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LAW OF THE SEA

Marine scientific research

Report of the Secretary-General

CONTENTS

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CONTENTS (continued)

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List of acronyms and special terms

CD-ROM	Compact disk - read only memory
ERS-1	European Space Agency Remote Sensing Satellite No. 1
GEOSAT	Geopotential eatellite launched by the United States Navy
GLORIA	Geological Long-Range Inclined Asdic: sea floor imaging device towed by vessel capable of covering great range
JQOFS	Joint Qlobal Ocean Flux Study
OTEC	Ocean thermal energy conversion
POSEIDON	French altimetric aatel ite mission
SAR	Synthetic aperture radar
SEABEAM	High frequency seismic system for detailed mapping of sea floor
SEASAT	First satellite, launched by the U.S. National Aeronautic and Space Agency (NASA), dedicated to the studying of the ocean surface
TOGA	Tropical Ocoaa and Qlobal Atmosphere programme
TOPEX	Oaean Topography Experiment Satellite, launched by NASA, with a eoghistiaated altimeter for measuring the surface topography of the ocean
WOCE	World Ocean Ciraulation Experiment

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I, INTRODUCTION

1. The present report is submitted to the General Assembly pursuant to the request in paragraph 19 of its resolution 44/26 of 20 November 1989, in which it requested the Secretary-General to prepare for it at its forty-fifth session a study on marine saientific researah in the light of the provisions of the United Nations Convention on the Law of the Sea. 1/ In that resolution the Assembly had taken note of the report of the Secretary-General on the protection and preservation of the marine environment (A/44/650 and Corr.1), submitted in pursuanae of resolution 43/18 of 1 November 1988 and had expressed its conviction of the urgent need to increase the scientific knowledge of the marine environment.

2. The 1982 United Nations Convention on the Law of the Sea substantially extended national jurisdiction offshore and inoreased the rights and obligations of aoastal States in the marine environment and in the exploitation of its resources. The Convention also places a legal obligation on States to apply sound principles of resource management within the exclusive economic zone, and it establishes the régime for the conduct of marine scientific! researah in that zone and on the continental shelf. The right to exploit the resources of the exclusive economic zone implies a responsibility for proper management concomitant with the duty not to inflict damage on the interests of other States. However, it is evident that proper management requires a knowledge base and a national saientific and political infrastructure to identify and provide viable solutions to any existing or potential problems,

3. The recognition that the ocean is a resource capable of making a growing and substantial contribution to sustainable economic development and also the recognition of the need to understand its role in the total global system have placed new and inoreased demands on marine science. At the same time, increased interest in coastal and shelf processes has been parallelled by a growing need to understand the holistic behaviour of the total global ocean system, particularly the way in which it acts as a control on climate variability through circulation and heat exchange.

4. As the Secretary-Qeneral indicated in his report to the Assembly at its forty-third session, "ensuring sustainable development in the future utiliaation of marine resources and environment will require special attention" (ibid., para. 72). The report emphasizes that "far from being a mature science, oceanography is still in the process of discovery and the chief source of new understanding comes from new observations, not from theory. Qlobal prediction models must be verified in any event against observations of the state of the ocean, such as sea level, temperature and salinity, and must be compared with measured fluxes of heat, water, particles and gases between the atmosphere, the ocean and the ocean floor. The ocean sciences are thus entering an intensive data-gathering phase that will last through to the late 1990s and perhaps beyond" (ibid., para. 73).

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5. The increasing world population places an ever growing pressure on land-based resources. The demand for marine products and ocean services will increase in parallel and strengthen the need for marine reseatah. There is now widespread concern that man's activities may be adversely affecting the earth's environment and the sustainability of its resource base. The ocean plays a dominant role in maintaining the life-supporting system on earth through its interaction with the atmosphere, although the details of that role have yet to be fully understood. Concern over the environment and its changes is likely to shape the future of marine programmes in research and services at all levels, that is, local, regional and global,

6. It will come as no surprise that the major issues identified in this report as requiring concerted action by States and international ao-ordination by organizations concerned are predominantly environmental issues, including the conservation of the living resources of the oceans. They include the following:

(a) *Creation* of national and regional marine scientific research capabilities to adequately provide sound scientific bases for development and management of marine resources, living and non-living;

(b) Research and monitoring of marine pollution;

(c) Qlobal climate research programmes and associated large-saale oceanographic experiments to observe and understand air-sea interaction, the impact of the ocean on climate, and vice-versa;

(d) Coastal dynamics and sea-level rise;

(e) Development of global ocean observing systems to support marine scientific research and ocean uses.

7. Marine science is like any other science in that it relies on observation and tested hypotheses. However, marine scientists face a variety of time and space scales. The question of scales is important because in order to understand the global system, the determination must be made of those scales upon which the physical, chemical and biological processes interact with the global system. There is a need to study processes at intermediate and smaller scales in the individual disciplines of physics, chemistry and biology just as there is a growing need to study the large-scale questions. While the full value of a research project may not be immediately apparent, it is inherent in the nature of scientific research that an offshoot may have greater significance than the intended goals of the project. Large-scale projects *are* of special importance to the international community in that they call for collaboration among institutions and States, However, they are costly and logistically difficult to carry out but they benefit from and are dependent on international co-operation and planning.

8. For the successful implementation of such small or large-scale projects, it is important to ensure that international co-operation and co-ordination is pursued at the bilateral, regional and global levels as appropriate. Furthermore there also must be a legal framework within which this co-operation and co-ordination can deve 1 op.

