Application of Euler Deconvolution of Gravity and Magnetic data for Basement Depth Estimation in Mizoram Area

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Abstract

The exploration activities in Mizoram area is limited by certain constraints. The area is extremely difficult logistically being covered with dense forest, hilly & drastically undulating topography and geologically complex surface & subsurface with highly folded, thrusted and faulted beds. Recent information on discoveries of hydrocarbon around Mizoram area i.e. Cachar, Tripura and Bangladesh hydrocarbon discoveries, have created interest towards this area. The quality of seismic imaging in this area is affected by complex ray-path geometry associated with thrust-fold tectonics. Rightly so, Oil India Limited (OIL) carried out integrated geological, geophysical and geochemical studies for identification and analysis of the prospects in this area. Gravity-magnetic technique is also deployed in the area to facilitate mapping of the depth & topography for the basement to understand the basin architecture for hydrocarbon exploration.

In this paper, potential field data viz. Gravity and Magnetic data have been used through Euler Deconvolution technique for simultaneous depth and source estimation along 4 Nos. of 2D Profiles selected across the Block in W-E orientation. The basement depth thus estimated is varying between 13 Km to 16 Km which is in a close approximation to those inferred from other geoscientific procedures. The study reveals that the basement depth is higher in the eastern part compared to that of the western part of the Block which is in complete conformity to the general geology of the area.

Introduction

Oil India Limited (OIL) has started the hydrocarbon exploration activities in Mizoram area since 2007. The area falls in the Assam-Arakan-Tripura thrust-fold belt which is characterised by complex geology. The area has extremely difficult logistics with dense forest, hilly with drastic sub surface undulation. So far OIL has embarked upon an integrated geoscientific studies for identification and analysis of different prospects. Considering the constraints imposed by logistics, 2D seismic data with crooked line geometry was acquired. Additionally, a sufficient number of geochemical samples have been collected & analysed, geological mapping & modelling works have been carried out in and around the block area to arrive at a reliable geological model. However, studying the Basement depth & configuration have been a great challenging task in this area due to complex subsurface duplexes, imbricates & juxtapositions coupled with greater depths, despite of having fair to good quality of seismic data. Accordingly and to improve the level of confidence in delineating the basement & its depth and to conceptualize a realizable geological model; simultaneous Gravity and Magnetic data acquisition, processing, interpretation were taken up in the block area. In this paper, an attempt has been made for delineation & estimation of basement depth from analysis of Gravity and Magnetic data through application of Euler Deconvolution technique. Four numbers of different Profiles each having length of around 56 km, oriented West to East, have been used for the present study.

Area of study

The area of study, entire 3200 Sq.km of Mizoram Block, located in the Mizoram fold and thrust belt between Bangladesh and Myanmar, (Figure-1 (a & b)) is highly fraught with hillocks of very steep slopes ranging between 60- 80 degrees and intervening deep gorges. The hill ranges reach a height of around 1800m in Mizoram with most of these between 900-1300m in the working area. The general elevation increases towards East up to the Myanmar border as depicted in Figure-2(a). There are hardly any motorable roads except the National Highway, NH-54. The closest well drilled in the area is Rengte-2, situated at a distance of 54 Km to the North of the Block.

Geological setting of the Block

The area of study (Figure 1(b)) is located in the Chittagong, Tripura, Cachar and Mizoram Hills region along the western extension of the convex-westward Indo-Burmese fold-thrust (Assam-Arakan) belt and is characterised by the development of a frontal structural system of well-developed sub parallel fold-trains with North-South oriented culminations both-ways plunging (North & South), sliding over the actively subsiding Surma foreland basin of eastern Bangladesh. The amplitudes of the folds are higher towards the East and these folds gradually wane out towards Bangladesh in the West. The Indo-Burman orogenic belt defines the transpressional collision boundary between the Indian plate to the West and the Burmese microplate of Eurasia to the East, The central Mizoram Hills in the Exploration Block area includes a number of NW-SE oriented oblique shear, fault, and/or fracture systems that cut across and or merge with the dominant North-South structural systems. These sub-vertical to high-angle oblique faults have been interpreted as tear-faults, with an overall left-lateral sense of motion across the fold-belt, that have allowed the development of independent, North-South

