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Joint gravity, magnetic and crooked line seismic data interpretation to delineate the exploratory drilling locations in the Mizoram thrust belt area

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Summary

Hydrocarbon exploration in Mizoram, north eastern part of India is an exigent task for the geoscientists where the area of study covers with thrusted and faulted complex severs geological setting with extremely difficult hilly terrain. Due to abrupt complex terrain variation, normal 2D and 3D seismic surveys are not achievable and hence crooked line seismic survey work carried out. The depth range of sedimentation is more than 10 km and only seismic method is inadequate to demarcate the basinal structure. In that case for releasing the appropriate drilling locations, seismic interpretation complemented with gravity and magnetic interpretation to delineate the basement structure, identification and correlation of localized dominant faults, valleys and sedimentary structures for better exploration and exploitation. An integrated interpretation has been carried out by selecting the three common profiles viz; seismic, gravity and magnetic simultaneously to demarcate highs for the drilling locations. Euler deconvolution technique has been used for the estimation of automatic source depth locations along these three gravity and magnetic profiles. The results can be utilized for the integration and to reduce the exploration risk for precise perceptive of the basinal and basement structures and to improve the confidence level for proposing the drilling locations.

Keywords: *Integrated Interpretation, Thrust Belt Area*

Introduction

The study area is located in between Mizoram fold thrust belt between Bangladesh and Myanmar. The area has 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. from to the north boundary of the study area. The hill ranges reach a height of around 1800 m in Mizoram, however, most of these vary in between 900 m -1300 m; hillocks of very steep slopes ranging between 60 - 80 degrees and intervening deep gorges in the study area. The study area is shown in **Figure 1a** and the general surface topographies are shown in **Figure 1b** and **Figure 1c.** The basement depth study is still not clear as sedimentary layers are covered with more than 10 km. Hence, no clear findings of basement depth through seismic studies and only

Figure 1: Location map of the study area (a) and general surface topography of the study area in Mizoram state, India (b) and Geological setting of the Block(c).

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provides sedimentary information. During the past, the area was highly thrusted and faulted due to the tectonic movement and which caused upliftment of subsurface and undulation of basement depth. As basement depth study plays an important role for petroleum exploration and hence joint gravity and magnetic studies are carried out with seismic data for integrated interpretation. The area of study is surrounded by Tripura, Cachar, Chittagong and Mizoram hill region with western extension of the convex-westward Indo-Burmese fold-thrust (Assam-Arakan) belt. The folded belt of Mizoram is a part of Assam-Arakan Geosyncline which can be divided into a frontal sub-belt consisting of narrow box like anticline separated by wide flat syncline of Tripura and South Assam and inner mobile belt consisting of tight linear folds of Mizoram and West Manipur. The fold seems lighter towards the east and looks gradually wane out towards Bangladesh in the west. The Indo-Burman orogenic belt defines the transpressional collision boundary between the Indian plate to the western part and the Burmese microplate of Eurasia to the eastern part. However, the central Mizoram hills consist of a numeral NW-SE oriented oblique shear, fault, and/or fracture systems which cut across and or merge with the dominant north-south structural systems. There are two most significant important oblique fault systems which are Thenzawl and Pangzawl faults inside the block and while the Lunglei fault is in its southern part of the block. In the eastern part, Champhai plateau as a structural zone significantly greater tectonic upliftment rather than the central Mizoram hills and orienting N-S direction. The geological and the tectonic map of the study area, the oil and gas bearing surrounding zones and the general stratigraphy of the Mizoram area are shown in **Figure 2a, 2b and 2c** respectively.

Data acquisition in the study area

The seismic data acquisition work has been carried out using Aram-Aries equipment with group interval of 12.5 m and source interval of 50 m. Due to logistical constraints and difficulty for carrying conventional seismic data acquisition, crooked lines seismic data acquisition work has been adapted. 2500 gravity and magnetic observations at a spacing interval of 0.5 km to 1 km has been carried out. However, due to logistically very difficult area, attempt has been made to acquire data as per the availability and the accessibility through roads, nallas, foot tracks etc. Lacoste and Romberg Gravimeter with an accuracy of 0.01 mGal (LRG-Model-G) has been used for gravity data acquisition and Scintrex Magnetometer (SM) with an accuracy of 0.01 nTesla has been used for magnetic data acquisition. The general topography, complete Bouguer anomaly map and the total magnetic anomaly map of the Mizoram study area are shown in **Figure 3a, 3b and 3c** respectively.

