Intergovernmental Oceanographic Commission
Workshop Report No. 39

CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific

Suva, Fiji, 24-29 September 1985


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IOC Workshop Reports

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No.	Title	Publishing Body	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand 24-29 September 1973 UNDP (CCOP), 138 pp.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No. 20).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock)
4	Report of the Workshop on the Phenomenon known as "El Niño", Guayaquil, Ecuador, 4-12 December 1974.	FAO Via delle Terme di Caracalla 00100 Rome, Italy	English (out of stock) Spanish (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock) Russian
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique 28 November-2 December 1977.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Russian
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
18	IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No. 4)	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian Arabic
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Russian
24	WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
25	Workshop on the Intercalibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (superseded by IOC Technical Series No. 22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
29	WESTPAC Workshop on Marine biological methodology Tokyo, 9-14 February 1981.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	IOC, Unesco Place de Fontenoy, 75700 Paris, France	English (out of stock) Spanish
31	Third International Workshop on Marine Geoscience Heidelberg, 19-24 July 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
32	UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime Paris, 27 September - 1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish

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1. Opening of the Workshop

On behalf of the International Steering Committee of the Workshop, Dr. Gary McMurtry, the Chairman of the Committee, welcomed the participants and expressed his appreciation to sponsoring organizations (the Committee for Co-ordination of Joint Prospecting for Mineral Resources in the South Pacific Offshore Areas (CCOP/SOPAC), the Intergovernmental Oceanographic Commission (IOC), l'Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) and l'Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM). He thanked particularly the Government of Fiji for having invited the co-sponsors to hold the Workshop in Fiji, and the Mineral Resources Deparment of Fiji, the Technical Secretariat of CCOP/SOPAC and the local organizing committee of the Workshop for their co-operation in making the local arrangements.

Dr. McMurtry stressed that, among other objectives of the Workshop, guidelines should be developed for the use of submersibles and remotely operated vehicles (ROVs) in mineral resource assessment, resource management, and marine scientific and engineering studies. He also called attention to the desirability of establishing international co-operative programmes for their use in the region.

Then the Workshop was officially opened by the Minister of Lands, Energy and Mineral Resources, the Hon. Jone Naisara. He expressed his awareness of the usefulness of submersibles in marine scientific studies and mineral resource assessment on the ocean bottom. He requested the Workshop to develop long- and short-term research plans relevant to offshore mineral prospecting in the South Pacific for the benefit of CCOP/SOPAC member countries. He called for a spirit of international co-operation and genuine friendship such as that prevailing during previous workshops in the South Pacific. The full text of the Minister's statement is given in Annex II.

The Assistant Secretary of IOC, Dr. Kazuhiro Kitazawa, welcomed the participants on behalf of the Secretary of IOC, Dr. Mario Ruivo, who sent his best wishesfor the success of the Workshop. Dr. Kitazawa requested the Workshop to consider adequate arrangements for the development of regional co-operation with a view to ensuring efficient use and operation of submersibles, because of high operational costs and highly sophisticated technology in the use of submersibles. He also requested the Workshop to consider a training programme for scientists in the region to acquaint them with modern techniques and the usefulness of submersibles for marine scientific research.

The Workshop was attended by 72 participants from 13 (Australia, China, Cook Islands, Fiji, France, Kiribati, Japan, New Zealand, Solomon Islands, Tonga, Tuvalu, United Kingdom, United States of America). The List of Participants is given in Annex IV.

2. ADMINISTRATIVE ARRANGEMENTS FOR THE WORKSHOP

2.1 ELECTION OF CHAIRMAN AND VICE-CHAIRMAN

Dr. Gary Greene proposed Dr. Bernard Biju-Duval as the Chairman of the Workshop because of his experience in the use of submersibles, particularly those in international co-operative use. Dr. Biju-Duval was unanimously elected as the Chairman.

Mr. Ronald Richmond was unanimously elected as the Vice-Chairman of the Workshop.

2.2 DESIGNATION OF RAPPORTEUR

Dr. Neville Exon was requested to serve as Rapporteur for the Workshop, and kindly accepted this invitation.

2.3 SCHEDULE OF THE WORKSHOP

The Chairman introduced the schedule of the Workshop: the first three days would be spent on scientific and technical discussion, and topics related to new projects and future programmes. Organizational arrangements for the use of submersibles and ROVs* would be discussed on the fourth and fifth days. To provide active discussion among participants on those items, the Workshop decided to establish the following ad hoc Sessional Working Groups:

- Group A on Tectonics, Magmagenesis and Volcanic Processes, and Metallogenesis
- Group B on Exploration for Hydrocarbons in Southwest Pacific Island Arcs
- Group C on Geohazards and Engineering Geology
- Group D on Sea-bed Processes and Environments

Group A later subdivided into three sub-groups on Tectonics, on Magmagenesis and Volcanic Processes, and on Metallogenesis.

The participants in the four above-mentioned Sessional Working Groups were as follows:

Sessional Working Group A:

Rene Blanchet (Chairman - Tectonics Sub-section), Harmon Craig, Tony Crawford, Jean-Philippe Eissen, James Gill, James Hawkins (Rapporteur), Wally Johnson, David Karl, Jill Karsten, Read Keays, Loren Kroenke, Patrick Maillet, Gary McMurtry (Chairman - Metallogenesis Sub-section), Patrick Nanau, Polly Penhale, Jacques Recy, John Sinton (Chairman - Magmagenesis Sub-section), Brian Taylor (Chairman), Jules Temacon.

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* A List of Acronyms is given in Annex V.

Sessional Working Group B:

D. Ardus, J.M. Auzende, B. Biju-Duval, F. Campbell (Chairman), D. Falvey (Rapporteur), G. Greene, S. Helu, R. Smith, D. Tappin, D. Tiffin.

Sessional Working Group C:

D. Ardus, F. Campbell (Chairman), L. d'Ozouville, G. Greene (Rapporteur), K. Kitazawa, R. Smith, D. Tappin, D. Tiffin.

Sessional Working Group D:

Jim Eade (Chairman), Nic Flemming (Rapporteur), Chris von der Borch, Siniala Auenga, Stuart Kingan, Steve Nelson, Charles Phipps, Ian Lockley, Bill Burnett, Bruce Richmond, Michel Hoffert, Lou Eldredge, Sione Tongilava, Neville Exon, Marae Irata

3. ADOPTION OF AGENDA

The Agenda was ammended by the Workshop and adopted; it is attached as Annex I hereto.

4. OBJECTIVES OF THE WORKSHOP

The Chairman reminded the participants that the main objectives of the Workshop were to:

(i) help to determine the feasibility of using manned submersibles and remotely operated vehicles (ROVs) in South Pacific geological and geophysical exploration;

(ii) develop guidelines for their use in mineral resource assessment, resource management and engineering studies;

(iii) identify appropriate technologies and target areas for their use in the South Pacific region;

(iv) encourage the establishment of international co-operative programmes for their use in the region.

5. OVERVIEW PRESENTATIONS AND REVIEWS OF NATIONAL PROGRAMMES

The Chairman of the Workshop introduced the presentations with some remarks on the importance of submersible programmes, and how they must be related to other studies. A new generation of technology was available, which could produce exciting results from well-prepared projects. Abstracts of presented papers, and the names of the respective authors are given in Annex III.

Five papers were presented dealing with the capabilities of submersibles, and some scientific results from cruises. Bernard Biju-Duval indicated that the CYANA has a depth capability of 3 000 m, whereas the new vessel NAUTILE can go twice as deep. French projects are organized in a multidisciplinary programme with a large geoscience component. Co-operative and jointly financed projects are highly regarded, and a geo-science programme in the South Pacific will follow the SEAPSO cruises of the R.V. JEAN CHARCOT.

Michael de Luca dealt with NOAA's multifaceted submersible programme. There are no firm plans for ALVIN dives in the western Pacific. The University of Hawaiii presently uses the MAKALII which has a depth capability of 400 m, and will control PISCES V which will have a capablity of 2 000 m from 1986.

Hiroshi Hotta reported on the Japanese submersible SHINKAI 2000 and reviewed the results of dives around Japan. The JAMSTEC deep tow vehicle already used in Tonga does site surveys for the submersibles.

Jacques Angelier outlined the results of the French/Japanese "Kaiko" project in the trenches southeast of Japan, which used NAUTILE. Much has been learnt about subduction processes, and colonies of clams, believed to be supported by a methane-based food chain, were commonly found along the subduction line.

Don Tiffin outlined the capabilities of the Canadian PISCES IV submersible which has a 2000m-depth capability.

There followed general papers on aspects of southwest Pacific marine geology which could be studied in part by submersibles. Loren Kroenke outlined the history of basin development in the region. R. Wally Johnson dealt with submarine volcanism on the East Pacific Rise, along hot-spot traces, along island arcs, and in back arcs. He indicated that submersibles could provide a host of information on the composition of volcanic rocks, on metalliferous accumulations, and on volcanic hazards near population centres. Jim Eade outlined the composition of surface sediments, with nanoplanktonic oozes generally dominating in shallow water and red clay in deep water, with high volcanic admixtures near volcanic arcs.

Michel Hoffert pointed to a number of enigmatic features of manganese nodules and their distribution, and showed that many problems needed to be addressed by submersible studies, which are due to start in the North Pacific in 1986, using French equipment. Jim Hawkins dealt with the scientific problems which could be addressed in the arc/back-arc systems of the western Pacific, using ocean drilling and other techniques. Major areas of interest in the southwest Pacific include the Vanuatu and the Lau-Tonga regions.

6. ADVANCES IN TECHNOLOGY, RECENT RESULTS AND NEW STRATEGIES

Fifteen papers were presented on these subjects. Two, by Daniel Fornari and Patricia Fryer, dealt in some detail with swath mapping which had led to the definition of submersible targets.

Fornari described Seabeam and SeaMARC I work on the East Pacific Rise which culminated in ALVIN dives on seamounts revealing vein-filling sulphides.

Fryer's paper described SeaMARC II mapping in the Mariana's Arc that had revealed a variety of volcanic features.

A third paper, by Rene Blachet, described two areas off the Philippines and Taiwan, where Seabeam mapping in the trench/fore-arc region had identified potentially important submersible targets.

Three papers dealt with the CYANA submersible results in a variety of settings. Jean-Marie Auzende described results of passive-margin studies on the European and West African margins. Jean-Louis Cheminee dealt with a dive on the moderate-sized Teahitia volcano at the active end of a Tahitian hot-spot trace. Yves Fouquet described some spectacularly successful dives on the East Pacific Rise, which revealed, among other things, a massive sulphide deposit, largely iron sulphide, of more than 1 000 000 tonnes associated with a seamount 6 km from the spreading axis.

Bernard Grandvaux described the two French submersibles CYANA and NAUTILE, and the ROV systems, RAIE II, EPAULARD and S.A.R.

H. Gary Greene described the problems of mapping faults by submersible in the southern California borderlands, where earthquakes had displaced huge rockslabs downslope. He also pointed to petroleum-oriented submersible targets in Vanuatu.

A paper by Alex Malahoff dealt with pyrite-pyrrhotite chimneys found by ALVIN on the Galapagos Rise, and with low-temperature hydrothermal nontronite stacks found by the "Angus" camera system off Hawaii.

J. Frisbee Campbell described the problems associated with finding a suitable subsea route to carry geothermally derived electric power from Hawaii to Oahu. Steep, rough slopes and water depths of 2 000 m between Hawaii and Maui, surveyed by SeaMARC II, present the greatest technical problems.

A paper by John Delaney suggested the establishment of long-term ocean-bottom observatories at mid-ocean ridges to monitor rates of change in features and processes. Prototype instruments had functioned well, and such observatories could be employed in other tectonically active areas.

Lucius Eldredge pointed to the advantages of selective submersible harvesting of precious corals compared to non-selective harvesting by tangle-net dredging.

Harmon Craig stressed the importance of helium and methane anomalies in locating hydrothermal events. Helium plumes can be identified 3 000 km west of some East Pacific Rise vents.

David Karl described ALVIN dives during which the dense anoxic microbial communities near vents had been investigated, showing that biomass and growth rates were 3-4 times those in surface waters, and much greater than those elsewhere in bottom waters.

7. APPLICATION OF MANNED SUBMERSIBLES AND REMOTELY OPERATED VEHICLES (ROVs) TO SPECIFIC GEOLOGICAL PROBLEMS IN THE SOUTH PACIFIC

Charles Phipps described the characteristics of the relatively inexpensive submersible PLATYPUS, which can operate in water depths of up to 300 m.

Neville Exon described the shallow-water hydrothermal iron deposits associated with submarine volcanoes in a back-arc setting off Epi in Vanuatu, and suggested submersible studies there and over the shallow-water Kavachi volcano in the Solomons fore-arc.

Ian Lockley described the use of a Suva-based ROV, BENTHOS RPV 430, which has a depth range of 700 m. The equipment could be made available for scientific work at a reasonable cost.

Bernard Biju-Duval outlined the variety of techniques which had been used in Tahiti in examining the proposed route of a cold-water pipe for a shore-based OTEC plant.

Although John Craven could not attend the Workshop owing to travel problems, his abstract on Ocean Thermal Energy Conversion (OTEC) technology was presented here.

Nicholas Flemming described the results of a survey of the Cootamundra Shoals area off Darwin, Australia, aimed at finding traces of human or animal movements from Asia to Australia during periods of low sea level, and indicated the importance of future submersible dives in the region.

Charles Phipps outlined 1985 dives in the PLATYPUS on steep and gentle slopes in the Great Barrier Reef. The tops of two older reef levels were found at 50 m and 70 m, respectively.

Brian Taylor pointed to the complexity of the intermediate-rate sea-floor spreading and subduction in the Woodlark Basin, and of fast spreading in the Manus Basin, and showed that SeaMARC II studies, followed by submersible dives in water less than 2 500 m deep, could solve important problems.

A paper by Jacques Daniel described the collison of the d'Entrecasteaux Ridge with the New Hebrides arc, and suggested that 1985 Seabeam studies would reveal prime submersible targets on the Bougainville Spur off Malekula.

Patrick Maillet discussed the area of change between the southern New Hebrides arc and the Matthew-Hunter volcanic chain, and suggested that submersible dives should follow the 1985 SEAPSO cruise of the R.V. JEAN CHARCOT.

Harmon Craig presented the results of dissolved-gas studies of the water column in the Pacific region. Helium isotope ratios are low in the Banda arc, but high in the Sunda arc, apparently because continental crust is being subducted in the first case, and oceanic crust in the second. He also outlined plans for the early 1986 Papatua cruise to carry out similar studies in the southwest Pacific.

William Burnett described submerged island phosphorites from banks north of Fiji. He indicated that phosphorites were often associated with cobalt-rich manganese crusts, and suggested that both should be studied together, in part by submersible studies.

Four papers dealt with the North Fiji Basin. John Sinton showed that in the north there were three volcanic rock types apparently derived from four different mantle sources in the last million years - basaltic andesite, andesite and basalt - and pointed to a variety of submersible targets. Gary McMurtry showed that sediments near the south Pandora Ridge and at one locality in the western North Fiji Basin, showed evidence of hydrothermal activity: Jean-Philippe Eissen discussed the results of the EVA 12 cruise in the south in 1983, which showed that spreading had changed from northeastern to northerly axes two million years ago. The offset modern spreading axes will be studied during a SEAPSO cruise of R.V. JEAN CHARCOT in 1985, probably followed by submersible studies. Jacques Recy discussed the nascent spreading centres - the Coriolis and Vot Tande Troughs - in the New Hebrides back-arc to the west.

James Gill stressed the importance of a better understanding of the early stages of arc volcanos in the region. Prime submersible targets included the Valu Fa magma chamber in the southern Lau Basin, the volcanoes of the Tonga Ridge and Kermadec regions, the old volcanics off Fiji and Tonga, and the young volcanics associated with the Kandavu end of the Fracture Zone. A paper by Barbara Keating suggested four dive sites off Samoa, to better define the nature of young volcanism there.

Jean-Philippe Eissen outlined Seabeam and coring results from surveys of five areas off New Caledonia and the Loyalty Ridge carried out by the R.V. JEAN CHARCOT. Steep slopes, active erosion and tectonic scarps provided a number of submersible targets. Tony Crawford pointed to the variety of occurrences of high-SiO_2 , high-MgO, boninite-like lavas in the region, and speculated on their origin. Some occurrences could be the subject of submersible dives.

8. DEVELOPMENT OF NEW PROJECTS AND FUTURE ACTIVITIES

The four Sessional Working Groups (A, B, C and D) each presented a report and recommendations to the Plenary.

REPORT OF THE SESSIONAL WORKING GROUP A ON TECTONICS, MAGMAGENESIS AND VOLCANIC PROCESSES, AND METALLOGENESIS

INTRODUCTION

The south-west Pacific region encompasses a range of tectonic elements and volcanic provinces, each of which has potential mineral and/or hydrocarbon resources, the establishment and assessment of which can be aided by the use of submersibles and remotely operated vehicles (ROVs). The tectonic elements of the region include: arc-trench, subduction-zone complexes; major transform faults; back-arc spreading centres with a range of spreading rates and styles; mid-plate volcanoes; and oceanic plateaus. There are ancient and recently active elements present: their geological relationships are commonly complex and poorly understood. Nevertheless, increasing knowledge of the region's tectonic, volcanic and sedimentologic history provides a satisfactory framework for resource assessment. Furthermore, recent and imminent studies will provide necessary survey data for submersible studies.

A knowledge of the geological history of the region is needed to assess resource portential. This knowledge will be derived from the collection of data in poorly known areas, and from investigations into fundamental processes. The many plate and microplate boundaries in the region have complex and varied histories and styles. Although this complicates the search for resources, it also provides the necessary geologic framework for the concentration of potential deposits.

Investigations needed for further refining the context for resource potential assessment using submersibles and ROVs fall into three thematic problem areas: (i) Tectonics, (ii) Volcanology and Magmagenesis and (iii) Metallogenesis. These subdivisions are somewhat arbitrary and it is the inter-relationship of structure, heat, magma composition, hydrothermal circulation and deposition that ultimately control the size and potential economic viability of metal deposits. Arc/back-arc systems represent perhaps the clearest case for the inter-relationships between tectonics, volcanism and metallogenesis. However, since the investigative procedures and expertise are commonly different, these areas were dealt with separately.

Extensive ship surveys in the region including high-resolution bathymetric mapping and sonar imaging of selected areas makes the use of submersible technology particularly timely. Submersible studies will help in the selection of drill holes as part of the Ocean Drilling Programme.

ROVs can be used in exploration surveys and for locating dive sites. Together with manned submersibles, they are the essential tools for assessing mineral resources and for the understanding of engineering problems inherent in their exploitation. Other assessment tools include GLORIA, RAIE, and SeaMARC imaging systems, Seabeam and SeaMARC bathymetric mapping systems. The most appropriate techniques for target areas will be best obtained by co-operative projects utilizing technologies and scientific expertise from a variety of co-operating international bodies.

The 1975 CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji (IOC Workshop Report No.6), proposed a number of projects for establishing the background necessary for evaluating specific sources. These objectives were further refined in the 1980 CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia (IOC Workshop Report no. 27) and the 1983 CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific, Suva, Fiji, (IOC Workshop Report No. 35). The thematic topics and regional projects described below are recommended extensions to these earlier programmes aimed at the use of submersibles and ROVs. These proposals should be endorsed as part of the overall programme of the CCOP/SOPAC resource framework and assessment project.

TECTONICS

Manned submersibles and ROVs can help in the investigation of the tectonics of the south-west Pacific. Tectonic factors control (i) the sites of magmatism and associated hydrothermal activity (and hence the sites of potential economic mineral deposition); and (ii) the subsequent exposure and/or emplacement of these sites into economically exploitable regions. Understanding the tectonic controls on the sites of mineral deposition, and the processes of faulting, uplift and collision by which these deposits may become economic, is particularly important.

Tectonic processes that should be addressed by submersible and ROV programmes include:

SUBDUCTION

There is a wide range of subduction styles in the South Pacific. Oceanic crust is being subducted at oceanic trenches with azimuths varying from normal to oblique to transcurrent. Collisions of island arcs with seamounts, aseismic ridges, oceanic plateaus, continental margins and spreading ridges are occurring. Invesigations should comprise the following:

(i) Structure and deformation of the inner trench wall; tectonic accretion versus erosion; fabric development.

(ii) Hydrothermal circulation through the lower trench slope and fore-arc as a result of dewatering of subducted sediments/ crusts.

(iii) Fore-arc diapirs - their composition, structure and origin.

(iv) Uplift/subsidence history of the fore-arc basins and outer-arc high, and how they vary with subduction/collision style.

(v) Structure along deep sections (provided by canyons or faults) through the fore-arc basement.

CRUSTAL ACCRETION

All back-arc spreading styles and rates are represented in the South Pacific: from nascent rifting in the Coriolis/Vot Tande Troughs, through slow (<1cm/yr) spreading on the 176°E rift west of Fiji, to intermediate (5-8 cm/yr) spreading in the Lau, North Fiji and Woodlark Basins, to fast (10 cm/yr) spreading in the Manus Basin. In each of these environments, submersibles and ROVs could define the structural controls on the accretionary processes. Tectonic elements to be investigated include rift grabens (the sites of Koroko massive sulphide deposits), overlapping spreading centres, propagating rifts and ridge-transform intersections. The morphotectonic elements along and across strike need to be mapped to aid exploration for polymetallic sulphides. The distribution and activity of faults, fissures and vents is particularly important. The structural evolution of the ridge crest and its relation to hydrothermal venting (the proposed tectonic-magmatic-hydrothermal cycle) needs to be determined.

VOLCANISM

Tectonic aspects of volcanic processes include:

(i) doming and caldera formation;

(ii) rift zone and satellite cone development;

(iii) faulting and other edifice deformation;

(iv) subsidence and uplift.

Submersibles can investigate these tectonic processes by:

(i) making direct visual photographic and televideo observations, especially in areas that are inaccessible to ROVs;

(ii) obtaining specifically located samples;

(iii) measuring strike and dip of structural elements;

(iv) emplacing and servicing short- and long-term bottom instruments, including those of other programmes.

