

Marine Magnetic Profiles from the Direction Bank to the Kori Bank, Western Continental Shelf of India

M. V. RAMANA, V. SUBRAHMANYAM AND L. V. SUBBA RAJU
National Institute of Oceanography, Dona Paula, Goa 403004.

Abstract

Total magnetic field intensity measurements along two parallel NW-SE tracks from the Direction Bank to the Kori Bank show correlatable magnetic anomalies. High frequency positive anomalies observed northwest of Kathiawar coast terminating at about 21°N are interpreted due to the magnetic basement i.e. basalts at a depth of about 2 km. A low amplitude negative anomaly observed around 21°N (between 69°E and 70°E) may be due to the westward extension of the Narmada-Son lineament. Absence of significant anomalies south of these high frequency anomalies may be due to thin Traps or greater thickness of sediments. High amplitude and broad wavelength negative anomaly observed off Bombay (19°N, 71.5°E) is interpreted as due to contact or faulting of Precambrian formations and Deccan Traps.

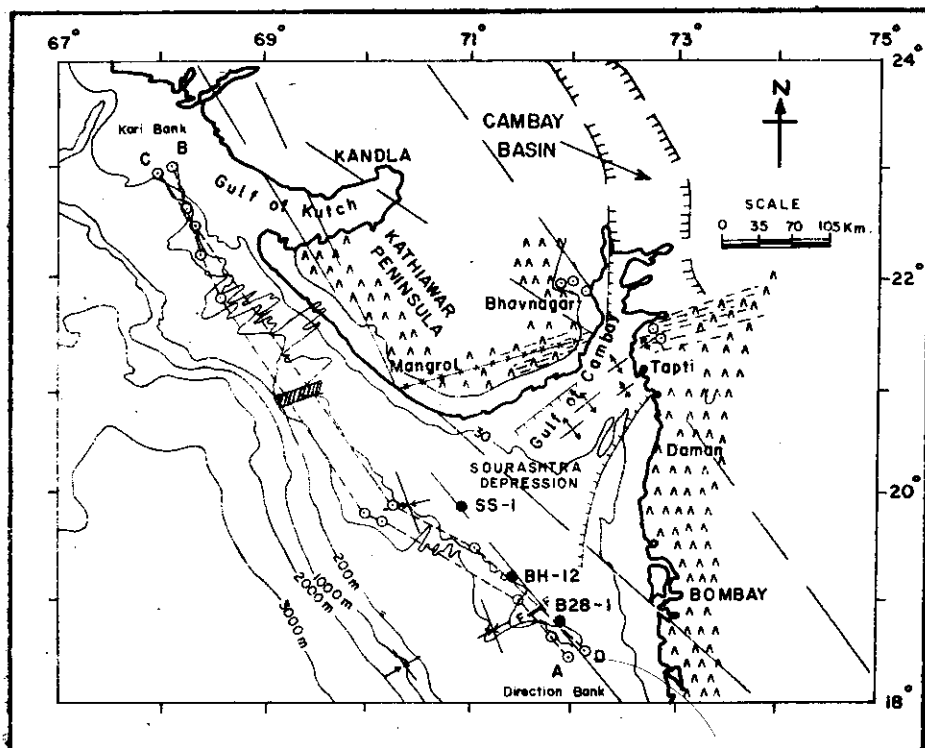
INTRODUCTION

The National Institute of Oceanography is carrying out systematic geological and geophysical surveys on *RV Gaveshani* for exploration of the Indian continental margins. During the 61st cruise, total magnetic intensity measurements were carried out with Barringer Proton Precession Oceanographic Magnetometer to study the nature of the basement from the Direction Bank to the Kori Bank along the western continental shelf between 18°20' and 23°N latitudes.

GEOLOGICAL FRAMEWORK

The two NW-SE trending cruise tracks AB and CD lie along the western continental margin. To the east of these tracks on the adjacent land, Deccan Traps of late Mesozoic to early Tertiary age are the major geologic formations. The Traps cover a large area of the Indian Peninsula to the west from Kathiawar in the north to Goa in the south and to Rajahmundry in the east (Sastry, 1981). The extension of the Deccan Traps offshore has been confirmed by extensive drilling of the Oil and Natural Gas Commission of India (Bhagawan Sahay, 1978; Raju *et al* 1971).

