Report of the CCOP/SOPAC-IOC IDOE International Workshop

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PREFACE

STATEMENT OF PURPOSE

The Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC) and the Intergovernmental Oceanographic Commission (IOC) in convening this IDOE Workshop mandated the development of a scientific work programme to focus on:

(a) the regional geology and tectonic framework of the oceanic-island arc-continental margins of the South-west Pacific: and

(b) the occurrence, mode of formation and environmental factors of manganese nodule deposits, hot brines, and metalliferous sediments in the South-west Pacific.

Accordingly, it was the express purpose of the Workshop, so convened, to develop a programme of scientific research and to define research goals, formulate research projects, and make recommendations for implementation and co-ordination. The programme should lead to a regional synthesis and to a greatly increased knowledge of the resource potential of the South Pacific region.

SUMMARY REPORT

1. Opening of the Meeting

The meeting was opened by His Excellency the Minister of Lands and Mineral Resources, Mr Sakeasi N. Waganivavalagi (the opening address is included as Annex III). Dr Hans Martin Schmid, Regional UNDP Representative for the South Pacific, welcomed the group on behalf of UNDP. The Deputy Secretary of the IOC, Dr Gunter Giermann, then welcomed the group in the name of both the Director-General of Unesco and the Secretary of IOC. Additional greetings were made by Dr Philip Kyaw Myint, Officer in Charge of the Mineral Resources Section of ESCAP on behalf of Executive Secretary of ESCAP, and Mr D. A. P. Muller, Chairman of CCOP/SOPAC. All of the last-named speakers thanked the Government of Fiji for hosting the Workshop. The opening session was chaired by the Honorary Chairman His Excellency the Minister of Lands and Mineral Resources. A list of participants is included as Annex II.

2. Election of officers and adoption of the agenda

Mr J. W. Brodie was unanimously elected to serve as Chairman and Mr R. W. Murphy as Rapporteur for plenary meetings. *Ad hoc* groups, which were selected on 3 September, elected their own Chairmen and Rapporteurs. The agenda was adopted (Annex I).

3. General Review presentations by invited lecturers, and
4. Specific geological problems and research interests

Twenty papers were read in the first two days of the Workshop reviewing the state of knowledge of the geology of the South Pacific region. These papers,

which served as the platform upon which the deliberations of the *ad hoc* committee were founded, may be classified into three categories:

(1) Regional syntheses and area reports.

(2) Topical discussions.

(3) Manganese nodules, metallogenesis, and metalliferous sediments of the deep ocean basins.

The list of papers is included as Annex VI. Selected papers are expected to be published as a CCOP/SOPAC Technical Bulletin in 1976.

5. Need for further work and plans for future investigations

Three *ad hoc* committees (Annex VII) formed the basic working units of the Workshop:

1. Committee on problems associated with marginal and inter-arc basins:
   Chairman: Dr W. Bullerwell.
   Rapporteur: Dr J. W. Hawkins.
2. Committee on convergent areas:
   Chairman: Dr C. A. Burk.
   Rapporteur: Dr H. L. Davies.
3. Committee on manganese nodules:
   Chairman: Dr J. E. Andrews.
   Rapporteur: Dr G. P. Glasby.

The two days consumed in deliberations resulted in the formulation of the Recommendations (Annex IV) and Programme of Research (Annex V).

The following projects are recommended for earliest attention because, in addition to their scientific merit, they are felt to be capable of early implementation.

Committee 1 (Marginal Seas and Basins)

Field Project 1-1: Active Basins: Study of the Lau Basin.

Field Project 1-2: Active Basins: Study of the North Fiji Basin.

Field Project 1-3: Active Basins: Study of the Bismarck, Solomon, and Woodlark Basins.

Field Project 1-4: Inactive Basins: Geophysical studies in the Coral Sea, including multi-channel reflection profiling.

Committee 2 (Convergent Areas)

Field Project 2-4: Melanesian Borderland.

Field Project 2-5: Evolution of the Fiji Platform.

Special Project 2-2: Energy and Seismicity.

Compilation Project 2-1: Regional data and syntheses.

Committee 3 (Metalliferous Sea Floor Deposits)

Compilation Project 3-14: Compilation of existing data on manganese nodules.

Compilation Project 3-13: Compilation of sediment analysis of existing samples.

Field Project 3-4: Manganese nodules: Marquesas Fracture zone transect.

Field Project 3-3: Manganese nodules: Cook Islands — Tuamotu transect.

6. Organizational arrangements and recommendations for co-ordination and implementation of future work

The discussions under this item are repeated in the general recommendations which are attached as Annex IV. Concerning potential co-operating institutions, the following contributions were made:

Dr G. Friedrich declared the existence of suitable research personnel and facilities at several German institutions and suggested the possibility of their participation in the programmes of field research.

Dr J. Hawkins expressed confidence that the scientific staff at Scripps Institution of Oceanography would look favourably upon the opportunity to participate in the programme; both in terms of personnel and in terms of committing an oceanographic research vessel, given the necessary funding.

Dr J. Andrews likewise stated that there could be interest at the Hawaii Institute of Geophysics in participation in the programme.

Dr D. Cronan suggested that Imperial College of Science and Technology, London is interested in undertaking geochemical investigations on sedimentary samples relating to the programme.

Dr J. Andrews advised that the investigators of the NSF-IDOE Manganese Nodule Project would be interested in participating in the studies of South Pacific nodules.

Drs G. Packham and D. Falvey said that the University of Sydney in conjunction with other Australian Universities would participate in programmes to the extent of available personnel and equipment. Compilation of data could be co-ordinated through Dr Packham's IGCP working group. Financial support would be required.

Dr Creighton Burk advised that the Texas Marine Science Institute is interested in participating in all aspects of the programme and specifically would contribute personnel and equipment for the seismicity project.

Dr Peter Dehlinger advised that the University of Connecticut Marine Sciences Institute is willing to participate in the marine geophysics programme to the extent of providing personnel and equipment.

Mr J. C. Mutter indicated the existence of suitable research personnel and facilities at the Australian Bureau of Mineral Resources and suggested the possibility of participation in some of the programmes.

The ORSTOM is interested in participating in many aspects of the programme and in particular will contribute scientific equipment and personnel to the seismicity project in the framework of the French National Programme.

7. Adoption of the summary report, the recommendations and the programme of research

The Workshop adopted the final report, the recommendations and the programme of research, the group expressed its sincere thanks to CCOP/SOPAC and IOC for jointly sponsoring the IDOE Workshop, in particular to IOC for providing the necessary financial support which enabled participation of a broad

cross section of the international scientific community. In taking note of the contribution of the host Government, the group thanked the Government of Fiji for providing the facilities and personnel which contributed immeasurably to the success of the workshop. The meeting also commended the plenary Chairman, Mr James Brodie, and Rapporteur, Mr Richard Murphy, for their invaluable contribution to the Workshop and particularly praised the work of the *ad hoc* Committee Chairmen and Rapporteurs in focusing deliberations and synthesising discussions. Finally, in recognizing the considerable efforts of the Organizing Committee, the group especially thanked Drs P. J. Coleman (Regional Geology) and G. P. Glasby (Manganese Nodules and Metalliferous Sediments) and Mr R. N. Richmond (Host Country Arrangements) for the excellent planning and preparations for the Workshop.

8. Closure of the meeting

The meeting was closed at noon on Saturday, 6 September 1975.

ANNEX I

AGENDA

1 Opening of the meeting.

2 Election of officers and adoption of agenda.

3 General review presentations by invited lecturers.

4 Specific geological problems and research interests.

5 Need for further work and plans for future investigations.

6 Organizational arrangements and recommendations for co-ordination and implementation of future work.

7 Adoption of the summary report, the recommendations and the programme of research.

8 Closure of the meeting.

ANNEX II

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ANNEX III

OPENING ADDRESS

His Excellency the Minister of Lands and Mineral Resources Mr Sakeasi N. Waganivavalagi

On behalf of the Government of Fiji, I extend to you our very warm welcome. It is indeed our rare privilege to welcome such eminent men and women of science to our shores.

You have travelled great distances from all parts of the world to participate in the International Decade of Ocean Exploration (IDOE) Workshop, jointly sponsored by the Commission for Co-ordination of Offshore Prospecting for Mineral Resources in South Pacific Offshore Areas — conveniently abbreviated CCOP/SOPAC – and the Intergovernmental Oceanographic Commission (IOC). This gathering augurs well for the future of international co-operation in exploring and exploiting the resources of the ocean.

Exploration and exploitation of the resources of the sea are not only capital-intensive, but they require a very high level of scientific skill and technology. Although our island homes are surrounded by vast stretches of the Pacific, some of us have little hope of harvesting the resources of the sea without international and regional co-operation because of the inadequacies of both capital and expertise. Your contribution in formulating the fundamental strategies for the projects with which CCOP/SOPAC will be involved during the international decade of ocean exploration, might prove to be the catalyst for more intensive activity in oceanic exploration in the South Pacific.

For small island nations in the Pacific, the ocean has been the source of livelihood and natural highway to the world beyond their shores. It has been the key element in our economic, social and political evolution. The international decade of ocean exploration is, therefore, of special significance to us.

Since Darwin, man's chief preoccupation has been the wresting of the secrets of earth's evolutionary history from the ocean. Recent scientific advances have added a new dimension to our expectations from the sea. In the face of depleting land-based resources, the future of life on this earth may depend on the success of scientific endeavours aimed at realizing our new found hope of exploiting the resources of the ocean. This workshop may make yet another tangible contribution towards that goal.

It was in 1972, shortly after our independence, that the inaugural conference of CCOP/SOPAC was held in Suva. This first IDOE workshop in the South Pacific, is a realization of a hope of those who initiated the formation of CCOP/SOPAC.

The member countries of CCOP/SOPAC are far removed from the traditional centres of intense and advanced oceanic research. For this reason, and the fact that the majority of our members are developing countries of the Third World, choice of priorities for developments have, of necessity, been confined to less capital intensive and fundamental areas of development. It is paradoxical that although the ocean has played a fundamental rôle in the lives of the people of the Pacific, and it has been the most dominant feature of our environment, we have not been able to either diversify much beyond our traditional patterns of exploitation of the resources of the ocean, or, intensify the exploitation of the resources which were the objects of our traditional preoccupation with the sea.

Perhaps the last quarter of the 20th century would be a phase of rapid technological advance. In this prospect is inherent a painful dilemma for the countries of the Third World. The prospects of bridging the ever-widening disparity of wealth and technology are becoming increasingly illusive. How will it be possible for us to satisfy the quest for the fruits of the modern technological age when even the most fundamental development aspirations of the Third World are frustrated by the phenomenal costs of depleting energy resources? – the threat of competing claims of rich nations whose capacity for consumption of those resources are ever-increasing and we are powerless to restrain? – the threat of pollution of our environment and the traditional sources of our food supply by nuclear explosion and release of lethal substances in our environment in the relentless pursuit of power?

