufacture of reference materials.

KIGAM, as representative organisation of the Korean Government, strongly wishes to support the SOPAC region by finding geoscience requirements from the member countries, that will extend the interests in exploration and development of the non-living resources in the region. In the early 1997, KIGAM mission will be negotiated with SOPAC Secretariat.

Modelling water depth and bottom type using remote sensing data in shallow coral reef waters*

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All the methods currently in use for passive optical bathymetry rely on the extraction of statistical parameters from a preliminary set of field data. On the basis of data recently published by the Universite Francaise du Pacifique, we demonstrate that the effective diffuse attenuation coefficients of light in shallow coral reef lagoon waters (0 to 5-6 m) can be derived directly from SPOT HRV channels XS1 and XS2. We also demonstrate that the non-vegetated foreshore provides a useful radiometric model for shallow bottoms at null depth in a coral reef lagoon. This allows for a complete calibration of the bathymetry mapping process using satellite images, and field data are only useful at the final step of ground truth, mostly for validation of the computed bottom reflectance, while the precision on the computed water depth is greatly improved.

The operational performances of this new algorithm are tested for water depth against a set of precision depth soundings specially collected in the shallow coral reef lagoon of the island of Moorea and the atoll of Rangiroa (French Polynesia).

The products are a map of the bottom reflectance and one of the water depth for shallow waters in the range 0 to 4-6 m. The average error on depth is ± 0.2 m at 2.5 m average depth. From 4-6 m to 15-25 m, the water depth is computed assuming a sandy bottom. Among over forty islands processed to date, examples are presented for the islands of Moorea, Bora Bora, Rangiroa, Tarawa, Tongatapu, Manihiki, Aitutaki, and Heron Island.

More ground truth exercises are needed. Once validated, this method will offer a cost-effective tool for the preparation of coastal base maps, and for the assessment and monitoring of living and non-living resources in shallow coral reef waters.

* paper presented at the 8th Australasian Remote Sensing Conference, Canberra, Australia, 26-29 March 1996, under the title "A coral reef lagoon, as seen by SPOT", and submitted for review to the International Journal of Remote sensing (June 1996).

Tsunamis in the South Pacific Region

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The South Pacific Forum nations could be subjected to tsunamis either from distant earthquakes, such as from Japan, Chile, Alaska, Hawaii or from local earthquakes generated in part of the circum Pacific belt close to these islands and atolls. From distant earthquakes, the tsunami travel times could be several hours, while noting that a tsunami will cross the entire Pacific Ocean in less than 24 hours. For locally generated tsunamis the warning time could be about one or two hours even less in certain instances. The Pacific Tsunami Warning Centre (PTWC) based in Honolulu, confirms the existence of a Pacific wide tsunami and also provides information on travel times to various locations. However, the PTWC would have no data on the expected magnitudes of the tsunami waves at various locations. Such data on tsunami amplitudes could only be generated through numerical models. Even though there is not much historical data available, whatever information exists on past tsunami events can be used to calibrate and validate these models. Observed sea level data set from the 11 SEAFRAME tide gauge stations of the South Pacific Sea Level and Climate Monitoring Project is also examined based upon the events of significant earthquakes in the South Pacific Forum Region.

The role of sidescan sonar in seafloor classification with a direct application to commercial fisheries management

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Demersal shelf rockfishes (*Sebastes*) are the target of an important shore-based fishery in the eastern Gulf of Alaska (945 million tonnes allowable catch). These fishes are difficult to assess using traditional techniques as they are closely associated with complex rocky habitats. The Alaska Department of Fish and Game (ADF&G) has been using an occupied submersible to conduct line transects for estimating density of demersal shelf rockfish since 1990. We have concentrated our efforts on yelloweye rockfish (*S. ruberrimus*) as it accounts for 90% of the commercial catch of this assemblage. Biomass of adult yelloweye rockfish is derived as the product of estimated density (for all rocky habitats), the estimate of area of suitable habitat within the 200 m contour, and average weight of fish from port samples by management area. Currently the estimate of area is based solely on the habitat description from bathymetric charts, with areas described as "JrockyK" or "JhardK" included in our analysis. Although not yet used specifically for management, habitat-specific densities are also estimated. These habitats have been defined based on in-situ characterisation. Yelloweye rockfish are significantly more abundant in areas with refuge spaces (i.e. caves, large cracks, overhangs or in boulder fields where both the boulder size and the void-to-clast ratio is large). We currently estimate the density of adult yelloweye rockfish in the Central Southeast Outside management area (CSEO) to be 2,929 fish/km².