The Kathiawar Peninsula is bordered by faults which were formed during the eruption of Deccan Traps. The Mesozoic sediments extending from the Indus basin southward into the Arabian sea and the Gulf of Kutch have been faulted and folded into several E-W trending anticlines and domes in Kutch. The geology of the Kathiawar Peninsula is largely covered by Deccan Traps which, in turn, are overlain by early Mesozoic and Tertiary sediments. Seismic surveys in the Cambay basin indicated that the onshore Tertiary formations extend to the Gulf of Cambay and the adjacent Arabian sea (Sengupta, 1967). South of the Gulf of Cambay, prominent NW-SE faults form a large palaeo high (Bombay High). The inner shelf of Bombay is characterised by horsts, grabens and normal faults (Murty *et al* 1981). Figure 1 shows the geological and structural elements of the area and the cruise tracks.



LEGEND

- | | |
|--|---------------------------------------|
| ┆ Basin Marginal Faults | ∩ Projected Total Magnetic Anomalies, |
| ○—○ Survey Tracks | *—* Faults of Subcrustal order |
| AAA Deccan Trap | ⊥ Axis of Anticline |
| ⊙ Volcanic Cone | ⊥ Axis of Syncline |
| --- Fault | ▨ Dike Swarm |
| ▨ Probable Extension of Narmada-Son Lineament (From Present study) | |

Figure 1. Geological and structural elements (adopted from Raju *et al* 1971 and Choudary, 1975) and cruise tracks of the study area.

DATA

Continuous total magnetic measurements were carried out along two tracks from the Direction Bank to the Kori Bank. The sensor was towed approximately 175 m behind the ship to avoid the magnetic effects of the ship. The data were collected at 12 sec. with an accuracy of ± 1 nT. The ship's speed was maintained at about 8-9 knots. The regional background was subtracted empirically from the observed total magnetic intensity values. The magnetograms during the survey period indicated no abrupt changes in the earth's magnetic field in the study area. Hence diurnal corrections were not applied. The residual magnetic anomalies were plotted and projected at right angles to the survey tracks.

The positions during the cruise were obtained with a Decca Receiver and the bathymetry was recorded on a Kelvin and Huges MS 45 echosounder (30 KHz). A comparison of magnetic and bathymetric profiles along the two tracks does not indicate appreciable correlation between topography and the total magnetic intensity field.

RESULTS AND INTERPRETATION

The most conspicuous features in both the profiles are (a) a series of positive magnetic anomalies of high amplitudes (220–250 nT) off Mangrol and towards north, (b) a low amplitude negative anomaly between $20^{\circ}45'N$ and $21^{\circ}N$, (c) a relatively magnetic smooth zone towards south and (d) further towards southeast a prominent high amplitude and broad wavelength negative anomaly (260–270 nT).

The magnetic signature along the two profiles indicate inhomogeneities and the complex nature of the crystalline magnetic basement (Fig. 2). Quantitative interpretation has been attempted for the determination of depth to the basement and

