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AD HOC COMMITTEE TO STUDY THE PEACEFUL USES OF THE SEA-BED AND THE OCEAN FLOOR BEYOND THE LIMITS OF NATIONAL JURISDICTION

SCIENTIFIC ASPECTS OF PEACEFUL USES OF THE OCEAN FLOOR

(Prepared by the IOC secretariat for the United Nations General Assembly *Ad Hoc* Committee to Study the Peaceful Uses of the Sea-Bed and the Ocean Floor Beyond the Limits of National Jurisdiction)

Preambular Note

During the meeting of the *Ad Hoc* Committee to Study the Peaceful Uses of the Sea-Bed and the Ocean Floor Beyond the Limits of National Jurisdiction in March 1968, the IOC was requested to furnish a paper on the scientific aspects of the problem. In view of the limited time before the next meeting of the *Ad Hoc* Committee (in June 1968), the IOC Chairman decided to ask the secretariat to compile a brief document summarizing available information on scientific knowledge of the sea-bed and on methods for its investigation. This document was prepared, largely by the secretariat (UNESCO Office of Oceanography) and with the help, in certain sections, of the staffs of WMO and IMCO.

The IOC Bureau and Consultative Council, during its 8th meeting, did not have an adequate opportunity to examine the paper in detail. Nevertheless it was agreed that the study, although preliminary in character, contained much useful information and should be transmitted to the *Ad Hoc* Committee, for use along with the ECOSOC report (E/4449/Add.1), the General Scientific Framework for World Ocean Study and other sources of information.

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(Prepared by the Secretariat of the Intergovernmental Oceanographic Commission for the United Nations General Assembly Ad Hoc Committee for Study of Peaceful Uses of the Sea-Bed and Ocean Floor Beyond the Limits of National Jurisdiction)

GENERAL INTRODUCTION

At a time when we are beginning to plan peaceful use of the sea-bed, it is indispensable to summarize our ideas on the subject. In the natural order of their realization, present-day peaceful uses of the ocean floor are:

i. The laying of underwater cables and pipelines;

ii. The exploiting of oil and mineral resources;

iii. The installing of scientific instruments (e.g. deep-sea tide gauges) and eventually of underwater laboratories.

Each of these activities requires a thorough knowledge of the ocean floor and of the superjacent environment and, for some applications, the amount of knowledge and data needed is very great.

To cover adequately all the kinds of knowledge needed and the ways of obtaining it, a complete modern course of oceanography (comprising all the disciplines) would be appropriate. In this paper, however, only the most important facts are selected and the most vital problems singled out, in order to demonstrate the degree of involvement of science. This selection gives the paper something of a mosaic pattern, allowing, nevertheless, presentation of essentials, e.g., explanation as to why certain scientific aspects are so vitally important and suggestions as to the further studies needed to render the practical work feasible and safe.

BASIC FACTS ABOUT THE OCEAN AND ITS FLOOR

(a) Major dimensions

Total surface of the ocean : 360 million km^2 (or 71% of the Earth's surface).

Average depth of the ocean : 3,795 m.

The area with depths between 4,000 and 5,000 m. represents 36.6% of the ocean floor surface.

Total volume of the ocean : 1,370 million km^3.

Average salinity of the oceanic water : 35‰

Continental shelf* (0 - 200 m) 26 million km^2 = 7% of the ocean floor.

Continental slope (290 - 2,440 m) 39 million km^2 = 11% of the ocean floor.

Abyssal plain (2,440 - 5,750 m) 284 million km^2 = 79% of the ocean floor.

Deep-sea trenches (more than 5,750) 11 million km^2 = 3% of the ocean floor.

The deepest trench is the Mariano in the Pacific = 11,034 m.

(b) The ocean as a dynamic system

The enormous mass of 1,370 million km^3 of the ocean's water is in perpetual movement. While the ocean's general circulation is wind-driven, the uneven distribution of solar heat over the Earth's surface and further redistribution of this heat by oceanic currents play their important roles in mutual adjustment of the atmospheric and oceanic circulation patterns. As a whole the ocean behaves much as a complicated heat engine. To fully understand and predict its behaviour laws of thermodynamics should be applied.

Horizontal movements in the ocean are several orders of magnitude faster than vertical ones: On average their relation to each other is as the relation of horizontal dimensions of the ocean to its depth. Major horizontal currents sometimes attain speeds of 3 to 4 knots. Vertical velocities in areas of well-pronounced upwellings are still fractions of a centimetre per second.

The ocean actively interacts with the atmosphere and with the bottom. Both the atmosphere and the ocean floor strongly influence the ocean's physics, chemistry and life. Equally important is the influence of the ocean on the atmosphere, on the ocean floor and on the continents.

Nearly everything in the ocean, at least on the time scales involved in our observations, appears to be in a state of dynamic balance : water itself, energy, dissolved salts and gases, living organisms. Local and temporal departures from this dynamic balance may cause major consequencies, both locally and elsewhere, in the ocean itself, in the biosphere and in the atmosphere. On a geological time-scale, however, this consideration is no longer valid and one may speak only of a temporary quasi-equilibrium. This quasi-equilibrium may be simply a momentary stage in the long, slow evolution which has undoubtedly been interrupted by abrupt major changes many times in the history of the Earth.

Accumulation of sediments on the ocean floor is slow. Although the rate of this accumulation is only from 0.1 to a few centimetres per thousand years, a considerable amount, estimated as being in the region of several hundred million tons of sediment material, is added every year over the whole surface of the ocean floor. Principal sources of sedimentation are : material brought by rivers from the continents; material resulting from coastal abrasion; material of biological origin (microscopic skeletons of plankton; shell coral and other detritus, etc.; chemical precipitation.

Currents redistribute in the ocean the suspended and dissolved matter

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* as accepted in oceanographic classification (adjacent and mediterranean seas included).

originally brought by rivers, as well as that resulting from coastal abrasion. While being transported away from continents heavier minerals may remain behind, separating from the lighter ones which continue to drift. Chemical and biological processes account for various transformations of organic and inorganic matter during its slow descent through the water layers to the abyssal depths. Terrigenous material mixes with organogene detritus such as shell fragments, coral sands or different calcareous and siliceous remnants of organic life. In some areas the planktonic portion of the sedimentation is even predominant. Calcareous material becomes solvent in cold water and precipitates in warm areas. Some metals, like manganese, undergo concentration in the form of nodules. Sediments rich in organic matter, once superimposed and trapped by impermeable layers, may be transformed into petroliferous ones.

Further slow transformations occur in the sediment layers themselves. There may, however, be quicker changes due to underwater volcanic eruptions as a result of which sediment layers can become interspersed with layers of lava.

The layers of sediments and the crystalline base on which the sediments rest are subject to tectonic forces of compression and expansion. The complicated topography of the ocean floor, with its mid-ocean ridges, rift valleys, underwater mountains and volcanoes, displays abundant features of past and contemporary transformations. Understanding them provides us with means to interpret the ancient history of the ocean basins and of the whole planet Earth. The origin of the oceanic water and of its salt content is closely related to this geological history. Knowledge of it can be particularly important for such practical aims as mineral exploitation, for example.

Selected bibliography:

1. SVERDRUP, H.U. et al. 1946. - The oceans, their physics, chemistry, and general biology. Prentice-Hall Inc., New York.

2. DIETRICH, G., 1963. - General oceanography, an introduction. Interscience Publishers, New York - London.

3. DEFANT, A. 1961. - Physical oceanography. Pergamon Press, Oxford - London - New York.

4. HILL, M.N. ed 1962-63. - The Sea. Interscience Publishers, Paris - New York.

5. Draft of a general scientific framework for world ocean study, 1964. - Intergovernmental Oceanographic Commission, UNESCO, Paris.

6. LACOMBE, H., 1965. - Cours d'océanographie physique. Gauthier-Villars, Paris.

7. Second International Oceanographic Congress, 1966. - Abstracts of Papers, Moscow.

8. VINOGRADOV, A.P., 1967. - Introduction to the geochemistry of the ocean (in Russian). NAUKA, Moscow.

CHAPTER I. PROBLEMS RELATED TO THE PROCESSES OF FORMATION AND TO THE GEOGRAPHICAL DISTRIBUTION OF MARINE MINERALS

Introduction

In relation to those uses of the ocean floor mentioned in the general introduction, the most relevant topics of research are :

- Amount and composition of material transported from the continents into the ocean and of that suspended and dissolved in the oceanic water.

- Suspended matter in the ocean and suspension currents.

- Deep-ocean sediments : stratigraphy and micropaleontology.

- Near-bottom processes and interaction on water-sediment interface.

- Well-rounded deposits on the deep-sea floor : pebbles - nodules - lava bombs - organogene concretions - spherules.

- Tectonic processes in the Earth's crust and in the Upper Mantle.

In addition to the findings of research, a considerable amount of specific and precise data on bottom topography, geophysical parameters, sediments and water masses above, is needed for all practical purposes associated with any use of the ocean floor. It is therefore essential that regular surveys be conducted to provide such data as required. A wealth of useful data exists in the world from surveys already accomplished. It is important, therefore, to know the degree of the present coverage of the ocean by :

- Bathymetric surveys.

- Geophysical surveys.

- Sediment sampling.

- Underwater photography.

I.1 Amount and composition of material transported from the continents into the ocean and of that suspended and dissolved in the oceanic water.

Every year about 36,000 km^3 of river water flows into the sea, charged with 12,700 million tons of suspended matter, of which large parts are useful minerals and ores. Approximately 3,000 million tons of dissolved material per year is also brought with the same water. This represents, however, a very small fraction of the total amount of salts dissolved in the ocean water (5.10^{10} million tons). It is well known that the chemical composition of the dissolved material brought by rivers is substantially different from that of the ocean itself. This fact does not permit acceptance of such a hypothesis as that of a slow accumulation of salts in the ocean due to supply by rivers, and calls for more complicated theories as to the origin of the oceanic water and the salts in it. Although very plausible theories describing their origin in the general context of the Earth's early history and evolution exist, scientists do not agree on which of these theories to finally accept as fully correct.

Neither the salts nor the suspended matter carried to the ocean by rivers remain unchanged there. Part of the suspended matter dissolves; part of the salts in solution is extracted by living organisms; a part of the suspended material originally brought goes into sediments either in its original form or after undergoing certain metamorphoses. While sediments accumulate on the bottom, the material remaining suspended or in solution participates in a complicated cycle in which the organisms inhabiting the ocean play a very important rôle.

The tables on the following pages give some figures concerning the chemical composition of the oceanic water, of the continental run-off, and their comparison.

TABLE I - Average chemical composition of oceanic water (according to A.P. Vinogradov)

($S = 35{,}00‰$; $Cl = 19{,}375‰$)

Chemical element	%	mg/litre	Chemical element	%	mg/litre
H	—	—	In	($1 \cdot 10^{-8}$)	0,0001
He	—	0,000005	Sn	$3 \cdot 10^{-7}$	0,003
Li	$1{,}5 \cdot 10^{-5}$	0,15	Sb	$5 \cdot 10^{-8}$	0,0005
Be	$6 \cdot 10^{-11}$	0,0000006	Te	?	—
B	$4{,}6 \cdot 10^{-4}$	4,6	I	$5 \cdot 10^{-6}$	0,05
C	—	28	Xe	?	—
N	—	0,5	Cs	$3{,}7 \cdot 10^{-8}$	0,00037
O	—	—	Ba	$2 \cdot 10^{-6}$	0,02
F	$1{,}3 \cdot 10^{-4}$	1,3	La	$2{,}9 \cdot 10^{-10}$	0,0000029
Ne	—	0,0001	Ce	$1{,}3 \cdot 10^{-10}$	0,0000013
Na	1,03534	10,354	Pr	$6 \cdot 10^{-11}$	0,0000006
Mg	0,1207	1297	Nb	$2{,}3 \cdot 10^{-11}$	0,0000023
Al	$1 \cdot 10^{-6}$	0,01	Sm	$4{,}2 \cdot 10^{-11}$	0,00000042
Si	$3 \cdot 10^{-4}$	3,0	Eu	$1{,}1 \cdot 10^{-10}$	0,0000011
P	$7 \cdot 10^{-6}$	0,07	Gd	$6 \cdot 10^{-11}$	0,0000006
S	0,089	890	Tb	?	—
Cl	1,93534	19354	Dy	$7{,}3 \cdot 10^{-11}$	0,00000073
Ar	—	0,6	Ho	$2{,}2 \cdot 10^{-11}$	0,00000022
K	0,03875	387,5	Er	$6 \cdot 10^{-11}$	0,0000006
Ca	0,0408	408	Tm	$1 \cdot 10^{-11}$	0,0000001
Sc	$4 \cdot 10^{-9}$	0,00004	Yb	$5 \cdot 10^{-11}$	0,00000052
Ti	$1 \cdot 10^{-7}$	0,001	Lu	$1 \cdot 10^{-10}$	0,00000012
V	$3 \cdot 10^{-7}$	0,003	Hf	?	—
Cr	$2 \cdot 10^{-9}$	0,00002	Ta	?	—
Mn	$2 \cdot 10^{-7}$	0,002	W	$1 \cdot 10^{-8}$	0,0001
Fe	$1 \cdot 10^{-6}$	0,01	Re	?	—
Co	$5 \cdot 10^{-8}$	0.0005	Os	?	—
Ni	$2 \cdot 10^{-7}$	0,002	Ir	?	—
Cu	$3 \cdot 10^{-7}$	0,003	Pt	?	—
Zn	$1 \cdot 10^{-6}$	0,01	Au	$4 \cdot 10^{-10}$	0,000004
Ga	$3 \cdot 10^{-9}$	0,00003	Hg	$3 \cdot 10^{-9}$	0,00003
Ge	$6 \cdot 10^{-9}$	0,00006	Tl	$1 \cdot 10^{-9}$	0,00001
As	$1 \cdot 10^{-7}$	0,003	Pb	$3 \cdot 10^{-9}$	0,00003
Se	$1 \cdot 10^{-8}$	0,0001	Bi	$2 \cdot 10^{-8}$	0,0002
Br	$6{,}6 \cdot 10^{-3}$	66	Po	?	—
Kr	—	0,0003	At	?	—
Rb	$2 \cdot 10^{-5}$	0,2	EmU	$6 \cdot 10^{-20}$	$6 \cdot 10^{-14}$
Sr	$8 \cdot 10^{-4}$	8,0	Kr	?	—
Y	$3 \cdot 10^{-8}$	0,0003	Ra	$1 \cdot 10^{-14}$	$1 \cdot 10^{-10}$
Zr	$5 \cdot 10^{-9}$	0,00005	Ac	$2 \cdot 10^{-20}$	$2 \cdot 10^{-16}$
Nb	$1 \cdot 10^{-9}$	0,00001	Th	$1 \cdot 10^{-9}$	0,00001
Mo	$1 \cdot 10^{-6}$	0,01	Pa	$5 \cdot 10^{-15}$	$5 \cdot 10^{-11}$
Tc	?	—	U	$3 \cdot 10^{-7}$	0,003
Ru	?	—	Io	$5 \cdot 10^{-14}$	$5 \cdot 10^{-10}$
Rh	?	—	Th^{228} (RdTh)	$7 \cdot 10^{-19}$	$7 \cdot 10^{-15}$
Pd	?	—			
Ag	$3 \cdot 10^{-8}$	0,0003			
Cd	$1 \cdot 10^{-8}$	0,0001			

TABLE II - Ionic composition of the continental run-off (according to O.A. Alekin)

	Ca^{2+}	Mg^{2+}	$Na^{+}+K^{+}$	HCO_3	SO_4^{2-}	Cl^{-}	Total
in mg/litre	13,9	3,8	6,1	47,6	11,9	6,4	89,2
in % of dry residue . .	15,6	3,7	6,8	53,4	13,3	7,2	100
Annual supply into the ocean in million tons	494	117	217	1692	423	228	3171

TABLE III - Chemical elements which are more abundant in oceanic water than in the continental run-off (according to A.P. Vinogradov)

Element	Ocean: in %	Rivers: in %	Element	Ocean: in %	Rivers: in %
Li	$1,5\cdot10^{-5}$	$1\cdot10^{-7}$	Ca	0,0408	$1,3\cdot10^{-3}$
B	$4,6\cdot10^{-4}$	$2\cdot10^{-6}$	Br	$6,6\cdot10^{-3}$	$2\cdot10^{-6}$
F	$1,3\cdot10^{-4}$	$5\cdot10^{-6}$	Rb	$2\cdot10^{-5}$	$2\cdot10^{-7}$
Na	1,035	$4,5\cdot10^{-4}$	Sr	$8\cdot10^{-4}$	$1\cdot10^{-6}$
Mg	0,129	$3,3\cdot10^{-4}$	I	$5\cdot10^{-6}$	$2\cdot10^{-7}$
S	0,089	$4\cdot10^{-4}$	Cs	$3,7\cdot10^{-8}$	$1\cdot10^{-8}$
Cl	1,935	$6,4\cdot10^{-4}$	Ba	$2\cdot10^{-6}$	$<3\cdot10^{-6}$
K	0,039	$1,5\cdot10^{-4}$	U	$3\cdot10^{-7}$	$1\cdot10^{-7}$

TABLE IV - Chemical elements which are more abundant in the continental run-off than in the ocean (according to A.P. Vinogradov)

Element	Ocean: in %	Rivers: in %	Element	Ocean: in %	Rivers: in %
Si	$3\cdot10^{-4}$	$6\cdot10^{-4}$	Ni	$2\cdot10^{-7}$	$5\cdot10^{-7}$
Ti	$1\cdot10^{-7}$	$5\cdot10^{-7}$	Cu	$3\cdot10^{-7}$	$5\cdot10^{-7}$
Cr	$2\cdot10^{-8}$	$1\cdot10^{-7}$	Zn	$1\cdot10^{-6}$	$2\cdot10^{-6}$
Mn	$2\cdot10^{-7}$	$1\cdot10^{-6}$	Pb	$3\cdot10^{-9}$	$\sim1\cdot10^{-7}$
Fe	$1\cdot10^{-6}$	$6,7\cdot10^{-5}$	Al	$1\cdot10^{-6}$	$5\cdot10^{-5}$
Co	$5\cdot10^{-8}$	$1\cdot10^{-7}$			

I.2 Suspended matter in the ocean and suspension currents

Suspended matter

It is important to study the distribution of suspended matter in the ocean as the information so obtained may provide scientists with guiding principles to better understanding of the geographical distribution of sediments in the ocean. By studying the distribution of ancient sediments conclusions may be come to as regards systems of currents which were predominent in the ocean at the time when the ancient sediment material was being deposited from suspension.

