

Marine magnetic studies in the northern Bay of Bengal, preliminary results

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Abstract—The bathymetric and total magnetic intensity data collected along six E-W tracks were analysed and presented as stacked anomaly profiles. The stacked bathymetric profiles reveal i) even topography upto 89°30' E longitude with intermittent longitudinal turbidity channels in between east of 85° E Ridge and west of Ninetyeast Ridge, ii) approximately N-S trending positive bathymetric feature (Ninetyeast Ridge) rising from average water depth of 3400 m to 2300 m conspicuous upto 10° N latitude, iii) immediately east of Ninetyeast Ridge a deep valley like feature corresponding to Sunda Trough and iv) the bathymetry becomes shallower to 1200 m while approaching Andaman group of islands. The stacked magnetic anomaly map depicts four magnetic anomaly provinces corresponding to i) 85° E Ridge complex, ii) newly identified approximately NNE-SSW trending basement high/ridge system iii) the Ninetyeast Ridge and iv) the Sunda Trough. A first order basement configuration model was generated across the Bay of Bengal. The model studies indicate higher values of magnetization of the causative crustal blocks resembling oceanic crust and the average crustal thickness varies between 10-12 km except the region covered by Andaman group of islands. Further the results obtained from magnetic model studies are well within the limits of computed layers (1-3) thickness from the gravity studies of MUKHOPADHYAY, (1988).

INTRODUCTION

Large sediment thickness was reported in the northern Bay of Bengal and the basement properties along with its configuration at selected locations was discussed by various workers (CURRAY and MOORE, 1971, MOORE and CURRAY, 1974, MOORE *et al.*, 1974, CURRAY *et al.*, 1977, 1979). The Bay of Bengal is traversed by 85° E subsurface ridge and Ninetyeast Ridge (approximate N-S direction). CURRAY *et al.* (1982) suggested the presence of deep basin like feature in between these two ridges filled by minimum 7-8 km thick Tertiary sediments. RAO and RAO (1985,86) and RAO *et al.* (1987) proposed the northern Bay of Bengal basement configuration and 85° E Ridge. VENKATESWARLU and CHATTERJEE (1988) isolated a fault like feature east of Andaman group of islands. The Eocene - Miocene events created a wide spread intraplate deformation from south of 10°S to 5°N and is seen as buckling and folding of the oceanic crust and high angle E-W trending faults (WEISSEL *et al.*, 1980, CURRAY and MUNASANGHE, 1989 BULL and SCRUTTON, 1990) and the intraplate deformation is observed to be an on going process. The present studies in the northern Bay of Bengal (Fig.1) were focussed to infer the nature of the basement, its associated structures and the overlying sediment thickness on the magnetic basement.

DATA

About 8200 line kilometers of bathymetric and magnetic data were collected along six E-W profiles spaced at 1 degree interval on board Diving Supporting Vessel Nanda Rachit during the field season 1989-90. Satellite Navigation System (Magnovox 1107) was used for obtaining the positions. Deep Sea Raytheon Echosounder (12 kHz) provided the continuous depth to seabed while Geometrics Proton precession type magnetometer

was deployed for measuring earth's total magnetic intensity measurements. No corrections were applied to bathymetric data and the stacked bathymetric profiles were plotted and shown in Figure 2. The magnetic data was reduced by subtracting the International Geomagnetic Reference field of 1990 (DGRF, 1985) computed at each observation point. The magnetic anomalies thus reduced were plotted and shown as stacked anomaly profiles (Fig.3).

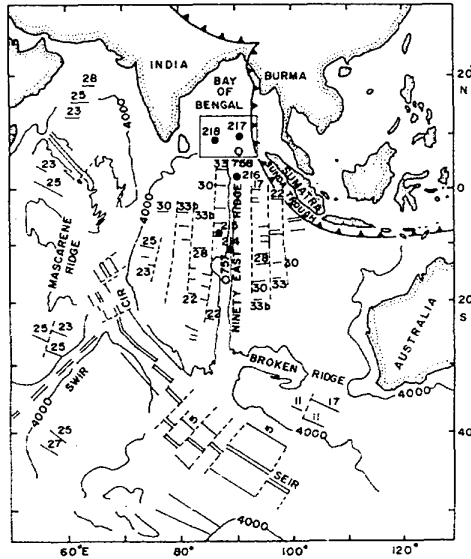


Fig.1. ODP (o) & DSDP (•) drill sites, regional physiography linear magnetic anomalies and structural features of the Indian ocean basin Modified from Schlich (1982), Stow and Cochran (1989). □ shows Northern Bay of Bengal study area.

