

Aeromagnetic Anomalies in the Bengal Fan

T. C. S. RAO & G. C. BHATTACHARYA

National Institute of Oceanography, Dona Paula 403004

Received 5 September 1975; revised received 28 November 1975

Aeromagnetic data recorded by the 'Project Magnet' have been analysed along 4 profiles in the Bengal fan. Some of the anomalies found are large and distinct and have shown good correlation in different profiles. From detailed studies of these anomalies the major trends in the basement layer can be delineated. These anomalies include an arcuate trench over the continental margins of India and Sri Lanka, the deep valleys in the central Bengal fan, northward extension of the Ninetyeast ridge up to 8°N and the continuation of the Java-Sumatra trench to the west of Andaman-Nicobar Islands. Some of the anomalies recorded at about 84° to 86°E and 2° to 4°N suggest that the Indira and Indrani fracture zones extend northward. Large thick sedimentary layers present in the central Bengal fan suggest a depressed oceanic crust in this area.

THE Ganges cone is the result of one of the most intense activities of denudation in the world resulting from the Mid-Miocene uplift of the Himalayas. It is estimated that about one billion tons of suspended sediment is carried into this area annually by the river Ganges, which bypasses the bar and continues into the deep water through a canyon called "swatch of no ground". The heavy sediment load that is drained into the Bay of Bengal forms a wide sedimentary fan called the 'Bengal fan'. It is about 1500 km wide and 3000 km long, and encompasses the entire Bay of Bengal. It slopes down to the south from 20°N to 10°S of the equator and it includes on its flanks the continental margins of India, Bangladesh, Burma and the submarine mountains of the Ninetyeast ridge.

Aeromagnetic data were recorded by the US Coast and Geodetic surveys in the Bay of Bengal, and adjoining areas under the "Project Magnet" programme. The data used in the present study were made available to one of the authors (T.C.S.R.). The area under the present investigation is confined to a part of the Bengal fan, between 80°E and 95°E in west and east and 1°N and 12°N in south and north respectively.

During the International Indian Ocean Expedition of 1960-65, thousands of kilometres of bathymetric profiles were run by ships of several nations. Bathymetric and physiographic chart of the entire Indian Ocean was constructed by Heezen and Tharp¹. Bathymetric chart of the Bay of Bengal was prepared by Rao² using the echosounding data recorded on board INS *Kistna* and the bathymetric data available at the Indian Naval Hydrographic Office. Bathymetric charts of the Bay of Bengal constructed more recently show several sea floor channels of turbidity currents origin, extending

from the "swatch of no ground" to the south of Sri Lanka.

Noprochnov *et al.*³ conducted a series of single station conventional explosive seismic reflection measurements in the Bay of Bengal and reported an average thickness of sediments as 2.4 km with the maximum sediment thickness of 3 km occurring off the Indian Peninsula at about 18°N. Curray and Moore⁴ identified from their continuous profiler and bathymetric records a remarkable development of very large fan valleys which sit on the crests of huge elevated expressways or ridges made up of the natural levee deposits of the channels. They also reported 2 prominent reflectors in the Bay of Bengal fan and interpreted them as unconformities associated with the last 2 epochs of major Himalayan denudation in the Pleistocene and upper Miocene. They have further suggested that the older sediments overlay the northern section of the Ninetyeast ridge which in turn has been uplifted during the Pliocene exposing these sediments. Eittrheim and Ewing⁵ discussed the seismic records collected in the area round 7°S and 81°E in relation to the mid-plate tectonics. These records have shown the presence of sediments of Ganges cone which gradually rise towards the surface and up-bowed, folded and faulted over a broad swell at the southern end of the cone. Naini *et al.*⁶ reported 9 distinct sedimentary layers all over the Bengal fan with their average P-wave velocities ranging between 2.05 and 6.22 km/sec. The thickness of the sediments up to 6.22 km/sec layer varied between 7 and 9 km with an average thickness of 7.87 km. In general it was observed that the sequences of layers from the sea floor through the layer 5 have a regional dip to the south whereas those below the layer 6 dip north and thus indicate a marked increase in the sediment thickness from south to north.

