Intergovernmental Oceanographic Commission
Workshop report No. 9

Report of the Second International Workshop on Marine Geoscience

held under the sponsorship of
the Intergovernmental Oceanographic Commission (of Unesco)
the Scientific Committee on Oceanic Research (of ICSU)
the Commission for Marine Geology (of IUGS)

Mauritius, 9-13 August 1976

Unesco

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The Scientific Workshops of the Intergovernmental Oceanographic Commission are usually jointly sponsored with other intergovernmental or non-governmental bodies. In each case, by mutual agreement, one of the sponsoring bodies assumes responsibility for publication of the final report. Copies may be requested from the publishing bodies as listed below or from the Secretary, IOC, Unesco, Place de Fontenoy, 75700 Paris, France.

No.	Title	Publishing Body	Languages
1.	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia [Report of the IDOE Workshop on]; Bangkok, Thailand, 24-29 September 1973. UNDP (CCOP), 158 p.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English
2.	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974. (Unesco Technical Paper in Marine Science, No. 20).	Division of Marine Sciences, Unesco, Place de Fontenoy 75700 Paris France	English Spanish
3.	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974.	IOC, Unesco, Place de Fontenoy 75700 Paris, France	English French Spanish
4.	Report of the Workshop on the Phenomenon known as "El Niño", Guayaquil, Ecuador, 4-12 December 1974.	FAO 00100-Rome Italy	English Spanish
5.	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February, 1975.	IOC, Unesco, Place de Fontenoy 75700 Paris, France	English Spanish
6.	CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	IOC, Unesco, Place de Fontenoy 75700 Paris, France	English
7.	Joint IOC/FAO(IOFC)/Unesco/EAC Seminar and Scientific Workshop to initiate planning for a co-operative investigation in the North and Central Western Indian Ocean (Nairobi, Seminar 25-27 March, Workshop 25 March - 2 April 1976).	IOC, Unesco Place de Fontenoy 75700 Paris, France	Full text (English only) Extract and recommendations - French Spanish Russian

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No.	Title	Publishing Body	Languages
8.	Joint IOC/FAO(IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters (Penang, 7-13 April 1976).	IOC, Unesco Place de Fontenoy 75700 Paris France	English
9.	IOC/CMG/SCOR Second International Workshop on Marine Geoscience (Mauritius, 9-13 August 1976)	IOC, Unesco Place de Fontenoy 75700 Paris France	English French Spanish Russian
10.	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring (14-18 June 1976, Monaco)	U.S. Government Printing Office Washington D.C.	English*
11.	Joint IOC/FAO(WECAFC)/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions	IOC, Unesco Place de Fontenoy 75700 Paris France	English Spanish

* the report and recommendations (but not the presented papers) will be issued in French, Spanish and Russian later.

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Workshop report N°6

SUMMARY REPORT

SECOND INTERNATIONAL WORKSHOP ON MARINE GEOSCIENCE

(Mauritius, 9-13 August 1976)

1. Opening of the Meeting

The meeting was opened by Mr. John David Ardill, Divisional Scientific Officer (Fisheries), on behalf of the Government of Mauritius. The Deputy Secretary of the IOC, Dr. Günter Giermann, welcomed the group in the name of the three sponsoring organizations, IOC of Unesco, SCOR of ICSU and CMG of IUGS. He thanked the Government of Mauritius for hosting and organizing the meeting. The Group acknowledged with appreciation the considerable financial contribution made by the Division of Marine Sciences of Unesco, and the US-IDOE Office of the National Science Foundation, Washington DC. A list of participants is attached as Annex II.

2. Arrangements for the meeting

The Deputy Secretary speaking in the name of the sponsoring organizations proposed Dr. Manik Talwani (USA) as Chairman of the meeting and asked whether there were any objections. Dr. Talwani was elected unanimously.

The Secretary then introduced the Provisional Agenda, which was adopted without change (See Annex I).

Four Working Committees were established by the Chairman as follows :

(a) Evolution of Oceanic Lithosphere (Committee Chairman : J. Ewing)

(b) Passive Margins (Committee Chairman : M.H.P. Bott)

(c) Active Margins (Committee Chairman : D. Hussong)

(d) Marine Sediments (Committee Chairman : E. Seibold)

3. Programme development

3.1 State of implementation of exercises 4.1 to 4.11 of the International Workshop on Marine Geoscience, Honolulu, 20-24 September, 1971.

The representatives of IOC and CMG introduced the documents made available to the Workshop by the IOC, CMG, USA (Office of the IDOE) and IGCP (of Unesco/IUGS). Dr. T. Gaskell, President CMG, was requested to summarise these documents and to take into account comments received by the Workshop. His final report is attached as Annex V.

3.2 Recommendations for continuation or finalization of existing exercises

The matter was discussed partly under item 3.1, and partly under item 4, by the four Working Committees established under item 2. Recommendations are therefore contained in the reports in Annexes IV and V.

3.3 Marine geoscience mapping in the framework of the Commission for the Geological Map of the World

The Secretary of CMG introduced a document on Marine Geoscience Mapping in the Framework of the Commission for the Geological Map of the World, prepared by the Secretary-General of the Commission for the Geological Map of the World (CGMW), of IUGS. He informed the Workshop that CGMW seeks the co-operation of marine scientists in order to :

- complete the continental thematic (geological, structural, tectonic, etc.) maps with data on the submerged areas,
- compile and publish maps covering the submerged areas which are not on the continental maps,
- compile information on the submerged areas for the maps with world-wide coverage.

The Secretary of CMG informed the Workshop that the Secretary-General of CGMW intends to create a special Sub-Commission (which would group together representatives of the major marine science institutions), to enable marine scientists to make the fullest use of their data. A first meeting of the Sub-Commission is scheduled to be held in Sydney, in conjunction with the International Geological Congress (August 1976). It is suggested that, inter alia, editorial committees will be formed for each ocean (or any sub-area), a convenor be designated for the preparation of a draft for the Tectonic World Wall Map (1:15 million), and a legend be proposed for the geological and tectonic maps.

The Workshop welcomed the initiative taken by CGMW, and recommended its support.

4. Consideration of new ideas for advancing the frontiers of marine geoscience

In order to implement this item, the Chairman had decided, as stated in item 2, to establish four Working Committees on the main subjects of interest : the evolution of the oceanic lithosphere, passive continental and active margins, and marine sediments, with particular emphasis on the sea-seabed and land-sea interfaces.

Two and a half days for discussion and programme drafting were allowed to each Group before the Final Programme was adopted (see Annex IV).

The Workshop adopted several recommendations addressed to the three sponsoring organizations of the Workshop, the Division of Marine Sciences of Unesco, the IGCP of Unesco, IUGS, etc., inviting them, inter alia, to draw the attention of Member States to the new Programme, to assist, in particular developing countries, in order to make their collaboration in the Programme possible, and to provide support for workshops, in particular regional ones, with the aim of further developing details of the Programme.

The recommendations are attached as Annex III).

5. Adoption of the final report including recommendations

The Workshop adopted the final report, with all its annexes, including recommendations and the Programme.

6. Closure of the meeting

The meeting closed at noon on Friday 13 August 1976.

