

Basement configuration of KG offshore basin from magnetic anomalies

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Marine magnetic anomalies along three representative profiles falling between shelf break and continent–ocean boundary in the offshore Krishna–Godavari basin were quantitatively interpreted for understanding the nature and structure of the magnetic basement using inversion technique. The interpretation of the anomalies shows that the magnetic basement lies deeper than the base of the sediments, i.e., acoustic basement identified by the seismic studies. This interpretation also shows that the magnetic basement is faulted along the NW–SE direction with the upthrown side lying to the north of the anomaly trend of this region. The coincidence of magnetizations observed through the present interpretation with that of charnockites of neighbouring EGMB and onshore K–G basin areas indicates that EGMB geology (charnockites, granitic gneiss, etc.) extends up to COB in the offshore K–G basin.

1. Introduction

The Eastern Continental Margin of India (ECMI) has been a seat of vigorous geophysical exploration for the last four decades. Its three major river basins, viz., the Cauvery, the Krishna–Godavari and the Mahanadi, are believed to be the result of the break-up of peninsular India from the combined Antarctica and Australia, and subsequent downwarping of the eastern part of the Indian shield (Sahni 1982). Hence, studies on ECMI and its river basins in particular would help one to understand the sequence of events that occurred during the break-up.

Of the three basins, the Krishna–Godavari (K–G) is a prominent petroliferous basin extending over an area of 28,000 km² on land, 24,000 km² in ‘shallow’ (up to 400 m) waters and 18,000 km² in deep waters (up to 2000 m) (Sastri

et al. 1973, 1974; Shenai and Rao 1982; Kumar 1983; Venkateswarlu *et al.* 1992a, b; Murthy *et al.* 1995).

The present communication reports the basement configuration of K–G offshore basin, based on the analysis of magnetic anomaly data (figure 1) collected onboard *RV Gaveshani* and *ORV Sagar Kanya* along twenty-nine coast perpendicular traverses between 17° and 14°N latitudes by National Institute of Oceanography, Regional Centre, Visakhapatnam.

The shelf edge, foot of the continental slope (FOS) identified from the bathymetry map (Subrahmanyam *et al.* 2010) of KG offshore basin and the continent ocean boundary (COB) derived from the gravity (Subrahmanyam *et al.* 2001) and seismic results (Gopala Rao *et al.* 1997) are presented along with the magnetic anomaly map in figure 1.

Keywords. Marine magnetic anomalies; offshore K–G basin; magnetic basement; extension of EGMB geology; continent–oceanic boundary.

