

VII.1

History of Oceanography of the Indian Ocean

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Ancient

From the earliest civilization to 322 BC: Man hoisted sail before he saddled a horse. Water-crafts were man's first major tool for his conquest of the world.

Indian Ocean was the first ocean used for trade but the last to be explored in detail.

Survey conducted by the Archaeological Survey of India (1953–1962) in the Kathiawar peninsula gives us the knowledge of the oceans from Harappan and Vedic times (3000 BC i.e. the Indo-Aryan Period).

The Harappans had to have a good knowledge of the tides so as to effectively operate the first tidal dock of the world at Lothal (20°31'N, 70°14'E) as the tidal range at the head off the Gulf of Cambay is about 6 m.¹ A close study of the Lothal dock reveals that the Harappan ocean-engineers had also solved the problem of desilting the dock and the maintenance of constant water-level in the channel.² Three perforated stone anchors and a Persian seal found in Lothal (2300 BC) and Indian teak found in Babylon remains (3000 BC)³ give evidence that trade with West Asian ports had been well established in the Bronze Age.⁴

The Harappans carried on brisk overseas trade with Bahrain, Sumer and African countries. The establishment of merchant colonies in overseas territories is attested by the occurrence of Indus seals and weights in Oman, Bahrain, Failaka and at Ur besides Kish, Brak and Arpachiya in Mesopotamia (Iraq) and at Hissar and Susa in Elam.⁵ After the decline of Indus cities, Dwarka and, perhaps, Prabhas on Gujarat coast, were busy ports for a short period in mid-second millennium BC, while the latter half witnessed further decline in overseas trade with Mesopotamia only to be revived in the first millennium².

Broach and Sopara on the west coast of India were busy ports trading with Babylon and Alexandria.

1. *Imperial Gazetteer of India, IX, 297*, Oxford Clarendon Press, 1908.
2. Rao, S.R., *Progress and prospects of marine archaeology in India*, National Institute of Oceanography, p. 76, 1987
3. Sircar, D.C., *Sir William Meyer Endowment Lectures in History*, University of Madras, 1965–66.
4. Markanday, S. and P.S. Srivastava, In: *Oceanography — The Past*, eds., M. Sears and D. Merriman, Springer Verlag, New York, pp. 551–561, 1980.
5. Rao, S.R., *Archaeological Survey of India, 78*, 1979.

But there is hardly any record about the shipping and commerce of India between 1900 and 300 BC. For the subsequent thousand years the information on ports, ship building and sea voyages is very sketchy. Among the Indian sources, *Arthashastra* and *Yuktikalpataru* deserve mention. Foreign writers include the anonymous author of *Periplus of the Erythrean Sea*, Pliny, Fa-Hien, Hu-en-Tsang, Itsing, Marco Polo, Al Biruni, Nicolo Conti and Ablel Fazl.

The first organised maritime expedition was sent by Queen Hatchepsut of Egypt (1478 BC) to explore the Southern Red Sea and the Somali coast. Chronicles of this expedition were engraved on the walls of the Queen's temple in Egypt.⁶

Trade between India and Jerusalem is mentioned in the Bible (1015 BC) during the Vedic Period.⁴

The Phoenicians (1000 BC), the greatest maritime people of antiquity, have left no writings. They had explored the Western Ocean and at the same time navigated the Euxine Sea and the Arabian Gulf. This knowledge is only through scriptures and from scattered notices of Greek and Latin authors. They were the pilots of Solomon's fleet.⁷