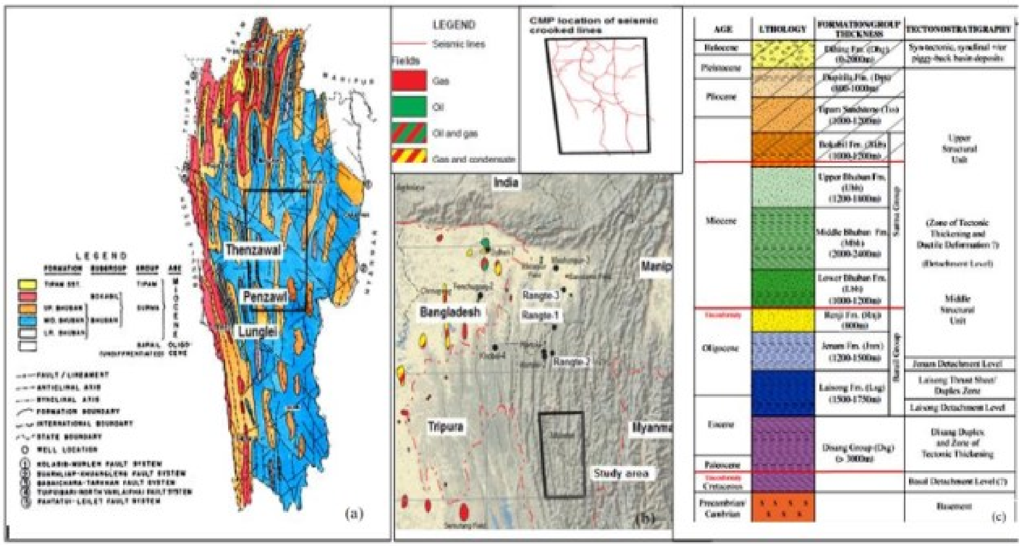

Figure 2. (a) Geological setting and tectonic map of the study area in Mizoram , (b) Oil and Gas bearing zones surrounding the study area and (c) General Stratigraphy.

Methodology for gravity and magnetic interpretation

Conventional Euler deconvolution technique has been applied on gravity and magnetic data for direct detection of basement depth. The rate of field changes with distance for estimating source location and depth of the causative bodies either using profile or gridded dataset using the Euler's Homogeneity equation as states in equation (1)

$$\left(x-x_0\right)\frac{dF}{dx}+\left(y-y_0\right)\frac{dF}{dy}+\left(z-z_0\right)\frac{dF}{dz}=N\left(B-F\right) \quad (1)$$

Where x_0, y_0 and z_0 are the source locations, F is the Magnetic field measured at x, y, z locations; B is the Regional value of the total field and 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) and higher structural index for quadrupole bodies and the irregular bodies **(Thompson, 1982; Reid et. al, 1990; Reid et. al., 2003, Stavrev, 1997)**. For profile data (as used in the instant case where y=0) each calculation has been run for different window length and SI to obtain the solution for different source locations & depths.

Integrated seismic, gravity and magnetic interpretation

An integrated approach has been used for the appropriate drilling location using seismic, gravity and magnetic and other geo-scientific data. The elevation coverage of the survey area suggests a group of anticlines and synclines structures orientated in N-S direction where the eastern part looks higher elevations compared to the western part **(Figure 3a).** The gravity anomaly map (**Figure-3b**) shows undulation causing causative source depth variation where smooth gravity shows deeper depth variation. The eastern part looks lower gravity causing deeper basement depth compared to the western part as per isostatic adjustment. In general, the gravity anomaly patterns follow N-S orientation throughout the study area which is similar trend like elevation data (**Figure 3a**). However, from the total magnetic anomaly map **(Figure 3c),** the anomaly pattern does not orient in N-S direction and does not follow a homogeneous pattern rather show scattered pattern.

Three seismic lines viz: Line-A, Line-B and Line-C along with gravity-magnetic data are jointly interpreted. Through seismic section sedimentary subsurface like Bhuban, Renji and Jenam are identified and from gravity-magnetic data basement depths are identified. Based on these correlations, several leads and drilling locations are identified.

