Paper ID: 2012171

Hydrocarbon Exploration in Mizoram: Challenges in a complex Geological Environment

Dilip K Mukhopadhyay[1], Ajoya Nanda Borthakur[2]

1. Department of Earth Sciences, Indian Institute of Technology, Roorkee 247667, India
2. NEF Project, Oil India Limited, Duliajan-786602, Assam (India)

Presenting author, E-mail: ajoya2@gmail.com

Abstract:

Mizoram is part of the geological province defined by Cachar-Tripura-Chittagong fold belt, which formed as a result of India-Burma collision and subsequent shortening. Although this fold belt is known to be a hydrocarbon province for more than a hundred years, the exploration in Mizoram has started with due earnest only in recent years. As Mizoram lacks natural resources and industrial base, its hydrocarbon potential should be fully explored for socio-economic reasons. The digital elevation data analyzed on GIS platform clearly shows that the fold belt in NE India is characterized by a series of anticlines and synclines with axial traces trending for tens of km in N-S direction. The intervening distance between two adjacent anticlines increases westward into Bangladesh. This, together with application of Elliot's bow-and-arrow rule, suggests tectonic transport direction from east to west. Petroleum exploration in the Mizoram exploration block operated by Oil India Ltd. faces a number of serious challenges. (1) Detailed geological mapping is difficult because of lack of outcrop and heavy forest cover. (2) Acquiring and processing (migration and depth conversion) seismic data are a challenge in this area with highly rugged topography necessitating crooked survey lines and with steep formational dips. (3) More than 1300 GLKM of 2-D seismic survey has been carried out within the exploration block but the processed seismic images are usually fuzzy. Consequently, definitive structural interpretation and identification of suitable drilling locations based on seismic reflection surveys become uncertain. We adopt section balancing technique using kinematically valid fold-fault geometric models in order to search for appropriate exploration strategy. The structural data collected during fieldwork has been used for structural modelling with seismic data as additional constraint where appropriate. Incomplete data set available for the Mizoram block does not allow derivation of any robust structural model but leads to multiple kinematically valid structural models. A series of E-W balanced cross sections have been constructed and allow us to model 3-D structural geometry. Initial drilling locations have been identified keeping in mind all the valid structural models.

Introduction:

Mizoram is part of the Assam – Arakan fold-thrust belt (FTB) in which large volumes of hydrocarbons have been discovered. Within the exploration block in Mizoram operated by Oil India Ltd., several parallel anticlinal traces have been mapped. Outcrop and regional correlations suggests that abundant reservoir units should be available. Geochemical data and hydrocarbon gas seeps suggest that a source rock or source rocks may be present, where hydrocarbons have been generated and therefore an active hydrocarbon system may be present. All of this information suggests that the Mizoram block area is highly prospective for carrying out hydrocarbon exploration. Further, the geo-tectonic positioning of Assam-Arakan Basin makes this area attractive for hydrocarbon exploration. Assam-Arakan basin exists in the intervening area of two collision zones, *viz*., the E-W India Eurasia collision zone to the north and N-S India-West Burma collision zone to the East. Therefore, tectonic activities/ elements are supposed to play in sedimentation and deformation as well as hydrocarbon generation, migration and entrapment. Though the area is very significant in respect of regional tectonic evolution and its set-up in relation to the development of the eastern margin of the Indian plate, no comprehensive work has so far been carried out to unravel the evolutionary process and history of this fold belt (Nandy *et al*., 1983)

The results of the collision between the Indian plate and the Burma plate are clearly visible on satellite images or topographic maps. The resultant structure is a series of curvilinear anticlines extending in N-S direction and separated by broad synclines that decrease in width toward the east. A major strike slip fault, the Thenzawl fault, crosses the regional anticlinal trends at the centre of the Mizoram block. The width of the synclines decreases and the complexity of the anticlines increases at a major boundary created by the Kaladan Fault system. A curious feature of the anticlinal trends in the region of the Mizoram block is that they increase in complexity and the interlimb angles of anticlines become more acute toward the Kaladan fault to the west (Fig. 1).

As with the Naga thrust system, the anticlinal trains are not the result of a single continuous thrust fault, but rather a series of overlapping sub parallel system of discontinuous thrust faults. Each thrust fault in the system produces a fold described by its length and displacement. Thus, the fold trains have multiple apexes or domes along their trends. The folds east of the Kaladan fault are hybrid folds developed by detachment folding that evolves into fault propagation folds (Sikder and Alam, 2003). Their interpretation shows that these folds originate from a detachment surface below which there is little deformation.