The *Rigveda*, the oldest scripture of India assignable to 1600 BC, refers to a naval battle fought by Bhujyu, son of Tugra, a Rishi king, against enemies in a distant island. When Bhujyu was shipwrecked with all his followers on his return voyage, he was rescued by two Asvins in their hundred-oared galley. The *Mahabharata* mentions that the Pandavas escaped from destruction in a ship constructed by Vidura and provided with weapons and equipment suitable for defying a hurricane. *Sisupalvadha* of Magha mentions that Sri Krishna, while going from Dwarka to Hastinapur, saw merchants coming from foreign countries in ships laden with merchandise and exporting Indian goods. The Pali texts referring to sea voyages mention occasionally the number of members and the quantity of special cargo carried in the ship. For instance, the *Raja Valliya* says that the ship in which Prince Vijaya was sent away by Sinhaha (Simha Babu) of Bengal could accommodate 700 followers of Vijaya. Vijaya landed in 543 BC, on the day of *Nirvana* of Buddha and was installed the king and became the founder of the great dynasty of Ceylon. The *Mahajanaka Jataka* mentions a ship involving 700 crew and passengers. The wrecked ship of *Valahassa Jataka* is said to have carried 500 passengers. Several paintings of ancient Indian ships could be seen in some of the caves of Ajanta.²

The *Satapathra Brahmana* (Veda 1000-600 BC) suggests that the cause of water motion in the sea is wind. During the Jain and Buddhist times (600-325 BC), in some Jain texts the Lavana Ocean is discussed, including its dimensions, abysses, tidal action, islands and the depths of water.⁴

6. Aleem, A.A., *Proceedings of the Royal Society, Edinburgh*, 73, pp. 333-343, 1972.

7. The history of maritime and inland discovery, *Cabinet Cyclopaedia*, 1830.

The Pali literature of the Buddhists give references to ocean trade and navigation with West Asian kingdom of Baveru, (identified as Babylon) and is said to have carried a peacock (*Jatakas*).

Aryasura's *Jatakamala* gives evidence of the knowledge of oceanography during the Buddhist period and describes a maritime code. It tells the story of Suparanga, a clever navigator, who assisted the sailors to sail from Bharukakkha (a port north of Bombay, now extinct) during a cyclonic storm and kept the ship afloat by keeping the sides firm by reinforcement with stones and sand and arrived back to the same port, after four months voyage, crossing seven seas, bringing along with them silver, gold, sapphires and beryls. Aryasura, in addition, distinguished between waves and currents.

Davids (1899)⁸, quotes a Buddhist passage referring to early sea trade. 'In the *Kevaddha Sutta* of Digha, 5th cent. BC, the Buddha says that the ocean-going merchants took with them a shore-sighting bird. Pliny mentions them as used by the Singalese in the 1st cent. on the Persian ships. Cosmas Indicopleute found this same custom in Ceylon in the 6th cent. AD, merchants depending on shore-sighting birds instead of observations of the sun or stars.'

Darius the Great (521-485 BC) appreciated the value of linking Persia with India and Egypt by sea, and for this purpose he organised some notable maritime operations.

The lanteen sail as exemplified in the Arabian dhow, the Bombay kotia, etc., came into use about 4th cent. BC but was used by Arabs and Hindus rather than by Egyptians or Greeks.

India was but a recent discovery in the time of Herodotus (445 BC). He stated that the Indus was the only river besides the Nile in which crocodiles were found.⁷

Asoka (322-302 BC) maintained trade and culture relations with southern and western kingdoms. The facts mentioned in the Buddhist texts have often been corroborated by the Greek writers. From the above facts it appears that the Indians of the Buddhist Period had a good knowledge of ocean navigation.⁴

Indian trade flourished between India and Egypt during Alexander's time (323 BC).⁹

Mauryan and Kushan Period (322 BC - AD 320): The epic *Ramayana* (600-200 BC) describes the concept of waves, the relation of tides with the moon and the influence of ocean on climate. The phenomenon of red tides is also mentioned. The Puranas (500 BC - AD 700) likewise give information about the oceans. The concept of seven continents and the causes of tides are discussed.^{9, 10}

8. Davids, T.W.R., *Journal of the Royal Asiatic Society*, p. 432, 1899.

9. Tripathi, M.P., *Development of geographic knowledge in ancient India*, Bhartiya Vidya Prakashan, Varanasi, 1969.

10. Singh, M.R., *Geographical data in the early puranas, a critical study*. Punthi Press, Calcutta, 1972.

The very intimate knowledge of Indian waters reflects the volume of traffic that had developed, at first slowly, under the Ptolemies and then much more rapidly when in the later part of 1st cent. BC Egypt became a Roman province. Strabo speaks of some six score ships in the Indian trade in his day and on the authority of Posidonius ascribes the first trading voyage to the reign of Ptolemy II (146–117 BC), the king under whom Timosthenius served. The leader was a certain Eudoxus of Cyricus, a widely travelled man who took as his guide an Indian trader, the sole survivor of a shipwreck in the Gulf of Aden who had been brought to the Egyptian court.