Information on concentrations of suspended matter near the sediment-water interface is important for the use of underwater photography. In some areas the turbidity of water near the bottom is quite significant and may prevent successful photography. The turbidity above the sediment surface may also change with the tidal cycle.

Studies of the composition of suspended matter and its comparison with that of sediments give scientists an insight into the transformations which such matter undergoes before reaching the ocean floor.

As was mentioned above, rivers bring into the oceans approximately 12,700 million tons of suspended matter. It is difficult to estimate the amount of additional material in suspension originating from coastal abrasion. Abrasive processes vary considerably from one geographical area to another, due to the different characteristics of the coasts involved. Although there is no general agreement between scientists as regards the exact figure, according to some estimations the supply of abrasive material into the ocean in temperate zones - where processes of abrasion are most intense - is of the same order of magnitude as that of alluvial material. In tropical zones the latter is considerably more important.

It is estimated that the average concentration of suspended matter in the ocean is 1 mg per litre and its total amount is consequently 1.37×10^6 million tons.

According to Lisitzin (1961) the chemical composition of suspended matter in various parts of the ocean is as follows :

TABLE V

	SiO_2 (amorphous)	$CaCO_3$	C organic	Fe	Mn	Ti	P
Indian Ocean	11.45	1.28	8.67	3.14	0.04	0.018	0.30
Mediterranean Sea	1.2	4.0	10.4	8.74	0.05	0.54	-
Red Sea	1.0	4.4	12.7	19.55	-	0.04	-

(in % of the dry residue)

It is of interest to note that out of the enormous amount of suspended matter brought into the ocean only 0.4% goes into sediments directly. Tracing the remaining part and its metamorphoses represents another important subject of research.

Suspension (or turbidity) currents

When sedimentation occurs on a slope the mechanical instabilities may build up until a disturbance, due to currents or an earthquake, triggers the sliding down of sediments along the slopes. While moving downwards the sediments mix with the surrounding water. This mixture's specific gravity may be considerably greater than that of ordinary sea water. Kuenen (1950) showed in an experiment that water mixed with mud and sand may travel down the length of a long tank filled with water without mixing with it and without losing much of its suspended load. In the well-known case of the Grand Bank turbidity current of 1929 it was estimated that the flow was 100 m. thick with a 5% concentration of very fine sand. Its speed, as found by comparing the times of successive cable breaks, was about 90 km/hr. Sand deposits found at great depths on or below the continental slope, sometimes between layers of pelagic sediments, would testify to the fact that a suspension current occurred in the past.

It is not yet established whether turbidity currents themselves incise submarine canyons or whether they simply most frequently occur in the canyons of the continental slope where instabilities are more likely to build up. It is certain, however, that turbidity currents are a cause of erosion. It is also certain that some submarine canyons have granitic walls which could hardly be incised by suspension flows alone. Thus the question of the origin of submarine canyons remains unanswered and further research is necessary.

Turbidity currents can be a danger for submersibles, underwater installations and divers.

It seems likely that fairly large-scale experiments will be necessary to study turbidity currents in their natural environment. A typical experiment might be as follows :

1) Various telemetering instruments should be placed in a submarine canyon, possibly with the aid of deep-diving submersibles to ensure that the instruments are in exactly the right positions in the axis and on the canyon's side slopes. Instruments should be capable of sensing changes in turbidity, density and grain size distribution. In aggregate they can give the dimensions, speed, and sediment distribution within a current. Cables from the sensors should lead out laterally from the canyon to a main cable on the continental shelf, as it may be anticipated that some instruments will be carried away.

2) Similar instruments should be placed in deep-sea channels and on fans around the mouth of the canyon. These locations are at least as important as those in the canyon as it is only in the region of channels, fans, and abyssal plains that the turbidity currents decelerate and deposit sediment. The depths may be very great and it will probably be necessary to telemeter by radio from buoys above the instruments.

3) A slump is usually generated in the head of the canyon and movement of the slump and the resulting turbidity current should be followed across the sea floor. The way of generating the slump needs investigation. Explosive charges a few feet below the sediment surface appear ineffective. However, canyon heads seem to fill partially with sediment and be flushed out by periodical slumping. It may be possible to place the charges when the canyon head is empty of sediment, and explode them when it has been partially filled. An alternative and perhaps more promising method would be to bring a marine dredge into the area and pump the canyon full of sediment. In effect this would accelerate sedimentation by littoral processes and trigger a slump at a time when the instruments were in place.

Descriptive regional studies of the topography and sediments produced by turbidity currents will also be profitable. For example, the grain size distribution, volume, and areal extent of individual turbidites is unknown but is needed for comparison with ancient ones on continents. Detailed studies are required with closely-spaced cores in order to trace sedimentation units. If the circumstances are favourable a high-resolution echo-sounder can give sub-bottom reflections on a turbidite which is recognizable in cores. This permits wider spacing of cores and more detailed mapping of the reflector than can be done from cores alone.

Some observed details of the topography of deep-sea channels may suggest that turbidity currents resemble rivers in that they meander and produce terraces. Many more observations, using deep submersibles and television, are needed before these phenomena can be understood.

Suitable regions for field experiments and surveys of turbidity current phenomena are numerous. Ideal areas with steep slopes are found in the Mediterranean, the Caribbean, off Melanesia, and off eastern Asia. These areas are less deep than others and instrumentation should be comparatively easy. However, the scale of processes may be different in the deep, open ocean basins, and eventually they also should be studied.

I.3 Deep-ocean sediments : stratigraphy and micropaleontology

Studies of the deep ocean sediments provide scientists with clues to understanding the geological history of our planet, its oceans and continents. Such background knowledge is important for meaningful exploration of underwater mineral resources. Without this knowledge any search for minerals would be conducted blindly.

Ideally, the succession of sediment layers in an undisturbed core should show a certain sequence of different climatic periods and, on a larger scale, a sequence of geological periods. As it happens, the facts observed in the cores of oceanic sediments are not always easy to interpret. The work of stratigraphers and micropaleontologists is reminiscent of the work of a detective who, in a search for the only correct solution, should combine in a true system a multitude of seemingly contradicting clues.

Deep ocean sediments can be divided into :

- pelagic sediments, including brown clay with less than 30% biogenous material, diagenetic deposits, consisting largely of minerals crystallized in the sea, biogenous deposits like foraminiferal ooze, diatom ooze, radiolarian ooze, coral reef debris;

- terrigenous muds having more than 30% of silt and sand of definite continental origin;

- turbidites caused by turbidity currents;

- slide deposits brought to the deep parts of the slope by slow sliding;

- glacial deposits derived from iceberg transportation;

- volcanic sediments.

The distribution of these types is fairly well-known. For example, calcareous material is limited to warm areas, while in cold zones it is dissolved before reaching the bottom.

Analyses of sediment cores show that nearly all sediments in the first few meters below the sea-bottom belong to the glacial and postglacial periods. In the Atlantic a considerable number of cores have been tested in order to establish the succession of cold and warm stages of paleoclimate by examination of the fossil planktonic foraminifera in various sediment layers, isotopic dating based on O^{18}/O^{16} ratio was also attempted. As a result, a sequence of glacial and interglacial periods was established, the last glacial stage having ended between 11,000 and 17,000 years ago, as confirmed also by C^{14} determination. In general, the cores of the Pacific do not show the same alternations indicative of warm and cool periods. In many places the clay cores are continuous without any apparent changes during the whole Pleistocene. In antarctica, ice-rafted sediments can be used as an indication of cold periods. Organic deposits with a higher content of "radiolaria" in interglacial times alternate with marine glacial sediments. One sequence, for example, contains three relatively warm stages. In the Arctic analyses show that even here distinct changes occurred in the past; the content of foraminifera being different at certain depths of the core.

The causes of some disconformities in abyssal sedimentation are still enigmatic. In a few cores, the hiatus in sediment accumulation is marked by an indurated surface, sometimes impregnated by oxides of manganese and iron, indicating a long period of non-accumulation. In many other cores, no such indurated surface is developed and it appears that at some time an erosion process removed rather rapidly the intermediate sediments and accumulation then continued normally to the present day. The first-mentioned situation cannot be explained unless one invokes bottom-water currents of sufficient intensity to prevent sediment accumulation for millions of years. The rapid removal of young sediments, followed by a resumption of normal accumulation, may be due to the action of transient density currents which erode the unconsolidated sediments briefly and then cease. Attempts have been made during the past decade to determine whether interrupted sediment sequences are characteristic of abyssal hills or of valleys, but no clear-cut answer has yet been obtained to this basic question.

Until now the stratigrapher has had to depend almost exclusively on paleontology for age-determinations and correlations in deep-sea sediment cores (except within that part of the Quarternary for which isotopic dating methods are available). Thus deep-sea sediment sequences can be put into a time-framework only in those areas in which the sediments are fossiliferous. Attempts are being made to find isotopic and sedimentary-petrological methods to serve as a basis for time-correlations of unfossiliferous sediments, and when these are successful it will be possible to extend paleo-oceanographic interpretations to large areas which are at present inaccessible to this field of research.

I.4 Near-bottom processes and interaction on water-sediment interface

Equal in importance to the ocean-atmosphere interaction exists an interaction between the ocean and its floor.

The bottom relief is submitted to transformations by endogene (Earth's interior) forces. Tectonic events like folding and faulting take place, volcanoes rise and eject lava and gases, changing the chemical and physical properties of the surrounding waters and influencing bottom currents.

Water movements also affect the bottom: tidal currents and turbidity flows form and reform the bottom relief on a smaller scale; they erode, transport and redistribute sediments and help the accumulation of some minerals and ores.

The problems connected with this interaction can be studied on two different scales: (1) with respect to the general situation of large parts of the sea, even of the whole ocean; (2) by examining in detail selected areas of only a few square miles or even square meters large. The differentiation between these two approaches has just begun. Progress of detailed small-scale studies of near-bottom processes depends largely on the development of instruments which would permit observing and recording of dynamic events quantitatively and synchronously. Only in the last few years has some important progress in this new direction been made (submersibles, underwater television and filming).

Extremely important from the standpoint of the formation of minerals are the chemical processes which occur near the water-sediment interface and in the upper unconsolidated layers of sediments. An important rôle in these processes is also played by micro-organisms. Coupled with biological transport of various chemical elements, these processes may account for the occurrences of such economically-important concentrations of minerals as, for example, manganese nodules. The general conditions of ventilation of a water basin under consideration are relevant to the types of both chemical and microbial conditions observed in the near-bottom area. The oxidation or reduction conditions may prevail, resulting in very specific distinctions in mineral composition of sediments. While the Black Sea is a classic example of a poorly ventilated basin with reduction processes being typical there, the open parts of the World Ocean are characterized by the absence of reduction conditions and by the presence of oxidized oozes and clays. Among the processes of great interest and importance which are still insufficiently studied and lacking accurate quantitative estimates is the process of chemical precipitation.

If it is assumed that the hydrocarbonates and mineral colloids, microelements and biogenous elements carried out by river discharge are precipitated, then CO_3'' - 826, $Ca^{\cdot\cdot}$ - 426, $Mg^{\cdot\cdot}$ - 34.5 million tons, sink yearly to the bottom of the ocean, that is in all 1,359 million tons of hydrocarbonates, calcium and magnesium. Furthermore, 360 million tons of colloids (in the form of oxides), 36 million tons of micro-elements and 18 million tons of biogenous substances will pass to the bottom in one way or another. Consequently the total quantity of precipitated matter is 1,773 million tons.

I.5 Well-rounded deposits on the deep-sea floor : pebbles - nodules - lava bombs - organogene concretions - spherules.

The longer the way of transportation of rock debris, once caught up by the flowing water of a river, the more rounded will it become. It will be rounded on the beaches too if it is broken off from a cliff and seized by waves. If such pebbles reach the slopes or canyon heads and roll down the canyon floors, they may become involved in slowly creeping mudflows or quick turbidity currents, which may bring them down to the abyssal plains. But all rounded forms found on the sea-floor are not necessarily pebbles. Under the same morphology, quite different phenomena may be concealed :

- nodules
- lava bombs
- organogene concretions
- spherules

Identification is further hindered by the fact that the abbve-mentioned forms may be covered by an organic crust concealing their real nature and origin. Therefore interpretation of bottom photographs (our only present source of knowledge besides dredged material) must be done with considerable circumspection.

True pebbles may also be found at great depths, having either been brought there by the above-mentioned method or having originated in areas which have become submerged. For example, ancient beaches have been discovered at depths of over a hundred meters (e.g., off Corsica), providing that after formation an important tectonic movement took place.

Some table mounts are covered with a layer of pebbles, proving that their platforms were formed by wave abrasion. If we find these platforms at great depths we can be sure that tectonic submergence took place. However, caution is necessary to prevent confusion of such pebbles with nodules, which may be found at any depth and which give no indications about tectonic movements.

Nodules are concentrates of certain metals and other chemical elements and their existence in the ocean is widespread. They are the most striking authigenic deposits of the sea floor. Mero (1965) supposes that they constitute the most common form of hardrock found at the surface of the Earth's lithosphere. While most of them are no larger than 25 cm., some with a mass of 850 kg. are known. Nodules grow around small rock fragments and such objects as, e.g., shark teeth. Their cross-section shows concentric layers corresponding to different phases of their formation.

Manganese and ferro-manganese nodules are the most common. (See "Resources of the Sea" Part One: Mineral Resources of the Sea Beyond the Continental Shelf. Report of the Secretary-General, E/4449/Add.1, 19 February 1968) Sources of manganese in the ocean are the continental run-off and submarine volcanoes. The respective shares of manganese supplied from these two sources is difficult to estimate since there was definitely a time in geological history when thousands of submarine volcanoes were active on the ocean floor, and also because of the very complicated way by which the manganese reaches the bottom sediments, both through biological transport and chemical precipitation. According to recent date, manganese accumulates over the entire ocean floor at a uniform rate of 2 mg. per cm^2 per thousand years. Its majority goes into fine grain sediment, only a small part of it participating in the formation of nodules which require some five million years to develop fully.

When a volcano erupts molten lava is ejected into the air, falling to the ground in the form of lava bombs. One may find such bombs on the sea-bed around existing volcanic islands or in the vicinity of submerged volcanic islands. Pillow lava is the result of submarine outflows. Broken pillow lava may resemble pebbles or cobbles.

Organogene concretions are spread all over the sea bottom. They may be dead algae, coral reef debris, etc., and in photographs are easily confused with pebbles. In some cases the seemingly rough surfaces of the sea floor are not built up by a course sediment, but are simply covered with a layer of broken and rounded material.

Spherules should also be mentioned, although they are much smaller in size than nodules and concretions. They are of cosmic origin and are normally of highly magnetic nature, resulting from an inner metallic nucleus surrounded by iron oxides. Spherules seldom exceed 0.2 mm. in diameter. It is supposed that the total accumulation of spherules over the Earth's surface is of an order of 2,500 to 5,000 tons annually.