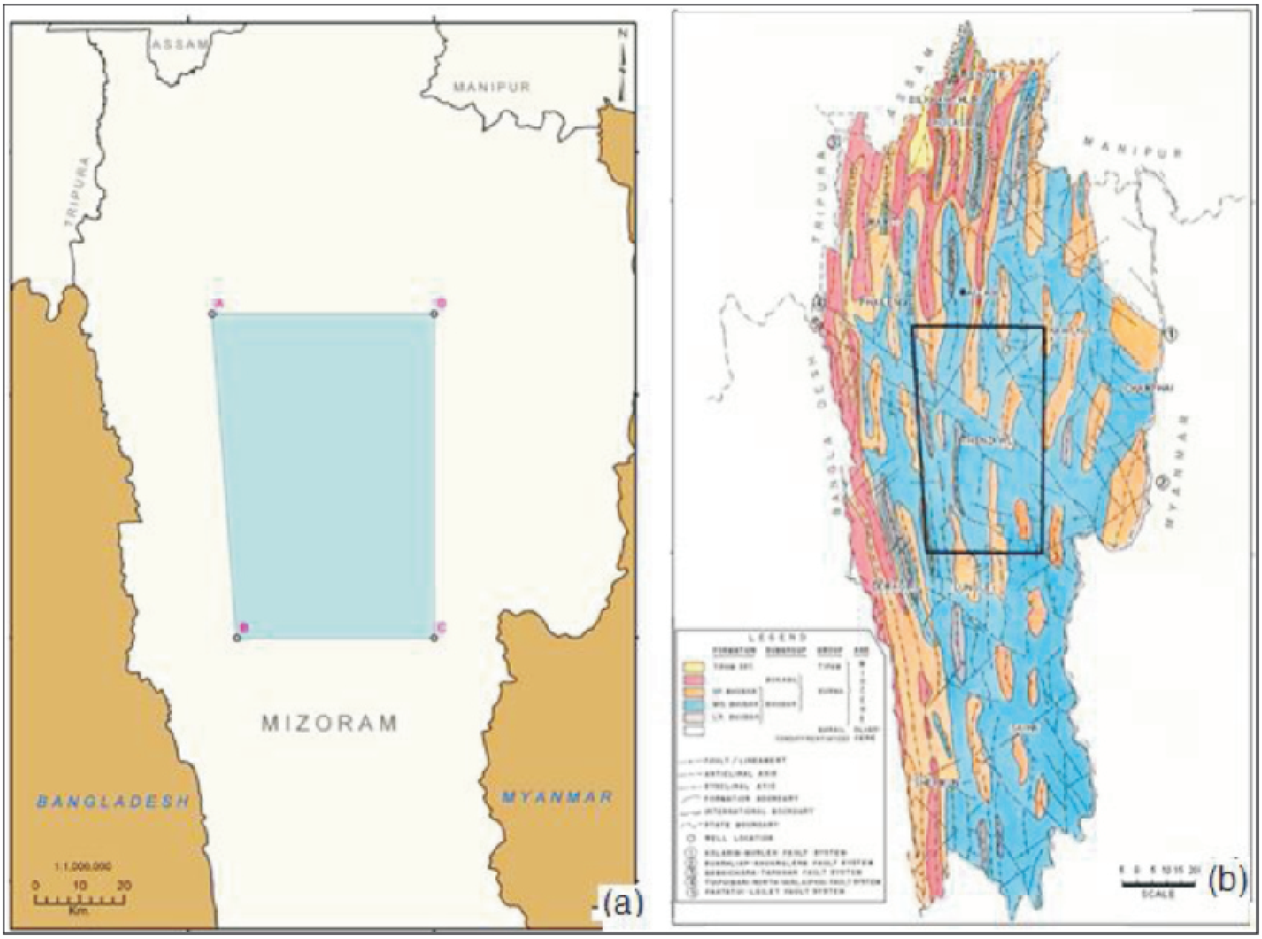

Fig. 1: Location map (a) and geological section of the block (b)

oriented structural systems on either side of the faults. Accordingly, these tearfault systems (lateral ramps?) are believed to originate along the Jenam-Laisong detachment surface developed coevally with the North-South oriented structures that either merge with, or are truncated by, the oblique fault systems. The Thenzawl and Pangzawl faults are the two most significant oblique fault systems within the Block, while the Lunglei fault is in its South. To the East Block, the Champhai Plateau defines a third structural zone which has apparently undergone greater overall tectonic uplift than the central Mizoram Hills and along which the distinct, North-South orientation of structural trends within central Mizoram becomes more complicated. The Basement in the Block area is expected to be within a depth range of 13 Km to 15 Km.

