Integrated Analysis of Gravity and Magnetic Data in the Upper Assam Shelf and Adjoining Schupen Belt Area - A Critical Review*

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Abstract

The exploration of oil and gas in the petroliferous Assam-Arakan Basin has been continuing for several decades. Gravity and magnetic (GM) data play an important role in the exploration, planning and integrated geophysical data interpretation. Poor quality and sparse seismic data arising from tectonic complexities and rugged terrain, particularly in the vicinity of the Schupen Belt area, confuse the interpreter in estimating proper sediment thickness and identifying the Basement marker in this thrust belt. Because of limitations of seismic imaging, the GM data can provide some meaningful information for interpreting the basement topography in the shelf as well as in the Schupen Belt region.

The objective of this study is to develop the prospect of thick Gondwana sediments through gravity modeling from the existing GM and seismic data in the Schupen Belt region and an explanation of high magnetic intensity, considering that ophiolite may be the cause of the tremendous magnetic high in the Schupen Belt area. The highly deformed slices of ophiolitic rocks can be seen along a linear belt and parallel to the Schupen Belt axis in Nagaland and Manipur states of NE India, which are known as the Naga Hills Ophiolites (NHO). The principal rock types include dunite, harzburgite, lherzolite, wehrlite, pyroxenite and mafic volcanics. An ophiolite is a section of the Earth's oceanic crust and the underlying upper mantle that has been uplifted or emplaced to be exposed within continental crustal rocks. The intrusion of ophiolite cannot be ignored as easily as the Schupen Belt which is a thrust fold area and has evolved due to numerous thrusts developed from collision of the Indian Plate and Burmese Plate.

Two types of gravity modelling are integrated with the available seismic data: 1) The conventional approach that basement is rising up, and 2) a new approach that the basement is moving down into the Schuppen Belt area, which is discussed here. The second

approach suggests the presence of thick Gondwana sediments of 5 to 8 km in the Schupen Belt region, which may give rise to hydrocarbon potential in the area.

Geological Framework of Assam-Arakan Basin

The Upper Assam foreland basin is situated in the far northeast of India, within the curve of the Assam Syntaxis which is a major orocline in the Himalayan Orogenic Belt. The Assam geological province reflects three distinct tectonic phases. The earliest was Late Cretaceous to Eocene block faulting and development of a southeasterly dipping shelf (Figure 1 and Figure 2). During the second phase, in Oligocene time, uplift and erosion occurred north of the Brahamaputra River, and many basement faults were reactivated with many basement-controlled structures becoming prominent. Oligocene uplift and erosion were followed by extensive late Miocene through Pliocene alluvial deposition. The resultant sedimentary column is as much as 7,000 m thick. The thickest section is along the Naga Thrust Fault and in the Dhansiri Valley where it is greater than 4,500 m. The thinnest section lies along the axis of the central basement ridge, where it is less than 2,000 m thick.

Geologically the Assam-Arakan Basin is divisible into eastern Himalayas in the north, Mishmi Massif in the Northeast, Naga Hills in the southeast, Shillong and Mikkir massifs in the southwest, upper Assam Valley in the center and the Tripura-Manipur geosynclinal fold belt in the south (Figure 2). Each of these units has its characteristic features. Between the two hills, eastern Himalayas and Naga Hills, lies the upper Assam Valley occupied by the Brahmaputra River and its tributaries. The Upper Assam Valley, at present, represents an intermountain platform basin developed between the eastern Himalayas and Naga Hills.

The basin has thrust margins on three sides, the Naga Hills Thrust Belt and Manipur Ophiolite Belt are on the south, the Main Frontal Thrust of the Himalayas, which was active from the Middle Miocene to present-day, bends around the Assam Syntaxis on the north and east. The basement of northeast India comprises various Gondwanide fragments, mainly Peninsular India (Indian Craton) and in the West Burma Block, with the Lhasa and Sibumasu Blocks framing the regional picture. The depth of the basement and sedimentary sequences along the Naga Thrust in the shelf area is shown in Figure 3.

GM Data Interpretation

The Bouguer anomaly map of Assam Valley shows many interesting and peculiar features (Figure 4a). In the Upper Assam Valley, roughly between the Brahmaputra River and the Naga-Patkai Hills, sediment thickness increases towards the southeast (Naga Thrust), and the gravity anomaly, instead of showing corresponding lowering, actually increases by 10 mGals. However, further southeast, beyond the Naga Thrust, the Bouguer anomaly increases abruptly and continues to rise in the area where data is limited, although sediment thickness is expected to increase significantly beyond the Naga Thrust. In the Dhansiri Valley area the Bouguer anomaly also becomes more and more negative from the eastern margin of the Mikir Hills to the Naga Thrust, mostly due to increase of sediment thickness.

Significant positive magnetic anomaly and progressive increase of Bouguer anomaly implies that the area has been involved in basement folding, i.e. basement has been pushed up by tectonic deformation. With this idea, gravity modelling along seismic Profile AA' (Figure 4a and Figure 5), which is passes through the well URM-2, has been carried out taking into consideration a drilled basement depth of 4320 m and the line is extended towards the Naga Hills and the Mikir Hills based on the gravity values only, where increase of gravity anomaly has been explained by raising the metamorphic basement. But this approach shows basement has to be modelled as shallow as 1.5-2.0 km deep, which is unrealistic (Figure 7)

Therefore, the presence of very thick volcanic type material, which has a density around 3.0 gms/cc and is also highly magnetic, is presumed which will satisfactorily explain both the gravity and magnetic anomaly pattern of the area. A model with this concept is prepared which shows presence of thick igneous material (ophiolite?) underneath the sediment (Figure 6). Implication of this model is that the folding has involved and moved up the oceanic basement (ophiolite?) in this area.

Similarly, this approach of gravity modeling was carried out for Profile BB' (Figure 8 and Figure 9) and Profile CC' (Figure 10 and Figure 11). In both cases, basement is going down, as evident from the seismic section, thereby increasing sediment thicknesses near the Naga Thrust, whereas the gravity is going up which suggest that if we have to account for the raising gravity accompanied by the high magnetic anomaly in the Schupen Belt region then we have to construct this type of model which would satisfy the data. This approach of intrusion of high magnetic material may be linked to the thrust-fold feature of the Schuppen Belt area of the Arakan Basin and related to the subduction of the Indian Plate under the Burmese Plate and presence of volcanic rocks in the Naga Hills (Figure 12).

