

# Historical developments in Marine Geology and some aspects of fine-grained sediments along the continental margins of India and Bengal Fan

V. Purnachandra Rao

National Institute of Oceanography, Dona Paula, Goa-403 004  
vp rao@nio.org

The geological and geophysical studies in the Indian Ocean date back to the nineteenth century. After the H.M.S. Challenger's expedition (1872-1876) several expeditions covered the deep Indian Ocean. The Andhra University, Waltair made pioneering investigations on the eastern continental margin of India in the early 1950s. However, the International Indian Ocean Expedition (IIOE: 1961-1965) is an important landmark in the history of development of geology of the western continental margin of India. Since then the morphological features of the continental margins and lateral variations in the sediment distribution along the continental margins are better investigated (Subbarao, 1964, Vora et al., 1996).

The characteristic features of the width of the shelf, depth at the shelf break and topographic features of the shelf and slope and their differences on the eastern and western margin of India have been brought out (Fig. 1A & B). The morphology of the shelf and slope varies widely on either side of the Indian margin. One of the significant findings is the occurrence of sixteen submarine canyons along the eastern margin of India (Fig. 2). Although many canyons start at ~ 400-500 m, some occur at ~ 50 m depth. Some occur off the rivers while others are associated with tectonic lineaments. Canyons are not found on the western Indian margin, except the one off Indus River.

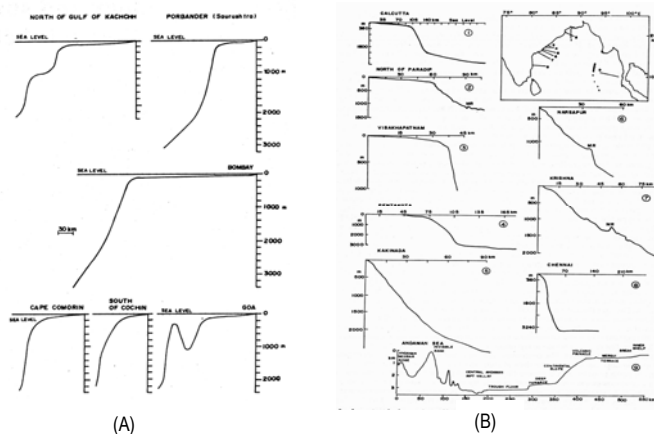


Fig. 1. Topography at certain locations on the western (A) and eastern (B) continental margin of India.

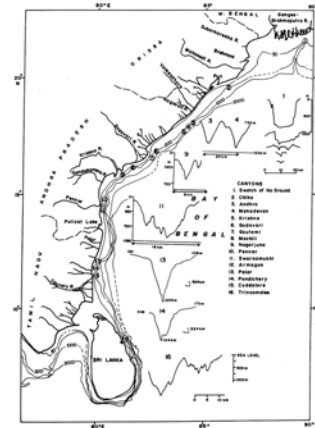


Fig2. Submarine canyons along the eastern margin of India.

Surficial sediment distribution shows terrigenous sediments are the most predominant sediment type along the continental margins and deep sea. The surficial sediments on the shelf can be divided into terrigenous, biogenous and chemogenic sediments (Rao and Wagle, 1997). Terrigenous sediments occur as sands in the near shore and silty clays on the offshore. The nearshore sandy zone (including heavy minerals) extends upto 35 m depth in eastern Indian margin and upto 15 m on the western Indian margin (Subbarao, 1964). The most important finding is the presence of relic carbonate/terrigenous sandy sediment facies of shallow water origin on the outer shelf even in areas off major rivers all along the western margin of India (Fig. 3). This facies, however, is largely buried under recent terrigenous clays along the eastern margin of India, except in small pocket areas off Chennai, Santapalli-

Visakhapatnam and Ganges. It is an indicative of low sea level conditions during the late Pleistocene/early Holocene. Authigenic minerals on the continental margins include authigenic green clays of the verdine and glaucony facies, phosphorites / phosphatic sediments, dolomites or barites. They are found to be associated with the relic zone and the adjacent upper slope. Biogenic sediments include relic sediments on the outer shelf, coral sediments on shallow Islands and pelagic sediments and oozes on the Mid-ocean ridges and deep sea floor. Organic-rich sediments on the shelf and slope are also an host of gas-charged sediments and sub-surface Gas Hydrates deposits. These were dealt separately in a different lecture. The slope sediments are silty clays with an admixture of abundant carbonate and/or siliceous tests. There are two large Deep sea Fans in the deeper Arabian Sea and Bay of Bengal known as Indus cone and Bengal Fan and

dominantly composed of terrigenous sediments brought turbidity currents originated at the river mouth. The sources of sediments can be deciphered precisely if the composition of the sediments is known.