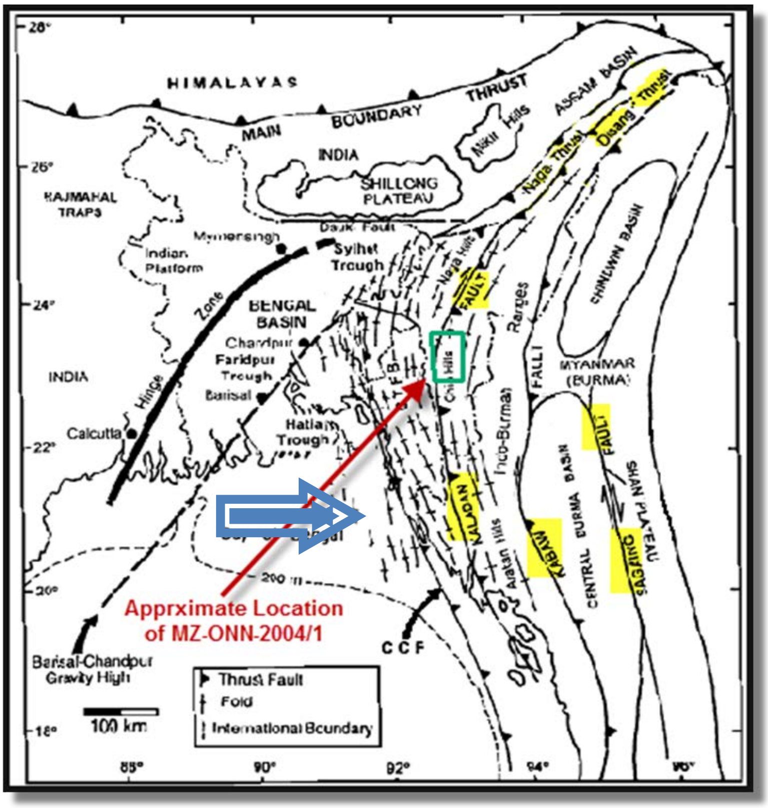

Figure 1: The map iillustrates the region's major tectonic elements. The Sagaing, Kabaw, and Kaladan/Disang faults are major structural and stratigraphic boundaries. The Chittagong – Cox's Bazar fault (CCF) may be a developing boundary eventually to belong to this set. Blue arrow is the approximate location of Sitakund Anticline. (Adapted from Alam et al., 2003).

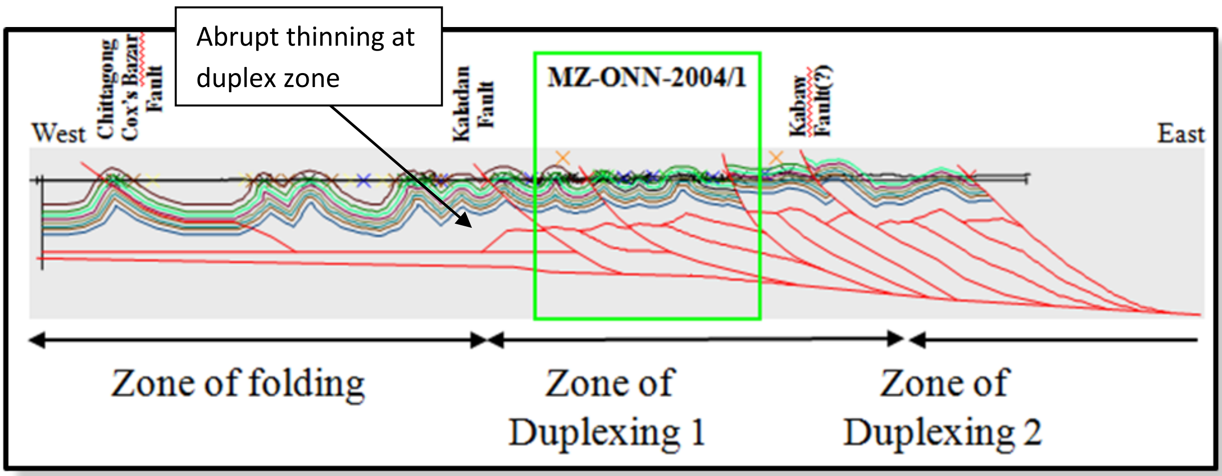

Figure 2: Regional cross-section by Mishra (2005) offers a simplified representation of the regional structure from the Bay of Bengal to Myanmar.

