Intergovernmental Oceanographic Commission

Workshop Report No. 31

Third International Workshop on Marine Geoscience

Held under the sponsorship of:

Commission for Marine Geology (IUGS)
Intergovernmental Oceanographic Commission (IOC) and
Division of Marine Sciences of Unesco
Scientific Committee on Oceanic Research (SCOR of ICSU)
Deutsche Forschungsgemeinschaft (DFG)
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Heidelberg, 19-23 July 1982

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No.	Title	Publishing Body	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia /Report of the IDOE Workshop on/; Bangkok, Thailand, 24-29 Septmber 1973 UNDP (CCOP), 138 pp.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No. 20).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English 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 Via delle Terme di Caracalla 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	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (full text) Extract and Recommendations also in: French Spanish Russian
8	Joint IOC/FAO(IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English

No.	Title	Publishing Body	Languages
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique, 28 November-2 December 1977.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, 16-18 January 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
		CPPS Señor Miguel Bakula Secretario General de la Comisión Permanente del Pacífico Sur Vanderghem 590 Lima 27, Peru	Spanish
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Russian

No.	Title	Publishing Body	Languages
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	IOC, Uneso Place de Fontenoy 75700 Paris, France	English
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
18	IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No. 4)	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English
21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Russian
24	WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
25	Workshop on the Intercalibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English

No.	Title	Publishing Body	Languages
26	IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
29	WESTPAC Workshop on marine biological methodology Tokyo, 9-14 February 1981.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	IOC, Unesco, Place de Fontenoy, 75700, Paris, France	English Spanish
31	Third International Workshop on Marine Geoscience Heidelberg, Federal Republic of Germany, 19-24 July 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian

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* These are only the Summaries of a more than 200-page-long Scientific Report which will be published separately, as a Supplement to the present Report, by the Commission for Marine Geology of the International Union of Geological Sciences (IUGS). This Report can be obtained from the Commission for Marine Geology or from the Intergovernmental Oceanographic Commission.

PREFACE

Purpose

The Third International Workshop on Marine Geoscience was organized to examine new ideas for advancing the frontiers of marine geoscience, in the light of recent research since the Second International Workshop on Marine Geoscience, held in Mauritius from 9 to 13 August 1976. On the basis of the analysis, the Workshop formulated recommendations for future research and associated actions that are of interest to the international scientific community, marine policy makers, governments and international organizations. These recommendations are presented in this report with a short account of the meeting and a review of the implementation of the recommendations of the Second Workshop. This report is being published by the Intergovernmental Oceanographic Commission on behalf of the sponsors of the Workshop, of which the IOC is one.

Ocean Science and Non-Living Resources

The Executive Council of the Intergovernmental Oceanographic Commission, at its Fifteenth Session in March 1982 approved Resolution EC-XV.1, which expressed the need for a scientific programme on "Ocean Science and Non-Living Resources". The need for such an international programme is given greater impetus by the adoption of the Convention on the Law of the Sea which is expected to be signed in December 1982.

Bearing in mind that the Third International Workshop on Marine Geoscience was scheduled for July 1982 and the Joint Oceanographic Assembly for August 1982, the President of SCOR was requested by the Secretary of IOC to prepare a proposal for a programme on Ocean Science and Non-Living Resources, which, having been endorsed by responsible members of the international marine geoscience community, would serve as the basis for developing future scientific policy of IOC in this field and provide a guide for the planning of programmes by IOC Member States with a view to the rational exploration of the continental margin and the deep sea for potentially valuable mineral resources.

The draft proposal was reviewed in detail and revised accordingly by the Third International Workshop on Marine Geoscience. It will be submitted to the Twelfth Session of the IOC Assembly in November 1982 as Document IOC-XII/8 Annex 2a. It is in fact an expanded version of the section on Ocean Science and Non-Living Resources in the present report (Annex IV.D), but with a greater emphasis on resource potential and application to developing countries.

At the same time, the Summaries in Annex IV hereto, are presented, <u>in extenso</u> in the Scientific Report published separately, as a Supplement to the present Report, by the Commission for Marine Geology of IUGS and by the Intergovernmental Oceanographic Commission.

1. OPENING

The Workshop was opened by Professor Dr. German Müller, Director of the Institut für Sedimentforschung, Heidelberg University, on behalf of the host country. Dr. Ken Hsü, on behalf of the Commission for Marine Geology, and Dr. Dale Krause, on behalf of Unesco and the IOC, then welcomed the participants and thanked the University of Heidelberg for hosting the meeting. Professor Dr. Eugen Seibold, President of IUGS and President of the Deutsche Forschungsgemeinschaft, addressed the meeting on his arrival on Friday, 23 July. As Dr. Ruivo, Secretary IOC, was unable to attend, he invited Dr. Günter Giermann to represent the Commission. A List of Participants is attached as Annex II.

2. ARRANGEMENTS FOR THE WORKSHOP

Dr. Ken Hsü was elected Chairman of the Workshop.

The Agenda is given in Annex I.

Four sessional working groups were established as follows:

A. Ocean margins (Chairman: R. von Huene)

B. Geological history of the oceans (Chairman: J. Thiede)

C. Ocean lithosphere (Chairman: R. Whitmarsh)

D. Ocean science and non-living resources (Chairman: E. Simpson).

A List of Acronyms is given in Annex V.

3. STATE OF IMPLEMENTATION OF THE PROGRAMMES OF THE SECOND INTERNATIONAL WORKSHOP ON MARINE GEOSCIENCE, MAURITIUS, 9-13 AUGUST 1976, AND RECOMMENDATIONS FOR CONTINUATION OR FINALIZATION OF EXISTING EXERCISES

The report of the Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976, was introduced to the meeting. Dr. Ken Hsü was requested to review the state of implementation of this report. He commented as follows:

The recommendations made by the Second International Workshop on Marine Geoscience were directed largely to IOC, CMG and SCOR. Many of these recommendations were implemented, thanks to the efforts of the International phase of Ocean Drilling-Deep Sea Drilling Programme (IPOD-DSDP) and to many institutes and individuals working on more conventional methods.

An item-by-item evaluation of the implementation is given in the following sections. It should be noted that the International Ocean Drilling (IPOD) has a structure comprising four site-selecting panels (on ocean crust, on passive ocean margins, on active ocean-margins, and on active ocean margins, and on ocean paleo-environments) which corresponds almost exactly to the four Workshop Committees that formulated the recommendations thereof.

Implementation of the 1976 Recommendations on Evolution of the Ocean Lithosphere

(i) IPOD-DSDP has implemented Recommendations 1a, 1b, 1c. Holes were drilled on the axis of spreading ridges. Transects of holes were drilled to establish the degree of homogeneity of the ocean crust. Drilling to the top of seismic layer 3 was achieved in 1982 during Leg 81 in the East Pacific Ocean.

(ii) The full range of seismological techniques has been applied to studies of the ocean lithosphere. Some of the significant discoveries have been reported by sessional working group C (Annex IV).

(iii) A comprehensive study of the ocean lithosphere has been established as an aim of the International Lithosphere Program established by IUGG and IUGS of ICSU with the support of CMG following recommendations of the Second Workshop.

(iv) Quantitative studies of the rheology of the outer layers of the earth are carried out by individuals at several centres (e.g., D. McKenzie at Cambridge University; P. England at Harvard University, etc.)

Implementation of the 1976 Recommendations on Passive Margins

The recommendation of concentrated investigations across passive margins has been implemented by IPOD-DSDP. Some 10-12 drilling cruises have been scheduled since August 1976 (in addition to the dozen expeditions prior to that date) to investigate:

(i) sediment structure,

(ii) nature and location of continental boundary, and

(iii) deeper structures.

The multiple-channel seismic reflection has been further refined and has yielded much useful information. Significant progress is reported in the summary presented by sessional working group A (Annex IV).

