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Integrated analysis of G&G data for delineating Sub-Basalt in Bengal Basin.

Abstract

Extension of Rajmahal trap and underlying Gondwana sediments towards eastern part of Bengal basin remains elusive as the overlying tertiary sediments is becoming thicker and no well have been drilled through. Seismic data below the Eocene limestone could not bring out clear events that can be corelatable to these two layers. An attempt is made to delineate basalt and sub-basalt by integrating available G&G data. For the study geological information along with gravity, magnetic, magnetotelluric, seismic and well data were studied and analysed.

A regional gravity anomaly map prepared by incorporating public domain Bangladesh gravity data brought out many known geological features such as Hinge zone, Kolkata-Mymensingh gravity high, Kishanganj fault etc. Horizontal gravity gradient map could bring out the trend of Hinge zone and its extension towards Bangladesh.

Gravity stripped map prepared by removing the gravity effects of post-trappean sediments and gravity effect of raised mantle brought the extension of sub-basalt sediments towards east of the basin.

GM modelling brought out that depth to basement is ranging from 2 -15 km or even more in eastern part of the study area and trap thickness increasing from west to east.

Introduction

Bengal basin, in the north-eastern India, had evolved through two distinct tectonic episodes. The first episode is believed to be occurred between Late Paleozoic-Mid Mesozoic times. During this period the basin was initiated as an intra-cratonic rift basin within Gondwana land and received the continental Gondwana sediments. The development of basin ended with wide spread volcanism during early Cretaceous when the continental flood basalts (Rajmahal Trap) covered the Gondwana sediments. Second phase of basin formation took place when Indian Craton separated out completely from the Gondwana land and kept on moving northwards. During this journey the peri-cratonic part on the eastern margin subsided continuously and received enormous volume of sediments from Late Mesozoic through Tertiary to Recent times in a passive margin set-up. Thus the Gondwana sediments and overlying Rajmahal traps buried deep below younger sediments.

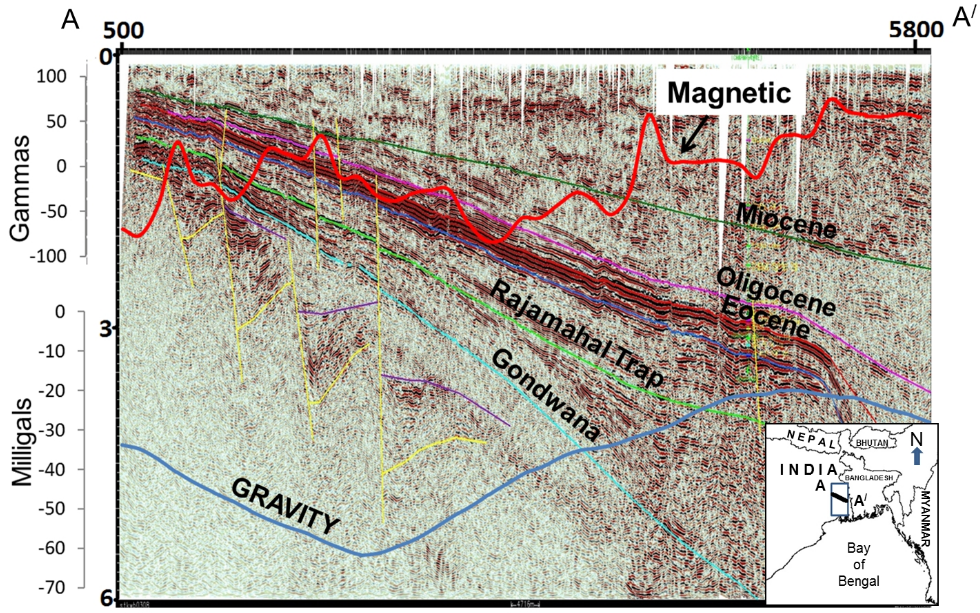

Fig.1. Interpreted seismic section along profile AA/ overlain by gravity and magnetic anomaly.