The Kaladan Fault system occurs near the western boundary of the Mizoram block. This fault system in association with the Disang Fault system to the north marks a major boundary within the Assam – Arakan Fold and Thrust Belt. Gani and Alam (2003) interpret this fault system as a deep-rooted thrust fault separating two accretionary wedges, formed during the filling of a remnant ocean basin. In this interpretation, the area of the Mizoram block lies in the region of a Cretaceous to Paleogene accretion complex while that Chittagong – Tripura Fold Belt originates in a Neogene accretionary wedge to the east. An observable change at the Kaladan Fault is that the surface folds become more complex with nearly vertical limbs. Although the seismic quality is not up to the desired quality in the Mizoram block, the data shows structural complexity in the entire time section recorded. A cross section constructed by

Mishra 2006 and slightly modified for this report (Fig. 2), provides a good characterization, if perhaps, slightly simplified, of the regional structure.

Structural Modelling:

In the structurally complex area of Mizoram, the first order control for trap formation as well as burial/exhumation and source rock maturation is expected to be structural evolution and geometry. We use techniques of cross-section balancing for the purpose of structural modelling. Balanced structural cross sections are essentially quantifiable structural modelling based on kinematically valid fault-fold relations. This allows us to devise an exploration strategy, including deciding the first set of drilling locations, with minimum risk. The data source includes geological map and structural data collected in the field, with seismic data as additional constraint. Since no drilling has been done as yet, subsurface lithological data is not available. Formational thicknesses have been derived from regional information available in the literature.

Four anticlines and intervening synclines in the northern part of the Mizoram exploration block have been taken up for initial structural modelling. The anticlines are named as Tuahzawl. Aibwak, Seling and Keifang anticlines (Fig. 3). Stereographic analyses of structural data suggest that the anticlines are fairly tight, sub-horizontal, upright, and sharp-crested, except for Keifang anticline, which is flat-crested. The formational dips are moderate to steep on the limbs of folds. We use the kinematics of decollement folding (Poblet and McClay, 1996), fault-bend folding (Suppe, 1983) and fault-propagation folding (Mitra,1990; Suppe and Mewedeff, 1990) with or without simple shear for the purpose of structural modelling.

The available data set does not allow for a unique structural solution. Several kinematically valid balanced cross sections could be constructed using the same data set (Fig. 3). These include parallel and similar folding above a decollement surface, forward-breaking detachment folding and ramp anticlines, such as fault-bend/fault-propagation folding, with breakthrough structures and with or without simple shear. Multiple valid balanced cross sections with the same data set do not render the technique untenable; rather it helps in better risk assessment of hydrocarbon exploration. Multiple valid structural models suggest that the strategy of drilling at the crest of anticlines except for Keifang anticline is not a sound proposition and deviated drilling from eastern limbs of the anticlines offers minimum risk. Detailed structural modeling of each of the anticlines helps in determining drilling trajectory.

Hydrocarbon Exploration:

Hydrocarbon discovery has already been established as seep liquids or through the drill bit around the Indo-Burmese fold-belt region during the recent past centuries (Fig. 4). Thick sandstone gas pay within Lower Bhuban formation (Lower Miocene) during 2009 in “Khubal Structure” in East Tripura has generated a new impetus to hydrocarbon exploration from Lower Bhuban reservoirs in Eastern Tripura and has helped in establishing Tripura-Cachar region as a part of giant petroleum gas province comprising of Bangladesh-Tripura-Cachar-Mizoram (Shyam *et al.,* 2011). The commerciality of hydrocarbon is yet to be identified within Kaladan-Kabaw Fault Systems except the new discoveries in the Lower Miocene play in Hortoki-1 (in 2012) in the north and of Plio-Pleistocene play in Rakhine Basin (during 2003-06) to the extreme southeast of Bay of Bengal. A huge pile of sedimentation was accumulated since early Miocene age in Tripura-Cachar-Mizoram fold-belt and sediment supply was probably from the north eastern and western fringe of Indian and Burmese plate systems respectively. Due to tectonic loading, sediment thickness probably becomes high from west to east of Kaladan fault system.

