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Significance of Gravity and Magnetic data over Thrust-Fold area — A Case Study in the Cachar area of Surma sub-basin of Assam Arakan Basin, Assam, India.

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Summary

Cachar province is a part of Assam-Arakan Fold Belt and geographically situated in the North-Eastern part of India. This area of Surma valley got much importance because of oil and gas pools were discovered in Badarpur field by Burma Oil Company way back in 1915. The hydrocarbon findings in this basin are not commensurate with the exploration efforts made in this area over the long period of 90 years. Of the 64 wells drilled in the Cachar area only 8 wells are gas producers out of which three wells are in Adamtila field, four from Banskandi structure and one from Bhubandhar field. This discovery ratio suggest that sediment thickness over the basement need more understanding for true modeling of the sub surface and need more concreted efforts. The Cachar area is traversed by long narrow anticlines and broad synclines in an almost N-S trend that swings North-Eastward towards the Northern margin. Moreover, several tectonic movements gives rise to a number of thrust and folds that caused structural complexity in the area. Seismic exploration in this complex tectonic regime is a challenge to both acquisition and processing especially in the absence of proper geological model. The other factors affecting seismic exploration are rapid variation in near surface geology, poor receiver coupling in hard-rock surface, shot hole drilling difficulty and wave field scattering. Exploration in such areas often requires a re-look in the existing data with the help of new technology and wider experience. This needs generation of conceptual sub-surface model of the area. Moreover, poor seismic reflection data of both 2D and 3D limits the imaging upto 1 second that too in a patchy pattern. Due to the limitation of seismic imaging, there have been consorted efforts to extract as much information as possible from gravity and magnetic data. Hence, this study is taken up to obtain broad understanding of the basement configuration and provide information on the probable sub-surface structural configuration under the known exposed structure within the sediments based on gravity and magnetic data.

Introduction

Assam-Arakan Basin is a typical polyhistory basin having more than one phase of sedimentation and tectonics. The Cachar area forms a part of N-S trending compressional thrust and fold belt of Assam-Arakan Geo-synclinal Basin encompassing approximately an area of 7000 sq.km. Tectonically, the Cachar area fall under ***frontal fold belt of Tripura – Cachar fold system*** (Fig-1).

The Study area lies between the longitudes 92^0 15' E to 93^0 05' E and latitudes 24^0 30' N to 25^0 00' N and falls in the Surma basin, bounded by the Barak river on its Northern extremity, by the Labak syncline on its eastern flank and Bangladesh border on its western and northeastern boundaries and Dhramanagar in its southern side (Fig-2).

The proven hydrocarbon pools in adjacent Sylhet district (structures like Sylhet, Chhatak and Atgram, etc.) of Bangladesh raise the Hydrocarbon prospectivity of the area considerably. The Cachar area is traversed by long narrow anticlines and broad synclines in an almost N-S trend that swings North-Eastward towards the Northern margin. Moreover, the area is influenced by three tectonic movements in E-W, NE-SW, N-S directions giving rise to a number of thrusts and folds. The N-S trending ridges are the northward extension of the Tripura hills running almost up to the Barak River, which flows almost east to west parallel to Barail range.

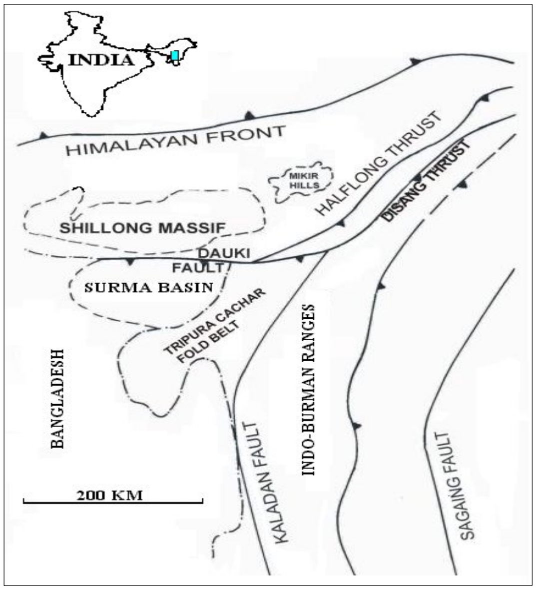

Figure 1. Geologic map of Assam- Arakan thrust-fold belt (After Zutsi, 1993).