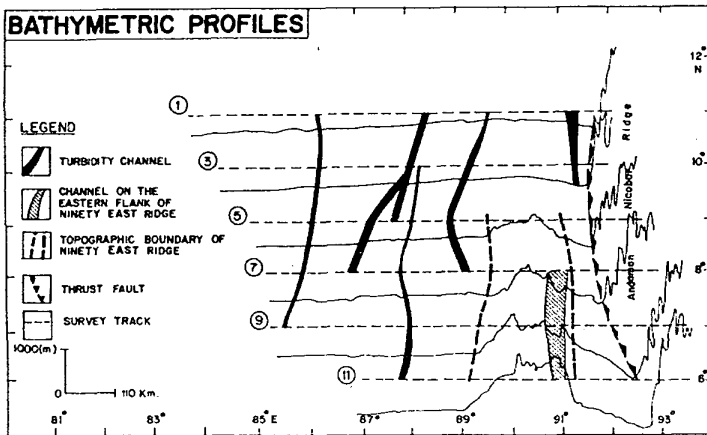


Fig. 2. Bathymetry along the tracks. The level of the tracks corresponds to the 3400 m water depth.

RESULTS

The bathymetry in the study area varies between < 1200 m to 4400 m. The average depth to the seabed is around 3400 m. Several turbidity channels (Fig.2) were noticed in the fan area and some of them are channel levee wedges of abandoned type as reported by EMMEL and CURRAY (1984). The channel widths in the study area in general vary from 5 to 27 km. The Ninetyeast Ridge exhibits a positive bathymetric expression upto 9°N latitude which rises from an average bathymetric contour 3400 m to 2300 m. This expression manifests as a gentle broad swell around 10°N latitudes and diminishes its amplitude. The maximum width of the Ninetyeast Ridge is around 240 km in the south and 160 km in the north. Immediately east of Ninetyeast Ridge, the seafloor is characterized by a valley like feature with considerable width (250 km) towards south and narrows to 25 km in the north corresponding to Sunda Trough. The maximum depth recorded in this trough is 4500 m. The bathymetry becomes shallower to 1200 m while approaching the Andaman group of islands and further, the sea floor is characterised by irregular topography with several pinnacles. The stacked magnetic anomaly map (Fig.3) reveals that the 85°E Ridge exhibits a large amplitude magnetic anomaly comprised of positive and negative polarities upto 9°N latitudes where as the amplitudes are relatively subdued and are ill defined in south. There is no definite recognizable anomaly signature associated with Ninetyeast Ridge. However, the eastern flank is associated with an isolated low amplitude magnetic anomaly. An approximately N-S trending positive magnetic anomaly (300 nT) is seen associated with Sunda Trough and the Andaman group of islands exhibit low amplitude magnetic anomalies. Approximately NNE-SSW trending prominent magnetic anomaly (>300nT) characterized by broad low and high is seen as a continuous feature extending from 6°N lat., 86°E long., to 10°N lat., 89°30'E long.

