

Gravity anomalies over a segment of Prathap Ridge and adjoining shelf margin basin, western continental margin of India

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Abstract—Bathymetric and gravity data totaling 2000 line km on the continental margin off Goa and Mulki, west of India have been studied. The free-air gravity anomalies vary between -60 to 25 mgals with prominent NNW-SSE trends in the outershelf region and ENE-WSW trends in the midshelf region. The subsurface extensions of the Prathap Ridge and shelf margin basin towards north and south were mapped. Two-dimensional model studies were carried out to infer the crustal structure. These studies revealed maximum thickness of 4 km. sediments over the shelf margin basin and the thickness of the crust thins out to 24 km. towards offshore.

INTRODUCTION

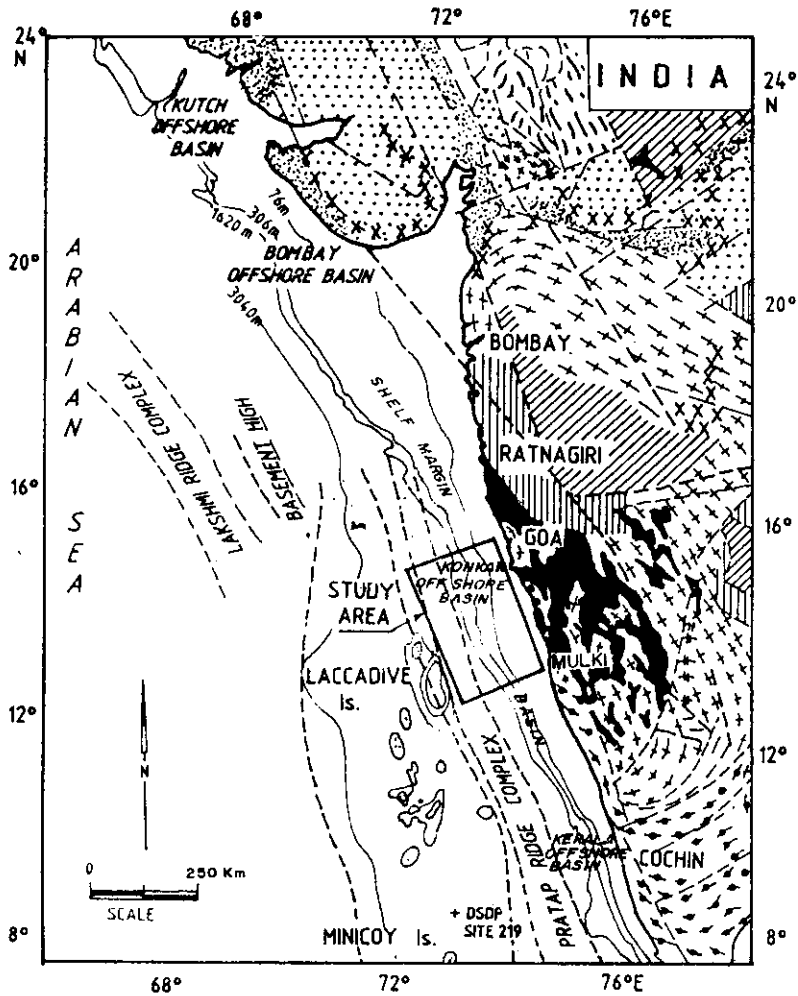
The seismic (refraction) studies were limited along the western margin of India and confined to the Laccadive Islands in the south (FRANCIS and SHOR, 1966) and to the shelf margin basin of Kathiawar coast in the north (CLOSS *et al.*, 1969). Bouguer gravity anomaly map at 10 mgal contour interval of the northwestern continental shelf of India was prepared and interpreted qualitatively (MURTI *et al.*, 1981). While gravity signatures due to the regional crustal features; the Lakshmi, Prathap and Chagos-Laccadive Ridges in the slope region were identified from thirteen widely spaced gravity profiles across the margin west of India (NAINI and TALWANI, 1982) (Fig.1). Crustal structure and density model for free-air gravity anomalies along a profile across the continental margin off Goa was interpreted (SUBRAHMANYAM *et al.*, 1989). Detailed geophysical studies were envisaged to understand the structural pattern of these offshore features. The present study is aimed to delineate the subsurface extensions of the Prathap Ridge, shelf margin basin and interpret structure and density model of the crust from free-air gravity anomalies under constraints from seismic reflection.