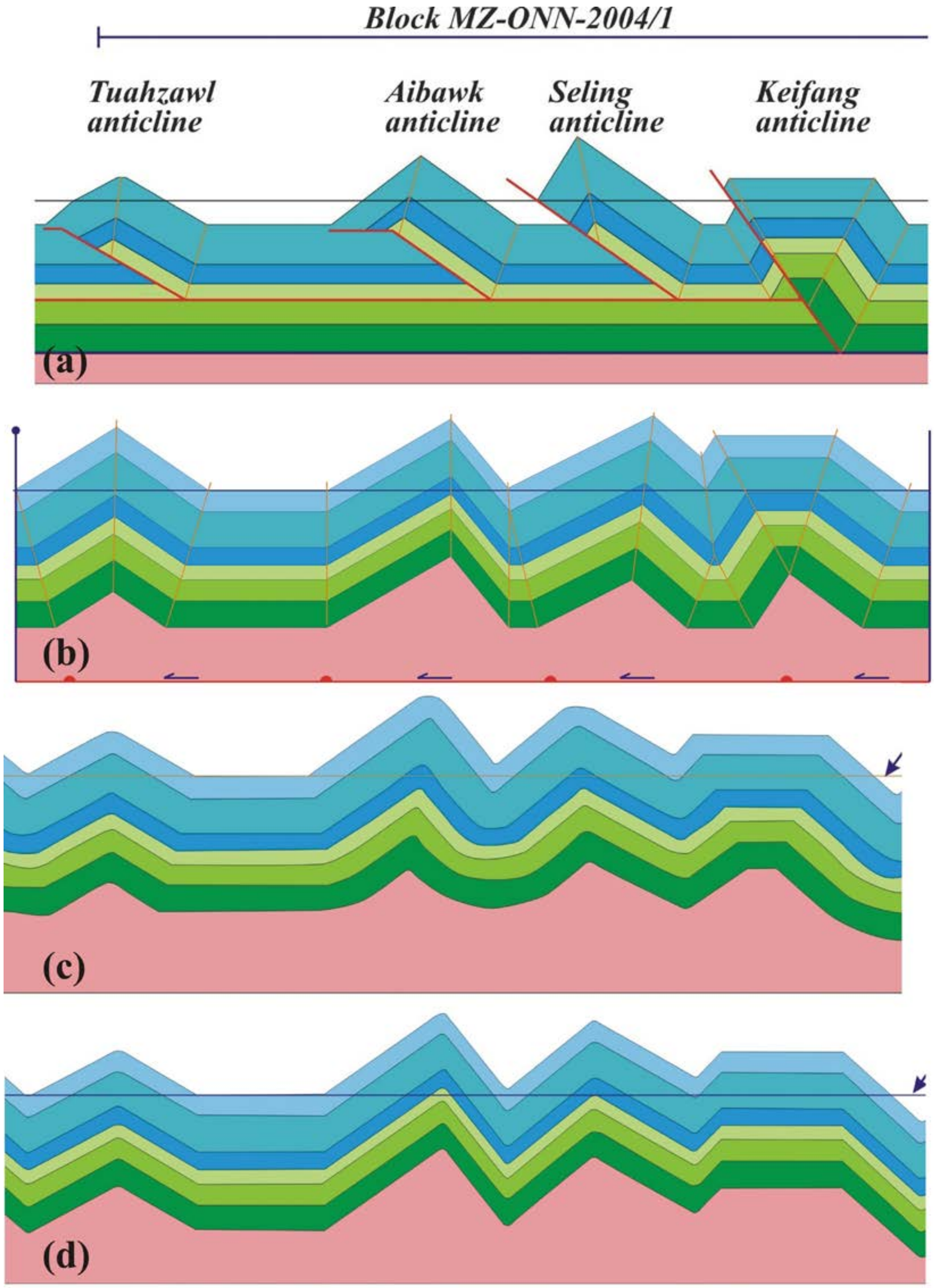

Figure 3. Examples of kinematically valid balanced structural interpretations for the four anticlines present in the northern part of the exploration block. (a) Models: fault-bending folding, fault-propagation folding and flexural flow with or without shear. (b) Models: detachment folding model, the folds developed on Disang Group rocks which acted as a ductile layer. (c) Models: parallel folding model with. (d) Models: similar folding model with minimum thickness.