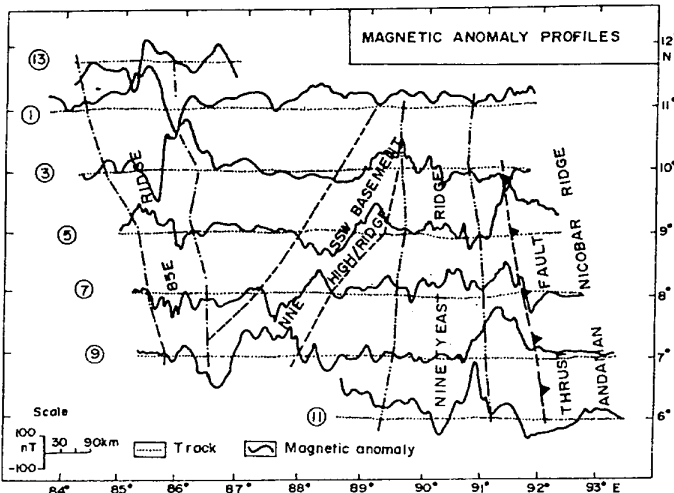


Fig.3. Stacked magnetic anomaly profiles.

DISCUSSION

The amplitudes of the magnetic anomalies observed on the Ninetyeast Ridge are relatively subdued when compared to the anomalies over 85°E Ridge and new NNE-

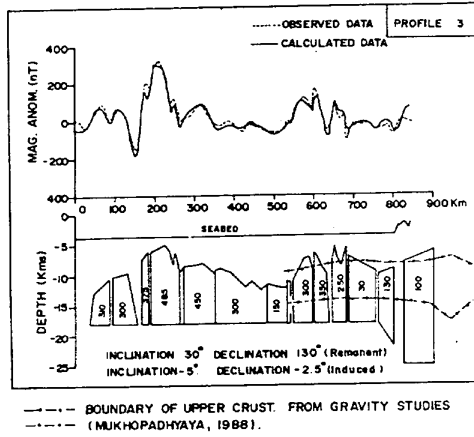


Fig.4. Total observed and computed magnetic anomaly and bathymetry along a representative profile across the Bay of Bengal. Computed anomaly is generated by two dimensional magnetic block models at bottom. The numerical values shown in each prismatic body multiplied by 10^{-5} corresponds to susceptibility.

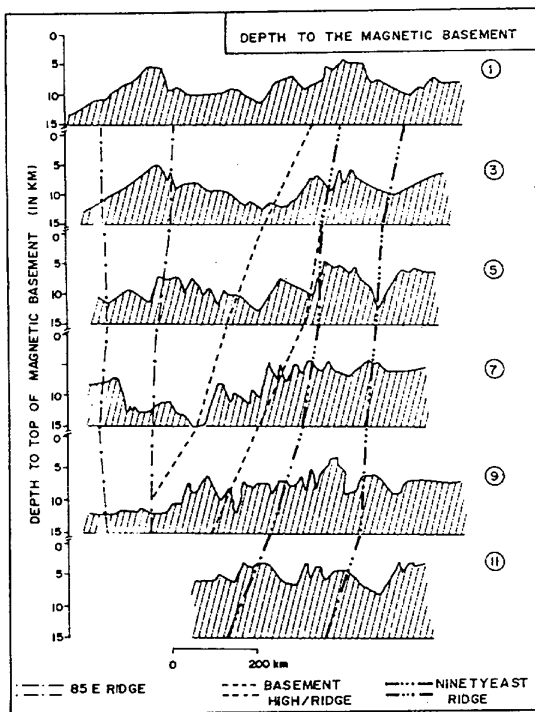


Fig. 5. Surface of the magnetic basement computed along the tracks (location of the tracks shown in Fig.2)

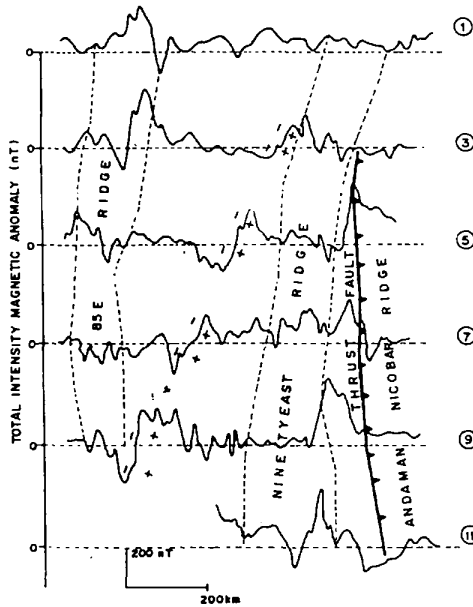


Fig.6. Continuous magnetic anomaly profiles across the Bay of Bengal showing numerous structures described in the text. (For locations, refer Fig.2). The - and + symbols correspond to long wave length NNE-SSW trending anomaly zone.

