

RECORD OF THE CRETACEOUS MAGNETIC QUIET ZONE IN THE DISTAL BENGAL FAN AND ITS SIGNIFICANCE IN UNDERSTANDING THE EVOLUTIONARY HISTORY OF THE NORTHEASTERN INDIAN OCEAN

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Introduction

Several plate reconstruction models have been proposed for the breakup of Pangea and the eastern Gondwanaland in which the east coast of India and the Enderby Landmass of Antarctica were juxtaposed and that the western margin of Australia lies of east of Greater India during late Jurassic (Royer et al, 1989; DuToit, 1937; Smith and Hallam, 1970; Norton and Sclater, 1979; Powell et al, 1988; Scotese et al, 1988). The early Cretaceous breakup of eastern Gondwanaland lead to the separation of India from the contiguous Antarctica-Australia around 133 Myr ago (Ramana et al, 1994) and set a stage for the evolution of the Bay of Bengal and the subsequent accumulation of sediments. The Bengal Fan was one of the thickest sedimentary basins of the World (Curray and Moore, 1971; Curray, 1991). Powell et al (1988) were of the view that the magnetic anomalies will be hard to find off east coast of India due to this huge sediment accumulation. Though extensive underway geophysical data was collected during the International Indian Ocean Expedition Programme (1959-65) (ex: Udintsev, 1975), and subsequent expeditions to unravel the evolutionary history of Indian Ocean (Mckenzie and Sclater, 1971), not much was known about the age and nature of the ocean floor of the Bengal Fan but for few speculations. Various plate reconstruction models (Royer et al, 1989) show the stage by stage evolution of the eastern Indian Ocean since late Cretaceous (84 Myr) to present. However, refined plate reconstruction models for the early opening prior to late Cretaceous are poorly constrained (Royer et al, 1992) due to the inadequate geophysical data particularly in the Bay of Bengal, northern Indian Ocean.

Recent geophysical studies (Ramana et al, 1994) in the northern Bay of Bengal revealed (Fig.1) the presence

of N30°E trending Mesozoic magnetic anomaly sequences M11 to M0 (corresponding to 132.5 to 118 Myr age old crust) and N120°E (\approx NW-SE) trending fracture zones. The direction of these fracture zones indicate the initial Indian plate motion from Antarctica-Australia immediately after the early Cretaceous breakup.

The crust between the magnetic isochrons M0 and 34, notionally referred as CMQZ (Poehls et al, 1973) was evolved during the Cretaceous long normal polarity (118-84 Myr). The magnetic anomalies observed in the CMQZ are subdued with amplitudes less than 50 nanotesla. Roots and Srivastava (1984) quoted that the mechanism for the occurrence of such magnetic smooth/quiet zones could be due to (a) period of non-reversal of the earth's magnetic field, (b) magnetization of the seafloor close to the magnetic equator, (c) spreading being slow that anomalies produced were too narrow to be individually resolved at the sea surface and (d) initial spreading between margins that were markedly oblique to the spreading direction with the consequent fragmentation of the ridge into short spreading segments and the resultant production of magnetic source blocks too small to be resolved at the sea surface. During this Cretaceous long normal polarity interval major plates reorganizations have been reported (Veevers et al, 1975; Powell et al, 1988).

Results and discussion

During the 101 cruise (April-May, 1995) of ORV Sagar Kanya, about 1200 line km of multisensored underway geophysical data comprised of seismic reflection (495 cubic inches airgun volume, 24 channel streamer, DFS V recording unit), magnetic, gravity and