Hydrocarbon Prospect of the Block

As discussed, the block is situated to the South and East of established petroleum provinces of Tripura-Cachar and Bangladesh. The nearest producing hydrocarbon field in Khubol in Tripura is 70 km from the northwestern edge of the block within Mizoram, 3 wells have been drilled to the North of the Mizoram Block by ONGC, till date, on same structure viz. the Rengte anticline. Rengte-2, the closest well lies 54 km North of the block, penetrated the Middle and Lower Bhuban Formations as well as the Upper Barail and Renji Formation but gave no indications of commercial hydrocarbons except some gas shows. Rengte-1, located 76 km to the North penetrated 3001 m of Middle Bhuban Formation. It encountered a number of repeated sections due to high angle reverse faulting. Two gas shows were encountered during the course of drilling at 2181 and 2211m. DST in the interval 2397-2408m yielded minor amount of gas. Rengte-3 drilled 106 km to the North drilled the Bokabil and Upper Bhuban Formations. The target horizons in this well appeared to be tight, containing only non-commercial gas shows. In neighbouring Cachar areas in the North, hydrocarbon exploration dates back to 1911 under the aegis of AOC / BOC. Exploratory drilling to shallower depths discovered commercial oil in Badarpur and non-commercial oil in Mashimpur. Since 1962 ONGC has carried out more than 12,000 GLK of seismic surveys and drilled more than 210 wells in Tripura-Cachar Basin. About 20 BCM of IGIP has been established in 17 gas fields.

Gravity & Magnetic Data acquisition in the Block

The Gravity and Magnetic data acquisition in the Block has been carried out by OIL through hiring the services of NGRI, Hyderabad during 2009-11. Gravity data has been collected using Lacoste and Romberg Gravimeter (Model G) with an accuracy of 0.01 mGal and Magnetic data has been collected using Scintrex Magnetometer (maintained for Base Station) and Geometrics Magnetometer (used for field data acquisition) with an accuracy of 0.01 nTesla at a spacing of

0.05 km to 1.0 km interval. The interpretation work has been carried out using more than 1900 G-M points. The complete Bouguer anomaly map of the Mizoram study area is shown in **Figure**-3(a). The N-E part shows low Gravity anomaly however S-W part shows high Gravity anomaly. **Figure**-3(b) shows the Magnetic anomaly map where the N-W part shows low Magnetic anomaly and S-W part shows high Magnetic anomaly. The Elevation profile shows that the eastern part of the study area is higher elevated compared to the western part. The trend of elevation is increasing from W-E direction, however gravity anomaly follows decreasing trend from W-E direction, which may be due to the isostatic adjustment. It can be inferred that the basement depth may be more in the eastern part compared to the western part. During the potential data processing, necessary corrections like free air and terrain correction, have been applied. The structural trend and undulating features of surface topography of this study area show the similar trend of observed gravity and magnetic field. The trend of gravity/magnetic anomaly normally oriented in the N-S direction which follows the similar pattern of surface topography of the various anticlinal features in this area. Finally Complete Bouguer anomaly and IGRF corrected magnetic anomaly map have been considered for further interpretation. The free air anomaly and the station interval location map are shown in Figure 3(c) and Figure 3(d) respectively.

Methodology and data interpretation

Euler deconvolution technique is an established procedure used to the rate of field change with distance to estimate the depth & location of the source, applied to Profile or gridded map data to solve the Euler's Homogeneity Equation which states that:

$$(x-x_0)\,dF/dx + (y-y_0)\,dF/dy + (z-z0)\,dF/dz = N\,(B-F)$$

Where x0 , y0 , z0 is the source location whose magnetic field is F measured at x,y,z and B is the regional value of the Total Field, N is the Euler's Structural Index (SI)which characterizes the source geometry. The SI varies from zero (for contact of infinite depth extent), 0.5 (for linear basement or dyke), 1 (for thin dyke), 2 (for pipe) and 3 (for spherical bodies). An Euler depth estimation increases with N and real bodies are simulated by superposition of bodies. For Profile data (as used in the instant case where y=0) each calculation has been run for different window length & SI to obtain the solution for different source location & depths. For the present study, four Profiles have been selected, passing through the Block area of Mizoram with W-E orientations, each of about 56 Km length. Profile-1 is passing through Lat: 23.1330 N in the southern part of the study area, Figure 2(b). In this Profile, elevation is varying from 250 m to 1200 m. The Gravity anomaly is varying from -58 mGal to 12 mGal. However Magnetic anomaly varying from -160 nTesla to 180 nTesla. Figure 4(a), Figure 4(b), Figure 4 (c), Figure 4(d) and Figure 4(e) show.