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Figure 1 shows a composite seismic section of northwest-southeast direction profile AA/ in which all the reflectors are dipping towards southeast gently up to Eocene hinge zone. Correlation with well data could be able to identify Gondwana sediments below the Rajmahal traps upto middle part of the profile as the continuity of the events could not be ascertain further. In contrary to seismic at the beginning the gravity anomaly is dipping till it reaches a low of -47 milligals near the middle of first half of the profile then it rises towards southeast to a maximum of -6 milligals near Eocene Hinge zone where the post trappean sediment thickness is more than 7 km. It clearly indicates the influence of high density long wavelength causatives far from this area. The increasing trend of observed magnetic data while the magnetic sources Rajmahal trap and basement is dipping towards southeast is well corroborated with reverse magnetic polarity of shallower Rajmahal traps.

Regarding hydrocarbon exploration many seismic campaigns had carried out in the past and few wells were drilled in the basin without any success. These could be able to bring out trap and sub-trappeans in the western marginal area of the basin. But the extension of Gondwana sediments in eastern part of the basin remains elusive as trap thickness and its burial is increasing towards east. With new input in the basin an attempt is made to delineate the basalt and subbasalts in the basin.

Gravity Data

A gravity anomaly map is prepared by merging vintage ONGC data and data acquired under NELP regime with public domain Bangladesh gravity data to have a better regional view of Bengal basin and its adjoining areas, (fig.2). The map shows a prominent gravity low at the middle part of the study area trending NNE-SSW, which bifurcates into two arms, one towards northeast direction which terminates/merges at Dauki fault in southern boundary of Meghalaya and other arm in north northwest direction towards Purnea and Madhubani depression. This gravity low may be due to accumulation of low density Gondwana sediments below Rajmahal traps as seen in seismic section (fig.1). The gravity high in the west may have combined gravity effect of exposed basement, shallow basement and higher density Rajmahal trap. Gravity high towards eastern part of gravity low, known as Kolkata-Mymensingh gravity high, may be due to effects of raised up of Moho, thickening of Rajmahal traps and absence or thinning of sub trappean sediment.

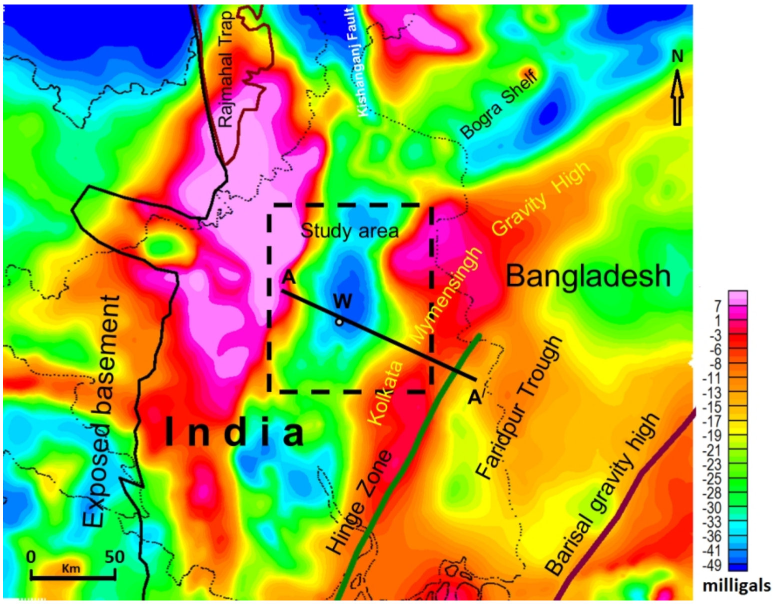

Fig. 2. Bouguer gravity anomaly after merging with public domain Bangladesh gravity data.

To analyze further residual gravity anomaly map along with three gravity gradient, two on horizontal direction and one in vertical direction are prepared and shown in figure 3. The residual gravity anomaly map shown in fig. 3(A) and vertical gravity gradient in fig. 3(B), which is sensitive to shallow causatives, brought out finer details. A number of isolated gravity lows and highs are seen in these maps. The gravity low is correlatable with low density sediment in the grabens and gravity highs to the horst in the western margin of the basin as seen in seismic section (fig.1).