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II. THE NEW LEGAL REGIME FOR MARINE SCIENTIFIC RESEARCH

9. The United Nations Convention on the Law of the Sea lay8 down a comprehensive global régime under which States are required to conduct marine scientific research and ao-operate in suah research. The Convention devotes an entire part (part XIII, consisting of 28 articles) to the question of marine scientific research. Several other part8 contain special provisions concerning marine scientific research as it relates to different jurisdictional zones or specific subject matters. Part XII, concerning the protection and preservation of the marine environment, and part XIV, dealing with the development and transfer of marine technology, are the most important in this respect. Indeed, part XIII is so closely linked to those two part8 that the three parts should be read together for all practical purposes. Of the 320 article8 of the Convention, about 100 deal with the exploration, exploitation, conservation and management of the resources of the sea, the training of personnel in those fields, and the applioation of science in the protection and preservation of the marine environment. These provision8 form the global legal régime for marine scientific research in A wider sense, and provide the basis for relevant bilateral, regional or other international agreements for the promotion of scientific investigation of the ocean and its resources.

10. The following sections demonstrate that the international community is now facing a growing challenge of better husbanding the oceans and their resources and that this requiter the universal strengthening of marine scientific research in all it8 fields. Since problem8 and phenomena of ocean space are mostly interrelated and respect no national boundaries, all scientific research issues identified need to be tackled through the joint efforts of States, often together with relevant international organizations. What is most needed now, therefore, is the closer co-operation and co-ordination among States and international organizations in further promoting and facilitating the conduct of such research, disseminating the knowledge, information and data obtained, and developing human resources urgently needed in many countries,

A. General principles

11. The Convention confirms the right of all States and competent international orqaniaatione to conduct marine scientific research (art. 238) and lays down a fundamental principle that such research shall be conducted exclusively for peaceful purposes (art. 240). Another general principle recurring throughout the Convention is the duty of States to co-operate in marine scientific research; indeed the régime for marine scientific research is designed to promote international co-operation. 2/

B. General duty to co-operate

12. The Convention clearly enunciates the fundamental duty of all States and competent international organizations to promote and facilitate tho development and conduct of marine scientific research in accordance with its provisions (art, 239). Then follows the general duty of States and competent international

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organiaations to promote international co-operation in marine scientific research for peaceful purposes (art. 242, para. 1). They are furthermore obliged to ao-operate to create favourable conditions for the conduct of such research and to integrate the effort8 of scientists in the study of the marine environment (art. 243).

13. The call for international co-operation is particularly stressed in the case of State8 bordering enclosed or semi-encloeed sea8, whioh are urged to co-operate with each other in exercising their rights and performing their duties, and are further obliged to endeavour to co-ordinate their scientific research polioiss and undertake where appropriate joint programmes of scientific research in the area (art. 123).

14. States are under a duty to promote international co-operation in scientific research on the sea-bed and ocean floor and subsoil thereof, beyond the limit8 of national jurisdiction, by participating in international programmes and enaouraging co-operation in suoh research by personnel of different countries and of the International Sea-Bed Authority (art. 143, para. 3).

15. On the basis of that fundamental duty to co-operate, the Convention provide8 for more specific obligation8 of States and international organizations. These focus on the following three subjects: (a) the consent régime; (b) the dissemination of information, data and knowledge) and (c) training, education and transfer of technology.

16. In addition, there is a fundamental duty found in part XIV of the Convention to assist the efforts of developing countries to acquire technology and scientific knowledge. The Third United Nations Conference on the Law of the Sea, sharing this sentiment, adopted, together with the Convention, a resolution on development of national marine science, technology and ocean service infrastructures. 3/

C. The consent régime

17. Recoqniaing the value to coastal States of detailed information on the marine environment and its resources, the Convention provide8 a legal framework for the acquisition of scientific knowledge in the exclusive economic zone and on the continental shelf. Under the Convention, marine scientific research in the exclusive economic zone and on the continental shelf shall be conducted with *the* consent of the coastal State (art. 246, pare. 2). The Convention establishes detailed rule8 and procedure8 for such research activities *on* the basis of this requirement. 4/

18. Under the consent régime coastal States must, in normal circumstances, grant their consent. They may however at their discretion withhold their consent to the conduct of a marine scientific research project in the exclusive economic zone and on the continental shelf if the project is of direct significance for the exploration and exploitation of natural resources, whether living or non-living) involve8 drilling in the continental shelf, the use of explosives or the introduction of harmful substances into the marine environment1 involve8 the

construction, operation or use of artificial islands, installations ant! structures referred to in the Convention) or contains inaccurate information or if the researching State or international organiaation has outstanding obligations to the coastal State from a prior researoh project (art. 246, gara. 5).

19. That qualified oonsent requires a ooastal State to have an adequate understanding of the scientific nature of each researoh project. The Convention stipulates that the coastal State shall establish rules and procedures ensuring that consent is not delayed or unreasonably denied, which further underline8 the need for a coastal State to reach the level of scientific knowledge necessary for a sound and objective assessment of the charaoterietias of the research project.

20. The Convention also provide8 that researching States or competent international organiaations may proceed with a marine scientific research project six months after the date the required information relating to the projeat was provided to the aoastal State, unless within four months of the receipt of the cnmmunioation containing such information the aoastal State ha8 informed the State or organiaation wishing to conduct the research that it was withholding it8 consent or that the information given does not aonform to evident facts or that supplementary information is required (art. 252).