Elevation plot, Gravity anomaly, depth section using Gravity data, Magnetic anomaly and depth section using Magnetic data against the Profile-1. The Gravity and Magnetic values are higher in the middle part of the Profile-1.

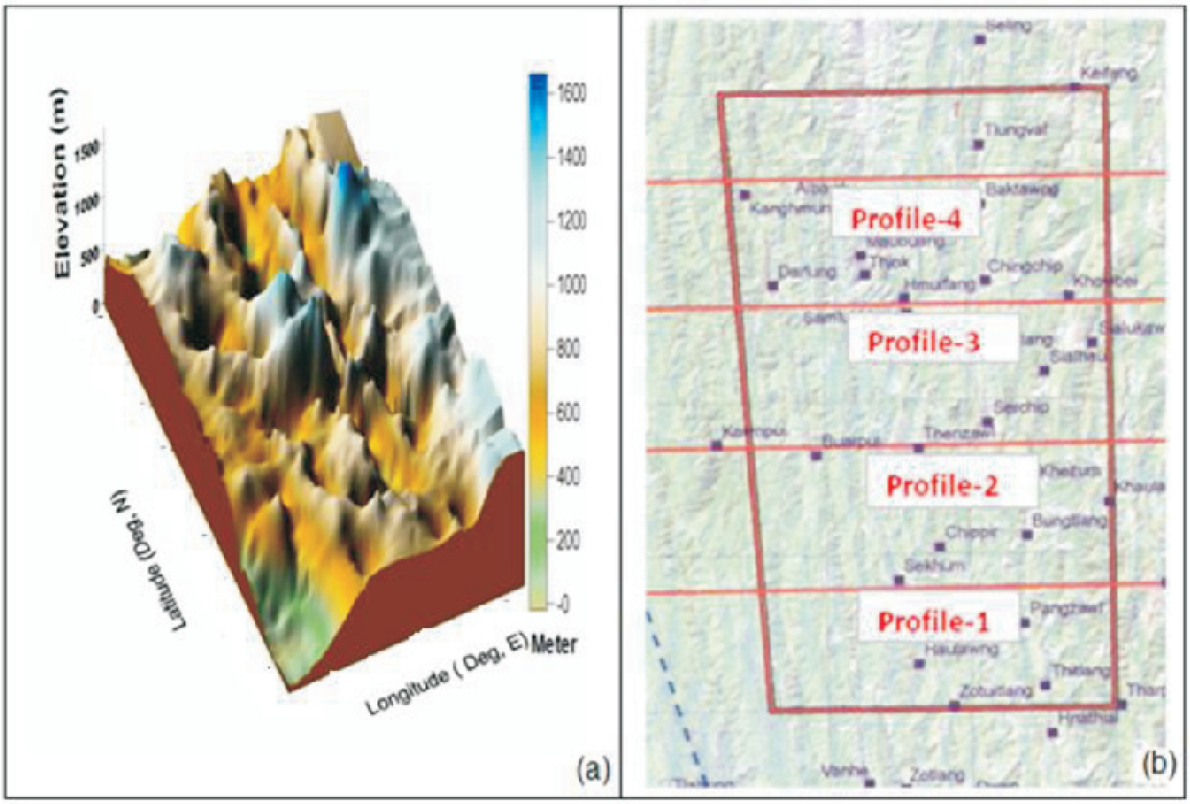

Fig. 2: Elevation map of the Mizoram block (a) and the study area shows 4-Number of Profiles location orienting from westward to eastward direction (b).

