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Crustal density model along Gopali- Port Canning profile, West Bengal basin using seismic and gravity data

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ABSTRACT

An integrated approach of processing and interpretation of the seismic, gravity, geological and structural details along Gopali- Port Canning Deep Seismic Sounding (DSS) profile, West Bengal basin has helped in deriving a crustal density model. This model clearly explains the trend, shape and magnitude of the Bouguer gravity anomalies across southern parts of the West Bengal basin.

The study pointed out that the thick sedimentary column (thickening towards east) and lateral structural variations in the middle and lower crustal layers coupled with structural trends in the basement have jointly contributed to gravity effect. The prominent lateral variations in the Bouguer gravity anomalies could mainly be attributed to regionally extending causative factors. The derived model is useful in understanding the complex structural trends of geodynamic importance.

INTRODUCTION:

Recent Alluvium extensively covers the Bengal basin. It is one of largest basins in the world. Its geometry is covered by step faults. It consists of a section of Mesozoic and Tertiary deposits, which in the deeper parts of the basin. Standard Vacuum Oil Company (STANVAC) and Oil and Natural Gas Commission (ONGC) drilled several wells have penetrated only the top sequence of sediments overlying the Cretaceous-Jurassic formations. The shallow seismic studies coupled with gravity studies and well logs have not yielded sufficient information regarding the deeper sedimentary column. All the geophysical methods (including seismic) and drilling in the area have been restricted mostly to the top of the Rajahmahal Traps, the deeper horizons being of less interest to oil exploration. Kaila et al 1992 have carried out a detailed study in West Bengal basin, India (Fig.1a). The study has revealed most important information about shallow and deeper structure.

We have utilized the 2-D seismic crustal velocity-depth section derived by using primary refraction and wide angle reflection data and their multiples (Reddy, Prasad & Sarkar 1998, Prasad, Sarkar & Reddy 2002, Prasad, Reddy & Sarkar 2003) for the present study. This is a refined model compared to the earlier model of Kaila et al., 1992. In the present study, an integrated interpretation has been made of available well litholog information, refraction and wide-angle reflection results (Prasad, Reddy & Sarkar 2003) and Bouguer anomaly data NGRI (1978) Fig.1b, covering the area between Gopali and Port Canning. The results obtained out of the integration are discussed in detail.

GENERAL GEOLOGY OF THE WEST BENGAL BASIN:

The Bengal basin is one of the largest basins in the world. West Bengal basin is surrounded by Bay of Bengal on its southern side, the Rajmahal hills on the northwestern side and the Shillong Plateau on the northeastern side. It is bounded on the west by Indian peninsular shield of Archean basement rocks and intracratonic Gondwana basins. The Naga- Lushai folded belt which forms part of the Himalayan-Burmese mobile belt, outlines the basin’s eastern limit. The Bengal basin comprising Indian and Bangladesh provinces is extensively covered by recent alluvium. Other geological formations exposed in the area include upper Jurassic to lower cretaceous Rajmahal Trap in the north and upper Carboniferous to lower Triassic Gondwana sediments along E-W trending Damoder river basin, in the west and Pleistocene, lower Precambrian and Tertiary rocks in the region west of Gopali (Tandon 1954). Just beyond the western boundary of West Bengal basin, the great Indian shield disappears below a blanket of alluvium.

Intensive geophysical surveys and deep drilling in the alluvial plains of the West Bengal (Sengupta 1966) revealed a thick section of Cretaceous and Tertiary sediments lying on a basement of basalt lava flows, presumably of the same age as that of Rajmahal group of volcanics.