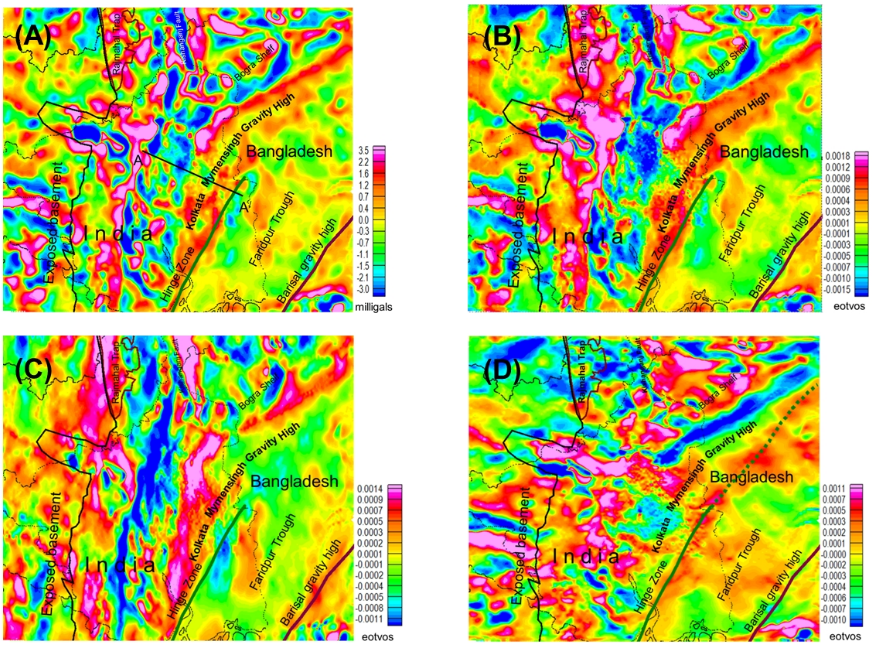

Fig. 3. (A) residual gravity anomaly map prepared after filtering wavelengths longer than 40 Km. (B) Vertical gravity gradient map (C) Horizontal gravity gradient map in E-W direction and (D) Horizontal gravity gradient map in N-S direction.

The horizontal gravity gradients brought a number of faults and edges. The gravity gradient along EW direction in fig.3 (C) has brought out clearly shelf margin fault and Kishanganj fault. While NS direction gravity derivative map in fig.4 (D) brought out the trend of **hinge zone** which was not clear in Bouguer gravity map and its extension towards Bangladesh. The same is validated from seismic, the continuous green line is marked from seismic overlain exactly on dotted line drawn on the basis of gravity gradients map.

MT data

About 750 stations of MT data were acquired in the study area. Frequency content in most of the stations is ranging from 750 Hz to 0.001 Hz except in few stations which are limited to 0.01 Hz. The high frequency resistivity at most of the stations are starting from 10-20 ohm-m which is coming down to 1-5 ohm-m at roughly 0.1-0.3 Hz. High error bars are seen at most of the stations at frequencies lower than 1 Hz.

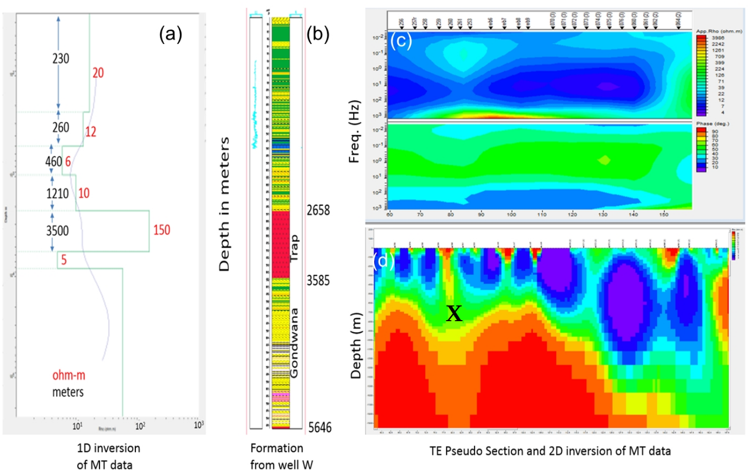

Fig. 4. (a) 1D Bostick inversion of a station adjacent to well W. (b) Formation of well W. (c) Pseudo section and (d) 2D inversion along AA/.

1D inversion of MT data shows a high resistivity region at a depth of 2200m while the adjacent well shows trap top at a depth of 2658m. Pseudo section shown in figure 4 (c) does not shows any high resistive layer followed by a low resistive layer which is supposed to be as per the well information. 2D MT inversion in fig. 4 (d) shows a low resistive layer in the upper portion followed by a gradually increasing resistive layer. This could not resolved the sub-trappean sediments which are supposed to be low resistive but in support to gravity data it shows a depression (X) in the high resistive layer (basement). Both the 1D and 2D inversion could not be able established a one to one correlation with well data. It may be due to high error bars caused by noise as the study area has network of rail lines, highways, thickly populated towns and villages. Another reason may be the trap resistivity from well data is roughly 20 ohm-m sitting below low resistive paleo sediments thereby a low resistivity contrast between sediment-trap-sediment.

