THE INTERNATIONAL INDIAN OCEAN EXPEDITION 1959–64

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As a result of a unique set of conditions, the Indian Ocean is possibly the most productive of all the oceans, biologically. Virtually nothing is known about it at the present time but it will undoubtedly become the best understood of all the major bodies of water after this multi-nation effort.

Over the next four years, a fleet of ships carrying scientists with their highly specialised equipment will be sailing in the Indian Ocean on new voyages of discovery, bringing one of the last unknown areas of the globe under intensive scrutiny. More than forty vessels with scientists from over twenty countries will cruise the waters of this vast body of water in a joint effort that has come to be called the International Indian Ocean Expedition. No ocean has yet received so much attention.

The Indian Ocean covers one-seventh of the surface of the earth and the countries bordering on it hold 25% of the world's population. Although this vast area is less known and less understood than any of the other oceans, there is sufficient fragmentary evidence to indicate that biologically it may be the most productive one. The international plan calls for a study of the entire system from below the bottom, through the water itself (with its biological contents and its physical and chemical characteristics), through the boundary between the sea and the atmosphere, and on upwards to the upper atmosphere. The scientific disciplines brought into play will include geology, geophysics, bathymetry, oceanography, biology, and meteorology.

One of the major objectives is the development of an oceanographic science in the Indian Ocean area with the associated institutions necessary to support it. The Expedition offers an opportunity for training in the marine sciences to nationals of the surrounding countries under the guidance of experienced scientists from outside.

The planning for this major oceanographic event has been in progress since 1957 under the aegis of SCOR, the Special Committee on Oceanic Research of the International Council of Scientific Unions. Late in 1960, UNESCO agreed to co-sponsor the Expedition.

The first question that usually arises in the minds of many people is:

How does the Indian Ocean differ from other oceans and of what significance is this?

The Indian Ocean has several unique features. Outstanding is the 180° reversal of the prevailing winds twice a year in its upper part at the onset of the northeast monsoon and the southwest monsoon. The monsoon wind reversal creates varying currents at different seasons of the year which, in turn, affect the entire oceanic circulation. As a result, there is on each of the four coasts of this ocean at some time of the year a wind setting up currents which create upwelling with a consequent increase in nutrient circulation. This plus the occasional observations of vast quantities of dead fish on the surface suggests that the Indian ocean may be one of the most productive bodies of water.

Equally unusual is the fact that this virtually unknown body of water is the sole major ocean which is open only at one end. It is fed at the closed northern end by the great rivers of the Middle East that run into the Arabian Sea and by those of East Pakistan, Burma, and India which carry fresh water and sediment into the upper part of the Bay of Bengal; cold water enters only from the Antarctic to the south. The currents of the Indian Ocean are ill-defined and there is great interest in whether an equatorial counter current exists similar to the ones found in the Pacific and Atlantic at considerable depths.

OBJECTIVES

The overall objective of the Expedition is to gain some understanding of the interaction between the earth, the sea, and the atmosphere.

Physical and Chemical Oceanography. The scientists associated with the project will try to find the answers to questions such as these:

1. How long does it take the winds to set up a current and how rapidly does a current deepen with time?
2. What proportion of the energy required to maintain an ocean current comes from the wind and what proportion from horizontal density gradients that are due to regional climatic differences?
3. How does internal friction and friction with the bottom influence the velocity-depth distribution?
4. What is cause and what is effect in the general circulation of the oceans?

A wide variety of observations will be needed to answer these questions. Almost every ship will cruise during both monsoons, measuring currents at the surface and at various depths, taking temperatures, and sampling the water for salinity and other characteristics at intervals of 10 to 100 miles. The major water masses will be defined and density layers described. The network of ship coverage planned so far is reasonably satisfactory for the region north of 40°S.; as the Expedition progresses, the gaps in the northern part should be filled in and observations in the southern part

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extended through co-operation with the Antarctic investigations.