In 1994 we began a pilot study using sidescan sonar to help delineate available habitat and identify areas of key habitat types in the Edgecumbe offshore lava field, an important fishing ground in the CSEO. In 1996 we expanded this sidescan survey using an AMS-150 sidescan (150 Khz) and collected bathymetry data concurrent with the sidescan. The result is a large mosaic of the seafloor off Kruzof Island, which covers approximately one fourth of the entire area of CSEO. The area is diverse in habitat, including areas of plutonic rock with Sitka Graywacke outcrops, sand and silt, cobble, and an extended area of lava. The lava surface exhibits well defined and little eroded aa and pahoehoe lava, lobate lava fronts, collapsed lava tubes, volcanic cones, and fault scarps. These habitat characterisations have been groundtruthed with direct observations from the submersible. The diversity and distribution of rockfish species appears to be related to habitat and depth, with the presence of suitably sized refuge spaces a key to demersal rockfish occurrence. For example, there are two large volcanic cones on the southern margin of the lava field that appear similar. However, one of them has significantly more fishes, both in terms of abundance and diversity. The sidescan clearly shows the key difference in habitat, with the J19 fmK pinnacle having an field of immense boulders on a flank of the pinnacle. This provides refuge habitat that is not available on the adjacent pinnacle.

We plan to use the level of categorisation available from the sidescan mosaic to redefine fishery habitats, and then collect fish density data for these habitat categories. We also plan to continue our sidescan work in conjunction with NOAA National Marine Fisheries Service, eventually mapping the entire eastern Gulf of Alaska. Seafloor classifications over a wide geographic region will allow us to significantly improve our fishery management plan for demersal shelf rockfish by allowing us to use habitat-specific densities. Ultimately, our efforts in ocean mapping will provide a permanent record of the seafloor for use in the management of living resources within the region.

Although this fisheries project is on-going in a sub-arctic environment, it can easily be applied to a variety of tropical and temperate species in the SOPAC region.

Geochemical investigations of hydrothermal influenced sediments from the Central Spreading Ridge in the North Fiji Basin

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Complex investigations of sediments sampled during the German-French cooperative research cruise SO 99 with the German RV SONNE in January 1995 were the scientific objective of the University Greifswald. One of the main aims was the geochemical characterisation of sediments with identification of hydrothermal signatures.

Hydrothermal influenced sediments from the active field "White Lady", the inactive area "Pere Lachaise" (Auzende et al., 1991; Bendel et al., 1993) and the new discovered one "Sonne 99" (Auzende et al., 1995; Halbach et al., 1995) were geochemically investigated (Table 1). In addition, sediments located at the east and the west side of the rift were also analysed for their minor elements (Table 2).

The hydrothermal precipitated sulphide mud from the active field "White Lady" is characterised by a high content of zinc and copper in connection with a low content of manganese, vanadium and barium. In the northeastern part of the inactive "Pere Lachaise" field the surface of the sulphide mud is covered with a thin manganese coating (5 mm). This might be a sign for occurrence of dispersed low-temperature fluids in this area. The central part of "Pere Lachaise" is covered with sulphide mud characterised by a high content of copper and barium.