21. There is a special provision (art. 247) in the consent regime for projects undertaken by or under the auspices of international organizations. In case8 where an international organization to which a aoastal State belongs or with which it has an agreement plans to carry out a research projeat either directly or under its auspices, the coastal State is deemed to have authoriaed the project if it approved the undertaking of the project when the decision was made by the organiaation or is willing to participate in it and has not expressed an objeation within four months of notification by the organiaation. That procedure would be of great use, particularly, in facilitating research project8 on a global scale.

D. Dissemination of information, data and knowledge

22. The publication and dissemination of information on research proqrammee and their objectives as well as knowledge resulting from marine scientific research are another form of the obligation to co-operate. For that purpose, States are obliged to promote actively the flow of scientific data and information and tho transfer of such knowledge, especially to developing States (art. 244).

23. This is particularly true in the implementation of the provisions dealing with proper conservation and management of living resource8 of the oceans in order to avoid over-exploitation and to maintain or restore populations of harvested species at levels which can produce maximum sustainable yield. The Convention provides for the promotion of international co-operation in acquiring scientific data and exchange of information on the conservation of such living resources (art. 61).

24. In the exclusive economic zone and on the high seas, State8 are required to contribute and exchange, on a regular basis, available scientific information regarding catch and fishing effort statistics and other data relevant to the conservation of fish Stocks. Thie should be done through competent international organizations, with the participation of all States concerned (arts. 61 and 119).

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25, The Convention imposes additional duties on States concerning the need to co-operate or co-ordinate their measures for the conservation, development and management of certain specified fish stocks or species in the exclusive economic zone or on the high seas. The general obligation for the exchange of relevant information and data in connection with those stocks and species contained in article 61 applies to such stocks and species. The specific stocks mentioned are those straddling two or more exclusive economic zones or the exclusive economic zone and the high seas (art. 63) and anadromoua stocks (art. 66). Other species mentioned are the highly migratory apeaira listed in annex I of the Convention and catadromous species (art. 67). In addition, special provisions are made with regard to co-operation in the conservation of marine mammals (arts. 66 and 120).

26. A similar obligation is found with respect to marine pollution. States are obliged to co-operate in order to promote scientific research and encourage the exchange of information and data on marine pollution (art, 200). States are required to endeavour to study, by recognized scientific methods, the risks and effects of marine pollution and to publish the results obtained or otherwise make them available to all States (arts. 204 and 205). A coastal State is also required to provide other States with a reasonable opportunity to obtain from it, or with its co-operation, information necessary to prevent and control damage as well as to the health and safety of persons and to the marine environment (art. 242, para. 2).

E. Training, education and transfer of technology

27. The general emphasis that the Convention places on the needs of developing States is particularly artioulatsd in the development of marine science and technology. Statoo aro obliged to co-operate in order actively to promote the development and trarsfer of marine science and marine technology on fair and reasonable terms and conditions. The need to promote the development of eaientific and technological aapaaity of States is highlighted in the fields of resource conservation and development, ocean research and the protection and preservation of the marine environment (art. 266).

28. In addition to existing arrangements, the Convention calls for expanded and new programmes for facilitating marine scientific research, the transfer of marine technology and appropriate international funding for ocean research and development (art. 270). States are also required to promote the establishment, particularly in developing aoaatal States, of national and regional marine scientific and technological research centres and the strengthening of existing centres (arts. 275 and 276).

29, More specifically, upon request by a coastal State, States snd international organizations, undertaking research in the exclusive economic zone or on the continental shelf, must provide it with an assessment of the data, samples and research results or provide assistance in their assessment or interpretation (art. 249, para. 1 (d)).

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30. In the area of protection and preservation of the marine environment, States are obliged to promote programmes of scientific, educational and technical assistance to developing States, including the training of scientific personnel and developing facilities for research, monitoring and educational programmes (art. 202).

31. Finally, States parties to the Convention are required to promote international co-operation in marine scientific research in the Area by ensuring that programmes are developed for the benefit of developing States with a view, inter alia, to strengthening their research capabilities (art. 143).

III. REVIEW OF PROGRESS IN URINE SCIENCES

32. Developments in marine scientific research are often categorized in terms of four separate scientific disciplines: physics, chemistry, biology and geology. However, there are strong and growing links among those various studies. Interdisciplinary research into problems as diverse as climate change, pollution and resource sustainability-are an indication of the growing maturity of marine studies as an integrated science.

A. Marine physics

33. Studies of the dynamics of the upper layer of the ocean, the behaviour of mesoscale eddies (the ocean equivalent of atmospheric cyclonic systems), equatorial dynamics and western boundary currents have laid the foundations for planning the major global programmes that are now under way. The brief SEASAT satellite altimetry mission in 1978 proved the feasibility of producing synoptic maps of ocean waves and of changes in ocean circulation. As a result, plans for future altimeters were developed; GEOSAT is already in orbit and plans for the ERS-1 satellite and the TOPEX/POSEIDON satellite are well advanced. Other satellites have mapped distributions of sea-ice, sea-surface temperature and other properties such as primary biological productivity.

34. During the next decade, vast quantities of observational data will be produced from ships and satellites, most notably as part of the Tropical Ocean/Global Atmosphere (TOGA) programme 1985-1995 and the World Ocean Circulation Experiment (WOCE), which started in 1990. One of the basic goals of the World Ocean Circulation Experiment is to find methods of determining long-term changes in ocean circulation. The possibility of interaction between widely separated geographical regions of the ocean, connected through meteorological events, has been confirmed and supported by atmospheric wave propagation theories and by numerical experiments. Within the Tropical Ocean/Global Atmosphere programme. studies of the El Niño phenomenon have linked large-scale tropical ocean-atmosphere interactions, Interest is focusing on responses of the ocean to green-house warming and the influence of the oceans on resulting climate changes, Already it is apparent that vertical mixing processes can produce significant regional variations. Some form of basic climate prediction, through the coupling of observations from an ocean obaerving syatem with an eddy-resolving numerical model, is expected by the year 2000.