Source rock potential in the land-plant–dominated organic-rich arenaceous/ argillaceous shales and siltstones of the middle and lower Miocene (Bhuban formation) is leading to the gas window. However, monotonous sequence of splintery shales from Cretaceous to Middle Eocene (thick lower to upper Disang Shale) could be suitable as source rock along with Mid-Oligocene (Intercalated shales of Jenam Formation) predominantly argillaceous sequence of shales consisting siltstones, mudstones and carbonaceous shale (Ranga Rao, 1983) (Table-1). Primarily, vertical migration is more relevant through fault and fracture systems associated with the fold-belt. These fault systems have been periodically reactivated through the present. Short up-dip migration along the flanks of the basin is also likely (Wandrey *et al.,* 2006). Trap and Seal is already proven along the fold-belt area. But, the geological age of fault systems and impact on depositional history of proven petroleferious horizon along this thrust belt area could be a vital part from hydrocarbon entrapment mechanism. The pace of exploration is slower along this fold-belt patch compared to surroundings, probably because of difficult logistics and geological challenges. The recent exploration results/findings in this fold-belt by exploration companies are highly encouraging equally from the possibility of giant discovery and for the prioritization of future exploration acreages along this least explored area.

Formation	Thickness (m)	TOC (%)	VR_O(%)	Kerogene Type
Up. Disang Gp.	>3000-2000	0.69-4.0	0.9-1.94	II & III
Jenam	1500-1200	2.5-4.5	0.64-1.2	II & III
Bhuban	>2400-1000	0.2-1.5 (U) 1.76 (L)	0.9-1.0	No Data
Bokabil	1200-1000	0.2-1.5	No Data	No Data

Table 1. Source Rock Data Compilation (after Rao, 2011; Curiale *et al.*, 2002; Schelling, 2009)

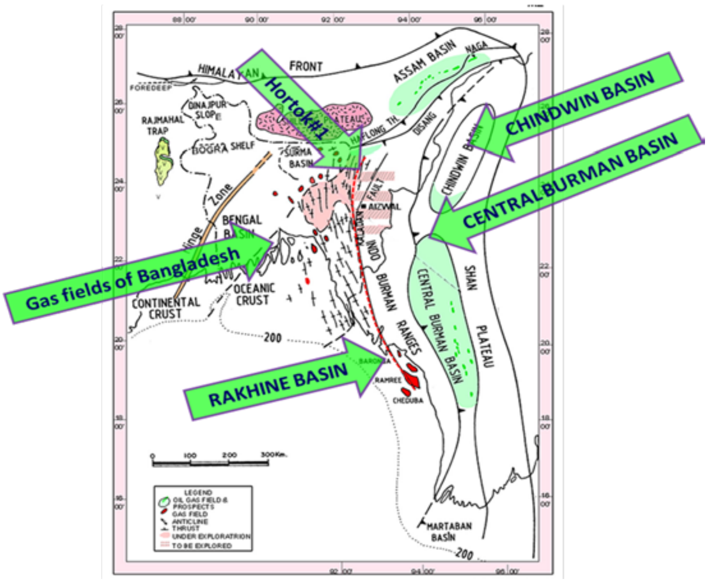

Figure 4: Regional Hydrocarbon Producing áreas, NE India (modified after Curiale *et. al.*, 2002)

Conclusion:

Hydrocarbon exploration in Mizoram is difficult due to lack of quality surface and subsurface geological information including seismic data. This is primarily owing to the fact that this is an area with very complex structural geometry and rugged terrain with heavy forest cover. In such a geologically challanging area with incomplete data set, cross section balancing based on kinematically valid fault-fold models is possibly the only approach that can be undertaken at the initial stage of hydrocarbon exploration.

References:

Alam et al., 2003
Gani and Alam (2003)
Curiale et. al. (2002) AAPG Bulletin, 86:625–652.
Mishra (2005)
Mitra, S. (1990) Fault-propagation folds: geometry, kinematic evolution, and hydrocarbon traps. AAPG Bull., 74:921-945.
Nandy et al., 1983
Poblet, J. and McClay, K. (1996) Geometry and kinematics of single-layer detachment folds. AAPG Bulletin, 80:1085-1109.
Ranga Rao (1983)
Rao, V. K. (2011) Potential Shale Gas Basins of India: Possibilities & Evaluation. IUGF,
Schelling, D. (2009)
Shyam et al., 2011
Sikder and Alam, 2003
Suppe, J. (1983) Geometry and kinematics of fault-bend folding. Am. J. Sci., 283:684-721.
Suppe, J. and Mewedeff, A. (1990) Geometry and kinematics of fault-propagation folding. Eclogae Geol. Helv., 83:409-454.
Wandrey et al., 2006