Faced with such harsh realities, it is little wonder that some of us in the developing world have come to view "the giant stride" taken in the name of mankind with a degree of scepticism. We are now in an age when man is advancing beyond the confines of terrestrial search for wealth and power, and he is venturing forth into the vast world of space in the hope of yet greater technological superiority, and probably greater wealth and tactical supremacy. When some of us in developing countries reflect upon the history of centuries of frustration, and see around us how nations have been manipulated in the process of their scramble for that elusive bone of economic fulfilment, it is little wonder that the most well meaning gestures of would-be benefactors are viewed with some suspicion.

Somewhat chastened by those adversities, some of us in the Third World are now looking at our prospects with considerable trepidations. However, it was the cumulative force of these adverse experiences which led us to seek in international forums, the proper definition of our territorial sea boundaries, so that we may exploit the legacy of our own environment. These beliefs have guided us into forming regional and international organizations to tackle the world's pressing problems in a spirit of co-operation. I can think of no other more erudite group of people than an international gathering of scientists, to put in a plea for greater co-operation and understanding in bringing the fruits of modern technological society to the shores of the Pacific.

I will now briefly outline for you the progress we have made in offshore exploration. The International Decade of Ocean Exploration was launched in 1970 the year in which Fiji became an independent dominion within the Commonwealth. By then we had already granted special prospecting licences to mining companies for the exploration of offshore magnetite sands, and oil. The granting of mineral prospecting licences, both inland and offshore, is governed by our Mining Act and the granting of oil exploration licences is governed by an establishment agreement, which largely updates our oil mines act but all oil exploration licences have to be approved by the Government in the first instance. The policy of our Government has always been to encourage mineral and oil exploration in Fiji. As a developing country with virtually complete reliance on commodities, particularly sugar, for our foreign exchange earnings, we have pinned some of our hopes on mineral exploitation to lend much needed impetus to our development programme. Fiji is no exception to the common restraints caused by dearth of local expertise and capital, but in spite of these shortcomings we believe that we can still have mineral exploration in Fiji. To make this possible, our legislation is suitably flexible, and our guarantees adequate to attract potential investors into the country. When we grant an exploration licence, there is also an implicit guarantee that an exploitation right will be granted at the appropriate time, provided, of course, the companies are able to convince us that they have the necessary means to mine any area, and that they are willing to co-operate with the Government to ensure that any adverse environmental impact will be minimized. We believe that our policies are conducive to the promotion of independent prospectors to take an interest in Fiji. This is evidenced by the fact that about 11 large companies are actively exploring for porphyry copper in our island arc environment, and two mining taxation agreements have been signed with companies which have reached advanced stages of exploration.

Two oil exploration licences are still current. One in Bligh water, to the north of Viti Levu, and one to the east of Viti Levu. Both companies have carried out detailed geophysical surveys over the past few years, and it is hoped that they will be able to carry out some drilling in the coming year, for we know that it is only by drilling that you can prove the existence of an oil reservoir. We believe that if oil and gas can be shown to exist in Indonesia, Japan, the South China Sea and Tonga, then there are hopes that oil and gas can be shown to exist in Fiji waters as well. I know that your deliberations will be along similar lines and hope that you will throw some light on such prospects in the South Pacific. While the oil companies are busy with their own exploration programmes, our mineral resources division is also busy with the collection of marine data, and with the reinterpretation of oil company data to enhance and increase our knowledge and understanding of the marine environment. We realize there is still much to be learnt on the occurrence and distribution of manganese nodules, and of phosphorites and other marine deposits in economic quantities, and that special emphasis will have to be placed on these studies.

Let us now have a brief look at what is happening in the other South Pacific Islands. Most of the islands of the SOPAC countries are very small in size although large in numbers. Like Fiji, they are heavily dependent on commodities such as copra for their livelihood. Over the past few years the enormous fluctuations in the price of copra makes it a somewhat unstable source of income. As time goes on, and populations grow, land resources are bound to become even more scarce, and reliability on copra industry will become even more precarious in these little islands. Progressively they will have to become more and more reliant on the resources of the seas for their livelihood and their existence. They will not only have to depend on marine resources for their nourishment, but also perhaps for their power, water needs, and minerals for their foreign exchange earnings. If this hypothesis is accepted as a future probability, then there is an urgent need to ensure that the Law of the Sea Conference is successful in safeguarding their claims for control of marine resources over areas of reasonable national jurisdiction. You will be aware that Fiji itself has been strongly advocating the archipelago baseline principle, as a means of defining the extent of our jurisdiction of our Island areas.

The vast ocean area covered by the SOPAC countries is relatively unexplored. Most of the work

carried out in the South Pacific to date has been carried out by American Universities. With the limitations of finance, expertise and other priorities, it is unlikely that the developing South Pacific countries will be able to carry out their own exploration programmes by the next decade. We will have to continue to rely on the expertise, ocean going capabilities, and funding by other institutions, to enable us to carry out a proper inventory of our marine resources.

It is because no one country can afford to carry out a full offshore programme, and because we realize that we cannot afford to wait a decade or so to do so, that we have joined together in CCOP/SOPAC to explore the oceans as a joint programme. CCOP/SOPAC will have to rely on United Nations funding and institutions of other advanced countries and shiptime support, to get the programme underway. The aid of the IOC in providing this workshop is a start to this programme, and we hope that it will lead to a number of operational programmes which would help, not only the South Pacific countries to realize their aspirations, but also the scientific community, in better understanding the complex tectonic forces which make up our earth.

Ladies and Gentlemen, I hope that you will find sufficient time from your serious preoccupations of the workshop, to see and enjoy nature's more aesthetic attributes around our coastline and the delights of our city. Unfortunately I cannot recommend anything more exciting in the way of an oil prospect than the mysterious seepage of oil in our industrial Walu Bay area. Our geological capability was put to test during the seepage but I must confess we failed to find the source of the leakage. I must warn you that the Mayor of Suva may seek your assistance once he gets to know that an eminent group of geologists are meeting at the Tradewinds Hotel.

May I once again wish you every success in the serious deliberations ahead.

ANNEX IV

RECOMMENDATIONS

The CCOP/SOPAC-IOC IDOE Workshop puts forward the recommendations that follow with the objective of promoting national programmes and regional studies in geo-sciences, of which one of the major outcomes will be an enhanced ability to make resource assessments that can contribute to economic developments within the South Pacific region.

The joint CCOP/SOPAC-IOC IDOE Workshop on Geology, Mineral Resources, and Geophysics of the South Pacific:

(1) *Recommends* that the Chairman of the Workshop transmit for approval the Summary Report of the Workshop including recommendations and the Research Programme which has been developed by the Workshop, to the next session of the CCOP/SOPAC, to be held in Honiara, 8-17 September 1975, and to the Secretary of IOC for submission to the Commission at its next Assembly session, to be held in Unesco Headquarters, 20 October-4 November 1975;

(2) *Recommends* that CCOP/SOPAC take active measures to explore ways and means of implementing the Research Programme and to develop appropriate capabilities within the Technical Secretariat to enable full and active participation in all aspects of the Research Programme;

(3) *Recommends* that the Secretaries of CCOP/SOPAC and IOC bring the Research Programme to the attention of other intergovernmental and non-governmental organizations, such as IGCP, CMG of IUGS, ICG, and all international and national institutions, laboratories and scientists interested in the region, inviting them to consider the programme, and to make it known to the Secretaries in which project(s) they wish to co-operate, keeping in mind that the programme is a preliminary one which should be periodically updated; *and that* the Secretaries of CCOP/SOPAC and IOC develop particularly close co-operation with IGCP, CMG and ICG;

(4) *Recommends* that the IOC Assembly consider providing assistance to the region in the fields of data and information exchange, including arrangements for collection, storage, retrieval, and assessment; *and* draws the attention of participants in the research projects to the desirability of taking part in such arrangements;

(5) *Recommends* that the Division of Marine Sciences of Unesco, the IOC, CCOP/SOPAC and ESCAP give assistance in the fields of training, education and mutual assistance to the countries in the region which need this urgently to build up their infrastructure; *that* countries having sophisticated equipment and manpower make this available to countries in the region, if so required; *and that* governments of countries which have inadequate geological services and institutions give higher priority to the establishment and extension of such services and institutions;

(6) *Recommends* that the Technical Secretariat of CCOP/SOPAC contact appropriate overseas and local universities to establish joint educational programmes in earth sciences; *that* the joint programmes be worked out to the mutual satisfaction of all parties *but that* the programme take a form which incorporates the following elements:

(a) The degree candidate does resident study at both an overseas and a local institution;

(b) The degree field project be within the South Pacific region and oriented toward the scientific and economic needs of the region;

(c) The candidate have dissertation advisers from both the local and the overseas universities and that necessary travel funds for dissertation advisers be made available from appropriate funding organizations.

(7) *Recommends* that institutions which sponsor geological and geophysical research in the South Pacific provide opportunities for scientists from other institutions, particularly those in the region, to enable them to participate fully in these research projects on board research vessels and in the relevant land-based institutions;

(8) *Recommends* that the Technical Secretariat of CCOP/SOPAC, on behalf of the Workshop, transmit proposals for deep drill holes which have been formulated in the framework of the programme, to the appropriate panels of the International Programme of Ocean Drilling (IPOD);

(9) *Recommends* that governments of countries in the region facilitate the conduct of the field projects through adequate provision of visas, clearances, logistic support, etc.;

(10) *Recommends* that the sponsoring bodies of the programme, CCOP/SOPAC and its parent organization ESCAP, and the IOC and Unesco, as well as national institutions and foundations, consider giving support for the publication of the results from the above exercises;

(11) *Recommends* that the sponsoring bodies CCOP/SOPAC and IOC schedule, at an appropriate time, a review of scientific work accomplished arising from the recommendations and specific projects for this Workshop; this review preferably as a symposium-workshop to take place no sooner than 1978 but no later than 1980.

ANNEX V (1)

PROGRAMME OF RESEARCH

Report of Committee I: Problems associated with marginal and inter-arc basins

INTRODUCTION

The South-west Pacific rim is characterized by the presence of numerous marginal and inter-arc basins some of which are partly bounded by active convergence zones. The CCOP/SOPAC region, in particular, affords excellent examples of both active and inactive basins which are eminently suitable for studies directed towards an understanding of their origin and evolution. A major objective of this proposed programme of study is to increase our understanding of the geological and geophysical properties of these basins; to determine similarities or differences in their origin and evolution, and to evaluate their economic resource potential.

Our current understanding of marginal or inter-arc basin suggests that at least some of them are formed by upwelling of fractional melts of mantle material. Thus they entail fundamental magma leaks which, like oceanic spreading centres, act as major conduits for the upward transfer of mantle-derived material. Thus, these are also primary features in the process of crustal generation and consequently play a major role in the initial transport and concentration of certain metallic elements of economic importance. The extensional phase of marginal basins may, in some instances, be succeeded by a collapse phase. This could either involve thrusting of marginal basin crust on to land (obduction) or its underthrusting beneath a new arc (subduction). The latter implies a recycling of marginal basin crust, and reconcentration—locally to ore grade—of certain metals. Such a situation is today strikingly represented by the Solomons - New Hebrides region. Young, active marginal basins offer the best opportunities to study unaltered basaltic crust, to look for brine or metalliferous mud accumulations and to map geophysical data such as heat flow and magnetic lineations.