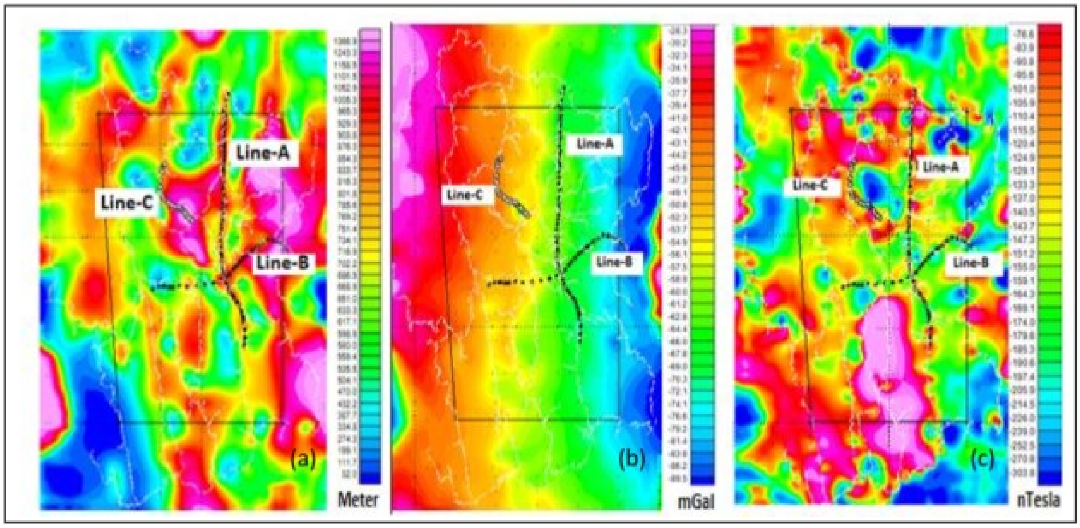

Figure 3. (a) Elevation map, (b) Bouguer gravity anomaly, (c) total magnetic field, of the study area. Three seismic crooked lines viz. Line-A, Line-B and Line-C and the CMP locations are also indicated.

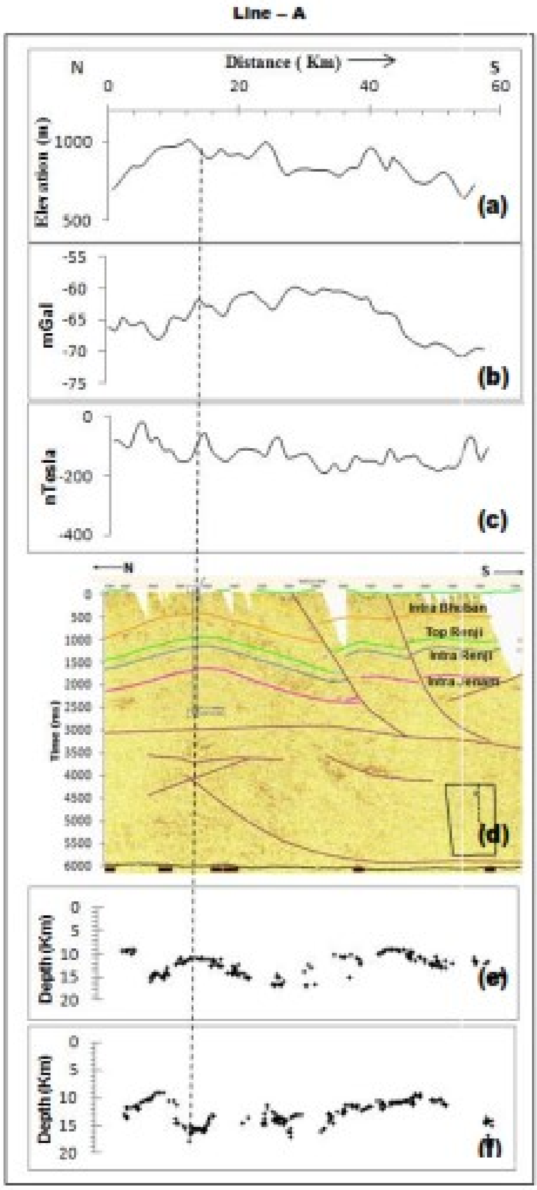

Figure 4. (a) Elevation, (b) gravity anomaly, (c) magnetic anomaly, (d) interpreted seismic section of Line-A, (e) depth from gravity data and (f) depth through magnetic data.