During this and return voyage their vessel was being driven by the prevalence of easterly monsoon. Jambolo, a Greek merchant, who while trading with Arabia was taken prisoner, stripped of his goods and put in a boat on the coast of Africa, was said to have been carried by the westerly monsoon from Africa to Ceylon. A freed man of Annius Plocanus was driven in a like manner to Ceylon. It appears at the same time or little later (AD 45), Hippalus, an enlightened navigator used this knowledge to sail across the ocean (according to the *Periplus of the Erythrean Sea*) direct to Western India and the south-west wind was therefore called after him, the "Hippalus". But by the time the *Periplus* was compiled, the three alternative routes to the Indus, to the Narmada and to the Malabar coast were well-known.¹¹

Pliny has but a passing reference to Hippalus, suggesting that between AD 73–77, when he was writing, the memory of the discoverer had faded somewhat from view.

The discovery of Hippalus opened a new ocean to Roman shipping but it is probable that Arabian and Dravidian craft had frequented that ocean for many centuries and they made use of the periodic changes of the monsoon.

Nothing was known of the Indian Ocean circulation in the 1st cent.

The particulars of the trade with the east are preserved for us in the *Periplus of the Erythrean Sea* written by one Arrian supposed to be a merchant of Alexandria.

Other Greeks followed Hippalus, improved upon him and continued to reach India in this daring way for 200 years or more. The whole period of the Julio–Claudian and Flavian emperors (31 BC – AD 96) was a golden age for Greco-Roman commerce with India and Arabia.¹²

Ptolemy's map (2nd cent. AD) represents the Indian Ocean as an enclosed sea bounded on the south by land extending from Africa to China, an error which remained uncorrected till the 18th cent. "James Cook". With Ptolemy we come to the end of the scientific oceanographers of classical times.

During the 3rd cent. AD, with the economic decline of the Roman Empire and the depreciation of the currency, all these Greek traffic withered away which was proved by the almost complete absence of Roman coins in India after Caracalla (AD 212–217).¹²

11. Taylor, E.G.R., *The haven finding art*, Hollis and Carter, London, 1956.

12. Hourani, G.F., *Arab seafaring in the Indian Ocean in ancient, early and medieval times*, Octagon Books, New York, 1975.

Pre-Islamic Arabs had a good knowledge of stars and their movements, relative to the movement of the moon, of wind directions and seasons and of ocean currents.¹³

According to modern sailing directions the normal rise of the tide in the Gulf of Khambat is 25 feet and it may reach upto 33 feet at spring tides while the tidal stream runs upto 6 to 7 knots, and even if the bay before it is (says the Periplus) safely crossed, the entrance to the river Narmada, leading to the city of Barygara (Broach) on its banks can be found only with difficulty. The shore is so low as to be invisible and there are shoals in the mouth of the river. It was for this reason (the writer continues) that the local ruler kept a number of fishermen in his employ who could act as pilots and bring boats up the channel. This is the first mention of pilotage in local waters.¹¹

Eratosthenes (surveyor of the earth, 194 BC) got the information of eastern coast of Africa from Timosthenius. He also mentioned India and Thinae. He was the first who used parallels and fixed latitudes of places in his map.