The amplitude of the folds ranges from 4000m to 6000m beside the area is run by many streams, rivers and large water bodies of stagnant water particularly in the intervening valley. The G.M. data of 755 stations spaced at about 1.6 km acquired in 1971 is used for this study.

Geology of the Area

The area is influenced by three tectonic movements in E-W, NE-SW and N-S directions. It is represented by the trends of Dauki tear fault, Naga thrust and Arakan fold belt. The structural style of sedimentary column in the Cachar area is mainly characterized by a series of NNE-SSW trending sub-parallel, elongated and narrow, tightly folded doubly plunging and highly faulted anticlines (Figure- 2). Structurally speaking, the hills or the ridges in this area represent the anticlines and the intervening valleys forming syncline. The anticlinal axex are spaced from 15 -20 km .Fig-3 represents the elevation contour of the GM Stations .

These anticlines are enechelon to each other and separated by broad, flat synclines. The anticlines are asymmetrical with steeper eastern limb gently dipping western limbs. Anticlines consist of exposed hard and compact rocks of older age. The anticlines being mostly narrow, sharply folded and steeper flanks are faulted.

The synclines in this area form the trough and consist ofsofter and younger formations. Geometry of fold changes conspicuously from open concentric in the west to the tight smaller folds in the east. The structural complexity increases progressively from the west to east. Fig-4 represents the surface geology and also important structural features. The Surma valley merges eastward into the southern part of Kohima synclinorium and Westwards into the Bangladesh side where the folds are gentler.

It is widely believed that the Assam-Arakan Basin had come into being during late Cretaceous times and the sedimentation started with marine transgression from SW which reached the Shillong Plateau in the north with the deposition of Mohadek and Longpur Formations as basin margin facies, while lower Disang shales in Naga-Lushai hills as relatively deep basinal facies. During Eocene time a general shallowing of the basin took place resulting in deposition of Sylhet limestone and Kopili alternations in the northern part of Shillong shelf area, whereas mostly argillaceous upper Disang was deposited in the deeper part of the basin, south of Shillong.[1]

The general horizon dip of the area is from West to East and of the order of 10 to 20 degrees. However from surface geological studies the dips are observed to be ranging from 10 to 60 degrees[6]. Adamtila structure is a gas producer from Bokabil-Upper Bhuban formation at different intervals ranging from 1087 to 1735m.

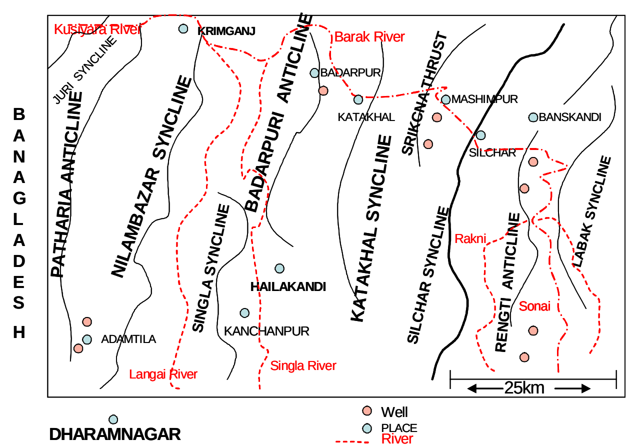

Figure-2: Location Map of the Cachar Area

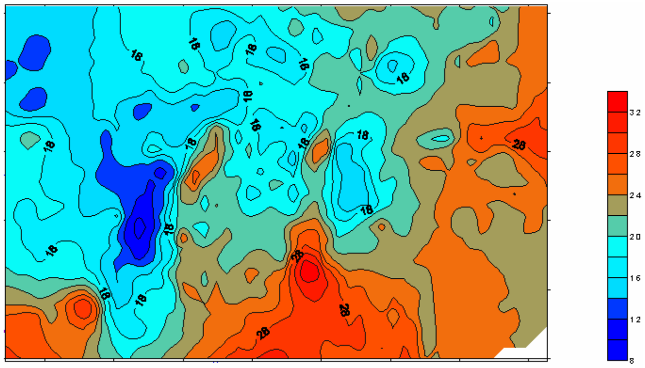

Figure-3: Elevation Map based on GM stations in the area.

Tectonic Setting

The entire Cachar area is tectonically disturbed with the presence of folds, faults, thrusts and over thrusts striking mainly in NE-SW direction. Towards the plains orogenic movements seem to decrease. The intensity of the folding and faulting is appears to be less in the belt adjoining the plains[2].

