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Previous Results

THE INDIAN OCEAN LITHOSPHERE

Around the Jurassic era, the Gondwana supercontinent broke into several continental fragments : India, Australia, Africa, Arabia and South America. Subsequently, the outward drift of the first four from the centrepiece continent of Antarctica initiated in the upper Jurassic led to the creation of the Indian Ocean to fill the intervening spaces. The new oceanic lithosphere therefore naturally incorporated the oceanic aprons accreted to all the surrounding constituent plates of Gondwanaland including the various spreading ridges, transform faults, a subduction zone as well as a late developed diffused zone of intra-plate deformation caused by compression of its ageing northern segment, in turn, produced by increased resistance to the northward penetration of the Indian plate at the Himalayan convergence. Throughout its evolution, changing rates and configuration of ridge axis volcanism as well as its passage over a number of underlying mantle plumes constantly modified this youngest of the oceanic lithospheres resulting in the development of complex structural and physiographic features (Fig.1.1) unusual to the ordinarily placid regime of ocean floor spreading that constructed the lithospheres of other world oceans. Detailed investigations of these characteristic features created under unusual conditions therefore hold considerable promise of illuminating their contexts and also provide fruitful grounds for testing refined models of the plate tectonic process.

The first systematic geological and geophysical investigations in the Indian ocean began with the International Indian Ocean Expedition (1959-65) which led to the mapping of its major physiographic features, and to the publication of an Atlas in 1975. This was followed by Deep Sea Drilling Project - (DSDP, legs, 22-29) and the Ocean Drilling Programme (ODP, legs 115-123) when geological and geophysical data were collected in several wells drilled up to the basement. A surprising recovery made during this operation was of the lower crust and upper mantle ultramafic rocks and gabbro from the Atlantis II fracture zone of the South West Indian Ridge (SWIR). Continuing research endeavours in the Indian ocean spurred by these earlier initiatives have since added greatly to our knowledge of its important

features: the spreading ridges and fracture zones, the sedimentary fans, Islands and Island Arcs.

The high resolution acoustic investigations of the relatively slow to ultra slow spreading mid-oceanic ridge systems of the Indian Ocean are most interesting and have deciphered the axial and off the ridge axes morphological

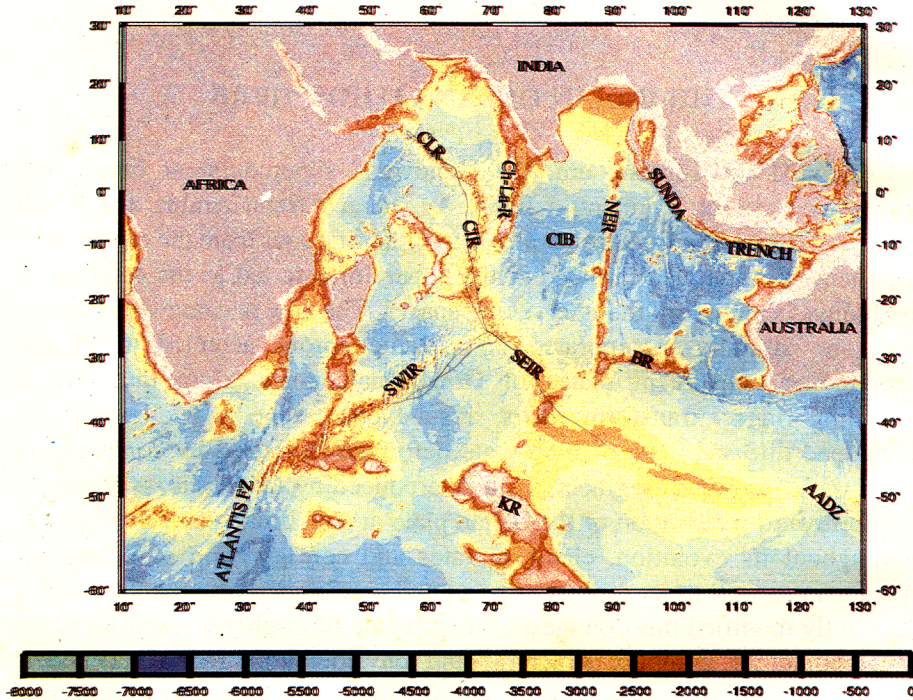


Fig.1.1. Generalised Indian Ocean Bathymetry (prepared from GEBCO, 1982 data). CLR - Carlsberg Ridge, Ch-La-R - Chagos Laccadive Ridge, NER - Ninetyeast Ridge, CIR - Central Indian Ridge, SWIR - South West Indian Ridge, SEIR - South East Indian Ridge, KR - Keruguelen Ridge, BR - Broken Ridge and CIB - Central Indian Basin.