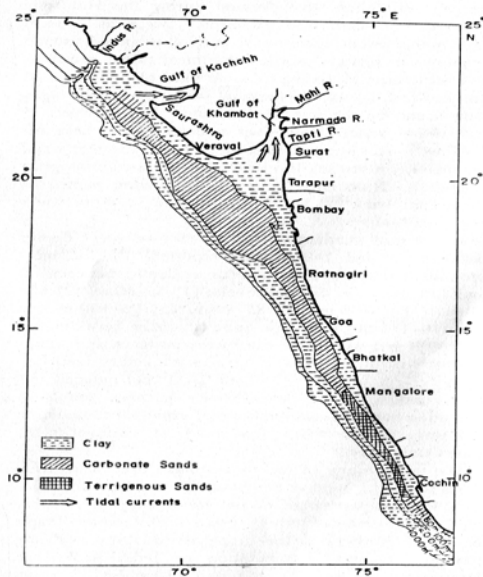


Fig. 4. Surface sediment of the western continental margin of India.

### Provenance of the Fine-grained sediments

Fine-grained terrigenous sediments deposited on the continental margins and deep-sea are mainly composed of clay minerals and amorphous material. The composition and relative abundance of the clay minerals are controlled by their source rocks and weathering conditions. However, their distribution on the continental shelf and slope is controlled by depositional processes, especially the current circulation patterns and settling of clay minerals in response to the salinity and energy conditions. As the source rocks and weathering conditions in the drainage basin of the rivers are known one can able to trace the provenance of the sediments in the oceans. Similarly, the Sr and Nd isotope signatures have been extensively used to characterize the provenance of detrital sediments. These isotopes are primarily controlled by the age of rocks. For example, the sediments weathered from the older crust have relatively more radiogenic Sr and non-radiogenic Nd than the sediments derived from the younger crust. Sr is more mobile than Nd and can be easily removed from soils during weathering. Sr isotopes are controlled by the degree of chemical weathering of source rocks, carbonate and phosphates in the drainage basin. Compositions of fine-grained sediments and Sr-Nd isotopes have been extensively used to understand the provenance of sediments on the Indian continental margins. The studies indicate that there are three distinct clay mineral assemblages: illite-chlorite-rich assemblage of the Indus, smectite-rich assemblage of the Deccan

Traps and kaolinite-smectite-rich assemblage of the Gneissic province (Fig. 5). The tidal currents operating at the Gulf of Kachchh act as barriers to the along-shore transport of Indus-borne sediments. The influence of SW monsoon current can be seen in transporting the Deccan Trap-derived sediment to further south along the shelf. Cross shelf transport of fine-grained sediments is evident especially along the southwestern Indian margin, where shelf width is narrow. The sediments on the continental slope of the NW India are an admixture of Indus-borne and Deccan Trap sediments. Sr and Nd isotopes are distinct for the sediments derived from glacial weathering and those derived from chemical weathering and also exhibit distinct variations for the clays derived from Indus, Deccan Trap and Gneissic rocks. Aeolian-derived sediments are identified on the northwestern Arabian Sea and are characterized by the dominance of palygorskite and sepiolite and to certain extent dolomite. These are transported from the arid landmass of the Arabia by winds. Similarly, the investigations on the eastern margin of India revealed six mineralogical provinces between Krishna and Ganges: Ganges province, Brahmani and Mahanadi province, mixed mineral province, Eastern Ghats coastal province, Godavari province and Krishna province. It is suggested that the Godavari-derived sediments transport northwards under the influence of NE flowing currents associated with SW monsoon winds and continue to deposit their sediment in the northern part of the shelf (Fig. 6). The sediments in the Andaman Sea have also been investigated.

