International Indian Ocean Expedition*

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WITH the dawn of the nineteenth century it became a custom among the leading maritime states to send out warships on combined surveying, exploring and politico-commercial cruises. These expeditions often would take one or more naturalists also. Prasad[1] has mentioned about the various expeditions that have worked in the Indian Ocean, and of the more recent ones mention may be made of the Swedish *Albatross*, the Danish *Galathea*, the German *Xarifa*, the Soviet *Ob*, *Zaria* (world's only non-magnetic research vessel) and *Vitiaz* expeditions.

Many countries, including India, are showing evidence of growing interest in oceanography and practical reasons for studying the oceans are mounting rapidly. Nevertheless, the study is proving to be one of the most difficult branches of science. Apart from the fact that the study of oceans involves the active collaboration of scientists from different scientific disciplines, it has also been well recognized that this is one of the most international of all sciences and is best studied on an international co-operative basis. Such a co-operation was first attempted at the time of organizing the *Galathea* deep-sea expedition. Fortunately this practice seems to have become an established tradition and countries sponsoring extensive expeditions invite scientists from other countries to participate in the expedition while the ship operates in or near their waters. During the last decade two such expeditions, the *Galathea* from January to May 1951 and the *Vitiaz* during October 1959 and May 1960, worked in the Indian Ocean. The author had the privilege of participating in both these and hence certain comparisons of the more important findings of the two expeditions have been made in this report.

Vitiaz expedition to Indian Ocean

Although the various expeditions mentioned earlier have covered parts of the Indian Ocean, none of them was meant exclusively for its investigations. The recent *Vitiaz* expedition is the only international one organized specifically for work in the Indian Ocean and it has carried out extensive and intensive work covering practically the entire area and almost all aspects of oceanography except marine microbiology.

As a part of the programme of international co-operation in oceanic exploration initiated during the International Geophysical Year, the Soviet Union undertook to work in the Indian Ocean. During 1956-57 the Soviet research vessel *Ob* carried out some preliminary investigations in the Indian Ocean during her two cruises back home from the Antarctic. Later, a detailed programme was drawn up and the Soviet expedition ship *Vitiaz* — the flag-ship of the Soviet scientific research fleet — was commissioned for the work.

Vitiaz was formerly the German cargo-cum-passenger liner *Mars*. In 1949 she was acquired by the Soviet Union, remodelled and equipped for carrying out oceanographic work. Since commissioning as a research vessel, *Vitiaz* completed 30 cruises in the Pacific and the thirty-first was to the Indian Ocean. It may not be out of place here to mention some of the details of the ship and her complement:

Maximum length	109·44 metres
Width along loading line	14·56 metres
Height from keel to upper permanent deck	8·75 metres
Depth below water with full load	5·86 metres
Displacement tonnage	5700 tons
h.p. of main engine	3000
Maximum speed	14 knots
Maximum working depth for deep-sea anchor, trawling and bottom corer	11000 metres

The ship has a crew of 66 and can accommodate 70 scientists. She has a cruising range of 18,500 miles and can carry adequate provisions, fresh water, etc., for her full complement of 136 persons for a period of 120 days. There are 14 well-equipped laboratories, viz. physics, meteorology, biogeochemistry, geochemistry, hydrology, plankton, icthyology, hydrochemistry, geology, benthos, isotope, marine technique, acoustics and electromechanical laboratories, a library, photographic darkroom and storage rooms for the various scientific equipment. In addition to the conventional navigational equipment the geology laboratory is equipped with six echo sounders to cover various depth ranges. Other details regarding the ship-board equipment such as the various types of winches and the wires used on them, deep-sea camera, etc., reference may be made to Sysoev[2].

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The aims of the expedition were: (1) study of circulation and distribution of currents; (2) characteristics of zones of fronts; (3) temperature balance between water layers and atmosphere; (4) carbon dioxide in ocean and atmosphere and monitoring changes; (5) optical properties of sea-water; (6) relief and sedimentation; (7) suspended particles, cosmic dust, etc.; (8) chemical processes in the sea; (9) distribution of fish, plankton and benthos; (10) primary production; (11) complex and characteristics of geographical zones of the ocean; (12) natural radioactivity of sea-water, animals and sediments; (13) development of instruments and methods for studying oceans; and (14) contact with foreign scientists and organizations.

Vitiaz left Vladivostok on 6 October 1959 and commenced with the first station in the Indian Ocean at *c.* 07°15'S and 126°E. While *Galathea* was mainly interested in the exploration of deep-sea fauna with emphasis on biological aspects, the *Vitiaz* expedition was more comprehensive, tackling practically every aspect of oceanography. As is to be expected of such expeditions, the interest was more in the oceanography of the oceanic and abyssal provinces rather than in the near shore conditions.

It is an impossible task to include within the scope of this paper a review of all the results and achievements of an expedition of this magnitude and further the vast amount of data gathered are yet to be processed and analysed. The following remarks are, therefore, to be considered in that background.