ANNEX I

Second International Workshop on Marine Geoscience

Mauritius, 9-13 August 1976

AGENDA

1. Opening of the meeting

2. Arrangements for the meeting

3. Programme development

    3.1 State of implementation of exercises 4.1 to 4.11 of the International Workshop on Marine Geoscience, Honolulu, 20-24 September 1971

    3.2 Recommendations for continuation or finalization of existing exercises

    3.3 Marine geoscience mapping in the framework of the Commission for the Geological Map of the World

4. Consideration of new ideas for advancing the frontiers of marine geoscience

5. Adoption of the final report including recommendations

6. Closure of the meeting

ANNEX II

Second International Workshop on Marine Geoscience

Mauritius, 9-13 August 1976

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ANNEX III

Second International Workshop on Marine Geoscience

Mauritius, 9-13 August 1976

RECOMMENDATIONS

The Second International Workshop on Marine Geoscience,

1. Recommends that the Secretary of the Intergovernmental Oceanographic Commission bring the Programme which has been developed by the Workshop to the attention of Member States and the appropriate subsidiary bodies of the IOC, the Division of Marine Sciences of Unesco, the Scientific Committee on Oceanic Research (SCOR) of ICSU, the Commission for Marine Geology (CMG) of IUGS, the International Geological Correlation Programme (IGCP) of Unesco and IUGS, the Engineering Committee on Oceanic Resources (ECOR), other intergovernmental and non-governmental organizations, all international and national institutions, laboratories and scientists interested in marine geoscience, inviting them to take into account the recommendations and proposals made by the Workshop when preparing their own future international, national or institution programmes, keeping in mind that the programme is a firm guideline for the next three years, and a recommended working basis for the decade to come, to increase fundamental knowledge of the land-sea interface, of the geology beneath the ocean floor, and of global geological processes, which are indispensable in improving the accuracy of location of mineral and hydrocarbon resources.

2. Recommends that the Division of Marine Sciences of Unesco and the IOC give assistance in the field of training, education and mutual assistance in the marine sciences to countries wishing to participate in the Programme established by the Workshop, with particular attention to developing countries which need urgent aid to build up their infrastructure; that countries having sophisticated equipment and manpower, make this available to other countries, if so requested; that institutions which sponsor geological and geophysical research, provide opportunities for scientists of developing countries, to enable them to participate in the planning and implementation stage of cruises under this Programme; and that countries, in general, facilitate the conduct of research recommended at the workshop, as concerns the provision of visas, custom and research clearances, logistic support, etc.

3. Recommends that Unesco, the IOC, and national institutions and foundations, consider giving strong support to regional and topical workshops to develop further the Programme proposed by the workshop, and for the publication of proceedings, maps, atlases, bibliographies, etc. resulting from the research conducted under the recommended Programme.

4. Recommends that the sponsoring bodies, IOC, SCOR and CMG, as well as other bodies interested in marine seismology, encourage international and inter-institutional collaboration to enable seismological experiments to be carried out which are beyond the resources of individual scientists and institutions.

5. Calls attention to the importance of carrying out concentrated investigations across passive margins to determine (a) sediment structure, (b) nature and location of the continent-ocean boundary, and (c) deeper structure, emphazising in particular the need for much more extensive deployment of multi-channel seismic reflection techniques, and for development of ocean bottom seismological and other equipment for long-term recording;

   Recommends that IOC with the assistance of SCOR and CMG, develops a programme to study the passive margins of the Indian Ocean;

   Recommends further that SCOR, CMG and ICG, with the assistance of IOC and the Division of Marine Sciences of Unesco, take steps to organize a symposium, preferably in 1978, dealing with the continent-ocean boundary at passive margins.

6. Recommends to IPOD that conventional downhole logging be carried out in all holes, and that encouragement and practical assistance be given to new types of downhole measurements;

   recommends further to IPOD that drilling to the top of seismic layer 3 and along transects of convergent margins remain a major objective;

7. Recommends that SCOR establishes two Working Groups on :

   (a) Oceanic Crust and Sea-Water Interaction,

   (b) Sedimentation Problems and Processes at Continental Margins;

   recommends that SCOR, in co-operation with ECOR, establish a Working Group on High Energy Environments and Sediment Management Problems;

   invites SCOR to stress again the importance of studies of fluvial supply, as defined in Exercise 4.4 of the recommendations of the First International Workshop on Marine Geoscience, Honolulu, and in the mandate of SCOR Working Group 46;

8. Recommends that SCOR and CMG set up Working Groups on :

   (a) Marine Geochronological Methods,

   (b) Cenozoic History of Ocean Basins, and

   (c) Depth Indicators in Marine Sediments;

   recommends also to SCOR that, if so requested, a symposia be held on the above subjects;

9. Recommends that the IOC and IHO, being jointly responsible for GEBCO, be asked to look into the problems concerned with the provision of bathymetric data in digital form for quick dissemination, on request;

10. Recommends that the new IOC Association for the Caribbean and adjacent regions (IOCARIBE), which is at present considering an active programme in marine geology and geophysics, be strongly supported in its work.

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(OF UNESCO)

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH (OF ICSU)

COMMISSION FOR MARINE GEOLOGY (FOR IUGS)

Second International Workshop on Marine Geoscience

Mauritius, 9-13 August 1976

ANNEX IV

PROGRAMME

SCIENTIFIC REPORT

Preamble

Marine geological and geophysical research in the oceans during the last twenty years has led to enormous advances in our understanding of geological processes in the earth. Geologically speaking, oceans are simpler than continents. Because this is so, studies in oceanic areas will continue to provide the key to the question "What are the processes which have controlled the generation and distribution of continental and oceanic crust ? " . Plate tectonics up to now has been of more intellectual than economic interest, but the understanding of crustal evolution within the framework of plate tectonics bears directly on many problems of social and economic importance.

Oceans are also simpler than land as far as living conditions and uniformity of chemical processes are concerned. This simplicity accounts for the rapid strides in the deciphering of the history of the ocean basins for the last 200 million years and argues for continued sedimentological studies in oceanic areas.

In the past, development of instrumental techniques in the oceans has been the single most significant factor in advancing our knowledge of the geology of the oceans. We are on the threshold of developing or utilizing a new generation of instruments and techniques which would enable us to learn about the fine and deep structure of the crust and about sedimentary and tectonic processes.

Any successor programme to the Geodynamics Project, the International Decade of Ocean Exploration and the Deep Sea Drilling Project must base a large component of its activities in the oceans if we are to make the most rapid advances in the most economical way.

We believe that a new programme must take into account the following points :

1. We must apply the full range of techniques available to geoscience to studies of the structure of the oceanic lithosphere. Better knowledge of its evolution and dynamics is crucial to the understanding of oceanic and continental evolution and of the interactions at ocean-continent boundaries.

   Of particular importance are :

   a. Geological and geophysical studies, on a fine scale hitherto feasible only on land, of a number of selected regions where the igneous crust is exposed, to test and refine tectonic, petrological, hydrothermal and dynamic models of accreting plate boundaries and to learn how certain characteristics of new crust change as the plate ages.

   b. Long-range seismic refraction and deep seismic reflection experiments, along with studies in earthquake seismology which emphasize long- and short-period surface waves and body wave delay times, to study the internal structure and lower boundary of the oceanic lithosphere as a function of plate age.

2. We must intensify study of origin and evolution of passive margins, particularly by investigating :

   a. deep crustal and mantle structure

   b. nature and location of continent-ocean boundary and

   c. structure of the sediment pile, for margins of various ages.

   We emphasize the need for extended deep drilling, wider deployment of multi-channel seismic reflection techniques for fine structure, and development of ocean bottom seismograph and other equipment for long term recording for gross structure at depth.

3. We must improve our resolution of the structure of active margins in order to understand the nature, extent, and significance of the transfer of portions of oceanic lithosphere to the continents.

4. As the structure of lithospheric margins becomes resolved, we must extend our model to include the temporal and spatial interrelationship of subduction zone processes, such as seismicity, volcanism, sediment movement and the vertical motion and deformation of the subducting plates and the overriding margin.

5. We have to learn about ongoing processes involved in the formation of recent sediments in the sea from surface to bottom, from land to deep sea.

