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Integrated interpretation of Gravity & Magnetic data for delineation of sedimentary thickness in deepwater block of Andman Basin

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Summary

Andaman basin in the south-eastern part of Bay of Bengal, the only convergent basin of India has long been an exploration target because of the established gas fields in the Irrawady delta system in Myanmar in the north and in the tertiary basins of Sumatra in the south.

For having idea of various subduction related tectonics elements in the area, satellite gravity data, have also been used. Based on gravity value, the area can be divided into two major parts, the low in the west and the high in the east, separated by a set of dense contours corresponding to the west Andaman fault. The western low corresponds to the fore arc low and the high in the east is related with the volcanic .

Seismic image, in this part shows very thin sediment where as gravity data demand additional four to five km sediments .The gravity fall is partially explained by thick crust and additional sediment. Gravity fall is about 140 mgal in the western side .Magnetic and gravity anomaly suggest presence of volcanic material

The crust in the area is deformed because of the active compressive regime. Much higher anomaly value in the east and high frequency features indicate thinner crust and presence of volcanic. Modelling shows that the basement in the area, particularly in the lows in the western flank of the fore arc is much deeper than what it seems to be from seismic data.

Introduction

Andaman basin in the southeastern part of Bay of Bengal (fig.1), the only convergent basin of India evolved as a result of subduction of the Indian plate underneath the southeast Asian plate following the break up of Gondwanaland in the early Cretaceous. The basin has an area of about 50,000 km2 with a thick sedimentary cover ranging in age from Cretaceous to recent. The basin has long been an exploration target because of the established gas fields in the Irrawady delta system in Myanmar to the north and in the tertiary basins of Sumatra to the south. Of the fifteen wells drilled in the basin so far, gas flowed in one well and presence of gas in middle Miocene limestones is indicated in several wells.

The present study area is a deepwater block (fig.2) is covering an area of about 11837 sq.km. Bathymetry in the area ranges from 100 meter to 3600 meter. The variation of bathymetry is due to the presence of topographic highs and lows related with fore arc, Volcanic and Back arc. About 4915 LKM of gravity and magnetic data have been acquired in the block. There is only one well AN-63-C-1, in the north of the study area outside the block on N-S profile AN-14. In this well Trap is encountered at 1100mts and trap is continuous upto drilled depth of 1800m. The present study deals with processing and analysis of gravity and magnetic data, and integrated modelling for basement configuration and exploration leads.

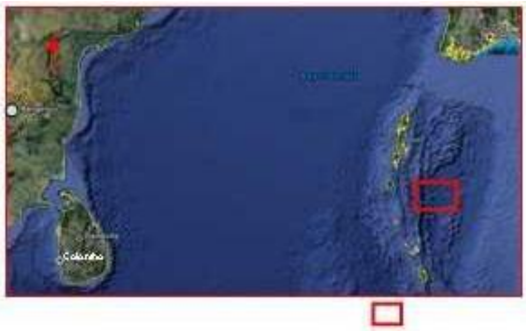

Figure 1. Location map of the area. Study area.

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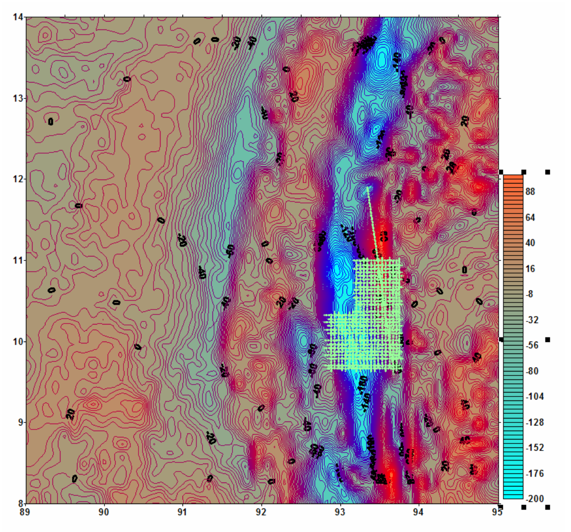