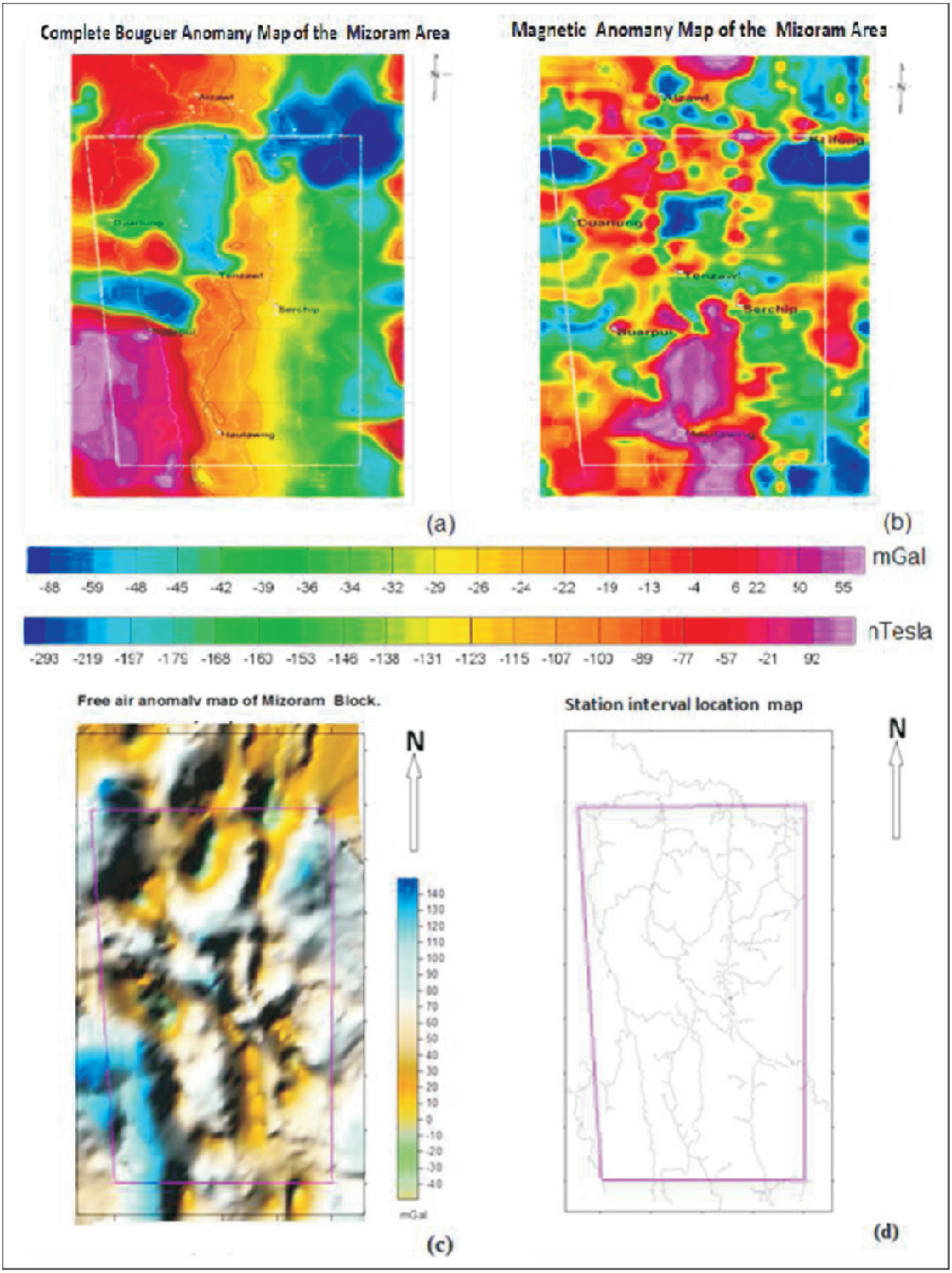

Fig. 3: Complete Bouguer anomaly map of Mizoram block. N-E part shows low Gravity anomaly and S-W part shows high Gravity anomaly (a). Magnetic anomaly map of Mizoram block, N-W shows low Magnetic anomaly and S-W shows high Magnetic anomaly (b). Free air gravity anomaly (c) and the station interval location map shows the data distribution in the study area (d).

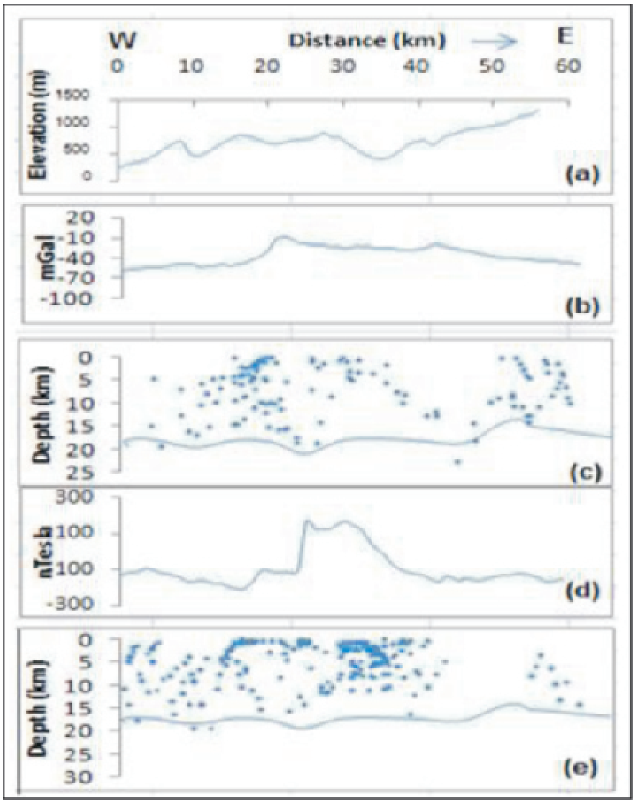

Fig. 4 : Depth estimation through Euler Deconvolution technique (a) Elevation (b) Gravity anomaly (c) Depth section using Gravity data (d) Magnetic anomaly (e) Depth section using Magnetic data (Profile-1).