I.6 Tectonic processes in the Earth's crust and in the Upper Mantle

After passing through the sediments - unconsolidated near the bottom, then semi-consolidated and finally consolidated - the crystalline base is reached. This base is part of the Earth's crust and is generally divided into two larger layers called Sial (with an average density of 2.67) and Sima (with an average density of 3.27).

The Sial is a light granite layer building up the continental blocks. Its fragments "float" on the Sima, which consists of a basalt (or gabbro) layer (found under the ocean floor) and a still deeper peridotite layer. Both are separated by the so-called Mohorovičić discontinuity, which is world-wide. Beneath the continents this "Moho" is bent down by the continents to a depth of 30 - 50 km; in ocean areas (where the Sial is lacking) it comes up to a depth of 5 km, or even less (0.5 km in some parts of the Pacific).

All types of intermediate crust (with sub-continental and sub-oceanic sub-types) are known to exist between a typical "continental" and a typical "oceanic" crust. Study of all these types is in progress, as was learned at the International Oceanographic Congress in Moscow in 1966.

In 1961 the U.S. "Mohole" project was started. Attempts were made to drill through the sediment layer for samples of simatic rock near the surface in some areas of the Pacific. Unfortunately, after a few years' testing, the attempt was deferred.

Two opposing tectonic forces : compression and expansion - influence the Earth's crust.

By compression mountain chains fold, an example from later geological times being the two immense belts girdling the world - the "alpine" belt beginning in Spain, continuing through the Alps, the Caucasus, the Himalayas, and ending in the Indonesian Islands; and the "Pacific" belt encircling the Pacific Ocean from New Zealand to the Andes.

Expansion produces a network of fracture-lines spreading all over the world and cutting sialic continents, as well as simatic layers of the ocean floor, into pieces. One of the most impressive land scars begins in Scandinavia, continues through the Rhine and Rhone valleys, turns east in the Mediterranean Sea, south again in the Red Sea, and ends in the East African graben system. There are some other features of the same kind in the oceans, the most characteristic being the mid-ocean ridges (e.g., the Mid-Atlantic, the Carlsberg Ridge, etc.).

Large amounts of volcanic material rose along the fracture lines, forming volcanoes or covering large parts of the sea-bed with traps. Some of the most important island groups (Hawaii, Canaries) are of volcanic origin. Sialic and simatic material evidently becomes mixed in the ridge areas, forming a special sub-type of crust. It can even be supposed that Sima outcrops on the sea bottom inside the rift valleys. Soviet scientists followed this idea (on the second cruise of the "Akademik Kurchatov" in 1967) and dredged some ultra-basic rocks from the rift walls of the Carlsberg Ridge (Indian Ocean). These rocks clearly have a simatic composition.

Another important subject recently studied is deep-sea trenches as, for example, those following the island arcs of the Pacific. Some facts, such as the downward bending of the Earth's crust and the frequency of earthquakes there, lead us to suppose that these trenches are undergoing lateral compression: the long term result of this may be the folding of the sediments they contain in large quantity.

The discovery of three underwater pools of hot (more than 40°C), high-salinity (more than 240‰) water in the Red Sea deeps was important. The largest brine pool is 12 x 5 km. Inside it, three distinct elevations were found which are thought to be volcanic craters. Some of the seismic reflexion profiles across the brine pools indicate faulting. Isotope studies show that the source of the brine water is the Red Sea itself, while the numerous metals found in solution derive from the sub-bottom rocks. It is supposed that rifting has caused fissures for the ascending ore solutions and descending sea water. It was calculated* that an ore body of 130 million tons is available there, including iron, manganese, cooper, zinc, silver, gold, etc. It is thought possible that similar hot brines may be found in the Gulfs of Aden, Akaba, California, etc., wherever recent and active rifts exist.

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* Ref. GRICE, C.F., 1968. The Red Sea's brines and heavy metals, Ocean Industry, 3, 3. pp.52-57.

I.7 Bathymetric surveys

Basic for every kind of practical and scientific work on the sea bottom is a bathymetric map. Even those activities limited to the surface of the ocean, like navigation, cannot develop without knowledge of bottom topography. Safety of navigation and possibilities of determining a ship's position in the open sea depend very largely on the reliability of nautical charts.

Nautical charts exist from the early days of navigation. At present they cover, on a variety of scales, the whole of the World Ocean with its adjacent and mediterranean seas. Nautical charts, however, do not give a clear visual presentation of the bottom relief and are therefore of little use other than for navigation purposes.

A nautical chart may be transformed into a bathymetric (topographic) map by drawing contour lines. In this way were made the first scientific attempts to give morphological presentation of the bottom relief (e.g., General Bathymetric Chart of the Oceans, by the International Hydrographic Bureau. (The fourth edition is now being published.) Scientists added to all previously collected soundings a considerable number made from research ships with greater precision and sometimes greater frequency in space for particularly interesting areas. Thus, scientists are able to draw contour lines nearer to reality by following scientific hypotheses on geomorphology. At every stage these interpretations reflect the present level of our knowledge of the geological history of the ocean basins and of the origins (and, consequently, the most likely shapes) of certain prominent morphological features. In this way a number of excellent scientific bathymetric maps of all over the world were prepared by different scientific groups. Some references are given at the end of the Selected Bibliography to Chapter I.

It should be mentioned that an up-to-date geological/geophysical atlas of the Indian Ocean is now being prepared through international cooperation under the aegis of IOC/Unesco as a follow-up of the International Indian Ocean Expedition of 1959-1965. The bathymetric maps of this atlas promise to be the most modern ever made.

Information concerning other bathymetric maps and, particularly, existing nautical charts, may be derived from the "International Hydrographic Bulletin" published monthly by the International Hydrographic Bureau, the principal international organism responsible for collection of ocean-bottom soundings (see Chapter IV) and for ensuring adequate coverage of the World Ocean by nautical and bathymetric charts (see also Resolution V-8 of the IOC in Annex I).

The question which now arises is whether the coverage of the World Ocean by existing bathymetric maps is adequate. The answer is that it is not. Scientific investigations of the ocean floor have reached the stage when hardly any better scientific use can be made of the soundings collected so far. One example is sufficient to demonstrate the situation: The Mediterranean Sea is the ancient centre of european culture. But as recently as ten years ago no morphological map of this sea was available. Even today, its general bathymetric map does not go beyond the scale of 1 : 750.000 and is still considered provisional (Ref. ICSEM charts, US Bathymetric Charts, etc.). More detailed and more precise maps of some parts of the Mediterranean have recently been constructed by the Oceanographic Institute of Monaco. Their scale is 1 : 50.000: 16 sheets will cover the area between Monaco and the Corsican coast. But even these maps, although including only new soundings, cannot be considered as complete. The situation as regards the open ocean is considerably worse.

The whole problem is that, in order to construct bathymetric maps of better quality (i.e., greater accuracy and scientific meaning) topographic surveying of the ocean floor should be started anew with the most modern instrumentation and methodology. Shortcomings of previous open ocean soundings have been :

i. Unreliable and inaccurate position-fixing of a surveying ship.

ii. Uncertainties in values of sound-velocity used for calculating precise depths of echo-sounding.

iii. Use of wide-angle echo-sounders.

iv. Insufficient space-frequency of soundings.

(Some of these problems are treated in greater detail in Chapter II.)

The above-mentioned lacks should be eliminated before new systematic surveys of bottom topography are organized on a global scale. This task is very much one for international cooperation since uniform methodology and a universally available precision navigation system may be developed only through the common efforts of all interested countries.

I.8 Geophysical surveys

Geophysical surveys comprising collection of seismic, gravimetric, magnetic and heat flow data, very often along selected profiles, are being conducted by all the major oceanographic countries of the world (USA, USSR, UK, Japan, France, Federal Republic of Germany, etc.) as part of their national programmes. Many geophysical surveys were made within the framework of such international expeditions as the IIOE, when information concerning the data obtained and the data themselves were exchanged. To a considerable extent geophysical surveys are conducted by private industrial and mining companies of some countries, with very little information being made public about their results. Some international organizations, such as ECAFE of the UN for example, conduct geophysical surveys of shelf areas with a view to the eventual organizing of exploitation of available mineral resources.

So far no complete international record exists of the geophysical surveying done at sea. In spite of the absence of such a record it is fairly well-known that the actual coverage of the ocean by geophysical measurements is very scanty. The first ocean-wide summaries are expected to be included in the Indian Ocean Geological/Geophysical Atlas of the IIOE. The development of basic principles of international exchange of marine geophysical data is on the agenda of the IOC Working Group on Oceanographic Data Exchange. If an improvement of the general situation, with coverage of the World Ocean by geophysical measurements, is to be achieved, the first thing to do would be to prepare a world inventory of marine geophysical data.

I.9 Sediment sampling

Although during the last few years a great many sediment cores have been collected from all over the World Ocean, one cannot speak of a systematic coverage of the oceans by sediment sampling.

There are certain limitations in present coring methods and practices which render rather difficult any large-scale generalizations or systematic presentations of the geographical distribution of sediments on sediment maps.

- Sediment cores are limited in length, being seldom longer than 20 m.
- On the whole, sediment samples are taken without a general plan - at best they are taken along profiles.
- The distances between the closest sediment cores are still too great, which makes correlation between them difficult or impossible. Therefore it remains uncertain whether the sediment characteristics obtained from a core are valid for a large area or if they represent a local exception.
- The analyses of sediment cores in laboratories are often delayed for years.
- Sediment cores taken by industrial companies or information concerning these cores are not generally available.
- There exists no international register of information concerning sediment cores.

Nevertheless, attempts are being made in the world's most advanced oceanographic laboratories to prepare, as far as the above situation permits, sediment maps covering various parts of the World Ocean. Some of these maps were shown at the recent Second International Oceanographic Congress in Moscow (1966).

I.10 Underwater photography

Photographic surveys of the ocean floor allow us to complete visually our more or less abstract impressions received from echo-soundings and sediment or rock samplings. Underwater photographs disclose the bottom microstructure and may provide valuable information on dynamic processes near the sea-bed.

As with sediment sampling, there is no systematic coverage of the ocean floor by photographs.

There is no limitation at present on the technical side for more general and systematic use of underwater photography. What is needed is international coordination and international exchange of information on all the photographs presently available.

Underwater television may help to improve coverage in shallow areas. Also, such technical innovations as photo-sledges (now in use by the Oceanographic Institute of Monaco) can provide for greater continuity, which is particularly important when mapping is involved.

I.11 Concluding remarks concerning international scientific cooperation

From the General Introduction and the short summaries given in Chapter I, it is evident that oceanographic research, even when restricted to specific problems of the ocean floor, is necessarily multi-disciplinary. It is logical, therefore, that the complex natural interactions in the ocean require for their study the close collaboration of scientists of different specializations. This is one of the reasons why there are so many international scientific organizations dealing with the ocean from so many different angles. The whole field of marine science may be divided into a number of systematic sections, either according to the fundamental disciplines of science involved (physics, chemistry, biology, etc.), or according to the objects of study (dynamics of the ocean circulation, ocean-atmosphere interaction, sedimentology, coastal processes, fishery research, etc.). Historically, the formation of international scientific bodies did not follow strictly any of these two lines of classification. The result is that we have some international bodies whose functions are all-embracing (e.g., SCOR, IOC), and other bodies whose functions are selective in one or another sense (IHB, FAO, WMO, IAPSO, etc.). There is also a regional approach to oceanic problems in which a particular geographical region was chosen as a basis for international cooperation (ICES, ICSEM, PSA, etc...).

Returning to the problems of immediate relevance to the study of peaceful uses of the ocean floor, one may say that the international scientific cooperation to be involved should comprise not only the disciplines pertaining strictly to the ocean but also those relevant to the atmosphere.

The physical conditions of the marine environment in which marine sedimentary material is formed and transported and the run-off of terrestrial sediments are to a varying degree influenced by atmospheric conditions prevailing both over land and oceans. Relevant meteorological research is mostly concerned with studies of the general circulation of the atmosphere and of climatic variations of the marine environment. In both fields the interaction between ocean and atmosphere is one of the predominant agents to be considered.

Research into ocean-atmosphere interaction processes can therefore provide an important input to marine geophysical studies of a more general nature, including bottom geology. The meteorological and oceanographic research involved, and the collaboration between WMO, IUGG and UNESCO/IOC in this respect, are mentioned in the report prepared under General Assembly Resolution 2172 (XXI) (Part 1, Chapter IV, appendices).*

* The last two paragraphs of this Section are contributed by WMO.

Selected Bibliography to Chapter I

ALEKIN, O.A., 1966. Chemistry of the ocean (in Russian). Gidrometeoizdat. Leningrad, USSR.

ALEKIN, O.A., 1966. The discharge of dissolved matter into the World Ocean. Second International Oceanographic Congress, Abstracts of Papers, pp.6-7. Moscow, USSR.

BARNES, H. ed.1963, 1964, 1965. Oceanography and marine biology. Annual Review, Vols. I, II and III. George Allen & Unwin Ltd., London.

BOURCART, J., 1958. Problèmes de géologie sous-marine. Masson, Paris.

DAWSON, E.Y., 1966. Marine botany, an introduction. Holt, Rinehart and Winston, N.Y., Chicago, San Francisco.

DOBRIN, M.B., 1960. Introduction to geophysical prospecting. McGraw-Hill, New York, Toronto, London.

EKMAN, S., 1953. Zoogeography of the sea. Sidgwick and Jackson, London.

GRICE, C.F., 1968. The Red Sea's brines and heavy metals. Ocean Industry, 3, 3, pp.52-57.

HARDY, A., 1956-59. The open sea. Collins, London.

HARVEY, H.W., 1963. The chemistry and fertility of sea water. University Press, Cambridge.

KING, C.A.M., 1959. Beaches and coasts. E. Arnold, London.

KUENEN, P.H., 1950. Marine geology, Wiley & Sons, New York, Chapman & Hall, London.

LISITZIN, A.P., 1961. Distribution and composition of suspended matter in oceans and seas (in Russian). Acad. Sci. USSR, Moscow.

PERES, J.M., 1961-63. Océanographie biologique et biologie marine, Presses universitaires de France, Paris.

POLDERVAART, A. ed. 1955. Crust of the earth, a symposium. Geol. Soc. Amer., New York.

RICHARDS, A.F., ed. 1967. Marine Geotechnics, Illinois Press, University of Chicago.

RUNCORN, S.K., ed. 1962. Continental drift. Academic Press, New York, London.

SHEPARD, F.P., 1963. Submarine Geology, 2nd edition. Harper & Row, New York, Evanston, London.

TWENHOFEL, W.H., 1950. Principles of sedimentation. McGraw-Hill, New York, Toronto, London.

VINOGRADOV, A.P., 1953. The elementary chemical composition of marine organisms. Sears Foundation, New Haven.

VINOGRADOV, A.P., 1967. Introduction to the geochemistry of the ocean (in Russian). NAUKA, Moscow.

WIEGEL, R.L., 1964. Oceanological engineering. Prentice-Hall, New York.

Selected Bathymetric Charts

INTERNATIONAL HYDROGRAPHIC BUREAU, Monaco.
General Bathymetric Chart of the Oceans (GEBCO) 3rd ed. 1938-42, (4th edition in preparation), 1 : 10.000.000.

HEEZEN, B.C. & THARP, M. Lamont Geological Observatory, USA.

(1) 1958, Physiographic diagram of the North Atlantic Ocean.

(2) 1960, Physiographic diagram of the South Atlantic Ocean, the Caribbean Sea, the Scotia Sea, and the eastern margin of the South Pacific Ocean.

(3) 1964, Physiographic diagram of the Indian Ocean, the Red Sea, the South China Sea, the Sulu Sea, and the Celebes Sea.

Geological Society of America, New York.

MENARD, H.W., 1960. Bathymetry of the Pacific Basin. SIO, La Jolla, USA.

GENERAL DIRECTION OF GEODESY AND CARTOGRAPHY. Ministry of Geology of the USSR.

1963. Bathymetric map of the Atlantic Ocean. 1 :20.000.000
1963. Bathymetric map of the Southern Hemisphere. 1 : 25.000.000
1964. Bathymetric map of the Indian Ocean. 1 : 15.000.000
1965. Bathymetric map of the Pacific Ocean. 1 : 25.000.000
1966. Bathymetric map of the Mediterranean Sea. 1 : 4.000.000

GENERAL DIRECTION OF GEODESY AND CARTOGRAPHY. Ministry of Geology of the USSR jointly with Interagency Geophysical Committee of the Academy of Sciences of the USSR.

1966. Bathymetric map of the Pacific Ocean. 1 : 10.000.000 (6 sheets).

MUSEE OCEANOGRAPHIQUE, Monaco. 1958 onwards. Carte topographique de la Mediterranee. (12 sheets already published), 1 : 750.000.