SSW trending basement high/ ridge like feature. Keruguelen Island began forming around 40 My ago on the Antarctic plate near to the South East Indian Ridge and represents the continuation of the hotspot activity presented on the Indian plate as the Ninetyeast Ridge. Basalts dredged from the Ninetyeast Ridge show large dupal characteristics similar to Keruguelen and Heard Islands inferring their genetic link. The principal cause for the compositional change of Keruguelen Island basalt was the migration of South East Indian Ridge away from the vicinity of plume and the plume derived melts suffer contamination by lithospheric magma and extensional tectonism and presence of thinner lithosphere would favour large depth melting interval for an upwelling adiabatic plume. This depth melting interval would have decreased as the plume becomes increasingly separated from the northward migration of Ninetyeast Ridge thus providing explanation for transition from tholeiitic to alkali basalts which possess low magnetite content. This perhaps caused the observed ill defined magnetic signatures over the Ninetyeast Ridge. The observed 75-360 nT magnetic anomaly (Fig.3) appears to be a real feature and may corresponds to a two dimensional intrusive like body. RAO and RAO (1985,1986) referred this feature as the Ninetyeast Ridge. But several workers opined that the Ninetyeast Ridge is not associated with any definite magnetic anomaly and the present studies indicate no significant anomaly character over the Ninetyeast Ridge except for an isolated anomaly on the eastern flank. We presume this anomaly feature to be an intrusive like body along the eastern flank of the Ninetyeast Ridge and this could be possible since SCLATER and FISHER (1974) suggested that Ninetyeast Ridge is a leaky transform fault marking the relative motion between the India and Australian plates and the magmatic material might have intruded

through the fault plane. Further east of the Ninetyeast Ridge, in Sunda Trough, the observed high amplitude magnetic anomaly is attributed to highly magnetized rocks probably serpentinites that occur along the axial parts of deep valley during the process of mantle upwelling near the subduction zone. MUKHOPADHYAY (1988) reported high density anomalous masses underneath the Sunda Trough and these high density rocks may be the fragments of oceanic crust. Approximately NNE-SSW trending prominent magnetic anomaly 160 to 375 nT having 140-220 km wavelength run across the study area is a noteworthy feature. This may be due to another basement high / ridge or Mesozoic linear magnetic anomaly trend (?) appears to be sandwiched between the existing 85° E Ridge and Ninetyeast Ridge. To examine the nature of the underlying crust in the study area, theoretical magnetic anomaly was computed (Fig.4) using the two dimensional model studies proposed by TALWANI and HEIRTZLER (1964) along the profiles under the seismic constraints of NAINI (1973) and CURRAY *et al.* (1982). The underlying rocks exhibit a very high susceptibilities (0.004) closely corresponding to that of the oceanic basaltic layer. The depth to the top of the magnetic basement has been computed for all the profiles and it varies < 5 km to 13 km (Fig. 5) with the crustal layer thickness around 10-12 km. In general the basement configuration across the northern Bay of Bengal is characterised by high corresponding to 85°E Ridge, a broad basin followed by another basement rise corresponding to the NNE-SSW trending basement high/ridge, another low west of Ninetyeast Ridge, and basement low east of Ninetyeast ridge (Figs.5 &6). More over the highly eroded basement south of profile 7 perhaps indicate its subaerial exposure during the past.