Medieval Period

AD 500 — Beginning of British Period: The sea is a boundless expanse — trust it little, fear it much — Amr Ibn Al.⁹

Troublesome currents near the mouth of the Gulf of Aden were noted in the 6th cent. by a Greco-Egyptian merchant Cosmas Indicopleustes, in his Christian topography written sometime between AD 535 and 547. In the 7th cent. the Greek sailors disappeared from the Arabian Sea to be replaced principally by the Arabs.¹⁴

Suleiman, a Persian sailor, appears to have been acquainted with the summer monsoon in the ninth century. Suleiman makes no mention of currents but he was aware of the semi-diurnal tide.¹⁴

In the 10th c., an Arab of Baghdad, Abdul Hassan Ibn Hussein Ibn Ali El Masudi wrote a book called "*The Meadows of Gold and Mines of Gems*" published in the year AD 947, contains the earliest reference to semi-annually reversing currents in the North Indian Ocean.¹⁴

The change in currents is mentioned again in the 12th cent. in the, "Geography of Abu Abdallah Mohamed Bin Mohamed El Edrisi" published in AD 1154. He also refers to the word 'Akaseer' for sand-banks not suitable for navigation in contrast to Dhahra (Zahra) for coral reefs, while cyclonic winds were frequently referred to as Al Tannin.¹³

Neither Masudi nor Edrisi state when the seasonal reversal of currents was first observed.¹⁴

Both El Masudi (947) and Ibn Jabir (1185) comment on protecting ships in the Indian Ocean and Red Sea against fouling organisms, holes being filled with palm fibres soaked in

13. Aleem, A.A., *Deep-sea Research*, 14, pp. 459-463, 1967.

14. Warren, B.A., *Deep-sea Research*, 13, pp. 167-171, 1966.

whale oil and plugged with Naura (a sort of calcium plaster) and painted with tar. Nails were not used in Indian Ocean ships until the 15th cent. Ibn Jabir, thought that the ships fixed together with ropes resisted impact on coral reefs to a better extent than those rigged with nails. Indian ships differed from Mediterranean ships in having lanteen sails unlike the quadrangular.¹³

Information on dimensions of seas, tides and navigation could be traced in such geographical books known as "Al Masalek Wal Mamalek" or "Kingdoms and Routes", most of which were written between 9th and 12th cent. These books were illustrated with maps. Of particular interest is the map of El Edrisi (1154).¹³

The earliest mention of rahmani (nautical directory) is by Al-Maqdis at the end of 10th cent. which gives the information of winds, coast, reefs, etc.¹²

The magnetic needle was known in China from ancient times but there is no record of its nautical use as a compass before the end of the 11th cent. by Arabs and Persian ships. The earliest European mentioned is in a French poem (12th cent.) and in the 13th cent. there are several references in French, Arabic and other literature. It never played more than a subordinate part in navigation in the Indian Ocean because of some technical defects and still more because it was not found necessary under the clear tropical skies, when the celestial bodies always gave sufficient guidance. Shore-sighting pigeons were also employed in some parts of the Indian Ocean.¹²

Steering by soundings was a form of Chinese pilotage.¹⁵

Arab scholars and seamen have contributed since the 9th cent., to European knowledge, among others, Arabic numerals, trigonometry and logarithms which facilitated calculations. This is in addition to the astrolabe in a new refined form, the quadrant represented by Al Khwari-zomi's staff and several accurate astronomical tables and almanacs. Without such tools, together with the lanteen sail introduced from the Indian Ocean through the Arabs, the great maritime voyages would not have been possible. It is to be added that until the beginning of the 15th cent. the Portuguese pilots had no quadrants and were using cumbersome Roman numerals. The science of astronavigation is undoubtedly an Arab development.

Altitude sailing, correction of latitude through the guards of the Little Bear as well as lunar distances were practised by Arab pilots.¹³

In the 14th cent. Abu Abd Mohammed Ibn Abd Allah El Lawati, known by the surname of Ibn Batuta, during his vast travels mentioned about whales, pearl fisheries, etc. He said that the Maldive islands were about 2000 in number.⁷ Ibn Batuta noticed that the voyages from Calicut and other Malabar ports to China were made only in Chinese junks.¹²

At the end of the 15th cent., the famous pilot Shihab al Din Ahmad Ibn Majid composed an excellent rahmani (nautical directory) based on his own experiences as well as on previous books. He also prepared a map of the Indian Ocean based on ancient literature. This map is

15. Ballard, G.A., *Rulers of the Indian Ocean*, Duckworth, London, 1927.

presented in his book *Mohit* (AD 1554) and he also discussed monsoon winds. Up to this time the Arabs remained the leading traders and mariners of the Indian Ocean. This lead was broken by the entry of the Portuguese into eastern waters. In 1498, Vasco-da-Gama took an Arab pilot (Ahmad-Ibn-Majid) to navigate his passage to India.¹²