Fig2: Deep water block with tectonic elements on Satellite Free Air anomaly map

Geologic set up

Andaman basin in the north eastern part of Indian Ocean is a part of the Island-arc system associated with the convergent plate boundary between the Indian plate subducting under the southeast Asian plate along Sunda arc. Trace of subduction is present in the Ophiolite exposure in the western boundary of Andaman- Nicobor ridge (Curray, 1979). The basin extends from Myanmar in the north to Sumatra in the south and from Malay peninsula in the east to Andaman- Nicobor ridge in the west. The Burmese and the Andaman arc together constitute a long continuous tectonic belt which links the eastern Himalayan collision zone in the north to the Indonesian arc in the south through the Sunda arc (figure 3,4,5,6).

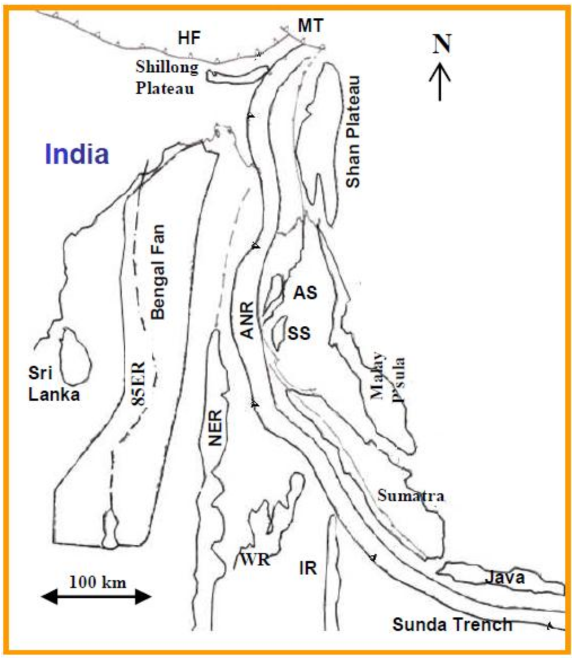

Figure 3 : Tectonic and physiographic elements in part of Northeastern Indian Ocean and Assam-Arakan area associated with subduction of Indian Plate underneath Southeast Asian Plate. Legend. HF: Himalayan front. SP: Shillong Plateau. MT: Mishmi Thrust. ANR: Andaman- Nicobor Ridge. 85ER; 850E Ridge. NER: 900E Ridge. AS: Alcock Seamount. SS: Sewell Seamount. WR: Wharton Ridge. IR: investigator ridge.

Andaman arc is linked to the western Pacific arc system through the Sunda arc forming a long chain of island- arc system (figure 3). There was considerable variation in the speed and direction of convergence between the Indian and

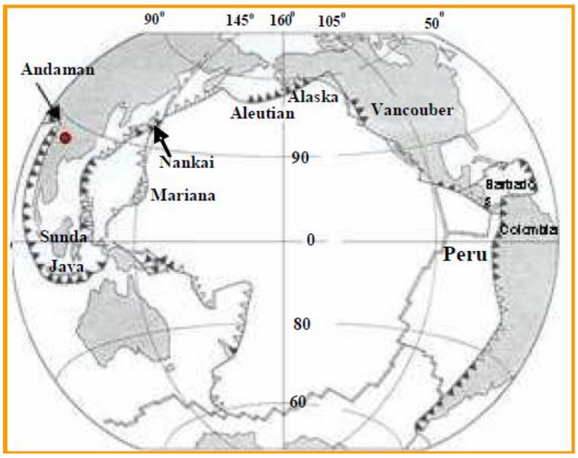

Figure 4:. Convergent plate margins in Indian and Pacific Oceans.

and southeast Asian plates. Oblique subduction, volcanism and other factors have added to the tectonic complexities of the area. The western part of the area with N-S trending faults and arc parallel seamount chain is more complex compared to the eastern part.