Conclusion

The model discussed here, where sediment thickness increases below the Naga Thrust, contradicts the conventional approach that the sediment thickness decreases and the basement is moving up in the Schuppen Belt region. So, many scientific studies are required to arrive at a consensus of the basement behavior in the Schupen Belt region. Gravity data points in the Schuppen Belt area are sparse, hence for better analysis it is recommended that the whole area be surveyed in a close grid of GM and magneto-tellurics along with field geological inputs. Seismic data with reasonable shot hole depth of 30-40 m, particularly in the foothills, would also provide useful information for imaging the Basement. This is a major task before the exploration community to validate the model and explain the high nature of magnetic anomaly in the Schuppen Belt area.

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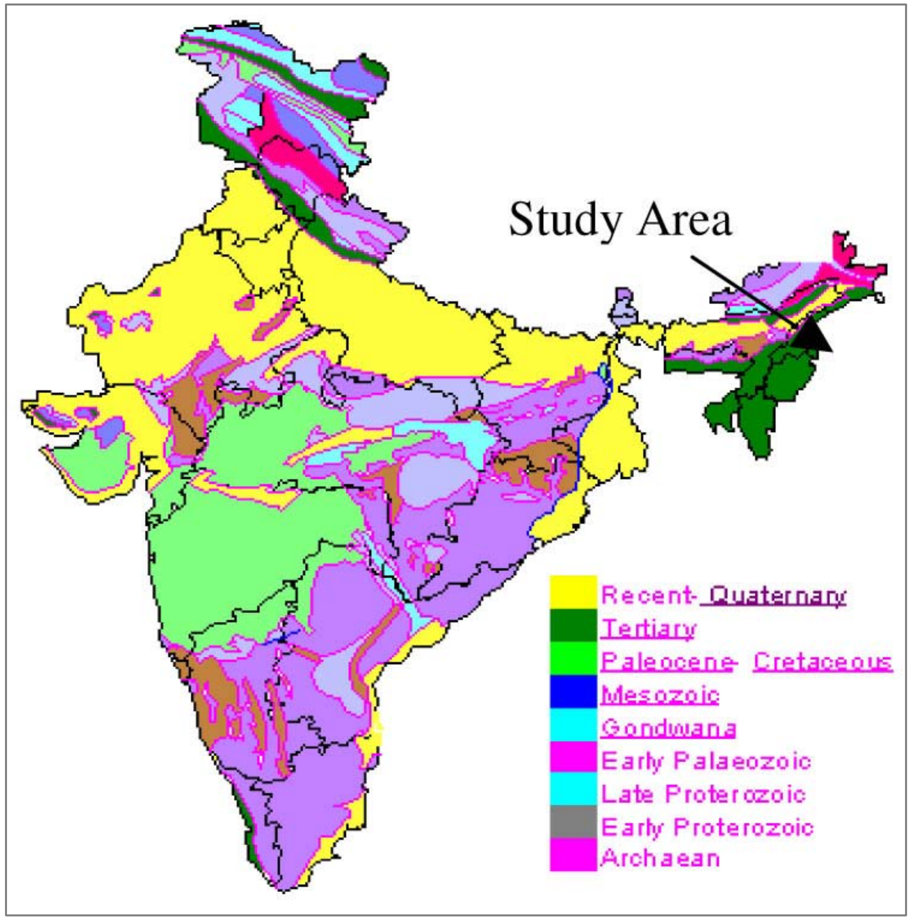

Figure 1. Simplified geologic map of India with location of the study area.

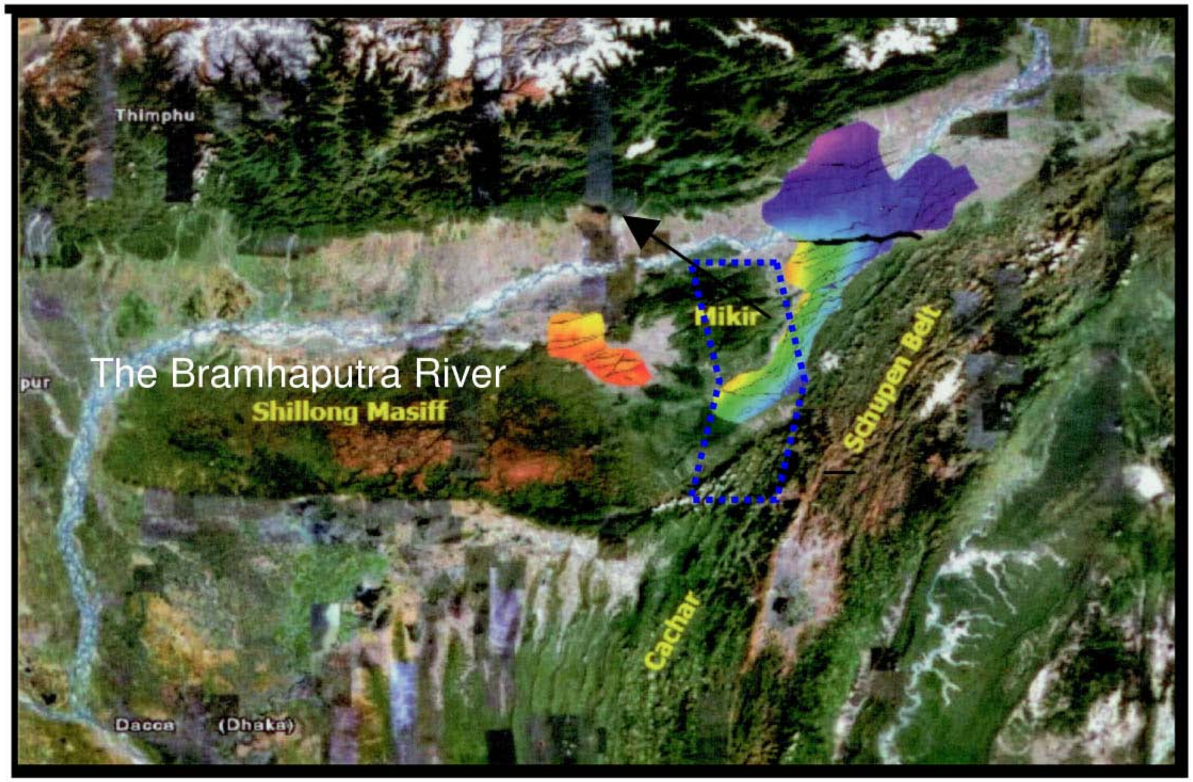

Figure 2. Satellite image of Upper Assam Shelf.