Implementation of the 1976 Recommendations on Active Margins

(i) Several significant transects (Japanese Trench, Mariana Trench, Middle American Trench and the Barbados Ridge) have been investigated by drilling.

Marine surveys and downhole logging were routinely carried out.

(ii) Deep-tow instruments and submersibles have been used by various groups in the study of active margins (e.g., X. Le Pichon, W. Ryan, etc.).

(iii) a) Direct measurements of plate-movements have been carried out on land (e.g., San Andreas Fault Zone) but not on sea-floor.

b) Dynamic considerations of subduction zone are components of various long-range studies (see summary of sessional working group A).

c) Study of driving mechanism is just beginning and much remains unknown.

There were two sets of recommendations on the study of marine sediments:

Implementation of the 1976 Recommendations on Sea-Seafloor Interaction

(i) SCOR has not yet established a working group on "Oceanic Crust and Sea-water Interaction", but steps are being taken.

(ii) SCOR has established a working group on "Sedimentation Processes at Continental Margins".

(iii) SCOR has not established a working group on "High-energy Environments and Sediment-management Problems".

(iv) Holocene sediment sequences are being studied by various groups with varying degrees of co-ordination (e.g., IGCP working groups). The importance of this problem is appreciated by the IUGS Council.

(v) SCOR Working Group 46 "River Inputs to Ocean Systems" continues to function and is expected to report to SCOR at Halifax in August 1982.

Implementation of the 1976 Recommendations on Marine Palaeo-environmental Analysis

(i) A technique for the recovery of undisturbed cores from the uppermost 50 metres has been developed. The new hydraulic piston-corer can continuously recover undisturbed sediment cores down to 200-300 metres sub-bottom.

(ii) Techniques of navigated bottom-sampling have been developed (e.g., by CNEXO, Paris).

(iii) SCOR has established a working group on "Marine Geochronological Methods".

(iv) Cenozoic history of ocean basins has been a main theme of IPOD-DSDP investigations and the results will be synthesized by the International Commission on the Lithosphere (ICL), Working Group 7, on "Geologic History of the Oceans".

(v) SCOR may soon establish a new working group on "Depth Indicators in Marine Sediments".

4. CONSIDERATION OF NEW IDEAS FOR ADVANCING THE FRONTIERS OF MARINE GEOSCIENCE

To consider this Agenda Item, the Chairman had decided to establish four sessional working groups, as indicated above in section "2" (ocean margins; geological history of the oceans; ocean lithosphere; and ocean science and non-living resources).

Each working group chairman presented a summary of programmes for advancing the frontiers of marine geoscience, which is given in Annex IV. These programme summaries provide a brief analysis of each topic and recommendations for further research and other associated actions.

Design of Future Co-ordinated Programmes

Particular attention was drawn to the programme of Studies of East Asia Tectonics and Resources (SEATAR) by its Chairman, Dr. J. Katili, which is one of the most succesful programmes in marine geoscience. He cited this programme as an excellent example to consider when designing the future programmes, involving joint research by developing and developed countries. SEATAR was established in 1972 as a joint exercise between the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP) of the Economic and Social Commission for Asia and the Pacific (ESCAP) and IOC, and has implemented substantial parts of the recommendations of the First and Second International Workshops in Marine Geoscience.

CCOP, which was originally concerned with prospecting of offshore minerals (tin, detrital heavy minerals), has developed in the course of time into an organization more and more involved with deep-sea scientific research, while IOC, being a research-oriented body, had shown more and more interest in resource research. So, to establish a joint CCOP-IOC body like SEATAR was a logical consequence of this development. The SEATAR programme concentrates on investigations along a number of so-called transects, being sections of the earth's crust covering major areas of plate interactions, each transect crossing arc-trench systems, adjacent basins and continental areas.

In the ten years of existence, impressive progress has been made. Geoscientists from within and from outside the region have participated in the implementation of the programme. Numerous research vessels operated in East and South East Asian waters, directly or indirectly carrying out surveys for the programme, while providing on-board training for participants from developing countries. Up to now, the expenditure may have reached over US 30 million dollars.

This ambitious programme was, firstly, able to mobilise research funds and capabilities on a massive scale, which were concentrated on specific portions of the earth's crust and resulted in a massive accumulation of primary data in a very short time; secondly, the programme proved to be an interesting vehicle to promote international co-operation in earth sciences, bringing together scientists and research institutes of developed nations like the USA, Japan, the Federal Republic of Germany, France, the United Kingdom, Australia and the Netherlands, with those of developing countries such as Thailand, Malaysia, South Korea and Indonesia; and, thirdly, the programme was a major enterprise in a multidisciplinary approach to scientific problem-solving combining various disciplines, such as seismology, gravity, palaeomagnetism, tectonics, geochemistry, age-dating, palaeontology etc.

Several factors contributed to the successful operation of the SEATAR programmes of which the most important are:

(i) The unique geological position of the area as the place of interaction of at least three gigantic crustal plates with all the accompanying phenomena, such as active subduction, active collision, active volcanism, formation of marginal basins, etc.

(ii) The region is endowed with rich mineral resources, such as hydrocarbons and hard minerals, which have attracted multinational mining and petroleum companies to carry out exploration on a large scale in some of the remote and unknown regions of the world.

(iii) The geographic situation of the region relatively close to developed countries, such as Japan, Australia, USA (Hawaii).

(iv) The similarity in the geological and geophysical features of the East Asian countries forming the western part of the Pacific Active Margin, formerly referred to as the "Ring of Fire".

(v) And last, but not least, the scientific leadership that is able to co-ordinate not only government agencies but also research institutes and universities within and outside the region and the multinational mining and petroleum companies which widely contributed towards the execution of the programme.

5. ADOPTION OF THE FINAL REPORT INCLUDING RECOMMENDATIONS

The Workshop adopted the final report with its annexed recommendations (Annexes III and IV).

6. CLOSURE

The main meeting closed on Friday afternoon, 23 July 1982. A final meeting of the organizers was held in Saturday morning, 24 July 1982.

ANNEX I

AGENDA

1. Opening

2. Arrangements for the Workshop

3. State of implementation of the programmes of the Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976, and recommendations for continuation or finalization of existing exercises

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

5. Adoption of the final report including recommendations

6. Closure

ANNEX II

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ANNEX III

GENERAL RECOMMENDATIONS*

The Third International Workshop on Marine Geoscience,

(1) Recommends that the sponsoring organizations (CMG, IOC, Unesco/OCE, SCOR, DFG) bring the programme developed by the Workshop to the attention of other appropriate international organizations and institutions, to the relevant subsidiary, in particular regional, bodies of the IOC, as well as to ECOR (Engineering Committee on Ocean Resources) as an official advisory body to IOC, urging them to take the programme and recommendations prepared by the Workshop into account when preparing their own future international, national or institutional programmes, keeping in mind that the programme is meant to be a working basis for the years to come, in order to increase knowledge so as to facilitate access to marine non-living resource deposits.

(2) Recommends that Unesco, through its Division of Marine Sciences, give high priority to young marine geoscientists in its fellowship programme, provide travel grants to marine geoscientists from developing countries to present their research results at scientific meetings and to facilitate co-operative research, promote a scheme of visiting lecturers in marine geoscience, and develop national assistance projects to strengthen marine geoscience.

(3) Recommends that developed countries and their institutions that sponsor geological/geophysical research, provide opportunity for scientists of developing countries to participate in the planning, implementation and evaluation stages of their research cruises.

(4) Recommends that developing countries establish regional bodies similar to CCOP (East Asia), CCOP/SOPAC (South Pacific), or the CCOP/IOC Joint Working Group on South East Asian Tectonics and Resources (SEATAR), in co-operation in the region with organizations such as the Intergovernmental Oceanographic Commission of Unesco.

The first task of such a body should be the establishment of an inventory of offshore resources including hydrocarbons, detrital heavy minerals and construction aggregates.