SHEPARD et al. 1964. Bathymetric chart of canyons outside east central Houshu, Japan. Geol. Soc. Amer. Bull. 75, 1 : 250.000.

SHEPARD et al. 1964. Submarine topography of the Gulf of California. Amer. Ass. Petrol. Geol. 1 : 900.000.

NICHOLS, H. & PERRY, B. 1966. Bathymetry of the Aleutian Arc, Alaska. 1 : 400.000 (6 sheets).

NEW ZEALAND, 1966/67. Island Chart Series and Coastal Chart Series, bathymetry, 1 : 200.000 and 1 : 100.000.

DE LEEUW, M.M. 1967. New Canadian bathymetric chart of the Western Arctic Ocean, north of 72°. Dept. of Energy, Mines and Resources, Ottawa, Canada.

MARITIME SAFETY AGENCY, Japan. 1966-68. Bathymetric chart of the adjacent seas of Nippon (4 sheets), 1 : 3.000.000.

MUSEE OCEANOGRAPHIQUE DE MONACO. (in preparation) - Cartes bathymetriques de la mer Ligure entre Monaco et la Corse. (16 sheets), 1 : 50.000.

CHAPTER II. SOME METHODOLOGICAL PROBLEMS RELATED TO SCIENTIFIC EXPLORATION OF THE OCEAN AND ITS RESOURCES

Introduction

Methodological studies are of particular importance at a stage when scientific research is called to render services to industry and economics. Basic scientific information should be universally applicable. Scientists themselves are permitted doubts in the data they obtain; they are aware of the limitations of their methods and the degrees of variability in the natural phenomena they observe. Engineers and technologists, seafarers and fishermen, if they use scientific information which they do not themselves collect, have no alternative but to trust it completely. Therefore the fundamental data for such a vast environment as the ocean should have a uniform degree of reliability which can be ensured only through a uniform degree of accuracy and comparability.

There are two groups of scientists: one holding the opinion that already far too many measurements have been made in the ocean and that the amount of data being added regularly to those already accumulated is much too great to cope with; and another maintaining that the ocean is still insufficiently covered by measurements and studied only very superficially.

Both groups are right and their views are not in contradiction. The amount of data concerning the ocean available at present is indeed very great. The scientific and practical use of these data is, however, very limited, due to the unsystematic way in which the data have been collected in the past, because of the conflicting methodologies employed and, in some cases, because of an inadequate degree of accuracy given by the primitive instrumentation of the past.

In many fields, more precise, more accurate and more systematic new data are now required. The time has come to pass from the reconnaissance type of data collection to systematic and detailed studies.

II.1 Precision navigation on the high seas

One of the key problems of marine research and of any other human activity on the high seas is that of finding one's exact geographical position. Originally this was the primary task of all navigators as soon as their ships left the area from which the familiar coast was visible. Thus the history of development of navigational means and methods is the history of navigation itself.

The problem acquired even greater importance with the development of naval and research fleets, which required far more accurate position-fixing than merchant ships.

Even within the research community the requirements for accurate position-fixing were not the same throughout. Physical oceanographers and marine biologists have never really been concerned with the problem as the objects of their study are either highly variable in space and in time or mobile. Only recently did studies of microstructure of water stratification and turbulence impress on physical oceanographers the urgent need to make navigation more accurate.

From the beginning, the demands of hydrographers, marine geomorphologists and geophysicists were very high. It may be said that, although well aware of the imperfections of conventional methods of navigation (dead reckoning, astronomical position-fixing) explorers of the ocean floor went ahead with their soundings and with the construction of nautical and bathymetric charts (see Chapter I, pp. 16-17), impelled both by scientific curiosity and practical needs. The result is that it is still impossible for a ship in the open ocean to return to exactly the same position it occupied previously. Once discovered, many prominent features of the ocean's bottom relief could not be confirmed by other ships for that very reason. This may explain in part the frequent disagreements between scientists concerning the exact depth of a seamount or a deep-sea trench.

When the exploitation of the ocean's mineral resources is started on the high seas, the problem of accurate position-fixing will become still more important. Precision and accuracy of detailed exploratory surveys will depend totally on the precision and accuracy of navigation. Finding a marker buoy in the open ocean could become a formidable problem in the absence of accurate navigation means. This is the reason for the prominence given to the particular methodological problem of ships' position-fixing in the open ocean.

It is perhaps useful to give at the beginning some basic information concerning routine methods of navigation currently employed by the vast majority of merchant, naval and research vessels.*

On the high seas, two methods are available to the navigator for position-fixing purposes; these are:

1) Astronomical observations whereby the navigator observes a celestial body or bodies among those whose data are included in Nautical Almanacs and other related rables. Each observation provides a position line. Two or more observations, taken simultaneously or within a time interval, provide a corresponding number of position lines which, transferred for the intermediate distance run, if this is the case, determine at the intersection the ship's position.

2) Radio position-fixing systems which, making use of electromagnetic waves, provide position lines used in the same way as the astronomical position lines. As this text refers to navigation on the high seas, radar is not included in the radio position-fixing systems, although it may often be used for such purposes by providing range and bearing of terrestrial marks or features.

Astronomical Observations

The methods available are numerous and have a varying degree of accuracy. Their common limitation is favourable weather conditions, i.e., mainly good visibility, clear sky at least partly, to allow for the observation, clear horizon and normal refraction. All methods under such conditions provide the degree of accuracy which is required for safety in the open sea, i.e.,

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* The following information was kindly prepared and supplied for this document by the Intergovernmental Maritime Consultative Organization.

about one nautical mile. The accuracy of the observation depends on a number of factors such as the quality of the instruments, the weather conditions, and the skill of the observer. A good observation and detailed calculation and interpolation can give a very accurate (below the one mile limit) result at the expense of time. Simplified methods and tables exist for the purpose of decreasing the time required for the calculation, at the expense of accuracy.

The errors which may be introduced into astronomical position lines, thus resulting in inaccurate fix, could be summarized as follows:

(a) Error of observation in the altitude. This could be a combination of errors due to the individual observer, to the instrument, to incorrect values of dip, refraction and other data concerning the observed celestial body. The cumulative error would result in the position line being plotted incorrectly. The most important contributing error in this group depends on the choice of incorrect values for dip and refraction. For this reason, position lines obtained when abnormal refraction is suspected are not reliable.

(b) Error due to inaccurate or incorrect deck watch readings. Such an error will result in incorrect hour angle which, in turn, will introduce an error in the calculated altitude; the position line will subsequently be displaced.

(c) Error inherent in the method used for the calculations. This is the cumulative result of errors in the formation of data taken from the Nautical Almanac and in the method by which the astronomical triangle is solved. Methods aiming mainly at simple and quick calculations by working only to a few figures, as well as the simplification of interpolations, are understandably less accurate.

(d) Error in dead reckoning between observations. This is introduced when a position line is transferred, and it is due to the fact that the course and distance made good between observations may differ from the course laid on the chart and the estimated distance. The effects of wind and waves, the existence of unsuspected current and compass faults are contributing factors. The final error in the plotting of the position lines and the resultant fix could be considerable. Individual contributing factors could either combine and increase the final error, or cancel each other partially or totally.

Radio Aids to Navigation

Radio aids to navigation are, in principle, considered free from human error of observation. However, they are liable to an error in transmitting or receiving, due to conditions which may be unfavourable to the propagation of electromagnetic waves. Such error is inherent to almost all methods at varying degrees. Accurate calibration is generally required to minimize the adverse effects of extraneous sources of interference. As an example, the following methods in common use are mentioned:

(a) MF direction-finding. This could be either a shipborne or a shore-based DF. The latter has a much greater range, although errors of up to 4° have been experienced at the greater ranges by night. Aerials in ships are not immune from sky wave effects; for this reason bearings could be inaccurate if both ground and sky waves are present. Ground waves from a distant transmitter could be deflected as they pass from land to sea or vice-versa; this refraction varies with the angle of incidence to the coast line. The resulting errors are difficult to assess and compensate. A first-class bearing is usually considered accurate within 2°. For more accurate position, with normal methods the range should not exceed approximately 100 miles.

(b) Consol. The system provides long-range facilities for position lines and required automatic transmitting ground beacons. In order to determine a position, it is necessary to obtain position lines from two independently operated stations; the lines obtained are shallow hyperbolae. Special charts or special tables are required, and the corrected mercatorial bearing may have an accuracy of ±0.2°. The useful coverage is limited to about 140° on either side of the base line, although this could be extended by use of sky waves at night. The system should not be used within 25 miles of the beacon. Errors are larger and variable by night, and at great ranges.

(c) Loran. It provides facilities for position-fixing at long distances, requires at least three transmitting stations, special shipborne receiver and special charts or tables. The position lines are hyperbolae. The system can handle an infinite number of observers at the same time, and the accuracy, which could be within 0.5% of the range from the mid-point of the base line, decreases as the observer moves away from the base line which joins a pair of stations.

(d) Decca. The system involves a number of fixed transmitting stations whose transmissions are received by special shipborne receiver. The position lines are also hyperbolae. In addition to certain fixed errors, variable error at the receiver could be caused by the presence of a sky wave component. The normally reliable limit of coverage is considered to be approximately 250 miles from the centre of a chain of stations. However, this safe maximum could be considerably increased in day-time. The use of continuous wave transmissions could theoretically provide an accuracy of ±10 yards near the base line between a pair of stations, although this is not always practicable due to constant and variable errors.

Other Systems

It is known that at present certain other systems have been developed or are under development (satellite navigation, inertial navigation, Omega system); these are expected to provide world-wide, all weather, highly automated and very accurate position-fixing. These systems, however, have not yet been in common use for civilian purposes.*

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* End of IMCO's contribution.

The most promising system for the future is satellite navigation. It was tried with success on the r/v "Chain" of Woods Hole Oceanographic Institution. Using one satellite, the ship's track was continuously recorded with slightly more accuracy than was attained with the astronomical method (±1 nautical mile). More recent tests with three satellites ensured an accuracy of ±0.1 nautical mile, which is very satisfactory.

Another substantial aid to future accurate position-fixing would be the installation of an ocean-wide network of manned or unmanned anchored buoys with well-determined coordinates. Buoys equipped with radar are already used for relative position-fixing in a number of small-scale open ocean studies. By this method the relative precision can be high enough (±1% of the distance between the ship and the buoy), but the general accuracy remains the same, i.e., the accuracy of the astronomically-determined position of the buoy (±1 nautical mile at best).

It is worth mentioning here some advantages offered by the very low frequency (VLF) navigation system developed recently specifically for oceanographic purposes. It was used aboard the US r/v "Atlantic II" in the Atlantic in 1963 and aboard the US r/v "Argo" in the Indian Ocean in 1964 during the International Indian Ocean Expedition. The advantage of this system is that it has a very long range of coverage. During the operations of r/v "Argo" in the central Indian Ocean distances from the shore stations involved varied from 6,000 to 10,000 nautical miles. The deviations of the VLF positions so obtained from the visual, radar or celestial fixes were of the order of several nautical miles. The system may be computer-operated. While not sufficiently accurate, it may provide an independent control of the dead reckoning in the areas where celestial fixes are impossible because of constant cloudiness.

It is evident that the eventual establishment of a world-wide navigation system for all-weather and all-purpose accurate position-fixing in the open ocean should be a matter for international cooperation and international agreement. The Intergovernmental Oceanographic Commission has already undertaken steps in this direction by adopting in 1961 Resolution I-5 "Aids to Navigation" (see Annex I to this document).

II.2 Precision echo-sounding and sound velocity

Echo-sounding is the only way to measure the depth of the sea bottom continuously. On the accuracy of echo-sounding depends the precision of our maps. Knowledge of the details of the bottom relief is important, not only for geological studies, but also for present and future technical installations on the sea floor, e.g., pipelines, cables, stations, etc..

Modern depth recorders determine the distance between sea surface and bottom by measuring the time taken by a sound impulse to reach the bottom and to be reflected back. Thus the correct depth is a function of reflection time and sound velocity in sea water. Recordings are made in the form of echograms from which readings of reflection times or corresponding depths are made for further correction, taking into account local sound velocity. The sound beam in the water spreads conically, with a beam width varying from 20° to 60° and an average velocity of 1,500 m/sec. The wide angle of the sound beam produces an undesirable effect, i.e., on the slopes it is not the actual depth under the ship which is recorded but the depth of the point on the bottom closest to the sound emitter. It often happens that several side-echos are recorded at once on the same echogram, making a correct reading impossible. To avoid such inconveniences, i.e., to suppress the side-echos, narrow beam echo-sounders are now being constructed. One of these has just been used on the German research vessel "Meteor". Its beam, no more than

5^{o} wide, is emitted from a stabilized underwater platform beneath the ship's hull. Thus the beam axis remains vertical even when the ship rolls and pitches heavily. Another problem is that sound velocity changes with water density which, in turn, depends upon temperature and salinity. Their values therefore have to be known all along the vertical water column and introduced in the formula for calculating the correct depth. Salinity and temperature measurements being very time-consuming, most echo-soundings are normally corrected through the use of tables giving average sound velocity values for certain geographical areas. There is no doubt that a certain percentage of error is involved in this operation since local variations of temperature and salinity may be considerable. It is also absolutely necessary for precision echo-sounding to have a power source with a strict frequency control. Slight variations in power frequency cause drops and rises on the echogram. It is important to be aware of the fact that most of the soundings done before 1950 were obtained without frequency control.

Maps with uncorrected soundings can be of some use to navigation. A ship's navigator can try to locate the position by comparing his own uncorrected echo-soundings with those on the map. If the published depths had been corrected the navigator would be in difficulty to find the position. Shepard (1963) gives an example showing that the corrected depths across the San Diego Trough are almost a mile off the uncorrected ones.

II.3 Calibration, intercalibration, intercomparison and standardization of instruments and methods.

To describe the ocean properly all measurements taken in it should be accurate and comparable. Two accurate measurements of the same element are not necessarily comparable. One instrument may measure accurately instant characteristics of a current, such as speed and direction, and another measure equally accurately integrated speeds and average direction over a certain period of time. These measurements are both accurate but not comparable. In such cases intercomparison tests may provide scientists with some conclusions as to the real correlation between the data measured.

Many instruments do not measure directly the elements of interest. Most currentmeters, for example, measure the number of revolutions of their rotor per time unit, instead of measuring the real current velocity. Electric salinometers measure conductivity or relative conductivity instead of salinity. Such instruments need to be calibrated against certain standards. For calibration, currentmeters are towed at a fixed speed in special tanks. Standard sea water with known salinity and conductivity is used as a reference point for salinometers.

It may happen sometimes that different systems of calibration have been used for instruments of the same type. Also, some instruments may have had more recent calibration certificates than others of the same kind. In order to check on old or doubtful calibration values, intercalibration tests may be conducted by carrying out measurements of the same elements, either simultaneously (when needed) or in other equal conditions by both reliable and "unreliable" instruments.

Finally, for all kinds of routine service or survey-type operations (as, for example, IGOSS or WWW - see following Chapter) where regular and numerous measurements of the same elements are involved, the instruments to be employed and the methods to be followed must be standardized. This means that the instruments should be of the same design, have the same sensitivity, and ensure the same degree of precision and accuracy. The methods of measurements and data reporting should be prescribed in advance and strictly followed by all concerned. The standardization thus achieved would ensure automatically a uniform degree of accuracy and full comparability of measurements.

As early as 1961, the Intergovernmental Oceanographic Commission called the attention of the world oceanographic community to the necessity for coordinated international efforts in making measurements in the ocean accurate and comparable (see IOC Resolution I-11 "Standardization and intercalibration of oceanographic methods and equipment" - Annex I to this document). UNESCO, SCOR, IAPSO and ICES responded favourably to this appeal and since 1961 a great number of international intercomparison and intercalibration tests have been conducted. They covered such areas as chemical analyses, plankton sampling, current measurements, optical measurements, etc. A standard plankton net was designed for the International Indian Ocean Expedition and the use of this net made possible the establishment of the International Plankton Collection of the Indian Ocean. The work undertaken by the organizations mentioned above is just starting. It is extremely important and very promising. There can be no doubt that, for the benefit of future detailed bathymetric and geophysical surveys, intercomparison tests will have to be conducted internationally for a number of relevant kinds of measurements including, for example, tests with different types of echo-sounders and different correction techniques.

It is equally important for any large-scale international exploratory activities to standardize procedures involved in data reporting. The amount of scientific and other relevant data which will be exchanged internationally in connection with various peaceful uses of the ocean floor promises to be extremely great. In order to permit efficient handling of these data through computerized systems, it is absolutely necessary first of all to standardize internationally the form of presentation of all the original data for computer input. With the very rapid development of automatic data processing systems on the national level, the importance and urgency of the international aspect of this work becomes fully evident. (See also Chapter IV.)