Offshore geology









Regional seismic reflection and drill well log studies by the Oil and Natural Gas Commission of India identified five major sedimentary basins along the western margin of India (RAMASWAMY and RAO, 1980). Among them, the shelf margin basin runs parallel to the shelf edge (Fig.1). Ortho-amphibolites and basalts were recovered from some of the islands in the vicinity of the study area (VALSANGKAR *et al.*, 1981; SIDDIQUIE *et al.*, 1987). Mafic intrusives off Malpe in 20-50 m water depth were interpreted by SUBRAHMANYAM (1987).

Offshore data

Bathymetric and free-air gravity data on the western continental margin off Goa and Mulki, India between 13°N and 15°30'N latitudes were collected along six NE-SW and four N-S profiles in water depths of 30-2000 m during several cruises of ORV Sagar Kanya. Continuous positioning of the profiles (Fig.2) was obtained using the Magnavox Series 200 Integrated Navigation System (INS). The system integrates the



LEGEND

- | | |
|---|---|
|  AREAS OF EASTERN GHATS FOLDING (ca. 2600 my) |  LATE PALAEOZOIC - MESOZOIC GRABENS/FAULT BASINS |
|  AREAS OF DHARWAR-INDO-ARAVALLI FOLDING (ca. 2600 my) |  TERTIARY - QUATERNARY GRABENS/FAULT BASINS |
|  AREAS OF SEMRI-CUDDAPH-FOLDING (ca. 1200 my) |  MESO - CENOZOIC PLATEAU BASALTS (LIMITS) |
|  AREAS OF VINDHYAN PLATFORM DEVELOPMENT (900 - 600 my) |  TECTONIC STRUCTURES : MAJOR & MINOR FAULTS |

(after Ray DK, 1977 &
Naini BR, Talwani M, 1983)

Fig.1. Physiography and regional structure (NAINI and TALWANI, 1982); major sedimentary basins (RAMASWAMY and RAO, 1980) along the western margin of India together with the geology and tectonic trends of the western India (RAY, 1977); DSDP Site 219 location is shown.

position of the vessel obtained from the dual channel satellite receiver with the speed and the course of the vessel. Bathymetric data was collected with a Honeywell Elac, narrow beam echosounder and bathymetric contour map was prepared (Fig.2). The gravity data was collected using the Bodenseewerk, KSS-30 model sea gravitometer. Free-air gravity anomalies were computed and stacked anomaly map (Fig.3) was prepared after correcting for misties.