Hydrothermal sulphide mud enriched with zinc, lead, barium and vanadium exists in the northwestern part of the field "Sonne 99". At the southern and the northern edge from the northwest part of the "Sonne 99" field occurs mud with a low calcium carbonate content below 15%, little enriched with copper and manganese like the central part of "Pere Lachaise". The high content of copper in the sulphide mud of "Sonne 99" and the high content of zinc in the central part of "Pere Lachaise" are corresponding with investigations of massive sulphides (Halbach et al., 1995) from this area. But in contrast to these results we found high Ba-contents in the sulphide mud of both fields.

Table 1: Minor element chemistry of the Central Spreading Ridge sediments.

Sample	Cu ppm	An ppm	Pb ppm	Co ppm	Ni ppm	V ppm	Ba ppm	Mn ppm
<i>White Lady</i> 93 GTV	35360	70200	131	19	<12	114	403	535
<i>Pere Lachaise</i> 18 GTV, NE part	745	669	40	66	103	241	266	6100
21 GTV, central part	4330	212	388	<12	<12	278	3320	501
<i>Sonne 99</i> 48 GTV-1	690	3560	1120	<12	<12	513	6060	810
48 GTV-2	744	1550	3030	29	<12	571	4390	946
48 GTV-3	670	8680	1450	44	<12	465	1170	2950
31 GTV, S edge	2130	777	162	56	69	206	948	2130
37 GTV, S edge	1614	598	46	50	53	189	886	5750
108 GTV, N edge	907	552	43	53	74	236	611	7980

At the east side of CSR high contents of Cu and Zn occur exclusively with a high manganese content. It has to be concluded that these metals are bound in manganese precipitates. West of CSR high contents of Zn and Cu are found with increased manganese substance as well as with humiliated one.

Table 2: Minor element chemistry of sediments located at the east and the west side of the Central Spreading Ridge in the North Fiji Basin.

Sample	Cu ppm	An ppm	Pb ppm	Co ppm	Ni ppm	V ppm	Ba ppm	Mn ppm
<i>East side of the rift</i>								
52 GK, 14-16	189	100	35	13	50	110	602	4740
43 GK, 5-7	210	121	35	25	75	99	536	5960
105 GK, 15-17	160	83	<12	<12	54	94	613	5080
<i>West side of the rift</i>								
33 GK, 23-25	218	129	18	25	71	114	753	5500
35 GK, 15-17	306	144	32	27	81	123	717	6770
36 GK, 19-21	261	168	35	32	85	139	573	5280
39 MC, 17-19	230	151	17	30	80	119	560	5720
40 MC, 11-13	248	13	25	133	<12	113	718	5810
33 GK, 31-33	455	293	20	57	80	233	2930	2230
36 GK, 27-29	268	290	<12	60	60	248	297	1400
39 MC, 21-23	255	269	<12	58	84	219	241	2830
34 KL, 21-23	261	273	16	47	63	245	239	1020

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Coastal erosion on small coral islands: an example from Tonga and its regional relevance

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The coastal zone on small tropical islands is increasingly at risk as development takes place. The zone is utilised for many purposes. Traditionally, as a source of food. But more recently as a source for the large volumes of aggregate required for major civil engineering works such as roads, buildings, shorefront protection, land reclamation and harbourworks. Increasingly this use conflicts with traditional uses, as well

as the rapidly developing tourist industry which demands 'unspoilt' beauty as well as all the modern amenities of life.

Coarse aggregate (boulder to gravel size) is obtained from quarries, normally located inland but sometimes on the coast. Fine aggregate (gravel to sand) is normally taken from the beaches. Over the short term, and as long as extraction is limited, the effects of beach extraction can be ameliorated by natural replenishment of the sand from the adjacent reef. However, if extraction exceeds natural replenishment the beaches are subject to degradation which not only is extremely unsightly but prevents beach use as a recreational facility. More importantly the beaches role as a buffer zone in protecting the land against the sea is reduced. The long term effect of over-extraction may only become plainly apparent when a major storm strikes. At this time the beach will be extensively reconstructed, but at the cost of erosion landward of the beach, which results in coastal recession. The eventual results of the sand extraction is that the beach is lost as a recreational resource and its role as a buffer zone protecting the land, diminished. During storm conditions as erosion proceeds valuable agricultural and building land is lost.