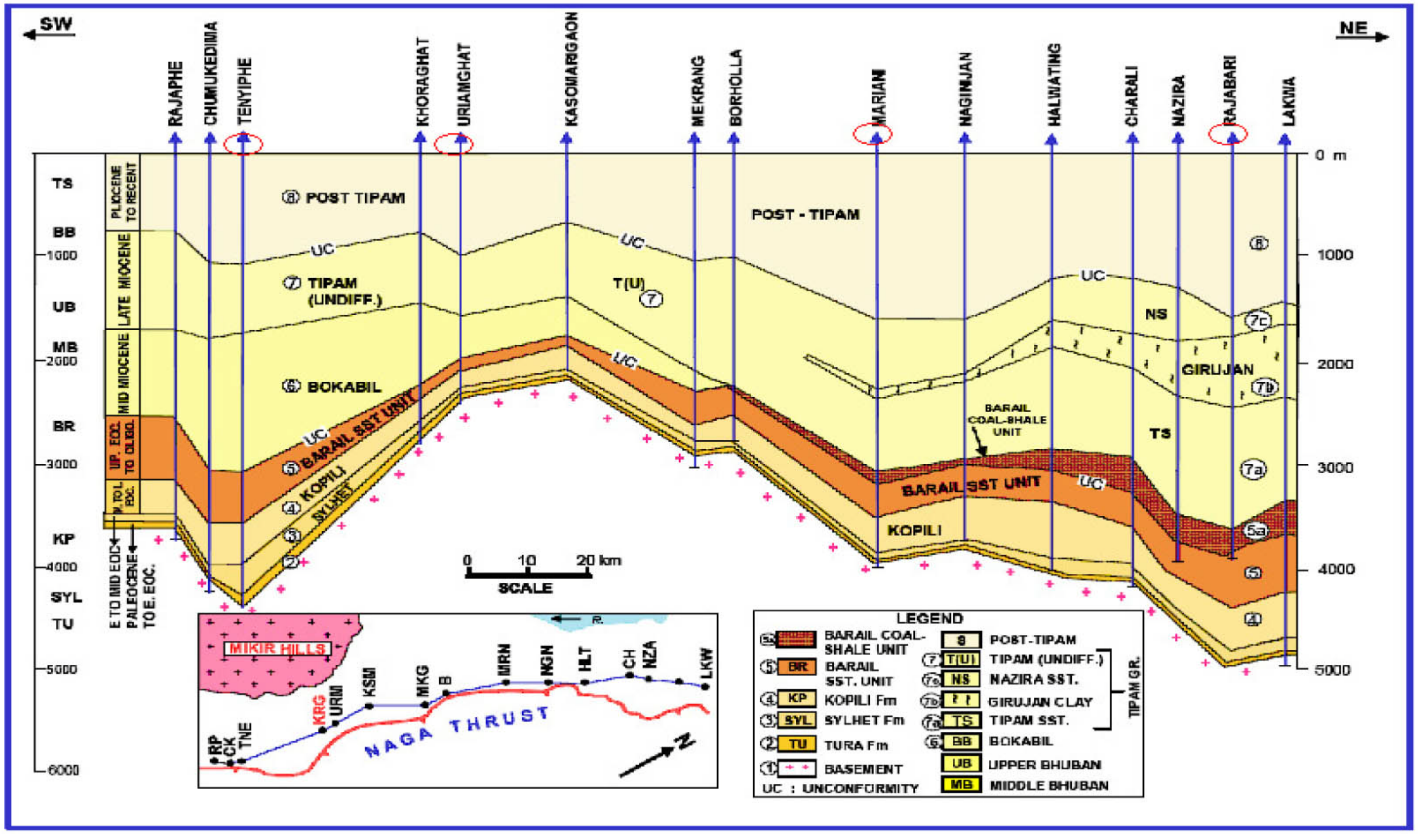

Figure 3. Geological cross section between the Bramhaputra River and Dhansiri.