ROVs are required to:

(i) map the distribution of tectonic elements;

(ii) map the sites of submersible dives;

(iii) extend the range of observations made by submersibles.

MAGMAGENESIS AND VOLCANIC PROCESSES

THEMATIC OVERVIEW

The South Pacific has a number of volcanic systems involving generation and eruption of magmas with widely variable chemical composition and volatile content, in a range of tectonic settings and water depths. Thus, this region is ideal for studying the inter-relationship between magma composition and the associated eruptive mechanisms and hydrothermal systems. Of particular interest are the unusual highly silicic magmas erupted in back-arc regions. The complex tectonic activity of this region, and its associated deformation of pre-existing structures, afford several opportunities to look at the exposed interiors of structural features.

Sophisticated techniques are needed to study submarine volcanism. Firstly, high-resolution swath-mapping tools and photographic surveys provide base maps for precision dredging programmes, to explore the broader scale relationships of tectonic setting, magma composition, and eruption mechanics. Secondly, precise submersible sampling of scarps exposing interior sections of volcanic edifices provides critical information on volcanic stratigraphy and the temporal evolution of magmatic activity.

SCIENTIFIC OBJECTIVES - GENERAL QUESTIONS

A number of questions regarding magmatic/volcanic processes in the South Pacific can be addressed using submersibles:

(i) What is the evolution of magma composition as volcanoes mature in arc, back-arc and intraplate settings?

(ii) What is the distribution of rock types in "normal" back-arc rift systems?

(iii) What is the role of eruption depth (pressure) on volatile constituents? How does this affect lava evolution and eruption mechanics?

(iv) What is the influence of magma composition on hydrothermal systems, including fluid composition, metallogenesis, and biological communities?

(v) What is the crustal contribution to arc lava compositions?

(vi) What role do variations in rates of spreading and magma supply play in lava composition?

(vii) How heterogeneous is the magma source in each tectonic setting?

(viii) What is the relationship of back-arc/arc/fore-arc lavas to rock of ophiolite series?

SCIENTIFIC OBJECTIVES - SPECIFIC QUESTIONS

Submersibles and ROVs can be used to address problems that are peculiar to specific settings. These include:

(i) Fore-arc and Arc

What is the nature and extent of fore-arc igneous activity? What are the implications of this for the thermal maturation of hydrocarbon-bearing sediments in these environments? Some fore-arc magmas have high metal contents, suggesting that fore-arc hydrothermal deposits are especially interesting.

(ii) Back-arc

What is the nature of lavas in nascent back-arc rifts? In such settings arc strata may also be sampled.

What is the nature of lavas in "unzipping" and/or propagating rifts in back-arc spreading centres? This includes back-arc spreading centres impinging on continental regions (e.g. western Woodlark Basin - Dawson Strait), the narrowing of the southern Lau Basin, and propagating of spreading centres in the North Fiji Basin south of 20° S.

What is the origin and development of silicic magmas in back-arc spreading centres? Such magmas may be associated with interesting eruptive phenomena and hydrothermal systems.

(iii) Intraplate volcanism/seamounts

What are the early stages in the development of intraplate volcanoes? Submersibles are particularly useful for the study of immature volcanoes which will eventually form the inaccessible core of larger edifices.

METALLOGENESIS

Manned submersibles and ROVs are needed to explore, and evaluate the economic potential of, submarine hydrothermal systems and their associated metal-rich deposits. Analysis of deposits recently found by submersibles in the eastern Pacific show that they are composed of sulphides, sulphates and oxides of Fe, Mn, Ba, Ca, Si, Cu, Zn and Pb with associated Cd, As, Ag, Co, V, Se, Hg, Au and other metals. Two major types of hydrothermal systems and deposits are found: (i) a low-temperature "Galapagos" type; and (ii) a high-temperature "21-degree N East Pacific Rise" type.

Systems needed for exploration of hydrothermal systems include SeaMARC, RAIE or GLORIA side-scan survey systems, remote camera systems, such as EPAULARD or the NOAA/HURL saturation camera/video system, and ultimately ROVs with some manipulative capability for sampling developed target areas.

Only manned submersibles, however, can accurately sample hydrothermal vent systems and measure their temperarure, chemistry and water/rock ratios. Questions of basic scientific interest and of the economic potential of such systems in back-arc basin spreading centres in the South Pacific include the following:

(i) Are the hydrothermal vent fluids and metalliferous deposits chemically different from those of the eastern Pacific?

(ii) What is the duration of vent fields?

(iii) How fast do the deposits grow?

(iv) What is the mineral age and chemistry of the deposits?

(v) What is the vertical extent and hence volume of the deposits? Submersibles can define extent and thus set the stage for drilling and/or in situ geophysical soundings.

(vi) What is the size and depth of the underlying magma chambers? Submersibles are needed to emplace sea-floor instruments.

(vii) What is the relationship of volcanism to venting?

(viii) What is the spacing of hydrothermal vents along the spreading axis and their relation to transform faults?

(ix) Do near-axis seamounts focus the hydrothermal activity of spreading centres?

(x) Is hydrothermal activity related to spreading rates?

The rationale for exploration for hydrothermal systems in the arch-trench environment includes: (a) the bulk of economic massive sulphide deposits are associated with calc-alkaline volcanics: (b) increased sediment/pyroclastic cover may cap or may host hydrothermal systems (e.g., deposits of the Kuroko/Besshi type); (c) the environment of deposition is relatively shallow, leading to relatively low-temperature sulphide deposits that are often enriched in the more economically desirable "volatile" metals (e.g. Ag, Au). Rifted arcs and fore-arcs may contain Boninite-hosted hydrothermal systems and deposits. Boninites contain unusually large concentrations of Pt-group metals, and host the Cyprus massive sulphide deposits.

The region contains both basaltic and andesitic seamounts. Andesitic seamounts are especially interesting because land volcanoes often display evidence of prolonged hydrothermal activity (e.g., fumaroles). Seamounts displaying evidence of fractionated magmas could have hosted prolonged hydrothermal activity. Submersibles are superior to shipboard dredging because of their accurate sampling. The relationship of seamount tectonics to hydrothermal systems, such as the possible association of venting with caldera development and rift zones, needs submersibles and/or ROVs.

Transform-fault zones may contain "pull-apart" rift basins with spreading centres and hydrothermal systems or they may contain active or fossil hydrothermal systems/deposits. Transform fault "A" in the FAMOUS area of the Mid-Atlantic Ridge contains evidence of active hydrothermal vents. Another area of investigation is the transform-ridge intersection, where large massive sulphide deposits have been discovered on the Explorer ridge off Canada.

Finally, seamounts on presumed traces of hotspots should be investigated. Are hotspot seamounts different from others? The Samoan chain is presumed to be an active hotspot trace. Other seamounts in the South Pacific contain active low-temperature hydrothermal systems, in particular Teahitia Seamount near Tahiti in the Society Chain, which was the site of the first submersible investigation in the South Pacific, and Macdonald Seamount in the Austral-Cook Chain, which has been dredged.

LIVING RESOURCES

The living resources of the South Pacific region include: precious corals, fish, and possibly hydrothermal vent benthic communities and their analogues. The economic potential of a precious coral industry in the SOPAC region is discussed elsewhere. The fishery resources were not considered at the present Workshop. The study of vent-type benthic communities, however, is uniquely suited to co-ordination and co-operation with geological expeditions using submersibles and ROVs.

The recent discovery and exploration of dense populations of metabolically active animals and microbiota at oceanic ridge crest hydrothermal vents caused oceanographers to re-evaluate some basic tenets concerning energy flow through deep-sea ecosystems. It is believed that the vent populations are uncoupled from the energy of sunlight and, instead, are ultimately supported by geothermal energy. Analogous deep-sea communities have been discovered at cold hydrocarbon seeps and at continental margin subduction zones. Current research activities include: (i) characterization of the taxonomy and physiological adaptations of these novel individuals; (ii) assessment of their *in situ* metabolic activities and growth rates; and (iii) general ecological relationships and flow of carbon and energy through these spatially restricted communities. Sample collections and experiments conducted to date would have been impossible without the use of submersibles capable of precise navigation and remote manipulation, both in terms of sample collection and *in situ* experimentation.

PROPOSED PROJECTS

A.1. *THE SAMOAN LINEAR VOLCANIC CHAIN*

Introduction

The Samoan chain is a unique regional feature. It is a linear volcanic chain that includes the exposed tops of volcanic edifices from Rose Island (atoll) in the east to Savaii in the west. The most recent voluminous volcanic activity has been the historic eruptions on Savaii where, in 1909-1911, silica-undersaturated magmas were erupted from vents aligned along the axis of the chain. This linear arrangement of vents follows the vector of relative plate motion and the orientation of the nearly east-west segment of the Tonga Trench. Whether or not the Samoan chain is a "hot spot" trace is not clear, but there must be a strong tectonic control on volcano alignment exerted by the complex flexure of the Pacific Plate into the Tonga Trench. There is a high probability of submarine volcanism between the islands at vents aligned along regional fracture systems. The chain offers an opportunity to look for hydrothermal and metallogenic activity associated with silica-undersaturated magmas that commonly have high concentrations of alkali, alkaline earth and transition metal elements.

Underwater explosive eruptions are possible in the island chain. Volcanic processes at older eruption sites, the temperature, viscosity and volatile content of the submarine magmas, and the alignment, location and spacing of these sites should be studied.

Projects

A.1.1 Regional surveying with Seabeam and ROVs for identification of potential vent sites; and use of deep-towed imaging systems to look for indications of vent systems.

A.1.2 Use of manned submersibles to collect samples and study vent systems and their faunal assemblages.

A.1.3 Study of the petrology and morphology of submarine eruptions in the chain by a combined study using shipboard surveys, ROVs and submersibles.

A.1.4 Study of initial stages of oceanic island (linear chain) development by detailed sampling and study of small intra-chain seamounts. This should be complemented by studies on land.

Available Data

Data on submarine morphology near the chain exist and there are extensive island geologic data. There is a need for detailed bathymetric charting with multibeam systems and ROV surveys to understand the tectonic fabric.

Recommendations

(i) That additional surveys be undertaken to understand the tectonic fabric of the sea-floor on the Samoan linear chain.

(ii) That ROV and manned submersibles look for possible sites of metallogenesis and evaluate potential hazards from explosive underwater eruptions.

(iii) That geological studies be continued to improve our understanding of tectonic and magmatic processes controlling the origin and evolution of the chain.

A.2 *TONGA-KERMADEC REGION*

Introduction

The Tonga-Kermadec region has the longest, straightest oceanic arc in the world and has played a central role in plate-tectonic theory for 20 years. Old ocean crust is being subducted to 700 km with low coupling between plates, resulting in back-arc basin opening. Along the entire length are distinctive magmas which are especially hot and anhydrous. As a consequence, there are unique scientific objectives which can only be achieved by the use of manned and unmanned submersibles. The objectives having the highest priority are embodied in the following proposed projects.

Projects

A.2.1 Seamount collisions with the arc.

The Cretaceous Osbourne and Capricorn seamounts are being delivered to the Tonga Trench, and similar seamounts are thought to have been subducted beneath most of Tonga over the last several million years as the Louisville Ridge swept southward. A French-Japanese diving programme on seamounts at the Japan Trench in 1985 has shown the feasibility of studying both the internal stratigraphy of the seamounts and the structural style of collision. In Tonga, the southward migration of the collision site also provides opportunity to study the fore-arc before, during and after collision, by measuring deformation south and north of the Louisville Ridge. The thermal regime and vertical tectonics resulting from this sweeping could be important to the petroleum potential of the fore-arc.

A.2.2 Geological history of the arc, especially in its earliest stages.

Submarine canyons near Tongatapu, in northern-most Tonga, and in Fiji, should expose the oldest rocks in the New Hebrides - Fiji - Tonga region. Observation of stratigraphic relationships and collection of accurately located samples will help in understanding the apparently anomalous magmatic phenomena accompanying arc initiation. Earliest volcanism, if partly boninitic as suspected, may result in high precious-metal potential.

A.2.3 Volcanic hazards and metallogenesis

Central Tonga, from Fonualei to Ata, includes three subaerial and at least five submarine volcanoes which have erupted in this century. At least two (Fonualei, Metis) currently have dacitic magma in their chambers, and Metis demonstrably is being fed by basalt. These features often result in explosive volcanism and tsunamis elsewhere, and could be sites of hydrothermal metal deposits. This region, therefore, provides exceptional opportunities to study the character and distribution of submarine pyroclastic deposits, studies of singular scientific value as well as of importance in assessing local volcanic hazards. Similar mapping of subaerial deposits has proven important on both counts, manned submarine observation plus accurately located samples seem necessary, and hydrothermal activity should be searched for.

A.2.4 Deep-water volcanism

Although less hazardous deep-water eruption of arc magmas is of scientific importance because such rocks are abundant and host many ore deposits in Papua New Guinea, Fiji and elsewhere, the modern process is totally unstudied because of inaccessability without submersibles. Also, such eruptions yield magmas least affected by crustal processes and therefore of greater value in identifying their source, and yield rocks retaining their distinctive volatile contents. Northern and southern Tonga, and Kermadec, are thought to be sites of small active volcanoes erupting at depths <1 km, and Monowai, at 26°S, was observed in 1977 to erupt a narrow plume of discoloured water, reportedly from great depth.

A.2.5 Subduction-transform transition

In northernmost Tonga, the plate boundary changes rapidly from convergent to transform in character. Study of the structural and magmatic consequences of this transition is important since one may find pull-apart basins whose magmatic and metallogenic history is of interest.

A.2.6 Vertical tectonics

The response of the Tongan platform to steady-state subduction, and to seamount collision, is recorded on its submarine terraces and the inner wall of the trench. Careful mapping and sampling will constrain geodynamic theories of lithospheric response to subduction phenomena.

A.2.7 Fore-arc diapirs

Small diapirs, or seamounts, occur along the outer (seaward) edge of the fore-arc in the Bonin and Mariana arc where they are targets for ALVIN diving in 1987. Similar diapirs are suspected in the Tonga-Kermadec region and should be investigated for comparison.

Available Data

The Osbourne seamount area will have extensive Seabeam and bottom photographic coverage by 1986, and be fully ready as a diving target. Capricorn seamount will have little coverage.

Fore-arc canyons near Tongatapu have been mapped, and some nearby single- and multi-channel seismic data are available.

Bathymetric detail is crude, and no volcanic edifices are known sufficiently to be clear objectives.

Some Seabeam maps will exist by 1986 and there has been Russian and Japanese dredging. However, coverage is spotty and there are no present plans to survey the area in detail.

Recommendations

(i) Manned diving south, near, and north of the Osbourne seamount is recommended. No work beyond that already planned for 1985-86 should be necessary. Preliminary Seabeam surveys of the Capricorn seamount area are recommended.

(ii) Seabeam coverage, and additional multichannel seismic coverage and dredging, of several fore-arc canyons in central Tonga or Fiji remain necessary precursors to site selection. Manned submersible study will be necessary.

(iii) SeaMARC surveys of the volcanic arc along the length of the Tonga and Kermadec region is recommended, followed by detailed high-resolution study and dredging of selected edifices. Manned submersible study will be necessary.

(iv) Additional Seabeam surveys probably will need to follow those obtained in 1985-86. Manned submersible study may not be necessary.

(v) Seabeam mapping of the outer part of the Tonga-Kermadec fore-arc will be necessary to identify possible targets.

A.3 *LAU BASIN*

Introduction

The Lau Basin presents problems for study that are fundamental to understanding the origin and evolution of back-arc basins. Of paramount importance to the region is the high probability of crustal magma chambers in the axial region that could be long-lived sites for hydrothermal circulation and the precipitation of metalliferous deposits. In the axial region there is a near-surface magma chamber (Valu Fa ridge) which gives rise to seafloor eruptions of dacitic (high silica) magma. There is evidence for metalliferous sediments and hydrothermal barite near the axial region. High-temperature, "primitive" basaltic magma formed by extreme fractionation of magmas is further support for the existence of long-lived magma chambers.

Special scientific problems are posed by the geometry of the Lau Basin and data on its crustal composition and tectonic-magnetic fabric.

It appears that the basin may be opening by propagation of an axial rift southward. The Valu Fa site is at; or near; the southern apex of this rift system. Crustal composition and rock-type distribution suggests an evolution in time and space from relatively hydrous basaltic melts moderately enriched in large-ionic-radius elements to anhydrous melts similar in most critical respects to mid-ocean ridge basalts. Complex spreading processes with overlapping spreading centres, ridge jumps and numerous point sources (seamounts) have been postulated.

We recommend that the extensive effort already expended, and the surveys to be completed within the next two years, be complemented and extended by use of ROVs and manned submersibles. It is expected that the Lau Basin will have one or more holes drilled during the Ocean Drilling Programme.

Projects

A.3.1 Back-arc spreading processes

Detailed studies of the tectonic fabric and relationships between tectonic-morphologic-petrologic features are needed to make a proper comparison with similar processes and features at mid-ocean ridge spreading centres.

A.3.2 Tectonic-magmatic controls on initial stages of back-arc basin evolution.

The role of propagating rifts that may split arc segments or separate arcs from older ocean crust need study and the Lau Basin is an ideal place for such study.

A.3.3 Origin and significance of silicic magmas in back-arc basins.

The Valu Fa magma chamber and Zephyr Shoal in the Lau Basin may offer insight into the origin of ophiolite rock type and are potential sites for hydrothermal metal deposition.

A.3.4 Active hydrothermal vents at axial magma chambers.

There are probably long-lived high-temperature (e.g., 1250°C) basaltic magma chambers in the Lau Basin. By analogy with the East Pacific Rise, these may give rise to hydrothermal vents, chimneys and sulphide deposits. These may be different from known vent systems because of differences in water depth (pressure) and the possible addition of enriched fluids derived from the subduction of old ocean crust in the Tonga Trench.

A.3.5 Biological studies

Because of its isolated setting and relatively young age (<4my), Lau Basin vent systems may have communities of unique marine organisms that could differ from those known on the East Pacific Rise.

Available Data

There are extensive data for the Lau Basin including multi-beam charts, seismic reflection profiles (single- and multi-channel), sea-floor photography, shipboard and airborne magnetic profiling, rock and sediment samples; deep crustal and mantle seismologic data and deep drill data from the Tongan Islands and Deep Sea Drilling Project hole 203. Additional multibeam and other shipboard data collections are planned during the next two years including water sampling to detect methane and helium plumes from possible vent sites and the use of GLORIA to study sea-floor morphology.

Recommendations

The Sessional Working Group recommends that:

(i) additional surveying, especially for water chemistry, be done to identify possible sites of hydrothermal activity;

(ii) sea-floor imagery by photography and acoustic imagery be used to map and interpret the tectonic fabric and identify vent sites;

(iii) manned submersibles be used to study and sample vent sites and to accomplish the other projects listed above.

A.4 *NORTH FIJI BASIN*

Introduction

The North Fiji Basin contains back-arc spreading centres, transform faults, triple junctions, and seamounts. These features are potential dive targets for studies of tectonics, magmagenesis, metallogenesis and biological resources.

Unique characteristics of the major N-S spreading centre (173° - 177°E) are: medium-fast spreading rates of 60-80 mm/year; diffuse seismicity between 15° - 20°S, which may indicate intense hydrothermal activity; evidence of progagation northward near 15°S and southward near 21°S; and the presence of off-axis seamounts (e.g., the Mont Du Nautilus near 20°S).

The 175°E spreading centre has the slowest spreading rate in the region (10 mm/year). However, the ridge is strongly magnetized and displays intense seismicity suggesting that the spreading centre is active.

Recent investigations of the South Pandora Ridge have shown that the seismically active ridge is in extension and that it is the site of recent volcanism and hydrothermal activity. Dive targets include deep (>4 000 m) rift basins and associated seamounts such as Horizon Bank, which rises to 40-m water depth.

Transform-fault dive targets include pull-apart basins; such as that found north of Viti Levu within the Fiji Fracture Zone. Silicic magmas accompany normal mid-ocean ridge basalt (MORB) within this pull-apart basin. Deep crustal sections may be exposed along the fracture zone walls, as well as fossil hydrothermal systems. The Hunter Fracture Zone presents the best example of the transition from oblique subduction to transform motion. Pull-apart basins and deep crustal sections may also be found in this area.

Four types of triple junctions are found in the North Fiji Basin: (i) two ridge-ridge-transform (RRT) junctions near 17° and 20°S along the major N-S spreading centre; (ii) a ridge-tranform (RTT) junction at 176° E along the Fiji Fracture Zone; (iii) a ridge-ridge-ridge (RRR) junction near 14°S on the South Pandora Ridge; and (iv) a subduction-ridge-transform (SRT) located near 23°S along the Hunter Fracture Zone. Intense hydrothermal activity may be associated with the intersection of these major tectonic regimes.

Projects

A.4.1 Precise description, measurement, sampling and assessment of the extent of individual vents or fields of hydrothermal systems and their deposits; e.g., South Pandora Ridge rift basins, 173-174 degrees N-S spreading centre, Fiji Fracture zone pull-apart basin.

A.4.2 Continuous, geological mapping along fault scarps and the stockworks of submarine hydrothermal systems, including rift valleys, calderas and the crustal sections exposed along major fracture zones; e.g., Fiji Fracture Zone, Hunter Fracture Zone, basin-wide spreading centres.

A.4.3 Precise sampling of volcanic edifices or flows along spreading rifts, off-axis volcanoes and propagating rift tips; e.g. basin-wide spreading centres, especially the 173°-174°E spreading centres at 15°S and <1°S. The information to be gained here and in Project 4.4 below is not only of keen basic research interest, but may also lead to accurate predictive models for locating hydrothermal fields.

A.4.4 Detailed descriptions and measurements of tectonic features along and across the axial zone of the spreading centres and fracture zones; e.g., basin-wide spreading centres and the Fiji and Hunter Fracture Zones.

A.4.5 Detailed geophysical surveys near and on the bottom, such as magnetics, gravity, electrical conductivity, heat flow, seismicity and seismic reflection/refraction surveys. Deployment of monitoring instruments such as Ocean Bottom Seismometers, geochemical monitoring packages, and biological monitoring packages; e.g., the most tectonically and/or hydrothermally active areas of the basin-wide spreading centres and fracture zones.

