Mapping the sub-basalts and Crustal architecture of the Cambay Basin through potential field modeling

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Summary

The Cambay rift basin in the northwest Indian shield has opened a new frontier for hydrocarbon exploration due to the presence of thick Mesozoic sediments beneath the Deccan traps. The present paper details the current understanding of crustal architecture and tectonic evolution of the basin with the help of seismically constrained potential modeling. The maximum thickness of the Trap is in the Mehasana-Ahmedabad basin and is estimated to be about 2-3 km. The Traps appear to be thinner/absent towards the Sanchor-Patan basin. Further, the comparison of 2-D crustal models from different parts of the basin suggest that the crust is thinner underneath Mehasana-Ahmedabad basin, and is associated with high-density magmatic bodies (3.0 gm/cc) at a depth of 24-25 Km.

Introduction

The Cambay basin is an intra-cratonic graben evolved following the extensive outpour of Deccan Basalts during late cretaceous on the western and central parts of the India shield (Biswas 1987). The basin is bordered by Radhanpur-Barmer arch in the west and the Aravali orogenic belt in the east. Three major tectonic lineaments, the NNW-SSE trending Dharwar orogenic belt and the ENE–WSW trending Aravali and Narmada orogenic belt, extend into the Cambay Basin (Fig.1). Several transverse faults divide the Cambay basin into six major tectonic blocks (Fig.2). Further, seismic and drilled well data in the basin indicate that at least 1200 m of Mesozoic sediments could be lying below the basaltic traps which form the floor of nearly 5000 m thick sediment sequences (Avasthi et al.,1971). Deep seismic sounding (DSS) studies in the region between Mehmadabad and Billimora revealed that the Moho depth varies from 31-33 km with a high velocity layer at the base of the upper crust (Kaila et al., 1981, 1990; Dixit et al., 2010). Although, a large number of geophysical surveys have been carried out in the Cambay Basin, only few tried to address the Mesozoic rifting history and the driving tectonic processes. In the present study, an attempt will be made to quantify thickness of the Deccan Trap volcanism and deep crustal structure of the basin. The study involves analysis and interpretation of vast amount of ground potential field data in conjunction with Deep Seismic Sounding (DSS) data through the 2-D gravity modeling.

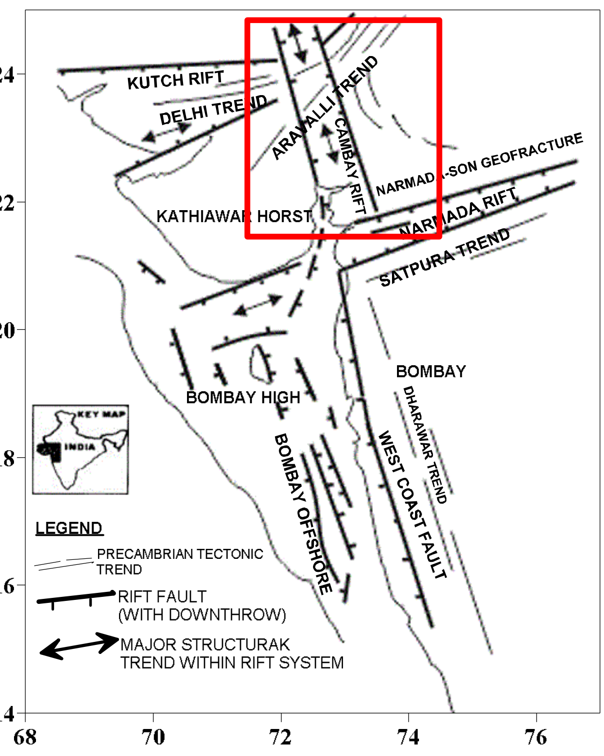

Figure 1: Regional Tectonic map of Western Continental margin of India. The study area is marked with the red rectangle.