features; the ridge propagating offset fabric of the SWIR and the South East Indian Ridge (SEIR); non-transform offsets, very large (~6000m) sea-floor

reliefs of SWIR; very short to long ridge segments; axial highs and depressions despite constant (70-80mm yr⁻¹) spreading rate of the SEIR. Several hotspots; the Kerguelen, the Reunion, the Marion, the Crozet and the Amsterdam/St. Paul and the Australian-Antarctica discordance Zone (AADZ) with cold mantle material and their role in transfer of energy fluxes from excess thermal energy areas to colder regions have been studied to explain the presence of some of the morphological features. The unique and exciting seafloor processes of the Indian ocean thus, became targets to study in greater detail under the aegis of the national, international and Inter Ridge programmes with a view to characterising the processes of the global ridge systems.

The second major crustal features are the sedimentary fans of the northern Indian Ocean. The Bengal Fan of the northeast Indian Ocean and Indus Fan of the northwest Indian Ocean are extending towards south for about 3000 km. The Bengal Fan with >16 km thick sediments is underlain by the early Cretaceous oceanic basement, the 85°E Ridge, the Ninetyeast Ridge and NW-SE trending fracture zones. The Indus Fan of about 11 km thick sediments is developed off the passive continental margin of Pakistan-India. The fan sediments are post-Eocene and overlie the late Cretaceous/early Tertiary clastics. The sediments recorded imprints of the past geologic and tectonic processes and have been studied to know the changes in plate motions and their reorganisations, build up of major geologic features like Himalayas due to collision, eustatic sea levels and sedimentation. The geological and geophysical observations have been utilized in identifying the volcanic edifice of the second order linear ridges e.g. the Chagos-Laccadive Ridge, the Prathap Ridge, the Ninetyeast Ridge and the 85°E Ridge. These features have been emplaced due to the passage of the Indian plate over relatively stationary hotspots. Understanding the process of continental rift, the associated volcanism and the evolution of passive continental margins are presently the targets for detailed studies. Focussed efforts are needed to evaluate their genesis. The Argo Abyssal Plain associated with a complicated tectonic fabric, sediment filled grabens, volcanic massifs, have been the targets in the ODP programmes, for sampling the oldest Mesozoic sediments and basement.

The only subduction zone of the Indian Ocean is the Sunda Trench that converges the Indo-Australian plate beneath the Burmese plate. Much of the ocean floor generated in the northeast Indian Ocean during the period 156 - 56 Ma (magnetic chron M26/M25 to A24) was consumed at an average rate of 4 to 6 cm/yr. The recent repetitive volcanism (1989-92) at the Barren Islands of the Andaman Sea mark the ongoing subduction. Thus, knowledge of the geometry, nature and age of the crust and quantum of sediments being subducted at the zone is critical in deciphering the stress pattern and mechanism, seismogenic zonation, volcanism and fluid flow, mass balance due to subduction and mineralisation of the region.

Indian ocean floor is also marked with the Island Arcs i.e. the Andaman and Nicobar Islands, chain of seamounts i.e. the Afanasy Nikitin Seamount etc. They are parallel to the major structural boundaries such as subduction zone and fracture zones. These volcanic edifices owe their origin due to excess volcanism at the ridge-transform junctions and further rejuvenation of mid-plate volcanism. The back-arc basin of the Andaman Sea with recent, 11 Ma evolving spreading centre and hydrothermal mineralisations are also interesting to investigate. The presently buried Wharton Ridge's interactions with the Kerguelen hotspot in the northeast Indian Ocean and repeated jumps of the ridge during 68 Ma - 42 Ma have tectonically implicated the large size of the Ninetyeast Ridge due to excess volcanism in the south and transfer of about 1200 km stretch of crust of Antarctic plate to the Indian plate between 86°E Fracture Zone and the Ninetyeast Ridge.