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35. This breakthrough will require the development of the observational system, of computers two orders of magnitude more powerful than at present, and of solutions to the fundamental problem in ocean modelling: how to couple the fluids of ocean and atmosphere while conserving numerically those parameters such as heat, moisture and momentum that are exchanged between them. Global studies and predictions are fundamental to regional and local predictions.

36. Processes at the break of the continental shelf are attracting renewed attention. There are indications that internal mixing vertically within the ocean is considerably enhanced there, in part because of the generation and breaking of internal waves. The interaction of ocean eddies with shelf waters and the role of cross-break jets in those exchanges are also likely to be elucidated by the application of numerical models and direct observation.

37. For seas of the continental shelf, the forecasting of storm surges is now a fundamental component of several flood-warning systems. Warnings of such events will be even more important if the weather were to become increasingly stormy and coasts more vulnerable. New studies seek to improve the flood forecasts by incorporating waves and depth-dependent currents into the computations. Also for shelf seas, particularly those influenced by strong tidal currents, a major effort is being undertaken to build on a recent breakthrough in the understanding of the physics of the formation of fronts, sharp boundaries between different water masses, which are known to be biologically significant.

38. Near-shore, the modelling of three-dimensional dynamics, particularly in the region of river discharges and through the spring/neap tidal energy cycles, is a necessary development before the more difficult problem of estimating chemical and biological fluxes within the coastal zone can be tackled with any confidence. For operational predictions and the monitoring of nearshore dynamics and pollution (for example, toxic algal blooms, the so-called red tides), coupled models, which include sediment and biological dynamics, tidal and meteorological forcing and river disoharges, are conceivable. However, the basic processes need further study before such reliable operational systems can be developed.

B. Marine chemistry

39. Developments in marine chemistry often follow progress in general chemical analytical techniques and in the wider development of *in situ* chemical sensors. This is especially true for organic chemistry where the overwhelming number of compounds present in very small amounts in sea-water requires rapid analysis. Marine pollution studies have been a major stimulus for marine chemistry research over the past years with those new analytical tools allowing the determination of many pollutants in very low concentrations, which were not previously detectable. In addition, by introducing artificial tracers in minute concentrations, marine scientists can now study the circulation and mixing of the sea.

40. Marine chemists are increasingly aware of the importance of hydrothermal circulation in the ocean crust, particularly in the vicinity of mid-ocean ridges, for the overall chemical composition of the oceans. Those are very recent

discoveries and much romaine to be done to quantify the rates of supply of minerals from these sources, and their fate. As a recent example of their effeot on ocean chemistry, significant depletions in oonoentretions of Phosghorous have been found in the waters above Paoifio sea-floor sites where hydrothermal fluids are being • mittrd, Research has shown that this is because, as the metal-enriahed fluids are discharged, the most abundant metals, iron and manganese, quickly precipitate out as metal-oxide particles, soavenging other chemicals from the sea water. Those particles, including Phosghorous, then settle to the sea floor around vent areas, forming metal-rich sediments.

41. Studies of chemical exchanges across the air-sea interfaoe and of the chemistry of the surface miorolayer of the sea are also at an early stage. Natural sea aurfaoe films are for the most part oomplex polymeric components; they differ significantly from plaae to place in thiaknese, pressures and spreading characteristics. This variability is significant because it affects the exchange of gases between ocean and atmosphere,

42. The influence of rivers and estuaries on the geoohemioal budgets of many elements, including carbon, is still a major unknown faotor in tho cycling of materials through the ocean. The problem is to determine the new fluxes of partiaulate and dissolved material (organic and inorganic) into the ocean and to learn how they are modified in passage through estuaries and ooastal waters. Studies of a few major rivers can serve as a focus for the many scientists who will participate in suoh investigations,

C. Marine biology

43, In common with marine chemists, biologists have been forced to rethink some basia ideas following the discovery of sea-bed hydrothermal vents, found particularly in the vicinity of sea-floor spreading sites, Rich but highly specialized faunas of very large metaaoane develop in the close neighbourhood of vents. Their discovery and that of high ooncontratione of bacteria were a major surprise. Lower temperature hydrothermal vents, found away from active ridges, are also charaoteriaed by extensive communities of organisms including clams, mussels, crabs and forests of giant tube worms. The organisms that live around the vents have highly specialized physiological systems suited to their unique chemical environment.

44, Specialized eulphur-reducing bacteria play a major role in the food web. The ecosyoteme use chemosynthesis rather than photosynthesis for their energy source. Similar ohemosyntheeis communities have now been disoovered around sea-floor regions where petroleum and other similar substances seep out and also around the decaying carcasses of whales. It is possible that whale carcasses distributed on the sea floor might serve as "stepping stones" for the dispersal of deep sea animals that depend on chemosynthesis.