Once marine resource-oriented programmes are established by regional workshops, it is advised to expand the scope of work into investigating the deeper waters in co-operation with developed countries.

Countries of a region such as East or West Africa that might wish to establish a regional body for marine geological-geophysical studies, including resource research, should take into account the organizational structure of SEATAR and should co-operate closely with the existing regional institutions such as the Regional Centre for Cartographic Services in Nairobi.

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* Technical recommendations are given in each of the Programme Summaries given in Annex IV.

ANNEX IV

PROGRAMME SUMMARIES*
(Summarized sessional working group reports)

A. Ocean margins

B. Geological history of the oceans

C. Ocean lithosphere

D. Ocean science and non-living resources

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* For details, see extensive Scientific Report of this Workshop published separately, as a Supplement to the present Report, by the Commission for Marine Geology and the Intergovernmental Oceanographic Commission.

ANNEX IV.A

SESSIONAL WORKING GROUP A - OCEAN MARGINS

Studies of modern and ancient margins, where oceanic and continental crust are joined, are of broad international interest because the margins contain the submerged continuation of the continents. The continents have supplied most of the earth's mineral and energy resources. In addition, margins are a common ground for geoscientists who work in the marine and non-marine disciplines, and margins are the common ground for studies of the modern dynamic analogies of the processes that once shaped the continents.

A review of the six years' progress since the Mauritius meeting shows that many recommended margin objectives were met, that other questions were not fully addressed, and that some unanticipated discoveries caused major shifts in the emphasis of margin study. At Mauritius it was recognized that multichannel seismic techniques were becoming available to the academic community; indeed, significant steps in knowledge have resulted from these seismic data, but they are available for only a few selected places. The desire for deep sampling was met by the use of some industry holes on passive margins and by alternate siting of shallower drill holes. In addition, significant new concepts about margins developed from conventional studies on land.

More specifically, the multichannel seismic data across a few passive margins show initial rapid subsidence, flexure of the lithosphere, and the topography of the original rifted crust. IPOD drilling has provided the first samples form the original sea floor of the early rifted Atlantic ocean off North Africa and North America. Pilot modelling studies show an interesting new approach to the establishment of mechanical and thermal models of the crust. Multichannel seismic records across active margins have clearly resolved the complex accretional structure at the front of a few subduction zones. Combined with the first drilling through slope deposits on three margins, the data have made clear a large diversity of structure. There is now a series of apparent paradoxes, such as extensional as well as compressional structures, subsidence as well as uplift, erosion system dominated by steady plate convergence. Since Mauritius, the emphasis on uniformity of active margin structure has shifted to an emphasis on their diversity.

The emphasis in the study of marine-sediment sequences has been highlighted by the study of inconformities and the effect of global sea-level change. Such studies are international, in the broadest sense, and concern the sediment sequences on margins around all oceans.

The contributions of these studies are complemented by studies on land showing, for instance, that much of western North America is an assembly of displaced terrains. Modern analogues of these terrains may be the present ocean plateaux or continental fragments of non-oceanic origin. The crustal mobility indicated by palaeomagnetic studies rivals that of continental drift and the opening of the Atlantic.

Problem-oriented surveys using expensive and sophisticated techniques are essential in selected margin areas. However, the great diversity of margin structure and history make it important to maintain a general programme of geological and geophysical mapping with less expensive technology to fill the many gaps in knowledge along little-investigated margins. Important temporal data from marine areas can be gained by conventional dredging and coring if there are opportune outcrops, and the marine data are significantly more informative if evaluated in combination with land data. A list of suggested studies or objects of study, under three headings, follows:

Active-Margin Problems

Dynamic evolution of convergent-margin systems with emphasis on the apparent synchronous and asynchronous relation of arc volcanism and back-arc spreading to subduction.

The hydrologic regime in subduction zones with reference to pressure, temperature and diagenetic processes.

Real-time measurement of tectonism at the front of subduction zones, including the recording of micro-seismicity, quantitative measurement of deformation, and of stress.

Passive-Margin Investigations

Intensify the investigations of the continent-ocean boundary and its related geological features.

Stress the importance of defining the vertical movements of the margin and the understanding of the apparent large variability of vertical movement in time and space.

Evolution of Sediment Sequences on Margins

Slope-sediment processes including detailed study of the mechanisms of sediment transfer in terms of dynamics, facies, and topographic provinces.

Unconformities and a study of their distribution in time and space to assess their global or regional significance and distinguish between the influences of changes in sea level and regional tectonics.

A study of sediment sequences that contain complete assemblages of depth-sensitive micro-organisms from the epi-bathyal environments.

Oceanic Plateaux and Allochthonous Terrains

Study the nature of selected large oceanic plateaux in various oceans with emphasis on their crustal structure, the structure of their margin, their motion in the past, their point of origin and vertical movements.

Study modern collision zones using geological and geophysical techniques.

Study the fragmentation of continents; in particular, the processes of continental rifting.

ANNEX IV.B

SESSIONAL WORKING GROUP B - GEOLOGICAL HISTORY OF THE OCEANS

Oceanic depositional environments record the results of processes and feedback mechanisms of changes in the lithosphere, hydrosphere, atmosphere and biosphere of the planet. Five themes have been selected out of the wide field of the geological history of the oceans because they seemed to be the most important ones and because they represent examples of the types, and quantitative nature, of research on the geological history of the oceans during the coming decade. In addition to the recommendations under the five themes, some general recommendations have been developed because they appear to be supported by ideas put forward in several of the themes.

General Recommendations

(i) Curation of samples

For many studies discussed by this group, appropriate samples of deep-sea sediment are essential. The curation and dissemination of samples, while of great importance, are not very attractive to funding agencies. For developing marine institutions, the availability of locally-obtained samples may be one of the most effective means of promoting collaboration with scientists from long-established institutions. The group recommends that international assistance be given to marine laboratories in developing countries to enable them to curate samples and to make information available that encourages their use.

(ii) Collaborative projects

We encourage organizations such as Unesco and its Intergovernmental Oceanographic Commission to support collaborative projects between developing countries and those with long-established laboratories. Not only is this an important means of accelerating the development of the marine geosciences in developing countries, but such collaboration is also, in a necessarily global study such as palaeo-oceanography or palaeo-climatology, very valuable for the access it gives to another region.

(iii) Shallow drilling

The improved coring techniques that have been developed in the course of deep-sea drilling over the past decade, and many of the scientific goals that have been defined under the geological history of the oceans, suggest the collection of high-quality, undisturbed, large-diameter sediment cores from the upper few hundred meters of the sediment columns in shallow to moderate water depths. The group encourages the improvement of such coring techniques and the development of drilling programmes in areas that have not been accessible hitherto.

Theme 1 - Marine Biochronology

Marine geochronology has made important and rapid advances over the past decade. A combination of biostratigraphic, radiometric and magnetostratigraphic methods provides, at present, low, precise and detailed quantitative dating techniques which can be used for most marine sedimentary columns. We stand on the threshold of new major advances in marine geochronology. The recent improvement in deep-sea coring techniques (hydraulic piston corer has resulted in direct correlations between plankton biostratigraphy and magnetic-polarity stratigraphy for the entire Cenozoic Era and part of the Late Mesozoic. Continued improvement of marine coring techniques and studies of continental exposures of marine sedimentary rocks will complete and improve the presently available stratigraphic methods, tools and choice of time scales.

Recommendations

(i) The M-sequence magnetic anomalies of the oceanic crust have given a pattern of geomagnetic polarity for the Late Jurassic and Early Cretaceous. As was the case in the Cenozoic, it is necessary to confirm this sequence in a separate medium and to date it biostratigraphically. Because of the induration of deep-sea sediments of this age, it will be impossible to use a Hydraulic Piston Corer (HPC) device to obtain suitable DSPD samples. If rotary drilling is employed, it must use a non-magnetic (Monel composition) drill-bit to avoid magnetic contamination of the DSPD magnetostratigraphy.