The aim of the presentation is to demonstrate the effects of unsustainable coastal development by using an actual example from Tonga. Thereafter to discuss and assess the relevance of the problem in Tonga to other islands in the SOPAC region. Practical aspects of the Tonga project will be considered including the methodologies involved and their relevance together with the results. The coastal resources will be placed in the context of alternatives.

Primarily, in Tonga, the project purpose was to investigate fine aggregate availability from the islands beaches and to recommend planning guidelines designed to minimise environmental damage and develop good working practices for extraction of sand from beaches.

The beachsand resource was assessed using rapid and straightforward methodologies and appropriate technology. Computer-compatible surveying and computer-aided drafting systems were utilised. This allowed for the rapid acquisition and computation of data and its graphic and digital presentation. The beaches were surveyed and sand thickness measured. From the survey results the quantity of sand on the beaches was calculated and the reserve life estimated at present extraction rates.

The replenishment rate from the reef was calculated using reef areas and reef productivity. The calculations showed that the extraction rates were in excess of natural replenishment from the reef by a considerable margin.

Interpretation of aerial photographs acquired over 25 years demonstrated that on those beaches subject to regular extraction, beach recession of up to 50 metres had taken place. The beaches had retreated at the expense of a fossil sand deposit landward of the beach. The question was posed; in what manner does beach recession take place, catastrophically, or by gradual increments? The question was to be answered sooner than expected.

Four months after the beach surveys had taken place, Tonga was struck by a major cyclone. The south and west coast beaches were most affected, and it was on these that significant beachsand extraction had taken place. In a twelve-hour period those beaches most frequently utilised over a twenty-year period were significantly modified. Those most recently used suffered the greatest change. On these up to 25 metres of the fossil sand deposit was reworked into the active beach. The active coastal zone had advanced landward by this distance. Another factor in the equation was the vegetation cover to landward of the beach and covering the fossil sand. Where the cover had been removed (by human activity) the effects were amplified.

The example from Tonga has, almost certainly with some minor changes in detail, analogues elsewhere in the region, in Kiribati, Tuvalu, Western Samoa, Cook Islands etc. What are the lessons to be learned? And how can problems of this nature be ameliorated? On small islands, resources are limited, especially those required for infrastructure development and required in large volumes. Absolutely, the numbers involved are small and measured in the thousands; relatively, where land is scarce and a precious resource, the effects of extraction are significant. Fortunately, in the case of Tonga, alternative, offshore sand supplies are available and are actively being evaluated and assessed to ensure that any extraction takes place with

the minimum of environmental damage. Over the longer term there is no doubt that left alone the beaches will recover and coastal erosion turn into coastal accretion. What is the situation in other island groups? How can the problems be addressed?

Ocean Drilling in the Tonga Forearc: subduction geodynamics, arc evolution and deformation processes at non-accretionary convergent margins (ODP Proposal 451)

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The objectives of the ODP drilling on the Tonga Ridge are to investigate crustal generative and destructive processes and effects operating at an interoceanic arc. In this example, the Tonga-Lau backarc-arc-trench system, which is presently characterised by regional extension linked to rapid trench convergence (170-180 km/My) and eastward trench rollback. ODP Proposal 451 places specific emphasis on investigating:

- (i) the nature, characteristics, and cause of suprasubduction zone arc magmatism and ophiolitic crustal formation above new interoceanic subduction zones;
- (ii) subsequent crustal generation processes and changing mantle sources that nourish backarc spreading (Lau Basin) and arc magmatism (Tofua Arc) in particular as speculatively thought to be instigated by the subduction of a lengthy chain of seamounts, the Louisville Ridge, beneath the Tonga Ridge; and
- (iii) background or long-term effects and rates of subduction erosion and the accelerated effects and rates hypothesized to be tied to the subduction of the Louisville Ridge.