45. The understanding of the processes of planktonic produotion at the sea surface is advancing through the use of standard carbon-14 uptake techniques and through colour sensitive satellite photography. Food-web dynamics are also studied through

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application of the 'arbon-14 uptake techniques; it aow appears that this method underestimates the total levels of production. One important practical aspect of studies of food-web dynamics is the enhancement of pollutants as they move up the food chain to levels where they may be eaten by man. Other aspects of marine biology being investigated include the role of different size fraotionn among planktonic primary producers, the role of bacteria in the plankton, and the contribution of non-planktonio primary producers to the organic carbon flux through the water column and through coastal and eetuarine regions.

46. Studies on ao-operative recruitment meahanirmr continue to develop. Regional s tudies, for example , in the south-west Atlantic, are being extended to other regions and to a variety of different species. The use of large-scale experimental facilities for biologioal studies of this kind is becoming more widespread, and can aot as a focus that stimulates interaction between soiertistn in different countries.

47. One of the most exciting marine biologioal discovrriea in recent years has been the identification of unexpected seasonal variations in the biologioal floc oonaentrations at. abyssal depths. These have been observed with a lag of only tens of days on the overlying rea-eurfaoe processes; the consequences of this close aougling between surfaoe and deep-sea biology are only beginning to be understood, but it is appsrent that the deep sea is neither as biologically inactive nor as ieolated as was previously thought.

40. Other fundamental atudiee in marine biology have been given new directions with the application of genetic theories and techniques developed in the wider scientific field. Conversely, marine biologioal studies have themselves aontributed to a fuller understanding of more general biologioal phenomena. For example, studies in marine biology have led to new medicines and to a better understanding of human nerves and muscles. They have even led to new designs in computer teahnology.

D. Geology and geophysics

49. Many aspects of marine geology and geophysics are fundamental to an understanding of the geology of the earth as a whole. In the earth sciences, plate teatonics now is universally accepted as the major oonoeptual framework for research, with emphasis on determining the rates end meohanirma of spreading from different ocean centree. Other studies focus on the details of small-plate dynamics and of triple-junction movements. Deep submersibles, both manned and unmanned, have played an important role in detailed surveys of the sea floor. More general surveys have been heavily based on acoustic systems such as GLORIA, which is now completing a B-year survey of the United States exclusive economic zone, and SEABEAM. Nevertheless, despite the success of tho concept of plate tectonics as applied over the past 20 years, several outstanding questions remain.

50. Examination of the detailed crustal morphology near mid-ocean ridges, and learning how they evolved are fundamental to understanding the process of emplaaement. The three-dimensional structure of the ocean crust near spreading ridges needs elucidation. Another major question relates to the nature and existence of layering within the general oceanic cruet.

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51. Research is also focused on inhomogeneities deeper in the mantle and the connection that they might have with the processes that drive the motions of the terrestrial plates. Relationships between sea-bed geology and the geology of regions of much thicker continental crust are still unclear. Indeed, one of the triumphs of plate tectonic theories has been to provide a oonoegtual framework, which ● ■♌□♋□♏♋ both continental and marine tectonics, in *the* absence of a detailed knowledge of these relationships.

52. The margins between the deep ocean and the shallower regions may be divided into aotivr and passive categories. Active margins, whiah are importeat sites of present-day tectonic end voloaaio activity, have been intensively studied in the past 20 years, but despite general agreement on the processes that operate there, several questions remain unanswered. For example, is there, as the Deep 8ea Drilling Project results have indicated, a zone of oruetal erosion between the deep-rea trenoh and the island arc? And what is the role of pore waters in the ● ubduotion process? Yraatiaal interest in these studies includes learning how the . ťfects of natural hazards in the active margins may be reduced, for example, by developing methods of predicting earthquakes,

53. Exploration of off-shore hydrooarbon deposits and their exploitation are now routine; as known fields beoome exhausted the major concern has shifted to the identification of new production areas, particularly those in deeper water. At these active margins there are possibilities of locating hydroaarhons, either in the mono between the trenah and the volcanic ara, which has many of the characteristics of passive margins, or in the baok arc basins, which are often thick and oovered with material of terrestrial origin, Recently, petroleum-like hydrocarbons have also been detected in hydrothermal vent areas. The hydrothermal oils are similar in struature to conventionally exploited crude oils, but have an age of only 5,000 years.

54. There are also good prospects of finding hydroaarbone at passive margins, in many ways those margins are the least understood areas *of* the ocean crust. A principal reason for this gap in knowledge is that many passive margins were formed by breakup a long geological time ago. The initial struotures and much of their subsequent history often lie buried under a thick layer of sediments. Commercial and scientific drillings in those regions, as well as seismic reflection profiling, are now adding new information thst will help to clarify the struoture of passive margins. Understanding the history of sedimentation and subsidence through the thermal history of the margin8 is en essential requirement for determining whether any hydrocarbons present might have matured to form oil end gas.

IV. RESEARCH TOOLS

A. Technology

55. Technology has had an enormous impact on marine scientific research, particularly on large-scale research and environmental monitoring projects. Progress in technology is generally easier to anticipate than progress in scientific understanding; the development of major equipment such as the GLORIA

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acoustic system or the TOPEX/POSEIDON ratellite and the pre-planning may take one or two decades. Nevertheless, there are rometimes major surprises in the performance of newly developed equipment.

56. The fundamental importance of satellite remote-aeneing for ocean monitoring is now well established. Synoptic measurements of waves, surface temperature, winds and ocean circulation from satellites will form the basis for future climate predictions, In biology, similar synoptic measurements of ocean oolour may quantify Primary production. Further applications of remote-sensing will include the investigation of the relationship between local, regional and wider-scale toxic red-tide events.