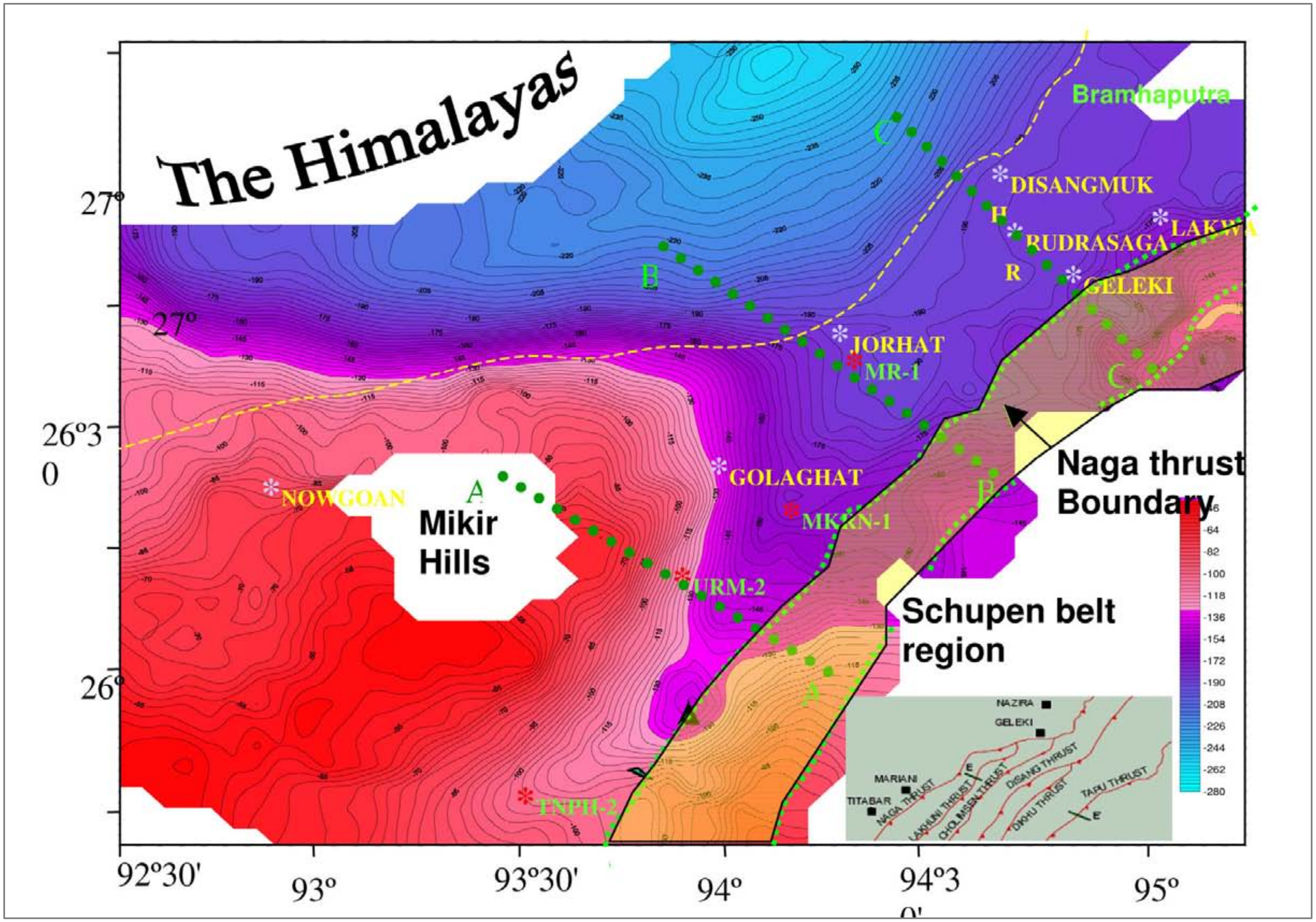

Figure 4a. Bouguer anomaly map of Assam (2 mGal contour interval).

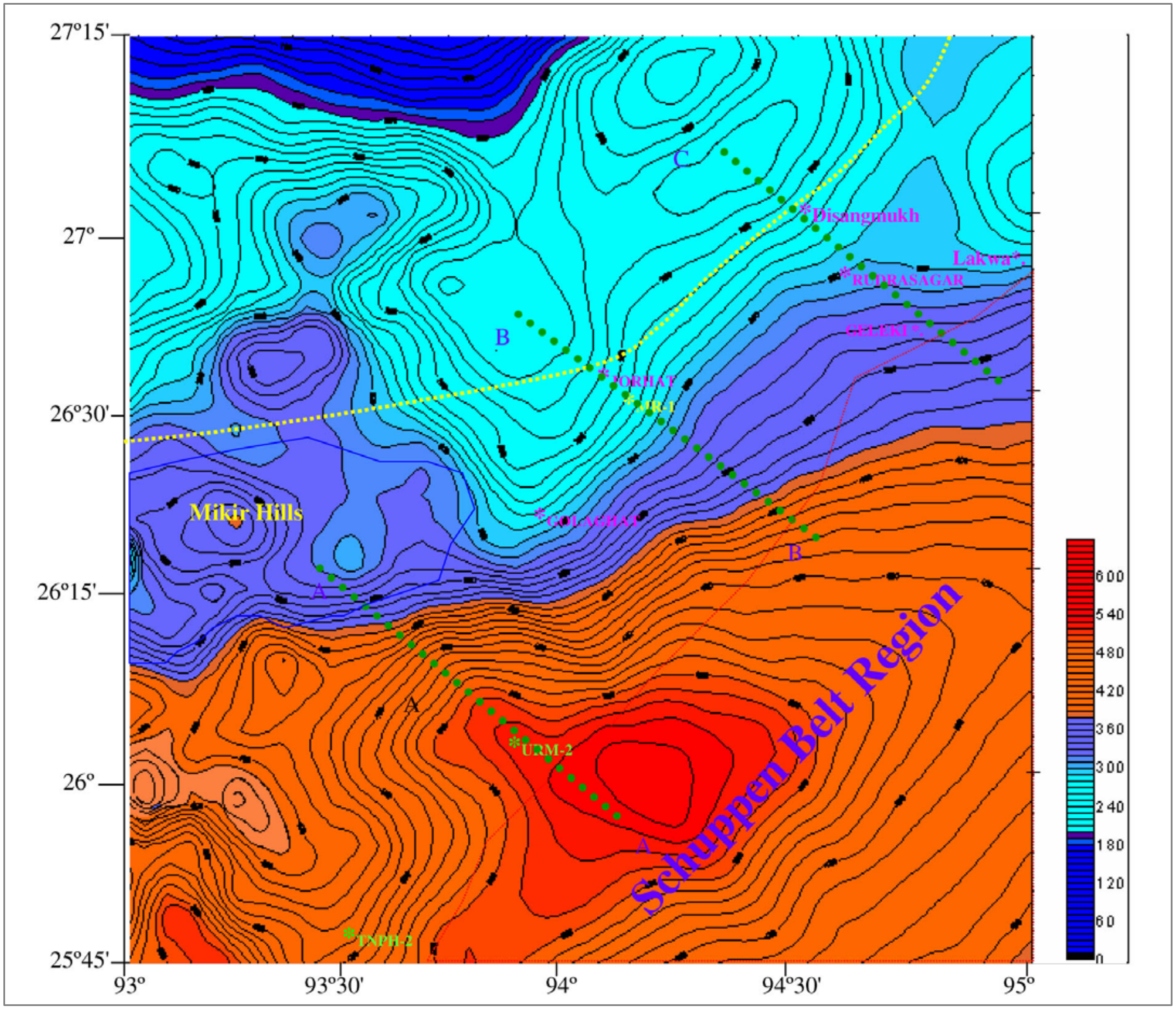

Figure 4b. Aero magnetic anomaly map of Assam (10 gamma contour interval).

