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Structural Evolution vis-a-vis Resultant Trap Geometries and Hydrocarbon Prospectivity Analysis using Structural Modelling Techniques- A Case Study on Cachar-Tripura-Mizoram Fold Belt.

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Abstract

The structural evolution of the Tripura-Cachar-Mizoram Fold Belt has been attempted by integrating data collated from various sources and utilizing the data integration and model building capabilities of the latest version of the Move 2013.1 software. The studies indicate a main deformational and structure forming episode of < 2 m.y, represented by an unconformity at the end of Pliocene. Detachment folding appears to be the predominant mechanism of fold formation in the Tripura area, combined detachment and fault related folding mechanism prevalent to be in Mizoram area and fault propagation fold in Cachar area. Saddles between plunging anticlines, areas where anticlinal axes abut against synclinal axes and sub-thrust areas between opposite hading thrusts could be prospective and target for exploration.

Introduction

The study area is located between latitudes 23^0N to 25^0N and longitudes 91^0E to 93^0E in the north–eastern part of India and lies within Tripura–Cachar-Mizoram fold belt. It forms a major part of the accretionary Outer Indo-Burmese Wedge (OIBW) between Kaladan Fault in the east and the inferred incipient Chittagong Coastal Fault (CCF) in the west (Sikdar and Alam, 2003). The structural evolution of the Tripura-Cachar-Mizoram Frontal Fold Belt has always remained enigmatic, primarily due to lack of data and inaccessibility of the terrain. This is rendered even more complicated by rugged topography, inhospitable environment and lack of field, seismic and well data. Poor seismic resolution in the cores of anticlines where seismic data does exist exacerbates interpretation problems. The lack of 3D depth domain data presents serious difficulties in the interpretation of strike and oblique slip movements in the area and in inferring the disposition of the regional detachment. Despite these issues an attempt has been made in this study to model the structure and tectonics of area by integrating all available geological, geophysical, seismic, well data, published literature and prevailing concepts in the state of the art Move 2013.1 software.DEM data obtained from the USGS, field geological data and maps of various vintages, remote sensing data, well data and depth converted seismic data were utilized to this effect. Prospectivity analysis has also been carried out from structural modeling results as well as understanding on regional structure and tectonics of the area.

Geologic and Tectonic Setting

The geology of Assam Arakan and Bangladesh began more than 250 Ma ago when the Pangean supercontinent broke apart. About 127 million years ago, the Bengal Basin was initiated when the Indian plate rifted away from Antarctica at the rapid rate of 18 cm/year.

Towards the east, oceanic-continental collision, subduction and compression gave rise to the Arakan-Yoma fold belt in Myanmar and Eastern India. This includes the present study area of Tripura-Cachar-Mizoram fold belt. The folding of the earth's crust in response to the eastward directed subduction of the oceanic crust beneath the Burmese micro plate and the scraping off of sediments are responsible for the growth of a series of sigmoidal, broadly north-south trending structures in Tripura-Cachar and the Chittagong Hill Tracts in the eastern part of Bangladesh, Maurinet.al. (2009).

Data Sets and Methods

Dip data analysis was carried out on Stereo net to find out the optimum tectonic transport direction, which was required to create structural cross sections for balancing and restoration. Stereonet plots indicated a dominantly E-W to 100^0-280^0 regional tectonic transport direction. Relevant field geological maps and sections of Tripura- Cachar- Mizoram area of ONGC field parties were collected, scanned, georeferenced and loaded in Move (*Fig.1*). Georeferencing was done using ArcMap 10 GIS software in UTM projection system in Zone 46 taking WGS 1984 as datum. Digitized maps were also loaded in Move for the study. Five profiles starting from South Tripura-Mizoram to Cachar were identified for constructing structurally valid and viable sections (Fig.1). SRTM data of north east India was downloaded from website http://dds.cr.usgs.gov/srtm/version/eurasia in .hgt format. The .hgt files were loaded on to the Move platform and a composite Digital Elevation Model (DEM) replicating the topography of the area at 70m resolution was generated for the area under study. The geological map of the area was overlain on the DEM in order to obtain a 3D perspective and to generate the topographic profile along the identified profiles. Depth converted seismic line where available then imported in 2D Move and available well data and out crop data was also used for constructing the balanced section. Forward modelling techniques were employed in areas devoid of surface dips and subsurface (well and seismic) data.The balanced sections were restored by starting with restoring the faults by *Move on Fault* algorithm at Tipam level to remove the post folding displacement. Afterwards, individual anticlines were restored by Flexural slip and Trishear algorithm to understand the timing and amount of deformation (Fig.2).