Selected Bibliography to Chapter II

Aids to Navigation, IOC Resolution I-5, 1962. Doc. NS/176 - Summary Report of the First Session of the Intergovernmental Oceanographic Commission, UNESCO.

Anonim. Offshore operations: positioning systems. 1967, Staff report, Undersea Technology, 8, No.2.

JANSKY & BAILEY, 1962. The Loran-C system of navigation. Washington, D.C.

KRAUSE, D.C., 1967. Sea Floor Relief. US National Report, 1963-1967, to the Fourteenth General Assembly of the IUGG, American Geophysical Union, Nat. Acad. Sci. NRC, Trans.Amer.Geophys. Union 48, No.2, pp. 631-638 (with abundant bibliography).

LUSKIN, B., HEEZEN, B., EWING, M., LANDISMAN, M. 1954. Precision measurement of ocean depth, Deep-Sea Res. 1, pp. 131-140.

SHEPARD, F.P. 1967. Submarine geology. Second Edition, Harper & Row, New York, Evanston and London, John Weatherhill, Inc., Tokyo, pp.13-17.

SILVERMAN, M. 1965. Oceanographic application of very low frequency radio navigation in the Indian Ocean. Ocean Science and Ocean Engineering, 1, Washington D.C.

STANBROUGH, J. & KEILY, D.P. 1964. Long Range Relative Navigation by means of VLF Transmissions. Deep-Sea Res. 11.

SCOR 1968 Proceedings, Vol.3, No.2. Report of SCOR Working Group 21 on Continuous velocity measurements sponsored jointly by SCOR, UNESCO and IAPSO.

UNESCO Technical Papers in Marine Science.

No.1, 1965. First report of the joint panel on oceanographic tables and standards, 5-6 October, 1964, UNESCO/ICES/SCOR/IAPO.

No.2, 1965. Report of the first meeting of the joint group of experts on photosynthetic radiant energy, Moscow, 5-9 October 1964, UNESCO/SCOR/IAPO.

No.3, 1965. Report on the intercalibration measurements in Copenhagen, 9-13 June 1965, ICES.

No.4, 1966. Second report of the joint panel on oceanographic tables and standards, Rome, 8-9 October, 1965, UNESCO/ICES/SCOR/IAPO.

No.5, 1966. Report of the second meeting of the joint group of experts on photosynthetic radiant energy, Karuizawa, 15-19 August 1966, UNESCO/SCOR/IAPO.

No.6, 1967. Report of a meeting of the joint group of experts on radio-carbon estimation of primary production, Copenhagen, 24-26 October 1966, UNESCO/SCOR/ICES.

No.8, 1968. Third report of the joint panel on oceanographic tables and standards, Berne, 4-5 October 1967, UNESCO/ICES/SCOR/IAPSO.

Standardization and intercalibration of oceanographic techniques and methods, IOC Resolution II-19, December 1962. Doc. NS/180 - Summary Report of the Second Session of the Intergovernmental Oceanographic Commission, UNESCO.

CHAPTER III. PROBLEMS RELATED TO HUMAN ACTIVITIES AT SEA AND, IN PARTICULAR, TO THE FEASIBILITY AND SAFETY OF EXPLOITATION ACTIVITIES AT SEA

Introduction

Scientists, particularly those concerned with the conservation of nature, keep reminding contemporary society that large-scale intrusion of Man into Nature, particularly for purposes of exploiting its numerous resources, may have far-reaching consequences both for Man and his natural environment. Through a complicated chain of interactions these consequences may appear in a completely different sphere than that of the original intervention. Sometimes mankind itself may become the victim and may pay dearly in human lives for precipitate and careless interference.

These general remarks are fully applicable to the ocean and human activities there. We know already numerous examples when deliberate or accidental transplantations of living species from one sea to another upset profoundly the precarious ecological balance there causing, *inter alia*, drastic changes in local fisheries. Local overfishing may sometimes bring about the same effect. Use of explosives for seismic work, besides killing directly a part of the animal population, raises mud from the bottom in some areas and increases turbidity to such an extent that it may cause mass mortality of commercial fish species and other marine animals. What is generally called "marine pollution" is a complicated phenomenon with such numerous repercussions that it now calls for special research into its effects. This research is essential if marine pollution, with all its effects, were to be stopped and prevented for all future time. The recent tragedy of the "Torrey Canyon" demonstrated clearly this point of view.

It is well-known that there are various dangers which the ocean reserves for seafarers, fishermen and explorers and which will be equally dangerous to those who will venture to exploit its floor. To mention only a few, tropical cyclones, storms and gales, storm surges, icebergs, tsunamis, may threaten activities conducted from the surface of the ocean and from the shores. Turbidity currents and sand movements produced on the sea-bed by tidal and other currents may constitute a real danger for drilling rigs and other underwater installations as well as for submersibles.

The aim of this chapter is to demonstrate what ways and means exist to ensure the safest and wisest course of peaceful human activities at sea. The authors have selected only the most important aspects of the problem and, wherever possible, requested competent international bodies to supply the necessary information.

III.1 Forecasting of sea-surface conditions (wind, waves, currents, temperature, salinity) and associated problems of organizing synoptic observations on the high seas.

The provision of meteorological services*

Meteorology and hence WMO is involved in the provision of services in support of the safety and efficiency of a variety of types of operations at sea. In particular such services are being given in support of present-day exploitation of mineral resources at sea, with respect to activities which are carried out at

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* This section was kindly contributed by WMO.

or near the sea surface. It is assumed that development of the exploration and exploitation of the ocean floor and subsoil will require similar service to an increasing extent. The nature of these services is explained in the following paragraphs.

As in the case of other operations at sea it is likely that meteorological information will be required with regard to the design and construction of technical equipment which is exposed to surface conditions (ships or special marine structures). Factors involved include forces exerted by prevailing winds and by extreme gusts, shearing forces due to strong vertical wind shear, ice accretion, wave action and temperature variations. This information serves mainly in support of the safety of operations.

The safety and efficiency of the operations depend to a varying degree on atmospheric conditions and their effects on the conditions of the sea surface. Three different types of meteorological information are relevant in this respect.

(a) Accurate and detailed short-term forecasts of weather and wave conditions in support of the safe and efficient conduct of daily operations;

(b) Medium and long-range forecasts of the trend of weather and sea conditions and the probability of the occurrence of extreme conditions in support of logistic planning of operations, such as the provision of a regular supply of material and personnel to ocean stations;

(c) Climatological data in support of long-range planning of exploration and exploitation activities.

The services rendered by National Meteorological Centres in this respect, the scientific research involved, the rôle of WMO and of the World Weather Watch in its operations and scientific aspects have been surveyed in the report prepared under General Assembly Resolution 2172 (XXI) (Part I, Chapter IV, appendices).

The provision of oceanographic services

While national meteorological services have existed for a long time already and are well organized internationally through WMO, national oceanographic services, as distinct from research establishments, represent a considerably more recent development. They exist so far in the most advanced countries only, and their origin is closely related to the real practical needs to have reliable forecasts of oceanographic conditions.

A forecast of ice conditions in the Arctic seas for the purposes of navigation cannot be based solely on meteorological information. A thorough knowledge of currents is needed. This implies studies of water balance of the whole Arctic basin and its marginal seas and requires an appropriate observational network.

A forecast of the thermal structure of the main thermocline may be of interest and importance for both fishermen and those who operate submersibles. The technique of such a forecast is now being developed and its application will certainly require the cooperation of meteorological and oceanographic networks and services.

Timely tsunami warnings are very important in the areas where this disastrous geophysical phenomenon occurs frequently. The provision of these warnings requires appropriate observational and communication networks.

These few examples simply demonstrate the need for service-type oceanographic activities. The Intergovernmental Oceanographic Commission, being cognizant of this need, inaugurated in 1965 the International Tsunami Warning System in the Pacific (IOC Resolution IV-6, see Annex I), and adopted in 1967 the decision to establish an Integrated Global Ocean Station System (IGOSS) which should be the oceanographic counterpart of the World Weather Watch. (IOC Resolution V-20, see Annex I.)

The purpose of IGOSS is to provide more extensive and timely information on, and prediction of, the state of the oceans, and to support research on the processes of the ocean, so that nations can provide improved oceanographic services to increase the safety and efficiency of their marine activities. IGOSS should be a global oceanic system and should consist of national facilities and services provided largely by the participating countries themselves with coordination and support from Unesco, WMO, and other international organizations.

IGOSS is contemplated as a coordinated system responsive to the operational and research requirements agreed upon among the participating nations and utilizing the most modern observing, communication, and processing technology available. IGOSS should be a dynamic system, flexible enough to be adapted to scientific and technical advances.

IGOSS will be planned and operated closely with the WWW, including GARP. Information collected by IGOSS should be available to all countries and be presented in a form convenient for use.

IGOSS will be used only for peaceful purposes, due account being taken of the national sovereignty and security of States, in accordance with the provisions of the Charter of the United Nations.

IGOSS, which will be planned and coordinated by the IGOSS Working Committee of the IOC, should include the following components:

(a) The observational network comprising all types of ocean data stations and observational means, inter alia

- automatic autonomous telemetering buoy stations
- coastal stations and research vessels
- fixed ocean stations and mobile ships
- fixed off-shore platforms
- observational satellites
- other new means of observations which may be developed eventually.

(b) A communication service for timely transmission of data from the observational network to ships, land-based stations, or through communication satellites, and for further dissemination of these data and products among user nations.

(c) Designated centres for collection, processing, retrieval and dissemination of data.

III.2 Deterioration of materials in the marine environment and their protection against corrosion, fouling and boring.

Marine Corrosion

Marine corrosion is the destruction of a metal or alloy by chemical or electrochemical reaction with its environment.*

In the normal marine environment, this reaction is electrochemical. The corroding metal forms a product which, in the marine environment, is more stable than the metal itself. Sea water contains ions, particularly CL^-, which are inimical to the formation of protective oxide film. Sea water is also a good electrical conductor, allowing substantial corrosive electrical currents to flow from one place to another as a result of electrochemical reactions. Water temperature, salinity and the dissolved oxygen content affect the course of these reactions, but since in the natural environment the correlation between these three characteristics is complicated by a number of other natural processes (circulation, biological oxygen consumption, etc..), there seems to be no consistency between the different types of water masses in the ocean and the corrosion rates. It is known, however, that in oxygen-free water corrosion is greatly reduced.

Every engineer knows the dangers to various underwater metallic constructions and structures occurring from corrosion and corrosion-fatigue. Research into corrosion processes and protective measures against corrosion are undertaken widely on the national level by industrial enterprises, shipbuilding companies, etc.

Essentially, there are three methods of protection against corrosion :

(i) Coating by anti-corrosive paints, epoxy resins and plastics;

(ii) Cathodic protection;

(iii) Use of corrosion-resisting metals and alloys.

There exist extensive technical literature and bibliographic sources concerning marine corrosion and protective measures against it (see Selected Bibliography to Chapter III).

There is no doubt that further useful experience in this field will be accumulated through the expansion of engineering activities in the ocean. One particular aspect of corrosion protection regarding the design and use of in-situ type and laboratory instruments for marine research is, however, often overlooked in a number of countries. With Nansen bottles which are not coated reliable values of the oxygen content in the sea water they collect can never be obtained. Nevertheless the use of non-coated bottles still continues on a large scale. Hydro-optical equipment for both in-situ and laboratory use should be so designed as to prevent chemical reactions within the volume of water with which the measurements are carried out. Designs of electrical contacts, and even of single screws attaching different metallic parts of marine research instruments, should always be made, taking precautions

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* Definition from "A Glossary of Ocean Science and Undersea Technology Terms". Compass Publications Inc., Virginia, USA, 1965.

against all possibilities of corrosion. Many precious marine instruments have been rendered unusable by quick corrosion in the sea water or in the humid atmosphere of a ship where salt water droplets are an everyday feature.

International cooperation in marine corrosion studies and protection was till recently promoted by the OECD which, approximately one year ago, decided to establish an independent Permanent International Committee for Research on the Preservation of Materials in the Marine Environment. This Committee is now functioning and is open for membership to research institutions throughout the world. It also covers research activities in the field of marine fouling and boring.

Marine Fouling and Boring

The growth of marine organisms on pilings, ships' hulls and similar surfaces introduced by Man into the marine or estuarine environment and the damage caused by this growth to underwater structures have always caught the attention of marine scientists and engineers. Most research work is oriented towards preventing attacks by these organisms, largely because of the serious economic consequences.

Fouling is usually defined as an assemblage of living organisms on submerged or semi-submerged surfaces. In 1952 a monograph on marine foulers was published for the Bureau of Ships by Woods Hole Oceanographic Institution. This handbook, entitled "Marine Fouling and its Prevention", gives several important facts:

(1) Fouling is the result of the attachment of living organisms which reproduce by producing free-swimming larvae which become widely dispersed in the marine and estuarine environment and attach to, and grow on surfaces.

(2) The season of attachment is longest and the rate of growth of these organisms most rapid in the tropics.

(3) There appears to be no place in the oceans or estuaries where fouling will not occur at some time or other except for places in estuaries where the sea water becomes too diluted or where abiotic (toxic) conditions occur.

(4) The kinds of organisms that attach and the sequence of attachment varies from place to place and time to time, and thus has no practical bearing on the fouling problem.

(5) Surface texture, colour, inclination and degree of illumination may favour or retard the development of the fouling community but none of these factors can be modified so as to be a practical, effective fouling preventative.

These facts lead to the conclusion that the only satisfactory system for the prevention of fouling is one which would work for all organisms anywhere and at all times of the year. The basic aim is to prevent the attachment of larvae. Extensive research has shown that the most practical methods are either to make the surface toxic with anti-fouling paints or to introduce toxic substances into the immediate environment. The latter method may be applied to tubes or tanks conducting or containing salt water.

Literature on fouling also gives valuable information on environmental factors which may influence control measures on fouling organisms. The life history of and information on ecological factors of fouling organisms are available through the extensive literature on sedentary groups such as barnacles, ascidians and by bryozoa.

A considerable amount of work has also been devoted to the study of marine boring animals. Comprehensive literature on their taxonomy, distribution and ecology, as well as on economic aspects of their activity, is available. Important marine borers are known from eight different phyla of the animal kingdom: Porifera, Bryozoa, Phoronida, Mollusca, Sipunculoidea, Annelida, Arthropoda, Echinodermata; as well as from algae and fungi.

The damage caused by marine borers in a given locality has definite relation to the general oceanographic conditions. The limiting effects of temperature and salinity on the attach of several species of marine borers have been shown in several localities. The same applies to the fouling organisms transported with ships and their subsequent introduction into the ecosystem of their new habitat.

In spite of all the work on marine foulers and borers, many questions still remain to be solved. There have been few attempts to study the biology and interrelations of all the important species of marine borers and marine foulers sharing the same habitat and acting as mutually restricting or reducing agents. Steadily increasing shipping and changing environmental conditions in coastal areas caused by marine pollution, construction of canals, dams, etc., may change considerably the distribution of marine foulers and borers.

Study of these organisms, therefore, is not only of great economic importance for all activities relating to the sea, but also concerns the study of marine fauna and flora as a whole. Also important is the examination and possible control of the side-effects from anti-fouling systems which involve the direct release of toxic substances into bays and harbours.

III.3 Some aspects pertaining to the possibility of Man's life and work underwater.

Till very recently the history of oceanography has been the history of observing and measuring the ocean's phenomena and properties exclusively from the surface. The modern concept of a surface research vessel is a true reflection of this century-long history. It has, however, always been in man's nature to wish to penetrate below the ocean surface and to observe the underwater world as directly as he observes his familiar terrestrial environment. The realization of this wish began with the construction of bathyspheres and continued with adaptation of military submarines to research purposes. At the same time the development of free-diving techniques began, thus liberating man from the cumbersome diving suit with air tubes which linked him to the surface vessel.

A formidable fleet of deep-sea submersibles has emerged recently from the first line of technical development: Bathyscaphes for attaining the deepest parts of the ocean, diving saucers of very high manoeuvrability for the depth limits of the continental shelf and the slope, research submarines for medium depth ranges (to 4,000 - 5,000 m.) - about 30 different types constructed to date. It is not the purpose of this paper to give technical details of deep-sea submersibles. Readers are therefore referred to existing technical literature (see Selected Bibliography to Chapter III).

Free-diving with an aqualung progressed very rapidly after the Second World War. It was accompanied by extensive physiological studies and brought man to the possibility of diving to considerable depths under saturation conditions. During the past two years it has been proved that man can stay and work underwater at depths of 100 - 150 m. for several weeks. At the moment we may say that it is possible for a man to reach and stay at depths as great as 300 m., with attempts envisaged down to 600 m. It would not be fantastic to predict man's penetration as deep as 1,000 m. and perhaps more.