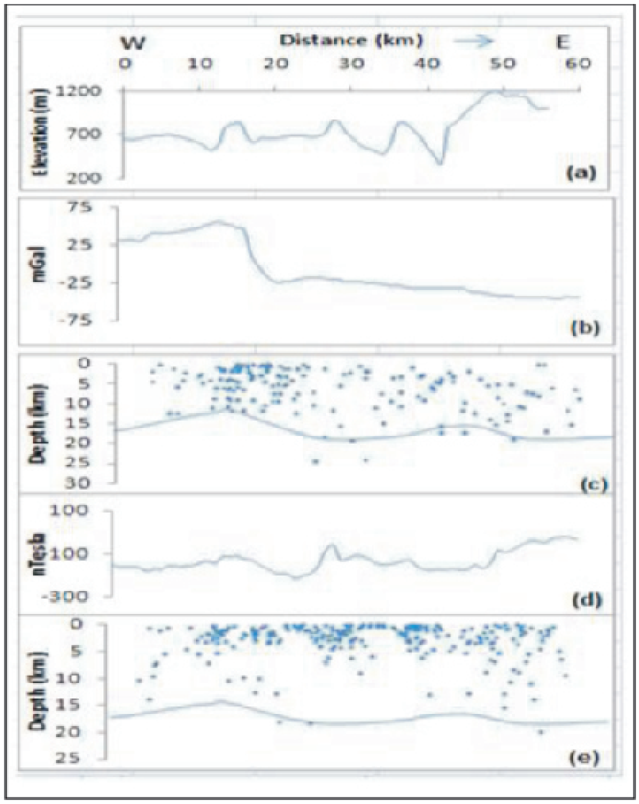

Fig. 5 : Depth estimation through Euler Deconvolution technique (a) Elevation (b) Gravity anomaly (c) Depth section using Gravity data (d) Magnetic anomaly (e) Depth section using Magnetic data (Profile-2).

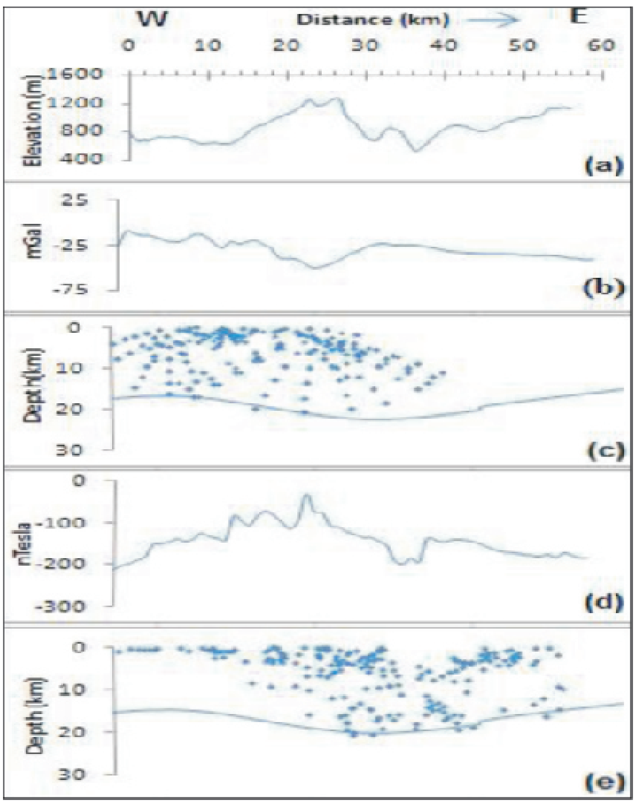

Fig. 6 : Depth estimation through Euler Deconvolution technique (a) Elevation (b) Gravity anomaly (c) Depth section using Gravity data (d) Magnetic anomaly (e) Depth section using Magnetic data (Profile-3)