The intrinsic and least understood morphological features of the Southern Indian Ocean are the numerous Islands: the Prince Edward (~118 m above sea level), Crozet Islands, Heard Island, St. Paul Island and St. Amsterdam Island and the plateaus; the Kerguelen plateau, Mascarene plateau etc. and the Fracture zones; Indira FZ, Indrani FZ and 86°E FZ.

A thorough study of the nature, structure and origin of the Indian Ocean crustal features is critical to understand their evolution, tectonism and reconstruction of the Gondwanaland for Paleo-times. Contrary to the plate tectonic concept, deformation of the Indian plate in its middle i.e. the Central Indian Ocean Basin (CIOB) has been reported in early seventies. Its structural boundaries are : in the north continental margin of India and Sri Lanka, in the west the Chagos-Laccadive Ridge, in the east the Ninetyeast Ridge, in the south the Southeast Indian Ridge. The area is covered with 0.1 km to 1.2 km thick sediments and is associated with seismicity, excess geothermal energy and anomalous free-air gravity. Its deformation signatures are even reflected in seafloor topography. The unusual and interesting phenomenon of the mid-plate region has drawn attention of the scientific community to map the crustal features and suggest tectonic model to account them. Over the years ship-borne geological and geophysical investigations have been carried out by various international groups of scientists. The deformation features of the seafloor have even been identified through the satellite gravity measurements. This formidable task of identifying the crustal features, the mechanism and tectonic forces responsible for the deformation will be incomplete in the absence of integrated geological and geophysical investigations.

An Indo-Soviet Joint Collaboration Project has been formulated under the Integrated Long Term Projects (ILTP) in areas of earth sciences sponsored by the Department of Science and Technology, New Delhi and the Academy of Sciences of the Soviet Union to study the crust and upper mantle structure in some critical regions of the Indian Ocean lithosphere, particularly of the Central Indian Ocean and modelling the dynamic evolution of the Indian Ocean lithosphere. The project envisages a critical review of the existing

information of the area, conduct shipborne investigations in critical areas, map geomorphic elements and crustal structure and suggest tectonic model to explain the unusual intraplate deformation in the area.

REVIEW OF PREVIOUS GEOPHYSICAL AND GEOLOGICAL STUDIES

The Indian Ocean floor was less studied compared to the other World oceans. Intense geological and geophysical investigations were carried out in this region only since the International Indian Ocean Expedition (IIOE) during 1959-1965. Scientific ships from 13 countries, including USSR and India, participated in the IIOE. The main results of the study were compiled in Geological and Geophysical Atlas of the Indian Ocean (1975).

In the Central Indian Basin (CIB), basic geophysical and geological data were collected during IIOE cruises of the R/V Vityaz (Shirshov Institute of Oceanology, USSR Academy of Sciences), the R/V Vema (Lamont-Doherty Geological Observatory, USA) and the R/V Argo (Scripps Institution of Oceanography, USA). These Institutes have continued the studies even after IIOE up to the end of sixties along with other Institutes. Results of the investigations were published in 1975 as an Atlas. (Geological and Geophysical Atlas of the Indian Ocean, 1975).

The intraplate deformation in the Central Indian Basin was studied first by Eittreim and Ewing (1972) from seismic reflection profiles. High seismic activity was reported in this area (Gutenberg and Richter, 1954; Stover, 1966; Sykes, 1970).

The next important development in the study of the Indian Ocean floor was during DSDP. The sites 215 and 218 of DSDP and 717, 718 and 719 of ODP Leg116 in the northern CIB and sites 214, 216 and 217 of DSDP and 757, 758 and 756 of ODP on the Ninetyeast Ridge were drilled during DSDP (Von der Borch et al. 1974; Cochran et al. 1989). Underway geophysical investigations provided essential data, which were later used to determine age of onset of intraplate deformation (Moore et al. 1974). The National Institute of Oceanography, India has deployed ORV Sagara Kanya and many other research vessels as part of the national polymetallic nodules programmes and international and Indo-Russian bilateral collaboration programmes and generated considerable amount of geological and geophysical data. The data were analysed to understand crustal structure and tectonics of the region. (Qasim and Nair, 1988; Kamesh Raju et al. 1993; Krishna et al. 1995).

The geophysical study exclusively for the intraplate deformation was undertaken by the Shirshov Institute of Oceanology in 1976 during the 58th cruise of the R/V Vityaz (Neprochnov, 1976) and continuous seismic reflection profiles (CSP), magnetic and gravimetric data were collected from