Marginal and inter-arc basins are also potential traps for arc or continent-derived sediment which, in view of the thermal fluxes typical of active basins, may provide potentially favourable sites for the accumulation and maturation of hydrocarbons. Other basins may have formed by rifting in areas lacking vulcanism or high thermal flux in the adjoining areas. Studies are needed of both relatively older but still active basins as well as those which are inactive in

order to evaluate the tectonic and sedimentary histories of rocks which are potential sources and reservoirs for hydrocarbons. Studies of actively growing basins and their margins may lead to the development of models relating changes in lithofacies distribution and in thermal regimes to stages in the evolution of the basins. These models should prove useful to petroleum exploration in regions bounding older marginal basins where thick sedimentary sequences and high thermal fluxes in early stages of their evolution have provided environments favourable for the formation, accumulation and maturation of hydrocarbons.

The marginal and inter-arc basins are important features on the South-west rim of the present Pacific Ocean. It seems probable that they existed on the margins of ocean basins in the past. It is important to know their chemical and physical properties in order to understand their origin and to recognize their remnants in the orogenic belts of islands and continents. Some ophiolite belts may contain fragments of marginal basin lithosphere and some of the metal-enriched basal sediments of ophiolite suites may have formed at magma leaks in the marginal basins. The origin of many of these basins seems to be closely related to the plate convergence processes which characterize island arcs. Studies will of necessity be closely integrated with proposed studies dealing with the active convergence zones of the Melanesian Border land and the fossil convergence zones of the Fiji Platform. In addition, the active marginal basin studies will complement the proposed metallogenetic studies directed towards understanding the origin of metalliferous sediments.

OUTLINE OF PROPOSED STUDIES

The proposed studies may be divided into four phases:

(1) Data search and compilation.

(2) Field programme.

(3) Data reduction, evaluation and synthesis.

(4) Preparation of final report and dissemination.

An extensive data search probably is not necessary as much of it already exists in data banks at Scripps Institution of Oceanography, Hawaii Institute of Geophysics, Lamont-Doherty Geological Observatory, Woods Hole Oceanographic Institution, New Zealand Oceanographic Institute, Australian Bureau of Mineral Resources, ORSTOM, CNEXO and the Fiji Mineral Resources Division. It is also assumed that relevant oil company data would be available for inspection.

Compilation of these data and pre-cruise planning might involve from 6 months to one year lead time prior to the cruise. The international aspect of the programme would require one or more pre-cruise planning meetings of principal investigators, cruise chief scientists and participants from CCOP/SOPAC countries. Except for the longer-term Lord Howe Rise—Kermadec Rise transect, the proposed field programme would involve approximately eight cruise legs each one about a month long. In terms of economy of ship operation this would best be accomplished as a single major expedition. Concurrent work on both metallogenesis and the convergent margin programme would be included, and the whole CCOP/SOPAC expedition would probably involve approximately 12 to 14 months of ship operations. An important part of the field programme is the participation of personnel from CCOP/SOPAC countries as co-investigators and as trainees both in marine operations aboard ship and in subsequent data reduction and interpretation.

FIELD PROJECTS

The field projects are directed towards the study of both active and inactive basins. There are at least four actively spreading basins in the region—Lau, North Fiji (Fiji Plateau—see map Annex VIIIA), Woodlark and Bismarck. Available data suggest that although all share a common feature—namely the upwelling of basaltic material to form new oceanic crust—they exhibit marked differences in terms of tectonic setting and mode of origin. Proposed studies of inactive basins include the Coral Sea and a transect across the Lord Howe Rise to the Tonga Kermadec Ridge crossing the New Caledonia, Norfolk and South Fiji Basins.

The Committee proposes the following projects:

Active basins

Field Project 1-1: Active Basins:
Study of the Lau Basin

The Lau Basin has been the object of intensive study and is fairly well known in terms of its bathymetry, the geophysical properties of its crust and deeper mantle, and the petrology of its crustal rocks. There are models to explain its origin which are based on the proximity of the Tonga Trench subduction zone and on mantle counter-flow which is postulated in the deep mantle beneath the basin. Critical data required include a gravity survey and an upper mantle deep crustal seismic refraction study using sonobuoys and ocean bottom seismometers. These surveys should also include additional heat flow studies to broaden the data base for thermal modelling and to look for possible areas of hydrothermal circulation, together with conventional seismic reflection profiling. Additional rock and sediment samples are needed especially on the margins of the basin close to the Lau and Tonga Ridges. Selected areas on the Lau and Tonga Ridges need to be studied in order to compare surface exposures of rocks on the islands with the offshore units. The basin also seems well enough known to justify using the SIO Deep Tow instrument to study ridge morphology and to make near-bottom magnetic surveys. Three one-month cruises are planned for the Lau Basin.

Field Project 1-2: Active Basins:
Study of the North Fiji Basin

The North Fiji Basin is an extremely important feature which acts as an area of dilation between opposing convergent zones, the Tonga and New Hebrides trenches. The opposing trenches are separated by transform fault boundaries which are postulated to form the north and south margins of the active basin. In as much as the Lau Basin is spreading slowly (approximately 1 cm/yr half rate) the North Fiji Basin must have a much more rapid rate of opening (approximately 4.5 cm/yr half rate) to maintain the observed geometric and kinematic configuration between the trenches. It is important to note that while the Lau Basin is situated above a deep Benioff Zone (250-350 km), there is no such relationship for the central part of the North Fiji Basin. Maximum depths for the New Hebrides Benioff Zone are about 350 km but these deep focus earthquakes lie well to the west of the mapped and postulated spreading centres of the basin. Knowledge of the geology of the basin and the available data is sufficient to permit framing of tectonic hypotheses for future testing. It is proposed to conduct an extensive survey in the area between 13-22°S and 170-176°E in which continuous bathymetric, magnetic, seismic reflection and gravity profiles will be made. Rock dredging, sediment sampling and heat flow measurements will be made at suitable sites. Crustal refraction data will also be needed. Two one-month cruises are planned.

Field Project 1-3: Active Basins:
Study of the Bismarck, Solomon, and Woodlark Basins

These three small basins lie in a complex region of small plates as revealed by the seismicity. The Bismarck Basin has been surveyed extensively, there are excellent earthquake data to help recognize plate boundaries and a kinematic model based on magnetic anomaly data as well as the earthquake, gravity and bathymetric data has been proposed. Heat flow and petrologic data are needed and some additional magnetic lines are needed to test this model.

Preliminary geophysical data and petrologic data exist for the Woodlark Basin and a model for its geometry and origin has been proposed. More magnetic data are needed to test this model. The Solomon Basin is not well enough studied yet to allow development of a model for its origin. It is proposed that all three basins be studied concurrently and, because of their close proximity to the western end of the Melanesian Border study, the work should be closely integrated with the island arc study programme. These basins are critical to our proposed study because they offer an opportunity to compare basins having different ages of lithosphere and sediment cover and to compare the effects of their subduction, and the subduction of an active marginal basin ridge, under the adjacent (Solomon) island arc. The Solomon Basin Plate is being consumed in the Solomon Trench and the 3 m year old porphyry copper deposit at Panguna on Bougainville lies above this subduction zone. The active spreading centre in the Woodlark Basin is being consumed in the subduction zone beneath the New Georgia group and immediately above it occurs high temperature hydrothermal activity and sub-ore grade copper deposits.

Knowledge of these basins is also critical to an understanding of the tectonic features which lie to the southwest. The Solomon Basin needs to be considered in terms of its possible tectonic relationships to the onshore geology of the Papuan ultramafic belt and to be tied in with existing oil company data on Papua-New Guinea and the adjoining shelf. The kinematic history of the Woodlark Basin is important to an understanding of the regional tectonic framework especially in the area towards the east Coral Sea and towards the Pocklington Trough which may be an abandoned trench. The Bismarck - Solomon - Woodlark Basins area surveys would require two one-month cruises.

Inactive basins

Field Project 1-4: Inactive Basins:
Geophysical studies in the Coral Sea including multichannel reflection profiling.

The Coral Sea is fairly well mapped in terms of bathymetry, magnetic profiling, seismic refraction profiling and seismic reflection profiling. In addition, there are 2 DSDP holes in the basin and another one on the nearby Queensland Plateau. The basin originated in Eocene time and has accumulated up to 1 km of sedimentary fill. Nearly half of this is Miocene and younger. There has been an extensive survey of the shallow southern margin (Queensland Plateau) and northern margin (Papuan Plateau) of the Coral Sea Basin by BMR and it is proposed to extend this survey into the deep ocean basin itself and to the basin's deeply submerged eastern margin.

The major goal for the Coral Sea Basin programmes is to map its basement structure by reflection profiling, additional magnetic profiling and sonobuoy crustal refraction. Because of the thick and opaque sediment cover on the basin margins (in excess of 1 km and possibly up to 4 or 5 km) there is the strongest justification for using multichannel seismic equipment and digital processing of the data. In contrast to the presently active basins described above, the Coral Sea Basin may be due to rifting apart of older crust leaving "Atlantic margin" type boundaries. There is no indication that the basin formed behind a volcanic arc or was located above a subduction zone. If it was formed by rifting, there should be symmetric distribution of rifts and tilted fault blocks on both the southwest (Queensland) and northeast (Papua New Guinea) sides of the basin. Rift valley structures of this type of upper Cretaceous to Paleocene age may prove to be favourable hydrocarbon reservoirs and source materials as do rocks in a similar tectonic setting on the Australian northwest shelf and would be of potential economic importance in this area too. A one-month cruise is needed in the Coral Sea Basin.

Field Project 1-5: Inactive Basins:
Lord Howe Rise – Kermadec Tonga Ridge Transect

The transect from the Lord Howe Rise to the Kermadec Tonga Ridge crosses the New Caledonia Basin, Norfolk Ridge, northern Norfolk Basin, Loyalty Island Ridge, Three Kings Rise, the South Fiji Basin, Lau Ridge, Lau Basin, and the Kermadec-Tonga Ridge. The survey area will link on the west with the BMR survey of the Australian shelf and will cover an area in which 3 DSDP holes have been drilled; one on the Lord Howe Rise and two in South Fiji Basin. This proposal complements the proposed IPOD transect. A full range of geophysical profiling and geological sampling techniques will be applied, together with heat flow determinations.