Data were supplied in the analogue form on microfilms. Microfilms were enlarged and the data were digitized at intervals varying between 15 and 60 sec depending on the gradient of the field values. Total field anomalies were computed as the difference between the observed field and the regional field. The anomalies were plotted with their profile lines as the datum and are shown in Fig. 1 along with the profile numbers as given in the original data.

Total field anomalies along these profiles have been analysed to determine the depth to the top of the basement layer that causes these anomalies. The depths to the basement layer cited in the following analysis are considered to be equal to the horizontal projection of the essentially straight portion of the gradient of the magnetic anomalies under consideration. This is an approximation based on the theoretically observed proportionality between the horizontal width of a magnetic anomaly and the distance separating the causative body and the plane of observation. The results obtained

by such methods are dependent on the size, shape and orientation of the body as well as its magnetic latitude. It is difficult to keep continuity of all these parameters for the data are recorded along isolated profiles and therefore the depth determinations from these anomalies may have large errors as a result of simplifying the assumptions involved in these computations. These errors are further amplified in the case of composite anomalies because of the overlap of anomalies. The assumptions that are made for the depth estimates in the present paper are: (i) the magnetic trends are at right angles to the direction of the profile, (ii) the magnetic trends are elongate and transverse to the direction of the profile, (iii) the magnetic anomalies are caused by sharp discontinuities in the magnetic content of the igneous rocks or the undulations in the basement layer, (iv) the bodies extend infinitely downwards, and (v) the bodies are magnetized in the direction of the earth's magnetic field.

Several methods of depth calculations following the above procedure were developed. For the present computations, the method of Koulamzine *et al.*⁷ was followed, as this method does not need the prior knowledge of the datum line. The depths thus obtained are noted below the anomalies along each profile in Fig. 1.

For the convenience the area covered by the profiles is divided into 3 meridional zones. These are: continental margin, central Bengal fan and island arc and ridge system. The continental margin covers the area between the coastline and 84°E, the central Bengal fan between 84°E and 89°E, and the third region between 89°E and the end of the profile.

Over the continental margin the magnetic anomalies in the profiles 529, 538 and 308B are large and distinctive. They gradually become weak and narrow from north to south. In the profile 529, a large amplitude and low frequency negative anomaly is recorded off the Godavari delta. The depth to the basement computed from this anomaly is nearly 20 km and it is flanked on either side by a relatively much shallower basement. It thus forms a wide and deep basin-like feature in this region. Similar type of basin structures which are shallow and wide are also found from the anomalies over the continental margin in profiles 538 and 308B. The depths to the basements of these basins are 15 and 11 km in the profiles 538 and 308B respectively. When these are connected to each other a wide and deep trench is formed which is deeper at its northern side and shallower towards the south. An arcuate trench over the eastern margin of India reported by Rao⁸ from the bathymetric data appears to be the surface manifestation of the feature present in the basement layer which can be identified from the present magnetic data.

In the central Bengal fan, the anomalies are relatively weak except for one composite anomaly with its central peak at 85°E in the profile 538. The low amplitude and low frequency anomalies in this area are attributed to the deeper basement layer which is covered with thick sedimentary layers. Depths to the basement, computed from the magnetic anomalies, vary widely and indicate