While, according to published information, studies and experiments in the field of deep-diving and diving under saturation conditions were proceeding in a number of countries (France, Monaco, USA, USSR, UK) some international efforts were made to define the advantages which these new techniques offer to marine research. A panel on the prolonged stay of man underwater was created by the International Commission for the Scientific Exploration of the Mediterranean under the chairmanship of Commandant Cousteau. In 1965 this panel advanced the idea of establishing an international underwater research laboratory, which idea was further promulgated by the Intergovernmental Oceanographic Commission through its Resolution IV-16 (see Annex I). The panel was of the opinion that certain kinds of research in marine geology and also in experimenting with fine-scale turbulence, as well as some biological observations, may only be performed from an underwater laboratory. An opinion was expressed that in order to be effective such a laboratory should necessarily be mobile.

It is of interest to note that a large proportion of oceanographers holds very conservative attitude towards the idea of an underwater research laboratory. They still maintain that practically everything in terms of observations and measurements can be done from surface research ships or, if needed, with the aid of deep submersibles. It is also significant that, although many countries responded to IOC Resolution IV-16 by expressing their interest, no country has yet offered its support to the enterprise. All this stresses the only absolutely certain fact, viz., that much more research should be done on vital aspects of man's penetration underwater before public opinion is convinced in both the scientific utility and safety of such an enterprise.

The most important problems to be resolved are:

- Man's prolonged survival at great ocean depths, notably through his physiological adaptation by using adequate breathing mixtures.

- Provision of logistic support to permit sufficient independence of action, mobility and maximum security. This logistic support, apart from the necessary arrangements for safety, rest and supplies, includes underwater laboratory facilities for on-the-spot analyses and experiments.

One difficulty is to find suitable gas mixtures to breathe under various pressures, according to the duration and depth of diving. The effects of pressure are of two general types:

- Those for the most part mechanical, and associated with spaces inside the body that are normally filled with gas (middle ear, sinus, lungs). These effects can be controlled by appropriate training.

- Those which affect the physiology of breathing and require the application of a decompression process. These effects vary according to the breathing gas or mixture of gases used. Normal air may be used safely down to 45 or 50 m.; below this limit the nitrogen of normal air begins to exert a significant narcotic effect. So, for deeper diving, the oxygen must be supplied in a different mixture. Since an exposure over long periods to partial pressures of oxygen higher than 0.2 atmosphere is toxic for the human body, it is essential to dilute the oxygen with other gases to keep its partial pressure within this limit in function of the total pressure, that is to say, in function of the depth. Experiments have been carried out using breathing mixtures with hydrogen, helium, neon, etc. Of these, helium is the most commonly used. It has, however, certain disadvantages:

  - It is expensive.

  - Human speech becomes unintelligible. Special electronic devices have been developed to solve this problem and are now being experimented with.

  - The high thermal conductivity and specific heat of helium is such that divers lose far more calories through their lungs than they would by breathing normal air. This effect, added to the loss of calories through direct contact of the human body with the underwater environment, is probably the most notable limitation to the effectiveness of underwater workers. Experiments to overcome this difficulty are being conducted on the development of electrically and water-heated insulated suits.

Another major problem of deep diving is the compulsory release of accumulated gas from solution in the blood and other body fluids which must be achieved through decompression. This procedure usually requires a series of stops on ascent, to allow gases to escape from the body slowly enough to prevent the formation of bubbles in the blood. Standard decompression tables can be used for short periods and at depths not greater than 120 m. When the required operating depth is in excess of 120 m. the decompression time is so great that diving cannot be carried out safely without special decompression equipment. For example, a dive to 200 m. for one hour of work will require about 24 hours of decompression. A submersible decompression chamber is one step towards the solution to this problem. It would help divers to regain the surface in the best possible decompression conditions. But the final solution will probably be associated with saturation diving, which may be the key to extensive human exploration and exploitation of the sea-bed. In the latter case, once the diver's body is saturated with gas, the decompression time is fixed and does not increase with a longer stay under high pressure. Saturation diving has already enabled man to make successful experiments with underwater houses and laboratories.

It is certain that very deep diving will raise additional problems. Experiments have shown, for example, that the greater the pressure, the more difficult is the mechanical action of breathing, with the complication that the release of CO_2 from the lungs is less complete. Special devices will have to be designed to overcome this problem. There may also be a need for technology adapted to the underwater environment, especially concerning corrosion. Special tools will have to be developed to perform work in conditions close to non-gravity. Appropriate sources of energy must be chosen, according to power demands and duration of the underwater activities. These sources may range from batteries to nuclear power.

In conclusion, we may say that, once started, the penetration of man into the ocean depths will continue. There is no doubt that its progress will be closely related to the progress of peaceful uses of the sea-bed and ocean floor. There is therefore every reason to attach great importance to this particular field of human activity and to accord to it all necessary help available through international cooperation.

III.4 Marine Pollution as a result of human activities*

Industrialization, development of transport and in general an expanding technology are the cause of increasing marine pollution. The important forms of marine pollution in relation to their dimensions and international implications are pollution by oil, radioactive substances, chemicals.**

Oil Pollution

By far the most important type of marine pollution is that caused by oil and in particular by persistent oils, i.e., crude oil, fuel oil, heavy diesel oil and lubricating oil. These oils remain on the surface of the sea for long periods and are capable of being carried to considerable distances by winds and currents.

Oil pollution originates from various sources:

- Ships, including wrecks;
- Coastal industrial establishments;
- Underwater oil drilling and pipelines.

It is generally believed that most of the oil pollution comes from ships. The marked increase in pollution in the years following the last world war was undoubtedly connected with the increased movement of oil, specially crude oil from the oil fields to the refineries.

Large quantities of persistent oils are regularly discharged into the sea by tankers as a result of washing of their tanks and the disposal of their oily ballast waters. Dry cargo ships which habitually use their fuel tanks for ballast water also discharge oily ballast into the sea.

Recently, tanker accidents have proved dramatically the amount of pollution which can occur in connection with such accidents.

The amount of pollution originating from wrecks, sources on land and spillages from pipelines and during drilling operations has not yet been clearly assessed; it is, however, believed not to be of great significance at present.

Radioactive Pollution

Radioactive marine pollution is due to the release of waste products from nuclear establishments, nuclear ships, weapons testing and accidents during

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* This section was kindly contributed by IMCO.

** More detailed information on various categories of marine pollutants, compiled by the IOC Working Group on Marine Pollution, is given in Annex II to this document, together with IOC Resolution V-19 on the subject.

transport. During normal operations, the levels of pollution are not significant; the effects of accumulation through a certain length of time, and possible accidents, could easily bring pollution to critical levels.

Discharge of Chemicals

This form of pollution is largely due to industrial establishments discharging waste products in coastal waters or rivers. Waste chemicals are sometimes loaded on ships to be discharged in the open sea.

Monitoring of Marine Pollution

As far as discharge of oil from ships is concerned, Article IX of the International Convention for the Prevention of Pollution of the Sea by Oil requires that

"(1) Of the ships to which the present Convention applies, every ship which uses oil fuel and every tanker shall be provided with an oil record book, whether as part of the ship's official log book or otherwise, in the form specified in Annex B to the Convention.

(2) The oil record book shall be completed on each occasion, whenever any of the following operations takes place in the ship:

(a) ballasting of and discharge of ballast from cargo tanks of tankers;

(b) cleaning of cargo tanks of tankers;

(c) settling in slop tanks and discharge of water from tankers;

(d) disposal from tankers of oily residues from slop tanks or other sources;

(e) ballasting, or cleaning during voyage, of bunker fuel tanks of ships other than tankers;

(f) disposal from ships other than tankers of oily residues from bunker fuel tanks or other sources;

(g) accidental or other exceptional discharges or escapes of oil from tankers or ships other than tankers.

In the event of such discharge or escape of oil or oily mixture as is referred to in sub-paragraph (c) of Article III or in Article IV, a statement shall be made in the oil record book of the circumstances of, and reason for, the discharge or escape."

This, although limited to oil and not yet suitable for scientific use, seems to be the only case of international monitoring of marine pollution at its source.

Monitoring of radioactive marine pollution is a problem currently under discussion.

Control and Abatement of Marine Pollution

The only set of international rules exclusively directed to the control and abatement of marine pollution is the "International Convention for the Prevention of Pollution of the Sea by Oil, 1954, as amended in 1962.".

In connection with the studies initiated in IMCO following the "Torrey Canyon" accident, other more elaborate patterns for the international control and abatement of both accidental and deliberate pollution, and including pollutants other than oil, are being considered. Information concerning the current efforts in this direction undertaken by various organizations of the UN family and on further prospects of interagency cooperation is given in the Report prepared under General Assembly Resolution 2172 (XXI).

Selected Bibliography to Chapter III

Annotated Bibliography on Tsunami, 1964, in Russian and other languages, (from 1726 to 1962), "Nauka", Moscow.

BAUME, David A. 1967. Man is by far the best underwater working device we have got. Hydrospace, 1, No.1, pp. 62-69. Grampian Press Ltd.

Bibliography on Marine Corrosion, 1967. American Meteorological Society, Meteorological and Geoastrophysical Abstracts, Washington D.C.

BOND, George F. 1967. Man in the Sea. Oceanology International, 2, No.4, June, p. 28. Industrial Research Publications Co.

HAMILTON, R.W. 1967. Keeping men alive under water. Oceanology International, 2, No.1, Jan/Feb, pp. 20-23. Industrial Research Publications Co.

LITTAURER, E.L. 1966. Corrosion Protection. Geo-Marine Technology, 2, No.6.

Marine Science Affairs, 1967. A Year of Transition. The first report of the President to the Congress on Marine Resources and Engineering Development. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Marine Science Affairs, 1968. A Year of Plans and Progress. The second report of the President to the Congress on Marine Resources and Engineering Development. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

MENZIES, R.J. 1957. Marine Borers. Geol. Soc. America, Memoir 67, 1, pp. 1029-1034.

RECHNITZER, A.B. June 1967. Deep Submersibles. Oceanology International, 1968 Yearbook/Directory, pp. 24-25.

REINHART, F.M. 1965. Deep Ocean Corrosion. Geo-Marine Technology, 1, No.9.

TURNER, H.J. Jr. 1967. Marine Fouling. Geo-Marine Technology, 3, No.3.

Undersea Vehicles for Oceanography, 1965. ICO Pamphlet No.18, Interagency Committee on Oceanography of the Federal Council for Science and Technology, Washington D.C.

Woods Hole Oceanographic Institution, 1952. Marine Fouling and its Prevention. United States Naval Institute, Annapolis, Maryland.

Intergovernmental Oceanographic Commission:

1964 Draft of a General Scientific Framework for World Ocean Study, IOC/Unesco, Paris.

1967 Integrated Global Ocean Station System (IGOSS), IOC Resolution V-20, March 1968, Doc. SC/CS/150. Summary Report of the Fifth Session of the Intergovernmental Oceanographic Commission, IOC/Unesco, Paris.

1968 Recommendations of the First Meeting of the IOC Working Committee for an Integrated Global Ocean Station System (IGOSS), Doc. IOC/B-37, April 1968, IOC/Unesco, Paris.

1967 IOC Working Group on Marine Pollution, Annex to Report of Special Session of the ACC Sub-Committee on Marine Science and its Applications (Analysis of Replies to the Questionnaire). Doc. AVS/9/87, August 1967, IOC/Unesco, Paris.

1967 IOC Working Group on Marine Pollution, Recommendations, Doc. SC/CS/150, March 1968. Summary Report of the Fifth Session of the Intergovernmental Oceanographic Commission, Annex X, IOC/Unesco, Paris.

1967 Marine Pollution. IOC Resolution V-19, Doc. SC/CS/150, March 1968. Summary Report of the Fifth Session of the Intergovernmental Oceanographic Commission, IOC/Unesco, Paris.

1967 Radio Communication Requirements for Oceanography. Intergovernmental Oceanographic Commission Technical Series No.3, IOC/Unesco, Paris.

1968 IOC International Co-ordination Group for the Tsunami Warning System in the Pacific, 1968. Summary Report of the First Meeting, Doc. IOC/B-34, IOC/Unesco, Paris.

International Atomic Energy Agency:

1960 Disposal of Radioactive Wastes, 1 and 2. Conference Proceedings, Monaco, 16-21 November 1959. IAEA/UNESCO/FAO, Vienna.

1962 Disposal of Radioactive Wastes into Marine and Fresh Waters. Bibliographic Series, No.5, IAEA, Vienna.

1965 Methods of Surveying and Monitoring Marine Radioactivity. Safety Series No.11, IAEA, Vienna.

1966 Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters. Proceedings of a Symposium 16-20 May 1966, IAEA, Vienna.

Intergovernmental Maritime Consultative Organization:

1964 Pollution of the Sea by Oil. Results of an inquiry made in 1963, IMCO, London.

International Commission for Scientific Exploration of the Mediterranean:

1965 Pollution marine par les microorganismes et les produits petroliers. Symposium de Monaco, avril 1964, Secretariat Général de la Commission, Paris.

World Meteorological Organization:

1966 Meteorological Observations from Mobile and Fixed Ships. World Weather Watch Planning Report No.7, WMO, Geneva.

1966 The Global Data-Processing System and Meteorological Service to Shipping. World Weather Watch Planning Report No.15, WMO, Geneva.

1967 World Weather Watch: The plan and implementation programme. WMO, Geneva.

CHAPTER IV. PROBLEMS RELATED TO THE ACCESSIBILITY OF SCIENTIFIC DATA *

IV.1 Types of environmental information and related data facilities

It is useful to specify from the very beginning certain progressive steps of data processing in their logical order:

1. Primary Recordings:

   The original product (or a copy) directly resulting from a recording instrument (graph, paper tape, magnetic tape, film, etc.)

2. Primary data:

   Discrete (numeric) values of various oceanographic characteristics (on paper, paper-tape, film, punched cards, magnetic tape, etc.)

3. Reduced data:

   Any presentation, which reduces the amount of information contained in the primary recordings or data.

4. Documentation:

   Any verbal (printed) presentation of scientific results, or description of data; of methods or of circumstances of observations as well as bibliographic or source references to primary recordings or data.

Corresponding to these types of information there exist different types of data facilities.

Firstly, there are the true "data centres" which are primarily concerned with the machine manipulation of digital information as well as the conversion of analog records to their digital equivalent.

Secondly, there are the "documentation centres" (information service centres) that feature computerized selective dissemination of information complemented by modern micro-imaging techniques that yield rapid access with deeper and more specific retrieval. This type of centre uses an on-line, random-access computer and specializes primarily in information selection and acquisition, information dissemination through abstracting or the use of indexing techniques, information storage and retrieval, and information generation.

This sort of function, on a much more modest scale, was advocated at a meeting of the CSAGI in Moscow in 1958, where it was resolved that World Data Centres should provide a "limited information service", specifically

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* This chapter is based principally on material prepared by the IOC Working Group on Oceanographic Data Exchange and by its former Chairman Mr. C.D. Sauer (Canada).

with respect to reprints of publications concerning IGY subjects, and that the WDCs were to act as information centres in their respective disciplines. Some time ago SCOR created its Working Group No.12 on Marine Science Abstracts and Bibliographies, and recently the IOC adopted a resolution concerning Storage and Retrieval of Scientific Information (IOC Res. IV-12 - see Annex I), both of which point to the urgent need for establishing international mechanisms to provide selective marine information services.

Finally, there exist "data repositories" which fulfil routine library tasks such as assembling information, then storing, cataloguing, copying, and distributing the material without any further modification. The latter type of function is exemplified in most of the current IGY World Data Centres. Although this type of service satisfies the needs of some laboratories, the time and cost involved in converting published material to a machine processible form renders this approach prohibitive to most NODCs unless no other avenue presents itself. Therefore, most National Oceanographic Data Centres, when receiving requests for data from individual scientists or laboratories, will bend every effort to locate a source that is capable of providing the data in a machine compatible form.

IV.2 Automatization of data acquisition and processing

Signals coming from sensors placed in the sea can be recorded on digital magnetic tape. This procedure offers a number of advantages in terms of storage and reproduction of data, particularly with continuously sensing and recording instruments. Digital recording on magnetic tape can always be reproduced in analog form or in a digital print-out through the use of an appropriate computing facility.

Recording of seismic signals directly on magnetic tape is widely used in the oil industry and similar recording equipment is now being used for reflection surveying. New continuous recorders of salinity and temperature versus depth (STD) also allow recording on magnetic tape as well as analog type recording.

During recent years development of computing techniques also made it possible to replace various time-consuming operations of primary data processing by machine treatment. Thus it has become feasible, even aboard ship, to introduce instrumental corrections, to calculate such parameters as water density, dynamic anomalies and sound velocity, to plot station curves, to interpolate and to carry out quality control of data with the aid of computers.