6. We must refine the evaluation of the historical record stored in marine and especially in oceanic sediments to reconstruct the geometry and oceanography of ancient oceanic basins and their margins together with a recognition of changing processes and biological forms. In addition, one should attempt a global correlation of important sedimentary events.

REPORTS OF WORKSHOP COMMITTEES

(a) EVOLUTION OF THE OCEANIC LITHOSPHERE

Introduction

For the purpose of this report, the lithosphere is defined in a kinematic sense, i.e., the outer "layer" of the earth that is deparated into more or less rigid plates which undergo large lateral displacements without experiencing major deformation within the plate. Although the lithosphere may be described differently depending upon whether one is using evidence from seismology, from long term mechanical behaviour, or from thermodynamic considerations, there is reasonable agreement that there is an evolutionary process by which its thickness and mineralogical composition change from the time it originates at an accreting axis.

Salient fundamental questions are :

1) What is the nature and configuration of the lower boundary of the lithosphere ?

2) What are the physical properties and compositions of the lithosphere, and how do they change with time ?

3) What is the driving mechanism of plate tectonics ?

Two classes of experiment seem appropriate to address one or more of these questions : experiments with deep sensing capability to provide information about the gross structure, mechanical properties, composition, and lower boundary and other experiments to study, in considerably more detail than has been possible heretofore, the fine structure, composition, and evolution of the material comprising the uppermost part of the lithosphere.

The Gross Structure of the Lithosphere

Seismological Characteristics

Present concepts of the lithosphere have been largely derived from the kinematics of plate tectonics, and our knowledge of the composition of the lithosphere, its physical properties and lower boundary and of their evolution through time is meagre. The chief method of studying the interior structure of the earth has been seismology, but its application to the study of the large scale features of the lithosphere beneath the oceans has until recently been instrumentally limited. Ocean bottom seismographs developed over the last few years have overcome many of these limitations. The instrumental advances have been accompanied by increased sophistication in the interpretation of seismograms which allow the extraction of substantially more information from the observations. The observation of earthquakes and explosions by arrays of seismographs on the ocean floor can now be used to improve our knowledge of lithosphere.

Deep reflection profiling has already proved to be capable of mapping the M-discontinuity in some areas. With some modification of techniques the method may become even more effective and possibly also be useful to study structures within or at the base of the lithosphere.

Experiments which should be particularly fruitful in the coming decade include :

(a) Long range seismic refraction observations extending out to 2.000 km, giving penetration to about 400 km depth.

(b) Observations of earthquakes at teleseismic distance to establish patterns of time delay and attenuation beneath the receivers.

(c) Broad band conversations of surface waves over restricted paths to determine in particular the shear velocity structure of lithosphere of different ages.

(d) Observations of locally occurring earthquakes to determine the structure of the upper part of the plates and the nature and extent of the tectonic processes occuring there.

(e) Deep reflection profiling.

Mechanical Behaviour

The mechanical model of plate tectonics is based on the concept of a strong outer layer (lithosphere) which rests on a weak underlying layer (asthenosphere). The principal evidence for a lithosphere capable of supporting large stress differences for millions of year; has come from studies of the manner in which it supports surface loads. The lithosphere has been modelled as an elastic plate overlying a weak fluid substratum. Deformation studies near surface loads based on seismic refraction, gravity and bathymetry data have enabled a few estimates of the flexural rigidity and elastic thickness of the plates to be made. These estimates suggest that the thickness of the elastic lithosphere is substantially less than that determined from seismology or that deduced from thermal models of the plates. It is important to continue studies of the deformation of the lithosphere since these provide information on the long-term mechanical properties of the plates in contrast to seismic experiments which measure the short-term mechanical properties. Better estimates of the flexural rigidity and elastic thickness of the plates should be made and it should be established whether or not these parameters change with age. However, before reliable estimates can be made we need to improve techniques for estimating surface loads and determining precisely the geometry of deformation associated with these loads. At present estimates of plate rigidity are based mainly on bathymetry, seismic reflection and gravity data.

Electrical Properties

There is general agreement that the earth's interior is fundamentally a heat engine, yet little is known of its thermal state. Because of the strong relationship between electrical conductivity and thermal state, electromagnetic methods offer substantial promise of important new constraints on our thermal models. We encourage experiments based on the observation on the ocean floor of magnetic and electric fields with periods from hours to weeks. These observations provide information about the electrical conductivity on a vertical scale appropriate to the study of the lithosphere. These studies will be especially valuable when carried out at the same locations as seismic experiments studying gross lithospheric structure.

The Fine Structure of the Uppermost Lithosphere

Difficulties in correlating between a few closely spaced holes drilled into the igneous crust near the ridge crest, as well as the diversity of rock types which have been encountered, the large scatter in heat flow measured near ridge axes, and the increasing number of crustal seismic layers now being advocated, all suggest that the uppermost lithosphere is vertically and horizontally much less homogeneous than was previously suspected. More work is needed to establish the reasons for, and scale of, this variability.

Many more detailed studies of ridge crests, including their associated transform faults, are needed to provide constraints and tests for tectonic and petrologic models of the zone of accretion. The aim is to arrive at geological and structural maps of several test areas straddling the axis of slow (less than 2 cm/yr), medium (2 to 6 cm/yr) and fast (more than 6 cm/yr) spreading ridges for lithosphere less than 5 m.y. old. One must focus on defining the width of the zone in which the major tectonic activity takes place and the style of the tectonics. It is also important to determine the spatial and temporal distribution of rock types. The distribution of magnetic sources in the oceanic crust, inferred from the modelling of the magnetic anomalies, should be tied to the age and magnetic properties of the rocks sampled in the study areas. Similarly it is important to model the ridge crest gravity anomalies which have wavelengths of less than a few tens of kilometres.

The employment of a variety of recently-developed, complementary techniques will be needed to maximize the scientific return for the axial test areas, for example, multi-narrow-beam echo sounders, side-scan sonar (surface and near-bottom), deep-towed instrumentation, photo mosaics, and submersibles, together with deployment of bottom instruments.

The knowledge of the upper surface of the lithosphere should be supplemented by that of the shallow structure of the lithosphere. It is important to establish the existence (or absence) of magma reservoirs underneath the zone of accretion, how they are distributed in space, and if they exist episodically or permanently. The thickness and physical properties of the rigid layer at the axis should be determined in the same test areas.

A seismic experiment with an array of bottom seismometers using natural local seismic events and possibly bottom sources should be aimed at providing answers to the above and be focused on obtaining the P and S wave velocity distribution in the axial region and the degree of horizontal anisotropy.

To study the lateral and vertical variability of the uppermost part of the lithosphere, drill holes about 1 km apart should be located in groups in well surveyed areas, preferably young and with little sediment, where fault scarps and other geologic features which may influence this variability are more easily detectable. This should be carried out so that observations over distances of tens of kilometres can be interpreted more meaningfully. Such grouped holes should be drilled on slow, medium and fast spreading ridges. It will be essential to the solution of this problem to have continuous downhole logging of such parameters as density, velocity, porosity, natural gamma radiation, etc. in all the holes.

Concurrently, attempts should be made to improve the accuracy of the determination of seismic velocities and the resolution of seismic layers to relate them better to the rocks sampled in the holes drilled into the igneous crust. Other seismic measurements made in regions without drill holes should then become petrologically more meaningful.

The variability of heat flow measurements made near ridge crests has been related to the circulation of hydrothermal fluids. The extent and importance of such a process in the uppermost part of the lithosphere needs to be determined. This may be carried out using measurements of P and S wave velocities, bottom water temperatures and sediment thickness but probably will need the development of new techniques to rapidly assess small temperature differences in sea-water and to measure the permeability of crustal rocks. A recommendation to this effect will be found in Annex IV (d).