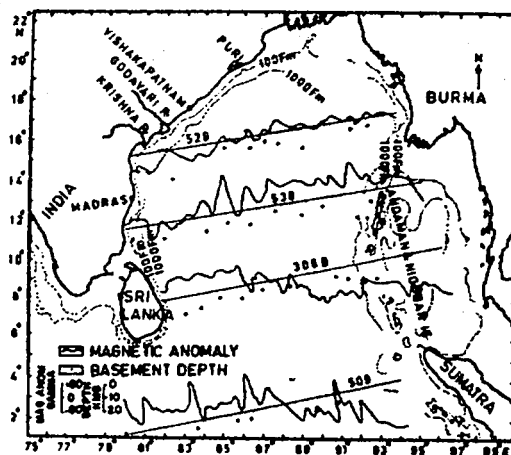


Fig. 1 — Magnetic anomalies and basement depths

the presence of valleys and ridges. Several such valleys and ridges are present in this area. These features bear a good correlation from one profile to the other and permit to conclude that they form continuous valleys covering all the 3 profiles. Curray and Moore⁴ also reported the existence of similar type of fan valleys associated with the ridges made up of natural levee deposits of the channels. Bathymetric charts of the Bay of Bengal have also enhanced the plausibility of sea floor channels by turbidity currents as suggested by Dietz⁶ which extend from "swath of no ground" to the south of Sri Lanka. In the central Bengal fan, the depths to the basement as revealed from the present study range between 6 and 9 km, except at 89°E in the profile 529 where it is nearly 11.5 km. In general, the basement layer appears to be at deeper depths at the northern side and becomes shallower towards the south, which agrees with the findings of Naini *et al.*⁶ that the deeper sedimentary layers in the Bengal fan have a regional dip towards the north.

To the east of 89°E, the magnetic anomalies in the profile 529 are weak and the depths to the basement, computed from these anomalies, show a gradual rise in the basement towards the east. In the profiles 538 and 308B, fairly large amplitude anomalies are recorded to the west of Andaman-Nicobar Islands. These anomalies have yielded the depths to basement as 13 and 14 km in the profiles 538 and 308B respectively and these form deep valleys. Peter *et al.*⁹ concluded from their gravity, magnetic and bathymetric data that the Java-Sumatra trench extends northwards to the west of Andaman-Nicobar Islands as a locally weak trough. In the light of this it may be inferred that the deep valleys identified from the present study are the continuation of the Java-Sumatra trench to the west of Andaman-Nicobar Islands.

In the profile 509, which lies to the south of the magnetic equator, the anomalies are positive up to 88°E and negative thereafter. Unlike the profile 308B, the anomalies in the profile 509 are large and distinct. The anomalies with large amplitude

and steep gradient at 84°E and 86°E appear to have resulted from the major tectonic events probably faulting. McKenzie and Scalter¹⁰ reported the existence of 2 fracture zones associated with the magnetic anomalies of similar character and named these as Indira fracture zone and Indrani fracture zone. The anomalies noticed in the present study along 84°E and 85°E appear to be the reflections of the northward extensions of the transform fault associated with these 2 fracture zones. The anomalies between 89°E and 91°E are well pronounced and they lie in the axis of the Ninetyeast ridge. From the nature of the anomalies and their locations it appears that the Ninetyeast ridge possibly extends northward. Similar type of anomalies but much weaker in magnitude are also recorded at 90°E in the profile 308B, and it appears that the Ninetyeast ridge may extend northward up to about 8°N. This may further be justified by the conclusion of Rao² while analysing the bathymetric records of the Bay of Bengal, that Ninetyeast ridge extends up to about 8°N.

The authors are thankful to the Department of Geomagnetism, USCGS, for supplying the data.

They also extend their thanks to the Director, NIO, and Shri H. N. Siddiquie for going through the manuscript.

References

1. HEEZEN, B. C. & THARP, M., *Physiographic diagram of the Indian Ocean, the Red Sea, the South China Sea, the Sulu Sea and the Celebes Sea* (Geol. Soc. Amer., Boulder, Colo.), 1964.
2. RAO, T. C. S., *Bull. natn. Inst. Sci. India*, **38** (1968), 421.
3. NEPRUCHINOV, I. P., KORYLIN, V. M. & MIKHINO, M. F., cited by J. R. CURRAY & D. G. MOORE, *Geol. Soc. Am. Bull.*, **82** (1971), 563.
4. CURRAY, J. R. & MOORE, D. G., *Geol. Soc. Am. Bull.*, **82** (1971), 563.
5. EITREIM, S. I. & EWING, J., *J. geophys. Res.*, **77** (1972), 6413.
6. NAISI, B. R. & LEYDEN, R., *J. geophys. Res.*, **78** (1973), 8711.
7. KOULMINE, TH., LAMONTAGNE, V. & NADEAN, A., *Geophysics*, **35** (1970), 812.
8. DIETZ, R. S., *Geol. Soc. Am. Bull.*, **64** (1953), 375.
9. PETER, G., WEEKS, L. A. & BURNS, R. E., *J. geophys. Res.*, **71** (1966), 495.
10. MCKENZIE, D. & SCALTER, J. G., *Geophys. J. R. Astr. Soc.*, **25** (1971), 437.