More and more research ships now have computers installea which, in addition to data recording and processing, may perform numerous other useful functions such as, for example, calculations necessary for satellite navigation.

The US bathyscaphe "Trieste II", for example, has a small-scale navigation and ship-control computer on board, making navigation near the sea bottom much safer.

The research vessel "Chain" of Woods Hole Oceanographic Institution used a computer on board, not only for satellite navigation but also for gravimetrical and magnetic field measurements. The "Silas Bent" of the US Naval Oceanographic Office can record simultaneously wide-beam and stabilized narrow-beam bathymetric soundings, magnetic intensity, gravity, sea surface temperature and sub-bottom profiles. On station, simultaneous measurements of depth, temperature, salinity, and sound velocity down to 6,100 m. are possible. The Naval Electronics Laboratory (USA) is attempting to compute isotherm profiles.

The USSR research vessel "Akademik Kurchatov" uses computers for navigation and data storage.

The use of computers in oceanography opens a new stage in marine research as it provides means whereby regular and frequent measurements from automatic station networks may be collected and processed. Such networks, in addition to automatic recording systems, may have in-built computing facilities to perform all the necessary primary data processing and may even transform the original data into more easily usable secondary products. This is particularly important for the forecasting of sea-surface conditions (see Chapter III). Planning of the Integrated Ocean Station System (IGOSS) by the Intergovernmental Oceanographic Commission will certainly be based on the most modern methods available.

For further successful development of automatic data processing a number of auxiliary problems should be solved. First of all, it is necessary to acquaint practising oceanographers with the techniques of programming and with all the possibilities computers offer to oceanography. In this connection wide exchange of information should be organized internationally through symposia and technical conferences.

IV.3 Development of the System for the International Exchange of Oceanographic Data

Current activities of the World Data Centres for Oceanography

Of all the World Data Centres operated till recently by the CIG (Comité International de Géophysique) of ICSU, those concerned with oceanography have been amongst the most active, especially from 1963 on. This success is due in large measure to the Intergovernmental Oceanographic Commission's unrelenting efforts in tackling the complex details involved in the international exchange of oceanographic data. IOC, in revising Chapter X of the CIG Guide to International Data Exchange, sponsored a provisional scheme which considerably facilitated data exchange. As more and more laboratories began using the system, working scientists' requirements were reflected in the changing techniques adopted in two subsequent revisions of the Guide. This points to the rapidly-changing needs of this multi-disciplinary science, as well as to the ready response to these demands by the IOC Working Group on International Oceanographic Data Exchange.

The collection of oceanographic material by the World Data Centres with respect to the programmes of IGY/IGC and IOC Declared National Programmes has been most encouraging. According to the latest estimate, data from approximately 150,000 oceanographic stations accumulated in the WDC system by the end of 1967. The amount of incoming data doubles every year. The volume of information supplied to working scientists and laboratories is equally satisfactory. Also, WDC catalogues are meeting the needs of the oceanographic community. In this connection it should be noted that the IOC recently recommended the adoption of a revised catalogue format. This format is now in use by WDC-A.

A matter of concern, however, is the relationship of World Data Centres for Oceanography to the rapidly-growing family of National Oceanographic Data Centres. The latter are primarily responsible for serving national needs and, in doing so, are in most cases surpassing the World Data Centres in sophistication. This fact is related to their respective funding. Increasing volumes of data, partly as a result of the rapid changes in oceanographic instrumentation, obliged these new centres to abandon considering the classic manual techniques and to use chiefly automated data-processing facilities.

In doing so they established themselves as true data centres, as opposed to the library function now being carried on by most World Data Centres.

Basic rules and regulations for international exchange of relevant scientific data

The Intergovernmental Oceanographic Commission published in 1967 the second revised edition of the Manual on International Oceanographic Data Exchange (IOC Technical Series No.4, 1967). It contains as its major part the Provisional Guide for the Exchange of Oceanographic Data. The word "provisional" signifies that it is being kept under continuous review by the Commission with its Working Group on Oceanographic Data Exchange and its scientific advisory bodies SCOR and ACMRR. This Provisional Guide contains a number of rules concerning such items as soundings, bottom samples, bottom photographs, topographic profiles, interim bathymetric charts, gravity and geomagnetic field measurements, heat flow, seismic refraction and reflection observations, etc. The guide lists the World Data Centres, Permanent Specialized, Regional, and National Centres and also describes the operational functions of all these Centres.

Copies of the Manual may be obtained from Unesco in English, French, Spanish and Russian.

Some aspects of future development of international exchange of oceanographic data

By IOC Resolution V-20A (See Annex I) the IOC Working Group was charged with reviewing and reappraisal of the whole international oceanographic data exchange system and, in particular, the future rôle of the World Data Centres for Oceanography. The Commission requested the Group to continue the development of means whereby geological and geophysical data may be more effectively exchanged.

When undertaking the above work the following aspects will be taken into consideration:

i. The development of instrumentation. It was noted that oceanography is presently undergoing a rapid instrumentation evolution which makes necessary an immediate re-evaluation of the techniques for handling data, from the points of view of National, Regional and World Centres. Oceanographic data acquisition had long been considered a personal effort, i.e., the collection of data used to be exclusively the work of individuals carrying out oceanographic research, usually from a ship at sea. Today the rapidly evolving aspects of automated collection, using modern data-logging devices, has radically changed this concept.

ii. Adaptation by NODCs. The type of data which will in future be deposited in the National Oceanographic Data Centres poses special problems in handling, storage and retrieval because of their immense volumes. In view of this, National Centres will have to adapt in order to cope with the anticipated "information explosion". It is obvious that the modest data repositories described in Section IV.1 would find themselves very heavily taxed when suddenly faced with the need to adapt to such changes.

iii. Adaptation and future rôle of WDCs for Oceanography. If the present trend continues, World Data Centres 'A' and 'B' for Oceanography may soon contain most of the available oceanographic data on the World Ocean. This means that they would actually be storing far more data than any of the National or Regional Oceanographic Data Centres. Because of this they would have to establish a standard archiving system to ensure rapid access to their data banks. It has always been recognized that one of the major rôles of the WDCs is to facilitate and expedite the exchange of oceanographic data between individuals and/or institutions. To readily cope with the effects of what is currently termed a "data explosion", one can either up-grade and strengthen the centres or cease to deposit primary records or primary data. The Ad Hoc Group on the subject, established by the IOC Working Group, considered : "... that primary records and primary data from high-density sampling devices are to be retained at the originating activity or National or Regional Data Centre, but that the corresponding reduced data should be transmitted to the World Data Centres. The extent of reduction will be a function of the type and volume of the measurements concerned. As more and more automated measuring devices replace traditional sampling procedures, World Data Centres will gradually need to move towards becoming essentially automated documentation centres. Notwithstanding the above recommendations, primary data should be available on request according to the principles to be specified in the Provisional Guide".

It is useful to note in this respect that more and more Data Centres have changed to "listing" the location of available data rather than "storing" the material in their centres. COSPAR, apparently, has been faced with a similar problem with regard to data from satellites and in one of its resolutions (IGY Bulletin No.61, July 1962) adopted a practice similar to that suggested in the paragraph above.

iv. Standard Format for Exchange. In considering ways and means by which international exchange could be accelerated, it became obvious that the ideal solution would be the introduction of a standard format which would link not only the World Data Centres but also the Regional and National Centres. However, it was subsequently established that national archiving systems and their associated formats would of necessity be closely linked to available data-processing facilities. Since these vary widely from country to country, it would not be possible to recommend one universal archiving system for oceanographic data. Rather each nation would have to develop the format best suited to its own needs and the automatic data processing facilities available. In doing so, it should, however, be aware of the need for compatibility with an IOC exchange format (yet to be specified). This mechanism would then facilitate and expedite the two-way exchange between nations through the World Data Centre system.

v. Standard Format for WDC Archives. The standard format constitutes the very foundation on which the WDC archiving system must be built. Therefore one must first try to establish what the future rôles of the World Data Centres will be and how the anticipated user demands might affect the character of such archives. Only then can the proper format be selected and the necessary specifications drawn up. This is why consideration of the future rôle of the World Data Centres for Oceanography should precede all discussions on the formulation of standard exchange and archiving formats.

IV.4 ARCHIVING AND RETRIEVAL OF METEOROLOGICAL DATA*

National Meteorological Services have for many years operated systems for the archiving of meteorological data and, where appropriate, of marine meteorological data, including those of ocean surface conditions. This work is coordinated by WMO. The data are used both for research and operational purposes. An example of an international archiving and retrieval project for marine meteorological data is that of "marine climatological summaries" prepared semi-annually by a number of designated centres, each of which is responsible for the collection and publication of data from a given ocean area. An example of a recent research project is the "Historical Sea Surface Temperature Data Project", in which four marine meteorological centres are preparing monthly means of individual years of several elements in a grid of small areas covering the world oceans and for a period extending over the last hundred years.

The advent of computer-based data storage and retrieval systems and the further development under the World Weather Watch of global systems of observation and data exchange have opened new possibilities for centralized modern archiving and retrieval systems on an international basis. This has resulted in the development of extensive archiving functions at World and Regional Meteorological Centres.

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Selected Bibliography to Chapter IV

Automatisation of the mass processing of oceanographic data. (In Russian) 1964, Trudy of the Institute of Oceanology, Acad. Sci. USSR. Special issue, 75.

BERNSTEIN, R. 1966. Data Processing at Sea. Geo-Marine Technology, 2, No.5.

BRANHAM, D.W. 1965. Shipboard Oceanographic Survey System. Ocean Science and Ocean Engineering, 1, Transactions of the Joint Conference and Exhibition, Marine Technology Soc., Amer. Soc. Limnology and Oceanography, Washington D.C.

BURKHOLDER, E.K. 1965. A systematic approach to oceanographic data gathering. Ocean Science and Ocean Engineering, 1, Transactions of the Joint Conference and Exhibition, Marine Technology Soc., Amer. Soc. Limnology and Oceanography, Washington D.C.

DORMAN, J. 1967. Computing Methods in Seismology. US National Report 1963-67, 14th General Assembly, IUGG, pp.423-426.

HENDERSON, G.C. 1965. Computer methods for analysing marine gravity and magnetic data. Ocean Science and Ocean Engineering, 1, Transactions of the Joint Conference and Exhibition, Marine Technology Soc., Amer. Soc. Limnology and Oceanography, Washington D.C.

JACKSON, Ch. B. 1967. Computers at Sea. Oceanology International, July/Aug.

KENNETH, E.P. & SMITH, P.F. 1965. The importance of digital techniques for oceanographic instrumentation. Ocean Science and Ocean Engineering, 1, Transactions of the Joint Conference and Exhibition, Marine Technology Soc., Amer. Soc. Limnology and Oceanography, Washington D.C.

LEENHARDT, O. & LEVY-SOUSSAN, G. 1967. Suggestions for drawing up highly accurate bathymetric charts. International Hydrographic Review, 44, No.1.

MERRIAM, D.F. 1965. Geology and the Computer. New Scientist, 20 May.

O'HAGAN, R.M. & SMITH, P.F. 1965. The use of small computer with real time technics for oceanographic data acquisition, immediate analysis and presentation. Ocean Science and Ocean Engineering, 1, Transactions of the Joint Conference and Exhibition, Marine Technology Soc., Amer. Soc. Limnology and Oceanography, Washington D.C.

ROSS, D.I. 1967. Storage and retrieval of geophysical data. Bedford Institute of Oceanography. BIO Computer Note 67-3-C, Canada.

Intergovernmental Oceanographic Commission:

1965 Manual on International Oceanographic Data Exchange, IOC Technical Series No.1, IOC/Unesco, Paris.

1967 Manual on International Oceanographic Data Exchange, 2nd Edition, Revised, IOC Technical Series No.4, IOC/Unesco, Paris.

1967 Summary Report of the Ad-Hoc Group on Format Standardization, IOC Working Group on International Oceanographic Data Exchange. Doc. IOC/V-13A, July 1967, IOC/Unesco, Paris.

World Meteorological Organization:

1967 Activities and Plans of the World Meteorological Centres. WMO, Geneva.

1968 Collection, Storage and Retrieval of Observational and Processed Meteorological Data. WMO (in preparation), Geneva.

1966 Catalogue of Meteorological Data for Research. WMO No. 174.TP.86, Geneva.

Data Processing in Meteorology - Proceedings of the WMO/IUGG Symposium on Meteorological Data Processing. WMO No. 180.TP.90, Technical Note No.73, Geneva.

ANNEX I

RESOLUTION I - 5

AIDS TO NAVIGATION

The Commission

Recognizing that accurate navigation is essential for detailed systematic oceanographic investigations, and further

Recognizing that systems of aids to navigation presently available for use do not generally meet the requirements of detailed oceanographic investigation except for limited specific areas and that such systems, if possessing the required accuracy should continue to be established in the interim,

Aware that several systems of aids to navigation, are presently under development which show promise of meeting the long-range ocean-wide requirements of detailed systematic oceanographic investigation,

Resolves that the Commission through its member governments actively encourage and support the continued development and subsequent establishment of a ground based long-range radio navigation system capable of meeting the world-wide requirements for detailed systematic oceanographic investigations; and

Recommends that in the establishment of the accepted world-wide ground based system of long-range radio navigation, priority be given to those areas for which no aids are presently available and for which large-scale oceanographic investigations are planned;

Further recommends that the International Hydrographic Bureau at Monaco, Intergovernmental Maritime Consultative Organization and the International Civil Aviation Organization be requested through their member governments to co-operate with IOC in the expeditious development, and subsequent establishment of a single national and international ground based long-distance radio navigation aid capable of meeting the accuracy requirements for detailed systematic oceanographic investigation (repeatability ± 50 m. and position accuracy ± 0,25 nautical miles);

Further recommends that steps be taken by Member States to assist those countries having ships taking part in the international co-operative oceanographic investigations to obtain and effectively use the equipment required for these navigational systems;

Further recommends that the development of other promising and economical systems of navigation even of lesser accuracy such as certain methods of satellite navigation, be actively pursued.

RESOLUTION I - 11

STANDARDIZATION AND INTERCALIBRATION OF OCEANOGRAPHIC METHODS AND EQUIPMENT

The Commission

Recognizing that there is a pressing need for a co-ordinated programme that ensures that oceanographic observations will be more meaningful and useful for oceanographic research in general,

Recognizing further that this can be accomplished by a carefully planned programme which includes to varying degrees the standardization, intercalibration and absolute calibration of observational methods and equipment, and that the formulation of such a programme should be carried out by those scientists most intimately involved in the collection and use of such data,

Convinced that in order to have comparable results this will probably involve some standardization of methods and equipment but equally convinced that world-wide standardization of all oceanographic techniques is not now desirable,

Aware that such a programme should proceed in an orderly fashion so that the final results will be the assurance that accurate oceanographic data can be mutually exchanged among oceanographers,

Further aware of the excellent work in this field being carried out by IAPO, ICES and ICSEM, and of the recent intercalibrations at Honolulu and aboard "Vityaz" and "Gascoyne" sponsored jointly by SCOR and Unesco,

Requests SCOR to undertake the following task:

Appoint as soon as possible working groups for the purpose of examining, summarizing, and criticizing the present oceanographic methods and equipment in common use to determine where these methods or equipment do not provide universally usable, accurate data, or where such data cannot presently be utilized to the utmost, and to recommend by report to the IOC appropriate steps whereby these methods or equipment should be made universally usable. This may in some cases be accomplished by standardization or by intercalibration, or by such methods as these experts may determine.

RESOLUTION IV-6

INTERNATIONAL ASPECTS OF THE TSUNAMI WARNING SYSTEM IN THE PACIFIC

The Intergovernmental Oceanographic Commission,

Recognizing the importance of providing timely warnings of the approach of Tsunamis in the Pacific Ocean,

Noting the report of the Working Group Meeting on the International Aspects of the Tsunami Warning System in the Pacific,

Commends the Working Group for its efforts and the comprehensive report of the Honolulu meeting submitted to this Commission,

Notes with appreciation the offer of the United States to undertake the expansion of its existing facilities in Honolulu to become the International Tsunami Information Centre,

Accepts the offer of the United States and recognizes the existing Tsunami Center at Honolulu as the International Tsunami Information Center of the Intergovernmental Oceanographic Commission,

Establishes an International Coordinating Group composed of interested member states in the Pacific to effect liaison among the participating Members, to promote exchange of information on developments of observing methods and of techniques of tsunami forecasting, to effect liaison with other interested organizations, and to provide advice on the operation of the International Tsunami Information Center,

Encourages ~~the member~~ states to exchange scientific and technical personnel among the various national Tsunami warning and research centers, and,

Commends to the governments of member states the implementation of the various technical recommendations included in the Working Group Report, and

Considering that the International Coordinating Committee on the Tsunami Warning System should be a function of this Commission rather than of Unesco,

Requests the IOC Bureau and Consultative Council at its next meeting to constitute the IOC International Coordinating Group on the Tsunami Warning System, meetings of which will be financed in a manner similar to other IOC subsidiary bodies, and further

Requests the Director-General of Unesco to consider furnishing the financial support to individual scientists who might travel from other countries to the International Tsunami Information Center for purposes of cooperative tsunami research and training in the operation of the International Tsunami Warning System ; The possibility of using the International Seismological Fund if established should also be considered.