The Lord Howe Rise is a mid-basin platform interpreted as a fragment of continental crust rifted from Eastern Australia during the late Cretaceous-Palaeocene Tasman Sea opening. The New Caledonia Basin is a long, narrow feature with thick sedimentary fill. It may have been formed at about the same time as the Tasman Sea. A DSDP hole was drilled at its southern end. The Norfolk Ridge links New Caledonia and New Zealand, having folded late Palaeozoic to mid Mesozoic sediments as its basement. In both of the areas of outcrop on the ridge there is evidence for obduction of sea floor in Oligocene. This strongly suggests that the Pacific-Indian plate boundary was located here for a time during the Oligocene. The Norfolk Basin, the Loyalty Island Ridge and the Three Kings Rise are features whose nature and genesis are poorly understood. The South Fiji Basin is a piece of oceanic crust accreted onto the present Indian plate during Eocene to Oligocene time. Some north-south magnetic lineations have been recognized in the eastern portion of the basin, but no kinematic model has been proposed for its formation. Cases can be made for either symmetrical or asymmetrical sea floor spreading. The northern part of the basin has rough basement topography draped with what is interpreted as Eocene volcanogenic sediments. The troughs have been filled with Miocene volcanogenic sediments derived from the Lau Ridge. In the southern part of the basin the sediment has been derived from New Zealand. The crest of the Lau Ridge has been largely built of Miocene volcanic rocks and sediments. The Tonga Ridge is similar and has Eocene basement exposed on 'Eua. The Lau Basin has been discussed previously. This transect crosses the Lau Basin at its junction with the Havre Basin, its southern counterpart.

This broad transect would make it possible to build up a regional understanding of the successive accretions that have occurred on the eastern margin of the Indian Plate. A spectrum of basin types and morphology is intersected as well as a variety of ridges bounding them. The ridges comprise an old continental block, a fold belt and an island arc complex. The transect also enables us to examine in detail the rifted contacts between the marginal seas and blocks of adjacent thicker crust. The study of the Oligocene convergent plate boundary on the Norfolk Ridge will shed light on the kinematics of the region and in general some of the processes of crustal thickening in orogenic zones.

The rifted continental blocks (Lord Howe Rise and Norfolk Ridge) in the area are future potential targets for hydrocarbon exploration. The understanding of these structures afforded by this transect would permit an evaluation of this potential.

Initially the investigations would involve a four-month programme of underway seismic, gravity and magnetic observations along lengthy traverses plus heat flow determinations, coring and rock dredging. After a preliminary assessment of the data, a series of more detailed surveys would be made during a second phase of investigations.

ANNEX V (2)

PROGRAMME OF RESEARCH

Report of Committee 2: Convergent margins

INTRODUCTION

We do not now know enough about the South Pacific to do more than recognize its importance in solving many fundamental problems about the evolution of the Earth. We do not yet have enough detailed data to actually solve these problems. We believe that continued, carefully directed and co-ordinated studies will not only enhance our basic understanding of the earth's evolution, but will also provide a basis for evaluating the future economic potential of the South Pacific — including both mineral and petroleum resources as well as potential for geothermal development and prediction of earthquakes and tsunamis. The aspects which we consider to be unique to the South Pacific are as follows.

A unique opportunity is available to study the composition and deformation of inner trench walls which are not obscured by a prism of accreted sediments. The sharp boundaries between the volcanic arcs and adjacent marginal seas are also uniquely developed in the South Pacific. One of the largest transform boundaries is also present in this region — the "Melanesian Borderland"—extending from New Guinea eastward to the Tonga Trench. This complex zone has close relationships to active exposed oceanic crust, active and ancient subduction, major ore deposits, hydrothermal occurrences and petroleum and geothermal potential.

The abundant seismic activity of the South Pacific provides the opportunity to study spatial and temporal variations in Benioff zones. This is fundamental to the concept of plate tectonics, and may allow us to make the next major advancement in tectonic understanding. The seismicity also provides the opportunity to study the nature of more local deformation as well as possible prediction of destructive earthquakes, volcanism and tsunamis.

The compressional tectonics of convergent zones has been described at length, but the South Pacific offers the opportunity also to study the related and poorly known vertical tectonics. The possible significance of fundamental longitudinal fractures is also apparent; not only as they may result from crustal convergence, but also as they may have controlled it.

Apparent ancient convergent zones, such as the Fiji-Lau trend, are also known, offering opportunities for studying the spatial and temporal evolution of convergent areas. The very important problem of the tectonic emplacement of oceanic crust ("ophiolites") onto non-oceanic crust can also be studied broadly and in detail in the South Pacific.

Petroleum occurrences are known in both active and inactive convergent zones. Petroleum seepages are known in the South Pacific (e.g. Tonga), and several exploration wells have been drilled throughout the region. Mineral occurrences include porphyry copper ore deposits and prospects, volcanogenic vein-type and stratiform base metal deposits, gold and manganese vein mineralization, gold placers, magnetite beach sands, bauxite deposits and lateritic nickel. An improved understanding of the regional geology and geological history will serve to stimulate and increase the effectiveness of mineral and petroleum exploration efforts.

PROJECTS

With the preceding considerations in mind we recommend that a group of basic projects be undertaken in the South Pacific. We have divided these into categories:

(1) *Compilation Projects (Regional Data and Syntheses Projects)*, which basically require encouragement and centralized focus;

(2) *Special Projects,* which initially will be undertaken as part of the Field Projects, but which are important enough to require special recognition, and;

(3) *Field Projects,* which may require co-ordinated and concerted efforts. Only the first two in this category turned out to be entirely newly proposed; the other two recognize and support the importance of present or planned programmes.

Of the two new studies, only the first (Melanesian Borderland, p. 44) requires major new and continued funding. The second (Fiji Platform, p. 45) will require assimilating and supplementing existing data on a more moderate basis. The third (Tonga-Lau, p. 46) and the fourth (Terminus of Kermadec Trench, p. 47) generally require only the support of existing or new programmes.

Compilation Projects

Compilation Project 2-1:
Regional data and syntheses

We consider each of the following topics to be critical to proper regional study of the South Pacific. Each inherently involves four stages of development:

(1) Collection of available data,

(2) Obtaining new data from available rock or other collections,

(3) Obtaining new collections for new data, and

(4) Analysis and dissemination of the synthesis in whatever form is most appropriate.

We recommend in each instance that the CCOP/SOPAC Technical Secretariat recognize and invite appropriate institutions, groups or individuals to see that the objectives of these programmes are accomplished.

Data distribution (Ship tracks, maps and charts): It is obviously important to know the location and nature of existing data and compilations throughout this region. Compilations of marine data have already been made at several oceanographic institutions, showing tracks of all academic and institutional ship cruises and the nature of the geophysical data collected, as well as the location of bottom samples. Similar information from private companies should also be added. We believe this can be done without difficulty.

Maps should also be prepared to show the location of published maps and charts of geology, geophysics, bathymetry and all other data pertinent to an understanding of the geology of this region.

Bathymetry: Accurate bathymetric maps are fundamental for all regional and local studies. It is proposed that existing information be compiled and contoured at a scale of 1:5 000 000, to serve as a base map for regional compilation and planning. (The South-west Quadrant map already being compiled for the Circum-Pacific Map Project could be adopted for this purpose.) The map should be updated as more information becomes available, and should be augmented by the preparation of more detailed maps at standard scales (1:1 000 000; 1:250 000) in areas of special interest.

Provenance of basic rocks: This project seeks to develop criteria for distinguishing basalts of the ocean floor, ocean islands, marginal basin floor and island arc volcanoes. Application of these criteria to South-west Pacific islands is essential to any regional synthesis and will complement attempts to genetically classify mineral occurrences (see below).

In the first place, chemical and mineralogical characteristics of basalts from known sources will

be established. This will involve the compilation of existing data followed by further sampling and analysis. Having established criteria, these will be given practical application in problem areas such as 'Eua (Tonga). Malaita (Solomons), and Pentecost (New Hebrides).

Mineral occurrences: A compilation of metalliferous occurrences and their geological setting would provide a basis for the classification of these occurrences, point to areas where further exploration is warranted and form a framework for further research into the spatial and temporal relationships between mineralization, volcanism and arc developments.

This compilation would largely derive from existing publications and files of government and industry, but may involve further investigation of any mineral occurrences which are inadequately known. The initial compilation would be made publicly available as quickly as possible with a view to stimulating exploration.

Sedimentary basins: The areal distribution of sediments in the region is important to the occurrence of petroleum and certain other mineral resources. Obviously, a knowledge of the age, thickness and distribution of sediments is critical to interpreting the geological history of the South Pacific region.

Broad, general maps showing the thickness and distribution of sedimentary basins throughout the region can be compiled with little difficulty from the geophysical data already collected in the region. If sediments less than 1 km thick above acoustic basement are eliminated, the task would not be difficult and the distribution of basins would be obvious.

This also meets part of the objectives of the Circum-Pacific Mapping Project, and the results would appear on the South-west quadrant of that series.

Paleomagnetism: Paleomagnetic studies permit the reconstruction of the history of movement (linear or rotational) of any body of magnetic rock. They are thus an essential tool in establishing the tectonic evolution of the region, which is, in turn, vital information for mineral and petroleum exploration.

A programme of work is required which encompasses systematic studies of existing data, as well as obtaining new data. The value of the data will be enhanced by accurate age control by radiometric and paleontologic methods (as noted below).

Radiometric dating: Probably the greatest single obstacle to full understanding of the geological evolution of the region, and hence of its mineral and petroleum potential, is the sparsity of accurate age information. It is proposed that this problem be resolved by the compilation of all existing data and by the selected collection of new data. New K/Ar dating equipment and personnel may be needed in the region.

Special Projects

There are two projects which we consider to be of unique importance to convergent zones in the South Pacific: one regarding seismicity and one relating to ophiolites. We expect that the initial objective will be carried out as an inherent part of various field projects, but the results should then be applied elsewhere in the South Pacific.

Special Project 2-2: Energy release and seismicity

The project seeks to undertake a series of interrelated studies which have as a common theme the release of seismic and heat energy. Such studies are especially appropriate in the South-west Pacific region, which is one of the most active seismic and volcanic regions in the world.

Benefits: In terms of immediate human benefits the project will seek to accelerate and expand current efforts in earthquake and volcanic prediction, including the tsunami warning system, and to accelerate investigation and development of geothermal power.

Scientific studies include studies of mineralizing solutions in present-day thermal areas, accurate delineation of magma chambers and of the structure and geometry of the Benioff Zone, and determination of accurate location of foci and focal solutions.

Work to be done:

(1) Geothermal measurements would be undertaken to locate new areas of potential geothermal power both on islands and at sea. This work would be an extension of existing and planned work on selected islands, as Efate Island, New Hebrides, Fiji, and the Solomon Islands.

(2) Earthquake and volcanic prediction. This requires the installation of an array of sensitive high-frequency seismometers on selected islands and on the ocean bottom, and also of tiltmeters to measure ground tilt, tide gauges and bench marks to determine secular changes in elevation, strain meters and magnetometers.

(3) Seismicity studies along Benioff Zones. The South-west Pacific is an ideal location for investigating the configuration and fine structure of these zones, down to their maximum depths. A network of ocean bottom seismometer (OBS) stations should be installed along selected trenches in conjunction with stations on islands and trench slopes. These studies should also provide information on the location of magma chambers, their sizes and possible migrations. At the smaller scale, it should be possible to use dense OBS and landstation networks to study the smaller fractures which may be either associated with or independent of magma chambers; the OBS stations would also be used in conjunction with marine crustal refraction surveys.

Ties with other work and existing projects: The proposed work would be closely tied in with the field projects of the Melanesian Borderland, the Fiji Platform, the Lau-Tonga Transect, the Kermadec Terminus, and the various basin projects in this overall programme.