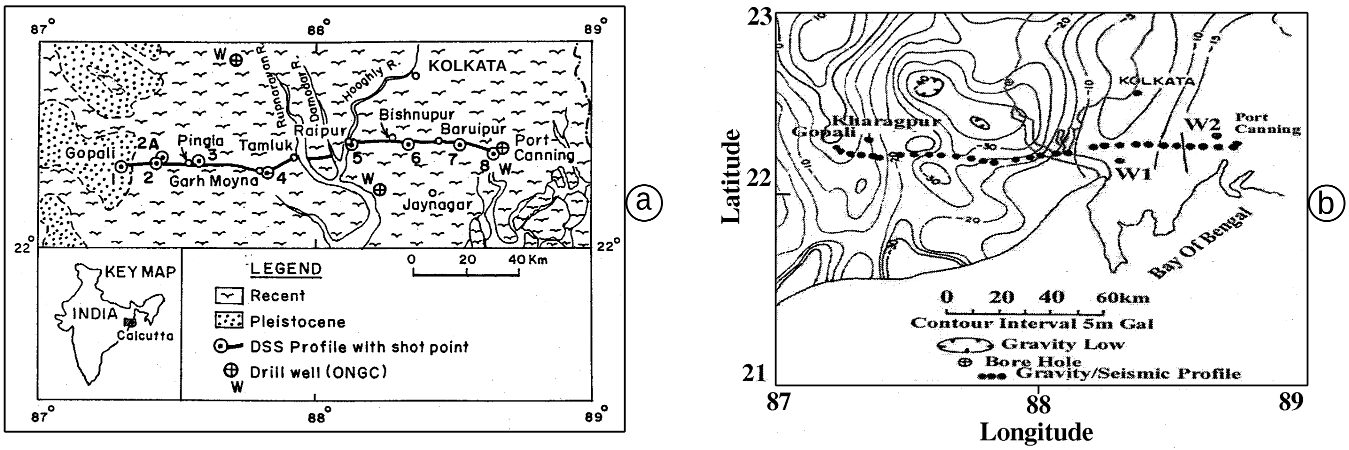

Figure 1a. Location map of the Gopali- Port Canning profile in the West Bengal basin on the geological map of the region. 1b. Bouguer anomaly map of the study area (NGRI, 1978)

CRUSTAL SEISMIC VELOCITY STRUCTURE ALONG THE PROFILE:

Reddy, Prasad & Sarkar (1998), Prasad, Sarkar & Reddy (2002), Prasad, Reddy & Sarkar (2003) have derived a well-constrained velocity depth section along this profile. Their study revealed a five-layered thick sedimentary column above the crystalline basement having velocities 1.50 km/s (Recent- Sub- Recent), 2.55-2.70 km/s (Pliocene-Pleistocene-Miocene-Oligocene), 3.80 km/s (Eocene), 4.5-5.0 km/s (Paleocene-Cretaceous-Jurassic) and 5.5 km/s with high velocity gradients. The third layer might correspond to limestone formations and appears to be a very good marker throughout the basin. The fourth layer represents Rajmahal Traps. The velocity 5.5 km/s might correspond to the Singhbhum group of rocks, which are exposed in the Singhbhum craton west of the profile. The crystalline basement velocity from the top of the granitic layer to the top of the LVL varies from 5.90 to 6.00 km/s layer. This may probably represent Archean and Precambrian granites and gneisses. A low velocity layer (velocity 5.7 km/s) that is present in the upper crust may be an intra crustal layer. The upper (velocity 6.4 km/s), mid (velocity 6.8 km/s) and lower crustal layer (velocity 7.5 km/s) are above the Moho (velocity 8.1 km/s). Velocity of 7.5 km/s noticed in the lower crust might represent magamatic underplating, a significant process of geodynamic importance. Such underplating noticed in Mahanadi basin (Behera, Sain & Reddy 2004) suggests the magnitude of the magmatic underplating in this region. .

GRAVITY MODELING:

The objective of gravity modeling is primarily to test a density model derived from the refraction and wide angle reflection data along the present profile and secondly to provide additional information for the geological interpretation of the seismic section. Gravity modeling places constraints on the validity of the crustal seismic model because if a model is not valid, it will be inconsistent with the observed gravity anomaly when reasonable density values, based on seismic velocity are used (Catchings & Mooney, 1991).