A strategy of drilling to determine N-S geochemical variations in basement rock, ash stratigraphy, and cross-arc history of vertical tectonism, is expected to establish the nature and origin of the ridge's Eocene arc massif, to document long-term processes and effects of crustal growth and thinning and changing magmatic sources including those hypothesized to be tied to the southward propagation of backarc rifting (opening of Lau Basin, initiation of Tofua Arc volcanism) in the wake of the southward progression of the Louisville-Tonga collision zone.

The Tofua Volcanic Arc, Tonga, Southwest Pacific: a review of historic eruptive activity

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The Tofua Volcanic Arc (TVA) forms a prominent tectonic feature in the southwest Pacific and is a classic example of an active oceanic island arc. The arc comprises a series of several dozen, active, dormant, and extinct, subaerial and submarine volcanic centres that have formed on a north-south trending submarine ridge, between latitudes 14.5°S and 26°S. In the central part, the arc is located 40-50 km to the west of the Tonga Platform. Active volcanism has been occurring along almost the entire length of the TVA since its initiation after the formation of the Lau Basin between 3 Ma and 5 Ma. For the purposes of this analysis, the TVA has been divided into three domains based on the morphology of the volcanic centres, the character and the relative age of the activity.

The section of the TVA between 26°S and 22°S (the southern domain) is composed of a dominantly submarine ridge. 'Ata is the only subaerial expression of this part of the arc. No reports of recent activity from this segment of the arc are known. Volcanic centres along this part of the arc may not have been active since, at least, the Pleistocene. As activity that may have occurred at these centres would have been submarine in character they may not have been reported.

The section of the TVA between 22°S and 18°S (the central domain) is composed of the many subaerial and submarine stratovolcanoes that have been active during historic times. Several centres, eg. Kao, are in an apparent state of dormancy, but are still considered potentially active. Historic activity has been

reported in the region of Hunga Tonga and Hunga Ha'apai, at Tofua, Late and Fonualei. Recent submarine eruptions at Falcon Island, Metis Shoal/Lateiki and Home Reef, have resulted in the formation of ephemeral islands and extensive pumice rafts. The activity reported has been both explosive and effusive in character. There has also been a number submarine events reported during historic times at centres located to the south of Tongatapu.

The northern section of the TVA between 18°S and its northern termination at about 14.5°S (the northern domain) also consists of a dominantly inactive submarine ridge. Towards the north end, however, periods of submarine activity occurred at Curacoa Reef in 1973. During this eruption an island was not formed but extensive pumice rafts were produced. Tafahi, a youthful composite cone is present to the north of Niuatoputapu. Although Tafahi is in an apparent state of dormancy, it is still considered potentially active.

The data presented here has been assembled to form a preliminary database of all known reports of volcanic activity that has occurred at centres along the TVA. It can be utilised during future studies that may particularly relate to the evaluation of the volcanic hazards in the region. Further work that is currently in progress will allow the refinement of this database in terms of the prehistoric (pre-1800) eruptive activity that may have occurred at the individual centres, particularly those within the central domain.

The importance of accurate bathymetric and seismic surveys in light of edge-of shelf considerations under the 1982 UN Convention on Law of the Sea (LOS Convention)

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The LOS Convention substantially extended the rights of coastal states over offshore resources. On continental shelves these rights can be claimed beyond 200 nm if certain requirements are met. To do so will entail the use of sophisticated, complex and costly marine geophysical surveying, sampling and mapping techniques over large swathes of ocean floor in order to delineate the edge of the shelf over which resource claims are asserted. These claims, substantiated by these geophysical data, must be submitted for approval to a special UN Commission within ten years of the coming into force of the LOS Convention for the sixty states who joined before November 16, 1994 and within ten years from their joining for those who joined afterwards. The geophysical criteria set by the LOS Convention for the delimitation of a continental shelf are unclear. The technical criteria for the data to be submitted to the Commission are non-existent, as the Commission has not yet been set up. Yet the ten-year time is running, and the LOS Convention makes no provision to reset the clock. This paper describes these issues in detail and examines their consequences for states considering making a claim for their edge-of-shelf resources.