Gravity stripping and modelling

As the horizons are dipping towards southeast and seismic, well & MT data could not established the existence of sediments below the trap in eastern part of the study area gravity stripping method is carried out. Based on availability of seismic horizons the study area is restricted to the blocks shown in fig. 5(i). A gravity effect of post trappean sediments is computed by integrating seismic & well data (fig. 5(ii)). Figure 5(iii) shows the long wavelength gravity effects which are generally due to raise mantle. These gravity effects are subtracted from the observed gravity shown in fig. 6(i). The resultant output is shown in figure 6(iv). Literally as effect of post trappean sediment and rise mantle has removed from the observed gravity the remaining gravity effect is supposed to be the combined effect of Rajmahal trap and sub trappean Gondwana sediments. In which the trap having positive density contrast will be giving a positive gravity effect while the Gondwana sediment which has negative density contrast will give a negative gravity effect. As the trap thickness is increasing towards east (from seismic) the more will be the positive gravity effects, therefore, the areas where negative gravity is seen in this map indicates the existence of low density Gondwana sediments. One such area below the Kolkata Mymensingh gravity high is in the area marked L.

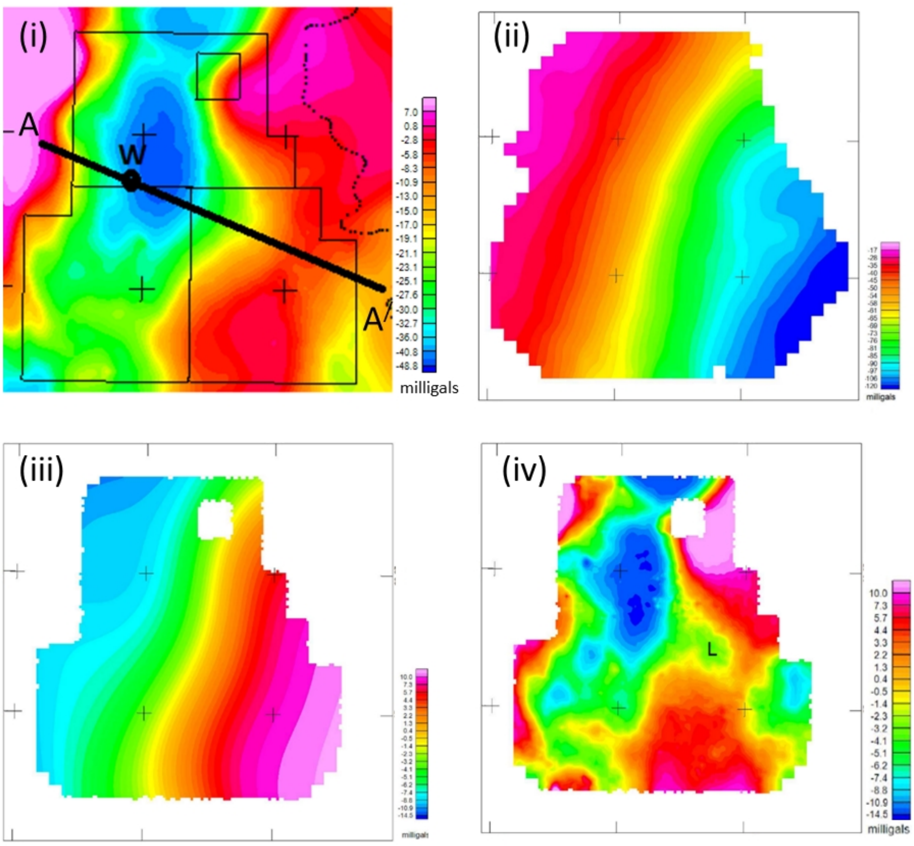

Fig.5. (i) Observed gravity, (ii) gravity effects of post-trappean sediments,(iii) gravity effects due to raised mantle and (iv) gravity effects of trap and sub trappean sediments.