Chemical analyses of water samples will throw light on these questions:

1. What is the distribution of plant nutrients and dissolved organic compounds in various parts of this ocean?
2. What is the effect of drainage water on sea water in a partly-closed basin?
3. How can one describe the circulation by Carbon-14 dating of the water?

Water samples will be analysed for oxygen, inorganic phosphorous, total phosphorous, silicate, nitrate, and trace elements as well as C-14.

Marine Biology. All ships will carry out a minimum biological programme by means of standard water sampling and the collection of specimens with various types of nets and trawls. The overall effort is designed to:

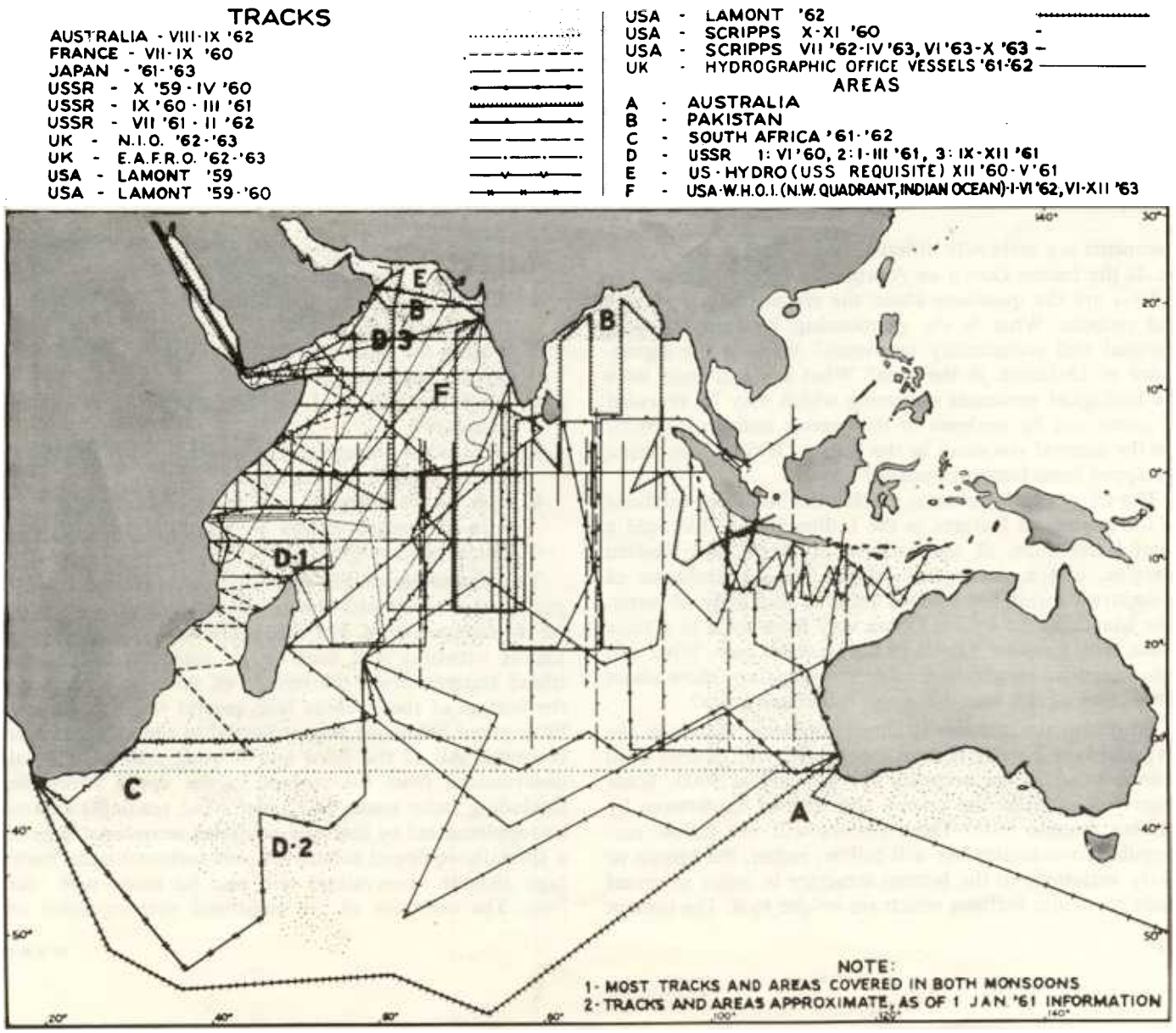
1. Study the three-dimensional distribution of plants and animals in the Indian Ocean.
2. Investigate the quantitative ecology of the plankton.
3. Collect as much information as possible about the fisheries of the Indian Ocean.