Some work is being conducted jointly on predicting earthquakes in the New Hebrides by the Cornell University Group and the ORSTOM. Also, the Bureau of Mineral Resources (Canberra) is studying volcanic eruptions in the New Britain area.

Earthquake prediction in parts of the U.S.A., Japan, China and the USSR has been a high-priority programme for some years and has met with considerable success. Because of high seismicity in the South-west Pacific, a large prediction programme could be established.

Recommendations: The CCOP/SOPAC Technical Secretariat should set up a group of specialists promptly to develop the details of specific programmes relating to energy release, in particular with regard to prediction and seismicity studies.

The work now underway in the area should be expanded at the earliest possible time. Important results may be anticipated within a few years of initiation of the programme.

Special Project 2-3:
Ophiolite recognition and tectonics

Benefits: As known carriers of nickel, chromium, copper and platinum ores, the oceanic ophiolite suite needs recognition wherever possible. In addition, an understanding of the tectonic environments in which ophiolites have been emplaced may make it possible to define or even predict areas in the South-west Pacific that are suitable for intensive prospecting for this metalliferous oceanic suite.

Work to be done:

(1) Detailed field and geophysical studies to determine relationships between members of the ophiolite suite and their mode of emplacement (including gravity, magnetic, refraction, and structural and stratigraphic mapping).

(2) Petrological studies of the rocks and associated ore deposits in terms of mineral chemistry, petrographic and petrofabric characteristics and major trace element and isotope studies.

(3) Age determinations of all members of the ophiolite assemblage and associated ores to determine ocean crust age, origin of the ores, the timing of tectonic events, and correlation between various South-west Pacific ophiolites.

(4) Evaluation of the economic potential of each ophiolite mass in terms of primary concentrations of metals in both the igneous and sedimentary members, or in terms of secondary reconcentration caused by the process of emplacement.

(5) Comparison of South-west Pacific ophiolites with other described examples which have also originated as obducted slabs, as island arc crust, as intruded solid slivers, or within marginal basins, or from known ocean floor sites.

Ties with other projects: Similar projects are known for North Auckland, New Caledonia and Papua-New Guinea as major investigations on obducted sheets, and for solid intrusions in New Caledonia. In particular, the New Caledonia work needs additional facilities for close-inshore geophysical surveys (magnetic, seismic, gravity) in shallow water inside the Great Reef. Other smaller projects are proceeding in the Solomons and New Hebrides on presumed ophiolite occurrences, but all of these projects need to be expanded, collated and assessed.

This ophiolite project is an essential part of the proposed Melanesian Borderland study. Results from that area could be extrapolated to ophiolite occurrences elsewhere in the South-west Pacific.

Recommendation: It is recommended that CCOP/SOPAC assemble a group of specialists who should define precisely the parameters for recognition of ophiolite suites and their tectonic settings, and to define specific field programmes.

Field Projects

Field Project 2-4:
Melanesian Borderland

The Melanesian Borderland denotes the Bismarck Archipelago, Bougainville, the Solomon Islands, the Santa Cruz Group, and the en-echelon-disposed submarine horsts and grabens from Santa Cruz east to the termination of the Tonga Trench. Considered as a broad swath, it is the boundary between Pacific and Indo-Australian plates. It is a region of great complexity on large and small scale.

Within the project are examples of complex fracture systems on large and small scale, anomalous arc features (e.g. Solomon Islands), zones of puzzling seismicity, supposed subduction zones lacking subduction products, supposed arc reversals, chaotic bathymetry, disrupted old plate boundaries, unusual "ophiolite" occurrences, and other aspects worthy of individual study.

Benefits to be derived:

(1) Petroleum. The project area already has been a target for petroleum exploration and drilling. Significant new information may encourage further industry exploration.

(2) Minerals. The Panguna mine and the presence of other geologically similar intrusions mark the region as an important porphyry copper province. Systematic prospecting has identified onshore and offshore gold, bauxite, massive sulfides, lateritic nickel, chromite, manganese, rare earth, asbestos, and magnetite deposits. Interpretation of regional and local tectonics will guide future exploration.

(3) Geothermal energy. High heat flow areas may provide a viable domestic alternative to imported energy sources.

(4) Earthquake and volcano eruption prediction. Prediction studies are well advanced elsewhere in the world and their local application is important to this seismically and volcanically active region.

(5) Survey co-operation and technical training. The

project requires co-operation from the existing geological surveys at least of five South Pacific countries or territories. It will provide stimulus and training for their personnel in scientifically important and sophisticated programmes.

(6) Scientific results. The manifest scientific benefits which will accrue from this project (see Introduction) are coincidental and complementary to the aims of economic development.

Work to be done:

(1) Collate and review existing marine and land geological and geophysical data and so pinpoint and allot priorities to specific areas and aspects.

(2) Seismically define existing fault zones and plate boundaries by accurately locating earthquake foci and systematically determining focal mechanism solutions.

(3) Prepare a detailed bathymetric map of the region, concentrating on the Santa Cruz Island to Samoa sector.

(4) Geophysical work:

(a) In the Santa Cruz Island to Samoa sector obtain detailed gravity, heat flow, magnetic and reflection data. Obtain refraction profiles parallel and perpendicular to the plate boundary.

(b) North-west of this sector, obtain above data to fill in gaps in existing data, e.g. gravity to the north of Bougainville. Where possible, reflection profiles should be continued sufficiently close to shore to permit correlation with existing studies of on-land strata.

(c) Obtain refraction and gravity data to assess submarine extensions of the Papua-New Guinea ophiolites.

(5) Investigate magma characteristics in this tectonic environment by obtaining comprehensive geochemical data for all recent volcanic centres (e.g. Choiseul, Solomon Island), from islands, seamounts and sea floor between Santa Cruz and Niuafo'ou Island, from the sea floor north and south of the Vitiaz Trench, and from older portions of exposed islands.

(6) Relate chemical and structural characteristics of ore deposits within the region to the foregoing data.

Ties with other projects:

(1) Data collation and plate boundary definition are partially being done now by external institutions and by an IGCP project based at Sydney University.

(2) Other proposed projects with high relevance include the Fiji Platform, Lau Basin, North Fiji Basin, and Woodlark Basin Field Projects, and the basalt provenance, radiometric dating, and ore and ophiolite syntheses projects.

Time-frame: Present activities within the area should continue for at least a few years. With speedy and persistent implementation of the project, significant results at the disciplinary level will come forth within a year. After three years a preliminary synthesis should be possible. Final syntheses should emerge in 5 to 7 years.

Recommendations: It is urged that every effort be made to fund every aspect of the project which is intensely inter-disciplinary and the aspects of which are interlocking. It also is urged that CCOP/SOPAC establish a working group as soon as possible to define practical details and logistics of the project.

Field Project 2-5: Evolution of the Fiji Platform

Benefits: Provides an excellent opportunity to study rotational tectonics and to further the understanding of the development of convergent arc systems by viewing such a system in an intermediate stage, and to help resolve part of the evolutionary history of the area between the New Hebrides and Tonga Trenches.

Several examples of Kuroko, massive sulphides, and porphyry types of mineralization as well as manganese, bauxite, and phosphate occurrences are known to exist in the islands. Petroleum exploration is already underway in various parts of the Fiji Platform. From the project, the prediction of the locus of economic concentration of metal sulphides and hydrocarbons associated with the convergent arc systems should be possible. The project may also help in the exploration of the land and offshore geothermal potential of the area.

Work to be done:

(1) Seismicity: Data available are mostly deep-focus earthquake studies by the Lamont-Cornell groups, and shallow-focus earthquakes north of the Great Sea Reefs and off south-eastern Viti Levu. Shallow earthquake studies are needed on the Fiji Platform and Rotuma, including first-motion studies, to determine whether areas are still detectably active; to determine the locus of possible ancient subduction zones and to search for data to check possible rotational movement.

(2) Seismic Refraction: Data available are only sparse reconnaissance sonobuoy refraction lines. Detailed refraction data are needed, including tied refraction studies between Viti Levu and Vanua Levu, Vanua Levu and Lau, Viti Levu and the Yasawa Islands, and on the Great Sea Reef. These data will determine crustal structure between the islands, define the major WNW fault inferred from magnetic data and determine basement characteristics in Great Sea Reef.

(3) Bathymetry and Seismic Reflection: Fairly detailed data are available in Bligh Water and Western Koro Sea. Gaps yet to be covered are south in Viti Levu, north and east of Vanua Levu, and around Yasawas and Lau-Koro Sea. Such work will increase knowledge of platform and basement structure and possible control of basement and platform development and may locate potential trap structures for hydrocarbons.

(4) Gravity and magnetics: Aeromagnetic coverage with line spacing from 1 mile over land to 30 miles over sea now exists. Some gravity stations exist on Viti Levu and Vanua Levu, together with a few traverses across the islands. A detailed NW-SE aeromagnetic regional survey is needed and more detailed gravity surveys on islands and Great Sea Reef. Indications of crustal and basement structure will be greatly improved by these data.

(5) Paleomagnetics and Radiometric age dating: About 12 paleomagnetic analyses are available but with poor age data. Detailed sampling of all types and ages of rocks is needed, including K/Ar dating. These studies are obviously critical to determine temporal migration and rotational movements.

(6) Heat Flow: Three heat flow measurements in drill holes are available, and some measurements of temperatures in thermal springs. Added measurements in offshore areas adjacent to onshore geothermal spring localities are needed to determine the thermal history and regime of the area and possible relation to hydrocarbon development.

(7) Associated magmatism and metallogensis: There is some published evidence of island arc volcanic suites, but more detailed work, with attention to different bodies, and to compositional variations of multiple intrusions are needed, with concomitant laboratory studies (metallographic). This should help to establish the relationship between composition of volcanic suites and tectonic setting; to establish the locus of ancient arcs and spatial relationships with present platforms and to determine sulphide mineral association with compositional varieties of plutonic or volcanic rocks.

(8) Geological: Fairly good 1:50 000 geological maps of most islands have been published but completion of geological mapping of Lau and Kandavu is important. Geomorphological studies are needed, and reinterpretation of geological units and structures in light of geophysical data should be done.

(9) Drilling: Deep holes to basement are needed on Great Sea Reef and Lau Ridge, and also in basin areas (these may have to be by encouragement to private companies to complete drilling down to the basement in some cases).

Ties with other objectives and projects, and time frame: Study the evolution of an arc system through time. The area is partly subaerial and partly submerged, but the submerged portion is within probing reach of geophysical tools, and very good geological maps are already available.

The evolution of the Fiji Platform is intimately tied with the evolution of the Tonga and New Hebrides Trench systems. Thus the study is associated with the Melanesian Borderlands Study and the Energy Release and Earthquakes Project. Some parts of the project could begin immediately and should be fully operational within 18 months, with significant results available in 2 years. A regional synthesis should be possible in 5 years.

Recommendations: The CCOP/SOPAC Technical Secretariat should invite expert scientists mutually and promptly to define details of the programme. All details of this project, except for those specified for private organization, should be funded fully.