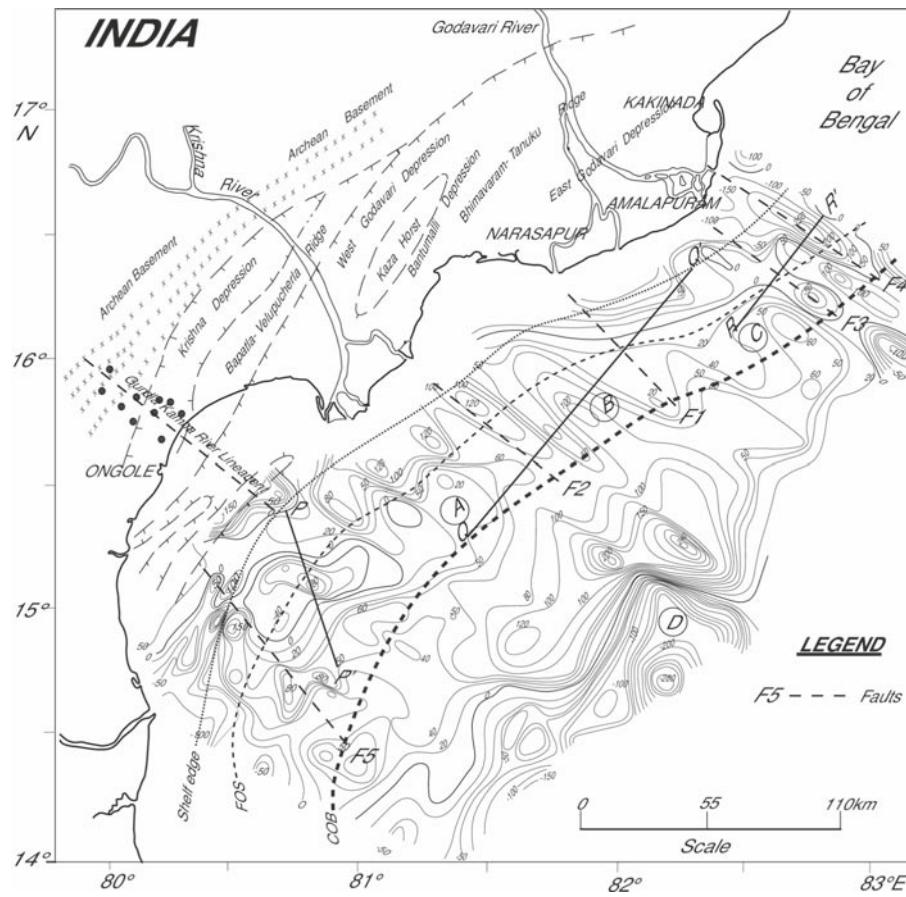


Figure 1. Total intensity magnetic anomaly contours over K-G offshore basin. Zones A, B, C and the three representative profiles, P-P', Q-Q' and R-R' are shown. Land geology and tectonics are also shown.

2. Magnetic anomalies of offshore K-G basin and their character

The magnetic anomaly contour map prepared at a variable contour interval brings out a conspicuous NE-SW trending anomaly pattern, over which several anomaly closures of varied amplitudes are superimposed. This anomaly map along with the single beam and multi-beam bathymetry data was earlier investigated qualitatively wherein the anomaly closures are attributed to the extension of the proved graben-horst type basement on land into the Bay of Bengal (Subrahmanyam *et al.* 2010). Several fault lineaments, e.g., F1, F2, F3, F4, and F5 were also identified based on the bathymetry signatures and magnetic anomaly trends. The fault lineaments F1 and F2 correlate well with land river lineaments of Godavari and Krishna rivers respectively indicating their probable offshore extension. The fault lineament F3 was shown as offshore extension of the major river Godavari, and F4, F5 indicating cluster of intrusions suggested by high frequency, short wavelength magnetic anomalies. The multi-beam bathymetry map off Narsapuram in the continental margin area (Pattan *et al.* 2008) brought out a NW-SE trending topographic rise

extending towards the land and appearing to abut the trend of the Bhimavaram-Tanuku Ridge at the coast.

Based on the anomaly character, the study area can be divided into four zones, viz., A, B, C and D. While zones A, B, and C fall in the continental margin of K-G basin area, zone D falls in the abyssal plains of Bay of Bengal. The anomaly zone A is sheared and shifted by an intervening NW-SE trending anomaly zone B bounded by the fault lineaments F1 and F2 (figure 1). In zone A, bounded by fault lineaments F5 and F2, the anomalies generally trend in SW-NE direction and have amplitudes between -80 and +120 nT. This zone is also associated with an isolated anomaly at 79°45'E longitude and 15°N latitude which is having a limited lateral extension, and of bi-polar nature. The zone B is associated with NW-SE trending anomaly closures with magnitudes varying between +40 and +120 nT lying between shelf edge and COB. These anomaly trends are earlier assumed to be due to the offshore extension of Bhimavaram-Tanuku Ridge (Subrahmanyam *et al.* 2010). Several smaller NW-SE anomaly closures of magnitudes varying between +50 and +120 nT can also be observed

between coast and zone A which are interestingly terminating at shelf edge on the NW side and at FOS on the SE side. In contrast, zone C (lying in the northeastern end of the study area beyond the fault lineament F1) is associated with high frequency short wavelength NW–SE trending anomalies of amplitude varying between +20 and –250 nT. This zone corresponds to the Godavari graben on the shore. Zone D, which falls in the abyssal plains of the Bay of Bengal is associated with a conspicuous NE–SW trending anomalous feature extending between 81° – 82.5° E longitudes and 14° – 16° N latitudes with amplitudes of anomalies varying between –280 and +240 nT. This conspicuous feature was earlier attributed to a submerged volcano without giving any explanation to its origin (Venkateswarlu *et al.* 1992b). However, this anomalous feature when interpreted along with its associated gravity low could be attributed to a buried structural high formed by volcanic activity in a normal geomagnetic period after Cretaceous magnetic quiet period (Swamy *et al.* 2009).

3. Inversion of magnetic anomalies

In the present study, an attempt is made to interpret quantitatively the magnetic anomaly data falling under zones A, B and C to understand the nature of magnetic basement in the area of continental margin of the offshore K–G basin. For this purpose, several magnetic profiles lying between shelf edge and COB were constructed from the magnetic anomaly and inverted for the structure on magnetic interface using the FORTRAN programs, TMAG2DIN, TSHEETIN and others (Radhakrishna Murthy 1998). Three representative profiles, P–P', Q–Q' and R–R' falling one each in zones A, B and C are presented in figure 2 along with the inferred structures. This inversion scheme TMAG2DIN assumes that the basement is magnetized in an unknown direction and the direction of magnetization is also estimated by trial and error. The program determines the initial values of depths to the magnetic interface below the anomaly points for the chosen magnetization and improves them iteratively, employing Marquardt's optimization algorithm. Similarly, the inversion scheme TSHEETIN attributes the anomalies to a thin horizontal sheet of matter and estimates its location and depth.