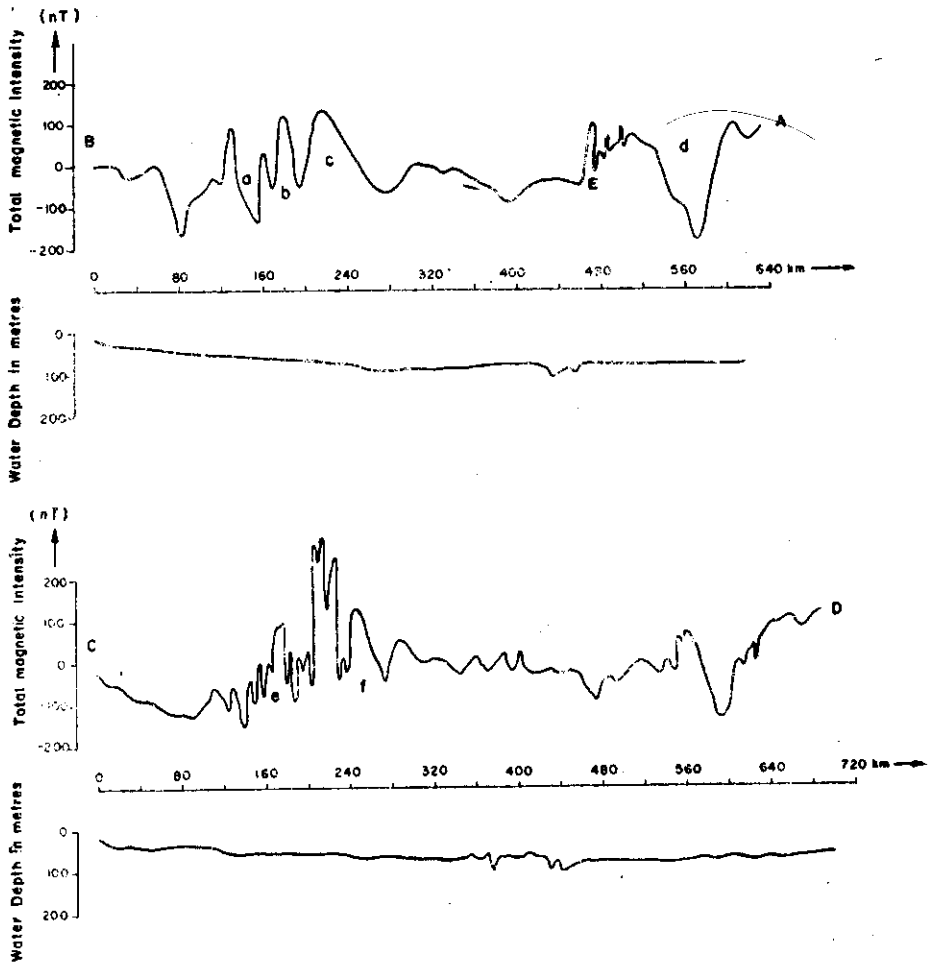


Figure 2. Residual total magnetic anomaly signature along the tracks and bottom topography.

other body parameters (Fig. 3) using the conventional graphical methods (Peter, 1949; Koulomzine *et al* 1970; Qureshi and Nalaye, 1978).

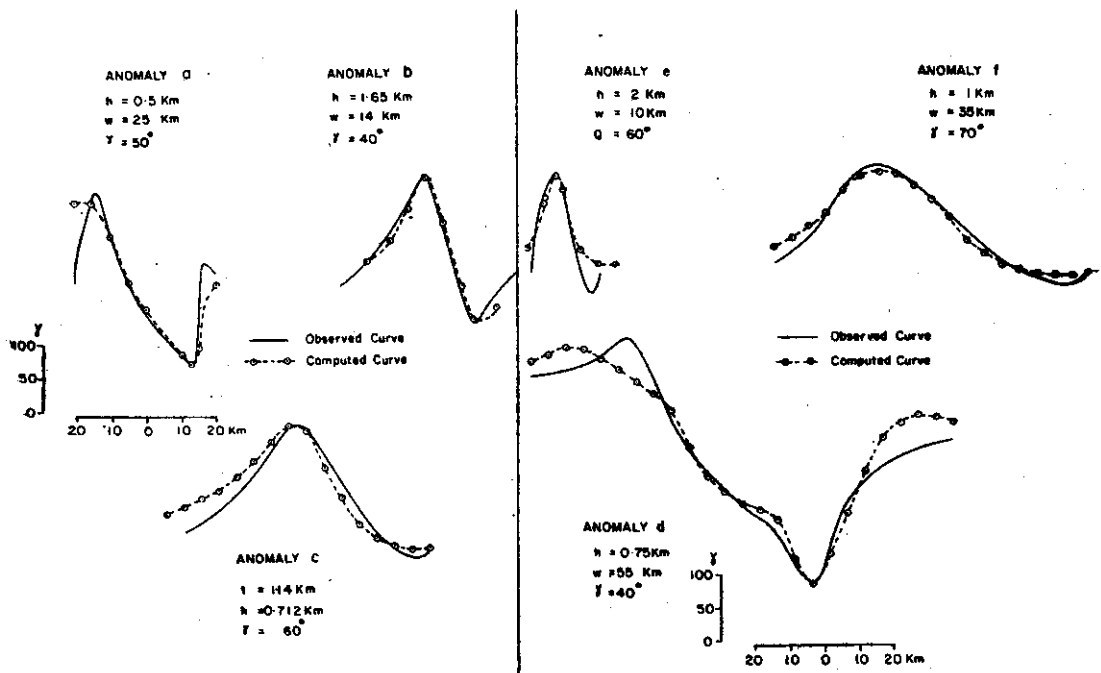


Figure 3. Interpretation of magnetic anomalies along the two profiles A-B and C-D.

A series of NE trending high frequency positive anomalies are observed off Mangrol and further north. The source for these anomalies may be the Deccan Traps at a shallow depth of about 1-2 km. The depths obtained are supported from the earlier studies of Rao (1969), Naini (1980) which also indicated about 1.85 km thick lithified sediments. The high amplitude anomalies may be due to the introduction of magnetic material through subsequent faulting. Closs *et al* (1968) proposed a system of faults south of Kori Bank and off Kathiawar coast. The magnetic anomalies observed in the present studies also support the occurrence of such faults.