Some vessels will make biological oceanography their primary mission during part or all of a cruise. In addition to the minimum programme, they will concentrate on such biological phenomena as:

1. Coastal upwelling around the entire Indian Ocean.
2. The study of equatorial divergences.
3. The study of coral reefs and their surrounding environments.
4. The problem of massive fish mortality.
5. The special problems surrounding regions of convergence.

Marine Geology, Geophysics, and Bathymetry. The topographic features and geology of other oceans have been studied in some detail during the last few years but vast gaps still exist in the knowledge about the Indian Ocean. These gaps are now beginning to be filled in by the recent

CRUISES COMPLETED AND PLANNED 1959-1963



cruises of the United States ships *Vema* and *Argo* and the U.S.S.R.'s *Vityaz*. A bathymetric chart of the Indian Ocean shows great distances between contour lines and a lack of detail which is characteristic of our knowledge of this area. Three general groups of problems require detailed investigation:

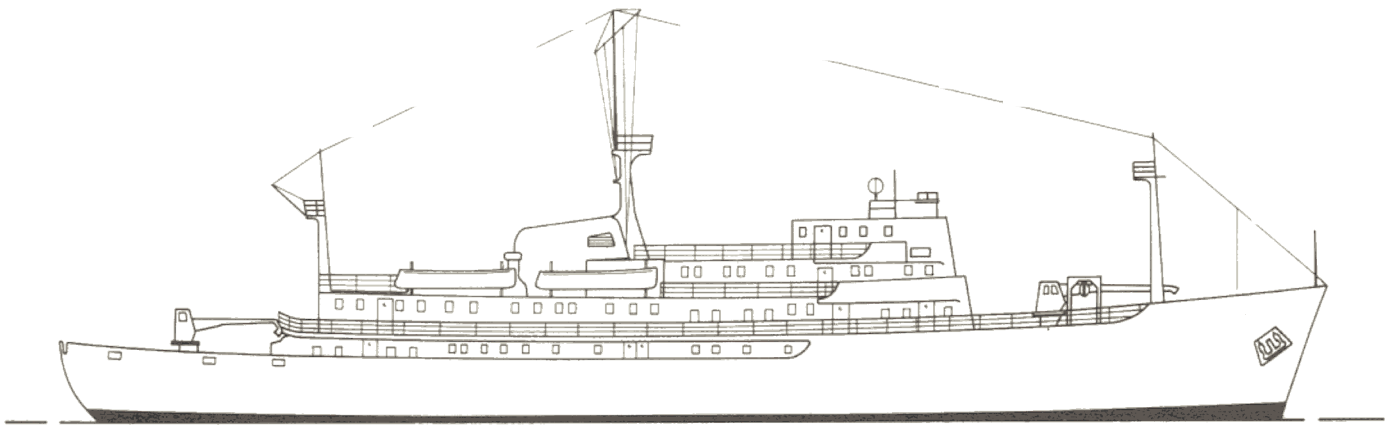
First, what are the major crustal features of the bottom? What are the characteristics of the trenches, of the mid-ocean ridges, of the rift zones, of the basins and the continental margins? The arrangement of these components and their relationship to the structures of the bordering continents are markedly different in the Pacific and Atlantic. Is the Indian Ocean an Atlantic or Pacific type ocean?