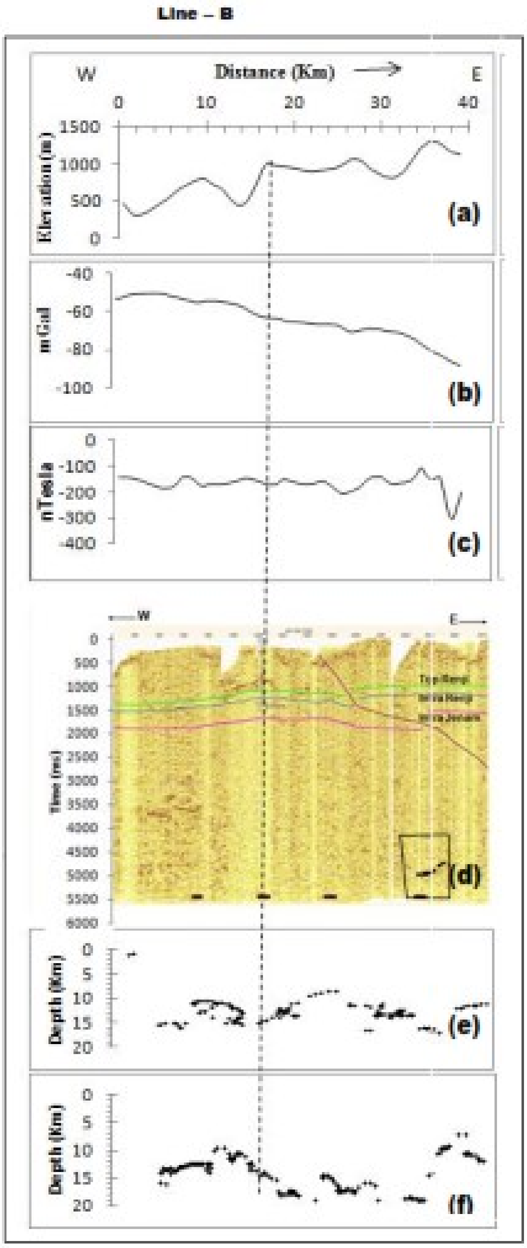

Figure 5. (a) Elevation, (b) gravity anomaly, (c) magnetic anomaly, (d) interpreted seismic section of Line-B, (e) depth from gravity data and (f) depth through magnetic data.

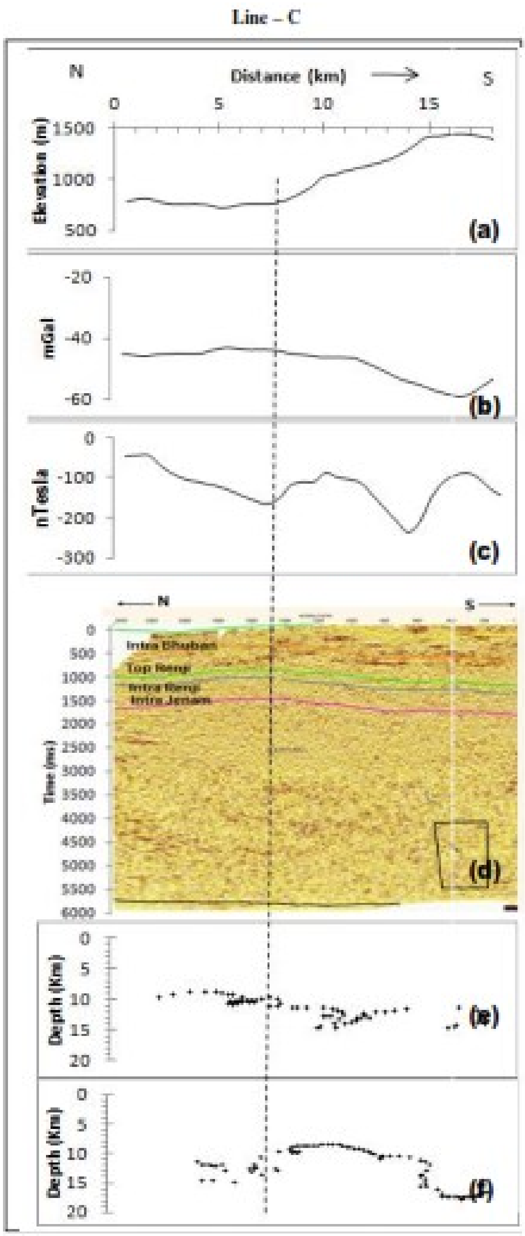

Figure 6. (a) Elevation profile, (b) gravity anomaly, (c) magnetic anomaly, (d) interpreted seismic section of Line-C, (e) depth from gravity data and (f) depth through magnetic data.