57. Nevertheless, the satellite view of the oceans is literally superficial; the transmitted radiation is indicative of conditions only a few microns below the surface. However, measurements with synthetic aperture radar (SAR) have uaexpeatedly shown large-scale patterns of surface roughness that are thought to be related to second-order dynamics of internal motions. Results are encouraging, but measurements of internal ocean properties will not rely on SAR alone. Drifting buoys fitted with thermistor chains, acoustic devices and meteorological instruments will alro be an important component of future ocean monitoring systems. These buoys can alro provide sea-truth for satellite measurements. Legal problems must be overcome and precautions taken to avoid interference with shipping and to prevent their intrusion into coastal orators where they may be unwelcome.

58. However, drifting buoys are also limited to near-surface measurements. Other solutions must be found for the more general collection of ocean data at depth. Now power sources, hydrodynamic design principles and material technology make possible to design unmanned data-gathering submersibles, capable of trans-ocean passage over a period of weeks. When operational, these submersibles will make vertical sections on passage through the oceans, returning to the surface at intervals for ratellite transmission of data.

59. Acoustic topography, with detailed analyrir of travel times, promises integrated measurements of velocities and of vortiaity across vast distances within the oceans. Further improvement8 in the analysis of acoustic signals from active sonar systems promise much higher resolution of sea-bed features and more detailed mapping of sediment distributions and types. Deep-towed instruments can achieve detailed but limited sea-bed coverage at present; development of optical fibre aontrol systems will allow a faster and more sensitive response of vehicles at depth under the aontrol of ship-basrd scientists.

B. Data and information management

60. Synoptic measurements for climate prodiction will make great demands on the international date transmission and assimilation procedures established by the World Meteorological Organisation (WMO) and the Intergovernmental Oceanographic Commission (IOC). Fortunately, technology is also developing rapidly enough to allow the design of systems able to cope both with the volume of data and with the elaborate analyses that must follow. The full implications of rapid data

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transmission via telephone networks, optical fibre cables and satellite8 are being evaluated at present for future ocean data bases. Closer go-operation between agencies to make data instantly available from a distributed network will follow. So too will assimilating data into operational computer models.

61. Cheap and easy data storage and data transfer using CD-ROM technology are beginning to revolutionize the way in which individual scientists work, freeing them from adherence to major computing facilities. For example, a scientist in a developing country with CD-ROM data bases and a personal computer will be well quipped to undertake extensive local studies and to place them in a regional and wider context. As an example, the United States National Oceanographic Data Center has prepared a compact disc that contains over 1.3 million temperature/salinity depth profile8 taken in the Pacific Ocean between 1900 and 1988. Another CD-ROM prepared by the United States Qeologiaal Survey contains full details of the GLORIA acoustic sea-bed mapping of the Gulf of Mexico.

62. Beyond the oolleation, exchange and analysis of data, another major challenge is only beginning to be tackled: presenting the results in a form that allows further manipulation and application, even by relatively unskilled users. To achieve this goal, aomputer-related atlooes are now being evaluated for presentation of satellite images. Further developments are also underway to produce personal computer-based atlases with zoom, overlay and plot facilities for a wide range of ocean parameters; more elaborate manipulations using Geographic Information System teahnology are also envisaged. The market for such user-friendly information systems needs to be developed, but one attractive option is to make them widely available at low cost for educational purposes.

63. Even local access to extensive library facilities will become less important, because indexes and abstracts of papers can be made available, for example, on CD-ROM. Five years of oceanographic abstracts are easily aontained on a single CD-ROM for loos1 reference. 5/ Complete journals should be available eventually in a similar format, with minimal problems of storage and maintenance. The legal and financial problems of copyright and charges will have to be overcome before the full technical potential can be realized. Nevertheless, the opportunity will be there for all countries, developing and developed, to exploit and accelerate the information cycle.

V. MAJOR RESEARCH ISSUES

64, Many of the issues facing ocean science are inherently interdisciplinary and proasnt major technical and logistical challenges. Experience has shown that truly interdisciplinary collaboration among scientists is unusual and difficult to arrange. Multidisciplinary projects are more common, but the separate disciplines are often poorly co-ordinated and the results inadequately synthesized. In part, this reflects the different approaches taken by different disciplines themselves and in part by the structures of the different institutions involved. The difficulties must be overcome if the scientific and eoaial challenges of the future are to be understood. 6/

65. Beyond the integration of basia saientific disciplines, there is a further need for the scient'fic community to provide the bes+ possible information and to explain clearly the nature of saientifia knowledge, Policy makers also must make efforts to understand and appreciate the nature and limitations of saientific knowledge. International exchanges of scientific information must go beyond exahanges between saientists alone; they must reach and be understood by decision makers.

A. Marine resource management

66. The living resources of the oceans have been exploited over very long periods of time through traditional fisheries operations, but the practice of cultivating and managing marine living resources is *just* beginning. In many cases, the living resources of the oceans have been depleted as result of over-exploitation or recruitment failure aaused by environmental *change,* natural or man-made. For exsmple, 95 per cent of the world's fish catch is reported by the World Commission on Environment and Development to be threatened by overfishing (see A/42/427, annex, chap. 10, pare. 9). Fisheries research, therefore, is continuing to focus on what causes fluctuations in year-class size of marine fish stocks, This will require large-scale studies at sea and more interdisciplinary co-operation, and enhanced collection, exchange and storago and retrieval of data, Large-scale experiments to examine biological and technical multispecies interactions will also be necessary,

67. Although fish farming in the coastal zone can be enhanced by careful coastal management, it is vulnerable to pollution in a way quite different from mobile off-shore fioh stocks: fish farms cannot move to another area when local disturbances such as toxic red-tide blooms occur. When linked to other schemes, for exsmple, ocean thermal energy conversion, such as that now in operation in Hawaii, which provides deep, nutrient-rich water, coastal mariculture promises high productivity and effective stock management. Similarly, the application of modern advances in genetics and biotechnology hold promise of enhanced utilization of the ocean's capacity for food production. A major increase in the production of pharmaceutical products by the application of biotechnology to natural resources from the ocean can also be antiaipated.