RESOLUTION IV-12

STORAGE AND RETRIEVAL OF SCIENTIFIC INFORMATION

The Intergovernmental Oceanographic Commission,

Recognizing the rapidly expanding volume of information concerning the results of marine research and the urgent need to ensure that the information be readily retrievable by scientists concerned with every aspect of marine research in all parts of the world, and by all those concerned with these matters in both government and industry;

Noting the need for all such information not only to be retrievable but for this retrieval to be as speedy as possible, together with the acknowledged inability of even the largest national organizations, or the World Data Centres, to accept these tasks at the present time;

Noting also the efforts already being made by the Fisheries Division of FAO, with the assistance of various international and national institutions*, to provide an intelligence and information retrieval service, especially through their Current Bibliography on Aquatic Sciences and Fisheries, both as concerns marine (and fresh water) research in general and fisheries research in particular (Report of the 3rd Session of ACMRR and IOC/IV-18), and the views expressed by SCOR Working Group 12 on Marine Science Abstracts and Bibliographies, concerning the need to ensure the maintenance and further improvement of these services as a minimum requirement, with the consequent need for maximum support by all countries concerned;

Recognizing further that these objects cannot be achieved by irregular support (already one collaborating body having been forced to conclude its operations for lack of funds), so that continuing and expanding support is required;

Recommends that Member States, together with SCOR and ACMRR, urgently consider what steps might be taken, in collaboration with other interested bodies, to ensure, for the promotion of oceanography in general, that sufficient funds, facilities and staff are made available for the provision of a retrieval service adequate to the needs of the international marine research community, and

Requests Unesco meanwhile to consider ways and means of developing increased collaboration with FAO with a view to enlarging coverage of various disciplines by the CBASF.

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* (ICES, CSIRO (Australia), VNIRO (USSR), UNESCO, and, until recently, ASIRC (University of Rhode

RESOLUTION IV-16

INTERNATIONAL UNDERWATER LABORATORY

The Intergovernmental Oceanographic Commission,

Recognizing that the establishment of an International Submarine Laboratory, for use as an applied science centre involving prolonged periods under water and open to all research workers, is of interest to the Intergovernmental Oceanographic Commission,

Hoping that member countries, appreciating the importance of the results to be expected from such a laboratory, will cooperate in making it a reality,

Decides to communicate to member countries all such information as may be supplied to it on this subject by the responsible authorities.

RESOLUTION V-20

INTEGRATED GLOBAL OCEAN STATION* SYSTEM
(IGOSS)

The Intergovernmental Oceanographic Commission,

Considering the growing need for oceanic data on a global scale, by a wide range of users, including workers in research, engineering, navigation and commerce, fisheries and forecasting services and in order to further the scientific study of the ocean and atmosphere;

Recognizing the activities of the World Meteorological Organization and particularly the marine aspects of its World Weather Watch (WWW);

Noting the advice of the International Telecommunications Union that an initial plan and programme for an Integrated Global Ocean Station System should be prepared by early 1969, 'this plan to include the geographical distribution of oceanographic stations, their system of operation, the deployment of frequencies in the system and the manner in which oceanographic information is to be transmitted';

Noting further Resolution 9 (Cg-V) of the 5th Session of the World Meteorological Congress which stresses the need for closer cooperation between WMO and other international agencies concerned with marine activities, such as IOC, including the establishment, as required, of joint working groups (IOC/V-22A);

Decides to establish within the Commission a permanent Working Committee for an Integrated Global Ocean Station System, with a membership of no more than twelve of those member states which are most active in this field, the Chairmen of the various subsidiary groups (ex-officio), observers and representatives of other interested organizations;

Authorizes the Working Committee:

(i) to plan and coordinate an IOC programme of studies and services in oceanic areas, both within the Commission and jointly with WMO and other organizations;

(ii) to act as the Commission's authority for the discharge of its responsibility for the IGOSS work of the IOC/WMO Panel of Experts on Coordination of Requirements and those groups on Data Exchange, Telecommunications and Ocean-Atmosphere Interaction, as detailed in Resolutions V-20A, 20B, 20C, 20D, 20E hereafter, and

(iii) to form additional panels of experts, as considered necessary.

Invites the WMO and other organizations to consider favourably cooperation with the above Working Committee.

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* as defined in the report of the 1st Meeting of the Working Group on Fixed Oceanographic Stations (Annex V to UNESCO/NS/180)

RESOLUTION V-20 A

OCEANOGRAPHIC DATA EXCHANGE

The Intergovernmental Oceanographic Commission,

Accepts the report of the third meeting of the Working Group on Oceanographic Data Exchange (IOC/V-13), appreciates the recommendations contained in the report of the Ad Hoc Group on Format Standardization (IOC/V-13A), and applauds the Working Group for its work on the Second Edition (Revised) of the Manual on International Oceanographic Data Exchange as approved by the 7th Meeting of the Bureau and Consultative Council (IOC/B-30), and particularly thanks the Canadian Oceanographic Data Centre for its assistance on these matters.

Amends the terms of reference of this Working Group (Res. I-9) by adding the following :

a) to review and reappraise the whole international oceanographic data exchange system as recommended in Section 8 of the report "International Ocean Affairs" (IOC/V-INF.111), and as reaffirmed in Recommendation (ix) of the summary of the recommendations of the Working Group meeting in The Hague in September 1967 (IOC/V-4);

b) to continue and encourage the present work leading towards format standardization for use with automated techniques for data input, storage, retrieval, dissemination, and exchange, but recognizing the considerable financial implications inherent in such automation;

c) to continue the development of means whereby geological, geophysical, biological, special air-sea interaction data, and data from "continuously recording" sensors are incorporated into the international oceanographic data exchange system.

Directs the Working Group to establish and maintain close collaboration with National and Regional Data Centres and with those groups of the Working Committee concerned with various aspects of the Integrated Global Ocean Station System (IGOSS); and

Invites WMO, FAO and other interested organizations to send observers to the meetings of the Working Group.

ANNEX II

RECOMMENDATIONS OF THE FIRST MEETING OF THE IOC WORKING GROUP ON MARINE POLLUTION

(Paris, Unesco, 14-17 August 1967)

As a result of the exchange of views on various aspects of the problem of the present state of pollution of sea water, the IOC Working Group on Marine Pollution,

Being concerned about the fact that pollution of the sea with domestic, industrial and agricultural wastes by land run-off, by ships and by other ways, can result in important modifications of the natural conditions of sea water which can have harmful effects on the vital activities of marine organisms, cause detriment to the biotic resources of the sea, can be dangerous to human health and cause economic loss, diminish the aesthetic qualities of the sea and coasts and reduce the quality of the water for industrial uses,

Having the objective of organizing an efficient study of pollution, of the process of auto- and artificial purification and of the control of water pollution with a view to its eventual elimination,

Believes that the time has come to treat all kinds of marine pollution as listed in the Report of the Working Group as facets of a single problem requiring concerted action by chemists, radio-chemists, marine biologists and micro-biologists, physical and chemical oceanographers, engineers, lawyers, administrators, etc.;

Believes that co-ordination is needed on both national and international levels of all environmental pollution studies and preventive measures;

And consequently recommends that the Fifth IOC Session:

(a) draw the attention of the IOC members to the need for further research and dissemination of information on oceanographic and other related aspects of marine pollution falling into the broad categories of:

(i) detection and measurement of various chemical and micro-biological constituents of marine pollution;

(ii) tracing and predicting their fates;

considering that the following specific fields of research may be identified as the most important ones:

development of relevant physical, chemical, physico-chemical and radio-chemical methods with special consideration to the transition elements of the Periodic Table and to the oil content of the marine environment;

standardization of methods of sampling and analysis in oceanography, including spectrographic and chromatographic methods;

the establishment of models of the dilution and dispersion of pollutants in the open sea, coastal waters and estuaries, which can be used for the prediction of the concentrations of pollutants at chosen distances and directions from the point of discharge;

the understanding of the bio-geochemical circulation of pollutants;

the micro-biological degradation of marine pollutants including oil;

the determination of the effects of sub-lethal doses of the more important pollutants on ecosystems;

the establishment of the most appropriate ways of determining the toxicity of various pollutants independently and in combination under various environmental conditions;

(b) request IOC members to make such arrangements as necessary in order to have such research conducted on a continuing basis, to make accessible as much as possible of each country's experience and information on problems of marine pollution, including its oceanographic aspects, to consider the possibilities of maintaining records of discharges of pollutants into the high seas, and to promote research on these problems and on measures for pollution control. This might be achieved by designating, wherever practical, a central national governmental body which could, inter alia, act as an agent to facilitate international exchange of scientific and technical information, research plans and experience;

(c) request SCOR, in co-operation with ACMRR and IAWPR, to study what international scientific action on the non-governmental level can be taken in order to facilitate research referred to above;

(d) request the interested organizations of the United Nations family to agree on the appropriate machinery to ensure joint action by these organizations in the field of marine pollution, which machinery, inter alia, should:

(i) formulate a system for regular reporting by national sources to appropriate regional or international bodies, of discharges of pollutants (in addition to oily substances the discharge of which from ships is already recorded under the International Convention for the Prevention of Pollution of the Sea by Oil) directly into the high seas by ships or by other means, and of other deliberate, accidental, or otherwise unavoidable discharges which may have international effects;

(ii) maintain international registers of discharges of the kinds defined under (i) above (dates or period of each discharge or dumping; the composition and quantity of the materials discharged; the nature of the container, if any; the site (latitude and longitude); the method of transport to it);

(iii) improve the exchange of information internationally concerning research relating to marine pollution and specifically through:

maintaining a register of institutions and workers in the field of marine pollution which shall be available to member countries;

circulating to countries information on national laws and regulations relating to pollution control;

circulating to countries reports on progress on pollution control;

circulating information on research in hand;

(iv) provide for the due input of the relevant oceanographic data and information resulting from the co-ordinated research by IOC members;

(v) prepare proposals for further steps to be taken internationally towards the control of marine pollution;

(e) authorize the IOC nominee to the United Nations Secretary-General's Group of Experts on the implementation of the United Nations resolution 2172 "Resources of the Sea" to draw the attention of that Group to the above recommendations and to the necessity to reflect them in those proposals which that Group will formulate, and to request this Group to consider the needs for bilateral and regional co-operation on pollution monitoring which might involve responsibility of regional organizations such as ICES and ICSEM.

TABLE OF MAJOR CATEGORIES OF POLLUTION

For each type of pollution, the general categories of effect most frequently associated with that pollution type are indicated by crosses in the appropriate column. Where judgement was possible, the most important category of effect for a particular type of pollution is indicated by a circled cross. The final colum gives reference numbers to footnotes where illustrative examples of the categories of pollution are given.

Major categories of pollution		Harm to living resources	Hazards to human health	Hindrance to maritime activities	Reduction of amenities	Reference to illustrative examples
		General categories of effect				
Domestic sewage (including waste from food processing)	Direct microbial	-	(x)	-	x	1
	Indirect microbial	-	(x)	x	-	2
	Eutrophication and related processes	(x)	x	x	(x)	3
Industrial waste products	Heavy metals	x	(x)	x	-	4
	Petro-chemical	-	x	x	-	5
	Oils, etc.	-	-	x	(x)	6
	Pulp and paper wastes	(x)	-	-	x	7
	Pesticides	x	(x)	-	-	8
	Detergents	x	-	-	x	9
	Radioactive materials	-	(x)	x	-	10
	Heat	x	-	x	-	11
	Solid objects	-	-	x	x	12
	Dredging spoil	x	-	x	-	13

Footnotes to Table

1. Direct contamination of beaches near discharges of inadequately treated sewage can lead to bacterial and virus infections and non-aesthetic conditions with consequent adverse effects on tourism.

2. Bacterial or virus infection can be caused by eating raw shellfish harvested from areas contaminated by sewage and this also leads to adverse effects on the fishing industry.

3. Discharge of sewage or other organic wastes leads to increases in nutrient salts and changes in their proportions in the sea and so to quantitative and qualitative changes in the phytoplankton which may: (a) have adverse effects on shellfish; (b) if they involve increases in toxic species, lead to poisoning by eating contaminated shellfish; (c) lead to non-aesthetic conditions resulting from the mass production, mass mortality and decomposition of marine organisms.

4. Filter-feeding invertebrates and also fish larvae, etc., which are sensitive to changes in the quantities of certain elements normally rare in sea water, take in metals such as copper, zinc and mercury originating from industrial wastes. In various circumstances this causes the death of the organisms, the spoiling of the flavour of shellfish and the poisoning of consumers of the organisms.

5. Wastes from petro-chemical industry cause spoiling of the flavour of marine products and danger to man through the consumption of organisms in which carcinogens have accumulated.

6. Oily substances may clog nets, spoil the flavour of fish and shellfish, kill sea birds, contaminate beaches. Some methods of treating oil on beaches and on the sea surface involve the use of materials toxic to marine life.

7. Sulphite effluents with high biological oxygen demand cause non-aesthetic conditions, destruction of shellfish beds and hindrance to migrating fishes.

8. Insecticides and residues, such as chlorinated hydrocarbons and organic phosphorous compounds, are persistent and highly toxic to marine anthropods and may accumulate in other organisms with consequent health hazards to predators including birds and man.

9. The SCOR/ACMRR Working Group is not aware of any specific examples but, considering that detergents have a high phosphorous content, is of the opinion that the bio-degradation of the short-chain detergents could add to the eutrophication effect of domestic waste.

10. Because of the rigid control exercised over the atomic energy industry since its inception, the Working Group has no examples of adverse effects brought about by the discharge into the sea of radioactive effluents. There do exist, however, the potential dangers of nuclear accidents as hazards to health. Of particular concern are the radioactive isotopes of those elements which are normally rare in sea water and which are readily taken up by marine organisms.

11. Under certain conditions, warm water discharges from large electrical power plants can lead to: (a) excessive growth of vegetation which interferes with navigation; (b) increase in fouling and boring organisms on vessels and structures; (c) thermal blocks which interfere with migrations of fish; (d) when associated with other types of discharge, increased microbiological activity and thereby oxygen depletion with consequent adverse effects on living marine resources.

12. Floating and sunken solid objects, such as drums, wire, bottles, timber, vehicles, plastic articles and other persistent materials can: (a) interfere with navigation and fishing operations; (b) provide a habitat for boring organisms; (c) when washed up on shores, reduce amenities; (d) adversely affect the benthic habitat.

13. Discharge of clay, silt, etc., from dredging, and also possibly from mining and drilling operations, may: (a) increase the turbidity of the water with adverse consequences to marine life; (b) cover hard bottom with soft layers which impede spawning of fish and settling of shellfish; (c) because of high nutrient content of interstitial water, add to the nutrient salt concentration of the sea and hence to the problems associated with eutrophication; (d) interfere with navigation and fishing operations.

RESOLUTION V-19

MARINE POLLUTION

The Intergovernmental Oceanographic Commission,

Being concerned about the fact that pollution of the sea with domestic, industrial and agricultural wastes by land run-off, by ships and by other ways, can result in important modifications of the natural conditions of sea water, which can have harmful effects on the vital activities of marine organisms, be detrimental to the biotic resources of the sea, be dangerous to human health and cause economic loss, diminish the esthetic qualities of the sea and coasts and reduce the quality of the water for industrial uses,

Being convinced that further improvement in the coordination of international aspects of marine pollution is needed,

Bearing in mind that a number of international agencies is already concerned with research on pollution, its effects and control,

Being informed of the FAO World Conference on Marine Pollution and its Effects on Fishery Resources and Fishing Operations to be held in Rome in 1969,

Recommends that the IOC inform the FAO of its desire to participate, if called upon, in this Conference.

Accepts the Report and the Recommendations of the IOC Working Group on Marine Pollution with minor modifications.

Recommends that the organizations of the UN family involved or interested in pollution problems explore the possibility of forming a joint group of experts to ensure that necessary scientific information is available to those agencies responsible for conservation of resources, pollution control and abatement.

Instructs the IOC Working Group to continue development of programmes on the oceanographic research aspects of marine pollution, including monitoring aspects. If an alternative scientific group under the joint sponsorship of the interested UN organizations were to be established, the IOC would have to reconsider the position of its working group on marine pollution.