The Driving Mechanism

Though we now have a reasonable knowledge of present and past plate motions, we still have little understanding of how they are maintained. It is generally accepted that the energy source is thermal convection, and there are good theoretical reasons to believe that the convective circulation is complicated and not closely related to plate motions. Though numerical and laboratory experiments can suggest the likely form of the convection, it is obviously of major importance to compare them with geophysical observations. Unfortunately, there are few surface manifestations of mantle convection. Observations are dominated by the mechanical and thermal properties of the lithosphere. A promising approach depends on the relation between the long wavelength gravity anomalies and the variations in water depth. Both are believed to be direct expressions of mantle motions. Similar gravity anomalies exist in continental regions, but there the elevation is dominated by lateral variations in density. The major limitation of this approach is the lack of sufficient high quality marine gravity profiles. Better global coverage is badly needed, especially in the southern hemisphere.

A major recent advance in determining the gravity field, particularly at longer wavelengths, depends on satellite altimeter data, which can only be used for this purpose over oceanic regions. Limited theoretical studies already carried out suggest that such surveys can be used to determine the spatial distribution of mantle circulation. Such knowledge would represent a major advance in understanding how the mantle acts as a heat engine to maintain the plate motions.

Recommendations

I. That drilling into the oceanic crust by IPOD/DSDP be continued with vigour at carefully surveyed sites,

Conventional downhole logging be carried out in all holes, and that encouragement and practical assistance be given by IPOD/DSDP to new types of downhole measurement,

New geophysical techniques be rapidly developed to study and map the upper kilometre or so of the crust so that a better choice of drill site can be made and so that drilling results can be related better to geophysical measurements.

It is particularly recommended that :

a) holes be drilled on the axes of spreading ridges;

b) carefully chosen, closely spaced holes be drilled to establish the degree of lateral homogeneity of the igneous crust;

c) drilling at least to the top of seismic layer 3 remain a major objective of IPOD.

II. We recommend the application of the full range of seismological techniques to studies of the oceanic lithosphere. Of particular importance are :

a) Long-range seismic refraction experiments;

b) Observations of body-waves from teleseismically occurring earthquakes;

c) Surface-wave measurements;

d) Local observation of earthquakes on the ridge axes;

e) Deep seismic reflection experiments.

III. We recommend the study of the uppermost part of the oceanic lithosphere, with a wide range of geological and geophysical techniques, on a scale hitherto feasible only on land. This fine scale approach, initially applied to a small number of areas on the ridge axes and flanks, would allow tectonic, petrological, hydrothermal and dynamic models of accreting plate boundaries to be tested and developed. These studies should be extended to older parts of the ocean in order to understand the complete evolution of the upper lithosphere.

IV. We recommend that quantitative studies should be made of the long-term rheology of the outer layers of the Earth. We propose that studies of the deformation of the lithosphere caused by surface loads should be continued in order to determine the mechanical properties of the plates. We also propose studies of the relationship between long-wavelength gravity anomalies and residual depth anomalies because of the information they may contain on deep processes occuring not only within, but beneath the plates.

(b) PASSIVE CONTINENTAL MARGINS

Introduction - The main problem

Passive Margins mark the area between continental and oceanic crust within plates. Such Margins formed at plate boundaries either by rifting at an accretionary boundary or by transform faulting at a ridge offset. Crustal structure has been extensively investigated beneath ocean basins and continents, but knowledge of the nature of the intervening zone (sediment and deep structure) is rudimentary. Nevertheless, these are regions of strong differential vertical movements.

Tectonics at plate boundaries has received much attention during the last decade and there have been great advances in our understanding of the underlying processes. Comparable advances have yet to be made in understanding the tectonic and sedimentary sequence of events associated with formation and development of passive margins. The main questions are :

(1) How have passive Margins evolved ?

(2) What are the underlying tectonic mechanisms ?

These questions apply to each of the three successive stages :

(1) pre-rifting; (2) early opening; (3) mature stage.

An answer to these questions depends largely on determination of the shallow and deep structure, and on interpretation of its geological development. The questions pose a fundamental geological problem which is now becoming prominent, but their solution is also important in evaluating potential resources of a passive Margin. The most promising oceanic areas with regard to economic potential are expected to be in the vicinity of margins.

The passive margins vary greatly in structure, but are divisible into (1) rifted, and (2) sheared types. It is important that attention is given to both types in future investigations. Microcontinents provide a specific case of the problem. These need to be distinguished from other quasi-continental features, otherwise we consider that they can be investigated by the same approaches.

Classification of problem

The Inter-union Commission on Geodynamics Working Group 8 mid-term report classified the specific problem areas as follows :

(1) Continent-ocean boundary

(2) Vertical movements

(3) Deep structure

(4) Transverse structures

(5) Quasi-continental features (e.g. microcontinents).

In order to answer the major questions as to how passive margins evolve and thus develop a geodynamic model in space and time the group suggested investigations of three specific types as outlined below. These are closely interrelated and interdependent.

Approach to solution

1. Structure of Sedimentary Layers

The thick sediment sections in most passive continental margins provide valuable evidence of the vertical movements which are evidently a characteristic feature of this tectonic zone which separates continent from ocean basin. Of particular practical and scientific significance is the evidence which sediments provide about environment of deposition. Improved criteria and indications are urgently required of the amount, sense and rate of vertical crustal movements.

The importance is stressed of improved knowledge of the whole sediment succession from the most recent to the basal sediments. These should provide valuable information relating to the initial stages of rifting, continental drift and vertical movements of opposing continental margins.

In order to determine the subsidence history of passive margins, detailed studies should be made of palaeoenvironments with special emphasis on facies sequences, hiatuses, and palaeodepths, together with an exact chronology of margin sediments.

Studies of the detailed structures within margin sediments should be related to the causative mechanisms of the dominantly vertical gross movements which are superimposed upon primary, penecontemporaneous, and diagenetic sedimentary structures.

Acoustic stratigraphy to the base of the sediments should be established over wide areas by closely-spaced traverses using deep-penetration high-resolution seismic techniques (which require improvement).

The latter data must be supplemented by sampling by conventional techniques and especially by deep drilling to basement at carefully selected localities. The DSDP and IPOD programmes of JOIDES represent a promising start and the earnest hope is expressed that appropriate data from resource-oriented deep-drilling will be made available for scientific purposes. Deep-drilling for scientific purposes should also include the routine use of downhole logging techniques.

These approaches will enable the established acoustic stratigraphy to be interpreted in terms of lithology and age. This in turn will permit stratigraphic correlations with known successions onshore (where they can be studied in more detail) and in the deep ocean basins. Hence we may have a means of bridging the gap, in time and space, between continents and ocean basins.

The evidence thus derived for vertical movements in continental margins should be interpreted (1) within the broad framework of continental epeirogenic movements of regional extent and (2) in relation to the detailed history of plate evolution.

2. Ocean-continent boundary

The mapping of the zone between oceanic and continental basement is required for any precise pre-drift reconstruction and for determining the processes involved during the stages of rifting. A number of investigators have demonstrated that this zone is not necessarily associated with constant bathymetric contours or any distinct morphological features.

The nature of this zone is poorly known at the passive margins. We have no knowledge of whether there is a sharp boundary or a gradational zone consisting of different blocks of mixed oceanic and continental crust (either altered or unaltered). The solution to this important problem is complicated by the presence in many regions of magnetic quiet zones, evaporitic basins, rough sea-floor topography, post-rifting volcanic activity, large sedimentary overburden, uncertainties in eliminating the isostatic "edge effect" from the free-air gravity anomaly, interpretational difficulties in seismic refraction work (as a result of the steep topography and lack of knowledge of structure and velocity distribution within the sediments), and limitations in conventional analogue reflection techniques.