(ii) Integrated investigations of magnetic stratigraphy and biostratigraphy in continental exposures of marine sedimentary rocks will be needed to provide independant but compatible confirmation and dating of the M-sequence polarity chrons (time sequences). The existence of possible, unconfirmed polarity chrons within the Cretaceous quiet zone should be thoroughly investigated with the intention of making magnetostratigraphic correlations of the Middle Cretaceous stages.

(iii) Biochronology will remain the most precise dating possible for these older magnetic polarity chrons. However, geophysicists and geologists alike will require a more precise temporal framework for the computation of geological rate processes. For this reason, additional radiometric dating of the Cretaceous and Jurassic stages must be encouraged, with particular emphasis on providing calibration points for Mesozoic magnetobiochronology.

(iv) HPC sampling of additional sites spanning the Miocene and in particular the middle and upper part, where magnetobiostratigraphic correlations (particularly in the calcareous plankton) are inadequate, deserves a high priority.

(v) HPC sampling at low-to-mid-latitude sites which will yield better data on the integration of calcareous and siliceous plankton zonations, particularly in the Palaeogene.

(vi) HPC sampling to reinforce (support) or modify the magnetobiostratigraphic correlations that now exist. In numerous instances current correlations are based upon one or two observations. While we do not expect major changes in magnetobiostratigraphic correlations of the major epoch-series boundaries of the Cenozoic, we may expect not insignificant modifications (refinements) of some intra-epochal datum levels and/or zonal boundaries with additional data.

(vii) Oriented HPC sampling in various latitudes to determine the isochrony or heterochrony of biostratigraphic datum events. This is a necessary part of recognizing the existence of biogeographic provinces in the stratigraphic record and in the subsequent reconstruction of palaeoclimatic and palaeo-oceanographic history.

(viii) An important goal of marine geochronology, whether in the analysis of oceanic anomalies or sediment magnetostratigraphy, must be to establish more precisely the times of major changes in ocean floor spreading and, in particular, the nature and the timing of initial rifting and early spreading.

(ix) Co-operation between seismic and biostratigraphic specialists is encouraged in order to determine the reality of (supposed) globally synchronous sedimentological events (e.g., inconformities, eustatic sea-level changes) and their use as chronology markers ("event stratochronology").

(x) The group encourages biostratigraphers to quantify their determinations of datum events for the purpose of providing a more refined plankton biochronology.

(xi) The group strongly advises the interdisciplinary co-operation of biostratigraphers, geochemists and geophysicists in all aspects of research that lead to an improvement in marine geochronology.

Theme 2 - Climatic Changes

Climatic changes in time represent probably the most important driving function for the dynamics of the marine deposits and palaeoenvironments. Pelagic and hemipelagic sedimentary sequences provide data bases to support the study of the climate changes throughout the last 150 million years. The improved sampling techniques of deep-sea coring now allow study of the long-term trends in the climatic conditions over many millions of years, as well as short-term variability of climate. Besides the long-term climatic changes, it seemed important to consider major climatic thresholds and to carry out high-reduction studies of climate variability. The climate record of the past 20,000 years, the history of deep-water dynamics and climate-ocean interactions close to continents, as well as polar climates, deserve particular attention.

Recommendations

(i) Long-term climatic change

(a) Continuing efforts must be made to increase the global and temporal coverage of available sediment samples for analysis. A drilling vessel and piston coring will be essential facilities for the foreseeable future.

(b) Synoptic reconstructions of global climate at different stages in the tectonic evolution of the ocean basins should be made, and support should be given to collaborative projects with this objective.

(c) In planning the future sampling of early Cenozoic and Mesozoic sediments, sample preservation is an important consideration. Some coring should be concentrated on areas where these sediments are outcropping at the sea floor or only at a shallow depth. Giant Piston Core (GPC) sampling may be valuable in such areas.

(d) Effort must be made to increase the availability of high-latitude samples from both hemispheres.

(ii) Major climatic thresholds

(a) Synoptic studies of global climate immediately before and after major climatic thresholds are crossed should be made (for example, immediately before and after the rapid cooling near the Eocene-Oligocene boundary).

(b) Efforts to retrieve undisturbed and continuous records of these times of rapid transition from one state to another must be continued.

(iii) High-resolution studies of climate variability

(a) Extensive studies using a time resolution of better than 5,000 years, and using several different quantitative techniques, should be made in different parts of the geological column.

(b) High-resolution records from the marginal sea environments should be obtained, since these may prove to contain amplified records of climatic variability that may prove to be very slight in the open ocean at some times in the past.

(c) Use of the principal of tuning sections of the record of climatic variability to astronomically known frequencies should be extended whenever the presence of a signal related to these astronomical variables can be detected. This in turn should be utilized to calibrate accumulation rate data and other geological rate processes such as plate motions.

(iv) Climate record of the past 20,000 years

(a) Synoptic climate reconstructions at selected time slices during the past 20,000 years, particularly using sediments from relatively close to the continents and on the continental shelf, should be encouraged from all areas. Such studies will give rise to international collaboration, and will assist in the understanding of local coastal processes, the generation of nearshore deposits of economic interest (placer deposits, phosphates), and of variations in marine productivity. Local initiatives should be encouraged, since an international project organized at too early a juncture might become too unwieldy, or stifle local initiatives.

(b) The impact of climate variability over the past few centuries on the assumed steady-state physical and chemical properties of the deep ocean (mixing time over 1,000 years) should be evaluated. This concerns deep water mass genesis and the input of major rivers from areas subject to regional rainfall variations.

(c) Several climatic transitions similar to the last deglaciation should be studied in detail so that the underlying general similarities can be separated from peculiarities of the last deglaciation. Similarly, several intervals of glacial initiation should be studied to avoid making predictions on the basis of a particular glacial onset which might prove to have been anomalous.

(v) History of deep-water dynamics

(a) Techniques that address the dynamics and mixing of the deep ocean in the geological past require further development which should be promoted by a working group.

(b) Carefully planned coring and drilling programmes should be devised to cover long vertical traverses that monitor the deep-water mass structure. More attention should be given to coring shallow areas where the intermediate water masses may be monitored.

(c) Areas should be sought where coring permits the evaluation of possible changes in the thickness of the low-latitude warm-water pool. This requires coverage of the upper few hundred meters at several latitudes and poses considerable problems at present, but is important to the understanding of past ocean climate.

(vi) Continental climate in climate-ocean interactions

(a) More studies should be made of the means by which indicators of continental climate (pollen, dust, phytoliths, river mud) enter the marine sediment.

(b) Sediment records from the continental margins should be utilized to make better reconstructions of the continental climate record, which is seldom available in continuous deposits on the continents themselves.

(c) Long stratigraphic records from lake sediments should be obtained and studied from a palaeoclimatic point of view. It would be desirable for samples from such cores to be made freely available in the same way that samples from the deep sea are generally freely available.

(vii) Sea-ice and floating icebergs

(a) Techniques for the reconstruction of past sea-ice and floating ice limits should be developed and tested.

(b) A concerted effort should be made to evaluate the scattered evidence for ice rafting in the early Cenozoic.

Theme 3 - Polar Oceans

The polar oceans today represent unique environments because of their cold hydrospheres and because of large ice-shields on the adjacent land masses. They are poorly known because it is so difficult and expensive to do research in polar seas. An understanding of past and present plate movements and accretionary tectonics in the polar areas will be required before a complete model of even late Mesozoic and Cenozoic world-wide plate motions can be achieved. The cold environments are the result of a long-term climate deterioration since the end of the Mesozoic. Upon this is surimposed short-term, regularly recurring, climate shifts between colder glacial periods and warmer intra-glacial periods. This evolution should be monitored in the polar ocean but very little is known up to now.