The following stratigraphic sequences have been established in the area based on cuttings, lithology, elector-log properties and regional geology.

Age	Series	Formations	Maximum thickness in meters	Density gems /cc
Recent and Pleistocene	……..	Alluvium and high level terraces	……….	2.0

……………………………Unconformity………………….

Pliocene	Dihing	Coarse conglomeratic sands and clay	400	2.1to 2.2

……………………………Unconformity………………….

Mio-Pliocene	Dupitala	Upper Dupitala Lower Dupitala	2800 500	2.1to 2.3

……………………Unconformity………………….

Miocene	Tipam	Gurujan Clay Tipam Sandstone	1500 1600	2.4to 2.5
	Surma	Bokabil Bhuban	1500 4000	

……………………Unconformity………………….

Oligocene	Barail	Renji Jenam Laisong	1000 1200 2400	2.5to 2.55
Eocene	Disang	Upper Disang Lower Disang	2000 2000 +	2.55 to 2.6

……………………Unconformity………………….

The above chart gives sequences up to Tertiary Level. Underlying formations are the Upper Cretaceous sediments Jurassic formations consisting of metamorphosed rocks and Sylhet Traps and finally the Shillong series rocks that form the basement rocks. No borehole data or any other method confirming the deeper formation is available. So, this should be only the logical sequence, with some possibility of uncertainty factor due to facies changes which are very much localized[2,5].

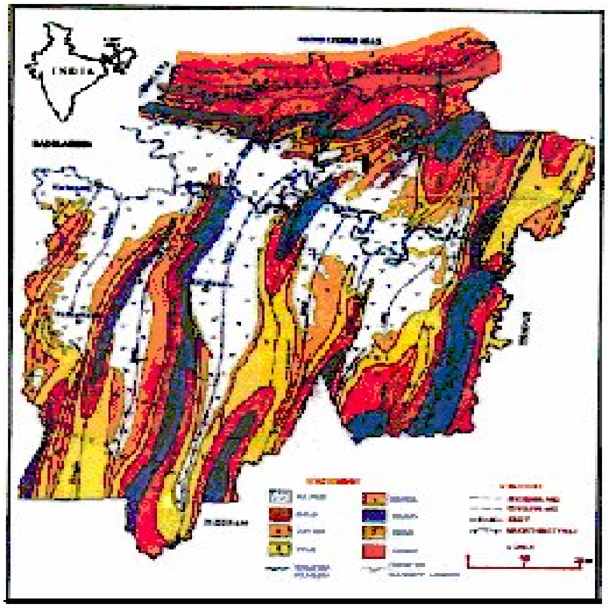

Figure-4: Geological Map of the Cachar Area

Discussion

Gravity anomaly data can be confidently correlated with the causative if the effects of the factors influencing the gravity values are properly accounted for. The anomaly value having significance in hydrocarbon exploration is a small fraction of absolute gravity value and also of the variation caused by latitude, elevation and other factors. Hence, proper corrections to reduce the observed anomaly values to a common datum are crucial. Because of inverse square dependence of gravity on distance, the correction for the elevation of the observation point is very important.

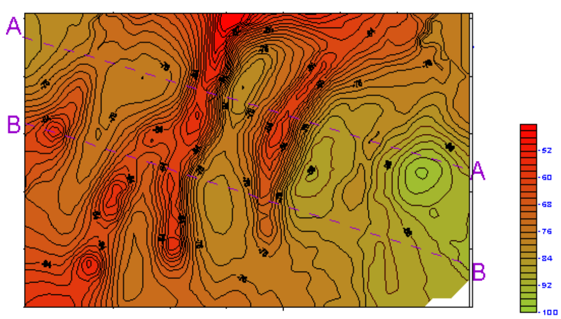

Figure-4: Free Air Gravity anomaly Map

Free Air Anomaly Map (Fig-5) is characterized by Sharp closures and nosings of alternating highs and lows. The high and low axes run along in almost NS to NE-SW direction. As the effect of material above mean sea level is included herein, the contours are quite zigzag and seem to be following surface topography very closely. Structural trends that are exposed in this area follow the Surface topography. Thus, from west to east, the north south running Patharia anticline (hills) on the western most boundary and Nilambazar syncline (valley), Chargola anticline (ridge), adjoining Singla Syncline, Kanchanpur-Badarpur anticlines, Katakhal synclinal axes, Mashimpur anticline, the Silchar Syncline, Rengte anticline and finally the Labak syncline on the Easternmost boundary have clearly been represented in the free air map.