As per Cabinet Cyclopaedia⁷ two pilots are mentioned, in Mozambique (i.e. a pilot from Mozambique) and one in Melinda (a pilot, Malemo Cana, Indian, of Gujarat), given to him by the king of Melinda. When the Portuguese showed Ibn Majid (the pilot who guided Vasco-da-Gama from Malindi to Calicut), their astrolabe and quadrants in 1498, he was not in the least surprised, saying that the Arabs had similar instruments. Aleem¹³ says that Ibn Majid could not have been Vasco-da-Gama's pilot. He says a Gujarati Moslem was the pilot.

The Arabs could not compete with the Portuguese and the other European nations, which followed later. Since that year Arab navigation in the Indian Ocean has undergone a slow decline. Unlike the Arabs, who still used the ships with sails, other nations had come with steam-driven and oil-driven ships.¹² Vasco-da-Gama and Magellan were the early oceanographers after the Phoenicians.¹⁶

The Russian voyager, Afanasi Nikitin, came to India in AD 1469 on an Indian ship. A good description of the Muslim Period (AD 1200–1757) was presented by Marco Polo, who visited India in the 13th cent. AD.⁴

There were seven expeditions from China between 1405 and 1433. During these expeditions they visited Java, Sumatra, Ceylon, Calicut, Siam, Cochin, Quilon, Aden, Mogadhishiu, Malandi, South Arabia and African coast. It has been suggested that Asian sailors never rounded the Cape of Good Hope because of want of courage rather than of technical equipment. After this the maritime activities were reduced to a minimum.¹⁷

The Chinese navigators knew the method of finding and running down the latitude.¹¹

From the *Voyage of Sulayman, the Merchant*, written by Ibn Wahab (1851), Fernand¹⁸ gives a vivid description of the maritime route to India and China. Arabian and Persian ships covered this route to China in four cycles, each lasting for a lunar month. During these voyages, pilots described places of freshwater, made notes on tides, typhoons and volcanoes. Navigation from Arabia to Cape Comorin was coined as being "under the wind".¹³

British Period

AD 1757–1947: Oceanography as an established science is still less than a 100 years old, being well established only after World War II.

Studies of the sea promised to extend the life expectancy of the country's sea areas and

16. Hardman, W., *Founders of Oceanography and their work*, Edward Arnold, London, 1923.

17. Needham, J., *Science and Civilization in China*, pt. III, Cambridge, 1971.

18. Ferrand, G., *Voyage de marchand Sulayman en inde et en Chine*, 1922.

to minimise the sacrifice of cargo that was spread each year on poorly charted waters.

Oceanography is the study of the world beneath the surface of the sea (definition by Henry Bigelow in 1928).¹⁹

In French the word oceanographic was used in late 1500s but did not survive. It reappeared in 1878 and was defined as "la description de l'ocean". At about the same time the Germans were using the word, "Thalassographic" to mean the study of gulfs and seas. In the early 1880s the German chemist Wilhelm Dittmar was among the first to use the word oceanography in English and by the close of the century it was in common use.

The Madras Meteorological Observatory was established in 1792. James Cooper published the first climatological atlas on the winds and cyclones in the Indian Ocean in 1801. The tidal observations in the Hooghly river started in 1707 (Wadia 1938).²⁰ The Australian ship 'Novara' (1857–1859) worked mainly in the Southern Asia, between South Africa and Amsterdam and San Paulo Islands. The 'Challenger' twice visited the Southern Indian Ocean but omitted the northern half. The "Gazelle" (1874–1899) cruised between Cape Town and Australia; and "Valdivia" (1895–1899) in the Red Sea, East Africa, Ceylon, Nicobar and Sumatra. The "Gauss" (1902–1903) made some observations in the Indian Ocean en route to the southern seas and so did 'Planet' (1906–1907).