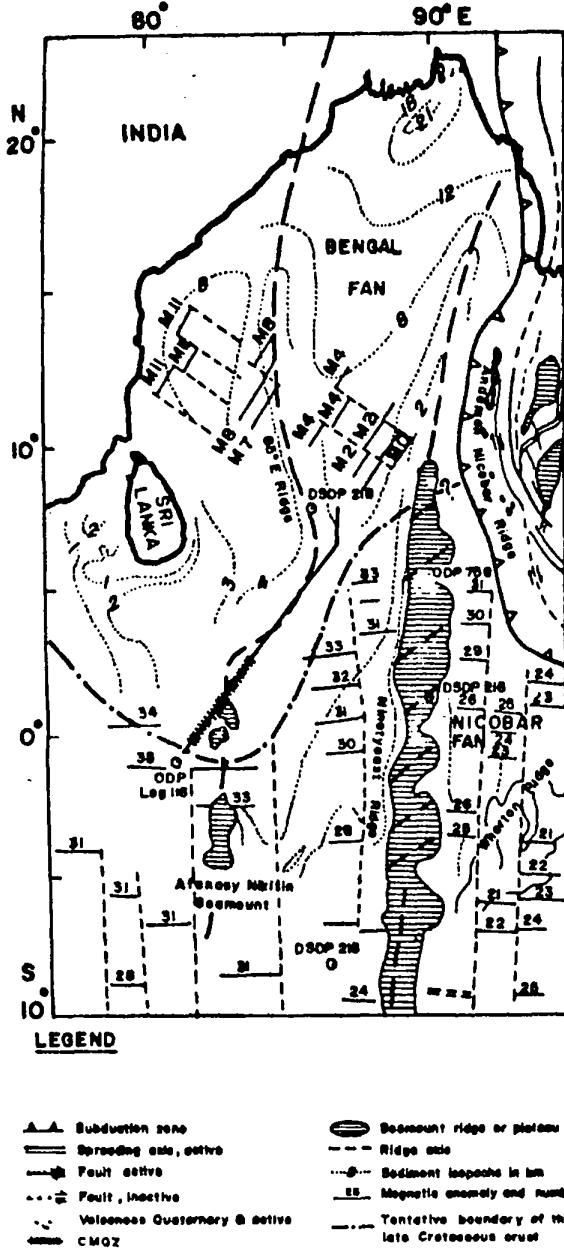


Fig.1: Tectonic summary chart of the northeastern Indian Ocean (Royer et al, 1989) and the Bay of Bengal (Curry and Munasinghe, 1991). The Mesozoic magnetic anomaly lineations and NW-SE trending fracture zones dominate the northern Bay of Bengal (Ramana et al, 1994). The thick line joining the sites of ODP Leg 116 and the vicinity of DSDP site 218

represents the multisensored geophysical transect (gravity, magnetic, bathymetry and multichannel seismic reflection data). The 415 km extent of the Cretaceous Magnetic Quiet Zone (CMQZ) sandwiched between the early Cretaceous and late Cretaceous crusts has been shown with hatching.

bathymetry have been collected along a transect joining the ODP (Ocean Drilling Programme) Sites of leg 116 and the vicinity of DSDP (Deep Sea Drilling Project) Site 218 in the Bay of Bengal.

The analysis of the geophysical data revealed a distinct record (Fig.2) of about 415 km wide CMQZ between the late Cretaceous magnetic anomaly A34 (≈ 84 Ma) and younger Mesozoic anomaly sequence M0 (118 Ma). This part of the smooth zone crust appears to be evolved with a half-spreading rate of about 1.2 cm/yr. The boundaries of the CMQZ are marked by a sharp difference in the magnetic field. This may be an edge effect and is due to the amalgamation of the CMQZ crust with the two different ages of the crust in the Bay of Bengal. The crust of the CMQZ between the magnetic anomaly isochrons M0 and 34 near the northern exposure of the Ninetyeast Ridge (Fig.1) appears to be affected by the subduction processes, resulted in a narrower width of CMQZ. This part of the CMQZ crust in the Bay of Bengal may be an exception so far as the width of the CMQZ in question is concerned. The plate reconstruction models hitherto presented by various authors are incomplete due to lack of the information about the age of the crust and trends of fracture zones in the Bay of Bengal particularly prior to the late Cretaceous. This lead to the speculation of India's breakup from the eastern Gondwanaland around magnetic isochron M0 (118 Myr) (Royer et al, 1992) and around M4 (126 Myr) (Curry and Munasinghe, 1991) and around 117 Myr (Banerjee et al, 1995). Further a small segment of magnetic anomaly zone off the east coast of India has been interpreted as a magnetic smooth zone prior to Mesozoic anomalies by Murthy et al (1993).

Mapping of this approximately 415 km wide CMQZ from the present studies in the Bay of Bengal serves as a vital missing link between the early Cretaceous and late Cretaceous crusts evolved during the rifting and drifting of the Indian plate from Antarctica-Australian plate. Further, our studies provide the observational evidence to develop a realistic plate reconstruction model of the eastern Gondwanaland after the early Cretaceous breakup. Based on the identification of CMQZ (present studies), Mesozoic anomaly sequence M11-M0 and N120°E trending fracture zones (Ramana