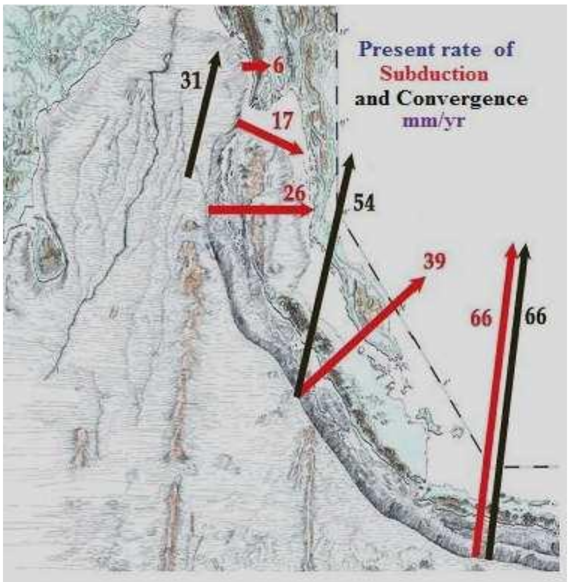

Figure 5 ; Rate of subduction and convergence of Indian plate (after Curray, 2007)

The magmatic arc in the area runs roughly north- south in a curvilinear fashion to the east of the accretionary prism. Following the definition that the forearc is the area between the volcanic arc and the outer edge oceanic trench (Dickinson and Seely, 1979), the area to the west of the volcanic arc has been taken as the forearc basin. Considering the volcanic Narcondam and Barren islands to be part of the present day volcanic arc, Raju (2005) placed the back- arc basin to the east of the Narcondam- Barren islands chain. Alcock and Sewell seamount complexes are two major morphological features in the area. These two seamounts are considered to be part of a single complex which was split into two by a phase of rifting during Miocene (Raju, 2005). Andamann-Nicobor ridge is filled with Bengal fan sediments sourced from the subducting Indian plate and is overlain by autocthonous shallow water forearc sediments (Curray, 1978). The structural style in the western part of the forearc basin has been interpreted to be caused by shale tectonics and wrench movements leading to a series of a structural highs and intervening lows adjoining the Andaman- Nicobor island chain.

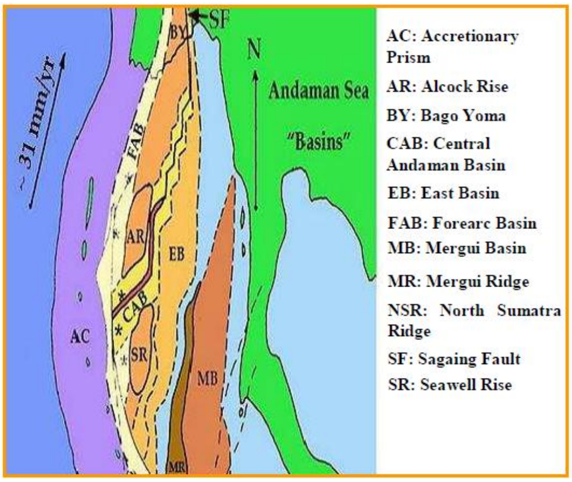

Figure 6. Tectonic elements in Andaman basin and adjoining area (after Curray, 2007)

Gravity and magnetic anomaly data

Gravity anomaly map:

Free air anomaly map of the area with contour interval of 4 mGal has been prepared (Fig. 7). Only few subduction related tectonic elements can be seen in ship borne gravity data because most of the covered area is confined to the fore arc and volcanic .The major features in the map are as-

- The most striking feature of the map is a significant rise anomaly values from about -170 mGal in the western side (fore arc) to about -10 mGal in the eastern side (volcanic arc).
- A prominent NNW-SSE trending gravity low.
- The gravity low corresponds to the fore arc.
- The gravity high trend in the eastern part, correspond to volcanic part in the East.
- High trend is taking a swing towards northwest with intermittent strong positive anomaly.