3.1 Inversion of anomalies in zone A

The interpreted magnetic basement under the profile P–P' in zone A along with the probable geological section below is shown in figure 2(a). This

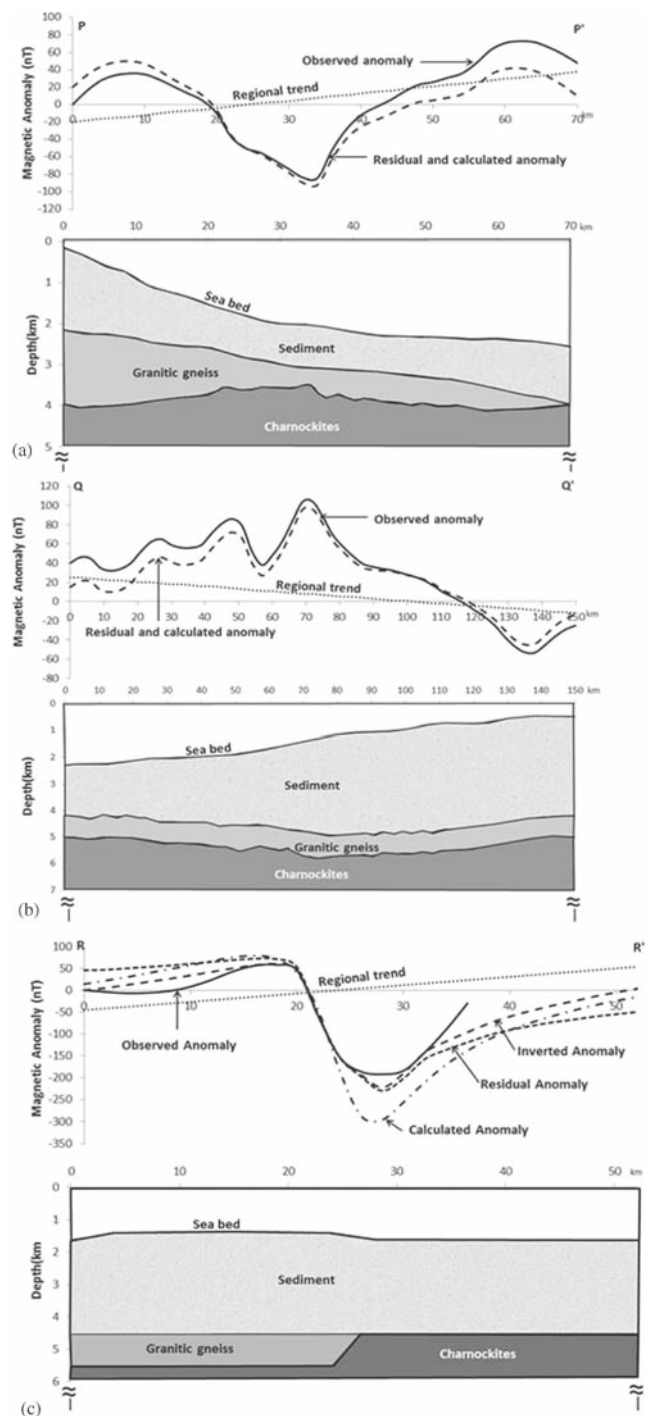


Figure 2. Interpretation of magnetic anomalies along profiles P–P', Q–Q' and R–R' with probable geological cross-section above charnockite basement.

profile runs 70 km along the continental slope in NNW–SSE direction and falls between shelf break and COB. The interpreted magnetic basement below this profile lies deeper than the base of the sediments, i.e., acoustic/granitic basement marked as granite gneiss in figure 2(a), as adopted from the sediment thickness map (Curry 1991). The inferred magnetic basement typically shows an upwarp (or horst-like structure) in the middle

of the profile P–P'. It is at a mean depth of 4.0 km and is magnetized with an effective magnetization of 600 nT, dipping up at 40°. These values are in good agreement with those of inferred magnetizations of charnockites in the neighbouring areas of Eastern Ghat Mobile Belt (EGMB) and onshore K–G basin (Radhakrishna Murthy and Bangaru Babu 2006; Swamy *et al.* 2008). It is therefore inferred that a magnetic basement is different from the acoustic basement and by analogy, it can be assumed to be constituted by charnockites. Thus a magnetic charnockite basement lies below the granitic basement in this offshore region also, as in the case of EGMB onshore. At the end of the profile, the magnetic basement appears to be touching the granitic basement beyond which the granitic/charnockitic basement may totally disappear. This situation is similar to the exposed charnockites in the onshore EGMB.