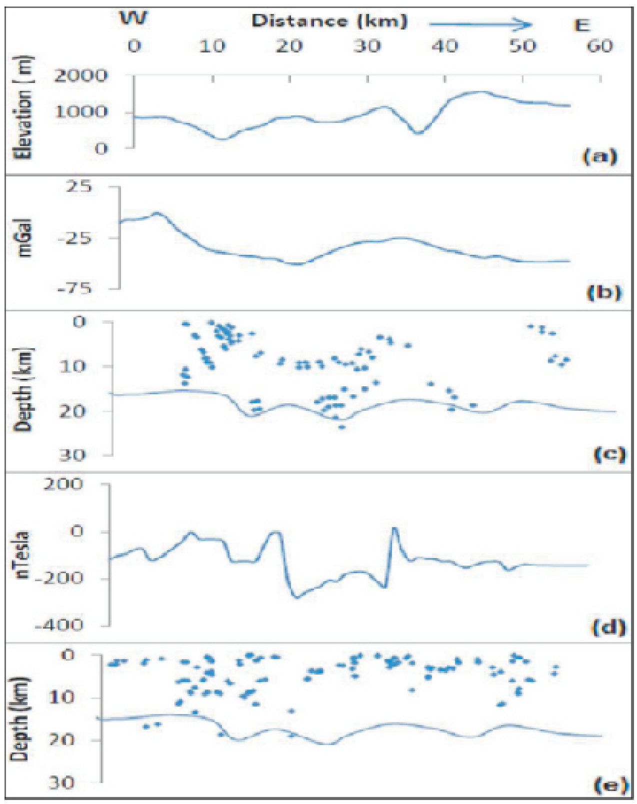

Fig. 7 : Depth estimation through Euler Deconvolution technique (a) Elevation (b) Gravity anomaly (c) Depth section using Gravity data (d) Magnetic anomaly (e) Depth section using Magnetic data (Profile-4).