Available Data

Present coverage of conventional geophysical data is limited. Detailed Seabeam bathymetry with some bottom photographic reconaissance and preliminary sampling of rocks, water and sediment currently exist for a limited portion of the Fiji Fracture Zone north of Viti Levu (SONNE 1985 cruise). This has located several potential dive targets within the newly discovered pull-apart basin.

However, beginning with the 1985 cruise of the R.V. JEAN CHARCOT, Seabeam coverage of the 173°-174°E and 176°E spreading centres between 16°S and 22°S will be undertaken. Bottom camera surveys, as well as dredging and water sampling;will take place in selected areas. In early 1986, the R.V. THOMAS WASHINGTON will carry out detailed hydrographic sampling along the 173°-174° E spreading centre and the South Pandora Ridge. Later in 1986, the R.V. MOANA WAVE will survey the South Pandora Ridge and the 173°-174° E spreading centre from the triple junction with the South Pandora Ridge south to at least 17°S with SeaMARC II. Saturation photography of selected targets, dredging and sediment coring will also be undertaken. Together, the above-mentioned information will greatly enhance our ability to select specific dive targets.

Recommendations

(i) Need for detailed site surveys:

Ideally, detailed multibeam bathymetry, side-scan acoustic imaging and saturation photography, as well as bottom sampling and hydrocast surveys, should be carried out before a dive target is selected, and especially before hydrothermal vent dive sites are selected.

The minimum information necessary is detailed multibeam bathymetry. Because bathymetry does not give information on the bottom character (e.g., talus slopes), side-scan imaging of the target areas is also important; bottom photography can sometimes substitute for such imaging, but is best used for supplementary information.

(ii) Detailed survey areas:

Many targets can be adequately surveyed using various combinations of the bottom characterization and remote sensing techniques mentioned above. However, only manned submersibles or ROVs with manipulation capabilites will be able to conduct successfully the detailed projects envisioned above.

(iii) Tools to carry out dive programme:

Because most of the aforementioned dive targets lie in water depths exceeding 3 000 metres, manned submersibles such as NAUTILE, SEACLIF or ALVIN will be necessary to carry out most of the exploration and research. Some of the shallower seamount slopes and summits, however, may be surveyed by submersibles such as CYANA, PISCES or MAKALI'I.

A.5 *NEW HEBRIDES ARC*

Introduction

The west-facing Hebrides intra-oceanic island arc is associated with the underthrusting of the Indo-Australian Plate beneath the North Fiji Basin. While a typical arc-trench system is developed in the north and south, the central part presents some unusual features. Notably, a compressive stress regime prevails across the Central New Hebrides including the back-arc zone near Maewo and Pentecost, while a tensional stress regime prevails at the rear of both the northern and southern sections of the arc, as indicated by troughs such as the Coriolis Trough. Arc volcanism has occurred from the early Oligocene to the present.

Various authors have provided reconstructions of the history of the Hebrides arc, but a lack of consensus on details still exists.

Projects

A.5.1 Vertical tectonics

Normal subduction processes are quite well documented in the N and S parts of the New Hebrides arc. (Uplifted coral reefs; horst graben-like features).

A.5.2 Oblique subduction

A good example is in the southern New Hebrides, with the transition between "normal subduction" (still occurring south of Aneitium) and oblique to transform movements which affect the Matthew-Hunter ridge.

A.5.3 Ridge-trench collision

Two occurrences in the New Hebrides arc: the d'Entrecasteaux Zone (see abstract by Daniel et al.) and the Loyalty/South New Hebrides "collision" zone (see abstract by Maillet et al.).

A.5.4 Plateau collision

West Torres Massif

A.5.5 Arc rifting/nascent spreading

The New Hebrides troughs were discovered in 1966 behind the volcanic line, at a distance of 40 - 60 km and have an average width of 40 km and a water depth of from 2 500 to more than 3 000 metres. Morphological features such as elongated shape, steepness of the flanks and strike-slip faults suggest an extensional origin; but the bathymetry cannot define the stress directions precisely. As the trough floor topography is not even (features exceeding 1 000 metres), the extensional pattern is not thought to be simple (uni-directional) but probably oblique, and possibly multi-directional.

The bathymetry of the back-arc zone east of Maewo-Pentecost-Epi is poorly known. A compressive stress regime is deduced from the tectonics of the islands (Maewo and Pentecost) and the interpretation of focal mechanisms.

A comparison with the results obtained on the fore-arc region in the d'Entrecasteaux zone will permit us to test the hypothesis that the troughs may be a direct consequence of the subduction/collision of the d'Entrecasteaux zone.

A.5.6 Initial stages of arc development

(See also abstract by Maillet et al). This item could be documented between Aneitium island (mainly tholeiitic) and Matthew-Hunter ridge (calc-alkaline), along a series of seamounts which link the NW-SE trending New Hebrides arc and the E-W trending Matthew-Hunter ridge.

A.5.7 Volcanic hazards

A satellite-transmitted ARGOS station will be installed on Matthew volcano in spring 1986 for fumarole temperature measurements and daily seismic event recordings. This equipment may be extended to some active volcanoes of Vanuatu (Epi-Ambryn area) in the near future.

A.5.8 Volcanic stratigraphy

Study of the flank scarp of the Coriolis Trough will allow construction of a stratigraphic section of the arc (more than 1 800 metres) and of some volcanoes (e.g., Tutuna) (see abstract of Recy and Maillet).

A.5.9 Hydrothermal metallogenesis

Could be investigated by submersibles on three targets:

(i) Seamounts between Aneitium and Matthew-Hunter (cf. early stage of arc development).

(ii) Seamounts off Epi (see abstract).

(iii) Coriolis-Vot Tande troughs at the back of the arc (possible hydrothermalism related to incipient stage of spreading).

Available data

Many cruises have been made over the last ten years. ORSTOM organised about 8 cruises (some of them with CCOP/SOPAC) to collect geophysical information including bathymetry, magnetics, gravity, single-channel seismic reflection and seismic-refraction data. Two cruises were made by USGS (1982-1984) in the framework of the Tripartite Programme to collect geophysical data and carry out multichannel seismic reflection profiling. Bathymetric maps at different scales are printed or about to be printed by ORSTOM and USGS:

A Seabeam survey will be made (SEAPSO cruise by IFREMER and ORSTOM) in 1985-1986 on the d'Entrecasteaux-New Hebrides collision zone, on the Loyalty-New Hebrides trench saddle, in the back arc troughs, and on the southern part of the arc area.

Recommendations

In the New Hebrides arc region there are many excellent examples of targets. From a scientific point of view, some of the targets are unique in the southwest Pacific. For example, the Coriolis-Vot Tande back-arc troughs, may be the best examples of the early, tensional phase of a (nascent) back-arc basin in the region.

The Sessional Working Group recommended use of submersibles:

(i) at the d'Entrecasteaux ridge collision to study the accretion of slices of the d'Entrecasteaux ridge onto the inner wall of the fore-arc;

(ii) at the incipient Loyalty Ridge collision to study the early stages of collision of a ridge with an arc and the nature of this unknown volcanic chain;

(iii) investigations on seamounts between Aneitium and Matthew, and along the Matthew-Hunter ridge to clarify the nature of the petrologic transition between the cental part of the arc and the calc-alkaline Matthew-Hunter ridge; they could also allow investigation of hydrothermalism related to the initial stages of arc volcanism.

A.6 *BISMARK SEA REGION*

Introduction

Four topics of interest are: (i) submarine volcanism, possible hydrothermal mineralisation; biota and structure of the fast-spreading Manus Basin; (ii) volcanic-hazard assessment and structure of the submarine parts of two active volcanoes in the Bismarck volcanic arc; (iii) the nature of recently discovered, youthful, flat-lying flood lavas north of Manus Island; and (iv) the nature of the sea floor above a possible magma chamber near Mussau Island.

Projects

A.6.1 Manus Basin

To study the nature of the volcanism, hydrothermal activity, and tectonics of the Manus Basin spreading axis, including deep crustal sections on large transform escarpments. As this is the fastest back-arc spreading centre, the intensity of hydrothermal circulation and the concentration of associated massive sulphide deposits is likely to be great.

A.6.2 Rabaul harbour

To examine structures on the two new sea-floor bulges considered to represent emplacement of shallow magma bodies that are the cause of the current volcano alert at Rabaul.

A.6.3 Ritter volcano

To study the submarine parts of the debris-avalanche caldera walls (formed in 1888) where the lower stratigraphy of the volcano is exposed, to search for hydrothermal sea-floor vents in the caldera, and to identify and study lithologics of the debris-avalanche deposits.

A.6.4 Off-shore Manus lavas

To examine and collect the young flood lavas exposed in fault scarps north of Manus Island, and to study associated hydrothermal manganese deposits.

A.6.5 Mussau

To study the seafloor effects of a shallow magma chamber identified from seismic reflection profiles.

Available Data

Good bathymetry and/or reflection profiling are available for all areas. SeaMARC surveys are planned for Manus Basin and Rabaul.

Recommendations

ROV and/or manned submersible studies (< 3 000 m depth) are recommended for all five areas. Surveys of the Rabaul bulges are needed as soon as possible in view of the current alert.

A.7 *WOODLARK BASIN/SOLOMON ISLANDS*

Introduction

The Woodlark Basin contains a spreading axis with an intermediate spreading rate (70 mm/yr). It is actively propagating into continental crust in Eastern Papua in the west, and is actively subducting beneath the western Solomon Islands in the east where fore-arc volcanism is taking place at Kavachi.

Projects

A.7.1 Woodlark Basin spreading axis

To study the nature of the volcanism, hydrothermal activity, biota and tectonics of the Woodlark Basin spreading axis, including deep crustal sections on large transform escarpments.

A.7.2 Woodlark Basin propagation

To study the nature of the sea floor including particularly any polymetallic-sulphide deposition related to felsic volcanism in Dawson Strait, and to examine the large seamount east of the propagating apex.

A.7.3 Woodlark Basin subduction

To study the arc-type volcanism, hydrothermal activity, and related structures at the TTR triple junction west of the New Georgia Group.

A.7.4 Kavachi volcano

To study surface outcrops and hydrothermal vents on this active, andesitic fore-arc volcano, and to identify evidence for slumping and other mass-wasting processes.

Available Data

Good bathymetry and reflection profiling are available for all areas. A SeaMARC survey is planned for the triple-junction area in late 1985. Detailed bathymetry is available, and hydrocast/sampling planned in the West Basin.

Recommendations

ROV and/or manned submersible studies are recommended in all four areas (depths to 4 000 m). The rift propagation survey is of particular interest in view of the apparent relationship of Kuroko deposits to felsic magma chambers.

A.8 *EASTERN FLANK OF MANIHIKI PLATEAU*

Introduction

A unique opportunity presents itself to observe, map, and sample by submersible the exposed upper crustal rocks of an oceanic plateau. Drilling on the Manihiki Plateau of DSDP site 317 revealed pelagic carbonates, underlain by metal-enriched volcaniclastic sediments which, in turn, are underlain by MORB basement lavas. The basalt was depleted in copper, indicating mobilization of the copper, and indeed, flakes of native copper were found in the volcanicrustic section.

Perhaps the best exposures of the upper crustal section of the plateau, however, occur along the steep fault scarps along the eastern margin. These scarps, which probably formed during a spreading ridge jump from the centre of the plateau into the Penrhyn Basin, may contain the record of crustal evolution and the development of hydrothermal venting, subsequent rifting and formation of hypogene deposits, and seamount evolution.

Projects

A.8.1 To define the igneous basement stratigraphy and determine the evolution of upper crustal rocks of the Manihiki Plateau.

A.8.2 To investigate in detail the basalt-sediment interface with a view to determining the type and style of hydrothermal vent development.

A.8.3 To investigate the effects of a subsequent rifting episode, including those of possible thermal rejuvenation involving hydrothermal fluid migration and the remobilization of metals.

Available Data

The metalliferous layer that has been widely traced in reflection profiles and was recently sampled in small areas of the northeastern part of the plateau during a cruise of the R.V. SONNE; detailed Seabeam data were also obtained.

SeaMARC surveys of the seamounts and scarps of the eastern margin of the Manihiki Plateau will be undertaken in 1986.

Recommendations

The Sessional Working Group recommended use of a deep-diving submersible with a 6 000-m depth capability on the scarps of the eastern flank of the Manahiki Plateau, for mapping and sampling of the upper crustal section.

CONCLUSION

At this stage the Sessional Working Group felt that attempts should be made to initiate the following as soon as possible:

Explore, with manned submersibles during 1986-87, areas of shallow submarine volcanism and mass-wasting, capable of explosive eruption or tsunami generation. Rabaul should receive highest priority. Other areas (e.g., Ritter, Papua New Guinea, Epi, Vanuatu, Tinakula, Solomon Islands, Metis and Fonuale, Tonga) should also be explored if possible, although additional site survey may be necessary in some instances.

Active search for potential sites of metallogenesis should be pursued. Studies of water-column chemistry, to look for anomalies related to plumes from hydrothermal vent systems, should precede more detailed searches with sea-floor imagery and use of submersibles.

REPORT OF SESSIONAL WORKING GROUP B ON EXPLORATION FOR HYDROCARBONS IN SOUTHWEST PACIFIC ISLAND ARCS

INTRODUCTION

A selective programme of mapping and sampling submarine outcrops in a number of southwest Pacific island-arc sedimentary basins could profoundly influence current estimates of regional resource portential, and greatly assist current research programmes aimed at promoting hydrocarbon exploration. Commercial exploration for hydrocarbons is a high-cost, high-risk, potentially high-reward undertaking. In the region, most island arc sedimentary basins are undrilled "frontier basins", or have been the subject of limited and/or narrowly focussed exploration programmes. In general, all southwest Pacific island-arc basins would be regarded as very high-risk areas, although some exploration is current in Fiji and Tonga. Some companies are attracted to such areas because they may contain a wholly new, extensive and highly rewarding petroleum province. Most companies, however, are deterred from even considering exploration in this region by the very high risks.

Such high-risk assessments may be modified by the gathering and analysis of a body of commercially relevant geoscientific framework data. Risk assessments involve estimates of basin source, reservoir and seal potential, as well as the history of source-rock maturation.

Increasingly, governments of the region are utilizing the scientific research capacity of their government-funded research agencies (such as national geological surveys) and/or intergovernmental co-operation to conduct mission-oriented research programmes. These are specifically aimed at obtaining geological framework data for promoting commercial petroleum exploration. Such programmes also lead to the development of new general geological concepts, which may lead to new exploration play concepts.

Typically, the first stage of a frontier-basin framework study is a regional geophysical (multichannel seismic) grid. Geological data are an essential follow-up. A highly valuable, but expensive method is the so-called "continental offshore stratigraphic test", or COST well. These have been drilled particularly in the United States' offshore regions. Such wells avoid wildcat drilling targets and concentrate on stratigraphic data: age, depth, lithology, seismic velocity, depositional environment, source potential, maturation and heatflow. Regional play concepts are then developed by extrapolating these data basin-wide. Risk factors are often significantly reduced by the availability of hard data on relevant exploration parameters.

Other methods of obtaining relevant geological data include dredging and sea-bed sampling from manned submersibles. The latter is both useful and precise where canyons and scarps expose sections of basin fill. Papers presented at the present Workshop show that submersibles had been particularly useful in studying the stratigraphy of continental-margin sedimentary basins (Bay of Biscay, Morocco, Mediterranean, Santa Barbara Channel). The following regional proposals focus primarily on frontier, or substantially under-explored, basins of the region where significant stratigraphic exposures are known and can be precisely sampled from a submersible.

Other relevant studies which may be conducted by manned submersibles include direct examination and sampling of hydrocarbon seeps. These have been reported from Tonga and Fiji. Since all the island-arc basins are at or near an active plate boundary, key faults are often expressed in the sea bed. These can also be studied from manned submersibles.

Finally, it should be noted that data relevant to the petroleum potential of island-arc sedimentary basins are also relevant to studies of the evolution of island arcs, themselves. Thus, the following regional programmes are all relevant to the aims and objectives proposed by Sessional Working Group A.

PROPOSED PROJECTS

B.1 *NEW IRELAND BASIN, PAPUA NEW GUINEA*

Area of Interest

New Ireland Basin lies south of the Manus - Kilinalau Trench system, and north of the islands of Manus, New Hanover, and New Ireland.

Geological Background

Sediments are up to 5 km thick. Seismic data suggest thick carbonate sequences with the possibility of hydrocarbon potential. This is supported by outcrops of Tertiary carbonate rocks on islands in the central part of the Basin. However, most of the Basin is not accessible for sampling.

Steep fault scarps lying E-W to WNW truncate the southern margin of the Basin west of New Hanover and south of New Ireland. Another major active N-S fault system runs through the Basin between Manus and New Hanover, with high steep scarps and deep holes exposing basin sediments. Along these scarps it is possible to observe, measure and sample the Tertiary section which can be extrapolated into the heart of the Basin by reference to multi-channel seismic data already available.

Data Available

Oil exploration companies have obtained several hundred kilometres of multi-channel seismic data. Several thousand kilometres of single-channel seismic data are available, and a recent cruise of the S.P. LEE in 1984 obtained multi-channel seismic, single-channel seismic, gravity and magnetics data, and sampled several outcrop areas. Bathymetry is well known on a scale of 1:250 000.

Data Requirements and Project Definition

Dive sites are in two general areas. First, the scarp-bounded southern basin terminus is ideal. It is protected from heavy weather, has possibly hundreds of metres of exposure in near vertical cliffs, and exposes the sub-sediment basement rocks on the deep parts of the faults. Maximum depth is about 2 200 m. The second area is in the N-S fault zone where scarps are up to 2 km in height with slopes exceeding 45 degrees, indicating the degree of movement taking place.

These scarps expose sedimentary and volcanic sections and possibly deeper parts of the sub-sedimentary basins. The N-S fault zone is not as well connected seismically to the thick central basin area but could provide sedimentary and petrologic data on basin formation. A dramatic change in sedimentary and tectonic history occurs across the fault zone. Seabeam or SeaMARC is needed to define locations of dives, and more seismic data are needed across the N-S fault zone. Further preliminary dredging could also be useful.

B.2 *FORMATION SAMPLING FOR HYDROCARBON ASSESSMENT IN VANUATU*

Area of Interest

Central Basin of Vanuatu; depth ranges from a few hundred metres to 3 000 m.

Three primary dive sites are proposed:

(i) Santo Submarine Canyon - Big Bay region of Espiritu Santo Island.

(ii) Steep scarp (>40-degree slope) on eastern side of Espiritu Santo Island (>1000 m high).

(iii) Small scarp on eastern slope of Malokula Island.

Geological Background

Over 5 km of Tertiary (primarily Neogene) sediments fill the Central Basin and these sediments are folded and faulted up against the flanks. Several places exist where a thick stratigraphic section is exposed and these are promising sites for sampling by submersible.

Available Data

At all proposed dive sites there are good-quality geophysical data consisting of multi-channel seismic,single-channel, high-resolution (Uniboom and 3.5 kHz) seismic reflection profiles and magnetic and gravity profiles. Detailed bathymetric data have been collected in some of these areas by the Australian Hydrographic Service. Dredged samples are also available.

Data Requirements and Project Definition

Although many data are available for the proposed dive sites, much of the geophysical data has been collected on a reconnaissance basis and more detailed high-resolution seismic data obtained by side-scan sonar, GLORIA or SeaMARC are desirable. Seabeam and bottom photography should be done. The purpose of the project is to examine and collect in situ rock samples for stratigraphic and source rock analyses for hydrocarbon resource evaluation.

Anticipated Results

Detailed, in situ stratigraphic sampling of exposed lithologic sequences will reveal age, depositional environment, porosity, permeability, and source rock potential. As most targets are relatively low in the sequence, proper sampling would replace expensive drilling, but be complementary to ODP drilling proposed for this region.

B.3 *MARGINS OF THE FIJI PLATFORM*

Area of Interest

The perimeter margins of the Fiji Platform in three principal locations:

(i) Baravi Basin off southern Viti Levu at an average depth of 2 000 metres.

(ii) Yasawa shelf and slope west of Viwa Island off north-western Viti Levu, in a depth range from shelf edge to 2 000 metres. Recent bathymetric surveys have revealed slopes of more than 80 degrees.

(iii) Koro Sea margin off eastern Viti Levu in depths up to 2 000 metres.

Geological Background

Site (i) regional geology is described in CCOP/SOPAC Technical Bulletin No. 3 (1980). It has been speculated that this was once connected to the Central Basin of Vanuatu prior to formation of the North Fiji Basin.

Sites (ii) and (iii) lie at the western and eastern ends, respectively, of the Bligh Water Basin. This Basin has been explored and drilled for hydrocarbons on its northern and southern flanks. Regional stratigraphy and basin evolution is still poorly understood. The Basin has been evolving throughout the Eocene to Recent, in parallel with the complex history of volcanism and intrusion observed on Viti Levu. Understanding the evolution of the Bligh Water Basin is clearly most important in understanding the evolution of island arcs in general.

Data Available

All three areas are covered, at least to some extent, by regional seismic and bathymetric data, which are adequate for preliminary project definition.

Data Requirements and Project Definition

All three areas require detailed bathymetry/Seabeam to define accurately the slopes, scarps and canyon walls that are known to exist. In all cases, vertical sampling of stratigraphic sequences can be achieved.

Anticipated Results

The stratigraphic history of Bligh Water Basin has, to a limited extent, been defined by exploration wells Great Sea Reef - 1 and Bligh Water - 1. Subsidence of, and deposition in, this and other fore-arc or intra-arc basins has continued alongside complex arc evolution. The proposed sea-bed sampling programme will extend knowledge of the Basin stratigraphy, allow deeper (basement?) sampling, better definition of arc

evolution and the resource potential of arc-associated basins in the southwest Pacific.

B.4 *TONGA FORE-ARC BASIN*

Area of Interest

Fakalati Canyon on the east side of the South Tonga Platform at approximately 22° S. The platform is flat-topped (400-500m depth) with steep sides where depths of 5 000m are rapidly attained. The canyon is cut into the sedimentary section and it is thought that much of this is exposed.