Whether the seismic structure of the crust is consistent with gravity model or not, gravity effects have been computed for the seismically derived structure and compared with the observed gravity Bouguer gravity anomalies. Crustal cross section, along Gopali-Port Canning profile (Fig.1a), West Bengal basin (Prasad, Reddy & Sarkar 2003), Bouguer gravity anomaly values NGRI (1978) (Fig.1b) have been made use of in this present integrated study. SAKI Fortran program (Webring 1986) has been used to derive a two-dimensional density model of the profile. Selecting a proper choice of average densities for the layers is a main problem in crustal modeling especially in view of the various assumptions made for velocity density relations (Mathur 1974). In the present case, information of the Borehole samples from shales, Sylhet Limestone, Rajahmahal Traps and Gondwana Sediments is available, adding considerably to the quality of the modeling.

The density values used for the present study by Barton 1986 and the density values from borehole samples are in agreement with the density values derived by other workers (Evans & Crompton 1946; Choudhury & Datta 1973; Verma & Mukhopadhyay 1977; Tiwari 1983 and Mukhapadhyay, Verma & Ashraf 1986). The average density of the sedimentary column was calculated along the Gopali- Port Canning profile mainly using borehole samples information at close intervals along the profile.

The seismic velocities in the crust were converted to density values using the relationship derived by Barton, 1986. From this the upper crustal density has taken as 2.78gm/cc. The densities for the middle crust layer 2.83gm/cc and at the lower crustal level the density value is 3.05gm/cc. The density 3.30gm/cc value is for Moho layer. Taking the above values the gravity effect of this multi-layered sub-surface configuration was calculated. Adjusting the density values of different blocks of the subsurface within permissible limits (Reddi, Mathew & Kailasam 1967, Barton 1986) a better match has been obtained with the observed Bouguer gravity data. Fig.2a reveals a satisfactory match between the observed and calculated Bouguer gravity values. The derived density-velocity model is shown in Fig.2b.