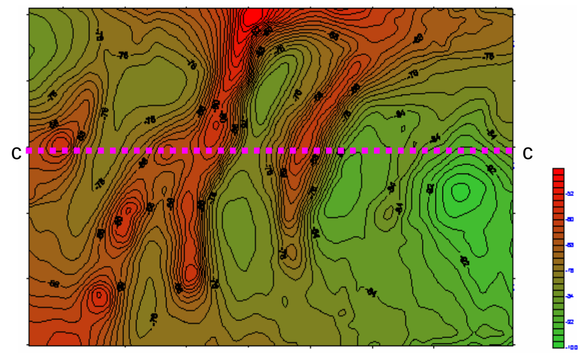

Figure-6: Bouguer anomaly map with ρ = 2.0 gm/ cc.

Bouguer Anomaly Map (fig-6) shows the contour values rise towards the West and North and fall towards the East and South. This may be indicative of the fact that the basement is deepening towards East and South i.e. rising in the Westward and Northerly direction. The gravity highs and lows corroborate very nicely the respective anticlinal and Synclinal axes of the sedimentary structure.

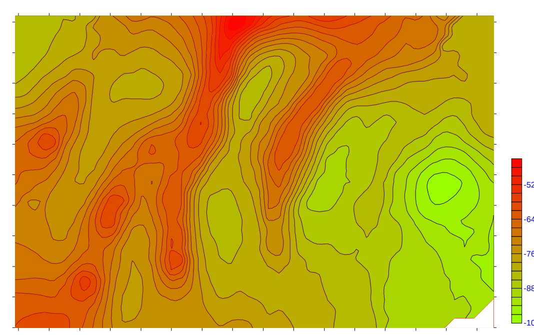

Figure- 7: Bouguer anomaly map with ρ = 2.3 gm/ cc.

Two gravity profiles AA and BB are generated having sufficient gravity stations straddling important topographic features over Free Air and Bouguer anomaly maps are generated to observe the variation pattern of anomaly curve with different rock densities.

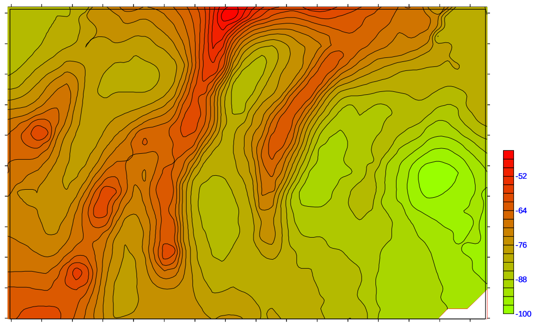

Figure-8: Bouguer anomaly map with ρ = 2.6 gm/ cc.

It has been observed from the Bouguer anomalies map prepared at different densities like 2.0, 2.3, 2.6, 2.8 and 3.0 (Fig-6 and 7) that the anomaly behavior is almost identical and corresponds to the free-air anomaly map of the area which may be indicative of shallow causative.

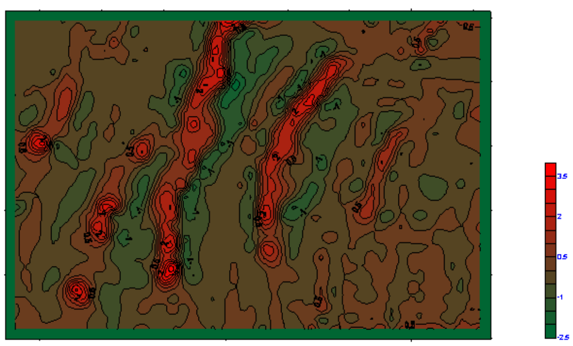

Figure-9: First derivative map of Bouguer anomaly map .

The first derivative map (Fig-9) suggest that sharp and shallows anomalies present in this area are very strong that again indicates a shallow causative.