The two area is separated by West Andaman fault. Large positive gravity anomaly in the eastern side indicates emplacement of large amount of volcanics and probable oceanic crust as identified by Curray et al (1978). However, low gravity of about -170 mGal in the western side indicates a huge pile of sediments and possible continental crust.

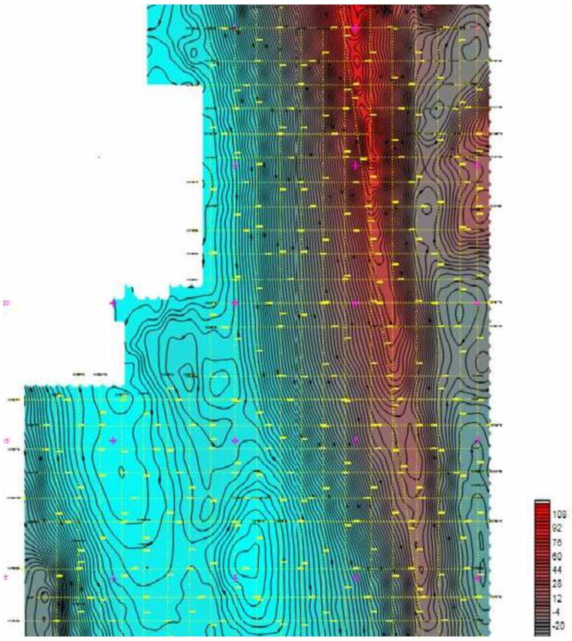

Fig.7:Free air Anomaly map

Satellite altimeter derived free air anomaly data (Fig. 2), covering larger area, shows following prominent features.

- A gravity high on the accretionary prism to the west of WAF.
- Low to the west of the accretionary prism corresponding to the trench.
- Prominent gravity high with high frequency feature of volcanic arc to the east of the forearc low.
- Large amplitude highs having small aerial extent for the intrusives and seamounts.
- A linear NE-SW trending low trend related to Andaman rift which separates Alcock and Sewell seamounts. This trend changes to north-south both in the north and in the south.
- A roughly north-south trending low in the backarc related to the deep terrace to the west of Alcock and Sewell seamount complex and an area of positive gravity anomaly value to its east.

Magnetic anomaly data

Magnetic anomaly map with contour interval of 50 nT is shown in fig.8. In addition total magnetic field and Analytical field maps have also been generated, (fig .9). The major features in the magnetic anomaly data are discussed below.

- In the western and eastern margin of the fore arc many bipolar magnetic features in North-South Linear fashion are observed which may be due to the presence of sharp magnetic bodies. The wave length and the frequency of the magnetic field suggest that the causatives are shallower and their east west aerial extent is less than the North-South extent. (Volcanic?)
- A strong positive anomaly in the central part of the area.
- The magnetic high in the eastern part of the fore arc region of the Andaman basin can be attributed to the presence of ophiolite and other igneous rock present in the volcanic and back arch region. It also indicate shallow basement in comparison to the basement of the fore arc part of the Andaman basin. The dispersal of the basaltic flow during volcanic eruption and their subsequent deposition in the rift period can be attributed to the orientation of large and small magnetic high.

Analytical signal map shows lot of positive features here and there but in the eastern margin of fore arc their concentration is more. Analytical signal also confirm that the depth of causatives are shallower.