A low amplitude negative anomaly of 50 nT was observed to the south of these high frequency anomalies (between $20^{\circ}45'N$ and $21^{\circ}N$). The airborne magnetic anomalies offshore and on land (Mishra, 1977; Mishra and Hari Narain, 1977) indicated a linear tectonic feature ($20^{\circ}-22^{\circ}N$, $69^{\circ}30'E$) offshore and a broad magnetic low occupying a portion of the Vindhyan Basin which is connected with the Narmada-Son lineament. The anomaly observed in the present study off Mangrol, however, is prominent with a magnetic low.

The magnetic low (shown as hatched portion in Figure 1) is observed in both the profiles with an approximate ENE-WSW strike direction. Bhagavan Das and Patel (1984) reported that the Narmada-Son lineament is characterised by the presence of three groups of faults trending ENE-WSW (E-W), NW-SE and NE-SW (NNE-SSW).

The observed ENE-WSW magnetic trend well coincides with that of the reported trends of the Narmada-Son lineament. The observed low amplitude in the magnetic field may be due to the thick cover of non-magnetic sediments over the lineament.

The magnetic anomalies in the central part of the two profiles are relatively smooth, thereby indicating the absence of major tectonic events within the basement. This may also be attributed to the thick cover of non-magnetic sediments or to basalts being too thin to generate an appreciable anomaly. The bore hole logs (SS-1, B₃, B₇) indicated about 4490-6000 m sediments over the Cretaceous basement in the Gulf of Cambay and adjacent areas (Bhagwan Sahay, 1978; Agrawal and Singh, 1980; Raju *et al* 1971; Basu *et al* 1980). A high amplitude short wavelength anomaly E is observed in the profile AB. The anomaly may have originated due to shallow basement subjected to tectonic disturbance and later intruded by highly magnetised material.

A significant NE-SW trending broad negative anomaly (260-270 nT) off Bombay may be attributed to faulting or difference in the levels of Precambrian formations and the Deccan Traps. The depth to the top of the magnetic basement computed is about 1.7 km. The computations agree well with the data obtained from bore hole logs. The Precambrian basement is met at a depth of 1950 m (BH-12) and Deccan Traps at 2545 m (B 28-1) in the area. Bhagwan Sahay (1978) reported extensive faulting in the vicinity of BH-12. The seismic reflection studies and magnetic surveys off Bombay also indicated faulted anticlinal features with its axes N-S and major faulting towards eastern flank.

Spectral analysis (Green, 1972; Dahl, 1982) of the two profiles indicate that the average depth to the crystalline basement is of the order of 2.8 km. Figure 4

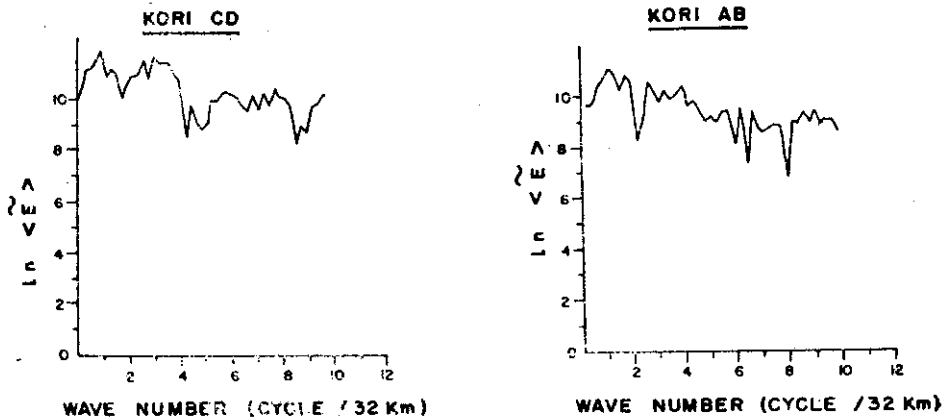


Figure 4. Computed power spectrum for profiles A-B and C-D.

represents the spectrum of the two profiles. Roser (1974) interpreted the magnetic anomalies over the Arabian sea using the Fourier harmonic analysis and reported a depth to the basement of 4 km off Kathiawar and 4-6 km off Bombay. The depth to the basaltic/Precambrian basement obtained from the present study agrees with the bore hole data of Oil and Natural Gas Commission, while Roser's computations are on the higher side. The higher depths were possibly due to the longer profiles

lengths extending for offshore and an analysis of segments of the longer profiles may provide better correlation with the actual depths to the basement.