Bouguer curves (Fig-10) suggest that the effect of density of rocks has little play for Bouguer anomaly pattern of the area. The reversal of Magnetic values may be due to a) erosion of highly Magnetic sediments from the crest of the structure, b) Irregular basement magnetization, c) remnant magnetization at few spots

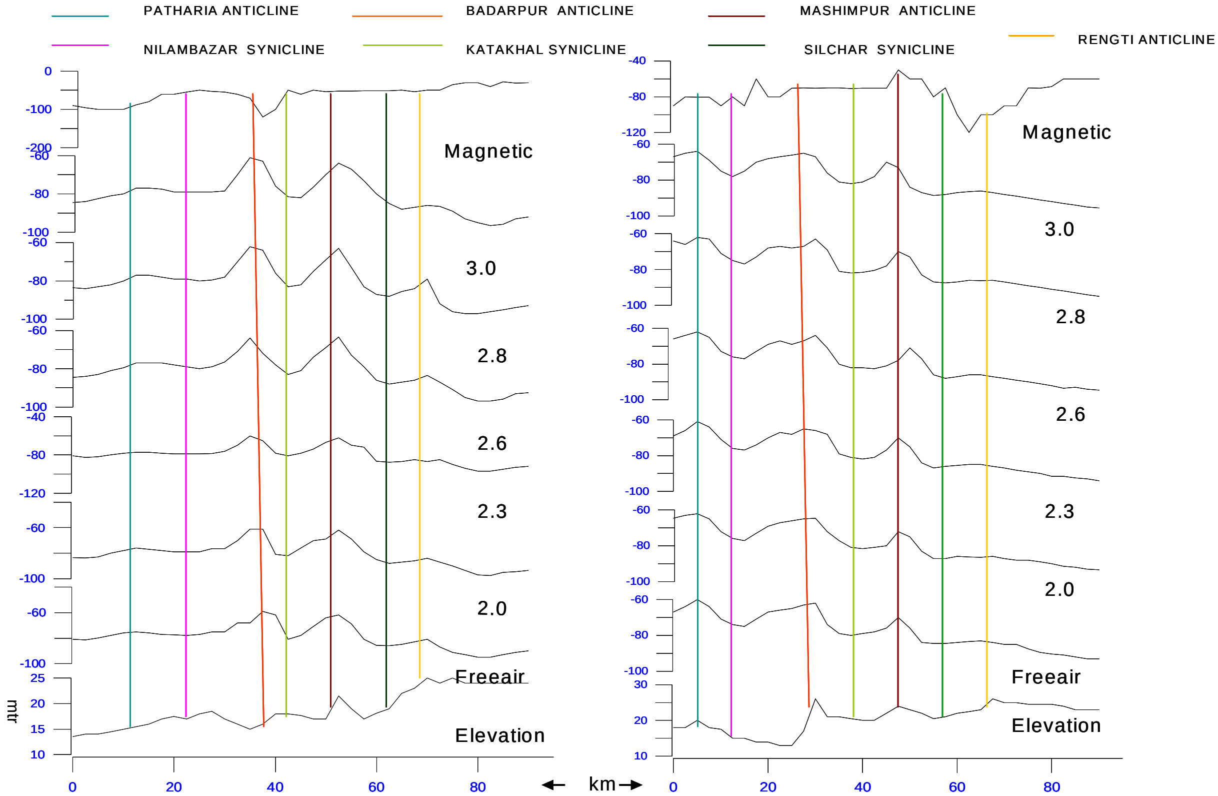

Figure 10 : Bouguer anomaly with different densities along profile (a) AA (b) BB (Number along side BA curve: density in gm/cc).Anticline and Syncline are corerated and marked along the two profiles.