The 'Dana' (1928–1930) cruised around the Carlsberg Ridge and 'Snellius' (1929) in the Malayan Archipelago.²¹

The hydrographic survey on the Indian coastal areas were begun in 1832 by the Royal Indian Navy. The Marine Survey Department of the Indian Navy was established in 1874 and RIMS 'Investigator I' was commissioned in 1881 (Investigator I and II between 1880 and 1925).⁴

Modern oceanography was born on Dec 21, 1872, the day on which HMS 'Challenger' was put to sea from Portsmouth, England, on her great voyage of discovery that lasted nearly 4 years and during which she sailed round the world, across the three great oceans, Atlantic, Pacific and Indian. While the plans for the Challenger expedition were being drawn up, the Royal Asiatic Society of Bengal approached the Government of India to carry out similar searches in the northern part of the Indian Ocean. The first appointment of a Surgeon Naturalist to the Marine Survey of India was actually made in 1875, though the Survey did not possess a sea-going vessel until 1880, when the RIMS 'Investigator' was launched. The 'Investigator' was supplied with apparatus for deep-sea research by the presentation of a selection of gears that had

19. Bigelow, H., *Report submitted to the National Academy of Sciences, USA from the NAS Committee on Oceanography*, p. 1, 1929.

20. Wadia, D.N., *Progress of science in India during the past twenty-five years*, ed., B. Prasad, Indian Science Congress Association, Calcutta, pp. 86–132, 1938.

21. Aleem, A.A., and S.A. Morcos, *Deep-sea Research*, 31A, pp. 583–588, 1984.

actually been used by the 'Challenger' during her round-the-world cruise. For nearly 50 years a succession of Surgeon Naturalists had been carrying out the investigations of deep-sea fauna of the Indian waters in the Laccadive Sea.

Darwin (1842)²² was among the first to study the Indian Ocean reefs at Cocos, Keeling and Mauritius in 1836.

In January 1887 Capt. Murray asked for Capt. Wharton's help to collect some samples of beach rocks and coral reefs from Christmas Islands, who in turn asked Capt. Maclear (HMS 'Flying Fish') to do so. Murray, whilst analysing, found a pebble of pure calcium phosphate previously unknown from coral islands. Murray again asked Wharton to arrange a thorough exploration including the collection of rocks from the highest part of the islands as well as from the shore. Capt. Pelham Aldrich (HMS 'Egeria') was ordered to visit the islands during a sounding survey that he was to undertake from Malaya to Mauritius. During October 1887, a ten day exploration of Christmas Islands was undertaken and 21 geological specimens were collected for Murray. He again identified calcium phosphate and became convinced that rich beds of this rock were to be found on Christmas Islands. As a result of his findings, the British took possession of this Island on June 6, 1888.

A series of cruises were organised by the Royal Indian Marine Ships (RIMS) in the Indian Ocean, from 1881 onwards.

J. Stanley Gardiner and R.B. Seymour Sewell (1899–1900) sailed to Minicoy through Maldiv Islands to Addu Atoll. Sewell worked in the Maldives, Andaman and Nicobar Islands and led the John Murray expedition in 1933–34. Alexander Agassiz (1903) also cruised through Maldives in 1901–1902 but his account is of little value.²³ In 1858, the Australian frigate 'Novara' on a world cruise visited Car Nicobar. During this expedition rock samples and fossils were collected by geologists.

The Danish research vessel 'Dana' had crossed the Western Indian Ocean from Ceylon to Madagascar and Mombassa during circumnavigation from 1928–1930 and had discovered the Carlsberg Ridge.

The joint Anglo–Egyptian Expedition sailed on September 3, 1933, from the port of Alexandria on board the Egyptian research vessel 'Mabahiss'. It was a nine month long expedition with its 10 cruises and 209 stations which undertook research in the Red Sea and the Western Indian Ocean. It remained the longest and the most thoroughly organised expedition to work in the Northern Indian Ocean till then. At the time of this expedition the Indian Ocean was almost a "mare incognita" and indeed remained so until the International Indian Ocean Expedition. However, in Egypt, this expedition is remembered as the most important boost to its development. As a result of this expedition, Egypt was able to have its own expedition in the

22. Darwin, C., *The structure and distribution of coral reefs*, Gordon, Smith Elder, London, pp. 214, 1842.

23. Stoddart, D.R. and M. Young (eds.), *Symposia of the Zoological Society of London*, 28, pp. 584, 1971.

Northern Red Sea and gained enough skill in oceanography to found the first department of oceanography in the country, the growth of what is now the Egyptian Institute of Oceanography and Fisheries.