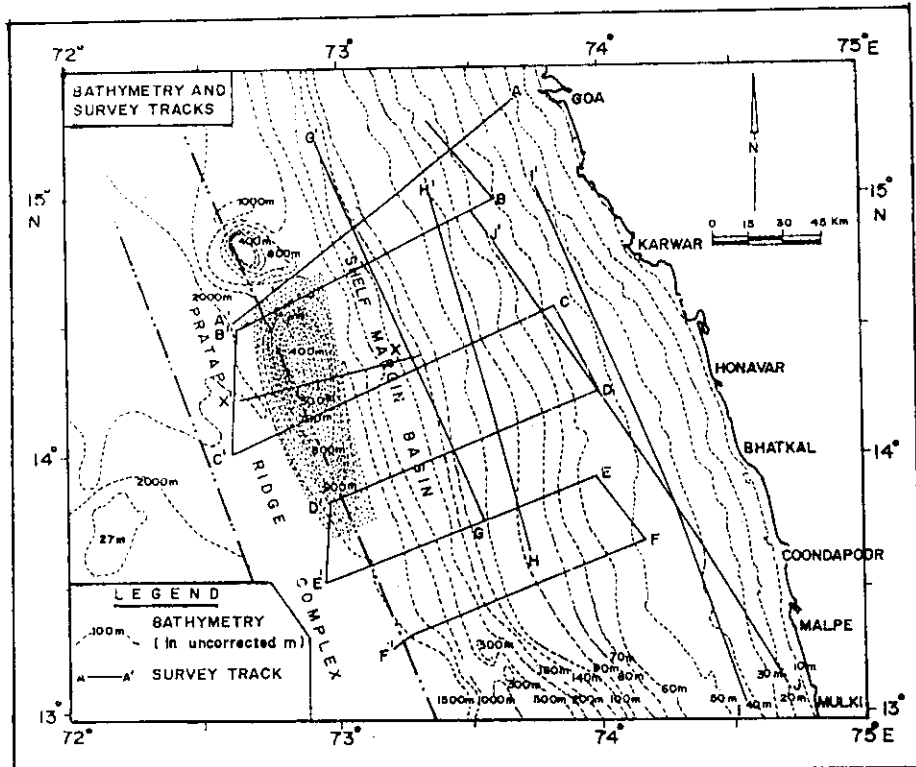


Fig.2. Detailed bathymetry of the study area with the location of profiles. The stippled area indicate the topographic expression of the Prathap Ridge.

RESULTS AND DISCUSSION

The continental shelf in the study area is 75-90 km wide and water depths range from 30 to 2000 m (Fig.2). The bathymetric map reveals an even topography and a gently dipping sea floor with an average gradient of 1:870 up to a water depth of 100 m. A steep gradient of 1:20 is observed between 100 m and 1000 m. An isolated prominent NNW-SSE trending positive bathymetric feature between 1000 and 2000 m water depths forms the eastern boundary of Prathap Ridge complex (NAINI and TALWANI, 1982) in the study area.

In the study area the free-air gravity anomalies vary between -60 to +25 mgal and show prominent NNW-SSE and ENE-WSW trends in the outershelf region and in midshelf region respectively (Fig.3). The free-air gravity anomaly along with bathymetric profiles are shown in figure 4. Gravity anomalies of varying amplitudes

-60 to 10, -40 to 10 and -10 to 20 mgals are observed in the southeast, central and northern parts of the shelf region upto 100m water depths. Two prominent anomalies trending NNW-SSE with amplitudes of -35 mgals low and of 65 mgals high occur between 100 and 1000m, and beyond 1000m water depths respectively. This gravity high depicts a clear expression of N-S trending subsurface expressions of the bathymetric relief. The axis of the feature lies on the eastern boundary of the Prathap Ridge complex.

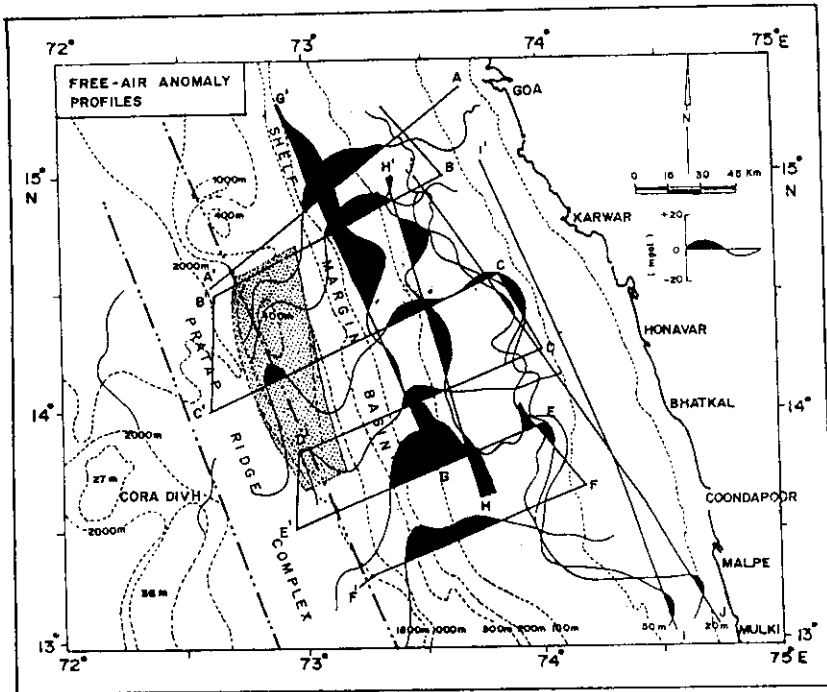


Fig.3. Stacked free-air gravity anomalies plotted perpendicular to the survey tracks. The stippled area indicate the topographic expression of the Prathap Ridge.