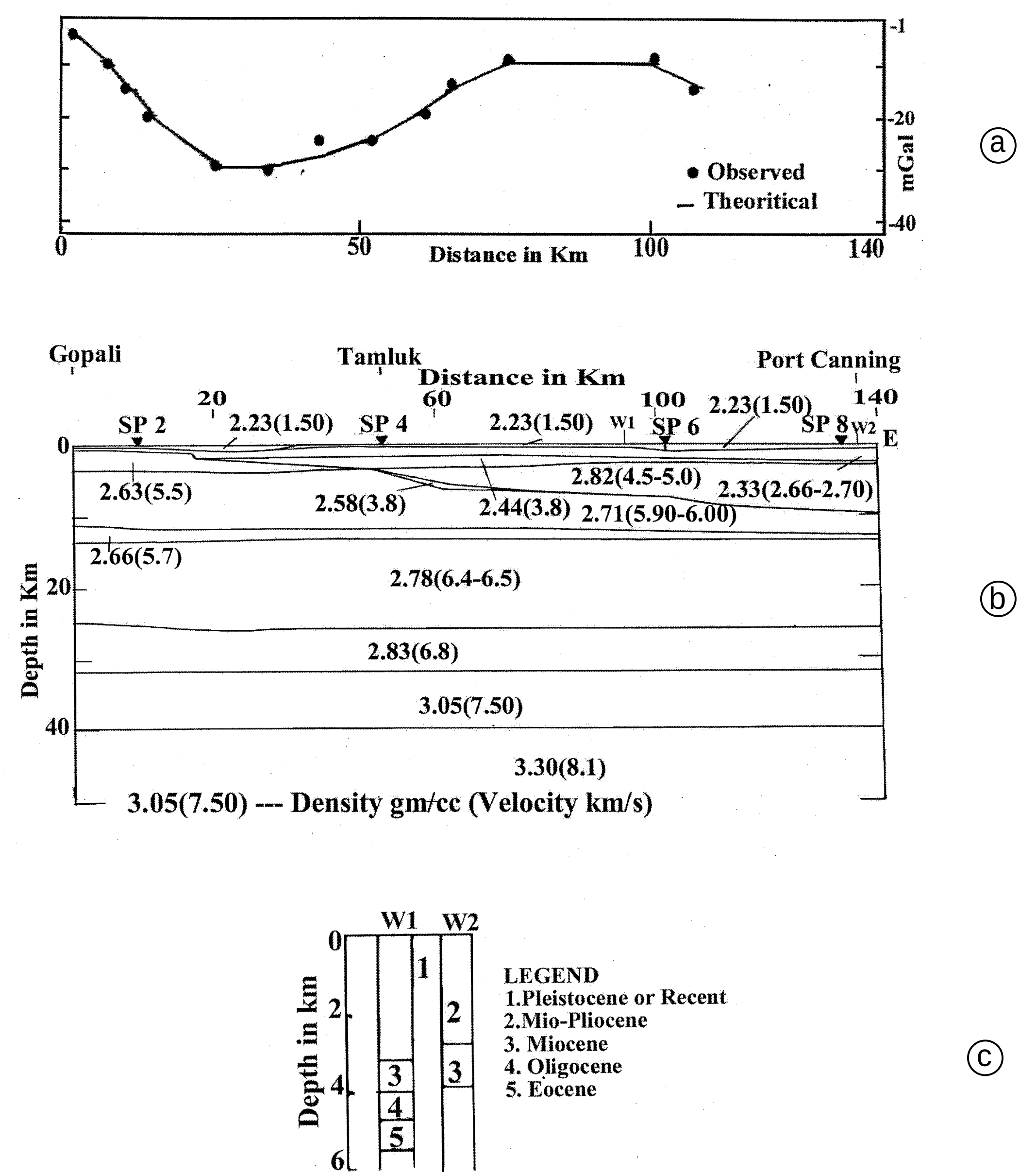

Figure 2a. Bouguer gravity anomaly data plotted along the Gopali-Port Canning profile and 2b. 2- Dimensional density model along the profile. 2c. Lithology of boreholes.

DISCUSSION:

In general, gravity modeling with several bodies of variable geometry and density is more valuable for excluding rather than proposing structural models (Holliger & Kissling 1992). In the present analysis to a considerable extent this ambiguity has been eliminated due to seismic control. From gravity modeling which was constrained by seismic and borehole data, it is evident that the Bouguer anomaly values could be correlated well with the seismic results along Gopali- Port Canning DSS Profile in terms of the trend, shape and magnitude of the anomaly values. From the Systematic analysis in modeling the gravity data, the effect of sedimentary, upper, middle and lower crustal columns (Fig.2b) seems to have cumulatively contributed significantly. Tiwari (1983) has shown that a major component of the Bouguer anomaly could be due to the high-density sedimentary column below the Tertiary sediments. Form the present study (Fig.2b) it is evident that this finding is more or less appropriate as the thickness of sedimentary column is significant compared to the overall thickness of upper, middle and lower crustal columns.

Due to considerable overlapping of velocities for different rock formations of varying densities, direct conversion of velocity into density was found impractical. As such we have used the relation of velocity and density values (Barton 1986) for obtaining the subsurface crustal column. Our selection of Barton's relationship has yielded very good results. This study clearly points out that the crustal density model (Fig.2b) explains the lateral variations in the gravity anomaly values along the profile.

The lithological data (Fig.2c) from the wells of W1 and W2 clearly indicates that below Recent, sub-Recent, Pliocene-Miocene and Miocene- Oligocene formations, there is a thick column of Eocene formations. The layer with velocity 3.8 km/s might probably be associated with Eocene formations. The formations below the Eocene layer could be Cretaceous- Late, Middle and Early (Kaila et al. 1992, Prasad, Reddy & Sarkar 2003). The layer with velocity 4.5-5.0 km/s may correspond to Rajmahal Traps of Early Cretaceous age.

The present exercise clearly shows that the lateral variations in the gravity anomaly values along Gopali-Port Canning DSS profile are explained by the crustal model (Fig.2b).

CONCLUSIONS:

Integrated interpretation of seismic and gravity data coupled with geological and structural details has helped in deriving a crustal density model along Gopali-Port Canning profile. The model explains well the lateral variations in the gravity anomalies.

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