With these inputs gravity modeling along the profile AA/ has been carried out by constraining horizons from seismic and well data. An averaged density of 2.2 gm/cc for recent sediment, 2.8 gm/cc for trap, 2.5 gm/cc for paleo sediment and 2.3 gm/cc for Gondwana sediments are used for gravity modeling along the profiles. Figure 6 shows the gravity and magnetic modeling of AA/ which is extended in either side to incorporate long wavelength features.

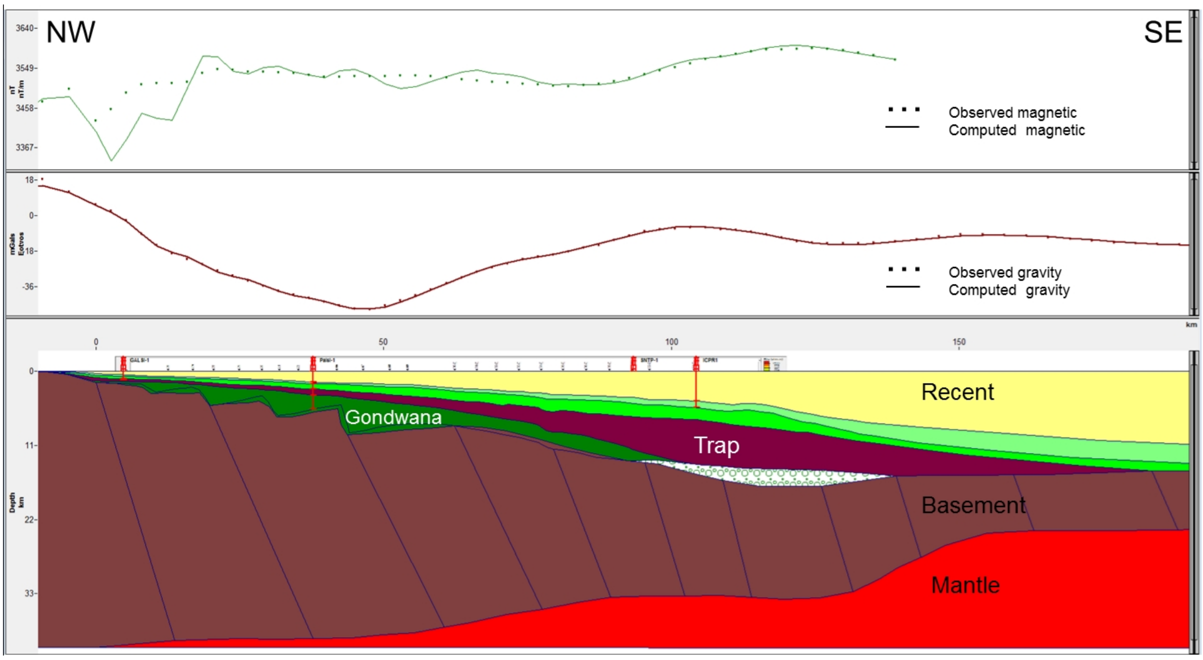

Fig.6. Gravity modeling along extended profile AA/.

Gravity modeling shows the Rajmahal trap is varying from few hundred meters in the west to more than 5 km in eastern part of Bengal basin, thickest near hinge zone. As demanded in gravity modeling thickness of Gondwana sediment is more than it appears on seismic where gravity low trend is prominent, in this places the basement depth may go up to 9 km. Also there is low density sediment below the trap in and around hinge zone which may belongs to Gondwana series being thickest near profile AA/ and thinning to the north as well as in the south. Depth to Moho in the study area is ranging from 40 km in the western part to 30 km near hinge zone and further shallower in the east.

Conclusions

Integrated study brought out the prominent gravity low in the middle of study area is found to have thicker sediments than anticipated from seismic. Depth to basement in this area may be up to 9 Km.

Gravity striping supports the extension of Gondwana sediment in the eastern part of the study area.

Gravity modeling shows that the isolated gravity depressions in residual gravity and vertical gravity mapsare due to presence of Gondwana sediments.

The depth to basement is ranging from 2 Km to 17 Km in the eastern part of the study area while the Rajmahal trap thickness is increasing from 0.2 Km in the western part to more than 5 Km in the east. North South horizontal derivative of gravity data has brought out clear trend of hinge zone which coincide with the trend of seismic.

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Keywords

Gondwana, Hinge zone, Residual, Derivatives