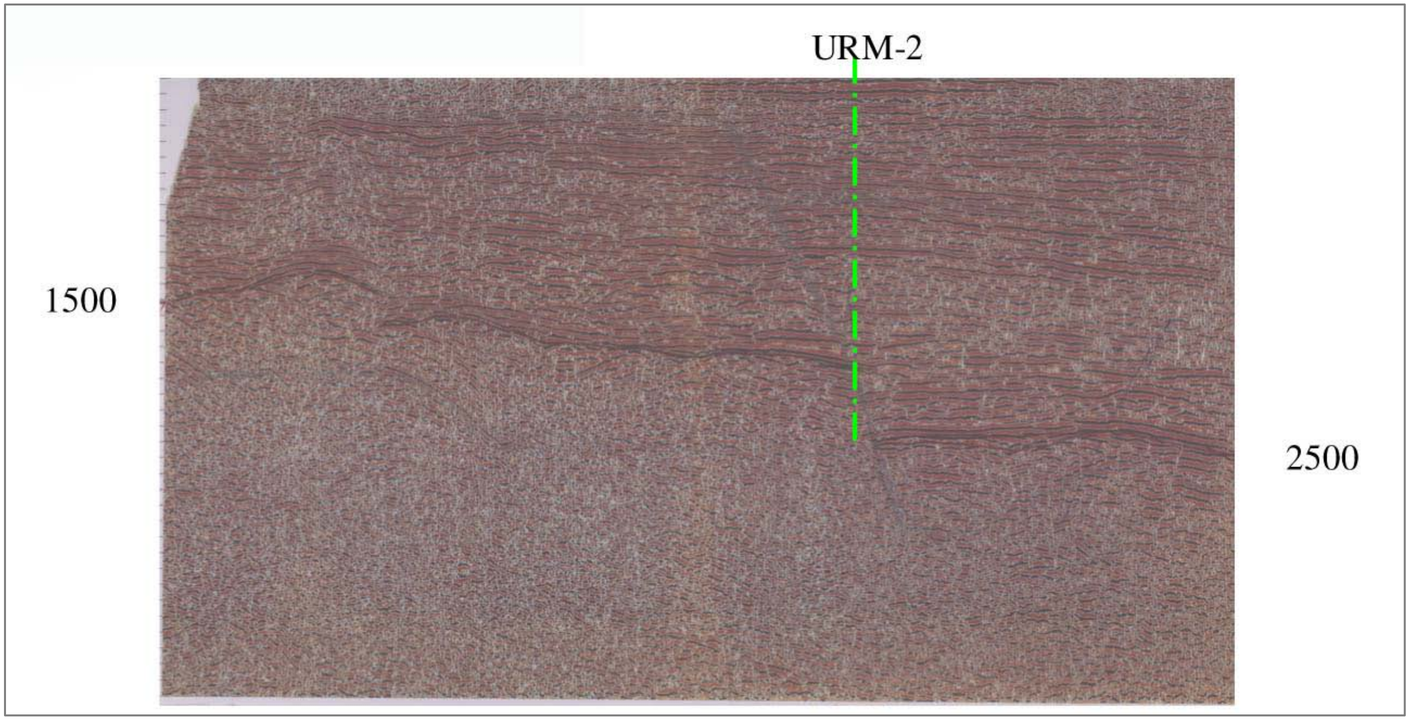

Figure 5. Seismic section (15 km long) through well URM-2.

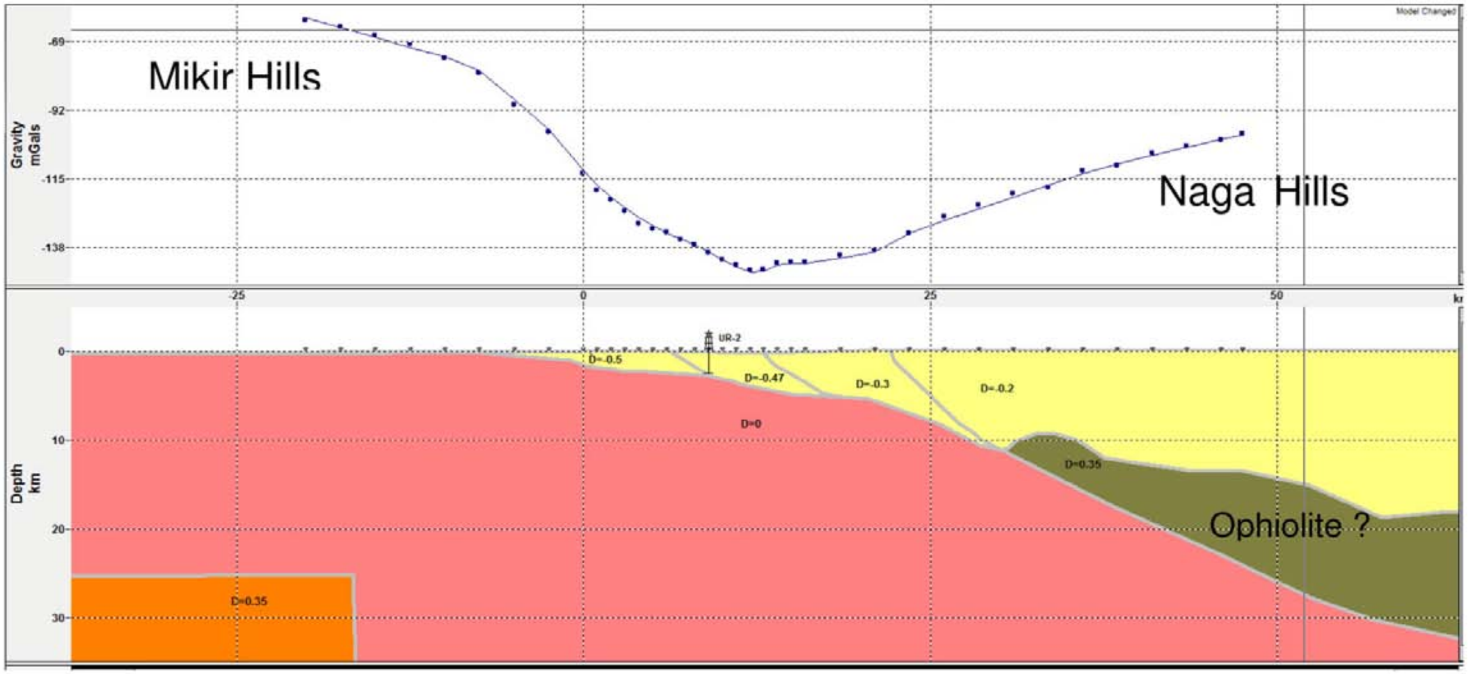

Figure 6. Gravity modelling along the Profile AA' and passing through URM-2 (located on Figure 4a). The line has been extended towards the Mikir Hills (NNW) and the Naga Hills (SSW) based on gravity values only.