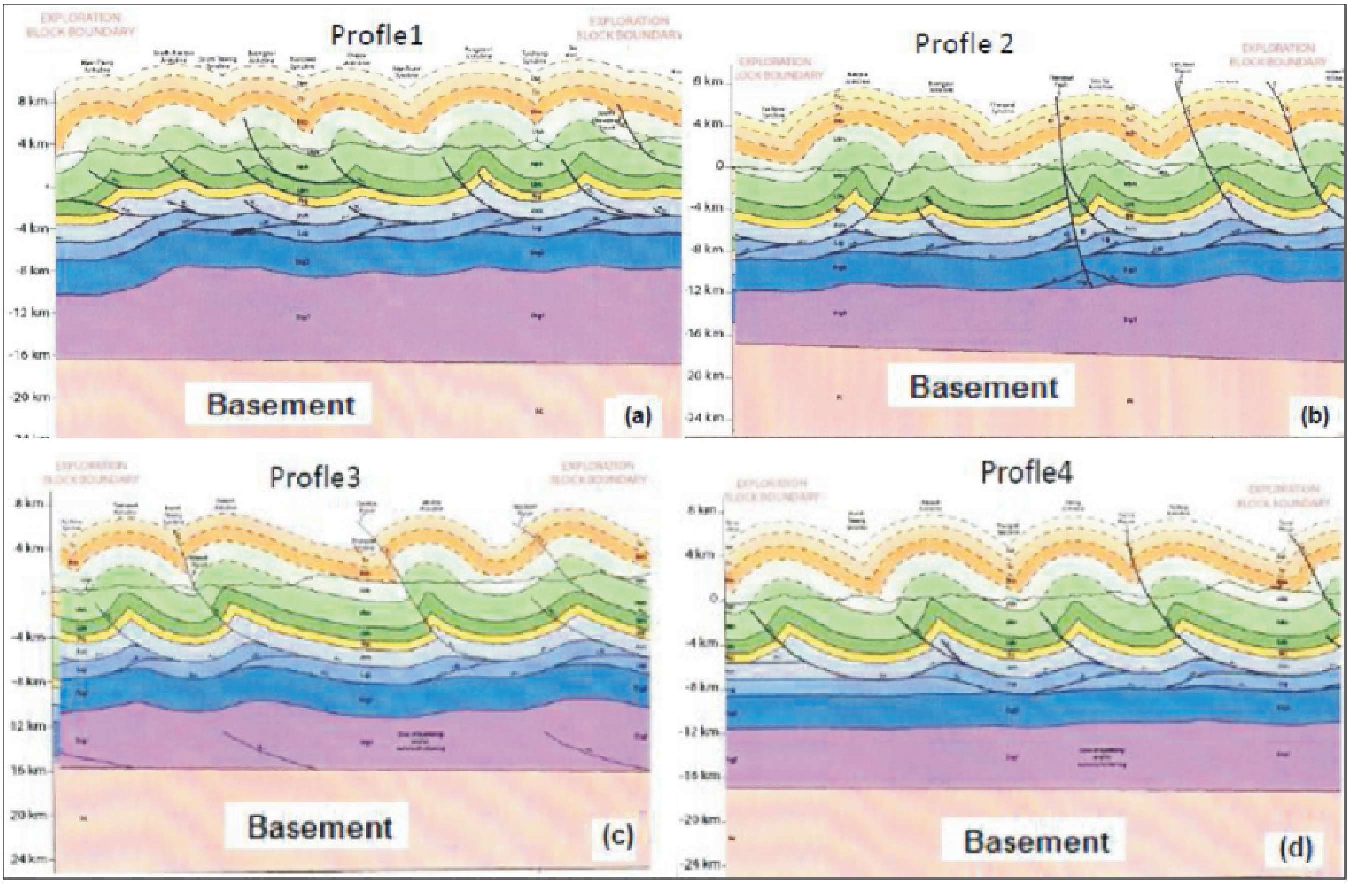

Fig. 8: Geological cross section along the Profile-1 and the basement depth (a), Geological cross section along the Profile-2 and the basement depth (b), Geological cross section along the Profile-3 and the basement depth (c) Geological cross section along the Profile-4 and the basement depth (d) (after Schielling, 2008).

Here, the Basement depth estimated varies from 14 to 16 km. The geological modelling carried out by OIL and as per the structural mapping carried out by Dr. D. D. Schelling, 2008, the basement depth also varies from 16 km and higher (Figure- 8(a)).

The other Profiles viz. Profile-2, Profile-3 and Profile-4 are passing through Lat: 23.2660 N, Lat: 23.40 N and Lat: 23.530 N, respectively. Depth estimation through Euler Deconvolution technique using Gravity and Magnetic data (Figure 5(b) and Figure 5(d)) against the Profile-2 has been shown in Figure 5 (c) and Figure 5 (e). Similarly the depth section using Gravity and Magnetic data (Figure 6(b) and Figure 6 (d)) against the Profile-3 has been shown in Figure 6 (c) and Figure 6 (e). In both the Profile-2 and Profile -3 the basement depths varies from 13 km to 16 km. But as per geological modelling Depth estimation against the Profile-3 and Profile-4 are starting from 16 km (Figure 8(b) and Figure 8 (c)) and more or less identical. In the Profile-4 where the Magnetic anomaly is much undulation (mainly in the middle part) the same may be attributed to the presence of fault (Figure 7 (d)). The depth calculation against the Gravity and Magnetic data (Figure 7 (b) and Figure 7 (d)) are shown in Figure 7 (c) and Figure 7 (e). The depth of basement varies from 14 km to 17 km, however as per geological modelling the depths are estimated as 16 km or higher (Figure 8 (d)); thus the depth estimation from present study appears to be a close match.

Conclusions and Discussions

In oil exploration accurate estimation of the depth & orientation of various geological discontinuities and mainly delineation of basement have always been vital as the total sedimentary sequence, their thickness, depositional time & pattern provide essential clues to arrive at a plausible model for hydrocarbon exploration from its Generation, Migration and Entrapment (GME) point of view. The challenges in arriving at the basement configurations specially where conventional data acquisition encounters its inherent limitations due to surface, near surface and/or subsurface complexities, objective oriented potential field data acquired with due accuracy have always been of an essential exploration input. In areas like Mizoram Blockwhere the terrain does not permit the recording of conventional 2D seismic data acquisition with regular geometry (instead crooked line geometry has been adopted), the deep seated basement depths estimation through other geoscientific techniques could be the only choice for drawing a dependable geological model to predict the GME of hydrocarbon in the area & the subsequent development strategy to probe the prospects by designing & planning a suitable development strategy including planning of cost intensive exploratory drilling.

The Euler Deconvolution technique applied on four selected Profiles in the present study, using Gravity and

Magnetic data has not only been successful in deciphering the deep seated basement depth & its configuration but could also be of great use in validating the geological models conceived from other geoscientific studies. The conclusion drawn from this study in regard to depth, basin dip etc. matches well with the prevailing concept on tectonics of the area that postulates the active subsidence of the Surma basin in eastern boundary of the India Plate along the western extension of the convexwestward Indo-Burmese Plate, which is towards further East of the Block. Further application of the Euler Deconvolution procedures on gridded map could also be of immense use in validating the inferences drawn as above.

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