The results of the earlier expeditions have shown how inadequate our knowledge is on the various animals inhabiting the deeper regions of the Indian Ocean, and this is true to a certain extent of the pelagic organisms too. This has been further evidenced by discovering new species of animals and establishing that even some of the known species have a much wider distribution than hitherto supposed. This was particularly noticed in the case of many deep-sea fishes which were formerly reported from the Pacific and Atlantic but not from the Indian Ocean. The known depth limit of life has been pushed to some 2·5 km. lower down after the *Galathea* expedition and as a result of the present expedition the depth limits of several groups of animals have been still further extended. Of the several new species of animals recorded, particular mention may be made of the ones belonging to the interesting group Pogonophora.

Extensive measurements of primary production were carried out by using ^{14}C, a technique devised during the *Galathea* expedition and now recognized as the best method available for the measurement of organic production. Production was found to be somewhat low in certain parts of the tropical region of the open ocean, but extensive areas of rich production have been noticed in the equatorial region, especially the regions of upwelling. Such regions of high productivity have been noticed near Java trench where the surface water is pushed westward by the trade-winds causing upwelling and in the western part of the Indian Ocean, in the region of the equatorial counter-current.

The first attempt at a comparison between the density of animals on the ocean floor of the tropical waters and southern hemisphere and those of the North Atlantic and other waters was made during the *Galathea* expedition. This showed that in tropical and subtropical coastal waters the weights per square metre are considerably lower, 50 to 100 times lower, than in similar waters in north-west Europe. The general rule that density of bottom animals decreases, with increasing distances from the coast does not appear to be the case in all tropical waters, e.g. near East Africa, the maximum density has not been found near the coast but between 100 and 150 metres out. The present findings seem to be in general agreement with this as the bottom fauna was noticed to be relatively poor in many regions of the tropical part of the Indian Ocean. Such organisms like polychaetes, nematodes, sipunculids, isopods and tanaidacids were found to be present in all samples.

Data for a detailed study of the distribution of the different water masses such as the central water mass, the equatorial water mass, the Antarctic intermediate water mass, etc., were collected and preliminary analysis indicated the need to revise some of the existing views on the subject.

One very significant fact which emerged from the study of the water masses is that at all places sampled in the Indian Ocean the oxygen at the bottom is fairly high and nowhere was found an oxygen-low layer. The investigations carried out by *Galathea* and *Vitiaz* in the various trenches reaffirmed that living organisms exist even in the deepest layers of the ocean. Up till now vertical migrations of large plankton organisms up to a depth of 6000 metres have been demonstrated and the probability of migrations affecting still deeper layers cannot be overruled. That being the case the disposal of radioactive wastes into any part of the Indian Ocean is not desirable as these are likely to be transported to the surface and dispersed by the animals living at the bottom, and this mode of dispersal may prove to be more rapid than by the movements of water masses, although evidence has been collected in support of the fact that abyssal water currents are stronger than formerly believed, an observation first made during the *Galathea* expedition.

The bottom contour was continuously studied with the aid of echo sounders and a new submarine mount about 2350 metres high rising from a depth of about 3500 metres was discovered at about 13°55′S and 53°38′E, and it was interesting that the top of the mount was free from sediments. In this connection it may be mentioned here that *Galathea* recorded a similar submarine mount 2800 metres in height rising steeply from an otherwise level bed 4000 metres deep between the Seychelles and Ceylon.

Seismo-acoustical study of sediments by the reflection method was carried out off Java near the Sunda trench and off the coast of Zanzibar. Detailed study of sediments was conducted at several places by taking core samples using gravity and piston corers. Some of these core samples reveal interesting geological history. At certain places where the depth exceeds 5500 metres these samples showed that the sediment had an upper thin layer of red clay, followed by calcarious mud and a mixture of calcarious mud and *Globigerina* ooze and in the deepest layer again red clay. This phenomenon is not common and where it occurs it is probably indicative of the fact that several thousands of years ago the depth at the particular place was of the same order as at present, but at some period the depth decreased, as suggested by the calcarious mud and *Globigerina* ooze above the red clay, followed by a subsequent sinking to the present depth which accounts for the thin top layer of red clay characteristic of depths of 5000 metres or more. Another interesting feature discovered as a result of the study of sediments was the presence of pure beach sand at the lower portion of a core sample. At about 04°43′S and 46°50′E at a depth of *c.* 4700 metres a 10-metre core sample was obtained, which consisted of an upper 2 metres of red clay mixed with calcarious ooze, and a layer of grey-green mud. The remaining 8 metres of the core were pure sand. This seems to be the first time such a core sample was obtained in the open sea and the nature of layering is suggestive of land subsidence. Many geologists and zoogeographers have believed in the existence of a land bridge connecting Africa and India by way of Madagascar and the Seychelles. There is supposed to have been a southern Palaeozoic continent called Gondwanaland including Sclater's Lemuria, which has met with the same fate as the famous Atlantis. However, not only are the mainlands and islands separated by ocean depths between 3000 and 4000 metres, but recent studies of their fauna and flora strongly contradict the idea of any connection, at any rate since the beginning of the Cretaceous period 60 million years ago. Nevertheless, the present interesting discovery recalls to one's mind the ' lost continent ' and reopens the question of its existence in the geological past.