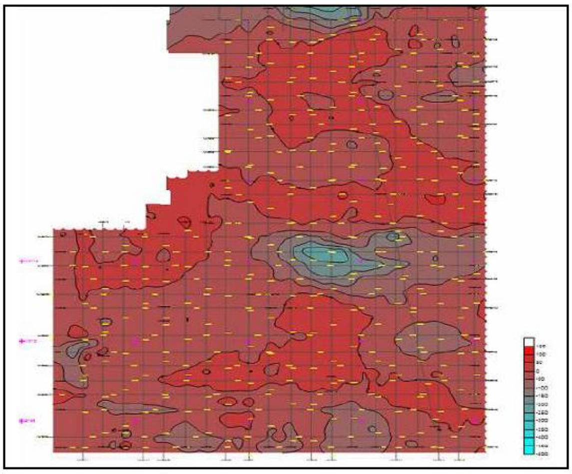

Fig.8 Magnetic Anomaly map

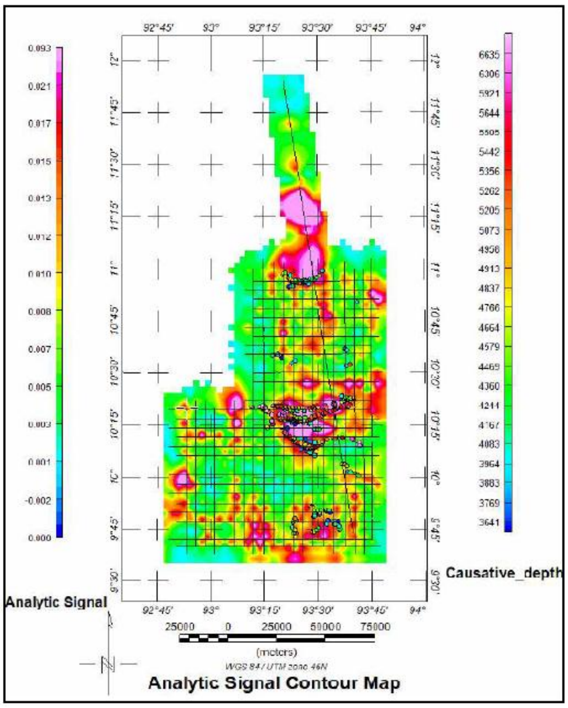

Fig.9 Analytical Signal map

Modelling results:

Satellite altimetry derived gravity data indicate that the trench is more than 200 km west of the western boundary of the blocks. The east dipping Benioff zone in Andaman is estimated to be down to 200 km focal depth and have dip of about 300 (Mukopadhyay, 1984). Based on theses, depth section along the profiles AN-12 and AN-06 were prepared. The part of the depth section is largely constrained by seismic data. Results of models are shown in fig.10.

The depth model has fairly reproduced the main observed gravity anomaly features which are:

- The low to the west associated with Andaman-Sunda trench and another low for the forearc about 240 km east of the inner trench. These two lows are separated by the high related to Andaman-Nicobor ridge.

- Typical gravity response of volcanic arc with intrusives and seamounts in the eastern part of the model.

- High frequency and high amplitude features associated with the intrusives.

Gravity modelling shows that the basement depth at trench part is about 10-11 Km. In the accreationary prism depth to basement is varying between 3 to 9 km and in fore arc it becomes about 11 Km. The additional sediments indicated by gravity modelling is shown in dark green. In back arc depth to basement is about 6 km.

There is some mismatch between the absolute values of the observed and computed anomaly values, particularly for the small wavelength gravity features possibly associated with shallow and small causatives which in the absence of seismic data could not be properly incorporated in the extrapolated parts of model.

Taking clue from the results of modelling of the above profile, modelling of ship-borne gravity data has been done along a number of E-W seismic profiles with initial depth model based on seismic data. The modelling profiles are: AN-21 (fig.11) and AN-42 (fig.12).

The profiles in the southern part of area are partly in fore arc and partly in volcanics where as the major portion of the profiles in the north fall in volcanic. The depth models obtained by gravity modelling have reproduced fairly well the main tectonic and physiographic features in the area.