Environmental studies of a manganese nodule field in the Peru Basin (SE Pacific)

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Deep sea mining of manganese nodules actually will have an environmental impact on the seafloor and on the water column. However, we are far from being able to predict the possible consequences. Therefore, in 1992 and 1996 multidisciplinary environmental studies were conducted with R.V. SONNE in a manganese nodule field of the Peru Basin where in 1989 a long-term and large-scale seafloor disturbance and recolonisation experiment, called Discol, had been started also with R.V. SONNE.

The bathymetry of the seafloor was mapped using the hydrosweep system. Distribution and type of sediments were investigated by the parasound system, and by collecting surface samples and sediment cores. Deep towing of a sidescan sonar system revealed outcropping volcanic cones and a nodule coverage of variable density. Along the tracks of a photo sledge a great variability of nodule coverage and bioturbation was observed. Furthermore, extensive bottom-mechanical and biological investigations of

near surface sediments were completed on board. Additionally, analyses of the settling velocity of suspended surface sediments were completed.

Manganese nodules and crusts were collected at 165 locations. In many aspects the nodules differ from those of the Clarion-Clipperton Zone: big cauliflower-shaped nodules with growth rates up to 120 mm/Ma may reach a maximum size of 24 cm in diameter, maximum abundance may be 50 kg/m², the mean size of buried nodules is bigger than that of surface nodules. The reason for these characteristics is due to the relatively high bioproductivity in surface waters which produces a strong upward Mn flux in the sediment column and a Mn precipitation above a redox boundary 10 cm below the seafloor.

Histograms showing the distribution of size and shape of nodules clearly indicate that their growth history is different for basins, slopes and tops of seamounts and ridges. We observed an asymmetric distribution of nodules around morphological elevations.

Nodules with diameters >7 cm show mainly diagenetic, and to a minor degree hydrogenetic growth. Smaller nodules of the same assemblage are composed mainly of hydrogenetically grown Mn-oxide. Diagenetic growth may be dendritic or dense, finely laminated. The dense diagenetic growth is found only on the lower side of nodules where optimum diagenetic growth occurs near the redox boundary. This level is not reached by the small nodules. Alternation of dendritic and dense diagenetic growth layers is explained by stepwise upward movement of nodules by benthic organisms. Bottom photographs and core sections show an increased benthic activity compared to that of the Clarion-Clipperton Zone. Benthic lifting prevents most of the nodules from being buried. Big nodules, however, which stick to the stiff sediment below the redox boundary cannot be moved any more and get buried. Therefore, buried nodules are mostly bigger than surface nodules. Buried nodules are always brittle due to the onset of dissolution. Their occurrence is restricted to Quaternary sediments.

Hydrothermal precipitates such as Mn-oxide, goethite, opal and quartz were found at 9 locations on seamounts and ridges. Such precipitates form nuclei of nodules and crusts on top of volcanic elevations. They may occur due to hydrothermal processes connected to relatively young off-ridge volcanism. A CTD probe attached to a photo sledge revealed anomalies of temperature up to 0.1°C which indicates a recent post-volcanic low-temperature hydrothermal activity.

Multidisciplinary research in the Peru Basin is expected to help to assess the environmental impact of potential nodule mining.

Drowned carbonate platforms of the northwest Pacific: testing Darwin's hypothesis for the formation of atolls and barrier reefs.

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The origin and near-term fate of atolls is not only important as an academic question, but also because of the vital concern to the people and installations on them. Can a rapid rise of sea level render them uninhabitable, or will they grow upward to keep their form? We must look to their past history.

A Darwin's Model: Differential growth rates create rim and lagoon

Darwin's 1842 hypothesis for the origin of atolls has two distinct parts:

- i) The subsidence part; corals and coralline algae grow on a subsiding foundation. As the foundation subsides, the carbonate sediments build upward apace.
- ii) The differential-growth part; well-nourished corals and algae on the platform edge grow upward fast enough to keep up with subsidence. Biota in the interior parts of the platform are under-nourished and can't keep up with subsidence, thus forming a lagoon. In this model, the atoll rim is entirely constructional.