At the time the 'Mabahiss' sailed from Alexandria, the Arabian Sea was certainly as Stanley Gardiner (1933)²⁴ wrote, "one of the least known of oceanic areas". While the continental coastal waters and the shallow regions around the major island groups had been reasonably well surveyed because of their navigational importance, very few soundings were available in the deeper mid-ocean regions. The most important of the very few echo-sounding runs in the region was that of the 'Dana' between Colombo and Seychelles in 1930.

By the time the 'Mabahiss' returned she had obtained continuous echo-sounder records for the greater part of her 22000 nautical mile track so that Farquharson's (1936)²⁵ bathymetric charts contained all the major topographical features of the region which the echo-sounder records produced along with three major discoveries.

The first of these was the discovery of a series of NE-SW trending ridges in the Gulf of Aden which are now recognised as transform faults between the African and the Arabian plates.

The second major advance was the further mapping of the Carlsberg Ridge confirming Schmidt's guess that it extended towards Socotra. A cruise from Karachi to Bombay revealed a series of gullies and ridges parallel to the coastline.

Scientific discoveries of 'Mabahiss' included taxonomic studies. The main accomplishments of the expedition were in bathymetry, physical and chemical oceanography and in geological and mineralogical investigations.

The main physical oceanographic results of the expedition was the pattern of water-flow between the Red Sea and the Gulf of Aden and the general circulation within the Arabian Sea. The main objective of the 'John Murray' Expedition was the study of the biology of the Arabian Sea and particularly the bottom living animals which could be collected in trawls and dredges.²⁶

A more or less azoic area of the sea floor extending from about 100 m to 1300 m depth off the coast of Arabia and somewhat deeper in the Gulf of Oman was an unexpected discovery. The mud brought up smelt strongly of hydrogen sulphide. This was the first record in the open sea.

Gilson's report (1937)²⁷ is an excellent summary of the state of knowledge of phytoplankton ecology which was developing rapidly during the 1920s and 30s.

Gilson's contributions and others confirmed earlier work indicating the importance of thermal stratification of the water column in controlling primary productivity.

24. Gardiner, J.S., *Geographical Journal*, 81, pp. 570-573, 1933.

25. Farquharson, W.I., *Scientific Reports — The John Murray Expedition 1933-34*, 1(2) pp. 43-61, 1936.

26. Deacon, G.E.R., and A.L. Rice, *Deep Sea Challenge*, UNESCO, 1986.

27. Gilson, H.C., *Scientific Reports — The John Murray Expedition 1933-34*, 2(2), pp. 21-81, 1937.

Post-Independence Period

1947–1990: From 1947 onwards considerable resources began to be diverted towards the study of the oceans with the primary object to obtain more food from the sea. Thus the investigations in ocean science started to be concentrated mostly in the fields of marine biology and fisheries. A few universities initiated courses in marine biology and oceanography at the post-graduate level. With the setting up of Central Marine Fisheries Research Institute in 1947, the need for oceanographic investigations as an integral part of marine fisheries research was finally recognized.²⁸

The post-war developments in oceanography in other countries were in the form of long round-the-world expeditions. Ships which cruised in the Indian Ocean either took Indian scientists on board for short periods or provided material for research. Notable among these ships were 'John Murray' from the United Kingdom; 'Albatross' from Sweden; 'Galathea' from Denmark; and 'Vityaz' from the Soviet Union. Indian marine biologists utilized these opportunities and in their investigations in near-shore and coastal waters, developed a substantial amount of knowledge on marine life. On the works done by Indian scientists, several well-known marine biologists from abroad remarked that they were amazed to find works of such high quality coming out of laboratories which were equipped either poorly or with very modest facilities.