Integrated detailed geophysical and geological studies are mandatory for the determination of the nature of the zone between ascertained oceanic and continental crust. These studies include :

(a) the mapping of the sediment distribution and configuration of basement in this region utilizing multi-channel digital seismic techniques.

(b) determining the type (composition) of basement and overlying sediments by :

- velocity determination from combined multi-channel and seismic refraction measurements (ocean bottom seismographs, long and short range sonobuoys, two-ship refraction, and wide angle reflection combined with land recordings).
- determination of density distribution from detailed surface ship gravity measurements. (Knowledge obtained from seismic measurements will be of great significance in interpretation of gravity measurements).
- determination of magnetization contrasts obtained by detailed surveys, particularly in the deep water magnetic quiet zones.
- locating areas suitable for sampling (dredging and coring) of basement and pre/post-rift sediment outcrops.
- very deep drilling on the well surveyed "typical" passive continental margins. We particularly encourage all available downhole measurements to accompany drilling.

We strongly recommend that the above studies be undertaken at passive continental margins of different ages as well as at passive continental margins located at conjugate positions on either side of the ridge axis.

3. Deep transition

Gravity observations indicate a gradational transition between continental and oceanic structure, but the nature of the crustal and upper mantle transition cannot be assessed from present information or using present methods. An understanding of the deep structure at different stages of margin development is essential for understanding the mechanism of tectonic development. The main problem is to determine the velocity, density and thermal structure with depth as it varies laterally beneath the margin. In addition to existing gravity and seismic approaches, we suggest that new initiatives as follows will be needed :

(a) Long range refraction experiments carried out in carefully planned lines across and parallel to the margin. The full range of modern methods of instrumentation and interpretation will be needed (ocean-bottom seismometers, ocean-bottom hydrophones, S-waves, amplitude studies, etc), Digital seismic reflection should also be used in attempts to yield information on the lower crust and perhaps even upper mantle; this may require very long arrays.

(b) Surface wave and teleseismic body wave studies are needed to determine the deeper structure (mantle) beneath margins. This will necessitate deployment of seismometers at the ocean bottom, with long recording capabilities. We see the development of such long recording equipment as an important instrumental development which needs to be made.

(c) At present passive margins are regarded as seismically inactive, but there may be small magnitude earthquakes undetected by the present seismic network. Micro-earthquake studies using ocean bottom seismometers or hydrophones may yield important information on stress release.

(d) Heat flow is virtually unknown across passive margins. This is important for evaluation of processes in the deeper crust and mantle, and of the thermal evolution.

(e) Magnetic variation studies (including magnetotellurics) need to be pursued in an attempt to determine the deep electrical conductivity distribution, this being related to temperature distribution beneath passive margins.

(f) Measurement of earth tides by recording gravimeter and other means across margins may be useful to study lateral variation of rheological properties in the lithosphere.

Recommendation

We call attention to the importance of carrying out concentrated investigations across passive margins to determine (a) sediment structure, (b) nature and location of continent-ocean boundary, and (c) deeper structure. In particular we emphazise the need for much more extensive deployment of multi-channel seismic reflection techniques, and for development of ocean bottom seismological and other equipment for long-term recording.

(c) ACTIVE MARGINS

Introduction

While recognizing that active lithospheric plates also have boundaries undergoing divergence and shear, for the purposes of this Workshop we concentrated on consideration of convergent margins. The divergent margins are regarded as the starting point for the considerations of the evolution of the lithosphere, and are covered elsewhere in this workshop report. Shearing plate boundaries are being given considerable attention by non-marine geoscientists, particularly for obvious reasons of earthquake hazard related studies (e.g. the study of the San Andreas fault system). The location and delineation of shearing margins beneath the oceans remains essential.

We recognize that many basic problems of convergent margin structure and evolution, including the inter-relationships of the rate and direction of plate convergence, the configuration of the Benioff zone, the amount of subducted as opposed to accreted sediments, the distribution of subduction zone associated vulcanism, the formation of back-arc and inter-arc basing, etc., have been raised by previous workshops as by individual investigators, yet these problems remain largely unresolved. In many regions even the location of plate margins, including mini-plates and complex island-arc and basin configurations, are not adequately defined. Studies of these problems are essential and we fully support them. We feel, however, that these problems will yield to present day geological and geophysical exploration techniques and scientific attitudes, so we will not reiterate them in this report.

Our discussions have let us to the identification of those fundamental problems whose solution remains elusive. After enumeration of these problems we conclude our report with some recommendations for the study of these fundamental problems.

Fundamental problems

1. The nature of the accretionary prism

Although most marine geoscientists agreed that some oceanic material is generally emplaced on the overriding lithospheric plate as the oceanic plate is subducted, the extent, composition, and stability of this prism of accreted material is still a matter of conjecture. It is essential that we understand :

(a) the mechanics of subduction related to trench and island arc formation

(b) the amount of oceanic sediments and/or crustal rock that is subducted (and thus is potentially available as a source material for magma related to the subduction zone), and

(c) the possible distribution and significance of overriding continental margins that are being eroded, rather than accreted.

The composition, stability, and structure of the accretionary prism is, of course, of particular importance to an evaluation of these large sediment bodies as a potential location of economically valuable hydrocarbons.

2. The fate of the descending slab

The deformation and character of the descending oceanic plate has only been traced for a few kilometres after it is overridden, if we hope to understand the seismic structure of the subduction zone, as well as the temperature, pressure, and geochemical requirements for magma generation, we have to improve our knowledge of what happens to the subduction oceanic plate. Beyond the obvious scientific appeal of using this knowledge to understand the mechanics, origin, and eventual termination of subduction, we are optimistic that such knowledge will be useful as an aid towards understanding and predicting contemporary vulcanism and the location of past plutonism responsible for emplacement of economic ore deposits.

3. The significance of obduction

Obduction is frequently called upon as a tectonic process responsible for the emplacement of ophiolitic suites of rocks, and sometimes associated economically valuable statiform sulphide ore deposits. In our opinion, however, the existence of a presently active obducting convergent margin is not apparent. Further study of ophiolites as possible oceanic crustal material is necessary in order to establish the significance of obduction as a viable tectonic process.

Recommendations for further study

In the previous section generalized problems which we regard as being of particular importance to the understanding of convergent plate boundaries, have been described. Many other important problems are not mentioned, often because it was felt that they are, or will soon be, given appropriate attention. Similarly, in this section some ideas for future study that it is hoped might help resolve some of the gaps in our knowledge of active converging plate boundaries, will be put forth. Again, the list is not all-inclusive. For example, the deployment of arrays of seismometers has proven invaluable for resolving the fine structure of the Benioff zone. However, these studies are expected to continue, so they have not been included. Only studies which may be overlooked, will be described.

It is difficult to disseminate and synthesize all the marine geological and geophysical data available on the active converging plates. Synthesis is required in order to switch efficiently from a broad reconnaissance approach to active margin studies to a programme of detailed study of particularly significant locations.

1. Concentration of studies in significant transects

It is recognised that active margins are structurally complex and require detailed, multi-disciplinary study employing higher resolution data acquisition techniques, not just more ship tracks. To accomplish such expensive and time-consuming studies, we recommend that efforts be concentrated along a limited number of transects across margins that are carefully selected as likely to yield maximum scientific benefit from detailed study. Marine surveys adjacent to well mapped and understood land areas are, for example, particularly useful. The chosen transects will be across what would then effectively become "type sections" of various styles of convergent margins. The concentration of data aquisition would permit full usage of recent advances in marine geophysical instrumentation at the chosen transects. Such studies should include, for instance, multi-channel reflection seismic profiling to provide as much structural detail as possible, particularly in the accretionary prism and inner trench wall. We would also suggest the relatively long-term (a month or more) deployment of arrays of ocean bottom seismometers that would provide detailed information on the low-magnitude seismicity that should accompany oceanic slab deformation both before and after subduction, as well as earthquakes generated in the accretionary prism and inner trench wall by imbricate thrusting, slumping, etc.