Recommendations

(i) Antarctic exploration should be conducted in the following systematic manner area by area:

(a) aerosurveys (magnetic, gravity);

(b) marine seismic surveys (3.5 kHz, single and multi-channel);

(c) drilling, site-specific coring and dredging.

The tectonic history and structure of the margin and associated basin can usually be evaluated in step (a) using well defined techniques. Logistics are difficult but not insurmountable. Aerosurveys can be conducted by long-range aircraft or by helicopters supported with ice-breakers.

Priority areas for aerosurveys are: Weddell Sea, Eastern Ross and Bellinghausen Seas, to correlate magnetic anomalies between Marie Byrd Land and Campbell Plateau, and the Northern Victoria Land Margin to provide constraints on the predrift position of Tasmania.

(ii) Shipboard and ice-floe drilling for research purposes in ice-covered waters should be evaluated. To ensure that maximum skills and state-of-the-art techniques are utilized, a working group to evaluate methods, feasibility and scientific objectives for Arctic drilling and long cores and dredges should be immediately established.

(iii) If feasible, Arctic drilling and long coring for research purposes is of highest priority. Objectives would be multiple:

(a) determine nature of structural basement;

(b) obtain information on composition and facies of Cenozoic and Mesozoic deposits;

(c) determine Arctic palaeoclimatology and palaeo-oceanography, and,

(d) especially determine the onset and timing of northern hemisphere glaciation.

A working group should be established to evaluate the feasibility of such drilling.

This would require a major effort by a research ice-breaker to sample pelagic, hemipelagic and terrigenous sediment suites from a number of different sites north of Svalbard.

(iv) The organization of an Inter-Association Commission within IUGG has been proposed, to:

(a) promote Arctic physical science and the sharing of ideas and data;

(b) provide a permanent forum for international discussion planning, and co-ordination of Arctic research;

(c) publish, as part of the IUGG "Geological Newsletter", Arctic information to inform interested scientists and organizations of planned activities between scientists and to facilitate utilization of common logistics.

The group supports the proposed plan.

(v) Sources, pathways and flux rates of sediment components in ice-covered oceans should be studied in great detail. Only a few sediment-trap data are available up to now, and additional data are urgently needed. Sediment-trap deployment around Antarctica and in the Arctic Basin should be encouraged.

Theme 4 - Ocean Fluxes

Bulk sediment and individual component mass-flux rates provide parameters for the quantification of sedimentation and for the evaluation of the causes of change within an absolute frame of reference. Variations in maximum rates in time, either long-term trends or short-term events, reflect the integrated effect of control of global tectonics, ocean circulation, primary production and climatic conditions. A detailed understanding, therefore, of present sediment fluxes in the ocean can be directly applied to the ancient sediment record, provided adequate stratigraphic control is obtained and overprinting of characteristics due to later events can be recognized and removed.

Recommendations

(i) Geologically useful, integrated, net flux rates of total matter should be measured in key environments of the world's ocean; for example, marginal seas and deep ocean; seasonal, latitudinal variability; oligotrophic vs. eutrophic.

(ii) Detailed component analyses of material fluxes are encouraged to facilitate recognition of fractionation in sedimentary assemblages due to dissolution, remineralization and biological re-packing, to ecological successions of plankton communities and to scavenging of particle-reactive elements.

(iii) A search for, and identification of, conservative tracers or specific indicators, and the monitoring of their flux rates, in order to quantify the sources and pathways of certain elements.

(iv) A more precise determination of global patterns of modern accumulation rates should be undertaken.

(v) A better understanding of the processes in the benthic transition layer will have to be achieved to relate water-column fluxes quantitavely to sediment accumulation.

(vi) Efforts should be continued to develop transfer functions that link accumulation rates of suitable constituents in Holocene sediments with primary production, with deep-water oxygenation, with terrigenous material and hydrothermal inputs. Such transfer functions calibrated in Recent environments can then be applied to estimate past oceanic fluxes from the accumulation rates in ancient sediments.

(vii) Studies of seasonal variability of flux rates should be encouraged to broaden the spectrum of oceanic calibration scenarios for the geological record. Temporal and spatial variance of accumulation rates in Quaternary and ancient sediments ought to be investigated to estimate the range of possible interpretation.

(viii) The chemical changes induced in pre-Pleistocene sediments by aging and burial need to be assessed quantitatively. The recovery of ancient sediment sequences near submarine outcrops and in areas with thin sediment cover should be encouraged. A systematic survey of seismic reflection profiles should be undertaken to identify such regions of minimal diagenetic overprint of sediments of particular ages. Future coring programmes should be planned to recover undisturbed and long cores form such areas.

(ix) Every effort should be made to measure geotechnical properties of recovered sediments and to establish and refine stratigraphic control in such sequences.

Theme 5 - Rare and Unusual Events

Events influencing the geological history of the ocean can be rare by their nature, but they can also be rare because of their magnitude. Suhh events have often led to catastrophes, with a major impact on the palaeoenvironment of the oceans. Examples of such events are impacts of celestial bodies. The most normal, but recurring, event in the ocean was the development of widespread anoxia in Mesozoic times, when large amounts of organic carbon were collected in the deep oceans and in epicontinental seas during a time of high eustatic sea level stand.

Recommendations

(i) Rare events

Geologically rare events may have greatly influenced the geological history of the oceans and of the atmosphere, leading to catastrophic evolutionary changes. Our recommendations to study this problem are:

(a) to search for geochemical indicators to decipher the occurrence, the nature and the magnitude of rare events;

(b) to conduct experiments to relate the observed geochemical anomalies to currently observable or theoretically possible unusual processes; and

(c) to carry out palaeontological investigations to determine the rate, the geographic selectivity of accelerated extinctions. A study of the consequences of such unusual happenings might help us predict the consequences to biological evolution of man-made catastrophic environmental changes.

(ii) Anoxic events

(a) The early Toarcian and Cenomanian-Turonian anoxic events appear to correlate with the extinction of certain taxonomic groups. This proposed correlation needs detailed examination in the light of proposed habitats of the affected groups.

(b) Preliminary Italian data suggest that the Cenomanian-Turonian boundary black shale is characterized by an iridium anomaly of comparable or greater magnitude than that at the Cretaceous-Tertiary boundary. This needs to be verified, and other black-shale sequences need to be examined; although the geochemical behaviour of iridium is poorly known, its extraterrestrial provenance has been recently taken to indicate major cosmic "events" in the earth's history.

(c) It is still not established whether the shorter-term anoxic events are synchronous within the limits of palaeontological resolution. The synchrony or otherwise of these events needs to be established by isotopic or, if possible, palaeomagnetic stratigraphy.

(d) The significance of the ubiquitous presence of smectite in Mesozoic black shales needs to be considered: is there any genetic connection with volcanic activity?

(e) If anoxic events reflect periods of anomalously high organic productivity, the process that initiated and terminated this phenomenon needs to be understood.

(f) Anoxic events must influence the carbon-isotope reservoir; the nature of the interaction needs to be established. A detailed carbon-isotope stratigraphy needs to be established; this may identify important episodes of source-rock genesis.

(g) Given that Cretaceous anoxic events correlate with $+\delta^{13}C$ excursions the "heavy" carbon events in the Palaeocene and mid-Miocene need to be evaluated against other contemporaneous oceanographic phenomena. The flux rates of elements in related sequences that contain black shales need to be evaluated to estimate the duration of anoxic events.

ANNEX IV.C

SESSIONAL WORKING GROUP C - OCEAN LITHOSPHERE

Introduction

The oceanic lithosphere measures as much as the outer 100 km of the earth beneath two-thirds of the earth's surface. This report accentuates how little we know even about the top five kilometres or so under the sea floor. Naturally, the report is biased towards the uppermost levels of the lithosphere because this region is more accessible to a variety of geological and geophysical techniques. Recently, two other sets of recommendations about the ocean crust and lithosphere have also been collected together by two different groups of marine geoscientists. They have been published by JOI Inc. (Conference on Scientific Ocean Drifting, 1982) and the International Lithosphere Programme. Our recommendations, where different from those in the above-mentioned reports, reflect the individual expertise of the working group members and do not necessarily imply a different set of priorities.