A broad southwest trending free-air gravity low, -60 mgal over profiles I-I' and J-J' (Fig.3) is observed off Bhatkal and Malpe in 20-40m water depths. The steep gradients of the gravity low may probably indicate the presence of deep seated faults. The positive anomalies (10 to 20 mgals) on the inner and midshelf regions (upto 100 m water depth) are localized, while the anomalies further offshore correspond to the Prathap Ridge Complex and shelf-margin basin.

Two-dimensional crustal structure model studies of the free-air gravity anomalies on the profile C-C', under constraints from seismic reflection results over the profile X-X' (Figures 5 and 6) across the continental margin off Goa and Mulki were carried out using the method of TALWANI *et al.* (1959). RAMAKRISHNA (1988) has shown the presence of Conrad discontinuity at an interface between 10-20 km with densities 2.6/2.9 gm/cc on the adjoining coast. The model is generated assuming five layers of water, sediment, upper crust, lower crust and upper mantle with densities 1.03, 2.3, 2.6, 2.9 and 3.27 gm/cc respectively (Fig. 6). Maximum sediment thickness of about 4.0 km were considered for construction of the crustal model. Two-dimensional isostatic

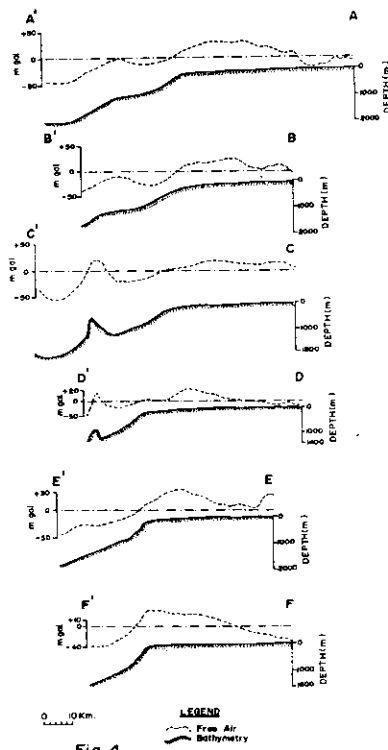


Fig. 4

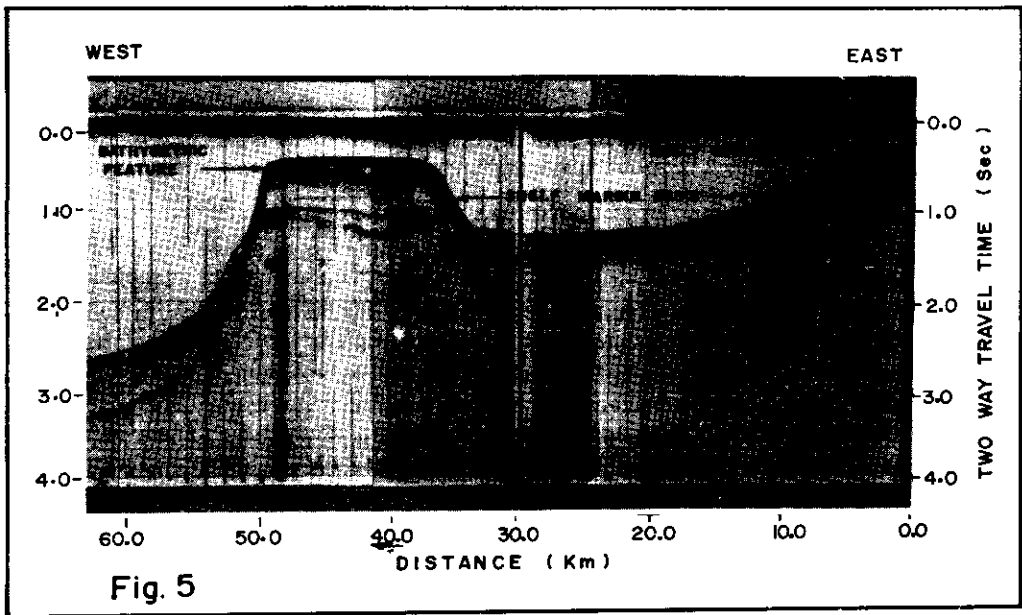


Fig. 5

Fig.4. Free-air gravity anomalies along with bathymetric profiles.