CONCLUSIONS

1) The magnetic anomalies indicate that the crystalline basement on the north-western continental shelf is inhomogeneous.

2) The anomalies a, b, and c observed to the north of Mangrol are due to NE-SW to ENE-WSW trending subsurface disturbances (faults) and subsequent intrusion of magnetised material through weak zones.

3) The low amplitude magnetic low observed (21°N, 69°20E) off Mangrol may be the westward extension of the Narmada-Son lineament (?).

4) A relatively magnetic smooth zone in the central part of the two profiles indicates a deeper basement or the Traps may be too thin or absent to generate magnetic anomaly.

5) The broad negative anomaly d, observed off Bombay may be due to fault contact or the difference in the basement levels of Precambrian formations and Deccan Traps.

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References

- AGRAWAL, R. K. and SINGH, V. B., (1980) Continental shelf of Kutch-Ratnagiri coast—a regional analysis of seismic data. *Workshop on geological interpretation of geophysical data*, pp. 19-26.
- BASU, D. N., BANERJEE, A. and TAMHANE, D. M., (1980) Source areas and migration trends of oil and gas in Bombay offshore basin, India. *Bull. Amer. Assoc. Petrol. Geol.*, v. 64, pp. 209-220.
- BHAGWAN DAS and PATEL, N. P., (1984) Nature of the Narmada-Son lineament. *Jour. Geol. Soc. India*, v. 25 (5), pp. 267-276.
- BHAGWAN SAHAY, (1978) Geology of Bombay high and adjoining structures. *Offshore southeast Asia Conference*, pp. 1-11.
- CLOSS, H., BUNGENSTOCK, H. and HINZ, K., (1968) Results of seismic refraction measurements in the Arabian sea. *A contribution to the International Indian Ocean Expedition-Meteor.*
- DAHL, C. R., (1982) Gravimetrisk og magnetotrisk under skelve av Hougesundshalvoya. *Unpublished Cand. Scient. thesis, University of Oslo.*
- GREEN, A. G., (1972) Magnetic profile analysis. *Geophy. Jr. Royal. Astr. Soc.*, v 30, pp. 393-403.
- KOULOMZINE, T. H., LAMONTAGNE, Y. and NADEAU, A., (1970) New methods for direct interpretation of magnetic anomalies caused by inclined dikes of infinite length. *Geophysics*, v. 35, pp. 812-830.
- MISHRA, D. C., (1977) Possible extension of the Narmada-Son lineament towards Murray ridge (Arabian Sea) and eastern syntaxial bend of the Himalayas. *Earth and Planet. Sci. Lett.*, v. 36, pp. 301-308.
- MISHRA, D. C. and HARI NARAIN, (1977) Airborne Geophysical survey—A case study from central India. *Jour. Geol. Soc. India*, v. 18, pp. 104-110.

- MURTY, K. V. S., PRASAD, B. N. and RAWAT, G. S., (1981) Structure of Continental margin off Bombay. *Workshop on Geological interpretation of Geophysical data*, pp. 41-48.
- NAINI, B. R., (1980) A Geological and Geophysical study of continental margins of western India and the adjoining Arabian Sea including the Indus cone. *Unpublished thesis, Lamont-Doherty Geological Observatory*, pp. 1-172.
- PETER, L. J., (1949) The direct approach to the magnetic interpretation and its practical application. *Geophysics*, v. 14, pp. 290-320.
- QURESHI, I. R. and NALAYE, A. M., (1978) A method for direct interpretation of magnetic anomalies caused by two dimensional vertical faults. *Geophysics*, v. 43, pp. 179-188.
- RAJU, A. T. R., CHAUBE, A. N. and CHOUDARY, L. R., (1971) Deccan Trap and the geologic frame work of the Cambay basin. *Bull. Volcanologique*, v. 2, pp. 521-538.
- RAO, T. C. S., (1967) Seismic refraction measurements in the Gulf of Cambay and Kutch. *Proc. Symp. on Upper Mantle Project*, pp. 342-34
- ROSER, HANS-ALBERT, (1974) Fourier analysis of widely spaced magnetic profiles from north west Indian Ocean. *Geol. Jb. E.*, pp. 81-98.
- SASTRY, M. V. A. and LAHIRI, T. C., (1981) Life during Deccan Trap episode. *Geol. Soc. India, Mem. 3*, pp. 279-286.
- SENGUPTA, S. N., (1967) Structure of the Gulf of Cambay. *Proc. Symp. on Upper Mantle Project*, pp. 334-341.

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