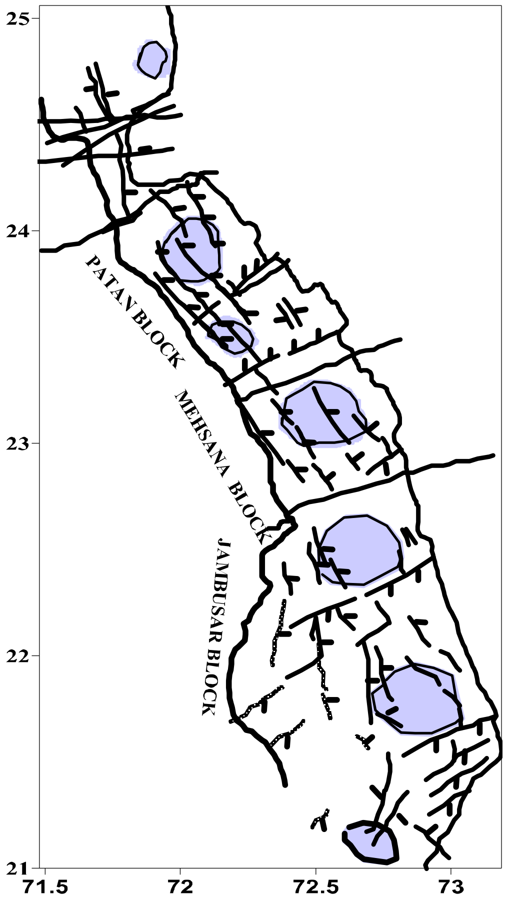

Figure 2: Tectonic map of Cambay basin

Data and Methodology

The depth to the trap surface (Fig. 3) is prepared based on the synthesis of results obtained seismic reflection and refraction with control from well data (Avasthi et al., 1971; Kaila et al., 1990). Bouguer gravity data (Fig. 4) utilized in the present study is compiled from the published gravity anomaly maps available for the Indian shield region (NGRI, 1978).

In order to understand the crustal architecture of different segments of the Cambay basin we have performed 2-D gravity modeling along the two regional transects (AA' and BB'). For this purpose, Bouguer gravity anomaly data were extracted from their respective grid. The initial geometry along these transects was considered based on the well data and Deep Seismic sounding (DSS) results available in this region (Avasthi et al.,1971; Kaila et al., 1981, 1990; Dixit etal., 2010). These studies indicate that depth to the Deccan Trap surface (Fig. 3) increases from northern part of the basin to southern part of the basin with maximum accumulation of sediment in the Ahmedabad-Mehasana (3-6 km) and Broach blocks (3-8 km). Further, a high velocity layer of 7.2-7.4 km/sec was also reported from the DSS studies. Finally, the initial geometry of the layers was adjusted iteratively till a reasonable fit was obtained between the observed and calculated anomalies. Here, gravity response of the model was computed with the help GM-SYS software, which uses the algorithm developed by Talwani et al. (1959).