The first part of the model was confirmed by drilling at many atolls. The second part has not been confirmed and is highly questionable because the sediment accumulation rate in lagoons is sufficient to fill them in less than 100,000 years.

B Purdy's model: Subaerial erosion forms rimmed bowl, which drowns as atoll

An alternative hypothesis, first coherently propounded by Purdy in 1974: the rimmed saucer form is created by subaerial erosion of a flat carbonate platform during an episode of emergence.

C Pacific Cretaceous Guyots: how do they help choose between the hypotheses?

Recent studies of drowned Lower Cretaceous carbonate platforms in the northwest Pacific show more than 100 platforms drowned about 100 Ma, subsequent to a relative sea-level fall of about 200 m that allowed a subaerial, rimmed-saucer karstic landscape and wave-cut benches to form. Following resubmergence, shallow-water carbonate sedimentation did not resume, and the erosional atoll landscape is preserved. The Pacific guyots show us that the atoll form can be purely erosional.

D Relation of atolls to Pleistocene sea-level fluctuations

Sea-level rises and falls during the last 700,000 years have been of a special character, with a sawtooth pattern in cycles of about 100,000 years. A fast rise is succeeded by a long, stepwise fall to a major low stand, then the next quick rise, and so on. This pattern may be especially favourable for creating the subaerial rimmed landscape that drowns to form an atoll: before the saucer fills, sea level falls again.

Morphology and evolution of the remnant Colville and active Kermadec ridges south of 33°30'S

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Swath MR1 data from the remnant Colville and active Kermadec arc margins, south of 33°30'S (SW Pacific), record the structural morphology and evolution of the rifted, and now separate portions, of the proto-Colville-Kermadec Arc flanking the actively widening southern Havre Trough back-arc basin associated with Pacific - Australian Plate convergence. Both the remnant Colville and active Kermadec arc margins comprise opposing, asymmetric, partially basement exposed, segmented ridges. Differences in morphology between the two ridges are, however, observed. The single, near linear, border fault system, with relief of ~1000 m, along the western edge of the Kermadec margin is interpreted to be the exposed fault escarpment of a major, west-dipping, detachment fault. In contrast, two major zig-zag border fault systems along the eastern edge of the Colville Ridge, bounding a back-tilted ridge flank terrace, are interpreted as major antithetic faults between the remnant arc and back-arc region. This contrast in structural morphology coincides with, respectively, lesser and greater degrees of both active tectonism and channel - canyon erosion, on the remnant Colville and active Kermadec margins. These differences are interpreted to reflect the progressive trenchward collapse and associated greater rift flank uplift and incisive erosion of the Kermadec footwall contrasting with the non-collapse and relatively lesser rift flank uplift and ridge erosion of the Colville hangingwall. The data provide further constraints on the early evolution of the Havre Trough in particular, and back- arc basins in general.

Distribution characteristics of cobalt-rich manganese deposits for the mining design

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The importance of cobalt-rich manganese deposits for a future cobalt resource has recently been well recognised. Though the geological information is currently being accumulated, there is insufficient geotechnical data of the deposits to aid the design of the mining system. Recent studies of geotechnical distribution characteristics of the deposits are introduced and the fundamental characteristics of the mining system are discussed in the paper.

An attractive zone for the mining is selected first of all. Distribution characteristics of crust and nodule types of the deposits, and the shallow burial of the deposits are considered as the parameters for the selection. Microtopographic distribution characteristics of the crust type deposits are clarified for the design of the miner's manoeuvring and excavating mechanisms. An estimation of the ore contamination by the substrate rock is introduced. Geotechnical properties of seamount sediments coexisting with the deposits are studied. Size distribution and water content of the sediments are summarised. The cohesion and internal friction angle measured by cored samples are introduced.

On the basis of these data, fundamental requirements for the miner and mining system are discussed. Preliminary design of the miner and mining system will also be mentioned.