Line-A suggests that the elevation profile **(Figure-4a)** is undulating surface varying from 600 m to 1000 m. The same gravity-magnetic profiles are shown in **Figure 4b** and **Figure 4c** respectively. The variation of gravity field varies from -60 mGal to -70 mGal and magnetic field varied from -10 nTesla to –200 nTesla. The interpreted seismic sections shows different sedimentary formations like Bhuban, Renji and Jenam are shown in **Figure-4d**. Basement depth estimation using Euler deconvolution technique from gravity data and magnetic data are shown in **Figure-4e** and **Figure-4f** respectively. The basement depth estimated from both the gravity and magnetic data show in average 12 km. Through seismic dataset **(Figure 4d),** the clear high anticlinal features are identified within the Bhuban, Renji and Jenam formations. The basement depth also shows undulation as per gravity – magnetic studies. It can be inferred that the variation of subsurface in this area may be caused due to the basement undulation / tectonic disturbances took place during past. The proposed drilling location along the seismic line-A as marked in dotted vertical line passing through an anticline in seismic data (**Figure 4d**) and gravity data **(Figure 4e**) which looks logically justified, however the basement may be fractured, thrusted and faulted. Hence, the depth estimation does not show clearly anticlinal feature in magnetic data, however in gravity data, there is no much variation found.

Similarly, the elevation along the seismic Line-B is shown as anticline with undulating topography varying from 500 m to 1400 m (**Figure 5a**). The gravity anomaly varied from -50 mGal to -90 mGal (**Figure 5b**), magnetic anomaly varied from -150 nTesla to -300 nTesla (**Figure 5c),** interpreted seismic section (**Figure 5d**), the depth estimated through gravity and magnetic data are shown in **Figure 5e** and **Figure 5f** have been jointly analyzed. The depth estimated through gravity-magnetic data using Euler deconvolution technique is in average 12 km in both the cases. The drilling location is identified by seeing the high anomalous zone in seismic which is reflected in all the formation like Bhuban, Renji and Jenam. However, from magnetic depth section, location marked looks more logical and justified compared to the gravity anomaly and depth section.

Similarly for drilling location along the seismic Line-C has been carried out. The elevation plot looks trough / valleys and undulating topography varying from 600m to 1400 m (**Figure 6a**), gravity anomaly variation from -42 mGal to -58 mGal (**Figure 6b),** magnetic anomaly variation from -50.0 nTesla to -250 nTesla (**Figure 6c**), seismic interpreted section (**Figure 6d**), depth estimation through gravity data (**Figure 6e**) and average depth evaluation through magnetic data (**Figure 6f**) have been estimated as 12 km. The drilling location has been identified and proposed along the dotted line which is passing through high anomalous zone and intersecting Bhuban, Renji and Jenam formations and correlating gravity and magnetic data.

Discussion and conclusion

An integrated approach using gravity, magnetic and seismic data have been considered to optimize the probable drilling locations in such kind of geologically complex area where elevation varies from 300 m to 1800 m. Basement depth study has been carried out jointly by gravity-magnetic data using Euler deconvolution technique and the results are corroborated with the seismic data with other geo-scientific data for integrated approach. The sedimentary layers marked in the seismic lines suggested that the drilling locations are identified within a high anomalous location passing through the different formation viz. Bhuban, Renji and Jenam. As the area is highly thrusted and faulted due to the tectonic disturbances, the upper subsurface formations are affected due to the upliftment/undulation of basement depth. Hence exploratory locations are identified in both highs in sediments as well as basement upliftment. It can be inferred that, such kind of highly thrusted, faulted and undulated area an integrated approach through seismic, gravity and magnetic studies make more confidence and more logical envisage with reducing the exploration risk for better prospect identification and proposing the drilling locations with proper justifications for hydrocarbon exploration and exploitation.

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