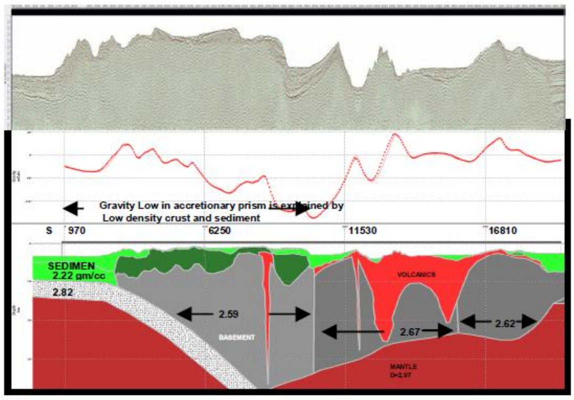

Fig.10 -Gravity Modeling along Profile AN-12

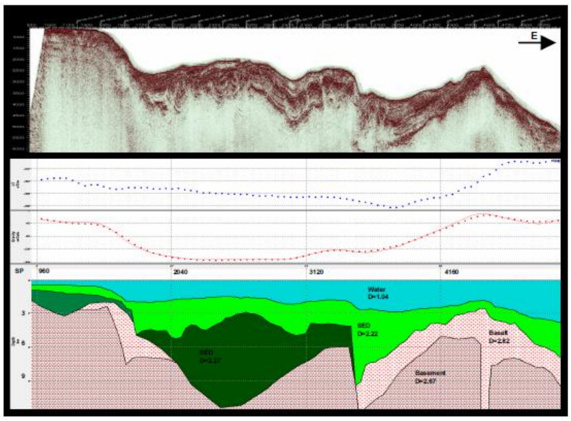

Fig. 11 Gravity modeling along AN-21

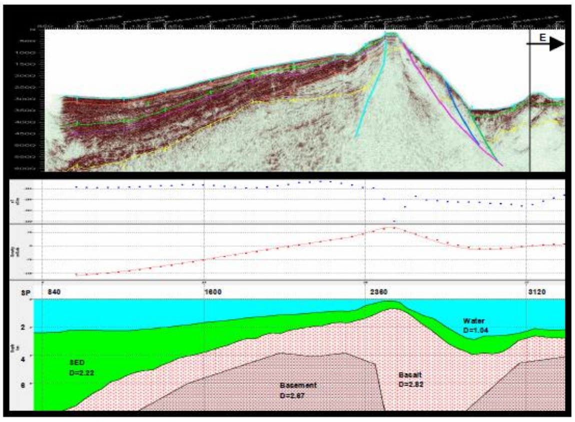

Fig.12 Gravity modeling along AN-42

Sedimentary thickness in the low ranges from 6 km to 11 km including bathymetry in the in the fore arc.

The eastern parts of the models are characterised by volcanic plugs and thick basalts with thin sediments. Thickness of the sediments overlying the basalt ranges from 1 km to 2 km in the volcanic.

Limitation

In the absence of well data, Gravity model is constrained by the seismic marker which is of poor quality due to intense active tectonics.The gravity profiles in the northern part are of in adequate length which passes over the volcanic region only which is 3D in nature.so some observed gravity trend could not be fully reproduced due to limitation of 2D –modeling

Discussion

The lows with thick column of sediments in the western flank of the forearc are likely to be good source area for hydrocarbons. Gas shows and gas indication in quite a few wells just outside the study area (in the north) indeed, lends credence to the hydrocarbon? generation potential of the lows.

Conclusion

Gravity modelling has reproduced fairly well the subduction related tectonic elements in the area with good quantitative agreement between observed and computed gravity values.

The basement is much deeper than what it appears to be from seismic data, particularly in the lows in the western part of the forearc. Western flank of the forearc low holds thick sedimentary column. Sedimentary thickness in the north ranges from 6 km to 11 km including bathymetry.

Eastern part of the area is characteristic of a volcanic arc. There are a few lows in the east where the thickness of sediments overlying the volcanics ranges from about 1 km to 2 km.

The crust thins considerably towards east of WAF but it is not possible to infer about the nature of the crust because of presence of intrusives and volcanics.

The lows with thick sedimentary column in the western flank of the forearc are likely to be good source area for hydrocarbons. Structurally favourable locations between the lows but to the east of the fault are interesting locations for probing.

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