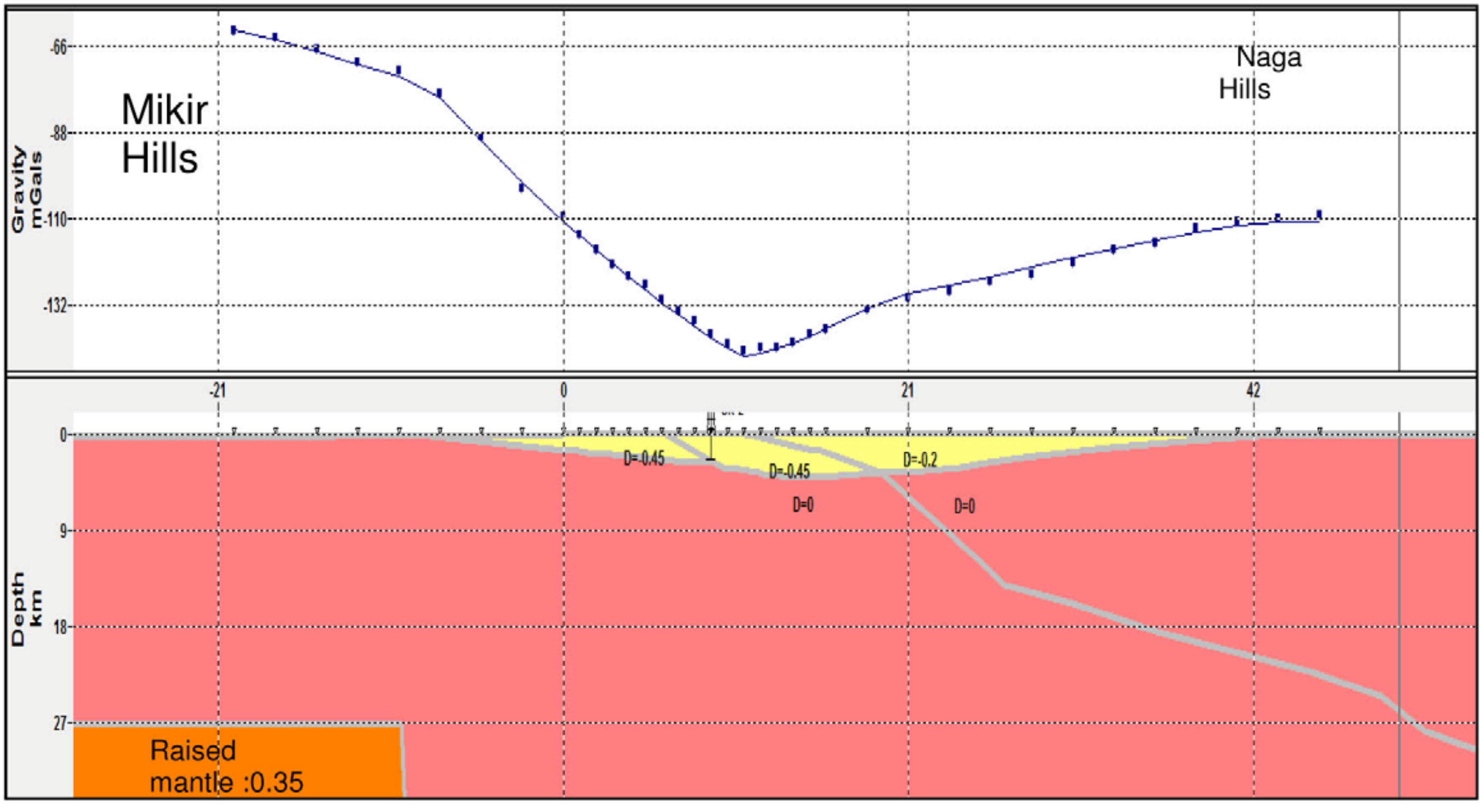

Figure 7. Gravity modelling (Alternate model) along a Profile AA' through well URM-2. The modelling has been extended towards the Naga Thrust (SE) and towards the Mikir Hills based on the gravity values only.

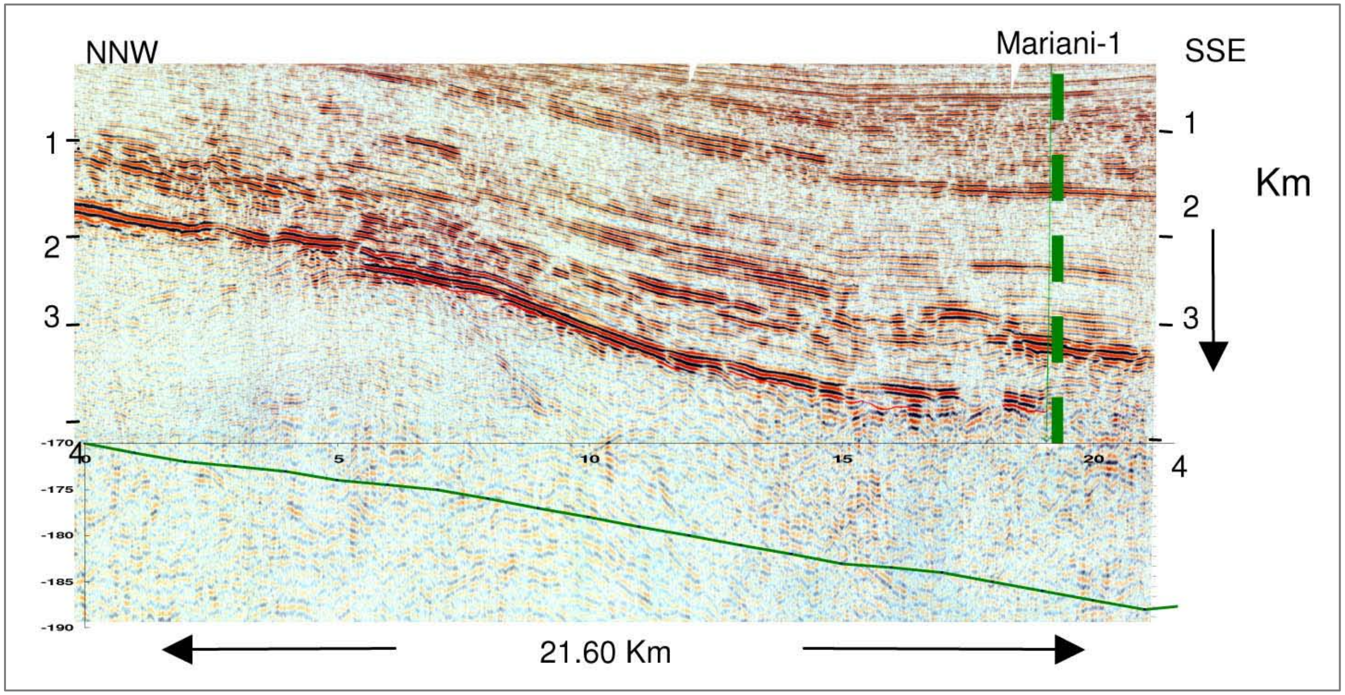

Figure 8. Profile BB’, a depth seismic section starting adjacent to Bramhaputra and ending near the Schuppen Belt.