Accreting Plate-Boundaries

Accreting plate-boundaries are the places where new oceanic lithosphere is created and usually are situated on the so-called mid-ocean ridges. The broad features of such plate-boundaries and their variation with spreading-rate have been adequately described. However, we still lack a clear understanding of the associated volcanic and tectonic processes, particularly as regards what is going on beneath the sea-bed. Although predicted to exist, no magma chamber has yet been located under a slow-spreading ridge. Several hydrothermal systems have been discovered on different ridges but the sub-bottom leaching and flow regions associated with such systems are not understood. The depth and shape of the ubiquitous normal faults which parallel spreading axes are unknown. Detailed studies of microseismicity can probably solve their problem. There are many examples of highly attenuated crust beneath transform faults (and fracture zones) but the geological processes that give rise to such crust can at present only be hinted at.

Upper Crustal Problem

The study of the upper igneous crust has benefitted enormously from material obtained by DSPD and lately during IPOD. It is vitally important that scientific drilling in the oceans should continue so that holes may be drilled to greater depths (at least to the top of seismic layer 3, not yet sampled) and into more areas of Jurassic and Cretaceous crust.

As the lithosphere is carried away from a spreading axis, various processes work to alter its properties. These processes, largely controlled by, or dependent on, the circulation of seawater within the crust lead to important changes in the bulk magnetization, permeability, seismic velocity and mineralogy of the crust. More work is needed, particularly to provide a background for real practical problems such as waste-disposal.

The sediments accumulating on top of the igneous crust undergo important diagenetic changes. It is important to determine how the mineral assemblages produced by diagenesis reflect their palaeo-environment. There is scope for considerable further field and laboratory work here.

Sub-Crustal Lithosphere

The base of the lithosphere may be defined either on seismic, mechanical or thermal grounds. Nevertheless, it is clear that we possess very little hard data in any of these areas to provide constraints on quantitative physical and petrological models of the creation and evolution of the lithosphere.

The sub-crustal lithosphere is more accessible to study by seismic techniques than by any other means. It has been demonstrated already that, in several areas, the top two kilometres of the sub-crustal lithosphere possess P-wave azimuth anisotropy. How deep does this persist? There are indications that real differences may exist between the Atlantic and Pacific lithospheres. The seismic field studies must be expanded to include not only long-range seismic refraction profiles but also observations of teleseismic events by sea-bed arrays. Further refinement of quantitative petrological models and laboratory experiments at higher temperatures and pressures (ultimately 30 kbar and 1000°C) are essential.

As the lithosphere ages it thickens, but the rate of thickening and the petrological processes involved need to be much more closely defined.

Within-Plate Processes

Measurements and observations can be made within plates that relate to the driving force acting on plates. The state of stress within a plate can be deduced from earthquake first-motion studies, particularly in areas where there seem to be incipient plate-boundaries. Faulting and volcanism within plates, including passive continental margins, deserve further study.

Sub-Aerial Ocean Fragments

In many parts of the world, fragments of ocean crust and deep-sea sediments, some much older than any known submarine crust today, are exposed on land. Although some important changes may have occurred in such material as a result of its translation to the sub-aerial environment, it can nevertheless provide valuable and easily accessible samples. It is recommended that, where the situation is suitable, holes be drilled into such formations and that these holes be logged.

General Recommendations

(i) A full suite of modern geophysical instrumentation is already beyond the reach of any one institution. With the increase in complexity and cost of new instruments there will be fewer and fewer institutions in a position to own and operate such equipment. Eventually, marine geoscience will be deprived of the use of the most up-to-date methods and the advancement of the science will suffer.

Marine geoscience has become "Big Science". In other fields of "Big Science" the expensive facilities are operated as international facilities (an example is CERN) and perhaps the time has come to consider such an International Co-operating Centre for Marine Geoscience. It is therefore recommended to IUGS, IUGG and SCOR that an ad hoc committee of experts be appointed to investigate the feasibility and practicability of establishing such a centre and to report back by 1984.

(ii) In the light of the important advances already made in the study of geological and geophysical processes in the upper oceanic crust as a result of samples and measurements provided by the Deep-Sea Drilling Project, and in view of the potential for future valuable work afforded by downhole instrumentation and deeper holes, we recommend that scientific drilling in the oceans be continued and that plans for such drilling be strongly endorsed.

Technical Recommendations

The working group on the ocean lithosphere recommended that:

(i) Scientific drilling in the oceans should not cease after the present phase of drilling ends in 1983.

The following supplementary recommendations under (i) are dependent upon such drilling:

(a) High resolution studies of in situ mineralogical and geochemical gradients should be carried out coupled with laboratory experiments in order to determine rates of diagenesis and mineral formation.

(b) The palaeo-environmental implications of diagenetic facies and marker-mineral assemblages should be synthesized by time interval and tectonic setting, including the interaction of aqueous and sedimentary processes.

(c) More igneous upper crustal material be obtained from Jurassic and Cretaceous crust, from deeper layers (sheeted-dyke complex and below) and from high latitudes.

(d) Holes should be drilled to determine the scale of lateral heterogeneity within igneous basement and its relation to basement faults and relief.

(ii) Comparative global investigations of hydrothermal systems from different tectonic settings should be carried out.

(iii) Sub-aerial studies of ophiolites and other relict deep-sea crustal fragments should be continued, and plans to drill logged holes into such formations should be particularly encouraged.

(iv) Experiments to detect and delineate magma chambers at slow-spreading ridges should be carried out particularly with the use of seismic and electrical conductivity techniques in regions of present-day hydrothermal or eruptive activity.

(v) Studies of the tectonics of accreting plate-boundaries and transform faults should be made using microseismicity to trace faults at depth.

(vi) Geological models of transform fault zones should be developed with the aid of precisely located samples and geophysical measurements to explain the thinned crust under such zones.

(vii) Investigations of all aspects of the sub-Moho lithosphere should be encouraged. Long-range seismic refraction profiles, laboratory studies of candidate mineral assemblages at relevant temperature-pressure conditions and quantitative petrological modelling are particularly important.

(viii) Methods should be developed to study present-day lithospheric stresses within the oceanic part of plates in order to constrain models of plate-driving forces and of the processes going on at incipient plate boundaries. Such methods might include earthquake prediction studies, electrical and seismic anisotropy observations and long-term downhole measurements.

ANNEX IV.D

SESSIONAL WORKING GROUP D - OCEAN SCIENCE AND NON-LIVING RESOURCES

Introduction

The 1970s were the International Decade of Ocean Exploration. As a result, we have witnessed a decade of intensive exploration of the ocean floor, particularly with respect to the deep oceans. Our knowledge of deep-ocean mineral resources and offshore hydrocarbon deposits is therefore much more comprehensive than before.

In fact, hydrocarbons remain the most important marine mineral resources by far. Very considerable effort has gone into the study of off-shore margins with a view to finding sedimentary basins that are prospective for hydrocarbons. Nonetheless, there are large areas of the world's continental shelves where further prospecting is necessary.

Of the inorganic minerals, only comparatively near-shore shelf deposits to depths of about 40 metres have so far been recovered commercially. Sand and gravel (for aggregate production) remain the most important of these deposits. In the U.K., for example, offshore aggregates compose 15% of total aggregate production. Significant production also occurs in other maritime countries such as Holland and Japan. Nonetheless, offshore aggregate production has been carried out principally by private companies with little scientific input, although this situation is slowly improving, with studies of the impact of the mining on shore-line processes becoming more apparent. For many maritime reasons, offshore aggregate is likely to remain the principal offshore inorganic mineral recovered over the next decade and substantially more effort needs to be devoted to the location of these deposits and to the potential environmental impact of mining these deposits (biological studies and evaluation of impact on coastal processes).