Geological Background

The multichannel seismic data in this area have been compared with hydrocarbon wells drilled on the island of Tongatapu 100 miles to the north. A volcaniclastic section of Eocene to Pliocene age has been penetrated in these wells and this continues southward into the project area. Four seismic packages have been identified and traced into the area; up to 5 000 m of section is present. Much of this section is exposed in the canyons.

Data Available

Single and multichannel seismic, bathymetric profiling (12 and 3.5 kHz), gravity and magnetic data are available for the project area. Dredging has also been carried out but dates only of Miocene age obtained.

Data Requirements and Project Definition

To complement the data set already available, a Seabeam survey would provide additional definition for submersible sample sites. A survey is needed which would indicate the nature of the substrate, whether this is composed of debris flows or whether sites could be identified for sampling which would adequately cover the succession. It is anticipated that the R.V. JEAN CHARCOT will be able to carry out this survey during Leg 5 of the SEAPSO Project.

Anticipated Results

This proposed submersible project would sample much of the representative sedimentary section, enabling the rocks present to be sampled, dated and analysed for source rock potential. Horizons older than Miocene should be present and correlation could be made with the drilled sections further north. This would provide better information on the development of the Tonga Platform with particular relevance to hydrocarbon prospects.

RECOMMENDATIONS

(i) In the project areas described above, site surveys are required: Seabeam or other very detailed bathymetry; plus SeaMARC-type surveys, bottom photography and dredging.

(ii) A manned submersible diving and sampling programme is strongly recommended in each area.

(iii) In Vanuatu and Tonga, integration with the proposed Ocean Drilling Programme should be attempted to maximize regional benefits.

(iv) In general, programme integration with other projects proposed by the other Sessional Working Groups is recommended.

REPORT OF SESSIONAL WORKING GROUP C ON GEOHAZARDS AND ENGINEERING GEOLOGY

INTRODUCTION

Manned submersibles and, in many cases, remotely operated vehicles, allow study of subjects in the marine world previously restricted to subaerial observation through the use of remote video and still cameras, mechanical manipulators and drills and visual observation. Preliminary studies using other state-of-the-art technology such as GLORIA, Seabeam, SeaMARC II, single and multichannel seismic reflection, bottom photography and remote bottom sampling need to be completed to identify appropriate targets. The range of problems that require the application of this technology to provide an understanding of hazards and the mechanisms that may initiate them embrace volcanic eruption, seismicity, faulting, slope stability and mass transport.

Studies in geohazards and engineering using these tools in the South Pacific should focus on these general classes of problems. This Sessional Working Group has attempted to specify areas needing study that may also apply elsewhere. For example, OTEC site-survey dives performed in Hawaii and Tahiti and proposed for Fiji would apply to other areas with similar bathymetric conditions, and studies of fault rupture in Vanuatu would be relevant to other areas where fault offsets are found underwater.

To accomplish the objectives set out by those projects every effort should be made to use all available tools. Research vessels operating in the region should be encouraged to survey sites appropriate to these studies.

Evaluation of available data for potential geohazards in the southwest Pacific indicates that three major regions are important targets for submersible and ROV investigations. The first region is Rabaul Harbour, Papua New Guinea, where a sea-floor volcanic eruption is likely and studies of sea-floor deformation, seismicity and mass wasting can all be undertaken in a relatively small area. Short-term and long-term studies can be done and either a manned submersible or ROV could be used.

The second important area is the Central Basin of Vanuatu where geohazard studies can be undertaken along with submersible investigations significant to hydrocarbon appraisals, hydrothermal mineralization and sea-floor sedimentary processes. Studies pertinent to seismicity, sea-floor deformation and mass wasting can also be undertaken in a relatively small area. The close proximity to islands makes it possible to make not only short-term investigations, but long-term monitoring as well.

Fiji, the third area of interest, lies southeast of Suva, where a major submarine slump occurred generating a damaging tsunami in 1953. Although more preliminary site investigations need to be done before submersible or ROV studies can be undertaken, the study is important because of the tsunami generation potential.

PROPOSED PROJECTS

C.1 *OBSERVATION AND MONITORING OF A DEVELOPING SUBMARINE VOLCANO, RABAUL, PNG*

Area of Interest

Rabaul Harbour, New Britain Island, Papua New Guinea. Caldera floor approximately 200m deep.

Geological Background

Rabaul Harbour lies in a breached caldera with active subaerial volcanoes located along the north and northeastern rim and on the western side where a volcano grew from a submarine reef in 1874 to become a part of of the mainland in 1983. Recent seismic events coupled with onland uplift suggest that shallow magma is on the move and another submarine eruption is likely.

Data Available

Intermediate penetration and high-resolution seismic reflection profiles have been collected in great detail over an area where sea-floor upbowing appears to be occurring. Detailed bathymetric data to monitor sea-floor changes have been collected twice in the past two years with 100-m line spacing over a large area.

Data Requirements and Project Definition

SeaMARC or side-scan sonography is needed to define potential dive sites. Bottom photographs are desirable. SeaMARC II work is planned for the near future. The purpose of diving in Rabaul is to:

(i) Examine and monitor sea-floor upbowing where a new submarine volcano may form. A manned submersible is preferred so that close examination and instrument implantations can take place. Short-term observation, sampling and photography, and long-term monitoring studies are needed.

(ii) Document sea-floor displacement along faults over the area where the sea floor is upbowed. Instruments and reference points to measure fault displacement need to be situated on the sea floor.

(iii) Another objective is to examine and monitor sea-floor movement in the vicinity of a slump that is mapped near the uplifted sea floor.

This project is significant to studies of volcanic eruption prediction and could reduce adverse impacts of volcanism on people and property.

Anticipated Results

Determination of the amount and rate of displacement over an area where magma is being injected into the shallow sub-surface prior to sea-floor eruption.

Determination of the instability of sea-floor materials near an incipient submarine volcano. Determinaion of the possibility of catastrophic sliding that could create tsunamis in Rabaul Harbour. Assistance in predicting the next volcanic event.

Recommendations

SeaMARC II studies should be undertaken in Rabaul Harbour by the R.V. MOANA WAVE when it arrives in the region to undertake Tripartite surveys.

There are many submarine thermal vents for which no reliable temperature or other data are available. Monitoring these by emplacement of appropriate instruments will provide useful data on precursor temperature changes.

C.2 *VOLCANIC-TSUNAMI GENERATION, TINAKULA, SOLOMON ISLANDS*

Area of Interest

The active volcanic island of Tinakula, Santa Cruz Islands Group, Eastern Province, Solomon Islands. Water depths range from 0 to 2 000 m.

Geological Background

Tinakula is a volcano on the active volcanic chain of the northern New Hebrides Arc. Recent catastrophic eruptions have permanently displaced a village and a large landslide along the northwestern flank is suspected of having generated a tsunami; and appears capable of generating more.

Data Available

One multi-channel seismic profile across the submarine landslide exists.

Data Requirements and Project Definition

A detailed survey using high-resolution, seismic-reflection, SeaBEAM and side-scan sonar is needed. Bottom photography is desirable. Examination and monitoring of volcanogenic mass wasting. A large failure of the flanks of Tinakula is capable of generating a tsunami that could affect local inhabitants of neighbouring islands. A manned submersible or ROVs could be used to undertake experiments necessary for evaluating volcanogenic tsunami generation.

Another objective is to document and appraise volcanogenic mass wasting on the submarine flank of an active volcano.

Anticipated Results

Observation and measurement of landsliding and volcanic scouring along the flank of Tinakula will allow determination of potential tsunami hazard and the need for safety measures. Understanding the process of mass wasting on the submarine flanks of an active volcano will assist in evaluation of submarine landslides.

Recommendations

A survey in detail using Seabeam side-scan sonar and high-resolution seismic reflection gear.

C.3 *SUBMARINE VOLCANIC ERUPTIONS, EPI AND KARUA VANUATU*

Areas of interest

Southeast end of Epi Island, Vanuatu. Water depth ranges from 500 to 2 000m.

Geological Background

Three active volcanic cones exist along the floor of a submerged volcano off Epi, which itself is a dormant volcano associated with the active volcanic chain of the New Hebrides Arc, Vanuatu. Active vents are periodically associated with the cones. In addition, Karua volcano is periodically emergent off southeast Epi.

Data Available

Detailed high-resolution (uniboom and 3.5 kHz) seismic reflection profiles and bathymetric data exist. One underwater TV traverse has been made in the Epi area. Dredge and core samples have been collected in both volcanic areas.

Data Requirements and Project Definition

More underwater photography, Seabeam or SeaMARC and side-scan sonography would be desirable.

The objective is to document submarine volcanic cone development and to monitor growth. Seismic reflection profiles show excellent stratigraphic formation history, and follow-up in situ examination and sampling would assist in prediction of volcanic eruption recurrence intervals. The Epi cones are near populated islands and assessment of volcanic eruption periodicity could help planning to reduce danger.

Anticipated Results

Evaluation and documentation of submarine volcano development. Better volcanic eruption prediction.

Recommendations

SeaMARC II or Seabeam and side-scan sonar surveys should be undertaken. Manned submersible desirable.

C.4 *SUBMARINE LANDSLIDES AND LOCAL TSUNAMI GENERATION SITES, CENTRAL BASIN REGION, VANUATU*

Area of Interest

Central Basin of Vanuatu; depth ranges from a few hundred metres to 3 000m.

Three primary dive sites are proposed:

(i) Santo Submarine Canyon - Big Bay region of Espiritu Santo Island.

(ii) Steep scarp (40° slope) on eastern side of Espiritu Santo Island (1 000m high).

(iii) Small scarp on eastern slope of Malekula Island.

Geological Background

Submarine landslides have been mapped along Santo Canyon and in the Big Bay area of Espiritu Santo Island, Vanuatu. Many more submarine slumps occur along the eastern flanks of Malekula and Espiritu Santo Island, along a zone of active seismicity and recent faulting.

Data Available

At all proposed dive sites there are good quality geophysical data consisting of multi-channel, single-channel, high-resolution (Uniboom and 3.5 kHz) seismic reflection profiles and magnetic and gravity profiles. Detailed bathymetric data have been collected in some of these areas by the Australian Hydrographic Service. Dredged samples are also available.

Data Requirements and Project Definition

Although many data are available for the proposed dive sites, many of the geophysical data are on a reconnaissance scale, and more detailed high-resolution seismic, sidescan sonar, GLORIA or SeaMARC data are desirable. Seabeam and bottom photography should be done.

The objective is to examine and evaluate mass wasting in the Central Basin of Vanuatu. Many of the mapped slumps are capable of generating local tsunamis. Another objective is to examine and document active sea-floor faults along the western margins of the Basin. Seismic activity monitored from onshore networks in the region should be refined with ocean-bottom seismometers placed along the fault zones.

Anticipated Results

Prediction of tsunami generation and documentation of mass wasting. Instrument implantation will allow for evaluation of geotectonic properties. Documentation of recent displacement along active faults. Amount of displacement may be determined and will assist in evaluation of potential tsunami generation.

Recommendations

Seabeam transects are required in areas of proposed dive sites when they are in the region and, if possible, follow-up with GLORIA or SeaMARC surveys. Bottom photography would be desirable, but is not necessary. Proposed manned submersible programme to be integrated with the proposed Drilling Programme.

C.5 *OCEAN SUVA FORE-REEF SUBMARINE CANYONS, FIJI*

Area of Interest

Suva fore-reef slopes; submarine canyons to depths of 1 200m.

Geological Background

Land geology known
Suva Basin report by Brocher/Holmes (1985)

Data Available

Reconnaissance bathymetry
Single-channel seismic reflection

Requirements and Project Definition

Bathymetry-Seabeam, side-scan sonar, sedimentation rates.
In situ measurement of sedimentary properties such as shear stress and bulk modules, current directions, transportation of sediments, bottom photography.

Anticipated Results

If slumping is generated by seismicity, this could in turn generate local tsunamis which could endanger the foreshore of the city of Suva. Possibility of predicting the occurrence of slump-generated tsunamis in the Suva region.

C.6 *OCEAN THERMAL ENERGY CONVERSION (OTEC)*

Area of Interest

Coral Coast, South Viti Levu
Bathymetry - zone of interest lies from reef front to the 1 000-m isobath.

Geological Background

Land geology known and mapped. Reef structure in area has been drilled and a typical cross section developed.

Data Available

Bathymetric data; coring/sampling done in zone of interest; drilling of reef platform to find bedrock

Data Requirements and Project Definition

Seabeam (to be done in December, 1985); side-scan sonar.
Once these data have been collected, possible routes for a cold-water pipe may be identified, and all that is required is a submersible dive to inspect slope conditions along proposed routes.

Anticipated Results

If all data collected are favourable for OTEC then plans for a pilot plant may be finalized.

RECOMMENDATIONS

(i) Continue the collection of background data needed prior to manned submersible and ROV use.

(ii) Centralize data relevant to future submersible and ROV projects in a data repository at CCOP/SOPAC that could be accessed by interested scientists.

(iii) Encourage ships of opportunity to collect the data needed, preparatory to diving programmes.

(iv) Use manned submersibles and ROVs for stratigraphic formation sampling and placement of *in situ* measurement equipment relevant to hydrocarbon assessment.

(v) Use manned submersibles and ROVs to study areas by direct observation, *in situ* measurements and installation of long-term monitoring instrumentation where potential for serious geological hazards exist.

(vi) Use manned submersibles and ROVs to inspect OTEC pipeline routes after route selection using traditional methods has been been completed.

REPORT OF SESSIONAL WORKING GROUP D ON SEA-BED PROCESSES AND ENVIRONMENTS

INTRODUCTION

Detailed studies of sea-bed processes and environments are an essential aid to the exploration and possible exploitation of sea-floor mineral deposits, phosphorites, cobalt-enriched crusts, manganese nodules and heavy minerals, for example. Studies of this type are also of significance for improving our understanding of basic sedimentological, geochemical and biological processes that are relevant to prediction of geological hazards, to the search for resources such as precious coral, and to hydrocarbon exploration. Manned submersibles and ROVs, deployed in carefully researched locations, have the ability to add considerably to our knowledge of many of the above factors. Their use in the southwest Pacific region was, in fact, one of the recommendations of the 1983 CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-Scientific Marine Research Required or Assessment of Minerals and Hydrocarbons in the South Pacific (Suva, Fiji, 3-7 October 1983).

Many of the papers presented at the present Workshop underscore the obvious potential for the use of such equipment in the context of sea-bed processes and environments. Several of the papers report on actual preliminary use of a submersible and an ROV in the region.

The Sessional Working Group on Sea-bed Processes and Environments identified three areas of particular relevance:

(i) The deep sea (manganese-nodule research).

(ii) Open-ocean plateaus, ridges and seamounts (cobalt-enriched crusts, manganese nodules, phosphorites).

(iii) Nearshore areas (coral-reef studies, precious coral, submarine-canyon processes, placer minerals).

The Group drew up recommendations for projects on:

- Submarine phosphorite deposits
- Cobalt-rich crusts and plateau nodules
- Deep-water manganese nodules
- Corals, black coral and precious corallium
- Carbonate development of coral reefs
- Depositional environments and sediment transport
- Eustatic sea-level changes and placer deposits

PROPOSED PROJECTS

D.1 *EXPLORATION FOR SUBMARINE PHOSPHATE DEPOSITS IN THE SOUTH PACIFIC*

Objectives

(i) Define the serial extent and depth distribution of phosphorite in the region.

(ii) Examine the relationship, if any, between submarine occurrences and those on oceanic islands (composition, age, etc.).

(iii) Define the association between Mn/Fe crusts and phosphorites in terms of their co-occurrence and genesis.

Geographic Regions

(i) General locations

Open-ocean phosphorite occurs on the summits of seamounts and on the slopes of continents and islands, and guyots. Depths of occurrence are from the edge of the continental shelf down to approximately 1 500m on some seamounts. Insular phosphorite formed during previous low-sea-level stands and may be found under present-day atoll lagoons (as at Mataiva).

(ii) Specific locations

Submersibles can be applied to the search for submarine phosphorite in basically the same areas as where Co-rich Mn crust exploration is planned. They often (though certainly not always) occur in close association with each other and the exploration strategy can be similar, so it is efficient to integrate both projects. Lagoonal deposits of phosphorite are expected to have at least some overburden and thus are best explored by drilling.

Areas of interest for submarine phosphate deposits include the shallow banks and deeper (few hundred metres) guyots along the northern Melanesian Borderland. Also, in the vicinity of the Northern Cook Islands such as the Manihiki Plateau, associated seamounts, and flanks of islands.

Research Phase

Virtually all of the phosphorite studies in the South Pacific must be considered as being in the research phase. Additional reconnaissance studies in conjunction with Co-crust work should continue with surface ship, remotely operated drill, and dredging operations.

In an area where deposits have already been discovered, such as the N. Melanesian Borderland, the seamount north of the Tokelaus, Tasman Sea guyots, etc., a submersible programme would be extremely helpful in obtaining oriented samples and defining the depth relationships of phosphorite and associated Mn crusts.

Applied Phase

The only known potentially commercial phosphorite deposit is on the Chatham Rise, and a submersible survey should be made of this area.

Submersible and ROV Technology

A shallow (few hundred metres) diving submersible would be entirely sufficient for work on the guyots of the Melanesian Borderland. Work on the isolated seamounts such as those in the northern Cooks, for example, would require an operating depth up to about 2 000m. It is important that the submersible selected have a hand rock-sampling tool for sampling indurated rock from outcrops. The rock corer in use on the French submersibles should be ideal for this application.

Support Operations Required

Bathymetric surveying by Seabean etc. in support of submersible and ROV operations is considered sufficient. As phosphorite is very difficult, if not impossible, to recognize visually, bottom camera surveys provide useful but not diagnostic information.

Economic Importance

Phosphorites provide the main raw material for phosphatic fertilizers. In today's market, the smallest economic deposits consist of tens of millions of tonnes of rock phosphate. However, smaller deposits might be mined for local agricultural use.

Relevant Institutions

This work can be accomplished by institutions within the region with advice from overseas experts when appropriate. Personnel from USGS, ORSTOM, CCOP/SOPAC, NZOI, FSU and BMR have the experience required to carry out this exploration.

Recommendations

(i) Continue reconnaissance surveys with surface ships throughout the region.

(ii) Integrate the Co-crust and phosphorite efforts as far as possible.

(iii) Initiate submersible surveys to characterize in a detailed manner deposits already discovered.

D.2 *DISTRIBUTION, COMPOSITION AND ENVIRONMENT OF DEPOSITION OF COBALT-RICH CRUSTS AND PLATEAU NODULES*

Objectives

Detailed study of well surveyed areas where cobalt-rich crusts and/or nodules have been found.

Geographic Regions

Yet to be determined by surface vessel studies, apart from the Line, Loyalty and Society Islands where Co-rich crusts have been found. Ideally within island country Exclusive Economic Zones (EEZs).

Research Phase

Detailed bathymetric and sampling surveys of seamounts and plateaus which lie in favourable water depths of 800-1 500m. Sidescan imaging studies of prospective seamounts and plateaus.

Applied Phase

Not planned yet.

Submersible and ROV Technology Required

No appropriate technology is available in the South Pacific region. ROVs and submersibles capable of operating to 1 500m water depth are needed.

Support Operations Required

Various combinations of sampling, photography, TV video, Seabeam and SeaMARC.

Economic Importance

Cobalt-rich crusts and nodules are long-term resources which are unlikely to be mined in the next decade. In some cases they are associated with phosphorites.

Relevant Institutions

ORSTON, IFREMER, NZOI, HIG, NOAA, BMR, JAMSTEC, USGS, CCOP/SOPAC, and others.

Recommendations

(i) Develop an integrated international programme of cobalt-rich crust and plateau nodule research in the South Pacific, associated in some cases with phosphorite studies.

(ii) CCOP/SOPAC should co-ordinate and review work currently in progress and planned.

(iii) CCOP/SOPAC may then consider chartering an appropriate vessel to continue conventional studies.

(iv) Once work in progress is completed, these data should be used to select sites for detailed ROV and submersible studies.

D.3 *ENVIRONMENTS AND GENESIS OF DEEP-WATER MANGANESE NODULES*

Objectives

To locate precisely and study selected nodule fields in small areas where nodule grades and abundances are high, and to help solve numerous scientific and economic problems.

Geographic Regions

(i) General locations

The equatorial basins between about 15°N and 15°S, and in particular the region between the Line and Gilbert Islands, the Northern Cook Islands, and the Society Islands.

(ii) Specific locations

Detailed areas in the above regions, defined in particular by French and current Japanese cruises. Ideally within island country EEZs.

Research Phase

Detailed bathymetric and sidescan imaging studies of small prospective areas are needed. Latest nodule grade and abundance information should be considered.

Applied Phase

Not defined yet.

Submersible and ROV Technology Required

No appropriate equipment is available in the South Pacific. Deep-diving ROVs and submersibles capable of working in depths of 5 500m are needed.

Support Operations Required

Seabeam, SeaMARC, deep-tow photography, nodule and sediment sampling.

Economic Importance

Deep-water manganese nodules are a long-term resource. Present-day thinking suggests that mining is unlikely in the next decade.

Relevant Institutions

ORSTOM, IFREMER, NZOI, Japanese Metal Mining Agency, HIG, BGR, NOAA, JAMSTEC, and others.

Recommendations

(i) Continue the development of integrated international programmes of nodule research in the South Pacific.

(ii) Detailed surveys of possible South Pacific dive sites should be carried out, followed by submersible studies if appropriate. Only IFREMER's NAUTILE is presently capable of operating at these depths.

D.4 *BLACK AND PRECIOUS CORALS*

Objective

Inventory and collection of black and precious corals. For black coral, survey known locations beyond scuba-diving depths, and increase information within scuba-diving depth.

Geographic Regions

(i) Black coral

Predominantly in areas of known occurrence; to encourage preliminary investigation in remote locations.

(ii) Precious coral

General environment, hard-substrate plateaus and ridge areas to a maximum depth of 1 500m. Specific areas - Black Coral: Tonga, submersible or ROV survey; Precious coral: Indispensible Strait, Solomon Islands.

Research Phase

Encourage investigations when expensive and appropriate equipment may be available in the area. Submersibles should be used to determine rates of growth and recovery of Corallium and black corals. This information is essential for the development of resource and management strategies.