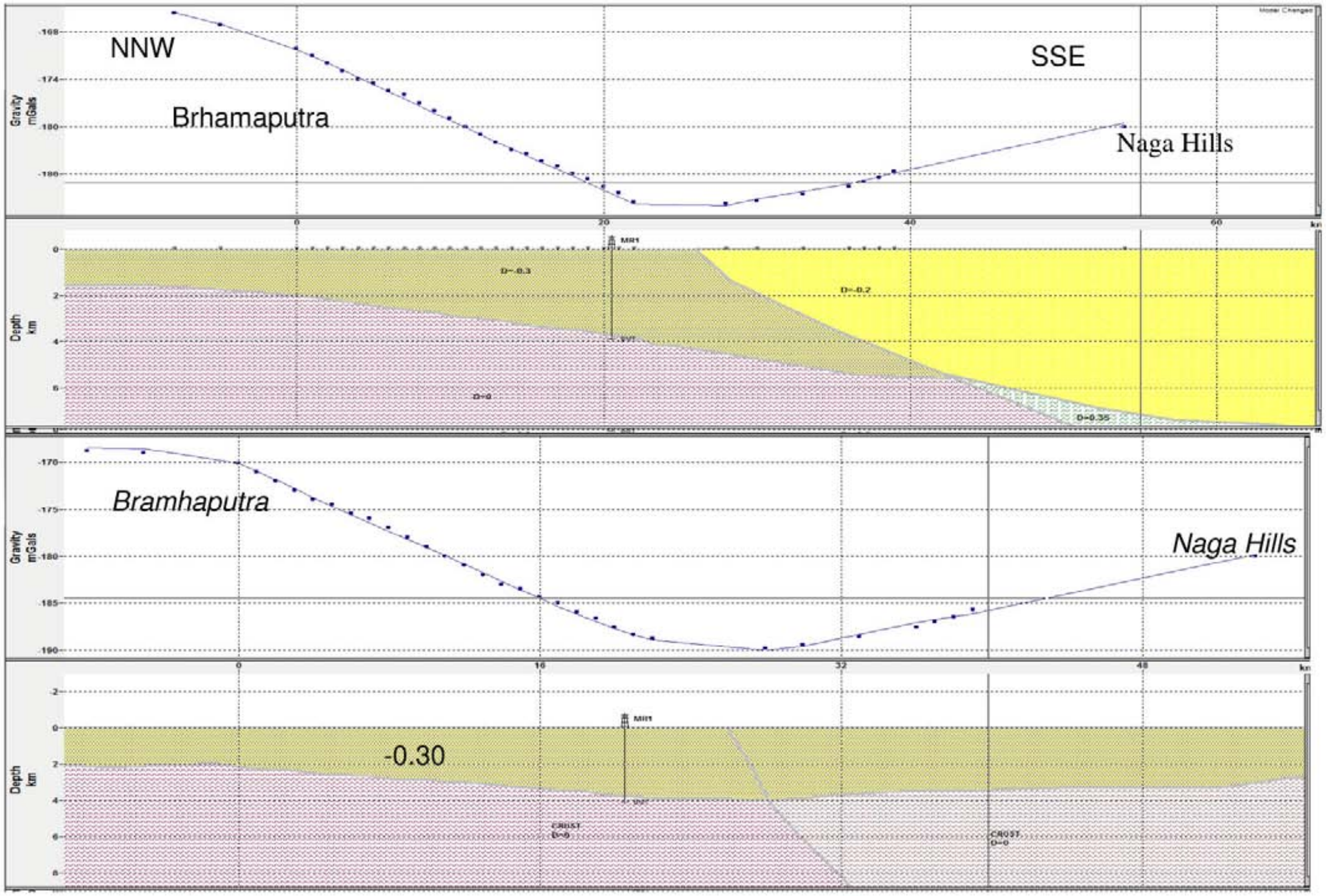

Figure 9. Two types of gravity modelling along Profile BB' through well MR-1. The model has been extended towards the Naga Thrust (SSE) and towards the Bramhaputra River (NNW) based on gravity values only.

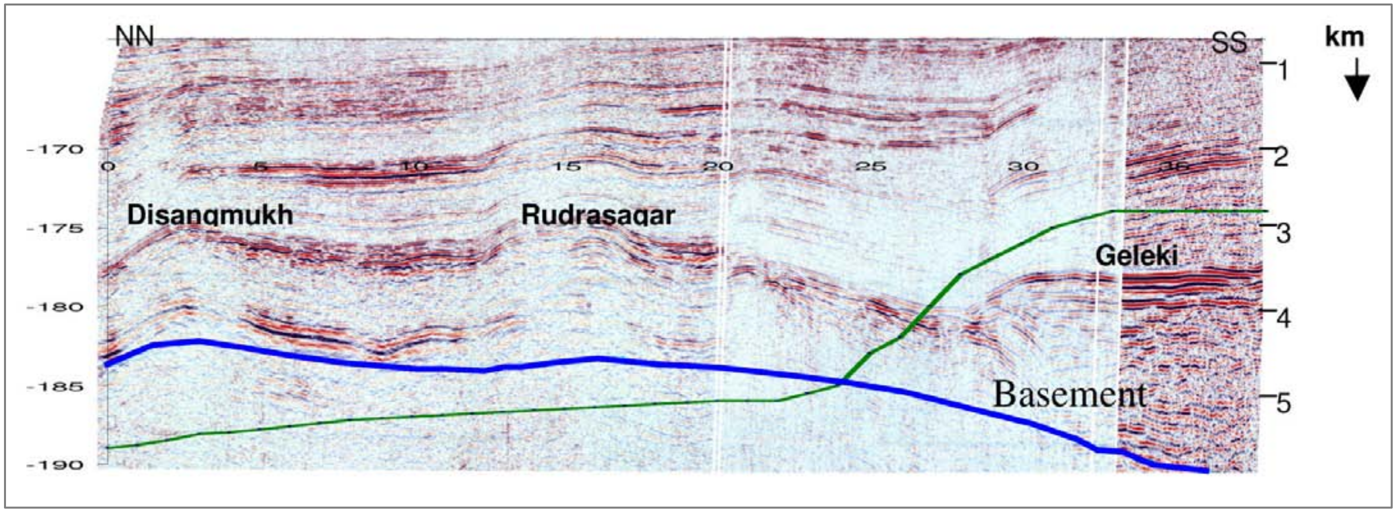

Figure 10. Profile CC’, a depth section from Disangmukh Field to Geleki Field over which gravity values are posted.