Fig.5. Seismic section showing the positive bathymetric high and the structure of the stratified sediments. For location of the profile X-X' see Figure 2.

gravity anomalies were also computed considering the simple Airy-Isostasy model for isostatic compensation. A depth of compensation of $T=30$ km was used together with density contrasts of 1.72 and 0.52 gm/cc at the water-crust and crust-mantle interfaces, respectively. The 30 km compensation depth was adopted from studies of crustal thickness in India by ARAVAMADHU *et al.* (1970) and KAILA *et al.* (1979).

The Airy-Isostatic anomaly (Fig.6) does not account for the shelf edge effect and it follows free-air anomaly. It thus appears that the sources for the anomaly lie in the crust.

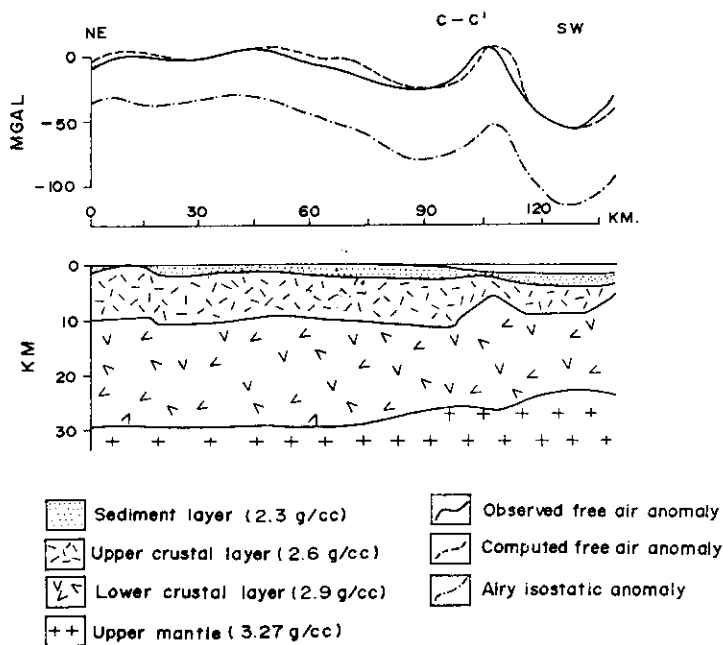


Fig.6. Profile showing two-dimensional interpreted density and crustal structure model from the free-air gravity anomalies. For location of the profile see Figure 2.

The excursions in the gravity anomalies in the shelf region are explained in terms of variations in the crustal layers bounded by steep gradients. The western shelf of India is an area of conjugate structures formed by horizontal and vertical movements of crustal blocks (BABENKO *et al.*, 1981). We presume that these gradients perhaps reflect basement faults. It is likely that the basement structure indicates the horst and graben formation controlled by faults. The regional gravity anomaly low beyond the shelf edge is accounted for increased sediment thickness, 3.0 to 4.0 km. The interpreted crustal structure model of the elongated NNW-SSE trending free-air gravity anomaly in the slope region reveals 6 to 7 km relief of the lower crustal layer with a 0.3 gm/cc density contrast. This relief in the crustal layer is interpreted in terms of the subsurface expression of Prathap Ridge. The crustal model also reveals that total thickness of the crust is 30 km below the innershelf with a gradual thinning to 24 km towards the seaward side.

CONCLUSIONS

a) Prominent NNW-SSE and ENE-WSW trends of the free-air gravity anomalies are observed in the outershelf and midshelf regions respectively.

b) The subsurface extensions of the NNW-SSE trending bathymetric relief over Prathap Ridge and the extent of the shelf margin basin in the study area are demarcated.

c) The horst and graben structure of the basement on the shelf is controlled by deep seated faults.

d) The crustal thickness in the study area varies between 24 to 30 km.

Acknowledgement-We thank the Director of the National Institute of Oceanography and Shri P.S.N.MURTHY, Head of the Geological Oceanography Division for permission to publish the paper. We thank Shri SHAM-KANT.G.AKERKAR for drafting the figures.

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