Applied Phase

Black coral: Economic and environmental studies using submersibles or ROVs to expand on the results of previous diver surveys, and extend knowledge of distribution, quality and density of coral trees over greater areas and to greater depths.

Submersible and ROV Technology Required

(i) Black coral: Submersible and ROV technology (to the required depth) is available within the region. Support personnel and suitable vessels exist within the region.

(ii) Precious coral: ROV and submersible technology are required in the depth range 600-1 500m. These do not exist within the region at the moment.

Support Operations Required

(i) Black corals: Surface research with good navigation and echo-sounding equipment, supported by side-scan and other systems which may be cost-effective when available. Side-scan is suggested for preliminary survey.

(ii) Precious coral: More detailed bathymetric surveys, needed especially in steep near-chore environments.

Economic Importance

(i) Black coral: Provide employment for craftsmen and support personnel. Good co-ordination of this project could result in a fairly rapid economic return. Production of artifacts will help to promote tourism and exports.

(ii) Precious coral: Potential development of cottage industry and export market.

Recommendations

(i) Black coral: ROV or submersible transect studies should be conducted in Tonga to obtain environmental and commercial data, and enable the development and planning of cottage industry.

(ii) Precious coral: ROV or submersible surveys should be made of ridges and banks in Indispensible Strait and north of Malaita in Solomon Islands to determine areal distribution and to sample specimens to determine quality.

D.5 *DEVELOPMENT OF CORAL REEFS AND ASSOCIATED CARBONATE ENVIRONMENTS*

Objectives

Comparative study of reefs in geologically different areas by

(i) Defining the age, rate of growth (or erosion), and geometry of reefs in tectonically active and volcanic areas.

(ii) Determining the influence of terrigenous or volcanic input in carbonate areas including depth of coral growth and rates of colonization of coral communities.

(iii) Determining sand budgets, rates of generation and loss from islands - offshore and into deep lagoons.

Geographic Regions

(i) General Locations

Stable areas - Great Barrier Reef; Tectonically active and volcanic areas - Solomon Islands, Vanuatu, and Fiji; Oceanic areas - Kiribati and Tokelau.

(ii) Specific Locations

The studies envisaged could be carried out in conjunction with precious coral surveys for a more cost-effective project. Solomons (Georgia Group); Vanuatu (Southern Santo, Lopevi Volcano); Fiji (Viti Levu - off Suva and the north coast); Kiribati (Tarawa) and Tuvalu (Funafuti).

Research Phase

Submersible and/or ROV surveys of the reef fronts and deep lagoon sedimentation and ecology, backed up by echo-sounder and side-scan surveys of specific areas. Sample collection using explosives.

Applied Phase

Definition of the state of the reefs (accretion or erosion). The lagoon study is directly applicable to the available sand budget for reclamation purposes on adjacent islands.

Submersible and ROV Technology Required

The use of a submersible for broader coverage backed up by a ROV with depth capabilities to 350m - 600m. This technology is available in the region.

Support Operations Required

Suitable ship, Mini Ranger for navigation, side-scan sonar, suitable echo sounder for surveying of specific areas of investigation. Equipment available in the region.

Economic Importance

Population pressures in some areas in the southwest Pacific have created an urgent need for studies of the integrity of the reefs and islands on which these communities live and depend. As most of the world's petroleum is obtained from carbonate rocks, it is important to have viable models on which to base interpretation of drill-hole and exploration data.

Relevant Institutions

University of South Pacific, Australian Universities involved in carbonate studies, University of Guam, AIMS (Townsville).

Recommendations

To develop a programme of studies to be funded over a three-year period from the end of 1986. Dives on reef location should be planned in association with other submersible or ROV programmes.

D.6 *DEPOSITIONAL ENVIRONMENTS AND SEDIMENT TRANSPORT*

Objectives

(i) Assessment of depositional and erosional processes, their causes and relationships, from shallow to deep ocean systems.

(ii) Geohazard assessment of processes acting within these systems.

(iii) Application of results to OTEC projects.

(iv) Applications of results to slope, submarine-canyon-fill and fan-facies models, and implications of substatic and isostatic sea-level changes.

Geographic Regions

(i) General locations

Upper portions of submarine canyons, both river-connected and shelf-edge detached canyons; shelf margins; deeper portions of submarine canyons, as well as submarine fans and fan valleys.

(ii) Specific locations

Canyon system, south coast, Viti Levu, Fiji; Markham and Waria river canyons, northeast coast of PNG; Santo Canyon, Big Bay, Vanuatu; and OTEC sites at Tahiti, Guam, south coast of Viti Levu.

Research Phase

Detailed bathymetric surveys of key areas using precision navigated echo sounding, or Seabeam if available. Associated geophysical observations, particularly seismic profiling. Sonar surveys (GLORIA, SeaMARC). Dive target identification, initially on outer shelves, upper slopes, and in upper portions of canyons. Submersible/ROV observations: in situ sediment sampling, stratigraphic sampling of canyon walls or slope scarps, direct observations of canyon processes, deployment of sensors.

Applied Phase

Identification of potential slump areas and their predicted impact (harbour installations, villages, etc.).

Identification of suitable corridors for undersea pipelines and cables, particularly in relation to OTEC projects.

In the longer term, upgrade knowledge of slope, submarine canyon and fan depositional and erosional processes and related facies models, as a predictive aid to hydrocarbon exploration in ancient equivalents.

Submersible and ROV Technology Required

Available within South Pacific region, to 350 - 700m. Imported technology: submersible required for deep-water (>700m) research.

Support Operations Required

Swath-mapping equipment (GLORIA; Seabeam or SeaMARC); seismic profiling equipment; vessel with dredging and coring winch, and A-frame, for follow-up sedimentological research.

Economic Importance

OTEC and geohazard-related projects on relatively short (cá. 5yr.) timescale.

Spin-off of aspects of facies models into petroleum exploration on longer (ca. 5-10 yr.) timescale.

Relevant Institutions

South Pacific area: CCOP/SOPAC, ORSTOM, IFREMER, Island Nation Geological Surveys, Sydney University.

Overseas: USA (several institutions), Flinders University of South Australia, HIG.

Recommendations

(i) Co-operative projects to be planned in specified areas.

(ii) Carry out detailed bathymetric and sonar-imaging surveys.

(iii) Selection of dive targets in areas specified.

(iv) Implementation of submersible/ROV programme.

D.7 *SCIENTIFIC AND ECONOMIC SIGNIFICANCE OF RELATIVE SEA-LEVEL CHANGES*

Objectives

To analyse eustatic sea-level changes in the region during the Quaternary and earlier periods; to estimate the implications for the occurrence of placer mineral deposits, the effects on models of hydrocarbon formation, effects on canyon formation, relevance to coastal defences and flood prevention, and relevance to climatic studies, palaeoclimates, and palaeo-oceanography.

Geographic Regions

Shallower than 1 000m, and mostly shallower than 500m. Sea-level indicators can be erosive or depositional. Useful features are eroded terraces, dateable coral, caves, submerged coastal and beach features, dunes, lagoon and marsh deposits, etc.

Because of the statistical treatment needed, it is important to obtain a good spread of data, from as many locations as possible.

Research Phase

The project is concerned with all periods of eustatic sea-level change, from the 1 000- to 100 000-year fluctuations of the Quaternary to tectono-eustatic fluctuations over tens of millions of years. Quaternary fluctuations are about 150m, and tectono-eustatic changes, about 500-1 000m. Because of vertical tectonic movements in the region, a large number of data points are needed to separate eustatic and tectonic factors. Emphasis is needed on absolute dating methods, and the precise relation of indicators to sea-levels. Vertical accuracy of estimates should be about 1-2m.

Applied Phase

IGCP Projects 61 and 200 concern global eustatic sea-level change during the late Quaternary, and are related to the dangers of coastal flooding and erosion. Data from the present project can be interpreted immediately within the framework of IGCP 200. Data relevant to placer deposits should be interpreted in association with CCOP/SOPAC and its work programme.

Eustatic data relevant to canyon formation and transport of sediments should be utilized in discussion with engineers concerned with coastal defences, and the slumping of sediments near the coast. Extreme value prediction for coastal engineering design is very important for areas liable to hurricanes. Information relevant to models of hydrocarbon formation should be passed to the oil exploration industry, and to departments of petroleum geophysics and geology in universities.

Submersible and ROV Technology Required

ROV and shallow submersible surveys are important to the proposed surveys. Both systems can be used efficiently to identify wave and solution notches, marine caves, erosive and beach terraces, submerged coral features related to sea level, etc.

Capacity exists within the region to conduct research using submersibles and ROVs down to the depths of 350-700m.

Equipment would need to be imported into the region for work down to 1 000 m. Most of the necessary research could be conducted without this equipment.

Support Operations Required

Accurate bathymetry, with access to original records. Scuba diving may be used for the shallowest features.

For depositional features, seismic profiling is relevant.

Economic Importance

Prediction of relative vertical changes of land and sea-level is the most immediate economic benefit. Design of coastal protection, flood prevention, etc., would be improved within a few years. Data relevant to the location of placer deposits would be available within 5-10 years. Canyon formation and data on hydrocarbon formation would pay off over longer periods. Climate studies should produce useable results within 10-15 years.

Relevant Institutions

Geology and geography departments in universities within the region.

Publications from IGCP 61 and 200 show hundreds of researchers concerned with the topic.

Recommendations

(i) An inventory of established and dated sea-level indicators should be created for the region, using IGCP 61, IGCP 200, and other sources.

(ii) Localities should be identified using bathymetry where sea-level indicator features are most likely to occur.

(iii) After compiling relevant background data, a series of exploratory dives should be conducted using ROVs and/or submersibles to identify precise depths of palaeo-sea-level indicators, and to obtain dateable materials.

(iv) The programme should be expanded progressively as data and experience are accumulated. It is especially important to obtain data from different tectonic environments, and in geographically widely separated areas.

(v) Data should be used to separate out vertical tectonic and eustatic factors.

* * *

The Workshop recognized the importance of acquisition of detailed information, such as photographic/televideo images of the sea bottom, as well as acoustical, geophysical and geological data, to facilitate targetted research with the use of submersibles and ROVs adequately and safely. The Workshop felt it necessary to establish close linkages with related international research programmes such as Ocean Drilling Programme (ODP) and relevant IGCP and IOC programmes. The Workshop noted that marine geological/geophysical studies with submersibles and ROVs are often carried out as interdisciplinary studies together with marine biological studies.

The Workshop endorsed the Recommendations submitted by the four Sessional Working Groups.

9. ORGANIZATIONAL ARRANGEMENTS FOR REGIONAL CO-OPERATION IN THE USE OF SUBMERSIBLES AND ROVS TO DEVELOP MARINE SCIENCE STUDIES IN THE SOUTH PACIFIC, AND RELATED TRAINING, EDUCATION AND MUTUAL ASSISTANCE COMPONENTS

The Acting Director of the CCOP/SOPAC Technical Secretariat, Mr. Cruz Matos, explained the Technical Secretariat's co-ordination activities on the region, particularly research cruises.

CCOP/SOPAC has 11 member countries. The Technical Secretariat, based in Suva, is an instrument of the Committee through which it can give effect to its decisions. Each member country has national work programmes related to its marine resource priorities. Regional programmes usually include the interests of several countries, and often include interest in adjacent international waters. Research proposals may affect regional and/or national programmes, and it is important to co-ordinate such research efforts to maximise the benefit of the CCOP/SOPAC members and the research organizations.

CCOP/SOPAC is organized with national contacts at both scientific and political levels in each country. Programmes, including research cruises, that are acceptable to the member countries can be accorded access into the EEZ's of member countries through the Technical Secretariat instead of having to deal with several nations separately. CCOP/SOPAC can assist with information, data, bibliographies, maps, and scientific contacts of value to the proposed research. Assistance in arranging for participation of national representatives or trainees on board research vessels is also a function of the Technical Secretariat.

Co-ordination of programme proposals with the eleven member countries of the southwest Pacific through CCOP/SOPAC could make the proposal more acceptable to some funding organizations in countries which support CCOP/SOPAC objectives.

The Workshop noted that the CCOP/SOPAC Technical Secretariat has a co-ordination role in the South Pacific. It felt that the use of submersibles and ROVs should be included as a part of research programmes to be implemented in the region, and be co-ordinated by CCOP/SOPAC Technical Secretariat, if necessary, to avoid duplication of effort.

The Workshop noted that adequate training is necessary for scientists and technicians from the region to acquaint them with techniques and the usefulness of submersibles and ROVs for marine scientific research. It recommended that such training opportunities be a component of all proposed programmes.

10. RECOMMENDATIONS

The CCOP/SOPAC-IOC Workshop on the Use of Manned Submersibles Remotely Operated Vehicles in the South Pacific,

. . . . . .

Recognizing the importance of further developing geoscientific knowledge in the uniquely interesting South Pacific region, and the appropriateness of the use of ROVs and submersibles in dealing with specific targets,

Also recognizing the importance of the acquisition of detailed photographic/ televideo, acoustical, geophysical and geological data to enable adequately and safely targetted submersible studies to proceed,

Emphasizing the need for submersible studies to address problems in the areas of tectonics, volcanic processes, mineralization, petroleum geology, geohazards, engineering geology, and seabed processes and environments, as outlined in Section 8, above.

Recommends that:

(i) the Chairman of the Workshop transmit for endorsement the adopted Workshop Report to the next session of STAR, to the Secretary of IOC for submission to the next session of the IOC Executive Council, and to the Director of CCOP/SOPAC Technical Secretariat for submission to the next CCOP/SOPAC Session;

(ii) a closely integrated research programme of geoscience studies, on land and at sea, be developed, with CCOP/SOPAC Technical Secretariat having a co-ordinating role, ensuring that interdisciplinary ROV and submersible dives are part of the programme in cases where they can provide information not available from other sources;

(iii) the Chairman of STAR, in consultation with the Secretary of the IOC and the Director of the CCOP/SOPAC Technical Secretariat form a STAR Study Group on the Use of Submersibles and ROVs which should report to future sessions of STAR on a regular basis and carry out the following major tasks, among others:

(a) advance the implementation of the recommendations of this Workshop;

(b) formulate, with assistance from IOC, an operational handbook on the use of submersibles and ROVs in the region;

(c) keep abreast of technology and advise CCOP/SOPAC member countries of advances in technology concerning submersibles and ROVs;

(d) identify those projects that can have short-term impacts in the CCOP/SOPAC region and actively pursue funding organizations to ensure their early implementation;

(iv) the Secretary of IOC and the Director of the CCOP/SOPAC Technical Secretariat and appropriate institutions and organizations bring the programmes developed by this Workshop to the attention of national/ international funding organizations for their consideration;

(v) opportunities be made available in conjunction with research projects in the region for participation and training of CCOP/SOPAC member country scientists and technicians in aspects of ROV and submersible studies as a component of all proposed programmes;

(vi) linkages be established with related international research programmes such as the Ocean Drilling Programme (ODP), the International Geological Correlation Programme (IGCP) and relevant IOC programmes;

(vii) copies of data from site surveys and from submersible and ROV operations in the SOPAC region be freely available and transmitted where requested to the CCOP/SOPAC data centre in Suva.

Noting that marine geoscience studies with submersibles and ROVs are often carried out as interdisciplinary studies together with living-resource studies,

Recommends that the Secretary of the IOC and the Director of the CCOP/SOPAC Technical Secretariat transmit the need for interdisciplinary co-operative research to the appropriate agencies dealing with living resources.

11. ADOPTION OF THE SUMMARY REPORT AND RECOMMENDATIONS

The Workshop adopted the Summary Report and a composite Recommendation which appears in Section 10 hereof.

12. CLOSURE OF THE WORKSHOP

On behalf of the Workshop participants, its Chairman and Vice-Chairman thanked the Ministry of Lands, Energy and Resources, CCOP/SOPAC Technical Secretariat and the local organizing committee for the excellent arrangements made for the Workshop. The Chairman also thanked the other sponsoring bodies - IOC, IFREMER and ORSTOM - for their contributions to the success of the Workshop and the participants for their valuable inputs into the discussions.

The Chairman closed the Workshop at 1830 on 29 September 1985.

ANNEX I

AGENDA

1. Opening of the Workshop

2. Administrative Arrangements for the Workshop
   2.1 Election of Chairman, Vice-Chairman
   2.2 Designation of Rapporteur
   2.3 Schedule of the Workshop

3. Adoption of Agenda

4. Objectives of the Workshop

5. Overview Presentations and Reviews of National Programmes

6. Advances in Technology, Recent Results and New Strategies

7. Application of Manned Submersibles and Remotely Operated Vehicles (ROVs) to Specific Geological Problems in the South Pacific

8. Development of New Projects and Future Programmes

9. Organizational Arrangements for Regional Co-operation in the Use of Submersibles and Remotely Operated Vehicles to Develop Marine Science Studies in the South Pacific, and Related Training, Education and Mutual Assistance Components

10. Recommendations

11. Adoption of the Summary Report and Recommendations

12. Closure of the Workshop

ANNEX II

OPENING STATEMENT OF THE MINISTER OF LANDS, ENERGY AND MINERAL RESOURCES, Hon. Jone Naisara

Distinguished Delegates, Representatives, and scientific staff of the CCOP/SOPAC Technical Secretariat, ladies and gentlemen, Ni Sa Bula. On behalf of the Government and people of Fiji, I extend to all of you a very warm welcome. I am honoured and pleased to have you here for the STAR Workshop on the Use of Manned Submersibles and Remotely Operated Vehicles in the South Pacific.

I am honoured becaused this Workshop is yet another confirmation of CCOP/SOPAC's status as the most important collaborative effort in science between South Pacific Island States and perhaps the best joint venture in any field. I am pleased because I have very much enjoyed my own association with CCOP/SOPAC which began several years ago.

We are aware that progress in the knowledge of the ocean and its resources is related to the development and utilization of new technologies. Submersibles, manned or unmanned, extend the capabilities of the scientists beyond the limits of the traditional laboratory and ship-based modes of investigation.

The potential use of submersibles in the ocean is a subject of interest to the South Pacific countries, and we are honoured that Fiji was chosen as the venue for this important workshop. We are proud that the subject was first recommended at the co-sponsored CCOP/SOPAC-IOC Workshop in 1983 which was also here in Fiji.

CCOP/SOPAC, IOC, IFREMER and ORSTOM, who sponsor this Workshop, have facilitated the assembly of an impressive core of specialists in the use of submersibles for this workshop. We will be informed of the advances in technology, recent results, and new strategies for manned submersible and ROV use in mineral resource assessment. In particular we will be apprised of the application of submersible and ROV technology to specific geological problems in the South Pacific.

We know that submersibles, I am told, remain controversial. However, if it were not for those famous dives of the French submersible CYANA and the US submersible ALVIN where unusual life forms were found and mineralization of seafloor sediments from "smokers" was discovered, we would be far behind in the investigation of oceanic ridges as potential resource targets. To observe such processes first hand allows for rapid evaluation and leads to proper direction of exploration.

The South Pacific is geologically dynamic and I am sure you will find diving here exciting and rewarding. As in all new endeavours, challenging problems will appear. It is anticipated that the key problems and problem areas will be delineated at these sessions. Through a concentrated group effort you should develop future research programmes, and in particular should formulate a specific work programme.

It is important that the programme that is developed has the right mix of short-term and long-term research projects. The South Pacific requires both long-term and short-term research, the former in the nature of studies that will have relevance to the short-term work that is coming later on, and the short-term work to look for specific mineral deposits.

This Workshop should concentrate on developing both long-term and short-term research work that is as relevant as it can be made towards the mission of effective off-shore prospecting for minerals in the South Pacific for the benefit of CCOP/SOPAC member countries.

A spirit of co-operation and genuine friendship has marked these workshops in the past, and I am sure that it is the "Island Way" for us to continue that spirit here in Fiji. I wish you the greatest success in this most important endeavour and urge you onward in our common interest.

It now gives me much pleasure to welcome you to the opening of this Submersibles Workshop.

ANNEX III

ABSTRACTS OF PAPERS PRESENTED AT THE WORKSHOP

SCIENTIFIC DEEP-DIVING PROJECTS IN THE FRENCH SUBMERSIBLE PROGRAMME

by
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Since 1974, the CYANA Submersible, designated to operate at depths of up to 3 000 metres, has carried out a great number of scientific expeditions and the results are of great interest. A new submersible, the NAUTILE, capable of exploring depths up to 6 000 metres (97% of the total surface area of the ocean floor) came into service in 1985.

From the results obtained in various disciplines and in many places in the oceans, the French projects are now organized in a multidisciplinary Programme comprising:

- ocean-crust studies, hydrothermal processes (structure, sedimentology, geochemistry, metallogeny, biology, microbiology, etc.);
- passive continental margins: stratigraphy, structure, palaeo-environments, morphogenesis, geological and biological evolution;
- deep environments on slopes and abyssal plains, multi-disciplinary studies, in situ experimentation, geotechnical and impact studies;
- structure and organization of abyssal ecosystems: organic carbon dynamics at the interface, food and nutritional mechanisms, physiology, etc.

The programme will take into account:

- specificity of the two submersibles;
- international collaboration;
- instrumentation and capability of manipulation at the bottom of the sea.

It is a part of a coherent exploration in which different tools have their specific use: optic and acoustic imagery, seismic investigation, deep drilling, etc.

SUBMERSIBLE SCIENCE PROGRAMME OF THE US NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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NOAA's Office of Undersea Research (OUR) supports legislated ocean mission requirements by providing an ensemble of undersea vehicles and capabilities to extend the ability of marine researchers beyond the limits of traditional laboratory and ship-based modes of research. In so doing, a submersible-based science programme has emerged as one of the principal research elements of OUR. Most important is the value of this research to NOAA's priority missions: Fisheries, Marine Pollution, Seafloor Properties and Processes, and Ocean Services.

During 1985 alone, submersible investigations will amount to more than 200 dive-days and will focus on issues related to resource depletion, pollution, development of new or underutilized fish stocks, and an assessment of the extent, distribution, and mineralogy of deep sea-bed deposits of polymetallic sulphide minerals.

Future submersible activities will include co-operative international investigations involving the Japanese submersible SHINKAI 2000, acquisition of a deep-diving submersible for NOAA's National Undersea Research Programme at the University of Hawaii, Re-establishment of a science programme in the Pacific North-west and Alaska, focusing on hydrothermal systems and fishery recruitment, assessment and productivity, and development of a co-operative international submersible programme with other nations.