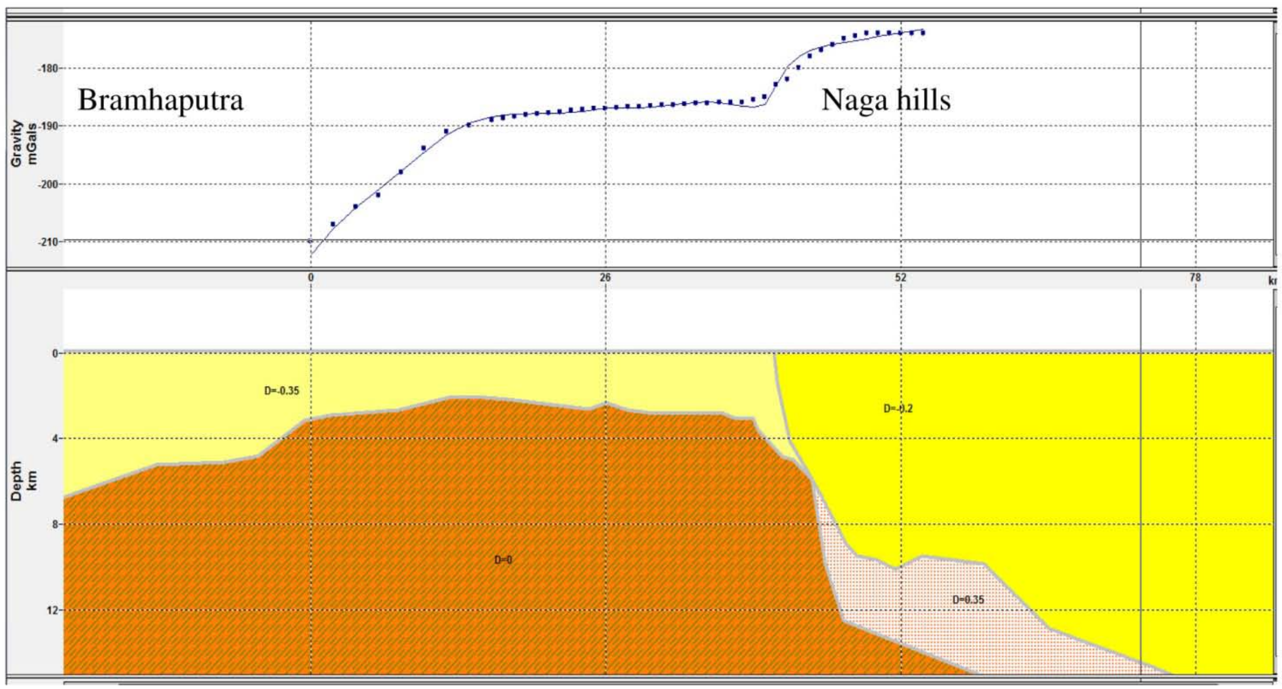

Figure 11. Gravity modelling along a Profile CC’ from the Disangmukh Field to the Geleki Field. The profile has been extended toward the Naga Hills (SSE) and beyond the Bramhaputra River (NNW).

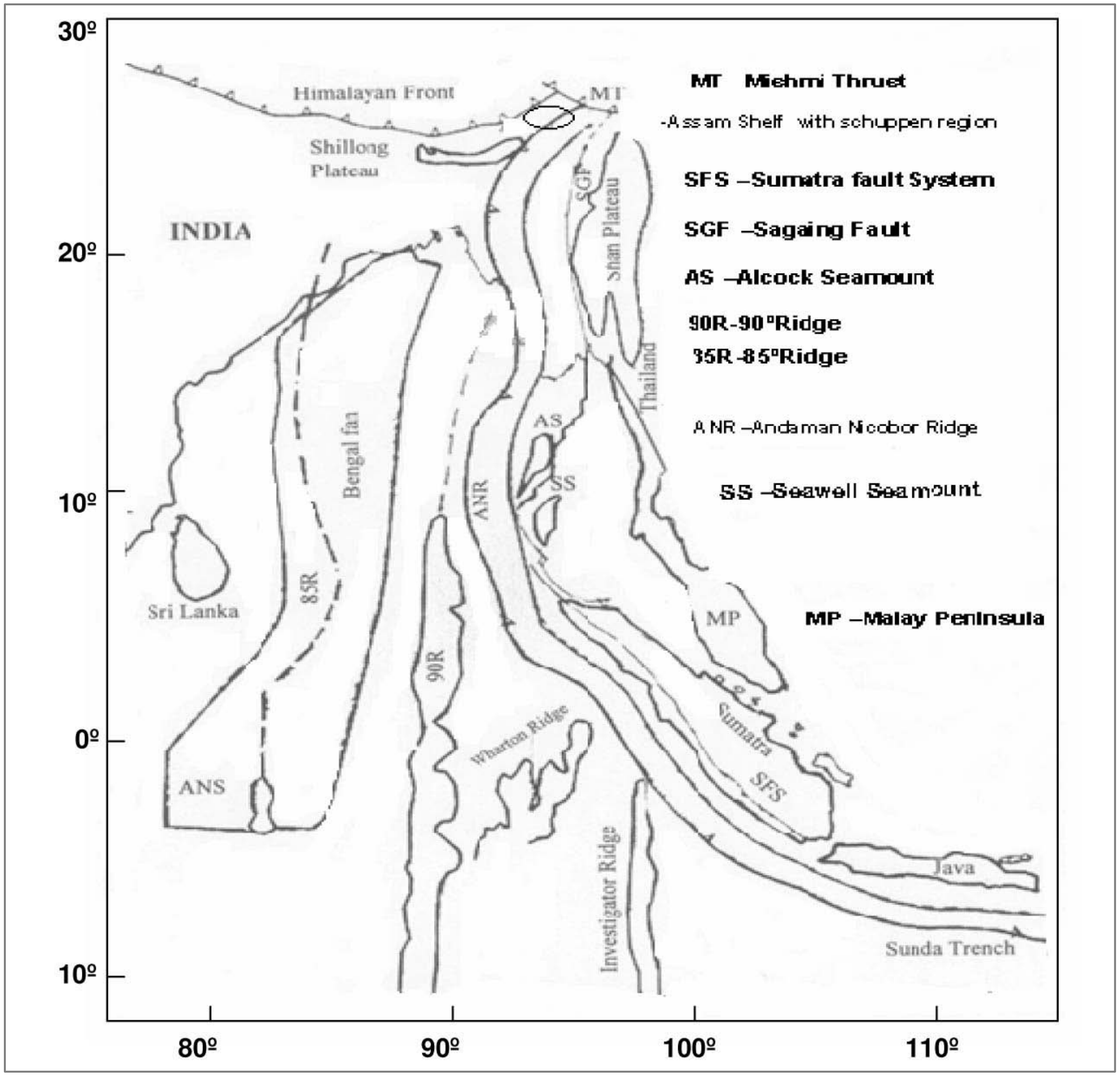

Figure 12. Major tectonic features of Indian Plate subducting under the Burmese Plate.