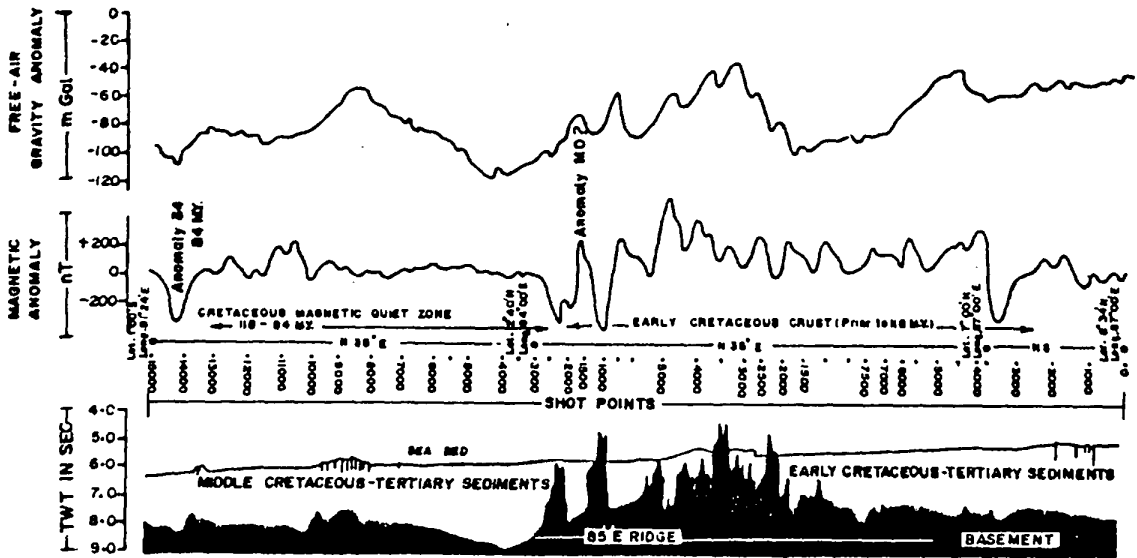


Fig. 2: The Composite geophysical anomaly map along the transect joining sites of ODP Leg 116 and the vicinity of DSDP site 218. Part of the transect crosses the axis of the 85° E Ridge. The free-air gravity anomaly profile is characterized by long wavelength lows most probably correspond to the 85° E Ridge (Liu et al, 1982). The free-air gravity profile is superposed with high frequency anomalies corresponding to the irregular pinnacles of the exposed basement. The magnetic anomaly profile from southwest to northeast depicts the late Cretaceous crust (isochron 34, 84 Ma), Cretaceous Magnetic Quiet Zone (84-118 Myr) and the early Cretaceous crust influenced partly by the 85°E Ridge. The line drawing of the unprocessed near trace record represent the seabed and the acoustic basement most probably the real basement. The basement of the CMQZ is relatively smooth and deeper.

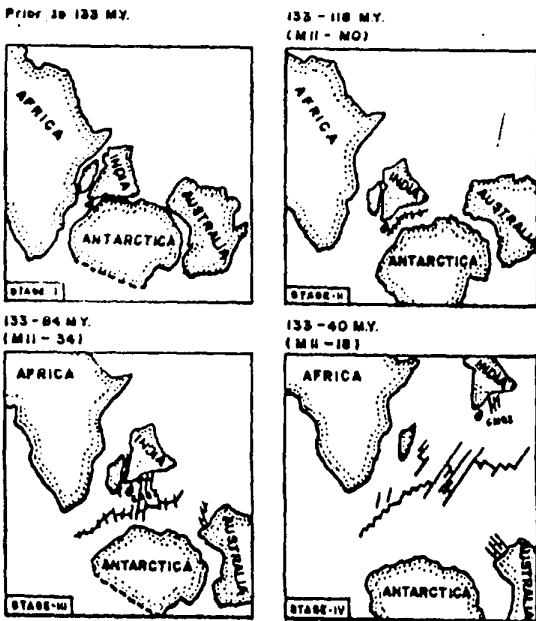


Figure. 3 Schematic representation of the breakup of eastern Gondwana landmass since early Cretaceous. Stage I represents the configuration of the continents prior to 133 Myr. During the stage II, India separated and moved in the NW-SE direction from Enderby Landmass of Antarctica and about 1000 km wide early Cretaceous crust represented by Mesozoic anomaly lineations M11 to M0, was evolved with an average spreading rate of 3.5 cm/yr. The spreading centre was being in between India and Antarctica. During the stage III, the spreading rates decreased to 1.2 cm/yr and about 415 km wide Cretaceous Magnetic Quiet Zone (CMQZ) was evolved. During this stage India started moving from NW to NS direction. During the stage IV, the northward movement of India was rapid and the late Cretaceous to late Eocene crust with various tectonic elements like fracture zones, plateaus, seamounts and extinct spreading centres were evolved in the Indian Ocean. The evolutionary history of the northeastern Indian Ocean was well documented since late Cretaceous to Present.

et al, 1994). A four stage evolutionary history of the Bay of Bengal has been proposed (Fig.3). During first stage, the breakup of the Greater India from the contiguous Antarctica-Australia plate initiated prior to 133 Myr. During the second stage (132.5-118 Myr) India separated from the Enderby Landmass of Antarctica and moved in approximately NW-SE direction producing M11-M0 anomalies. Around this time the continental extension between Antarctica and Australia took place and the eastern part of Greater India and Australia got separated producing M10 and younger anomalies on the western margin of Australia. During stage three (118-84 Myr), the direction of the Indian plate changed from NW-SE to N-S with a slow spreading rate of about 1.2 cm/yr with spreading center in between Indian and Antarctica-Australian plate and created about 415 km wide CMQZ. During this Cretaceous long normal polarity epoch the trace of the Ninetyeast Ridge was evolved (Duncan and Storey, 1992) in the Bay of Bengal as the Indian plate moved over the Kerguelen hotspot, and the India's separation from Madagascar took place. During stage four (84-40 Myr) India's northward motion accelerated and late cretaceous to late Eocene ocean floor was evolved with various tectonic elements like N-S trending fracture zones, plateaus, seamounts, extinct spreading ridges etc. in the north eastern Indian ocean.

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