We anticipate that the proposed International Phase of Ocean Drilling (IPOD) sampling along transects of convergent margins will provide invaluable geologic samples. It is imperative, however, that these very expensive samples be fully utilized by acquisition of a complete, multi-disciplinary set of complementary geologic and geophysical data along the drill hole transect. We recommend that any IPOD active convergent margin transect include :

(a) a complete marine survey, or set of surveys, including conventional geophysical profiling and sampling, high quality multi-channel reflection seismic profiles, and ocean bottom seismometer refraction studies to provide adequate data for the most efficient selection of drill-site locations;

(b) downhole logging of the IPOD drill holes to acquire all possible data on the <u>in situ</u> properties of the crust;

(c) instrumentation of appropriate drill holes with strain meters which can record these data after the drilling ship departs;

(d) appropriate post-drilling site surveys which are designed to answer questions arising from the comparison of the sampled rocks with what was anticipated as a result of the site selection surveys.

2. <u>Implications of contrast in approaches to study the oceanic and continental sides of active margins</u>

We are concerned that inadequate attention may have been given to the potential amplification of the differences between oceanic and continental geology and crustal structure across a convergent margin thay may be the result of the different experimental and observational techniques used to interpret these regions. In effect, practically all marine studies are remote sensing experiments, while most land geology is interpreted by more direct observation. The danger is that in the oceans we see the forest, but not the trees, while on land we may see only the trees and the forest is obscured.

Where possible it may be helpful to try to investigate each region with similar techniques. For example, we would urge the study of the oceanic regions with deep-towed (near bottom) seismic reflection instruments (acknowledging that such instruments must still be developed) in order to obtain higher resolution structural data in deep water. Such data would then be directly comparable to seismic reflection data collected in shallow water and on land. Similarly, consideration should be given to using submersibles for direct observation of the sea-floor geology at convergent margins for comparison with geologic features observed on land.

3. Dynamics of convergent plate margins

It is essential that the active convergent plate margins be modelled as dynamic features. At this time very little data exist which can be applied to such modelling, except on a coarse and relative scale. We recommend, as a start towards assembling the required data, that some generalized types of experiments be considered.

We would encourage the direct measurement of short-term plate motion; rates of convergence, and the vertical component of plate motions during convergence. This might be accomplished by a form of laser-earth satellite ranging, or by some other precise geodetic technique. The reconciliation of the commonly envisaged long-term steady motion of lithospheric plates with the short-term spasmodic motion demonstrated by subduction zone earthquake activity should provide valuable constraints on the precise modes of deformation and stress/strain relationships in plate collision.

We also recommend systematic consideration of the temporal relationships and interaction of the various dynamic components of the subduction zone, including seismicity, vulcanism, sediment characteristics and distribution, oceanic plate deformation, vertical motions of the colliding plates, and inter-arc and back-arc basin formation. What time delays exist between the occurrence of these activities ? Which of these dynamic events trigger other events, and then by what mechanism do these processes interact ? Of course in many cases these data must be acquired over long periods of time. The very long time-period tectonics have to be considered by analysis of convergent margins in various stages of development, including examples of the various types of convergent margins (oceanic-oceanic, oceanic-continental, and continental-continental) that are in an initial formation stage, are undergoing major alteration or are becoming inactive.

As part of the consideration of subduction zone dynamics, attention should be given to the indications of long-range stress propagation suggested by investigators who have documented statistically significant migrations of earthquake and volcanic activity around and between plate margins. If these relationships prove valid, they may have important implications for the interpretation of lithospheric physical characteristics and the driving mechanisms of plate motion and collision.

(d) MARINE SEDIMENTS

Introduction

Sediments formed in the sea and on land are really the most important constituents of the Outer Earth's Crust. They contain the most detailed and easily interpreted information of the Earth's History during the last 500 million years which includes the time scale, the changing environments and deformations.

Within the scope of this Workshop an attempt has been made to define :

(a) the most crucial gaps in our present knowledge on marine sediments

(b) a few fundamental questions that can be at least partly answered using new material and techniques available in the recent past and the near future and

(c) activities that would benefit by international co-operation.

Only two aspects were therefore concentrated upon: the processes involved in the formation of recent marine sediments and the reconstruction of marine palaeo-environments.

Sea-seafloor interactions

In general the qualitative properties and distribution patterns of recent marine sediments are known. However, most processes in the water column, from the surface to the bottom and within the interstitial water, are poorly understood. These processes affect input, distribution and losses of organic and inorganic particles, their accumulation rates and early stages of diagenesis. A more comprehensive understanding of these factors will help to improve interpretation of modern and ancient marine deposits as well as to solve economic problems such as the origin and occurrence of marine mineral resources and the management of the coastal areas in their function as a general resource for many nations.

A multidisciplinary approach together with the development of new techniques and instrumentation will be necessary to attack these problems quantitatively.

The following are needed :

(a) in situ observations and measurements of movement chemistry and particle content of water masses, of energy transfer and element fluxes at the benthic boundary, of sediment movement and benthos activities;

(b) long-term experiments to detect isolated critical events; and

(c) satellite and aircraft observations of sea state conditions, temperature and turbidity of surface waters for productivity and river input studies, etc. The experience of space technology, using remote controlled instrumentation could make important contributions to the above experiments.

Areas of specific investigation should include the sediment component inputs from various sources, starting with the elemental fluxes out of and into the seafloor in areas of magmatic activity, such as regions of new crust formation and vulcanism. The influence of these elements upon the alteration processes in the upper part of the crust and upon the composition of metal-rich deposits and manganese nodules and sediments in general, need further study.

The total biogenic input of calcium carbonate, silica, organic fractions and associated trace elements should be determined with special emphasis placed upon the less well studied siliceous and organic components. An estimate of the amount and rates of recycling of these constituents within the water column and at the benthic boundary should be made to determine the relation between surface productivity and the net accumulation of biogenic sediment on the deep-sea floor.

The input of terrigenous material by fluvial, ice and aeolian transport and the biogenic input, particularly in upwelling regions, provide the bulk of the components for the hemipelagic sediments found on and near the continental margin. Because these components are dispersed by boundary and other currents and internal waves, as well as by benthic life activities, long-term measurements should be made of the currents with special emphasis placed on the manner in which these dynamic processes control sedimentation on the continental slope and rise. Bottom shear stress measurements should be made in the environments where these fine sediments accumulate to evaluate critically the erosional and depositional processes. Field measurements should be complemented by laboratory studies. The flux of suspended material to the sea-floor, the resuspension of existing sediment and the recycling processes apparently are related to these water movements. Better in situ methods of sampling these suspended materials, particularly at the benthic boundary, will be required if the flux of components of the sea floor is to be quantified. These sediment analyses should be co-ordinated on a worldwide basis to ensure that the same sediment properties are being measured so that comparative studies of hemipelagic sediments from different margins can be made. A comparison of the eastern and western margin in the same ocean or in different oceans may be especially fruitful.

Although the high energy regime of the inner continental shelf and coastal region has been studied in greater detail than the continental slope, virtually all nations that have an oceanic border are experiencing great difficulties in controlling the natural processes that are shaping the nearshore and shore regions. Man-made structures have disrupted the natural equilibrium conditions of sand transport and created additional complex problems in sediment management. While this land-sea region is of great economic importance, there are only a few national co-ordinated studies and virtually no international studies to cope with this situation. More integrated studies from both an oceanographic and engineering point of view will be necessary in the next decade to meet the demands society will place on this high energy region.