A significant effort has been devoted to placers. At present, the cassiterite deposits from S.E. Asia remain the principal placer mined. In Australia, beach and dune sands are a major source of rutile and monazite, and in New Zealand, titanomagnetite is mined for steel production. In spite of significant effort to identify submerged strand-lines, off Mozambique, Australia and New Zealand, none of these is commercially viable under present circumstances.

Phosphorites are an important authigenic mineral which have been studied in a number of offshore locations, such as Morocco, South Africa, west coast of the USA, Peru and New Zealand. Quite apart from the geology of the deposit, a substantial market for the phosphate fertilizer is required. The most promising area at present appears to be the Chatham Rise east of New Zealand where a ready market (New Zealand) is available and existing supplies (Christmas Island) are running out. There remains a substantial amount of work that could be carried out on the genesis of this type of deposit.

In the deep sea, manganese nodules are the largest and the most interesting type of deposit from a commercial standpoint. Nonetheless, only a relatively small percentage of the nodules (less than 5%) remains commercially prospective. From a scientific point of view, the major aspects of nodule genesis are now understood. Future studies must be directed to special types of nodules and specific programmes that will answer critical problems. An example is the U.S. MANOP Program which will study quantitatively element fluxes to the nodules in a series of different environments.

A field that has burst into prominence over the last five years is submarine geothermal activity. Submarine vents discharging hot water with associated sulphide and oxide deposits have been discovered on various mid-ocean ridges. These have attracted considerable interest and have demonstrated the use of submersibles in scientific studies of the deep-sea floor. An area likely to attract increasing interest to its hydrothermal activity are island arcs, following the recent discovery of hydrothermal manganese crusts in the S.W. Pacific. Nonetheless, the Atlantis II Deep of the Red Sea remains the most likely hydrothermal deposit to be exploited in the near future. Very considerable effort has been directed in the last decade to the study of hydrothermal activity in the central Red Sea depressions, to assess these as a potential mineral resource and to study the likely environmental impact of mining. The sulphide deposits on the crest of the East Pacific Rise and Galápagos Rift can be considered only as a long-term prospect, although metal grades are high, and improved knowledge of their formation is also important in the location and study of fossil hydrothermal deposits. Any economic consideration of marine minerals must be objective and conservative and reject the earlier claims which today seem very optimistic. Whilst deep-sea marine minerals will one day come of age, this is unlikely to happen before the mid-1990s and unlikely to play a dominant role in the world's mineral economy. Nonetheless, marine minerals do represent a long-term resource and, for this reason, studies over the next decade are necessary to prepare us for their eventual mining.

1. Sea Floor Mapping

Following the publication in 1982 of the Fifth Edition of the General Bathymetric Chart of the Oceans (GEBCO) on a scale of 1:10 million, there is now a basic requirement for compilation and publication of regional large-scale maps (1:1 million and larger).

At sea as on land, the results of geological, geophysical and geochemical investigations are most usefully plotted on morphological (bathymetric) charts. The latter are prepared from international bathymetric data banks and data available from research institutions. Plotting and contouring of data is a skilled and exacting task, but one that has proved to be most useful for enabling prospective marine geologists to get a good feel for submarine morphology and the geological processes responsible. Moreover, it can be carried out by shore-based scientists and provides a most useful starting point for regional collaborative studies by countries that have common geographical affinities.

The large-scale bathymetric charts (e.g., International Bathymetric Chart of the Mediterranean, scale 1:1 million, 1982, IOC and IHO) serve as a useful basis for preparation of transparent overlays on which are plotted all available resource-oriented data, such as sediment isopacks and facies distribution; outcrops of basement and intrusive igneous rocks; gravity, magnetic and heat-flow anomalies and seismicity; structural and tectonic data, ocean/continent coastal boundaries, fracture zones, directions and rates of plate motions; distribution and grade of polymetallic and phosphate nodules and of building aggregate materials, sites of hydrothermal activity. These and many more relevant parameters will assemble cognate data relating to data assessment and provide useful resource inventories. A useful, but small-scale, example is the Circum-Pacific Map Project, currently underway through closely co-ordinated international collaboration.

Recommendation

That the IOC request the Joint IOC-IHO Guiding Committee for GEBCO to assist in the preparation of large-scale bathymetric charts and resource-oriented overlays of areas where it wishes to encourage collaborative studies among Member States with common interests and problems.

2. Nearshore/High Energy Environment

High-energy environments, such as beaches, tidal inlets and tidal channels, submarine deltas, barrier islands, submarine bottom forms and river mouths occur nearshore and on the inner parts of continental shelves. The studies of these areas are of considerable importance to the understanding of the sedimentary processes, which are controlled by the interplay between hydraulic forces and morphology. The material being moved is in the size range between large pebbles and fine-grained mud. Wind transport very often is an additional moving agency, resulting in large sand dunes which often contain enrichments of heavy minerals.

Scientific studies can be carried out in the areas with relatively modest requirements; i.e., small vessels and inexpensive equipment and limited scientific and technical expertise. The results of these studies here are of considerable regional value.

Research projects should be carried out in selected areas to cover the following subjects:

(i) Input from land (via rivers and estuaries) into the nearshore regions and onto the continental shelf. Investigation of dispersion patterns, depending on seasonal variations, etc.

(ii) Systematic prospecting and onshore and offshore exploration of heavy mineral sand deposits, establishment of models, with emphasis on the lateral and vertical variations.

3. Continental Margins

The studies of the geology and mineral resources of the continental margins would be a logical extension (in countries with limited expertise) of the studies in the nearshore areas.

The continental margins provide a large proportion of the present world oil and gas production and also have future resources.

However, the knowledge of other resources is rather limited even in some countries with offshore oil and gas production.

Mineral resources of interest in these areas will be placers, aggregates, carbonate sands and phosphorites.

Research projects should cover the following objectives. The knowledge of surficial geology (initially the sediment distribution can be compiled from charts) is necessary to draw up a programme for reconnaissance and identify specific areas for exploration. These could be followed by underway surveys and systematic sampling which would lead to the identification of areas for detailed surveys, ancient shore lines and a survey of sea-level changes (for placers), biogenesis or calcareous sediments (for carbonates) and for phosphates.

The projects carried out should cover the following subjects:

(i) High resolution sub-bottom profiling on the continental shelf could be carried out concurrently with studies of the continental margins.

(ii) The data gathered on recent and sub-recent changes should cover:

(a) sediment distribution, dispersion, pathways, drainage patterns and rates of sedimentation;

(b) palaeoclimates, changes in sea level, upwelling, monsoons.

4. Deep Ocean Floor

With the exception of hydrothermal deposits, the principal marine minerals of potential economic importance in the deep sea are manganese nodules and crusts. Although it has been estimated that there are some 10^{12} tons of nodules in the Pacific Ocean alone, only a small percentage of these nodules satisfy the requirements that the nodules contain 3% Ni + Cu + Co and occur in abundancies greater than 10 kg m^{-2} over an area sufficient for the production of a "20-year mine site". As a result, a new view of manganese nodules as a low-grade ore resource for nickel and copper which is in competition with other resources (such as nickel laterites) must be entertained. This view is different from that of a cornucopia which appeared to be present in earlier days following the publication of J.L. Mero's book "The Mineral Resources of the Sea" in 1965. It is now thought that nodules might be mined in the 1980s when various legal, economic and technical factors become more favourable.