Field Project 2-6: Tonga-Lau Transect

Benefits: Important parts of the new objectives described in the Introduction can be studied only in this project. Ultramafic and mafic rocks which may be ophiolites have been dredged from the inner wall on the Tonga Trench. These may represent exposed oceanic crust, and their position suggests that these basement rocks are not obscured by a wedge of accreted sediments, as is the case in most convergent zones of the world. Careful drilling into this inner trench wall would teach us much about the composition and structure of this important geological feature.

Similarly, drilling into the crust of the Tonga Ridge would determine the age and composition of the basement in this region. Two wells have been drilled for petroleum exploration into the sediments on this ridge, but the character and age of the basement are still unknown.

Sampling of acoustic basement on the Lau Ridge, a presumed ancient convergent zone, would then allow comparisons between adjacent active and inactive convergent zones. Such drilling on the Lau Ridge would also provide extension of the detailed work to be done under the Fiji Platform Field Project of this programme.

Drilling to determine the nature and age of the basement underlying the intervening Lau Basin and in the oceanic crust adjacent to the trench would then permit a spatial and temporal reconstruction of the evolution of convergent zones through this transect. These are all major objectives as noted in the Introduction.

Work to be done: It is obvious that the principal work to be done in this project is the drilling of a series of deep ocean core holes. The objectives described above are also the objectives of part of a longer traverse being considered by the International Programme of Oceanic Drilling (IPOD).

However, much preliminary work must be done prior to drilling, part of which is also being considered by IPOD. This includes detailed site surveys and a broad geophysical network at least 50 km wide along the transect in order to tie the drilling sites together and to put them into a reasonable regional framework.

In addition to the obvious geophysical surveys, efforts should be made to collect data from nearby exposed rocks and to collect bottom samples wherever possible.

Existing projects: Obviously, this transect is part of the objectives of a possible IPOD programme of drilling and related geophysical studies. If selected by them as a planned project, drilling would begin

about 1978 and work would be completed in several months. However, preliminary and important results would become available as soon as the geophysical studies were started.

Recommendations: The Committee strongly recommends to IPOD the importance of the Tonga-Lau Transects in understanding the geological evolution of the South Pacific and to solving many fundamental problems of geology in general.

Field Project 2-7:
Southern Tonga-Kermadec Trench Terminus

Benefits: Objectives are to learn about the unique tectonic environment which controls the termination of an oceanic trench, i.e. passage from an active ocean-continent boundary into an inactive boundary along the same trend.

There are fundamental geodynamic problems related to vertical tectonics and major longitudinal fracture zones and the problems related to the complete change of associated geophysical characteristics (gravity anomalies, Benioff Zone). The study of the structure and deformational history of the adjacent fold belt may provide evidence for the age of the formation of the oceanic trench system.

There is undisputed hydrocarbon potential in the longitudinal fold belt with thick sediments parallel to trench, both north and south of its termination. The profound change in structure and tectonic history of this belt appears associated with the trench termination. Thus the assessment of this hydrocarbon potential will greatly benefit from an understanding of the overall tectonics in the area of the trench termination.

Work to be done: Detailed bathymetry and multichannel seismic reflection profiling, refraction, gravity and magnetics, and bottom sampling must be done, particularly over basement highs immediately south of termination of the trench as well as on the East Cape Ridge. Also needed are heat flow measurements, some of which have already been obtained under CCOP/SOPAC project CCSP-1/NZ.2, while many offshore seismic, magnetic and gravity data are available from oil company surveys. These are presently under study by the Geophysics Division and Geological Survey, DSIR, New Zealand and preliminary compilations of gravity and structural maps have already been prepared. Extensive geological data including many drill logs of deep wells drilled for oil exploration in the adjacent fold belt, provide valuable additional information already available.

Ties with other objectives of projects: Definition of Indian-Pacific plate boundary south of Tonga-Kermadec Trench, and type and location of the continental margin to the east of New Zealand.

Projects CCSP-1/NZ.2 and 3 (CCOP/SOPAC Third Session 1974) both cover parts of this project. Additional work is being carried out, and planned, by the New Zealand Oceanographic Institute, the New Zealand Geological Survey, and the Geophysics Division, DSIR, New Zealand.

Work is presently underway and results are expected to come forth within the next 1-3 years, while an overall synthesis should become available in about 5 years.

Recommendations: We recognize this project as being of great importance and regional significance, and strongly encourage the respective New Zealand Government Institutions and Universities to pursue it with all possible means.

ANNEX V (3)

PROGRAMME OF RESEARCH

Report of Committee 3: Metalliferous sea floor deposits

FIELD PROJECTS

The Committee on metalliferous sea floor deposits of the South Pacific recommends that the following field projects be implemented:

Manganese nodules

Field Project 3-1: Manganese Nodules:
Manihiki Plateau

The plateau should be studied because it is an area of strong topographic contrast showing high but variable contents of manganese nodules and crusts. Study of this region will lead to an evaluation of the complex factors controlling the distribution of manganese deposits in a plateau environment (in particular the role of nucleating agents and bottom currents) and to the nature of cobalt enrichment in such regions.

Field Project 3-2: Manganese Nodules:
Ontong Java – Ellice Basin

A transect is needed from the Ontong Java Plateau to the Ellice Basin, centred at 170°E, 8°S. This would enable a comparison to be made with other plateau environments such as the Manihiki Plateau.

The basin lies beneath a high productivity zone which would enable comparison with nodule areas from the high productivity zones of the Equatorial North Pacific. The region is adjacent to volcanic seamounts and hydrothermal activity associated with fracture zones.

Field Project 3-3: Manganese Nodules:
Cook Islands – Tuamotu Transect

The transect should be made to enable a detailed survey of a region of strong topographic contrast encompassing high (up to 2.23%), but variable, cobalt contents. The survey area extends across basins between the Cook Islands Group and the Tuamotu Archipelago, permitting an evaluation of these basins as a source of ore-grade nodules. The study would also enable a comparison to be made with nodule deposits of the Hawaiian Archipelago.

Field Project 3-4: Manganese Nodules
Marquesas Fracture Zone Transect

A transect is needed crossing the Marquesas Fracture Zone, permitting an investigation of the distribution of manganese nodules and crusts across a fracture zone. The transect reaches the southern limit of the equatorial high productivity zone, permitting a comparison with the high productivity zone of the Equatorial North Pacific. Nodules with nickel content as high as 1.90% have been reported from the region.

Field Project 3-5: Manganese Nodules:
West Limb, East Pacific Rise

A transect is needed at 42°S extending from the South-western Pacific Basin at 140°W to the axis of the East Pacific Rise at 112°W. This is an area of extremely low terrigenous sedimentation due to the great distance from land. High nodule abundance (almost complete coverage of the sea floor) has been recorded in this region. The nickel content of the nodules varies from 0.7% in the deeper parts of the basin to 1.5% on the flanks of the Rise. The transect gives an opportunity to study the change from a high density nodule province in the basin to a possible zone of metalliferous sediments on the crest of the Rise.

Metallogenesis

Field Project 3-6: Metallogenesis:
Platform Kuroko-type deposits

Geoscientists should survey platform regions around island arcs in an attempt to locate potential massive sulphide deposits in pyroclastic sediments (Kuroko-type deposits). Such areas may include the region north of Vanua Levu (Fiji) and Efate and Epi (New Hebrides).

Field Project 3-7: Metallogenesis:
Submarine volcanoes

Geoscientists should survey active submarine volcanoes around island arcs in order to examine the effects of submarine discharges. This investigation should include chemical studies of rocks, sediments and bottom waters associated with volcanism. Examples of such regions include Kavachi and Cook volcanoes off the Solomon Islands and Epi, Eromanga, Ambrim and Tana off the New Hebrides.

Field Project 3-8: Metallogenesis:
Vella Lavella Graben, Solomon Islands

Geoscientists should study metal dispersions in marine sediments around the Vella Lavella Graben, extending several kilometres offshore. This project will involve a consideration of the relation between heat flow and chemical characteristics of the sediments.

Field Project 3-9: Metallogenesis:
Shallow water bauxites

Geoscientists should survey the shallow water bauxites forming in the vicinity of andesite volcanoes such as these found at Waghina and in the New Georgia group in the Solomon Islands. The bauxites contain over 40% Al_2O_3 as gibbsite and are of possible economic value.

Field Project 3-10: Metallogenesis:
Geothermal fluids

Geoscientists should investigate geothermal fluids to examine their role in metallogenesis, especially that of porphyry copper deposits. Regions to be surveyed could include Vella Lavella and Guadalcanal. The surveys should include isotopic studies (e.g. deuterium and oxygen isotopes) as well as inorganic species.

Metalliferous sediments

Field Project 3-11: Metalliferous Sediments:
Focal points

Regions for particular emphasis in studies of metalliferous sediments are the Lau Basin, Woodlark Basin, Solomon Basin, Bismarck Basin, and North Fiji Basin.

COMPILATIONS

The Committee on metalliferous sea floor deposits in the South Pacific recommends that the following regional compilations be made.

Compilation Project 3-12:
Existing data

The CCOP/SOPAC Technical Secretariat should compile all data on heat flow, core location, sediment mineralogy and chemistry, and pertinent geophysical data. The data base of all relevant nations should be consulted.

Compilation Project 3-13:
Sediment analysis of existing samples

A small group of specialist scientists with expertise in the area of metalliferous sediments as well as

knowledge of the tectonics of the region be formed which would evaluate the compiled data base. This group would examine samples which, although they have been collected, have not been completely analyzed. This evaluation would identify key areas where appropriate analysis of existing samples could be beneficial to our understanding of the area or recommend which area or areas might be suitable for further sampling or the initiation of a metalliferous sediment programme.

Compilation Project 3-14:
Existing data on manganese nodules

A small group of specialist scientists should be formed to communicate co-ordinate and organize research activities of the Manganese Nodule Project. These scientists should continue compilation of data for upgrading of existing charts and atlases on nodule fields and properties. This should also extend to compilation of data on underlying sediment chemistry. Also included is the evaluation and analysis of samples available and not previously described.

DISCUSSION, BACKGROUND, AND RESOURCE POTENTIAL

Manganese nodules

Present knowledge of manganese nodules suggests that prediction can be made with respect to occurrence and metal content. The South Pacific Ocean provides an excellent setting to test many of the theories of nodule origin. Testing of the theories will simultaneously yield data on the genesis and resource potential of nodules occurring in the South Pacific. Field work will be carried out in areas where no nodule data now exist as well as in areas where considerable information is available.

Several factors which must be evaluated as they relate to nodule occurrence and composition are:

(1) Sediment accumulation rates,
(2) Bottom current velocities (erosion),
(3) Availability of potential nuclei,
(4) Input of metals by surface water biotic processes,
(5) Tectonic setting,
(6) Nature and age of deposit substrata.

There are specific regions in the South Pacific where these five factors can be evaluated, compared and/or contrasted either amongst themselves or with other more thoroughly studied regions such as the North-eastern Equatorial Pacific and Indian Oceans.

Sampling programmes will be designed to provide the necessary specimens of:

(1) Nodules.
(2) Sediments.
(3) Bottom and interstitial waters.