68. There is an increasing interest in exploring the usefulnees of the large marine ecosystems to understanding the management of marine living resources in large ocean spaces. This holistic approach to research and management is beginning to gain ground in several regions of the world. There is probably a need to form regional management bodies or to encourage existing ones to develop management practices along those lines rather than to continue the more traditional single species approach to management that is currently employed. This will require major research into the ecosystems involved, which can only be tackled by nations acting in a co-operative manner and then implementing the results in the same way.

69. A few countries are beginning to extract tidal and wave power although the full potential is still untapped; renewable tidal energy and wave energy have many attractions, but schemes to exploit them also have implications for the development

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of sensitive coastal margin areas. As in the case of ocean thermal energy conversion, there are clear advantages for small, developing countries and islands in developing renewable ocean-based power sources.

70. An important reason for studying the sea is to enable optimum economic benefits from mining and hydrocarbon extraction. Hydrooarbona are now routinely obtained by drilling in water depths of a few hundred metres, typical of continental shelf seas. However, as discussed previously, there are reasonable scientific expectations of further reserves being found in deeper water, including the passive continental margins. In even deeper water, mineral deposits on the ocean floor, for example, in the form of nodules and as hydrothermal deposits, are likely to prove capable of commercial exploitation. The United Rations Convention on the Law of the Sea provides a legal framework within which those resources may be made available, but much of the underpinning science and technology remains to be developed.

B. Protection of the marine environment

71. The rational utiliaation of marine resources is now seriously threatened by pollution. The ocean, particularly in coastal areas, receives considerable inputs from anthropogenic sources through riverr and from the atmosphere, including nutrients and sediments. The ocean is also used directly as a repository for wastos but the practice of marine disposal is coming under increasingly stringent control.

72. The problems of pollution require multidisciplinary solutions. Research efforts are directed to studies of water quali ty, biological conditions, amenity protection and other marine uses including marioulture. Eutrophication, plankton blooms and red tides are local pollution problems of global concern. Human health is potentially at risk through the consumption of contaminated seafood and swimming in contaminated waters. The trend of contamination spreading from estuaries to coastal zones and thence to shelf seas is evident in many areas, and signals are also being detected in the open ocean that show contamination spreading globally. The potential biological effects due to long-term, low-level contamination are of growing concern, High priority conditions must be given to carrying out these studies, to establishing open-ocean baseline conditions and to assessing the local and regional impacts of anthropogenio pollutants. One goal to be achieved through the development of standardized regional monitoring activities and data management systems is a meaningful comparison of contaminant data.

73. Mixing and circulation as a mechanism for pollution dispersion can be simulated through numerical models driven by winds and tides, but the chemical and biological processes are more difficult to model and prediat. Regional studies are already underway to address concerns expressed for the health of the North Sea, the Baltic, the Mediterranean and the Caribbean Seas.

74. Important advances have been made in the field of the measurement and assessment of toxicity. It now appears possible to classify the mode of action of toxicants in such a way as to improve the ability to extrapolate from species to

species, or from acute to chronic, and from single species to higher levels of biological organization. Thus, although the ability to predict the potential harmfulness of chemicals on a multitude of species from a data base consisting of a very few species remaiae incomplete, considdrable progress has been made.

75, In summary, there is a need for co-ordinated international action to evaluate the level of pollutants in the ocean and the biological-ecological consequences. First models must be created that can simulate the processes of transport, mixing and dilution as they affect pollutants and predict the consequences. These models will then provide a reliable guide to nations and intergovernmental agencies developing policies for marine waste disposal.

C. Oceans and climate

76, Potential global warming brought about by the trapping of heat in the atmosphere by greenhouse gases is now a major concern. One of the principal greenhouse gases is carbon-dioxide, produced naturally and by the burning of fossil fuel. Carbon-dioxide levels in the atmosphere are known to be increasing, but not at the rate expected from industrial output; this carbon-dioxide discrepancy is thought to be due to absorption by the oceans. The rate at which the ocean can take up carbon-dioxide depends on the concentration levels and on the rate of exchange of surface ocean water with deep water. Thus, knowledge of three-dimensional ocean circulation is critical to the understanding of long-term carbon-dioxide concentrations in the atmosphere. The role played by marine phytoplankton in the process is also thought to be of major importance and is being actively investigated.

77. The ocean has been described as the fly-wheel of global climate, lessening latitudinal variations and seasonal extremes. Many aspects of sensitivity to climate change are relatod to the ocean, its circulation and ability to transport heat from the tropics to higher latitudes. Within the oceans, global modelling of circulation and eddy dynamics is a realistic goal by the year 2000, with the data from the World Ocean Circulation Experiment providing an observational input for testing and control of models. Such models will provide en impetus for quantitative biological and chemical flux studies on a global scale, building on initial work now underway in the Joint Global Ocean Flux Study (JGOFS) programme. Biogeochemical processes on ocean scales may be realistically modelled in the early decades of the next century.