Alternative means of exploring the ocean bottom will continue to be pursued by OUR to conduct research at depths greater than those at which a diver can be used safely. One such method will be to utilize existing technology in allied fields and incorporate such technology into remotely operated vehicles (ROV) to observe, manipulate, and sample deeper environments. Technological advance in such fields as fibre optics, acoustics, and video-imaging presents many opportunities to apply existing technology for the improved exploration of the marine environment. Presently, OUR is considering the purchase of a state-of-the-art ROV system that will be available as a "fly-away" package through any of NOAA's five national undersea research programmes. ROV technology is not viewed as replacing OUR's man-in-the-sea activities. Rather, such research activities are complementary to placing man safely underwater to conduct research and to target areas of study for detailed examination with manned submersibles.

THE DEEP-SEA RESEARCH ACTIVITIES AROUND JAPANESE ISLANDS BY SHINKAI 2000 AND JAMSTEC/TOW

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A manned submersible SHINKAI 2000 is the first Japanese vehicle capable of diving to a depth of 2 000m; it was built in three years and assigned in 1981 to its supporting mother-ship NATSUSHIMA. These ships were designed as a total system from the beginning under a concept in which these ships and a base-on-land should share their roles.

Precise underwater navigation is one of the most important functions in the system and acoustic transponder navigation is the most adequate one for the purpose. However, the pressure hull of the submersible has no room in which to install all the required instruments for navigation, such as the transceiver, computer, display, and so on. For this reason, it was decided that the mother-ship should take charge of fixing the location of the submersible. The location of the submersible and other directive information are transmitted through an underwater acoustic telephone to the submersible when required. This means that the mother-ship is not only the carrier of the submersible but also the headquarters of diving operations, and an active support vessel.

SHINKAI 2000 is capable of accommodating 3 persons in the pressure hull, which is about 2m in diameter, 2 pilots and 1 observer, for 8 hours on a regular diving schedule.

A manipulator, with six freedoms of movement, can grab objects less that 20kg in weight and 15cm in thickness. Observers will be able to bring instruments into the hull or install apparatus not exceeding 100kg in weight on an outside rack. Three portholes are located in the lower head of the hull for direct observations. A colour television camera on a pan-and-tilt gear provides visual information to the pilot in the upper sphere (navigator post). The scene through the camera is recorded on VTR and supplies significant information for scientific research purposes.

The submersible descends and ascends 2 000m in 1.5 hours It proceeds ordinarily at 1 knot but is able to accelerate to a maximum speed of 3 knots in case of emergency.

SHINKAI 2000 had made about 180 dives, including 95 scientific research dives, by the end of June 1985. The annual dive schedule is approved by the Steering Committee of the Science and Technology Agency of the Japanese Government one year in advance.

One of the most important subjects of study is earthquake prediction, especially in the waters close to the Tokyo-Shizuoka Prefectures. Another interesting subject is hydrothermal phenomena around Japanese islands. Biological investigations, particularly from the point of view of fishery resources, are a very important theme for Japan.

The scientific research dives, on the basis of the above-mentioned ideas, have been carried out in the waters off the northern part of Honshu, down to Okinawa, in the Pacific Ocean and East China Seas, so far, and will be continued to the northern Philippine Sea and the mid-Japan Sea.

Small-scale topographic and microtopographic investigations are carried out by means of deep tow techniques in advance of submersible operations on board NATSUSHIMA. The JAMSTEC/DEEP TOW has two types of towed bodies; one is installed with 70kHz side-scan sonar with 5kHz sub-bottom profiler, and the other is equipped with TV and still cameras. These are towed at 1 or 2 knots with a coaxial cable to 3000m at maximum. The camera-type towed body can be added to a sediment sampler, if necessary.

NAUTILE DIVES IN THE JAPAN TRENCHES: FIRST RESULTS OF THE FRENCH-JAPANESE KAIKO PROGRAMME

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The KAIKO programme included two main steps: in summer 1984 the KAIKO I Cruise of the R.V. JEAN CHARCOT Seabeam mapping, seismic-reflection profiles, etc.), and in summer 1985 the KAIKO II Cruise of the R.V. NADIR, with the new submersible NAUTILE. Both cruises were divided into three legs: the first in the Nankai trench area off southern Japan (including the Zenisu ridge), the second in the Izu collision zone and TTT triple junction off central Japan (including the Suruga - Sagami troughs and the southern Japan trench), the third in the Japan - Kurile trench system off northern Japan.

The interpretation of results took into account on-land information provided by numerous Japanese geological and geophysical studies, as well as some particular analyses of Late Cenozoic tectonics (especially in the collision zone of central Japan): an illustration of the complementarity of marine and on-land studies in such areas.

The 1984 KAIKO I Cruise enabled the Group to define and map accurately several target areas for the dives, and to obtain significant new results that may be summarized as follows:

- moderate strain related to the subduction of the Palau-Kyushu volcanic ridge in the Nankai Trench;
- structure of the Shikoku Basin Rift Valley, with fractures oblique to rift axis, indicating changes in the direction of opening;
- interpretation of the Zenizu Ridge as a piece of uplifted ocean floor with southward thrusting;
- structure of the TTT triple junction between the Pacific, Philippine Sea and Japan plates, and its probable evolution;
- structure of the Suruga and Sagami troughs on both sides of the central Japan collision zone;
- normal fault systems related to plate bending on the Pacific side of the Japan trench;
- deformation of submarine volcanoes in the subduction zone of the Japan-Kurile trenches (Daiichi Kashima and Erimo seamounts);
- transition from Japan trench to Kurile trench, and related strike-slip features.

The results of the 1985 KAIKO III Cruise (NAUTILE dives) can be partly summarized already, although a large amount of work must be done prior to extensive publication of conclusions (e.g. sample analyses):

- during each of the three legs, the structure of the inner walls of the trenches was observed in detail in some places, with submersible observations being made in the Zenisu ridge - Nankai trench to the south, and in the Japan - Kurile trenches to the north; a surprising feature was the common presence of populations of bivalves along tectonic contacts of the inner trench walls, at depths as great as 5.5 - 6km;

- the tectonic features related to the deformation of seamounts arriving at the trench were observed in detail (Daiichi Kashima volcano cut by normal faults and subducted beneath the inner wall where compressional tectonics dominate);

- other structural and stratigraphic studies were carried out in particular areas, such as the Boso canyon in the Sagami trough system (close to the collision zone) or the transition zone between the Japan trench and the Kurile trench;

- two tiltmeters (OBITs) and one seismometer (OBS) were set up by the submersible, at depths of about 4 km, on the top of the Erimo seamount.

In addition to the scientific results obtained by the KAIKO Group in the subduction zones off Japan (work in progress), the KAIKO II Cruise has demonstrated, from a technological point of view, the capability of the newly built submersible NAUTILE to operate at depths as great as 6000m with a large range of instruments.

CANADA'S SUBMERSIBLE PROGRAMME IN THE NORTH EAST PACIFIC USING PISCES IV

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Canada has built and used submersibles for many years. The PISCES IV has a design depth capability of 2 000m and has been used in programmes in deep-water fiords, on the continental shelf and slope, and on the East Pacific Rise ridge crest. Programmes in fisheries, pollution control, waste disposal, equipment deployment and recovery, and geological sampling and observation have been carried out. The submersible is supported by a barge for nearshore and inlet operations, and a mothership for offshore work. It requires a pilot and can take two observers. Bottom time depends mainly upon the use of battery power and safety factors.

Submersible limitations and advantages in geological programmes are considered. Results of the East Pacific Rise programme and other geological programmes are highlighted from the point of view of use of this highly specialized and very expensive equipment.

BASIN DEVELOPMENT IN THE SOUTHWEST PACIFIC

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Identification of tectonic elements of the southwest Pacific recently undertaken in conjunction with a major reinterpretation of the regional geological framework in terms of global tectonic theory reveals that outward migration of the Indo-Australia (I-A) Pacific plate boundary has progressed through the development of a series of accretionary basins and the formation of a succession of island arcs. Episodes of marginal basin formation have occurred along the eastern and northeastern margins of the I-A Plate from the Late Cretaceous to the present. Episodes of ocean-basin formation have occurred along the western margin of the Pacific Plate from the Jurassic to the Oligocene. Oceanic plateaux appear to have formed concomitantly with cessation of spreading in some of the adjoining marginal basins on the I-A Plate as well as along restrained arms of triple junctions on the

neighbouring Pacific Plate. Cessation of spreading in the Coral Sea Basin (ca. 53 Ma) and the D'Entrecasteaux Basin (ca. 28 Ma) has also given rise to four hot-spot trails: two down the eastern margin of Australia and two down the Tasman Basin. These trails reveal that changes in the combined motion of the Antarctic and Indo-Australia Plates have occurred precisely at times when new convergence zones developed between the I-A and Pacific Plates. Successive periods of convergence have occurred along different subduction zones in the Eocene, Oligocene, early to late Miocene, middle to late Miocene, and late Miocene to Holocene.

SUBMARINE VOLCANISM IN THE SOUTH PACIFIC: A WORKSHOP BACKDROP

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Submarine volcanism is by far the most important constructional geological process on the South Pacific Ocean floor, but remains much less well studied than volcanism in other oceans. Basaltic mid-ocean-ridge eruptive activity at the East Pacific Rise and at abandoned ridges farther to the north-west has dominated the seafloor-spreading history at least as far back as the early Cretaceous, and in places has included periods of excess volcanism producing enigmatic oceanic plateaux such as Ontong Java and Manahiki. Volcanic products of at least four mid-plate hot spots form seamount/island chains that sweep across the South Pacific floor, and submarine volcanism has dominated the island-arc/marginal-basin areas of the Melanesian Borderlands and Tonga-Kermadec where recent CCOP(SOPAC)-Tripartite (ANZUS) cruises have yielded a significant amount of new data on submarine volcanism.

An extended programme of direct observation and sampling of sea-floor volcanic rocks is of critical importance to petrologists concerned with the volcanic evolution of the South Pacific, with the geochemical evolution of the underlying mantle, and with the volatile composition and content of sea-floor lavas. Styles of submarine-volcano evolution, vesiculation effects, hyaloclastite formation, near-seafloor magma chambers, hydrothermal venting, metallic-sulphide deposition, subaerial-tephra distribution on the sea floor, volcanic hazards (phreatomagmatic eruptions, tsunamigenic collapses, pumice rafts), and instrumental monitoring of active submarine volcanoes, are all examples of the broad range of volcanological topics that are largely unresearched in the South Pacific region.

SEDIMENTS OF THE SOUTHWEST PACIFIC

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Dominant sediments of the southwest Pacific region are those commonly found in oceanic environments. Calcareous pelagic oozes occur on ridges and in shallower basins, and deep-sea clays and siliceous oozes are the common sediments in the deeper basins. Ashy oozes and ash-rich clays dominate along the island arc systems of the Indo-Australian Pacific plate boundary. Coarse ash and pumice deposits occur on shallow banks and ridges along the island arcs, and coarse benthic carbonates occur on banks and ridges throughout the region. Terrigenous sediments are dominant only locally in basins off the mouths of large rivers.

In the south-west Pacific, most common sources of sediment are plankton living in the surface water (0-200m) of the ocean, volcanoes along the active plate boundary system, and authigenic minerals and alteration products. Sediments of the region are distributed by winds, surface currents and bottom currents. The type of surface sediment present is a function of the nature and rate of supply, water depth, erosive power of bottom currents, and *in situ* mineral formation and alteration.

POLYMETALLIC NODULE INVESTIGATIONS USING SUBMERSIBLES

by
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A better knowledge of the location and genesis of manganese nodules and crusts will require detailed sea-floor observations by submersible. Only studies using the approach of land geologists can help resolve the problems of nodule grades, abundance, morphology and genesis.

Recent detailed bathymetric maps obtained by SeaBeam in deep-sea nodule fields show very varied morphology, with scarps, block-faulting and recent talus aprons. Direct submersible observations are necessary to understand this geomorphology.

Other questions arise from the relationship of detailed morphology to the location of different types of nodules. These include the nature of variations within a nodule field and of the limits of a field, and the relationship of nodules to the sediment they sit in.

Volcanic fragments are often associated with manganese nodules, internally or externally, and some nodule fields are broken by apparently young volcanic outcrops. The variability of bathymetry, the young volcanism, and modern gravity slides, indicate active tectonics in the infra-plate area. The design of a submarine nodule mining device must take this into account.

Deep currents have a direct influence on submarine morphology, and the genesis and distribution of nodule types. It is necessary to observe the effecto of currents on morphology, and measure modern currents.

Biotic activity is important in nodule areas. The types of attached organisms are different on different nodule types. Also, bioturbation is important in rotating nodules, and thus in their growth.

Many features of nodule fields cannot be explained, and it is certain that submersible studies will reveal completely new problems.

PROPOSED ODP DRILLING PLANS: WESTERN PACIFIC ARC/BACK-ARC SYSTEMS

by
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A scientific plan for ODP drilling in active arc/back-arc systems of the western Pacific was proposed in June 1985. A comprehensive study of accretionary systems (e.g., Sünda-Banda) and non-accretionary or erosional systems (e.g., Bonin, Mariana, Tonga) was proposed. Specific problems that deserve study include: (i) the significance and origin of uplifted blocks of oceanic crust, and diapirs of serpentinized periodotite present in the Bonin and Mariana fore-arc; (ii) the presence of arc-derived volcanic and plutonic rocks, as well as peridotite, on trench walls (e.g., Mariana and Tonga); (iii) the history of vertical movements in fore-arc and arc systems; (iv) nature of the basement under fore-arcs, the possible role of fore-arc magmatism and the history of island arcs recorded in fore-arc sediments; (v) the evolution of arc magmas and their relation to back-arc magmas; (vi) mechanical and petrologic evolution of back-arc basins; (vii) origin of silicic magmas in back-arc basins; (viii) favorable sites for metallogenesis in arc/back-arc systems. A fundamental problem is the possible role of arc/back-arc systems in the origin of ophiolites.

RECENT AND FUTURE DEVELOPMENTS IN UNDERSEA SURVEY AND INTERVENTION

by
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Heir to a long French tradition in the field of undersea investigation, IFREMER (formerly CNEXO) has, for more than 15 years, pursued an active policy of development of underwater systems for deep-sea survey and investigation. Through this policy, IFREMER has developed and operates, through its subsidiary company GENAVIR, one of the world's best systems of manned submersibles, towed and remotely controled vehicles, equipment and instruments specifically for very deep-sea exploration and work.

This presentation is a description of the most significant features of this system, its design and mode of operation, including technical, operational and economical aspects.

Inasmuch as industry is not yet (or exceptionally) involved in deep-sea work, IFREMER's past activity has been mostly concerned with scientific or long-term industrial work, such as nodule-field evaluation or hydrothermal resources, but a recent trend is to increase know-how by entering into partnership with industry in developments for offshore activities. Some current projects in this area are also presented.

INTEGRATION OF HIGH-RESOLUTION SEABEAN AND SEAMARC I SONAR DATA WITH SUBMERSIBLE DIVING ON SEAMOUNTS IN THE EASTERN PACIFIC: IMPLICATIONS FOR SEAMOUNT CONSTRUCTION AND EVOLUTION

by
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Recent advances in sonar technology have allowed marine scientists to unravel the fine-scale morphology and structure of ocean-floor volcanic and sedimentary terrain on the Mid-Ocean Ridge (MOR) axis, mounts, abyssal sea-floor, and active and passive continental margins. These new research tools are: (i) Seabeam multibeam sonar, which permits the real-time mapping of sea-floor topography with a resolution of approximately 10 metres, and (ii) SeaMARC side-scanning sonar vehicles (SeaMARC I and II) that can map the acoustic reflectivity of the sea floor over wide areas (5- to 10-km swath width), and resolve sea-floor features with just a few metres of relief. These sonar instruments and the data that they produce form the requisite precursors to detailed submersible studies of sea-floor terrain. When used in combination, the high-resolution bathymetric maps produced by Seabeam and correlative

reflectivity information provided by SeaMARC side-scanning sonar provide the "road maps" necessary to identify and investigate diving targets on the sea floor.

Such an approach has been used in the investigation of the morphology and structure of the East Pacific Rise (EPR) between 9°N and 13°N, and on seamounts west of the EPR axis near 10°N. The sonar and submersible data collected will be reviewed and discussed in the light of current models of EPR crest and seamount structure and evolution. In particular, we will focus on the interpretation of crustal deformational processes operating on the EPR crest and seamounts, and the implications that these data have for understanding magma chamber size, distribution and processes under the EPR axis and adjacent seamounts.

USE OF SEAMARC II ACOUSTIC IMAGING SYSTEM FOR GEOLOGICAL INVESTIGATIONS IN THE MARIANA ARC AND BACK-ARC ENVIRONMENT

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Portions of the Northern Mariana arc and back-arc basin have been surveyed recently using the SeaMARC II long-range sonar and bathymetry system. The SeaMARC II data provide the equivalent of an aerial photograph and a topographic map. The images of the arc and back-arc basin produced have substantially changed our understanding of the nature of submarine volcanism and tectonic processes in these environments.

The volcanoes of the arc are not simple volcaniclastic covered edifices often seen on single-channel seismic reflection profiles. They have primary structures such as rift zones, calderas, extensive flow fields; and secondary features such as satellite cones, summit cone complexes, collapse features and pit craters. The distribution of volcanoes in the arc and back-arc is related to regional and local tectonic control. Volcanoes are situated at sites of fracturing of the arc along strike and also occur along extensions of fractures in the back-arc basins. They also develop along the back-arc rift arc.

Large fault scarps form the margins of the back-arc basin. These scarps, never previously investigated, expose thick (up to 4 km) sections of arc basement, within reach of deep submersibles. The presence of numerous small volcanic cones and fractures between major arc volcanoes suggests that there may be secondary volcanic processes between major arc volcanoes. The economic potential of such processes has never been studied.

The outer arc of the Mariana system within about 100km of the trench axis is broken up by numerous seamounts. They are not volcanic but are formed by vertical tectonic movement in the fore-arc and by diapiric emplacement of serpentinized ultramafic material. Mounds, possibly hydrothermal in origin, are associated with them. The detailed observations of these arc and back-arc terranes with submarines are the next step in the attempt to detail the geology of these features.

FRENCH SUBMERSIBLES IN CONTINENTAL MARGINS

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Hitherto, the study of continental margins was principally concentrated on the study of the stable margins. The use of the submersible NAUTILE, which can reach 6 000m-depths, should give us, in the coming years, the possibility to accentuate the study of the active margins (trenches, collision and subduction zones).

On the stable northeast Atlantic margins, the existence of zones where the continental basement and its sedimentary cover are exposed, makes studies using submersibles very fruitful. These particular zones are essentially submarine canyons and large escarpments.

The submarine canyons offer the advantage of being often free from any recent cover and therefore giving us the possibility to make geological sections of a very good quality, either on their axis or on their flanks. We took advantage of this in the western Mediterranean during the "Estocade" and "Cyaligure" cruises, as well as in the northern Atlantic during the "Cymor I and II" cruises.

The large escarpments build high, very steep submarine cliffs which show outcrops of the continental basement and its cover. These escarpments often result from two processes: a building process consisting in an accumulation of sediments which are often carbonated and leading to very big cliffs made of massive limestones; and a breaking/destruction process of tectonic origin which rejuvenates the outcrop. The "Escarmed" cruise to the Malta escarpment, as well as the "Cymor I and II", "Cyadanois", "Cybere" and "Cyamaz" cruises to the escarpments of the eastern Atlantic margin contributed in a very significant way to the study of the stratigraphy of the structure and the vertical evolution of the stable margins.

This will be illustrated by the results obtained during the "Cymor" cruise on the northern margin of the Bay of Biscay, as well as the "Cyamaz" cruise to the Mazagan Escarpment. These

results can well be compared to the data coming from the drilling cruises of the GLOMAR CHALLENGER in the same areas, as far as the quality of the observations and samples is concerned.

SUBMERSIBLE OBSERVATIONS IN THE SOUTHERN CALIFORNIA BORDERLAND

by
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Geological observations from the research submersible ALVIN were made in the Southern California Borderland to determine sea-bed disruption due to active faulting. Detailed marine geophysical surveys in the region indicated that recent faulting had disrupted and offset the sea floor in several places within the Gulf of Santa Catalina. ALVIN was used to examine the sea floor along fault traces and to collect in situ rock samples from either side of a fault.

Because of the high degree of bioturbation and mass movement in the region, it was not possible to identify distinct fault scarps. It was concluded that, in such an environment, small-scale deformation could be observed from a submersible only if the site was visited shortly after fault movement had occurred However, rock samples taken by ALVIN in submarine canyons and steep escarpments believed to be controlled by faults confirmed the existence of faulting and recent (within Holocene time) displacement.

An equivalent type of sea-bed disruption occurs in the Central Basin of Vanuatu. Application of submersible techniques developed for the study of the faults in the Southern California Borderland in Vanuatu will assist in the evaluation of active tectonic processes in that region.

GEOLOGICAL CONTROL OF THE FORMATION OF POLYMETALLIC SULPHIDES AT HYDROTHERMAL VENTS *

by
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Detailed examination of the structural setting of polymetallic sulphides located at ridge crests and along the summits

* This paper was presented by Gary M. McMurty

of submarine volcanoes suggests that high-volume deposits are located on faults rather than along rift axis fissures. Polymetallic sulphide deposits in the form of coalesced chimneys have been observed to extend for distances up to several hundred metres along the boundary faults of the Galapagos Ridge, the Endeavour Ridge, the Juan de Fuca axial volcano and Loihi submarine volcano of Hawaii. Other sites of extensive fault-controlled hydrothermal activity have been reported along the axial rifts of the Explorer Ridge, and the axial rifts and summits of off-axis volcanoes of the East Pacific Rise. The water depths where hydrothermal deposits have been examined extend from 1 100 metres for the summit of Loihi to 2 700 metres for the eastern end of the Galapagos Ridge. Hydrothermal deposits consisting of low-temperature outer zones of iron oxide and nontronite, and high-temperature sulphides, have been found at the shallower and deeper portions of the ridge crest segments whose spreading rates range from 40 to 160 mm per year. This study of polymetallic sulphide formation on the ocean floor suggests that the development and size of the deposits is independent of the ridge-crest water depth and spreading rate. The largest deposits appear to have developed above normal faults of the inner rift valley during a period of prolonged tectonic stability lasting from tens to thousands of years. The large deposits developed during a long constructional phase interspaced between short extensional phases of ridge axis growth. The geological setting of the deposits is characterized by the presence of a sheet or lobate lava "cap rock" cut by talus-lined normal fault planes that form deep-source hydrothermal conduits. The fault planes extend from depths of a few hundred metres to several kilometres below the rift valley floor, where they tap the magmatically heated hydrothermal water trapped beneath the "cap rock". The constructional phase of ridge axis growth is characterized by an aseismic phase of high-temperature, high-volume, low-viscosity volcanic extrusion and the presence of hydrothermal vents. The extensional phase is marked by deep ridge-crest rifting and extensive faulting, low-volume pillow basalt volcanism, intense local seismic activity and an absence of extensive hydrothermal vents.