Next are the questions about the sedimentary processes and records. What is the relationship between the geophysical and sedimentary provinces? What is the significance of Dolomite in the area? What are and have been the biological processes occurring which may be revealed by cores and by analyses of the marine sediments? What are the mineral resources in the Indian Ocean which might be tapped from bottom deposits?

The third set of problems involve the boundary relations of the geological features in the Indian Ocean. We need a careful definition of the eastern, northern, and western margins, and a description of the general problems of boundaries within the various areas of this body of water. The islands in the Indian Ocean vary from coral to granite bases, with volcanic islands in the southern part. What will paleomagnetic records and other investigations show about the history of this ocean and the associated areas?

To obtain the answers to these questions, vessels in the Expedition will study bottom topography with precise echo sounders having an accuracy of one part in 5000. Some ships will examine the crustal structure of the bottom by making seismic tests. These cruises will not follow rectangular co-ordinates but will follow, rather, the known or likely variations in the bottom structure in order to reveal those particular features which are unique to it. The bottom will be sampled by taking deep cores periodically and by dredging at frequent intervals; underwater photographs will be taken also. At critical points, heat-flow measurements will be recorded and some ships will carry out magnetometric and gravimetric measurements.

Meteorology. Since atmospheric phenomena have much to do with the Indian Ocean's unique character, an understanding of the entire system also requires study from the upper layer of the ocean to the upper atmosphere. Meteorologists and oceanographers are interested in answering the following questions:



New oceanographic research vessel about to be constructed for the National Institute of Oceanography (U.K.)—one of the first of the new generation of research ships now being designed and built by the major maritime powers. About 260 ft. long and displacing 2800 tons, it will be completed early in 1962.

1. How can the large-scale atmospheric circulation of the Indian Ocean be described?
2. How can evaporation and vertical heat flux be determined over large areas?
3. What is the areal distribution of vertical flux of water vapour, heat, and momentum?
4. What are the local interface fluxes at the air-sea boundary?
5. What is the average energy transfer or heat budget for the atmosphere and the ocean?
6. How do we interpret satellite cloud photographs and infra-red measurements in terms of such meteorological observations?

The United States will probably undertake a substantial part of this phase with the assistance of nations bordering on the Indian Ocean. For this study, the existing meteorological networks will need to be supplemented by new island stations down the middle of the ocean and across the bottom of the Arabian Sea; several weather ships will be required below the Bay of Bengal to complete the ocean coverage. All of the fixed and floating stations will take observations from the surface to the upper atmosphere (including radio sonde and radar wind readings) and will be supplemented by specially-equipped aeroplanes, possibly a specially-equipped submarine, and meteorological buoys; high altitude observations will also be made with satellites. The objective of the combined oceanographic and

meteorological observations is to obtain a picture of the air-sea system in action on a broad scale over a period of time.

SPECIAL PROBLEMS

Navigation. Precise navigation is particularly desirable for bathymetric, geological, and geophysical work and for the study of currents. Unfortunately, the accuracy of celestial navigation is seriously affected by weather conditions and individual variations, and other systems are expensive for an area so vast. A number of alternative methods have been investigated, however, and one of these, involving the use of the United States' *Transit* navigational satellite, can provide an accuracy of 0·5 to 1 mile. After extensive tests of the system, the U.S. Navy has offered to lend a limited number of simplified receivers and computers to Expedition vessels but the delivery dates may be towards the end of the programme.

The existing *Loran A* and *C* are too expensive and could not achieve complete coverage and *Omega*, a very low frequency system, is unlikely to be operational in time. During the early phases of the Expedition, therefore, the participants will have to depend on celestial navigation and the *Decca* system although the U.S. is considering sun-trackers for daytime all-weather positioning for some of its vessels.