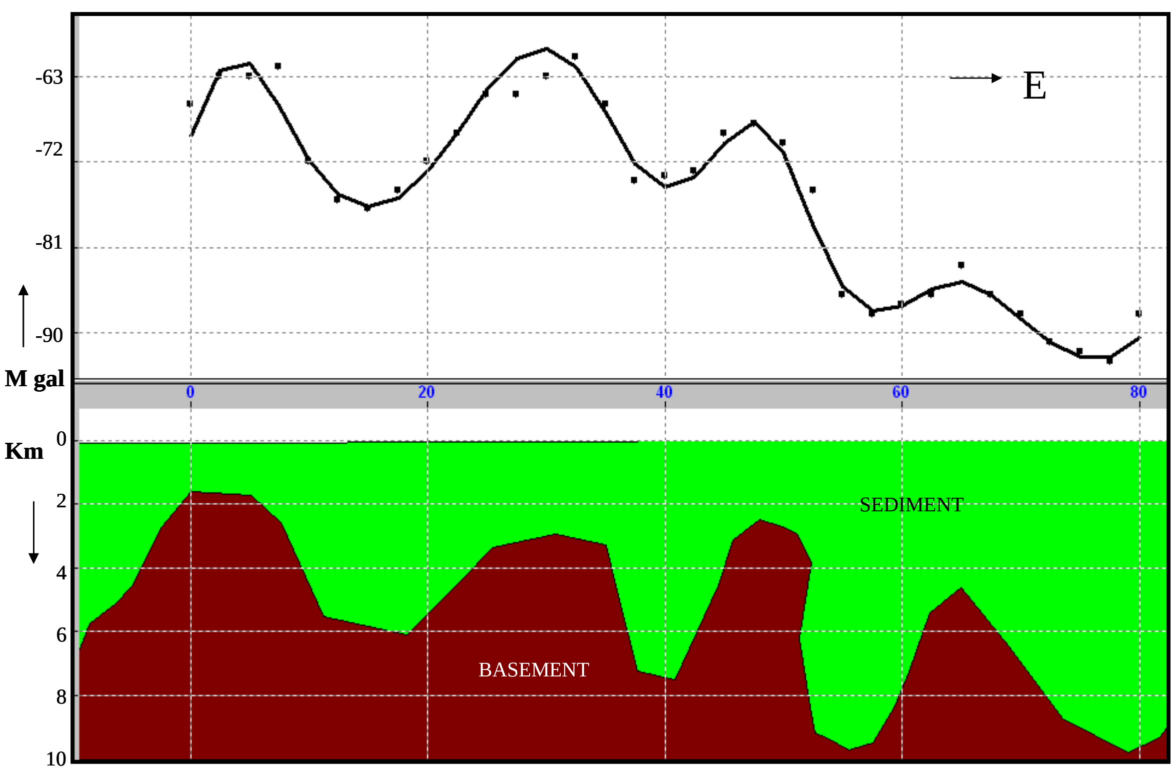

Figure-11: Gravity modeling across a line CC connecting two Extreme west and east boundaries of the Cachar area.

For better understanding of the area analysis of the sediment thickness below the anticlinal and synclinal zone , a gravity profile CC marked in Fig-6 of length nearly 97km running West to East straddling important topographic features and having sufficient number of gravity observation points is modeled (Fig-11). Only two layers , sediment and Basement are considered for modeling. Density used for sediment is 2.4 gm/cc and for basement it is 2.65 gm/cc. From the model it is observed that the gravity highs and lows are related with the Basement. From the surface morphology it is also seen that the topographic highs and lows are following the basement structuring which indicates that the area is highly influenced by the compressional activities.

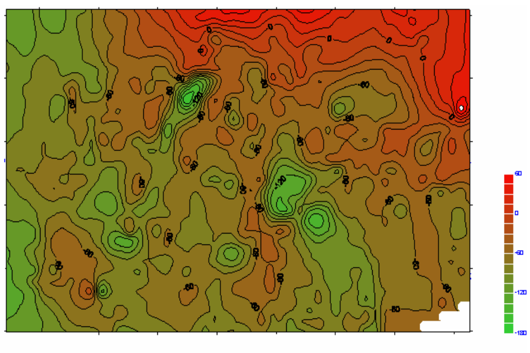

Figure-12: Magnetic Anomaly map of the Cachar Area.

Magnetic anomaly map (Fig-12) is characterized by the very board and low order anomalies with decrease of values towards the South which may be inferred as deepening of Basement towards South. One important features of magnetic anomalies over this area are of very low order ranging hardly up to 75 gammas, generally 25 to 50 gammas and of elongated shape, such that their North-South extension is greater than the Eastward extent. This is indicative of Basement and is in agreement with the Gravity modeling that the sediments of the Surma valley may attain a thickness of 6 -10 kms.

Conclusion

The present study has confirmed that the sediment thickness in the Surma basin from the gravity modeling is around 6 to 10 kms in the synclinal zones and the top of the causative in the anticlinal zones as around 2 to 5km approximately .However, it is certain from both the gravity and magnetic maps that the basement deepens towards the east and south as well. It can be confirmed that the structures giving rise to various gravity anomalies are mostly shallow origin and tend to die out with depth. The magnetic map in general reflects a fairly even basement. Further it is observed that these structures are becoming shallower and diminished in the northward direction and may be better developed beyond the south of the Cachar area.

Recommendation

High precession micro Gravity along with close grid Magnetic/Magneto-Telluric surveys is required to bring out the subtle traps and more precisely the basement configuration. These surveys may be extended south of the area to confirm the extent of anticline and synclinal zones.

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