78. A primary requirement for improving the simulation and prediction of climate is that systematic global observations of significant climate parameters are needed for the foreseeable future in order to refine the parametric formulation of climate-forming mechanisms, to provide a suitable description of the present state of climate as a basis for initiating predictions and to monitor variability of climate. Some important climate quantities, such a8 global atmospheric water transport and precipitation, surface winds and sea-state, and ocean surface dynamic topography, are only accessible by means of new observing systems. Another crucial requirement is the augmentation of conventional observations to provide systematic global observations, including remote areas that may not be essential for short-term weather forecasting.

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79. Global changes of climate affeat all countries. The most severe effeats become apparent in partiaular countries or regions, For example, the collapse of the Peruvian fisheries industry can be partially related to the occurrence of the El Niño phenomena, which links Pacific Ocean dynamics with changes in equatorial wind fields, Scientific understanding of the dynamics of the phenomenon allows some indication of a likely loss of fish stoaks up to a year ahead, but much work remains to be done, &other example at a regional level is the occasional failure of monsoon rains on the Indian subcontinent, a major concern locally; the reasons are also related, at present it is not known how, to global climate processes*

D. Coastal dynamics and sea-level rise

80 The coastal regions and adjacent seas are the most heavily used of the ocean areas and the most vulnerable to misuse. The delicate ecological and geological balance in coastal areas, partiaularly in estuaries, cannot be sustained without understanding the relationships between the physics and the chemistry and between the biology and the sediment dynamics. Here the rewards for proper coastal management are evident: mineral resources without beach erosio ', mariculture without pollution, discharge without damage.

81. Erosion along one length of coast is often balanced by accretion elsewhere) one error can be to stabilise an area of coast at great expense when this may lead to serious erosion elsewhere. Changes of land use, for example, the felling of tropical rain forests and the consequent increased rates of land erosion leading to more sediment being discharged into rivers, are also leading to different patterns of coastal erosion and deposition. Development of protection meohanisms based on cultivation of erosion-inhibiting coastal plants could be very cost-effective when compared with alternative developments of barriers or continual beach nourishment.

82. Coastal flooding and flood warning systems are best studied and operated in a broad regional context. For example, the whole of the North Sea behaves as a dynamic system in response to atmospheric forcing. Co-operation and data exchange as the basis for warning systems of imminent storm surge flooding are essential. Even more serious problems of storm surge flooding of low-lying coastal land are encountered in regions of tropical hurricane storms. Flooding in Bangladesh is an extreme, though not isolated example, where there are urgent requirements for reliable warning systems.

83, One of the long-term consequences of global temperature increases is likely to be an increase in global sea levels much in excess of the 0.15m generally observed over the past 100 years. Increases may b' due to warming and expansion of present ocean waters and to the melting of glacial ice. One cannot predict direct sea-level responses to global warming on the basis of present knowledge. The best, but still very crude, estimates suggest an increase in global sea levels of perhaps 0. 5m over the next 100 years. The impact on coastlines needs to be assessed so that a strategy for management of estuaries and wetlands and othe: low-lying land can be developed. Reaponses may be at a national or even a district level, but the warnings and possible avoidance strategies demand global studies and agreement.

84, Sea-level rise is an important element in the total ongoing problem of coastal dynamics and management. Equally important in the context of changing climate oould be the altered pattern and severity of storms that generate surges and coastal flooding. Strong international ao-ordination and exchange of expertise are an essential prerequisite for all coastal sone studies,

E. Global marine observing services

85. Long-term marine observing and foreaasting services are needed to monitor, understand and ultimately predict ocean changes and their consequences for mankind. There is an urgent need for an improved international system to provide data to disseminate information about the marine environment baaed on the data. However, at present, long-term marine observing and forecasting services exist for only a few selected ocean areas. The development and implementation of a comprehensive ocean observing system on a global scale to monitor changes in the ocean and to determine the effeot of the ocean on the atmosphere and global climate are a high priority issue. Specifications for a proposed system are now being considered by the international scientific community. The system will be administered by the World Meteorological Organisation and by the Intergovernmnetal Oceanographic Commission.

86. It is olear the global ocean monitoring systems must include observations at the coast and within the exclusive eaonomio zones of coastal States, as well as from deep ocean areas. In a period of global concern about the environment, there must be an objective international source of information from which to develop consensus policy decisions.

Notes

1/ Official Records of the Third United Nations Conference on the Law of the Sea, vol. XVII (United Nations publication, Sales No. E.84.V.3, document A/CONF.62/121, annex I,

2/ Alexander Yankov, "A general review of the new Convention on the Law of the Sea: marine science and its application," Ocean Yearbook, vol. 4 (1983), p. 164.

3/ Final Act of the Third United Nations Conference on the Law of the Sea (A/CONF.62/121), annex VI. Official Records of the Third United Nations Co- on the Law ot the Sea, vol. 17 (1984), p. 149.

4/ The Office for Ocean Affairs and the Law of the Sea has prepared a guide to the implementation of the Convention provisions relating to marine scientific research with the assistance of a group of technical experts. The guide is to be published in early 1991.

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Notes (continued)

5/ A CD-ROM - the ASFA Database - has been issued already. containing abstracts on the science, technology and management of marine and freshwater environments taken from over 5,000 sources since 1982. The database is sponsored by the Office for Ocean Affairs and the Law of the Sea, FAO, IOC and UNEP.

6/ UNESCO, Ocean science for the year 2000 (1984), p. 17.