Training. The development of oceanography as a science which is integrated into the activities of the Indian Ocean nations is an objective that is as important as obtaining fundamental scientific knowledge of the area. To achieve this end, UNESCO, several nations, various intergovernmental agencies, and some private foundations will assist in advanced specialised training of the nationals of these countries.

Biological Collections. Without a new facility, biological collections will overwhelm the traditional centres of taxonomic analysis—the museums and universities. To alleviate this problem, plans are being developed to establish a biological centre at a convenient point in India, to be operated by India with substantial assistance from UNESCO and participating nations. Biological samples will be divided by the ships, half of each going to the centre for basic classification and analysis. The collection will serve as an Indian Ocean reference source and, after primary sorting, specialists in various biological fields will be brought in for final analyses.

The Expedition is the first full-scale effort to co-ordinate oceanographic and meteorological observations in a single oceanic system. The findings will be published in part as papers by individual scientists in professional journals and these will be issued later as a collection of reprints. An atlas describing the Indian Ocean's characteristics will also be published.

PRESENT STATUS AND PLANNING

The preliminary phase of the Expedition will be completed early this year with the conclusion of extensive cruises by oceanographic vessels of the Soviet Union, the U.S.A., France and Australia. The balance of 1961 will be devoted largely to consolidation of information and detailed planning, although several countries around the Indian Ocean will be making cruises in the course of their normal operations and vessels from Britain, the U.S.A. and the U.S.S.R. will be operating in the area. From mid-1962 through 1963 there will be an intensive effort by virtually all the participating nations, using ships, buoys, submarines, aeroplanes, satellites, and island and shore installations for tidal and meteorological measurements. No detailed plans have been laid out for 1964 as yet but they will be developed later on the basis of accruing information.

The preliminary plans were drawn up by an international working group that was set up by SCOR early in 1960 under the chairmanship of Dr G. E. R. Deacon, director of Britain's National Institute of Oceanography; Dr V. G. Kort of the U.S.S.R. was vice-chairman of the group. During this period, the Co-ordinator visited sixteen countries in various parts of the world to stimulate interest and determine the extent and nature of their participation. A minimum plan was developed at a meeting in Copenhagen last July when sub-working groups met to outline the scientific objectives of the Expedition, define the problems to be investigated, and agree on procedures and standards. IAMAP (the International Association of Meteorologists and Atmospheric Physicists), in response to a request, set up a working group to co-operate with SCOR on the definition of a meteorological programme. WMO (the World Meteorological Organisation) agreed to assist in the programme for obtaining synoptic meteorological information. Preliminary plans were laid for close co-operation with SCAR (the Special Committee on Antarctic Research).

Within the basic framework, national committees in the participating countries proceeded to draw up detailed national plans which are being co-ordinated through personal contact and the rapid exchange of preliminary documents. By mid-summer of this year—at least a year before the major effort begins—there should be a series of detailed national plans available. Several international meetings, including the Tenth Pacific Science Congress in Honolulu late this summer, will enable many of the nations to exchange information. The Honolulu meeting will also offer an opportunity for a direct comparison of field techniques among Australian, Japanese, Russian, and U.S. ships which are expected to be there.

Plans are now being laid for the establishment of logistic centres around the Indian Ocean area and for the provision of laboratory space at various institutions for local working up of research material. To help overcome the shortage of scientists and technicians, particularly in the countries bordering the Indian Ocean, training facilities will be expanded and new ones set up, and at least sixty scientists from these countries will be given the opportunity for advanced training in institutions outside the region. Such training is to be specially directed towards participation in the Expedition.

The international character of this project and its consequent impact on all oceanography is indicated by the current activity of the nations involved. The fundamental science developed during the Expedition will serve as a base for understanding the processes of this vast oceanic system on which applied sciences can build for the direct benefit of the large population of the Indian Ocean area.