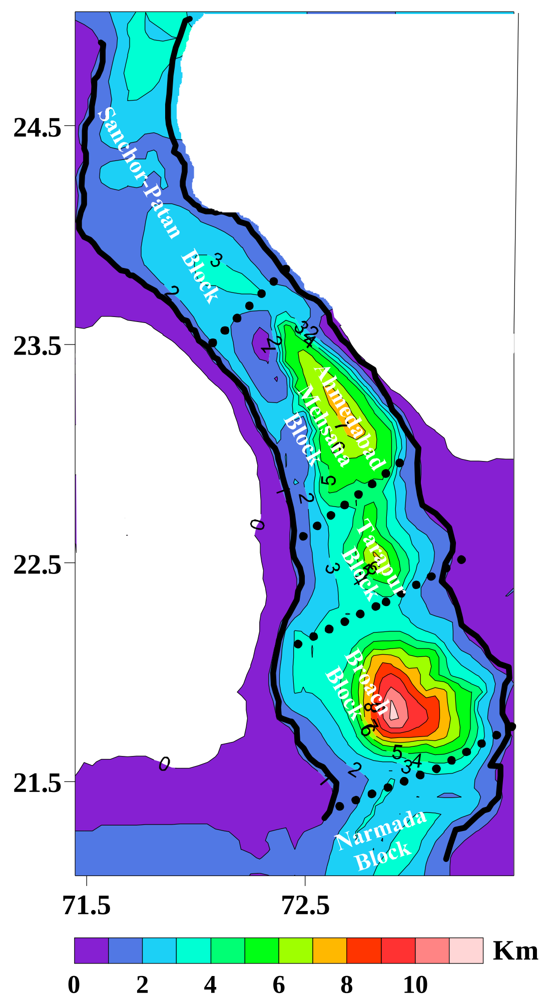

Figure 3: Structural map of the Deccan Trap surface

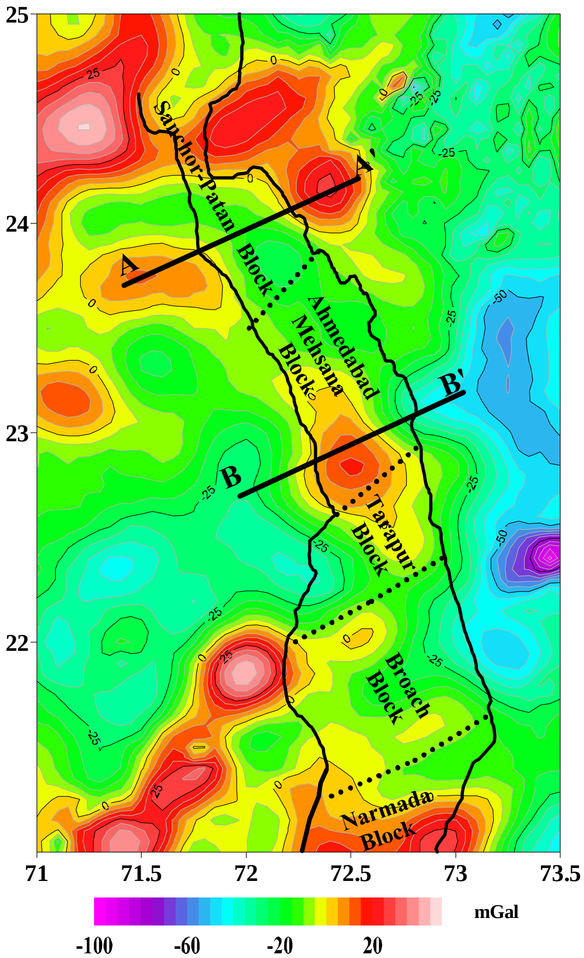

Figure 4: Complete Bouguer anomaly map of Cambay basin (after NGRI, 1978)

Table 1 Seismic velocities and their corresponding density values considered for 2-D gravity modeling

Layers	Velocity range (km/s)	Density (gm/cm3)
Sediments	2.2-3.3	2.4
Deccan Trap	4.3-4.8	2.8
Upper Crust	5.8-6.3	2.7
Lower Crust	6.5-6.8	2.85
Upper Mantle	8.1	3.3
Magmatic underplating	7.2-7.5	3.1

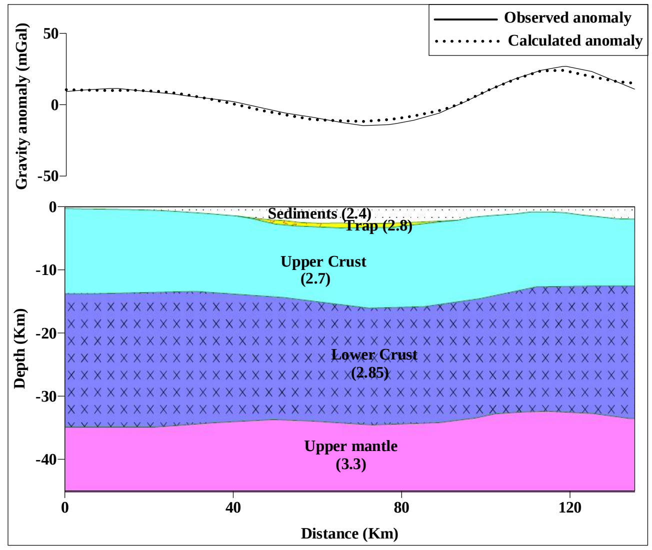

Figure 5: 2-D Crustal model across the Sanchor-Patan block (AA')