Earlier expeditions have reported that some parts of the open ocean, particularly waters from great depths, are free from suspended matter. But during this cruise sufficient convincing evidence has been collected to show that this belief is erroneous and is perhaps the result of inadequacy of the filtering technique; on the other hand, at all places and at all depths sampled suspended matter in varying quantities was present.

Undoubtedly, many more interesting and important results will emerge from the detailed analysis of the vast amount of data collected. This will not only help in increasing our knowledge of the largest unknown area on earth, the Indian Ocean, but also form the groundwork for formulating detailed programmes during the ' Assault on the Indian Ocean ' expected to be carried out during 1962-63 when at least sixteen ships from eleven different countries are expected to participate.

Why the Indian Ocean ?

Recently, considerable interest has been shown in the exploration of the Indian Ocean, evidently because it is the least known ocean and it has several unique characteristics. The Indian Ocean is a vast environmental laboratory well suited for the investigation of various fundamental physical oceanographic problems. It is a complete ocean system, yet small enough to be studied as a whole; while it is too large for a single nation's efforts, it is ideal for an international co-operative endeavour. It offers unparalleled opportunity for a wide variety of specialized investigations because the ocean extends from the polar region through the tropical waters to a little above 20°N. In its northern part it is divided into two small oceans, the Arabian Sea and the Bay of Bengal, each subject to radical seasonal reversals of wind, and nowhere else in the world is there such a phenomenon caused by the two monsoons which has a definite, yet not fully understood, effect upon the currents and the organisms in the water. All in all, a study of the oceanic processes here will not only substantially contribute to our knowledge of these in the Indian Ocean but will also help us in understanding many of the basic problems in oceanography.

Another important feature is the apparent productivity of this ocean. Until recently it was widely believed that tropical waters are comparatively poor, but recent investigations carried out both in the inshore waters of India and in the tropical open oceans indicate strongly the need to revise these views as there are increasing evidences (*vide supra*) of unusually high productivity, particularly in regions of upwelling, convergence and divergence. Reports of mass mortality of fish between Colombo and the Gulf of Aden, estimated to be millions of tons in an area of 1000 kilometres wide and 2000 kilometres long extending across the middle of the ocean, indicate the presence of enormous fish populations in the area which is an index of high productivity, particularly in the mid-ocean. These and many other problems await solution and the proposed international programme for the exploration of the Indian Ocean will furnish fundamental and valuable scientific knowledge, some of which will have direct and immediate bearing on the economic development and human welfare of the bordering countries.

As a preliminary to the intensive investigations contemplated, the Scripps Institution of Oceanography also is planning an expedition — *Monsoon* — to the Indian Ocean during 1960-61. The results of these expeditions will provide a basis for the better appreciation of the problems by the participating nations and will help them to formulate the final plans for 1962-63.

References

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Guide for the Preparation of 'Synopses' (Abstracts) of Research Papers

'Synopsis' or 'Abstract' is an author's summary of a scientific paper published simultaneously with the paper after editorial scrutiny by the editor. The purpose of a synopsis is not only to convenience readers, but also to reduce the cost and to expedite the work of abstracting journals.

The synopsis should comprise a brief and factual summary of the contents and conclusions of the paper, a pointer to any new information which it may contain, and an indication of its relevance. It should enable the busy reader to decide more surely than he can from the mere title of the paper whether it merits his reading it.

The author of every paper is requested to provide a synopsis of it, in accordance with the following suggestions.

Style of writing — Use complete sentences rather than a mere list of headings. Any reference to the author of the article should be in the third person. Standard rather than proprietary terms should be used. Unnecessary contractions should be avoided. It should be presumed that the reader has some knowledge of the subject, but has not read the paper. The synopsis should, therefore, be intelligible in itself without reference to the paper. For example, it should not cite sections or illustrations by their numerical references in the text.

Content — As the title of the paper is usually read as part of synopsis, the opening sentence should avoid repetition of title. If, however, the title is not sufficiently indicative, the opening sentence should state the objects of investigation. It is sometimes valuable to indicate the treatment of the subject by words such as: brief, exhaustive, theoretical, etc.

The synopsis should indicate newly observed facts, conclusions of an experiment or argument, and, if possible, the essential parts of any new theory, treatment, apparatus, technique, etc.

It should contain names of new compounds, mineral species, etc., and new numerical data such as physical constants; if this is not possible, it should draw attention to them. It is important to refer to new items and observations, even though some may be incidental to the main purpose of the paper; such information, though very useful, may otherwise be hidden.

When giving experimental results, the synopsis should indicate methods used; for new methods the basic principle, range of operation and degree of accruacy should be given.

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Length — The synopsis should be as concise as possible. It should only in exceptional cases exceed 200 words, so as to permit it, when printed, to be cut out and mounted on a card.