Recommendations

In view of the above, and the necessity to conduct some of these experiments by international co-operation, it is recommended that :

1) SCOR establish a Working Group

"Oceanic crust and sea water interaction"

to stimulate investigations in areas of mid oceanic ridges, submarine volcanoes, the central Red Sea, etc.;

2) SCOR establish a Working Group

"Sedimentation problems and processes at Continental Margins"

- to stimulate investigations of hemipelagic sediments, especially with their relations to water depth, contour and other currents, upwelling phenomena and
- to define key areas on both sides of the oceans for international experiments;

3) SCOR, in co-operation with ECOR, establish a Working Group

"High Energy Environments and Sediment Management Problems"

- to evaluate case history examples
- to stimulate further multidisciplinary investigations of complex interactions between morphology, sediments, water movements and benthic life
- to evaluate the consequences of disturbing natural equilibrium situations by human activities and
- to propose selected areas for concentrated research;

4) that existing activities be encouraged and that the IGCP of Unesco stimulate co-ordinated investigations of undisturbed Holocene Sediment Sequences

- with maximum time resolution and accuracy
- with special emphasis on climatic and vegetation changes
- for a better understanding of man's role as a geological agent.

5) again that the scientific and general importance of Studies of Fluvial Supply, as defined in Exercise 4.4 of the recommendations of the first Workshop on Marine Geoscience, Honolulu, and in the terms of reference of SCOR Working Group 46.

Marine Palaeoenvironmental Analysis

Geodynamic studies increasingly require input of historical information which can only be derived from the record of events preserved in the marine sediment column. Palaeo-oceanographic and related palaeoclimatological studies likewise lean heavily on precise environmental interpretations. Our ability to interpret this record of past events is at best highly inadequate, and becomes increasigly so as such studies are extended back in time. However, results of these studies applied on a global scale to the Quarternary record have been highly promising and should encourage us to extend the research back through the Tertiary and Mesozoic when our present ocean basins were evolving through early formative stages. Obviously much greater precision than presently exists will be required for such work. The ultimate pay-off could be great, however, from the view-point of immediate economic gains (e.g. oil and gas in continental margin basins) and for long-term scientific objectives related to our understanding of the evolution of oceanic environments and life, causes of global climate changes and vertical and horizontal displacement of the earth's crust.

A major weak link in marine palaeoenvironmental analysis is lack of detailed quantitative information on oceanographic, climatological, sedimentological, geochemical and ecological aspects of present-day oceanic environments. This knowledge is the most useful key to past oceanic environments. Such studies should include co-ordinated research in present-day basins, ranging from those of a restricted nature (e.g. the Black Sea) to fully oceanic areas. Concurrently with the above, research on the historical aspects of the ocean basins should be accelerated. More detailed and refined analysis of sedimentary facies should be carried out using sedimentological, mineralogical, geo-chemical and ecological methods. Special emphasis should be given to deposits such as black shales, evaporites and unfossiliferous sediments. These studies will require more sophisticated geochronological methods. This last point is particularly important for the problem of correlating and understanding widespread oceanic events.

Finally, models of oceanic circulation should be produced for past ocean-basin morphologies. For these investigations, we need more precise plate reconstructions with an emphasis on palaeo-depths and the positions of former continental margins.

A large volume of suitable core material is readily available from existing and proposed Deep Sea Drilling Project and IPOD holes and "open-file" oil company drillholes. Much of this material can be utilized even by small institutions for only a modest capital outlay, and use of this huge backlog of core data should be encouraged. Emerged oceanic sediments which outcrop in convergent plate boundaries provide an additional relatively low-cost source of sedimentary data for such studies.

For precise future studies, we need:

(a) improved drilling and recovery techniques; in particular, development of technology for recovery of undisturbed cores from the uppermost 50 metres;

(b) better navigated bottom sampling, located precisely with respect to morphology and structure, in order to gain information from areas not drilled, particularly when outcropping seismic reflectors are sampled;

(c) a refinement of methods of interpreting seismic profiles and correlating these with lithologies and facies changes (acoustic stratigraphy).

Recommendations:

In view of the above, it is recommended that :

1) SCOR, in co-operation with Unesco (IGCP), establish a Working Group

"Marine geochronological methods",

- to improve intercorrelation of the faunal and floral groups, including statistical approaches, absolute age determinations and magneto-stratigraphy, with emphasis on cross-correlation of all the above methods.

2) SCOR Working Group 40, or a newly constituted working group, promote studies on

" Cenozoic history of ocean basins",

incluging regional events such as early Tertiary charts, excursions of $CaCO_3$ compensation depth, sediment cycles and hiatuses, with emphasis on regional correlation of these events.

3) More intensive research be carried out on

" Depth indicators in marine sediments",

including special investigations of benthic organisms, authigenic minerals and sedimentary facies as depth indicators, further investigations combined with "Sea-Seafloor interactions (see page 16 above) in order to revise palaeodepth results and proposals for suitable deep sea drilling sites.

ANNEX V

Second International Workshop on Marine Geoscience

Mauritius, 9-13 August 1976

STATE OF IMPLEMENTATION OF EXERCISES 4.1 to 4.11 OF THE INTERNATIONAL WORKSHOP ON MARINE GEOSCIENCE

(Honolulu, 20-24 September 1971)

1. International Morphologic Mapping of the Ocean Floor

SCOR WG 41 was established, and at the International Hydrographic Conference in 1972, a resolution was agreed that IHB should co-operate with marine geoscientists on ocean floor mapping. A new IOC-IHO joint Guiding Committee for GEBCO has been formed with Dr. A.S. Laughton as SCOR nominee, and Dr. E.S.W. Simpson, Secretary of CMG, as CMG nominee and also as Chairman of the Committee.

New bathymetric charts (GEBCO 5th edition) are in preparation and it is planned to set up a GEBCO International Geoscience Unit to help with the compilation of further sheets of the series.

The IOC Assembly, at its eighth session, in November 1973, endorsed the need to prepare a new and precise large-scale bathymetric chart of the Mediterranean as a base for charts of other parameters such as gravity, magnetics, etc. In order to implement this, the International Co-ordination Group for the Co-operative Investigations in the Mediterranean set up an ad hoc group of specialists to develop the International Bathymetric Chart of the Mediterranean (IBCM), Mercator projection, 1: 1 million, using only recent soundings of high accuracy.

It has been suggested that GEBCO be asked to look into the problems concerned with holding a catalogue of bathymetric data in digital form for quick dissemination on request.

2. Studies of Continental Margins

(a) Active Regions

The IOC, jointly with the CCOP (of ESCAP), held a successful workshop in Bangkok in 1973 (IDOE Workshop on Metallogenesis and Tectonic Patterns in East and South-east Asia). The report of this workshop (Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia) was commented upon by SCOR. The work of CMG and SCOR ensured that the scientific work was of a fundamental nature, as well as looking after practical interests of finding new mineral resources.

In order to implement the Programme of Research, a CCOP-IOC Joint Working Group was formed (IOC resolution EC-V.18) and held its first session in Tokyo, 13-14 August 1975, in conjunction with the twelfth session of CCOP. At this session the group decided to change its name to "CCOP-IOC Joint Working Group on IDOE Studies on East Asia Tectonics and Resources" (SEATAR). The second session of this group is scheduled for November 1976, in Kuala Lumpur, in conjunction with the thirteenth session of CCOP. The report of the first session was adopted by the IOC Assembly, at its eighth session, in November 1975 (resolution IX-2).