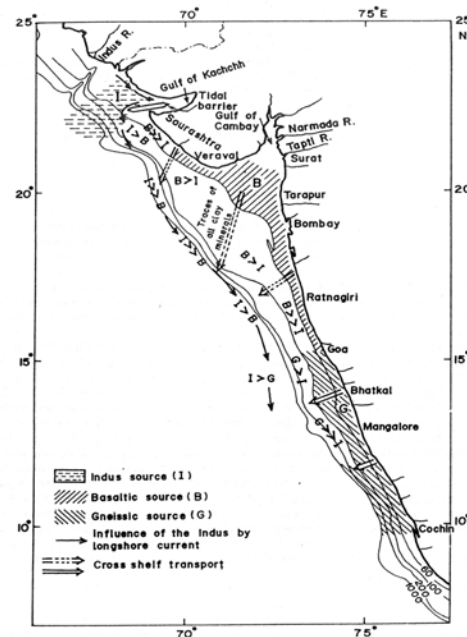


Fig. 5. Clay mineral provinces along the western margin of India.

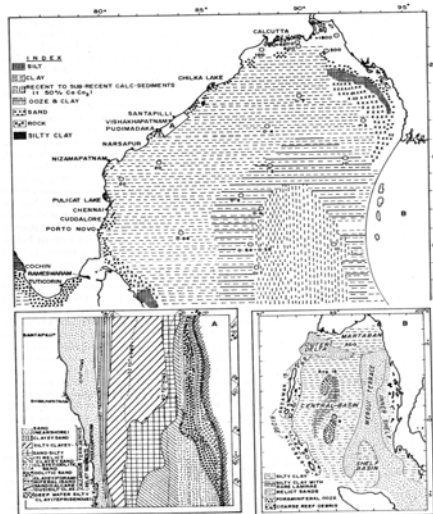


Fig. 6. Surface sediments of Bay of Bengal and Andaman Sea.

### Characteristics of Turbidites in the Bay of Bengal

The Deep-Sea Drilling Program (DSDP) and Ocean Drilling Program (ODP) sites drilled on the deep-sea Fans of the Indian Ocean brought out the characteristics of the sub-surface sediments and provenance of the sediments of the Bengal Fan (Rao and Kessarkar, 2001) and Indus cone (Naini, 1980). The oldest sediments in the Bay of Bengal are of Cretaceous age deposited after the split of India from the Antarctic landmass. Investigators could trace the changes in faunal and floral assemblages as the Indian Plate moved northwards from subtropics to tropics. When the Indian plate was collided with Asian landmass in Miocene the Himalayas were uplifted and modern Bengal Fan came into existence. As the Ganges-Brahmaputra (G-B) system draining the Himalayas continues to be the dominant source of sediment to the Bay of Bengal and distributed to the distal Bengal Fan by turbidity currents. The sediments of the Bengal Fan thus provide an unparalleled record of Himalayan erosion which in turn related to the climate and uplift history of the Himalayas. Several investigators have brought out understanding on the frequency and thickness of turbidites at different times and genetically relationship with the relief of the Himalayas and upliftment of Himalayas in different phases. The texture and composition of the turbidites vary widely. Similarly, thin bedded (5-20 m) to thick bedded (60 m) turbidites were found at different times. The rates of sedimentation varied between 15 and 350 m /My and highest sedimentation rates were recorded during Pleistocene. Three main sources of turbidity currents (TC) were recorded (Fig. 7): the TC originated from the Swatch of No Ground, TC from the southeastern Indian Margin and TC originated from the steep slopes of Sri Lanka. At the beginning, investigators thought that the Himalayan uplift and eustatic changes in sea levels are controlling factors

on the sedimentation of turbidites. Subsequent investigations based on the nature of turbidites (silt and mud turbidites) and, Sr concentrations and Sr -Nd isotopic composition of the turbidites revealed the precise provenance of the sediments. It was found that the relief and Himalayan upliftment in different phases have major controls on the turbidite sedimentation and, sea level changes have secondary importance. Similarly, the changes in the composition of the turbidites smectite, kaolinite (SK-rich) clays to illite, chlorite (IC-rich) clays at different times were thought to have originated from the turbidites originated from different regions. The Sr-Nd isotopes and  $\delta^{18}\text{O}$  studies of the quartz and feldspar yielded that both the clays were originated from the same region, but the turbidites of SK-rich levels indicate intense chemical weathering at low temperature.



Fig. 7. Clay mineral provinces of the Bay of Bengal. I-Smectite-rich province, II-Illite-chlorite and smectite province and III-Smectite-illite province.

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