3.2 Interpretation of anomalies in zone B

The profile Q–Q' runs for 150 km in the NE–SW direction in the centre of the anomaly map across the NW–SE trending anomaly of zone B. This profile also lies between the shelf break and COB. The interpreted magnetic basement under this profile with the probable geological section is shown in figure 2(b). Inversion of the anomalies along this profile puts the magnetic basement at a mean depth of 5.0 km with an effective intensity of magnetization of 700 nT again dipping up at 70° which are again in agreement with that of charnockites onshore. Interestingly, the magnetic basement in this case also lies below the granitic basement. However, it shows a downwarp from its mean depth showing no sign of a rise as observed in the multi-beam bathymetric map off Narsapur to justify the seaward extension of Bhimavaram–Tanuku Ridge at the coast. As the magnetization of the basement rocks thus obtained in this case also agrees with those of the charnockites, it can be concluded that the magnetic basement in this zone B is also composed of charnockites.

3.3 Interpretation of anomalies in zone C

The profile R–R', which was constructed across the high frequency short wavelength anomaly features (NW–SE trending) falling in this zone C was unsuccessfully tried for a possible basement structure using the same TMAG2DIN program. This attempt brought out the magnetic basement lying at depths of 3–3.5 km, which cannot be justified as the minimum sediment thickness observed from the sediment thickness map (Curry 1991) or the depth to the granitic/acoustic basement is around 4.6 km.

However, the profile was successfully inverted for faulting in the magnetic basement, using the model of semi-infinite horizontal sheet (figure 2c) using the FORTRAN program TSHEETIN (Radhakrishna Murthy 1998) developed based on the Werner deconvolution technique. This inversion scheme not only estimates the model parameters, but also the linear regional anomaly trend. The calculated depth (5.1 km) in this method corresponds to the depth to the center of the sheet. Thus for a throw of 1 km the depths to the top and bottom of the magnetic basement will be 4.6 and 5.6 km respectively with an intensity of magnetization of 1030 nT dipping at 53°.

This interpretation shows that the magnetic basement is faulted along the NW–SE direction with the upthrown side lying to the north of the anomaly trend of this region. This is consistent with the known data for the depth to the acoustic basement, which is shallow in the northern side compared to the southern side of the anomaly C. Further, this anomaly trend corresponds to the onshore Godavari graben, whose magnetic anomalies required the assumption of a faulted magnetic basement to explain its anomalies. The offshore situation is thus no different to the onshore situation.

4. Discussion

The present interpretation of magnetic anomalies along the three profiles in the offshore K–G basin indicates that the magnetic basement lies deeper than the base of the sediments, i.e., the acoustic basement observed in the seismic sections. Thus it can be inferred that the magnetic basement is different from the acoustic basement. The magnetization of the basement rocks thus obtained in this present interpretation agrees well with those of the charnockites in the neighbouring onshore areas and, therefore, it can be concluded that the magnetic basement in this part of offshore K–G basin is also composed of charnockites, which lies below the acoustic/granitic basement.

Australia, Antarctica and India have been a part of single landmass (eastern landmass of the Gondwanaland) during Precambrian times with EGMB and Enderby Land of eastern Antarctica forming a part of the Precambrian Gondwanaland Mobile Belt (Crawford 1974; Katz 1989; Fedarov *et al.* 1982). It is also evidenced through the geological and geochronological correlations that the combined India and East Antarctica landmass experienced a widespread granulite facies metamorphic event at about 1000–1100 m.a. (Kroner 1980; Grew and Manton 1986; Aftalion *et al.* 1988; Yoshida 1988), because of which charnockites have been

evolved and formed a part of EGMB and Enderby Land of eastern Antarctica. In the later stages, the breakup of the peninsular India from the combined Antarctica and Australia and subsequent downwarping of the eastern part of Indian shield formed three major river basins Cauvery, Krishna–Godavari and Mahanadi, along the east coast of India (Sastri *et al.* 1981; Sahni 1982) with COB along the ECMI forming the breakup line. Thus the coincidence of magnetizations observed through the present interpretation with that of charnockites of neighbouring EGMB and onshore K–G basin areas indicate that EGMB geology (charnockites, granitic gneiss, etc.) extend up to COB in the offshore K–G basin, with the COB being the seaward limit of the granulitic belt and for several coastal trends (Murthy *et al.* 1995; Subrahmanyam *et al.* 1995).

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