Gradually, joint international projects on fisheries began to be established. Notable among these is the Indo-Norwegian Project with its base first at Quilon and then at Cochin. Institutes such as the Deep-sea Fishing Station, the Central Institute of Fisheries Technology and others were also established to explore the fishery resources around India and to improve upon the fishing methods.

Of all the seas, the Indian Ocean is the only ocean which is subjected to the bi-annual reversal in the direction of wind-systems. This phenomenon is called the 'monsoon' and it has a tremendous influence on the livelihood and economy of the countries bordering the Indian Ocean. Realizing this little understood phenomenon and many other features of the Indian Ocean which are totally unknown, the world community of oceanographers launched a co-operative investigation called the International Indian Ocean Expedition (IIOE). This was the first major co-operative investigation of the Intergovernmental Oceanographic Commission (IOC) of UNESCO. The IOC was established in 1961, following the successful completion of the International Geophysical Year, 1957–58. The International Indian Ocean Expedition began in 1961 and ended in 1965. In this programme, about 40 ships and 50 countries participated. Notable among the ships which took part were 'R.V. Anton Bruun', 'R.V. Argo', 'R.V. Horizon' and 'R.V. Atlantis II', all of the U.S.A.; 'R.R.S. Discovery' of the United Kingdom; 'R.V. Vityaz' and 'R.V. Akademik Knipovitch' of the U.S.S.R.; 'F.S. Meteor' of the Federal Republic of Germany; and 'R.V. Varuna' and 'I.N.S. Kistna' from India. The Indian National Committee on

28. Qasim, S.Z. and R. Sengupta, *Indian and Eastern Engineers*, Bombay, 119, pp. 57–59, 1977.

Oceanic Research (INCOR) was established in 1962 by the Council of Scientific and Industrial Research (CSIR) to organize the Indian participation in the IIOE.

The Indian oceanographers made full use of the opportunities provided during the IIOE. Several young scientists obtained their training on board some of the foreign ships. A team of young scientists went regularly on board 'Kistna' to collect all types of information from the Indian Ocean in all weather conditions. India played host to different participating vessels in the programme and to the scientists from abroad. Thus, it can be said, that the IIOE helped in establishing a nucleus of well-trained oceanographers in India.

In 1962, an international centre, called the Indian Ocean Biological Centre (IOBC), was developed at Cochin with the help of UNESCO. Its function was to provide shore-based facilities for sorting and identification of zooplankton collected during the expedition by different ships. This effort gave rise to the publication of several well-illustrated atlases on zooplankton of the Indian Ocean.

The termination of the IIOE saw the birth of a new institution called the National Institute of Oceanography (NIO) in 1966 under the CSIR. This led to the long-awaited recognition of the science of oceanography in the country. The NIO with its headquarters in Goa and three regional centres at Cochin, Bombay and Waltair is the only institution in India devoted exclusively to the study of the oceans.

Parallel developments also occurred in the universities and today almost all branches of oceanography are being included in the curriculum of studies at the post-graduate level of several Indian Universities.

The first oceanographic research vessel of India 'Gaveshani' was commissioned in 1976 for NIO. This, indeed, helped in the evolution of old time oceanography in India into new time oceanography.

The organizations which are involved in research in marine sciences in India, as of now, are, National Institute of Oceanography, Geological Survey of India, Central Marine Fisheries Research Institute and several universities in the littoral states. The Department of Ocean Development, established in 1981, has as its task the co-ordinating and funding of all activities in marine sciences, including exploration and exploitation, in India. The country is having four large oceanographic research vessels e.g. 'Gaveshani', 'Sagar Kanya', 'Sagar Sampada' and 'Samudra Manthan'. All these ships are dedicated fulltime to explore the marine living and non-living resources along the 7500 km long Indian coastline and in the 2.015 million sq. km of exclusive economic zone. A wealth of data on physical including monsoons, chemical including pollution, biological including fisheries and geological including mineral resources from the Indian Ocean have been accumulated by cruises of these research ships.

India has initiated a venture to explore the Indian Ocean sector of the Southern Ocean (Antarctic Ocean) from 1981, as part of a National Programme on Antarctic Research. So far eleven expeditions went and came back from the icy continent.