Analysis and interpretation

The Bouger gravity map of the Cambay basin (Fig. 4) reveals several contrasting signatures from north to south. In sanchor-Patan block, low gravity (-25 mGal) values are observed in the in the central part of the basin with peak gravity values (10-30 mGal) over the flanks of the basin. In contrast to this, the Mehasana-Ahmedabad sub-basin is characterized with low gravity values (-25 to -45 mGal) at the marginal part of basin and high gravity values (10-30 mGal) in the intervening basin. Similar characteristics are also observed in the Tarapur sub-basin. While the gradually decrease in gravity values from west to eastern margin of the basin is noticed in the Broach block. Further, E-W and N-S trending gravity high closures of 20-30 mGal are also observed in the sanchor-Patan and Mehasana-Ahmedabad blocks respectively. Several authors have attributed these gravity high features either to Moho upwrap to shallow crustal level or the presence thick underplated material in the lower crust (Tewari et al., 1991; Singh, 1998). Further a disposition of gravity anomalies is also observed at the boundary between the each sub-basin.

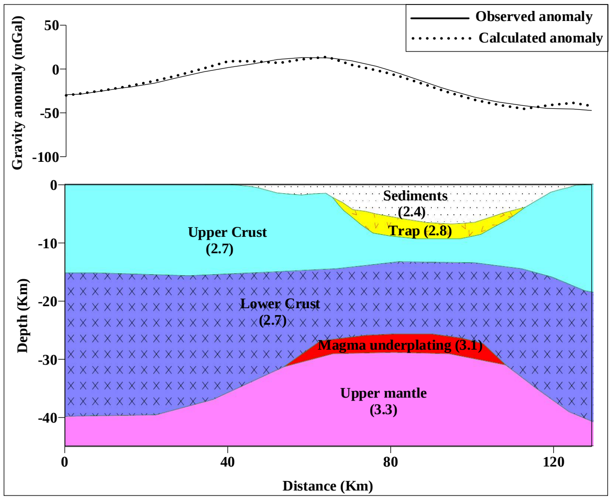

Figure 6: 2-D Crustal model across the Mehsana-Ahmedabad block (BB')

The seismically constrained gravity models that were presented below (Fig.5&6) provided new information about variations in the crustal structure along different segments of the basin. The model along AA' (Fig. 5) suggests that the crustal structure below the Sanchor-Patan basin is normal compared to the adjust Saurashtra and Aravalli regions. While the modeling results along BB' (Fig. 6) indicate that crust below the Mehasana-Ahmedabad basin is about 18-20 km thick with a high density body of 3.1 gm/cc at the lower crust and it gradually increases on the either side of the basin (Fig. 6). Earlier, Kaila et al., 1990 and Dixit et al., 2010 have reported such high velocity bodies (7.2-7.4 km/sec) in this region based on the DSS data. According these authors, these high velocity bodies were formed during the large-scale eruption of the Deccan volcanism on the western Indian shield due to reunion plume.

Conclusions

The combined interpretation of gravity and seismic data in the Cambay basin has provided valuable insights about the crustal architecture and tectonic evaluation the basin. Several key results of the study are summarized below:

- The maximum thickness of the Deccan traps about 2-3 km lies in the Mehasana-Ahmedabad basin. While in the Sanchor-Patan basin its thickness appears to be very thin.
- Moho depth varies from 31-34 km within basin and it increases gradually towards the marginal part of the basin.
- Crust below the Mehasana-Ahmedabad basin appears to be thin with a high density body at lowers crust. In contrast to this high density bodies were absent in the Sanchor-Patan basin.

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