All stations will be carried out using standardized sea-going and laboratory techniques to ensure internal consistency and comparability in quantifying the resulting data. Determination of abundance, physical characteristics (e.g. size distribution, weight, water content) and chemical composition of nodules is essential for both a fundamental understanding of nodules as well as their potential for resource exploitation.

Requirements for manganese nodule studies

Although several companies have conducted regional surveys for manganese nodules in the South Pacific, all have apparently opted to concentrate their future efforts on North Pacific areas. In order to attract commercial activities into the South Pacific, it seems necessary for scientific investigations to show the possible existence of deposits which might rival those to the north. This can only be accomplished by what amounts to prospecting promising regions and providing industry with data which can be used to evaluate an area and, if warranted, justify expenditure of funds for survey work in the region.

A comparison of data generally collected by scientific cruises researching the origin of nodules and industrial surveys aimed at obtaining information related to commercial exploitation reflects, in many cases, the different purposes for which it is to be used. If it is the intent of future cruises to provide industry with the required information, it is recommended that provision be made for modifying techniques in order to develop the following data:

Regional prospecting or ore reconnaissance

Multiple sampling and analyses of nodules from single sites.

Estimates of nodule abundance.

Bathymetry using narrow beam echo sounding.

Surveys of promising areas

Continuity of nodule grade over an area.

Nodule size distribution and physical properties (important to the design of nodule mining systems and in estimating nodule abundance from bottom photographs).

Nodule/sediment relationships (for design of pick-up system).

Sediment properties (trafficability).

Bathymetry and obstacles (for estimating mineable areas and development of mining plan).

Nodule abundance and continuity of population.

Nodule mineralogy (important for evaluating processing techniques).

Determination of accessory gangue material such as volcanic debris within the total sample, the nodule, and the sediment.

Prospects for exploitation of manganese nodules

An attempt has been made to evaluate the contribution that manganese nodules are likely to make to the world supply of the metals they contain. The pace and extent to which manganese nodules will be exploited depends primarily on four factors: technological research and development, the economics of both deep-sea mining operations and world metal markets, the extent of the resources and reserves, and the legal regime that will apply to the areas in which the nodules occur.

The main outstanding technological problem is the mining (that is, nodule recovery) system. There is reason to believe that this problem will be solved provided that there is an incentive to invest the major capital needed for the further research and development programmes.

As far as can be inferred from the information available, the cost of recovering nickel from deep-sea manganese nodule deposits is likely to be comparable to that of recovering nickel from medium-cost nickeliferous laterites. The scale of manganese nodule mining will be dictated by the extent to which they help to meet the predicted increase in world demand for nickel. Nodules will contribute only a very small proportion of the copper likely to be needed in the future. The role of cobalt and manganese may be larger.

Despite the very inadequate published data, it is possible to identify "prime areas" in which the average grade and abundance of nodules is higher than elsewhere. It was suggested that in all oceans there may be a total of about 7 million square kilometres of prime area. Perhaps two-thirds of this prime area contains nodules with more than 2.25% combined nickel and copper and as little as one-third may have an average abundance of 10 wet kg/m^2. Very tentatively, it is suggested that only about 20% of the prime area may contain both the necessary grade and abundance, leading to the possibility that the maximum mine site area may be only about 1.5 million km^2. It is emphasized, however, that other criteria must also be met. The number of mine sites capable of supporting a 3 million tonnes (dry) a year operation for 20 to 25 years might therefore be between about 30 and 50. Recoverable potential reserves of copper, nickel, cobalt and manganese in these sites would be of the same order of magnitude as the known reserves on land.

Metalliferous sediments

Background

Metalliferous sediments are characterized by anomalously high concentrations of Fe, Mn, and some other transition metals and anomalously low concentrations of aluminium compared to typical pelagic sediments. These sediments are presently found on active spreading centres, with perhaps the best examples being the sediments underlying the hot brines of the Red Sea and the sediments found near the crest of the East Pacific Rise. They also occur in the fossil record as the basal sediments directly overlying basement in many Deep Sea Drilling Project sites and as the metal-rich sediments overlying basaltic portions of some ophiolite sequences, such as the ochres and umbers of the Troodos deposit.

The observation that these sediments are associated with spreading centres and volcanism led some time ago to the suggestion that these deposits were the result of volcanic exhalations. There is a growing body of data that suggests the mechanism of enrichment of metals in these sediments can be more precisely stated as the result of circulation of sea water through cooling submarine basalts. The evidence for sea water hydrothermal systems is geophysical, chemical, and isotopic, as well as experimental, and these systems are now thought to be the main mechanism for removing heat from the cooling lithosphere, leaching metals from the crust, and an important means of altering oceanic rocks. When hot, metal-laden sea water enters normal, oxygenated bottom water, Fe and Mn hydroxides and oxides form, and a variety of minor metals are coprecipitated in the process. With this model in mind, the distribution of metalliferous sediments can be viewed as revealing the effects of water hydrothermal systems.

On the Nazca Plate for example, there are two major regions where metalliferous sediments are accumulating today:

(1) near the crest of the East Pacific Rise and
(2) within the Bauer Deep, a basin which lies between the now extinct Galapagos Rise and the East Pacific Rise.

The East Pacific Rise deposits lie above the carbonate compensation depth and are therefore diluted with varying amount of biogenous carbonate. The Bauer Deep deposits lie below the carbonate compensation depth and consequently, contain no biogenic carbonate. In addition there are other distinct chemical and mineralogical differences between the two deposits. The Bauer Deep deposits contain higher concentrates of Ni, Co, Ba, Al and rare earth elements compared to the East Pacific Rise deposits, which are relatively enriched in Fe, Cu, and Zn. The East Pacific Rise sediments are dominated by X-ray amorphous iron hydroxides, while Bauer Deep sediments contain abundant iron-rich smectite.

It is clear that the East Pacific Rise deposits are hydrothermal deposits linked to the volcanism along the spreading centre. The origin of the Bauer Deep sediments, however, is not as clear since these deposits do not occur in an area of known present-day volcanism. While it is possible that local volcanic sources of sediment exist within the Bauer Deep, the low accumulation rate of metals measured within this region and the distinctive composition can be explained by transport of some metalliferous components from the East Pacific Rise accompanied by the addition of some authigenic precipitation of minor elements from sea water. Because the Bauer Deep is a deep basin, relatively close to a spreading centre and in a region of very low detrital and biogenic deposition, the conditions of formation of this type of deposit may be rather rare. The degree of enrichment of the East Pacific Rise deposits is probably linked to the fact that this region has the most rapid spreading rate in the world and dilution of hydrothermally produced sediments by detrital and biogenous sediments is relatively low.

South Pacific

Good scientific reasons exist for studying metallogenesis associated with submarine hydrothermal

activity within the marginal basins. This environment was probably the locus for formation of many of the metalliferous sediments and massive sulphide deposits associated with obducted ophiolite deposits and it is likely that these deposits are being formed at present within the inter-arc basins of the South-west Pacific. Important differences may exist between the processes forming the metalliferous sediments in these deposits compared to the processes forming the metalliferous sediments on open-ocean spreading centres. For example, the production of local reducing environments, due to the utilization of oxygen by the hydrothermal system, may be more probable in the marginal basins. This could lead to the formation of sulphide phases not found in mid-ocean ridge metalliferous sediments and to different processes of concentrating metals.

With the existing data base, however, it is not clear which areas in the region might be most profitable for study. Some justification exists for believing marine hydrothermal systems presently exist within the Lau Basin, the Fiji Plateau and the Woodlark Basin. Other regions of known submarine volcanism such as those in the Solomon Islands and Tonga-Kermadec Ridge may also have associated hydrothermal systems. It is the view of this Committee, however, that substantial questions exist as to which specific areas are the most promising for research at this time. For example, some of the suggested inter-arc spreading centres cannot clearly be delineated by the available data, and although heat-flow data is available, there are no systematic compilations for the entire region. Also, while some coring and sediment composition data exist for the region, these data should be re-evaluated in light of what is presently known about marine metalliferous sediments.

Metallogenesis and ore formation

The genesis of ore deposits in island arc areas depends on the composition of source-rocks and the remobilization of heavy metals by hydrothermal and partial melting processes. Processes of formation of ore deposits in island arc terranes (e.g. Japan) have been deduced from detailed geological mapping and geochemical processes inferred to have taken place in submarine and fumerolic environments. The South Pacific region provides a unique setting for studying present-day mineral-forming processes which are only recorded elsewhere in the world in the stratigraphic columns. Field work recommended in specific areas of the South Pacific will greatly extend our understanding of geochemical processes leading to the formation of economic deposits of manganese, copper, and perhaps zinc, nickel and cobalt.

In the vicinity of present day island arc chains in the Solomon Islands and New Hebrides Islands, oceanic lithosphere carrying significant concentrations of dispersed heavy metals is subducted and partially melted at great depths in the earth. Heavy metals from the oceanic lithosphere or overlying mantle are transported in magma or hydrothermal fluids towards the earth's surface through calc-alkaline and andesitic strato-volcanoes. Here complex chemical processes involving leaching of the heavy metals by seawater seeping through the submarine volcanic pile take place, leading to the precipitation of manganese, iron and copper near the surface. There are several specific places in the South-west Pacific where these late-stage mineral-forming processes may be observed and studied directly.

ANNEX VI

LIST OF SCIENTIFIC PRESENTATIONS

1. **Regional syntheses and reports**

L. W. Kroenke	Evolution of deep ocean basins in the South Pacific.
G. H. Packham	Geology of South-west Pacific marginal basins.
J. Hawkins	Tectonic and petrologic contrasts between the Tonga arc—Lau basin—Samoan chain.
H. L. Davies	A geological and tectonic synthesis of Papua New Guinea.
P. J. Coleman	The Solomons as an aberrant arc.
J. Mutter	Coral Sea basin and Queensland plateau.
D. Falvey	Arc reversals and a tectonic model for the North Fiji basin.
J. Gill	Spatial and temporal correlations in volcanism in Fiji.
F. I. E. Coulson, R. N. Richmond, P. Rodda, L. W. Kroenke	Structure of the Fiji platform.

H. R. Katz	Tonga ridge sediments: tectonic setting and relation with the Lau basin.
S. Tongilava	Structural interpretation of two profiles across the Tonga ridge.
R. N. Brothers	On land ophiolites, North Auckland.

2. **Special papers**

R. N. Brothers	Obduction models for the South-west Pacific.
R. G. Burns	Metallogenesis of transition elements at convergent plate margins in the South Pacific.
R. W. Murphy	Petroleum in island arcs.
G. R. Taylor	Styles of mineralization and recent volcanic exhalative activity in the Solomons.

3. **Manganese nodules**

J. E. Andrews	Manganese deposits in the Pacific.
G. H. Friedrich	Manganese micronodules in deepsea sediments and their relation to manganese nodule fields.
T. Moritani	Some results of surveys for manganese nodule deposits by the Geological Survey of Japan.
M. A. Meylan	A comparison of the morphology and mineralogy of manganese nodules from the South-west Pacific basin and the North-east equatorial Pacific.
D. S. Cronan	Preliminary results of renewed manganese nodule investigations in the Indian Ocean.
A. A. Archer	The prospects for the exploitation of manganese nodules: the main technical economic and legal problems.