Restoration Results

The five profiles were constructed by maintaining spacing between the lines to highlight major differences in terms of shortening, erosion and structural styles from South Tripura to Cachar and from Mizoram to Tripura.All the anticlines were individually restored at each profile. Dupitila Formation is considered to be synkinematically deposited since late stage folding in growth strata has observed in Dupitila Formation. Basement involved vertical movements along deep seated faults were first restored. All post folding faults at Tipam level were restored by Move on Fault - Fault Parallel Flow technique.It was observed that no structure existed prior to Tipam (Lower Pliocene), which suggests that the main deformation episode was post Tipam (Late Pliocene; < 2 m.y.). After restoration of the profile at Tipam level, the sedimentary formations were decompacted (backstripped) sequentially up to the Disang Formation.

Profile 1:Tichna - Gojalia– Tulamura Anticline

The individual anticlines were integrated with the synclines and a complete balanced present day cross section with erosion reconstructed was prepared (Fig.3).The restoration results shows, the deformation appears to be coeval in all the anticlines in the profile. After restoration of the profile at Tipam level, total shortening was found to be **10.3%** (Fig.4).

Profile 2 : Rokhia-Agartala Dome - Baramura - Atharamura - Sardeng- Langtarai - Bhuachari - Sakhan - Tuipuibari - Pukzing - Lallen - Tuahzawl - Aizawl- Tingshul

A complete balanced present day section with erosion reconstructed was prepared (Fig.5). Before restoration of the profile, Dupitila Formation was decompacted to obtain the paleotopography of Tipam. All post folding faults at Tipam level were restored by Move on Fault - Fault Parallel Flow technique. Tipam Sandstone Formation was restored by Flexural Slip algorithm taking MSL as datum. Total shortening in this profile at Tipam level was found to be **10% (19 km)** (Fig.6).

Profile 3 : Atharamura - Batchia - Harargaj - Khubal - Langai/Jampai - Chatachura - Bhairabi - Rengte - Teidukhan–Bhuban

The restoration results shows, total shortening in this profile at Tipam level was found to be **12.5% (18 km)** (Fig.8). Effect of thick skinned tectonics resulting in shallower detachment and basement depth were observed in Langai and further east in Mizoram in this profile (Fig.7)

Profile 4: Adamtila - Chargola - Chatachura - Rengte - Teidukhan - Tingmun/Bhuban

Total shortening in this profile at Tipam level was found to be **18.5% (15 km)** (Fig.10). Effect of thick skinned tectonics resulting in shallower detachment and basement depth were observed in Rengte and further east in Mizoram in this profile (Fig.9).

Profile 5: Patharia - Chargola - Badarpur/Chandipur - Masimpur - Jiribam - Anticline in Manipur. . Anomalously high shortening has been observed in the Badarpur-Chandipur anticline and has been explained as due to a large strike slip and rotational component in the area. It is noteworthy that the depth to detachment is significantly less in the Badarpur-Chandipur anticline complex resulting in the outcropping of Lower Bhuban. Also, the Lower Bhuban outcrops only in the Badarpur-Chandipur anticline in the main central part of the Tripura-Cachar Fold Belt; elsewhere, it outcrops on in the eastern extremity of the study area in Mizoram. Total shortening in this profile at Tipam level was found to be **17% (18 km)** (Fig.12).Effect of thick skinned tectonics resulting in shallower detachment and basement depth were observed in Masimpur and further east in this profile (Fig.11).