As a result of a decade of intensive exploration for manganese nodules, the principal areas of occurrence of potential ore-grade manganese nodules are now fairly well-known, certainly for first-generation nodule mine sites; they are the equatorial N. Pacific between the Clarion and Clipperton Fracture Zones, the Perú Basin and the Central Indian Basin. Of these, only the Central Indian Basin remains largely unexplored. Essentially, these areas of economic-grade nodules all combine the feature of high to moderate surface-water productivity and low sedimentation rate. At present, there seems no indication that economic grade nodules occur within national Exclusive Economic Zones. The distribution and chemistry of nodules in the Indian Ocean generally remain poorly known relative to the Pacific and further regional surveys in this area are recommended. Other areas which appear promising and worthy of further study are the Perú Basin, the equatorial western Pacific and the southern sector of the Southwestern Pacific Basin south of about 40°S. Detailed investigations of small areas (100 km^2) outlining mining sites should be carried out principally by industry in co-operation with scientific institutions.

As a result of this decade of work, the main genetic aspects of manganese nodules have also been elucidated and it is now possible to differentiate the main genetic types of nodules. Ferromanganese nodules and crusts are not uniformly distributed in interesting areas. Large variations in abundance and composition (in particular) can occur locally. A better understanding of the factors controlling this variability in terms of temporal and spatial influences might increase the possibility of finding high-grade deposits or predicting the type of ferromanganese occurrence which is formed under certain conditions. The extrapolation of such genetic results to other oceanic areas appears to be a good way to test such hypotheses. Future studies in nodule genesis will probably concentrate on studies of element fluxes (as in the U.S. MANOP Program) in order to describe quantitatively the mode of formation of the nodules and crusts or to evaluate the different sources of metals. It will probably be necessary to study environmental parameters such as bottom current velocities, sedimentation rates and physico-chemical parameters of the seawater in much more detail on a local and regional scale to assess their effects, quantitatively, on nodule formation. Considering the laminated internal structures of nodules and crusts, the environmental changes and geological events related to the episodic growth history of the nodules should be investigated to recognize the temporal geological influences in their growth.

Recommendations

The following genetic aspects require more detailed studies:

(i) The influence of the Antarctic Bottom Water (AABW) since the middle Miocene on the nodule and crust formation particularly in the Pacific.

(ii) The reasons for the small-scale variability of the density and composition of the nodules over distances of 10 to 100 metres.

(iii) More detailed studies of the relationship of nodule abundance and character to topography and sediment thickness using new techniques and equipment such as SEA BEAM and DEEP TOW.

(iv) More systematic studies of seamount manganese crusts and nodules. These have tended to be ignored in the past because it has been assumed that these deposits cannot be mined due to the rugged topography. Nonetheless, these deposits have high cobalt contents in some cases and the reasons for this should be investigated. Areas of particular interest include Line Island Ridge, Mid-Pacific Mountains and the islands of the Tuamotu Archipelago. It has been estimated that an individual seamount may have up to 5 million tons of cobalt-rich ore (average 1.0% Co) between 1000-2500 m. The influence of vertical oceanographic parameters (oxygen minimum, lysocline and C.C.D.) in these deposits needs to be investigated.

(v) Comparative studies of fossil marine nodule occurrences with Recent seabed deposits to understand differences in the conditions of growth of these deposits.

(vi) More detailed studies on the relationship between nodule growth rate, chemical composition, and microstructure.

(vii) Geochemical studies and calculations to outline the element fluxes and metal sources supplying ferromanganese accumulation.

(viii) Mineralogical and geochemical investigations of manganese micro-nodules from different oceanic areas to understand their role in metal accumulation during diagenesis.

(ix) Countries and their institutions should be encouraged to use the facilities of the recently established ocean mineral data centre of the United Nations (UN/OETB) in New York and to provide their mineral data to this centre which closely co-operates with the International Ocean Data Exchange System (IODE) of the IOC.

5. Hydrothermal Activity

The question of submarine hydrothermal processes has been addressed by Sessional Working Group C, and thus need not be covered again here. Instead, attention will be focussed on the mineral deposits precipitated in such systems.

There are basically three types of metalliferous sediments deposited from hydrothermal systems. First are widely dispersed iron and manganese oxides admixed with silicates, which are the final precipitates from the hydrothermal solution and are common over large areas of mid-ocean ridges. These are low-grade deposits of no economic value in the foreseeable future. Second are sharply fractionated oxides and silicates which are intermediate precipitates from the hydrothermal solution, also of little or no economic value. Third are base-metal sulphides, particularly of Cu and Zn, which are usually very localized in lateral extent, and which are of potential economic value. Exploration for and evaluation of sea-floor hydrothermal deposits must therefore be focussed on this last group.

Because of their localized extent, quite unlike manganese nodules, exploration and evaluation methods for hydrothermal metalliferous sediments must be able to home in on very limited areas of the sea-floor. Because of the association of the deposits with areas of submarine volcanic activity, the first task is to identify such areas on the sea floor. This can best be done by regional bathymetric and geophysical surveys, including regional heat-flow studies. Once submarine volcanic areas have been located, the next task is to define areas of submarine hydrothermal activity within them. This can best be done by a combination of geophysical and geochemical methods. Studies of sea-floor magnetism can delineate areas of hydrothermally altered oceanic crust which could possibly contain hydrothermal vents. This can be followed up by sea-floor sediment sampling and the analysis of the samples for metals such as Mn and Hg known to be dispersed away from submarine hydrothermal systems. The concentration gradients of the metals can then be projected back to their source at the hydrothermal vents. Finally, detailed submersible or near-bottom photographic studies in the areas delimited by the earlier work should locate the hydrothermal deposits.

There are three sea-floor settings where further studies of submarine hydrothermal deposits should be carried out. Firstly, additional work is required on both fast and slow-spreading mid-ocean ridges in order to compare the nature of the deposits in each. To date, slow-spreading ridges have only yielded the intermediate and end products of the hydrothermal fractionation sequences mentioned above, silicates and oxides. Sulphides have only been discovered on intermediate and fast spreading ridges. Secondly, additional work is needed in island areas in order to compare their hydrothermal deposits with those on mid-ocean ridges. Thirdly, a search for hydrothermal deposits in the active parts of oceanic fracture zones is needed in order to see if such features can contain the deposits.

Recommendations

A comparative investigation be made of submarine hydrothermal deposits from different tectonic environments.

6. Environmental Impact and Protection

The Workshop strongly recommended that the exploitation af the marine non-living resources be carried out in an environmentally sound fashion with adequate precautions being taken to safeguard the natural environment, bearing in mind further that winds and ocean currents can transport pollutants over long distances.

ANNEX V

LIST OF ACRONYMS

AABW	Antarctic Bottom Water
CCD	Carbonate Compensation Depth
CCOP (ESCAP)	Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas
CCOP/SOPAC (ESCAP)	Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas
CERN	European Organization for Nuclear Research
CMG (IUGS)	Commission for Marine Geology
CNEXO (France)	Centre National pour l'Exploitation des Océans
DFG	Deutsche Forschungsgemeinschaft
DSDP	Deep Sea Drilling Project
ECOR	Engineering Committee on Oceanic Resources
ESCAP (UN)	Economic and Social Commission for Asia and the Pacific
GPC	Giant Piston Corer
HPC	Hydraulic Piston Corer
ICL	International Commission for the Lithosphere
ICSU	International Council of Scientific Unions
IDOE (IOC)	International Decade of Ocean Exploration
IGCP (Unesco/IUGS)	International Geological Correlation Programme
IHO	International Hydrographic Organization
IOC	Intergovernmental Oceanographic Commission
IODE (of IOC)	International Oceanographic Data Exchange
IPOD	International Phase of Ocean Drilling
IUGG (ICSU)	International Union of Geodesy and Geophysics
IUGS (ICSU)	International Union of Geological Sciences
MANOP (USA)	Manganese Nodule Programme
OETB (UN)	Ocean Economics and Technology Branch
SCOR (ICSU)	Scientific Committee on Oceanic Research
SEATAR (CCOP/IOC)	Joint Working Group on Post-IDOE Studies on East Asia Tectonics and Resources