ANNEX VII

AD HOC COMMITTEE PARTICIPANTS

Committee 1: Marginal and inter-arc basins

W. Bullerwell **Chairman**
J. W. Hawkins **Rapporteur**
E. M. Davin
P. Dehlinger
D. A. Falvey
H. R. Katz
B. Lynas
J. C. Mutter
A. G. Obermuller
G. H. Packham
P. Rodda
J. Reinemund
L. W. H. Taylor

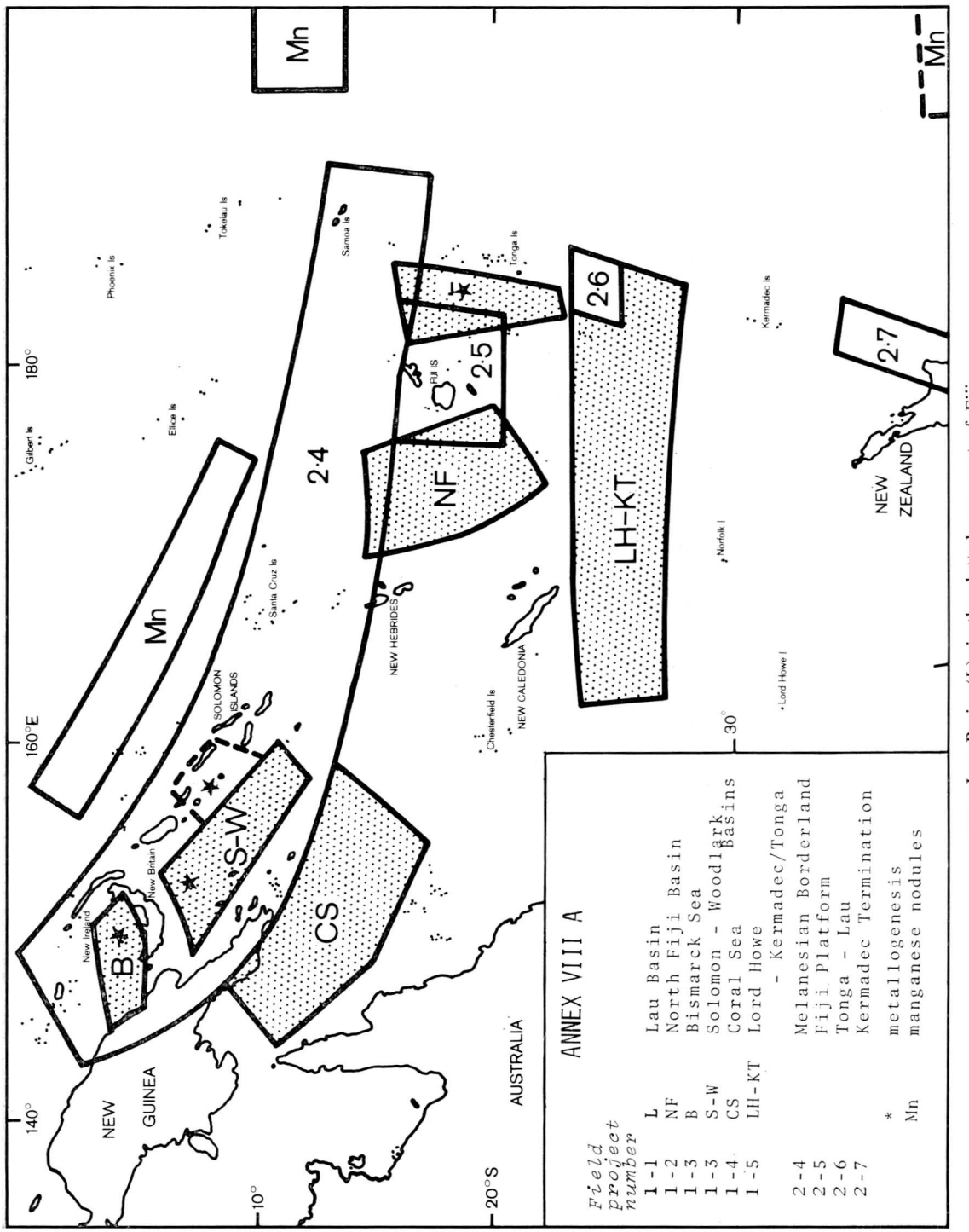
Committee 2: Convergent margins

C. A. Burk **Chairman**
H. L. Davies **Rapporteur**
R. N. Brothers
P. J. Coleman
F. Coulson
P. Dehlinger
J. Dubois
J. B. Gill
D. Hase
H. R. Katz
M. J. McDonald
S. P. Meyer
A. G. Obermuller
B. Rao
J. A. Reinemund
R. N. Richmond
S. L. Tongilava

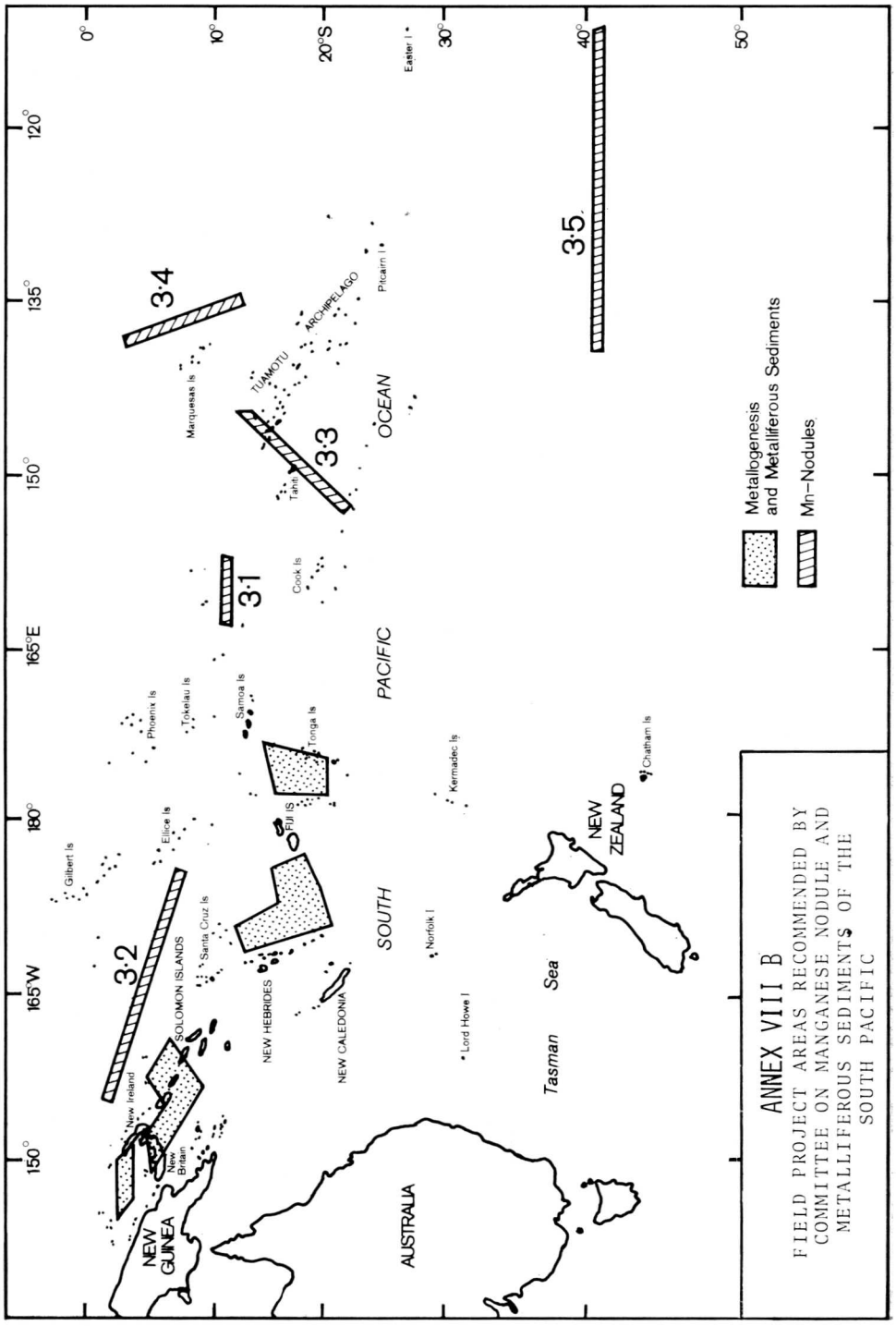
Committee 3: Metalliferous sea floor deposits

J. E. Andrews **Chairman**
G. P. Glasby **Rapporteur**
A. A. Archer
W. A. Brook
R. G. Burns
H. Colley
G. Cowan
D. S. Cronan
F. W. Dickson
J. Dymond
G. Friedrich
J. Greenslate
F. Inoke
S. G. Kingan
A. MacDonald
M. A. Meylan
T. Moritani
P. Muller
A. G. Obermuller
D. Pasho
H. Plummer
G. R. Taylor
G. H. Sawtell

ANNEX VIII



NOTE: Lau Basin (L) is the dotted area east of Fiji


150°
165°W
180°
165°E
150°
135°
120°
0°
10°
20°S
30°
40°
50°
3·2
3·4
3·1
3·3
3·5
NEW GUINEA
New Ireland
New Britain
SOLOMON ISLANDS
Santa Cruz Is
Ellice Is
Gilbert Is
Phoenix Is
Tokelau Is
Samoa Is
Tonga Is
Fiji IS
NEW HEBRIDES
NEW CALEDONIA
Norfolk I
Lord Howe I
Kermadec Is
Cook Is
Tahiti
TUAMOTU ARCHIPELAGO
Marquesas Is
Pitcairn I
Easter I
SOUTH PACIFIC OCEAN
Tasman Sea
AUSTRALIA
NEW ZEALAND
Chatham Is
Metallogenesis and Metalliferous Sediments
Mn-Nodules
ANNEX VIII B
FIELD PROJECT AREAS RECOMMENDED BY COMMITTEE ON MANGANESE NODULE AND METALLIFEROUS SEDIMENTS OF THE SOUTH PACIFIC

ANNEX IX

LIST OF MAPS ON DISPLAY

1 Geological map of British Solomon Is. (1:1 000 000) BSIP, 1969.

2 Location of Marine Geophysical Reconnaissance in the British Solomon Is. (1:1 000 000) (unpublished), BSIP.

3 Sedimentary Isochron Chart of the Ontong Java Plateau Between the Ocean Floor and Basaltic Basement, 2 sheets —Kroenke HIG, 1972.

4 Bathymetric Chart of the Ontong Java Plateau North of the Solomon Is. 1970, Kroenke HIG, 1972.

5 Rotuma Bathymetry (1:1 000 000) Cullen, NZOI, 1974.

6 Kandavu Bathymetry (1:1 000 000) Cullen NZOI, 1975.

7 South Fiji Basin—Bathymetry, Terrell and Packham, University of Sydney, 1974.

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