A RATIONALE FOR LONG-TERM OCEAN-BOTTOM OBSERVATORIES AT MID-OCEAN RIDGES*

by
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Knowledge and understanding of the distribution in real time of the processes that form and modify the oceanic crust lag far behind our ability to locate and resolve the products of those processes in space. The rapidly developing technologies of swath mapping, seismic profiling, and global positioning systems will

* Paper presented by Jill Karsten

soon provide an unparallelled capability for spatially resolving igneous, tectonic, and hydrothermal features on and beneath the ocean floor. Yet, certain fundamental questions about the mechanics and consequences of oceanic lithosphere generation and movement will not be answered by improved resolution of mapping techniques.

The oceanographic community is now in a position, scientifically and technologically, to initiate a decade-scale programme focused on temporal co-variation among the interactive processes that generate the oceanic lithosphere. With a philosophy akin to that of the major astronomical, magnetic, and volcanic observatories on land, it is now feasible to pursue a long-term scientific effort leading to the installation and maintenance of one or more multidisciplinary, instrumental "observatories" on selected spreading-centre sites.

The goal of this programme would be to document and model the timing of, and feedback mechanisms linking, thermal, mechanical, chemical, and biological interactions in the generation and aging of 60% of the planetary surface. The technological and intellectual synergism involved in successfully implementing this programme will provide a new generation of testable, heuristic models of oceanic lithosphere genesis.

THE POTENTIAL USE OF MANNED SUBMERSIBLES AND ROV'S FOR MICROBIOLOGICAL RESEARCH IN THE SOUTH PACIFIC

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The discovery and exploration of novel faunal communities surrounding ridge-crest hydrothermal vents and off-axis cold seeps constitutes an important area of oceanographic research. The field observations, collections and *in situ* experiments conducted to date could not have been made without the use of manned submersibles. The microbiological data base, obtained primarily from submersible investigations of the East Pacific Rise and Juan de Fuca Ridge, indicate that hydrothermal vents may represent important point sources of carbon and energy influx to the biosphere. These sources have not been considered in previous models of oceanic ecology. The detection of hydrothermal plumes at distances of 100 to 1000 km from their point of origin, and the potential flux from off-axis submarine volcanism (e.g. sea mounts, back-arc spreading) and from dewatering processes associated with plate subduction suggest that these energy sources may be more widely distributed and, hence, quantitatively more important to oceanic energy budgets than originally perceived. To test this important hypothesis, careful sample collections and *in situ* microbial growth experiments must be

performed at geographically distinct sites. Microbiological biomass and growth-rate data, collected from five separate hydrothermal vent fields, are presented and a research prospectus for future investigations is discussed.

THE HAWAII DEEP-WATER ELECTRICAL TRANSMISSION CABLE PROGRAM: ROUTE SURVEYS AND THE USE OF MANNED SUBMERSIBLES FOR INSPECTION OF PROPOSED ROUTES

by
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In an effort to get the State of Hawaii into a position where it is independent of outside sources for its energy needs, several major alternative energy programmes are being pursued. One problem common to several of these programmes is the need for an inter-island electrical distribution system. The Hawaii Deep-water Electrical Transmission Cable Programme is a joint effort of the State of Hawaii and the U.S. Department of Energy to determine whether it is feasible to design, build and deploy a suitable cable.

SeaMARC II and geophysical surveys, bottom photography and geological sampling programmes carried out along the deep-water portion of the proposed cable route discovered features that require more detailed study prior to cable deployment. These studies require the use of a deep-diving manned submersible and these are presently planned for mid-1986.

The shallow-water portions of the proposed cable route have been studied using presently available bathymetric and seismic reflection data. A late-Pleistocene coral reef was discovered at a depth of 100-150 metres. The surface of this reef is often covered with sand and thus appears to be a safe route for the cable to follow. Dives with the Research Submersible MAKALI'I were made at several locations on the reef; these confirmed that the reef surface would be an appropriate route for the cable to follow. More dives on this feature are planned to investigate areas where cross-reef structures may pose a potential danger to an electrical transmission cable.

VOLATILES IN OCEANIC HYDROTHERMAL VENTS

by
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"Volatiles" in submarine hydrothermal vents include such components as H_2O, CO_2, CH_4, H_2 and He. This paper reviews the concentrations of these components and the isotope ratios D/H, $^{18}O/^{16}O$, and $^{3}He/^{4}He$, in samples collected with the submersible R.V. ALVIN from the Galapagos, 21°N, the Guaymas Basin, and 13°N hydrothermal vent areas. Additional data from surface ship hydrographic casts on the East Pacific Rise (20°S to 35°S), in Loihi volcano (current site of the Hawaiian hotspot), and in the Mariana Trough, in which CH_4/He and $^{3}He/^{4}He$ ratios have been measured, are also discussed. Major results of these studies include: (i) evidence for boiling at 13°N from vent samples with salinities less than and greater than of sea water; (ii) "abiotic" CH_4 extracted from MORB vesicles together with H_2, CO_2 etc.; (iii) evidence for active vents in Loihi caldera and in the Mariana Trough; (iv) discovery of active vents on a "hotspot" section of the East Pacific Rise, on the East Rift of the Easter microplate; (v) existence of different volatile ratios ($CH_4/^{3}He$ and $^{3}He/^{4}He$) in MORB vs. plume vents; (vi) "isotope shifts" in D/H and $^{18}O/^{16}O$ ratios in vent waters, due to interaction between water and basalts. Colleagues associated in these various studies include J. Welhan, K. Kim, and Y. Horibe. Our future scheduled diving targets for continuing these investigations include Loihi volcano and the Mariana Trough.

FIRST MANNED SUBMERSIBLE DIVE ON THE ACTIVE INTRA-PLATE VOLCANO TEAHITIA (TAHITI)

by
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The Mehetia hot spot on the east of Tahiti seemed to enter a new phase of activity in 1981 (Mehetia Seismic crisis). Teahitia began new activity in 1982 with the March-April seismic crisis, in

which there were harmonic tremors indicating extruding lava flows. Teahitia is one of the four active seamounts forming the hot spot. This volcano is 12 km in diameter on a sea floor 3 000m deep with a summit at a depth of 1 450m. A dive with the manned submersible CYANA took place in December 1983, at the time of a small seismic crisis, from a depth of 2 700m to the summit caldera. The mean slope angle is about 20°; i.e., two to three times steeper than equivalent aerial volcano slopes (Mauna Loa, Pitou de la Fournaire, etc.). The deepest parts are covered by sediments, the thickness of which decreases with altitude. An indurated sediment layer one to two centimetres thick (probably hyatoclistites) was found extensively on the surface. At about 2 000-metres depth, the talus appears under thick pillow-lava flow (one to several metres in size) in stable accumulation took place around the volcano summit. Coalesced calderas are located on the summit, and active (and inactive) hydrothermal vents are found along the rims. The deposits' composition indicates iron oxides with some manganese foils. The rare earth element (REE) concentrations are high, and enriched in light REEs, with a positive europium anomaly. The rocks sampled are hawaiites and ankaramites. They have high concentrations in TiO_2 (3.3%) in K_2O (2.9 - 3.1%) and low concentrations in MgO (< 6%) and CaO (≃ 8%) compared with MORB.

POLYMETALLIC SULPHIDE DEPOSITS AT THE AXIS AND ON SEA MOUNTS AT 13 DEGREES NORTH ON THE EAST PACIFIC RISE: COMPARISON WITH OTHER DEPOSITS IN THE SOUTH PACIFIC

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Since 1980, two surface cruises and two diving cruises have allowed study of the intense hydrothermal activity and the numerous sulphide deposits occurring along 20 km of the axis and on off-axis seamounts. Depending on their location, the hydrothermal products can be classified in three main types: (i) At the axis, more than 100 small (<50m in diameter) deposits have been discovered, of which 25 are active. At one site, there are generally two or three spires 5-20m high, 5m wide, with black smokers on the side or at the top. The middle part is enriched in copper sulphide, while diffusing water at the outer part and at the base of the chimneys produces porous iron or zinc sulphide. (ii) On the walls of the graben, more lenticular sulphide deposits were destroyed along the faults, and cross sections through the sulphide lenses show zinc or copper chimneys at the top, porous iron sulphide enriched in copper in the middle part of the lens, and a stockwork made of silica, chalcopyrite and pyrrhotite cementing the altered basalt beneath the sulphide lens; (iii) on the seamount, 6km off the axis, is the most extended sulphide

deposit, 800m long, 500m wide and, in some places, more than 10m thick. The volume of this deposit was estimated to be between 1 and 5 millions tonnes. At the surface, the massive sulphides are depleted in zinc with small amounts of copper (~1%) and cobalt (~0.5%). Samples collected in cross sections along faults in the massive lens indicate that the copper content increases downward up to 10%.

Field observations and mineralogical study show that evolution of the edifices can be illustrated by four main stages: (i) low-temperature hydrothermal water diffuses through fissures in the basalt, and animal communities start to develop; this stage was observed on non-rifted domes at 17°S and 20°S on the East Pacific Rise; (ii) high-temperature (350°C) fluid discharges through copper chimneys; diffusing water produces porous iron and zinc deposits at the base of the chimney; this stage is observed within rifted ridge segments at 13°N, 21°30S on the East Pacific Rise; (iii) as the sulphide edifice grows intense and localized hydrothermal activity is replaced by extended diffusion of hydrothermal water, a mineralogical zonation is produced in the edifice; these more mature and massive deposits were observed at 13°N on off-axis seamounts; (iv) along the wall of the graben, the edifices are tectonically destroyed and a cross section through the deposit is observed; these old edifices were observed in a wide (>1km) graben at 18°30S and in some places at 13°N.

SUBDUCTION AND COLLISION FROM THE PHILIPPINES TO TAIWAN: RESEARCH TARGETS USING SUBMERSIBLES

by
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The passage from active subduction to active collision has been studied in three key sectors of the western Pacific, during three POP cruises of the R.V. JEAN CHARCOT in 1984 (using Seabeam, seismic, gravimetric and magnetic techniques): (i) the active margin of Ryukyu and its articulation with the active collision zone of Taiwan; (ii) the northern end of the Manila Trench and the passage from the Manila subduction zone to the Taiwan collision zone between the Luzon-Taiwan arc and the Asian margin; (iii) the southern end of the Manila Trench off the island of Mindoro, and edifice resulting from a collision.

Several new problems have been identified: the progressive passage or the abrupt passage from subduction to collision; real or potential slip strikes; passage from an accretion prism to a collision prism; morpho-structural signature of the plate boundary; disappearance on nearing the North Luzon fore-arc basin collision.

Thanks to a favourable morphology as shown by the Seabeam maps and, in particular, to the existence of numerous canyons occuring across the structures, targets for submersible investigations can be proposed.

SUBMERSIBLES AND PRECIOUS CORALS

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A wide variety of animals are considered to produce precious corals which include pink (red) coral, gold coral, bamboo coral, and black coral. Limited information is available about these corals among the islands of the Pacific. The more valuable forms (species of Corallium) are found at depths between 100 and 1 500m. Preliminary data show that, at present, commercial concentrations of Corallium are located north of 19°N latitude. To the south, this coral is known from waters between the Cook and the Solomon Islands; none was found in the equatorial water at Kiribati. Historically, precious corals have been harvested by several different dredging techniques. In 1972, a submersible was first used to collect corals in Hawaii. Initial information indicated that, even though more expensive, this method of harvesting was more selective and waste was less. Advantages and disadvantages of both methods are discussed. Additionally, visual observations can be made which help to establish more rational management strategies and plans. Model development depends on the accuracy of data collected.

SHALLOW OFFSHORE HYDROTHERMAL METAL DEPOSITS IN VANUATU

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Four submarine volcanoes, with their crests less than 200m below sea level, are present off the island of Epi in Vanuatu. Three of the volcanoes have been recorded as active in recent years. HMS HYDRA produced a detailed bathymetric map of the area in 1974, R.V. MACHIAS took some short cores near the vents in 1981, and R.V. S.P. LEE ran seismic, boomer and magnetic profiles and took several more samples in 1984.

Near-surface samples are mostly gray or brown volcaniclastic silty sands and silts dominated by volcanic glass. Five short cores contain brick-red silty beds up to 16cm thick. These beds are predominantly amorphous iron oxide, containing up to 27.5% Fe. They appear to be hydrothermal deposits, deposited as intermediate- to late-stage precipitates from solutions associated with the volcanoes.

A submersible programme around the vents should provide considerable information about shallow-water volcanism and hydrothermal products and might conceivably reveal easily accessible polymetallic sulphides.

USE OF MANNED SUBMERSIBLE PLATYPUS 1 IN RESEARCH OFF EASTERN AUSTRALIA

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PLATYPUS 1 is an ABS-classed two-man submersible. It has a design operating depth of 350m, up to 150 hours life support, manipulators, photographic and video capability. The submersible is owned by Platypus Marine Surveys Pty, Ltd. and is operated by Submersible Surveys Inc. Pty. Ltd. of Sydney, Australia.

The PLATYPUS 1 is either launched directly from a mother-ship or is towed on and launched from its own launch and recovery submersible platform. The latter allows safe operation in 2-3m swell conditions, using only a small vessel for towing. This avoids a large mother-ship with lifting facilities.

To date, the submersible has been used in: surveys for sewer outfall design - obtaining video records and information on the physical characteristics of the sediment *in situ*; for fisheries research on fish behaviour around artificial reefs off Sydney; insurance investigations of sunken vessels and for research on the character of the fore-reef and lagoon sediments on the Great Barrier Reef. The success of these operations has been significantly due to the vessel's ability to function well in bottom currents of up to 2 knots, which have been encountered off the Queensland and New South Wales shelf. In these current situations and in reef research in particular, where there is examination of high cliffs and overhangs and where the water movement tends to be shoreward, the use of an umbilical is extremely dangerous. The lack of any need for an umbilical gives the submersible a distinct advantage over any ROV.

Still photography and video have been obtained using either ambient light, the submersible's lights or a strobe light, as appropriate. Colour photos using ambient light for large topographic features have been obtained at depths of 160m. The 360° pilot visibility has been found to be extremely advantageous in these operations.

REEF-SLOPE EXPLORATION WITH ROVs

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The ROV (bless its transistors and tether) is a unique device.

Man has only just begun to use it as a tool to explore the reef slopes.

The problems of operation are numerous and varied and we are just beginning to address the many disciplines involved.

In the next few years we shall witness a major leap forward in terms of "man hours of observation" and useful work.

This paper outlines some of the problems and describes solutions that have been found.

GEOLOGICAL SURVEY FOR THE FRENCH OTEC COLD-WATER PIPE STUDIES

by
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A shore-based OTEC plant needs special studies to solve the technical difficulties of the pipe support system and the installation procedure.

The strategy for a geological survey comprises: (i) large-scale bathymetry by multibeam echosounder inshore and by narrow-beam echosounder in nearshore areas; (ii) detailed surveys of the irregularities of the relief in the range of one metre (RAIE and CYANA dives) to facilitate the choice of the pipe support system; and (iii) high-resolution seismic survey and Kullenberg core sampling to assess the nature, thickness and mechanical properties of the marine sediments.

The bathymetric profile is described and its characteristics have led to the choice of a path and pipe-support system. Present studies are focused on two solutions: (i) "fairleads" with many anchorages; (ii) the "heavy catenary and heavy sections".

POTENTIAL APPLICATION OF MANNED VEHICLES TO THE STUDY OF QUATERNARY GEOMORPHOLOGY OF THE NORTH AUSTRALIAN SHELF

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The north Australian shelf of the Arafura and Timor Seas extends approximately 900km by 400km, and was exposed to subaerial processes during Quaternary low sea levels. The exposed land mass almost linked Asia with Australia. Since the last high sea level, approximately 120 000 BP, there have been various configurations of archipelagoes and land bridges partially connecting the continents at different dates.

Previous research has revealed extensive calcareous platforms with upper surfaces at 35-50m, and sinuous valleys and troughs at 100-200m depth. Most of the platforms have no active coral-reef growth on them, thus making the previous subaerial landforms accessible. A submersible research programme is proposed to work in depths of 40-200m, to address the following questions:

(i) Why did coral reef growth not re-establish during the post-glacial marine transgression?
(ii) At what depths are there marine shoreline features?
(iii) What was the subaerial drainage pattern at times of low sea level, and was fresh water accessible to fauna and humans?
(iv) Was the vegetation sufficient to support a faunal population and/or humans?
(v) Was there a marine faunal productivity in the coastal zone sufficient to support a human population?
(vi) Are there submerged landforms indicative of possible human occupation?

A technical programme for carrying out the work is proposed.

SUBMERSIBLE STUDIES ON THE GREAT BARRIER REEF

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Several dives were conducted, in October-November 1984, on the outer slope of the Great Barrier Reef to maximum depths of 215 m using the Australian two-man submersible PLATYPUS 1. This paper deals particularly with those dives conducted off No. 5 Ribbon Reef in the north and Myrmadon Reef in the central province.

The profile off Ribbon 5 shows: (i) an upper talus and sand slope between 40 and 50 m; (ii) an extinct reef at 50-65 m; a lower talus and sand slope between 65 and 75 m; (iv) the brow between 75 and 85 m; (v) the wall between 75 and 200 m; and (vi) basal screes below 200 m.

Very little living coral occurs below 40 m but living algae extend down the wall. Halimeda is still growing at 100 m. The wall is vertical and composed of reef framework, forming laterally discontinuous ledges. This stratification is interrupted by narrow vertical fissures, wider canyons, caves, sediment chutes and fault scars. Partly rotated blocks perch as overhangs. The caves are up to 10 m across and occur on many parts of the wall but are commonest between 120 and 150 m. The basal screes dip 60-70°, with boulders of over 1 m across, embedded in a sandy/gravel and mud matrix.

At Myrmadon Reef, the profile is different and similar to that at Ribbon 5. Above 75 m the profiles are similar to that at Ribbon 5. Instead, below the brow at around 75 m, the reef drops at an angle of 60° through a series of terraces and ledges. It either continues at this angle to a depth of 200 m or gradually decreases in angle to less than 45° below 160 m. Rubble and screes are banked against the lower end of the slope.

Apart from the differences in profile, the main visual difference between Ribbon 5 and Myrmadon is the incredible cover of live coral at Myrmadon to a depth of 100 m. Below 50-60 m, gardens with Leptoseris and Pachyseris dominate the substrate. The lettuce-like rosettes of Leptoseris occur between 60-80 m, while plates of Pachyseria and, to a lesser extent, Endophyllia

predominate below 80 m, the colonies becoming less abundant and smaller down to 100 m. The profile at Myramdon is dominantly constructional.

Seismic studies indicate that the carbonate section of the Great Barrier Reef is about 250 m thick. Interpretation of the seismic data, together with the submersible observations, allows the definition of the main reef, subreef and fore-reef facies.

RIDGE SUBDUCTION, CONTINENTAL RIFTING AND FAST BACK-ARC SPREADING: PROSPECTIVE SUBMERSIBLE INVESTIGATIONS IN THE WOODLARK AND MANUS BASINS

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The eastern Woodlark Basin, spreading at 72 mm:yr, is being subducted end-on beneath the Solomon Island arc at > 100 mm/yr. A triple junction triangular zone is formed by Simbo ridge transform on the west, Ghizo ridge on the south, and the bathymetric trench to the northeast. The absence of a subducted slab in the triple junction area has allowed arc magmas to migrate laterally and contaminate ocean-floor volcanism seawards on the trench. Dredged rocks include boninites and Na-Ti basalts from Simbo ridge, porphyritic basalts of arc affinity from Ghizo ridge, rhyo-dacites from Kana Keoki sea mount: a submarine volcano which rises to 700 m at the eastern end of Ghizo Ridge.

At the other end of the Woodlark Basin, spreading is propagating to the west into the continental Papuan Peninsula. Peralkaline rhyolite volcanism occurs in the D'Entrecasteaux Islands just ahead of the spreading tip, and an axial volcano (of unknown composition) rises to 120 m below sea level just behind it.

The Manus Basin in the Bismarck Sea is the fastest spreading (100 mm/yr) back-arc basin. Bounded by major sinistral transform faults, the 150-km-long spreading centre is characterized by high-amplitude magnetic anomalies (due to Fe-Ti basalts, propagating rifts?), an axial horst at about 2 000m in the west, and an axial graben as deep as 2 600m in the east.

Extensive surveys of all three areas are planned in the near future, including SeaMARC II swath-mapping of the Manus Basin and possibly the Woodlark triple junction in late 1985, Craig's search for CH_4 and ^3He anomalies in both Basins in early 1986, and CSIRO sampling in the western Woodlark Basin later in 1986.

Most prospective dive sites are shallower than 2 500m. SeaMARC II site surveys for funded ALVIN diving in the Bonin rifts will be shown for comparison.

DIVE PROPOSALS IN AN ARC-RIDGE COLLISION SETTING: THE D'ENTRECASTEAUX/NEW HEBRIDES TARGET

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The underthrusting of the Indo-Australian plate beneath the North Fiji Basin is presumed to have been active since at least 5-6 million years ago. It is emphasized by a consequent shallow and intermediate seismicity and by the existence of the New Hebrides island arc. The underthrusting plate carries with it the West Torres Massif, the D'Entrecasteaux zone (DEZ) separating the West Torres and North Loyalty oceanic basins.