CONCLUSIONS

In general, a N-S trend prevails in the study area and 85°E Ridge is characterised by positive and negative magnetic anomalies of considerable amplitude. The Ninetyeast Ridge exhibits no definite recognizable magnetic anomaly except for an isolated moderate to low amplitude magnetic anomaly on the eastern flank of Ninetyeast Ridge complex and this anomaly has been attributed to an intrusive like body. A high amplitude positive magnetic anomaly observed in Sunda Trough might have originated from the high density serpentinized rocks. An approximately NNE-SSW trending magnetic anomaly appears to be a conspicuous feature and this may be due to another basement high/ ridge or Mesozoic linear magnetic anomaly trend sandwiched between 85°E Ridge and Ninetyeast Ridge. Model studies indicated the prevalence of oceanic crust underneath Bay of Bengal between 84°E to 91°E longitudes.

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REFERENCES

- BHOOPAL REDDY N.(1973) Ganges cone, a wide angle seismic reflection and refraction study. *Journal Geophysical Research*, 78, 8711- 8720.
- BULL J.M. and R.A.SCRUTTON (1990) Fault reactivation in the Central Indian Ocean and the rheology of the oceanic lithosphere. *Nature* ,344, 855-858.
- CURRAY J.R., D.G.MOORE, L.A.LAWYER, F.J. EMMEL, R.W.RAITT, M. HENRY and KIEKHEFER (1979 a) Tectonics of the Andaman Sea and Burma, In : *Geological and geophysical investigations of continental slopes and Rises*, American Association of Petroleum Geologists, Memoir 29, 189 - 198.
- CURRAY J.R., F.J.EMMEL, D.G.MOORE and R.W.RAITT (1982) Structure tectonics and geological history of the Northeastern Indian Ocean, In: *The ocean basins and margins*, A.E.M. NAIRN and F.G. STEHLI, editors, 6, 399-450.

- CURRAY J.R and D.G.MOORE (1971) Growth of the Bengal deep sea fan and denudation of the Himalayas. *Geological Society of American Bulletin*, 82, 563-572.
- CURRAY J.R and D.G.MOORE (1974) Sedimentary and tectonic processes in the Bengal Deep Sea Fan and Geosyncline, In : *Continental Margins*, C.A. BURK and C.L. DRAKE, editors, New York, Springer-Verlag, 617-627.
- D.G.R.F. (1986) IAGA Division 1, working group International Geomagnetic Reference Field division EOS, 67, 523-524.
- EMMEL F.J. and J.R.CURRAY (1984) The Bengal Submarine fan, northeastern Indian Ocean. *Geo Marine Letters*, 3, 119-124.
- MANOJ MUKHOPADHYAY (1988) Gravity anomalies and deep structure of the Andaman arc. *Marine Geophysical Researches*, 9, 197-210.
- RAO T.C.S. and V.BHASKARA RAO (1985) Geophysical studies over the continental margins of the east coast of India. *Marine Geology*, 67, 151-161.
- RAO T.C.S. and V.BHASKARA RAO (1986) Some structural features of the Bay of Bengal. *Tectonophysics*, 124, 141-153.
- RAO T.C.S., S.L. NARAYANA and K.V.L.N.S. SARMA (1987) Magnetic anomalies in the central Bengal Fan. *Indian Journal Marine Sciences*, 16, 15-18.
- SCLATER J.G. and R.L.FISHER (1974) Evolution of the East Central Indian Ocean, with emphasis on the tectonic setting of the Ninetyeast Ridge. *Geological Society of America Bulletin*, 85, 683-702.
- SCHLICH R. (1982) The Indian Ocean, Aseismic ridges, spreading centers, and oceanic basins, In: *The ocean basins and margins*, A.E.M.NAIRN and F.G.STEHLI, editors, 6, 51-147, Plenum New York.
- TALWANI M. and J.R.HEIRTZLER (1964) Computation of magnetic anomalies caused by two dimensional structures of arbitrary shape. *Computers in Mineral Industry*, A.G. Parks, editor, The School of Earth Science, Stanford University, 464-480.
- VENKATESWARLU P.D and P.CHATTERJEE (1988) Magnetic (total field) and Bathymetry studies in the Andaman Sea-A qualitative appraisal. *Journal of Association Exploration Geophysicists*, 4, 191-197.
- WEISSEL J.K., R.N.ANDERSON and C.A.S.GELLER (1980) Deformation of the Indo Australian plate. *Nature*, 287, 284-291.