At a special session of CCOP held in 1976 at Bangkok, the activities of many ships in the South-east Asian area were reported. The work at sea was supported by measurements on land.

(b) Inactive Regions

It was decided by the IOC that there was no need for a special IOC group since the South Atlantic continental margins were studied by many multi-national expeditions over several years often with the help of the US National Science Foundation (IDOE).

The work on both active and inactive margins has improved the knowledge of both recommended areas, and in some cases is continuing. The inception of this work is owed to a large extent to the proposals of the first International Workshop on Marine Geoscience, Honolulu. The problems of passive margins have come increasingly into focus during the past few years and a continuation of the programmes in more detail is recommended.

3. Geological and Geophysical Studies of the Mediterranean and Marginal Seas

The meeting recommended by the first International Workshop on Marine Geoscience has been arranged for October 1976 by the Institut Français du Pétrole (IFP), CMG and IAPSO.

Other work is being organised in the Mediterranean by IOC through the International Co-ordination Group for Co-operative Investigations in the Mediterranean.

Other marginal areas under investigation with the help of IOC, CCOP and US National Science Foundation (IDOE) are South-east Asia (2a above, the South Pacific and the Caribbean.

A successful IDOE Workshop, convened jointly by IOC and CCOP/SOPAC, and held in Fiji in 1975, recommended projects associated with mineral resources in the South Pacific, and some of these projects are underway using the limited resources of the South Pacific countries.

Implementation of recommended work in the Caribbean has been disappointing. However, in this area, which is considered to be important for the study of Marine Geoscience, the new IOC Association for the Caribbean and adjacent regions (IOCARIBE) is at the present time considering an active programme which in the opinion of the Workshop should be strongly supported.

4. Studies of Fluvial Supply of Sedimentary Matter to the Sea and its Longshore and Offshore Dispersal

SCOR established Working Group 46 (River Inputs to Ocean Systems) in 1974. This group consisted of geologists, engineers, biologists, geochemists and hydrologists and planned to hold a fact-finding symposium in 1977 to ascertain what gaps in knowledge exist in the subject. A second stage programme is planned in which at least three large rivers of the world will be monitored. There have been some difficulties in obtaining funding from the United Nations Environment Programme but it is now known that a solution to these difficulties is to hand. The UNEP, although interested in conservation, had agreed that the working group should confine its activities to finding fundamental facts about the processes involved and should not be concerned at all with pollution problems.

It was agreed that the original concept of this working group, which was formulated in April/May 1969 at the joint ACMRR/SCOR/WMO (AGOR) meeting on the Scientific Aspects of International Ocean Research (Ponza and Rome), was excellent, and it was regretted that such a long time had elapsed to produce so little action.

However it was agreed that the original concept should be continued.

5. Deep Drilling in the Oceans

The recommendations were to find out ways in which other countries might help the US finance the Deep Sea Drilling Project, and to assist in organising symposia to allow rapid dissemination of the results of the project. Financial participation has been agreed by some countries and the initial seven year phase of reconnaissance deep sea drilling (DSDP) has been succeeded by the International Phase of Ocean Drilling (IPOD). Symposia have been arranged at the instigation of CMG at many international conferences to emphasize deep ocean drilling results.

6. Active Ridge Crests and Active Fracture Zones

A Symposium covering these subjects was held at the XVIth General Assembly of IUGG, Grenoble, in Aug./Sept. 1975 and further symposia will be held at the 25th International Geological Congress, Sydney, Australia, August 1976.

Good examples of the modern practical approach are provided by the experiments FAMOUS and CAYMAN in which different geophysical techniques were deployed, backed by the use of submersibles.

It was agreed that this subject should be included in the present workshop consideration of lithospheric problems.

7. Palaeo-Oceanography

SCOR Working Group 40 was established in 1973. The group has been active in preparing a survey of the subject and in meetings in UK, USA and Germany (Fed. Rep). WG 40 is preparing for their first big symposium to be held during the Joint Oceanographic Assembly in Edinburgh in September 1976.

The meeting agreed that consideration should be given to extending this project both in scope and in time to be a general study of past marine environments.

8. Continuation of Magnetic Studies of World Oceans

Magnetic measurements over the past few years have proved to be an extremely useful tool in support of morphological input to maps of the ocean floor and in advancing theories of crustal movement.

The meeting agreed wholeheartedly with the recommendations of the first International Workshop on Marine Geoscience, Honolulu, and agreed that magnetic measurements should be firmly encouraged; in particular in the study of basement age of ocean floors and of magnetic quiet zones, and in other special areas of the world.

9. Deep Sea Mineral Resources

The recommended symposium is being arranged as part of the International Geological Congress, to be held in Sydney in 1976. CMG is convening the symposium in close co-operation with the Commission on Manganese of the International Association on the Genesis of Ore Deposits (IAGOD) and with ECOR.

The subject is receiving practical attention in IOC sponsored activities in South-east Asia, the South Pacific and the Caribbean.

Mineral Resources of the oceans were considered further by the workshop, as part of a general study of sea-bed sedimentation and other processes (Annex IV(d) above).

10. Investigation of Anomalous Oceanic Areas

Several symposia and investigations as proposed by the Honolulu 1971 Workshop have been held by the International Geodynamics Project and other groups. Studies include those of the Iceland region, the Azores, Micro-continents and the Walvis ridge. Since this was only a beginning of studies of the many anomalous areas, it was agreed that continuation of this subject should be recommended, for example an extension of previous work in the Western Indian Ocean between the Seychelles and Africa.

11. Geotraverses

Long lines of geological and geophysical observations crossing land and sea are proposed and are being started as part of the South-east Asia, South Pacific and Caribbean work.

The Workshop supported multi-disciplinary studies of the geotraverse type in key areas.

ANNEX VI

Second International Workshop on Marine Geoscience

Mauritius, 9-13 August 1976

LIST OF ACRONYMS

ACMRR (of FAO)	Advisory Committee on Marine Resources Research
AGOR (of WMO)	Advisory Group on Ocean Research
CCOP (of ESCAP)	Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas
CCOP/SOPAC (of ESCAP)	Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas
CGMW (of IUGS)	Commission for the Geological Map of the World
CMG (of IUGS)	Commission for Marine Geology
CNEXO	Centre National pour l'Exploitation des Océans (France)
DSDP	Deep Sea Drilling Project
ECOR	Engineering Committee on Oceanic Resources
ESCAP	Economic and Social Commission for Asia and the Pacific
FAMOUS	French-American Mid-Ocean Underwater Study
FAO (of UN)	Food and Agriculture Organization
GEBCO	General Bathymetric Chart of the Oceans
IAGOD	International Association on the Genesis of Ore Deposits
IBCM	International Bathymetric Chart of the Mediterranean
ICAITI	Instituto Centroamericano de Investigación y Tecnología Industrial
ICG	Inter-Union Commission on Geodynamics
ICSU	International Council of Scientific Unions
IDOE	International Decade of Ocean Exploration
IFP	Institut Français du Pétrole (France)
IGCP (of Unesco/IUGS)	International Geological Correlation Programme
IHB (of IHO)	International Hydrographic Bureau
IHO	International Hydrographic Organization
IOCARIBE (of IOC)	IOC Association for the Caribbean and adjacent regions
IPOD	International Phase of Ocean Drilling
IUGG (of ICSU)	International Union of Geodesy and Geophysics
IUGS (of ICSU)	International Union of Geological Sciences
JOIDES	Joint Oceanographic Institutions for Deep Earth Sampling
SCOR (of ICSU)	Scientific Committee on Oceanic Research
SEATAR (of CCOP-IOC)	CCOP-IOC Joint Working Group on IDOE Studies on East Asia Tectonics and Resources
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WMO (of UN)	World Meteorological Organization