The DEZ is an aseismic double-ridge complex that is colliding with the central protruding New Hebrides arc, clogging the trench and deforming the arc. The northern ridge (NDR) and the southern chain (SDC) apparently differ greatly in genesis and lithology. Whereas the NDR is composed of early Eocene MORB, the SDC shows two major bathymetric features: the Sabine Bank, a possible Eocene volcano, and the Bougainville Spur which is of unknown origin. Multichannel seismic reflection data suggest noticeable differences in the crustal deformation processes operating in these collision zones. We intend to test the relationship between the style of deformations and the nature of the ridges.

An extensive Seabeam survey planned in October 1985 will permit us to define the most representative deformation zones to be investigated by manned submersibles.

The objectives of the dives are to study: (i) the lithologies and ages of the NDR and the Bougainville Spur rocks near the impact zone; (ii) the sedimentary accretion and tectonic processes related to the collision; (iii) the chemical properties of the water related to the subduction/collision process and the existence of secondary mineralizations resulting from accelerated dewatering.

DIVE PROPOSALS IN AN ARC-RIDGE COLLISION SETTING: THE LOYALTY/SOUTH NEW HEBRIDES TARGET

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The New Hebrides Island arc provides two examples of arc-ridge collision. At 15-16°S, the D'Entrecasteaux zone clearly interrupts the trench, while south of 21°S the eastern edge of the Loyalty Islands ridge marks an inceptive collision with the trench. This second example corresponds to a change in the subduction zone morphology: a bathymetric threshold marks the trench, the 2-km isobath envelope delineating the island arc basement narrows, and the rear-arc disappears.

In this respect, there is a gap to be filled in the understanding of the petrology and tectonics of the New Hebrides arc, between Anatom island (20°10'S) and Matthew and Hunter volcanoes (22°S). Like most of the recent volcanics of the arc, the Upper Pleistocene formations of Anatom can be related to the island arc tholeiitic rock series. By contrast, the active Matthew and Hunter volcanoes are entirely made up of calco-alkaline acidic orogenic andesites.

The proposed dive targets are twofold:

(i) On the eastern border of the Loyalty Islands ridge, between 21°S and 23°S, where active normal faulting occurs. A Seabeam survey will be conducted in this area in October 1985.

(ii) On the southern New Hebrides arc, alongside an arcuate transect roughly oriented 21°S-170°E/22°50'S-172°E encompassing six seamounts (summit depth: 53 m to 1 200m) which link Anatom to Matthew-Hunter islands. A precise bathymetric survey for most of these seamounts is available.

The main objectives of the proposed dives are

(i) Search for fresh volcanic outcrops on fault scarps cutting the eastern Loyalty Islands ridge substratum, in order to understand the still unknown nature of this ca. 1000km-long ridge (hot-spot lineation, ancient island arc?).

(ii) Identification of the tectonic configuration of the basement of the southern New Hebrides seamounts, by locating and characterizing possible active faults and displacement.

(iii) Study of the petrological and geochronological evolution of the New Hebrides arc submarine volcanism, both vertically (on a single seamount) and laterally (among different seamounts), by sampling in situ volcanic products from various structural levels of these seamounts.

(iv) Description of active submarine volcanoes and localization and sampling of active hydrothermal vents.

A recent (< 2 million years ago) southward propagation of the New Hebrides subduction between Anatom and Matthew Islands may contribute to the specific characteristics of the area. The proposed submersible investigations, if fulfilled, should bring forth conclusive arguments to address this issue.

EXPLORATION FOR ACTIVE HYDROTHERMAL VENTS IN SOUTHWEST PACIFIC MARGINAL BASINS: PAPATUA EXPEDITION (1986)

by
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PAPATUA Expedition (SIO, R.V. THOMAS WASHINGTON, January-February 1986) will include a 40-day leg from Tongatapu to Rabaul, with three major objectives: (i) A search for active hydrothermal vents along the axes of the Lau Basin, Havre Trough, North Fiji Basin, Woodlark Basin, and the Bismark Basin, using shipboard measurements of methane profiles with collection of samples for laboratory study of helium concentrations and isotopic ($^3He/^4He$) profiles; (ii) sampling of volcanic gases on island volcanoes along the ship's track, for studies of helium and methane concentrations and isotope ratios for comparison with our extensive data on arc volcanic gases in the North Pacific and in Indonesia (where He isotopes correlate with the nature of the subducting crust in the two active arcs); and (iii) collection of back-arc basalts for studies of the origin of He and H_2O components by He and H isotope ratios as in the Lau and Mariana Basins. This paper describes the planned ship's track, sampling strategy for discovering vent field, rationale for arc volcanic gas studies, and what we can tell from the basalt studies. The hydrothermal vent surveys, our primary target, are intended as the basic groundwork for proposing ALVIN diving targets in future Pacific dive schedules.

PHOSPHORITE OCCURRENCES ON SUBMERGED ATOLLS OF THE FIJI PLATEAU

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In addition to the well documented occurrences of sedimentary phosphorite on continental margins, phosphate deposits are now known - partly as a result of recent exploration for cobalt-rich crusts - to be widespread on seamount and other relatively shallow features in the ocean basins.

The seamount phosphorites have petrological and geochemical characteristics that differentiate them from the shelf phosphorite facies, and suggest an unrelated mode of origin. Most seamount phosphorites have features diagnostic of a marine origin, and are associated with biotic calcite, volcanic detritus, and ferromanganese oxides. However, recent work by the authors on the North Fiji Plateau has shown that phosphorite occurs also on at least two guyots aligned within a series of shallow banks. It is suspected that this phosphorite, which significantly is accompanied by the mineral dolomite, formed in an atoll environment before deep submergence, and is actually of "insular" origin.

Unfortunately, the comparative study of these deposits has so far been hampered by a lack of effective sampling techniques, capable of dealing, with precision, with the extremely hard and often rugged sea floor on seamounts and guyots. We recommend that it be extended to resolve, in detail, the respective modes of origin of the isolated seamount phosphorites and those on the submerged atolls by the use of manned submersibles. These would constitute essential aspect of the investigation, facilitating accurate evaluation of the depth, thickness and spatial distribution of the phosphorites. They would also provide an ideal opportunity for assessing the nature and extent of the association between the phosphorites and the ferromanganese crusts.

PETROLOGY AND GEOCHEMISTRY OF SUBMARINE LAVAS OF THE NORTH FIJI BASIN

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New geochemical data samples from twenty-five dredges collected during R.V. KANA KEOKI Cruise KK8203 and R.V. SONNE Cruise 35/03 define three principal mantle source types underlying the

North Fiji Basin (NFB). The most common lava type collected is MORB, derived from highly depleted mantle sources. Lavas of this type with Mg $\gtrsim$ 50 have $Na_2O/K_2O > 20$, and are strongly depleted in large ion elements; e.g., K, Rb, Sr, Zr; plagioclase-saturated members conform to an olivine-plagioclase (-liquid) multiple saturation surface (cotectic) identical to that for MORB from major mid-ocean spreading centres. Two dredges from an area of highly oblique magnetic and bathymetric structure recovered MORB-affinity Fe-Ti basalts with up to 16.2 wt. % FeO. These samples may have been erupted along propagating rifts during an earlier, now inactive, spreading system.

A second major source type is slightly enriched in large ion elements. Samples of this type with Mg $\sim$ 50 have Na_2O/K_2O in the range 9-15 and plagioclase-saturated liquids conform to an olivine-plagioclase (-liquid) cotectic nearly identical to that for back-arc basin basalts (BABB) from the Mariana Trough and East Scotia Sea. This cotectic is displaced significantly toward plagioclase relative to the MORB cotectic. A third type includes lavas derived from alkali and other large ion-enriched sources that were slightly depleted in $^{143}Nd/^{144}Nd$ relative to that for the other (MORB and BABB) sources for NFB lavas. These lavas were primarily, but not exclusively, erupted along the presently active South Pandora Ridge-Rotuma lineament. The sources for some high SiO_2 (up to 57.6 wt. %) tholeiitic lavas from a small spreading segment near 16.3°S, 177.4°E are unclear at this time. The temporal, spatial and tectonic context of all sample types are a focus of this paper.

TARGET AREAS FOR SUBMERSIBLE INVESTIGATION OF HYDROTHERMAL SYSTEMS IN THE NORTH FIJI BASIN

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The North Fiji Basin (NFB) has four major tectonic regimes that contain promising areas for active and/or recent hydrothermal systems and their associated metalliferous deposits and benthic communities. These regimes are: (i) back-arc spreading centres; (ii) pull-apart rift basins associated with tranform faults; (iii) off-axis rift basins; and (iv) seamounts. The south central NFB is dominated by a magnetically well defined ridge spreading 35/48 mm/yr (half rate) which trends north between 173° and 174°E. The northern part of this ridge is seismically diffuse and relatively sediment-free; south of 20°S, seismicity increases and correlates with the ridge axis. Sediment cover in the neovolcanic zone may also increase because of proximity to the Vanuatu arc, producing sediment-hosted hydrothermal systems and deposits of the Guaymas Basin or Kuroko/Besshi type. Two similar regimes are: (i) a secondary, young spreading centre developing in the eastern NFB at 176°E, also north

trending, which is seismically active with little sediment cover; and (ii) spreading centres in the Vot Tande-Coriolis Troughs that could contain sediment-hosted hydrothermal systems.

High-resolution bathymetry has defined deeps within the seismically active Fiji Fracture Zone and Hazel-Holme (South Pandora) Ridge that are probalby pull-apart rift basins. Similar basins may occur along the seismically active Hunter Fracture Zone.

Off-axis areas that display evidence of hydrothermal activity include: (i) a basin with heat flow measured in excess of 30 HFU located about 200 km west of the central NFB spreading ridge at 17.5°S; and (ii) a basin about 100 km east of the ridge at 15.5°S that contains ferromanganese crusts 38 cm thick.

Seamounts associated with these rifts may possess active hydrothermal systems, whereas older NFB edifices should contain the fossil deposits of extinct systems.

THE NORTH FIJI BASIN SPREADING CENTRE NEAR 20° SOUTH: A GEOTECTONIC, PETROLOGIC AND HYDROTHERMAL DIVE TARGET

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The seismicity repartition, the high heat flow, the magnetic pattern and the thin sediment cover show that the North Fiji Basin is expanding along a north-south trending spreading centre between 17°S and 22°S, approximately located near 173°30'E, and active for at least 5 million years.

Recent investigations between 20°S and 23°S allow us to determine its location and morphology, and give some ideas about the geodynamics of this Basin:

(i) Between 20°S and 20°30'S, the axial zone is situated on a submeridian ridge, culminating at 2650 metres near 173°26'E.

(ii) Magnetic lineations can be identified up to 1.9 million years (anomaly 2) and give an average spreading rate of 7 cm/year.

(iii) After 1.9 million years, the identification of the anomalies is more speculative, since their orientation drastically changes to a N45°E trend, which should correspond to a spreading jump.

(iv) One large "off-axis" seamount, 500 m high, is located 18 km west of the axis near 20°15'S.

(v) Between 20°30'S and 21°S, the ridge axis is still morphologically well defined, but the magnetic lineations are progressively obscured, except the central positive anomaly, suggesting southward propagation for at least 1.9 million years.

(vi) The depth of the axis is progressively deepening along-strike, from 2650 m near 20°15'S to 2900 m near 21°S.

(vii) South of 21°S, the ridge is interrupted by a small trough, 3200 m deep, but no extensive transform fault could be identified.

(viii) The existence of a north-south spreading centre, located between 20°57'S and 21°20'S near 174°05'E, is assumed from sea-bottom morphology, though magnetic pattern is not very well developed in this area.

High-resolution Seabeam mapping and sampling investigations will be carried out next December on R.V. JEAN CHARCOT along the 20°S spreading centre, in order to define dive targets in this area. Complementary investigations will also be done in the central and eastern parts of the Basin, for exploring areas where spreading centres are not actually precisely located. Thus we shall try to understand their relationships and the connections with the Fiji Transform Fault, which forms the junction between the North Fiji Basin spreading centres and the Tonga subduction zone. Several of these sites represent potential complementary dive targets.

EARLY DEVELOPMENT OF ARC VOLCANISM

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Volcanism accompanying the initiation of subduction, the initiation of arc rifting, and the initial stages of individual oceanic arc volcanoes, all are scientifically important phenomena about which little is known. All can be addressed by submersibles in the southwest Pacific. The initial arc volcanism of the south-western Pacific, as in the Mariana-Bonin Basins, is Eocene to Oligocene boninitic and arc tholeiitic basalt to andesite. Submarine outcrops are needed for study. Recently initiated arc volcanism

may also be present along the Hunter Fracture Zone, in northernmost Tonga, and southermost Kermadec. Exposures are mostly submarine. Back-arc spreading centres are obvious diving targets, the Valu Fa Ridge of Tonga being the logical first choice. Dredged ferroandesites there are < 6000 years old, and probably historic. The Tonga-Kermadec Ridge is the site of several volcanically active arc seamounts. Curacoa in northernmost Tonga is in a geochemically atypical province. Several seamounts between 20°-22°S have been active this century. The best diving site, however, is Monowai at 26°S which may be in the earliest stages of development of a submarine arc volcano.

SUBMERSIBLE STUDIES IN THE SAMOAN ISLANDS*

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Within the Samoan Islands there are several very interesting sites for a geological dive programme. The prime dive site is situated in the Man'ua Group (American Samoa). This site (off the northwest tip of Tau) is the site of an 1890 submarine explosion. The summit of the volcano lies 40m below sea level. Because of the shallowness of this seamount, it is an excellent target for submersible studies. It also holds potential for massive sulphide deposits, since the origin and structure of this seamount is in many ways similar to that of Loihi seamount in the southeast Hawaiian Islands, where Malahoff reports mineral deposits.

Because the volcano reaches very shallow depths, we have an excellent opportunity to examine a large portion of a seamount and document details of the volcanic structure. We propose to do extensive sampling to obtain basaltic rocks for isotope geochemistry.

Another site of particular interest is on the northwest coast of Savaii (Western Samoa) where the major axis of alkalic volcanism reaches the sea. There, between 1909 and 1911, massive volcanism occurred. The lavas covered many kilometres of reef and cascade into the sea. Explosive eruptions of cinder occurred at the coast producing limited aquagene tuffs. We propose to examine the submarine flows and tuffs in this area. Geochemical studies of lavas from Savaii and Upolu suggest that the most enriched lavas occur at this site and it is the next site proposed. Further offshore sampling would assist in defining the isotope geochemistry of this island chain.

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* Paper presented by H. Craig

A classic site of the eruption of aquagene tuffs is the islet of Apolina, situated between Savaii and Upolu. We propose to explore the slopes of the crater in order to examine the mechanism of eruption and deposition of this very poorly studied class of volcanic eruption.

TARGET AREAS FOR MANNED SUBMERSIBLE EXPLORATIONS ON THE MARGINS OF NEW CALEDONIA AND LOYALTY RIDGE FROM PRELIMINARY RESULTS OF BIOCAL CRUISE

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During the BIOCAL cruise, on R.V. JEAN CHARCOT (10 August to 9 September 1985), four SeaBeam boxes were established on the steep margins of New Caledonia and Loyalty Ridge to document their main morphostructural characters and to specify their tectonic, erosional or sedimentary origin. Preliminary results need to be backed up by a manned submersible exploration. Visual observations and sampling expected from it would allow us to:

(i) verify structures of these margins considered as the result of faulted subsiding blocks;

(ii) search ancient erosional surfaces on both sides of New Caledonia;

(iii) try to make observations of upper members of the ophiolitic series eroded onland; and

(iv) explain the mechanism of basinal feeding by detrital supplies from the reef belt and land of New Caledonia.

These data would lead to a better knowledge of New Caledonia geological history, of sedimentary dynamics of Loyalty Basin and of the present behaviour of the edge of the Australian plate bulge near the New Hebrides subduction zone.

OCCURRENCE AND TECTONIC SIGNIFICANCE OF HIGH-SiO_2, HIGH-MgO LAVAS IN WEST PACIFIC ISLAND ARCS AND OPHIOLITES

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Lavas with high SiO_2 (>52%) and high MgO (>8%), which contain less than 10 modal percent mafic phenocrysts, appear to be limited in occurrence to western Pacific island arc/back-arc basin settings, or ophiolites generated in such settings. A review of experimental petrological data for high-Mg andesite compositions indicates that generation of such magmas occurs under H_2O undersaturated conditions at pressures less than about 15 kb (<50km), at temperatures greater than 1100°C. Boninite petrogenesis probably requires higher temperatures, and more H_2O in the source, and pressures less than 10 kb.

In all geophysical models for active subduction zones, ambient temperatures in the mantle wedge above the subducting slab at depths less than 50 km are less than 700°C, and indicate that special conditions, specifically a source of extra heat, are required to generate high-SiO_2, high-MgO lavas in island arcs.

Possible heat sources include: (i) a subducted active spreading centre (Victoria, Solomons); (ii) subduction beneath an active ridge (Marianas); and (iii) diapirs of source mantle for back-arc basin basaltic crust, ascending through sub-arc mantle (Tonga).

Each of these mechanisms is discussed and used to predict the sequence of magma types expected. These predictions are compared with known occurrences of high-MgO and boninitic lavas in modern settings, and an attempt is made to decipher the tectonic evolution of some "ophiolites" containing this magma type.

THE BACK-ARC TROUGHS OF THE NEW HEBRIDES ISLAND ARC: A MULTIPURPOSE GOAL FOR DIVING

by
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The New Hebrides arc is well documented because it has focused for many years the interest of teams from different countries and organizations, in the field of land geology as well as marine geology and seismology. A better geological knowledge of the submarine structures of the arc is now necessary for understanding the constructional evolution of this arc. In that regard,

many phenomena, such as reversal of subduction, rotation of the arc, extension of the subduction along the arc, have been invoked to explain the still controversial history of the New Hebrides.

The troughs at the rear of the New Hebrides arc extend only in the southern and northern parts of the arc. They do not exist in the central part of the arc, where the D'Entrecasteaux ridge is colliding with the arc before subducting. These troughs are simple or double grabens with a relatively flat bottom. The scarp of the flanks is more than 1500 m high. The presence of strong magnetic anomalies and of at least one seamount in the central part of the southern graben attests to either active volcanism of subcrustal magmatic diapirism.

These troughs probably result from a tensional stress regime related to the rolling back of the subducting plate. The lack of roll-back in front of the Central New Hebrides, due to the presence of the D'Entrecasteaux ridge, may explain the lack of back-arc troughs at this level.

These back-arc troughs might represent a very early stage of opening and thus would be a demonstrative example of nascent spreading. Although a volcanic activity is presumably related to these tensional features, the occurrence of a well-established spreading fabric is still speculative.

The New Hebrides back-arc troughs can be considered as a multipurpose goal for submersible dives:

(i) The scarps offer a cross-section of the arc which allows us to establish its stratigraphy over more than 1500 metres of thickness. Sampling by submersible is indispensable for elucidating the controversial history of the arc, and will provide a unique way for studying the volcanostratigraphy of the arc and the evolution of its magmatism.

(ii) The second objective is the study of the magmatism related to the tensional phase which originated these rear troughs, for comparison with the New Hebrides arc magmatism and the North Fiji marginal basin fabric.

The New Hebrides arc is a promising target where complementary studies could be conducted using <u>in situ</u> sampling on key submarine outcrops (submersible dives) as well as drilling (ODP).

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ANNEX V

LIST OF ACRONYMS

AIMS	Australian Institute of Marine Sciences
BABB	Back-Arc Basin Basalt
BMR	Bureau of Mineral Resources (Australia)
BP	Before Present
CCOP/SOPAC	Committee for Co-ordination of Joint Prospecting for Mineral Resources in the South Pacific Areas
COST	Continental Offshore Stratigraphic Test
DEZ	D'Entrecasteaux Zone
DSDP	Deep Sea Drilling Project
EEZ	Exclusive Economic Zone
EPR	East Pacific Rise
FAMOUS	French-American Mid-Ocean Undersea Study
GLORIA	Geological Long Range Inclined Asdic
HFU	Heat Flow Unit
HIG	Hawaii Institute of Geophysics
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IGCP	International Geological Correlation Programme
IOC	Intergovernmental Oceanographic Commission
JAMSTEC	Japan Marine Science and Technology Centre
MOR	Mid-Ocean Ridge
MORB	Mid-Ocean Ridge Basalt
NFB	North Fiji Basin
NOAA	National Oceanic and Atmospheric Administration
NZOI	New Zealand Oceanographic Institute
OBIT	Ocean Bottom Tiltmeter
OBS	Ocean Bottom Seismometer
ODP	Ocean Drilling Programme
ORSTOM	Institut Français de Recherche Scientifique pour le Développement en Coopération (previously, Office de la Recherche Scientifique et Technique Outre-Mer)
OTEC	Ocean Thermal Energy Conversion
OUR	Office of Undersea Research (of NOAA)
PNG	Papua New Guinea
REE	Rare Earth Element

ROV	Remotely Operated Vehicle
RRR	Ridge-Ridge-Ridge junction
RRT	Ridge-Ridge-Transform junction
SEAPSO	Seabeam dans le Pacifique Sud-Ouest
SIO	Scripps Institution of Oceanography
SRT	Subduction-Ridge-Transform junction
TTR	Transform-Transform-Ridge junction
TTT	Transform-Transform-Transform junction
UNU	United Nations University
USGS	United States Geological Survey

No.	Title	Publishing Body	Languages
32 Suppl.	Papers submitted to the UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime Paris, 27 September-1 October 1982	IOC, Unesco Place de Fontenoy Paris, France	English
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR) Halifax, 26-30 September 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa) Tenerife, 12-17 December 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific Suva, Fiji, 3-7 October 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36	IOC/FAO Workshop on the Improved Uses of Research Vessels Lisbon, 28 May - 2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36 Suppl.	Papers submitted to the IOC-FAO Workshop on Inproved Uses of Research Vessels Lisbon, 28 May-2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
37	IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region Basrah, Iraq, 8-12 January 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific Suva, Fiji, 24-29 September 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English