Structural controls on Hydrocarbon Accumulation

The absence of any piggy back basins suggests that the deformation has been coeval; meaning that all the structures in the Tripura-Cachar Frontal Fold Belt must have formed at the same time. Erosion is severe in Mizoram, where it is about 2.5 km-3 km east of the Sakhan Anticline and progressively increases from 2 km in Chatachura Anticline to about 4.5 km further east in Mizoram along Profile-2. A maximum of 4.8 km of erosion was inferred in the Teidukhan Anticline. The sharp increase in erosion to east is attributed to the raised elevation of structures in Mizoram due to thick skinned tectonics, greater compression and strike-slip effects.The Bokabils outcrop on the crests of the anticlines east of Sakhan and it is probable that the regional seal in Middle Bokabil has been extensively eroded in Mizoram.Exploration in Mizoram should, therefore, focus on deeper plays such as the Lower Bhuban and Renji formations. In sharp contrast, anticlines in Tripura are less eroded and less tectonically complicated. Many of them have proven to contain commercial quantities of hydrocarbon (e.g. Adamtila, Agartala Dome, Rokhia etc). The Middle Bokabil seal is generally well preserved and the magnitude of the diffuse strike slip component is low. It is also felt that areas where anticlinal axes abut against synclinal axes due to oblique displacement could be prospective for hydrocarbon exploration (Fig.14). Saddles between plunging anticlines (Fig.16) and smaller structures on rising flanks of synclines adjacent to the main anticlines and sub-thrust areas between opposite hading thrusts could be prospective (Fig.15). A low amplitude reversal has been observed on the western footwall of the Masimpur anticline within the Bhuban Group, which could be of interest for the exploration of hydrocarbons.

Discussion

The Restoration result shows, the main phase of structure formation has been during the major deformational episode at the end of the Pliocene (< 2 m.y.). Therefore, migration of hydrocarbons must have been synchronous with or younger than the orogeny at the end of the Pliocene. The uplift of the Shillong Plateau around 3-4 m.y. ago, with the development of the Sylhet Trough on the southern footwall side of the Dauki Fault, the concomitant deposition of a massive amount of sediments and the westward propagation of the accretionary prism within the Outer Indo-Burmese Wedge resulted in conditions ideal for the development of a Neogene petroleum system in the area. Short distance migration in an already established petroleum province is envisaged (Fig.13).The main source rocks are, in all probability, the shales within the Bhubans, particularly the Middle Bhuban and Bokabil formations.

Conclusion

Depth to regional detachment modelled in the study area is found to be 4.8 km in Renji Formation in the west near Rokhia, deepening to about 9km in Jenam Formation in the easternmost part of the area close to the Aizawl Anticline in Mizoram In addition to this, two shallower level detachments are present in Middle Bhuban and Bokabil in Cachar. A thin skinned deformation model is proposed for both Cachar and Tripura area, but a thick skinned deformation involvement is also invoked in the eastern part,north of Profile-2, in the form of basement related reverse faults resulting in block upliftment. Erosion increases consistently from west to east, from 50m in the western part of Tripura and Cachar to about 4.8 km towards the eastern part of the study area near Kaladan Fault.

References

Maurin,T. and Rangin, C., 2009. Structure and Kinematics of the Indo-Burmese Wedge : Recent and Fast Growth of the Outer Wedge. Tectonics, vol. 28.

Sikder, A. M., and M. M. Alam (2003), 2-D modelling of the anticlinal structures and structural development of the eastern fold belt of the Bengal Basin, Bangladesh, Sediment. Geol., 155, 209 – 226,doi:10.1016/S0037-0738(02)00181-1.

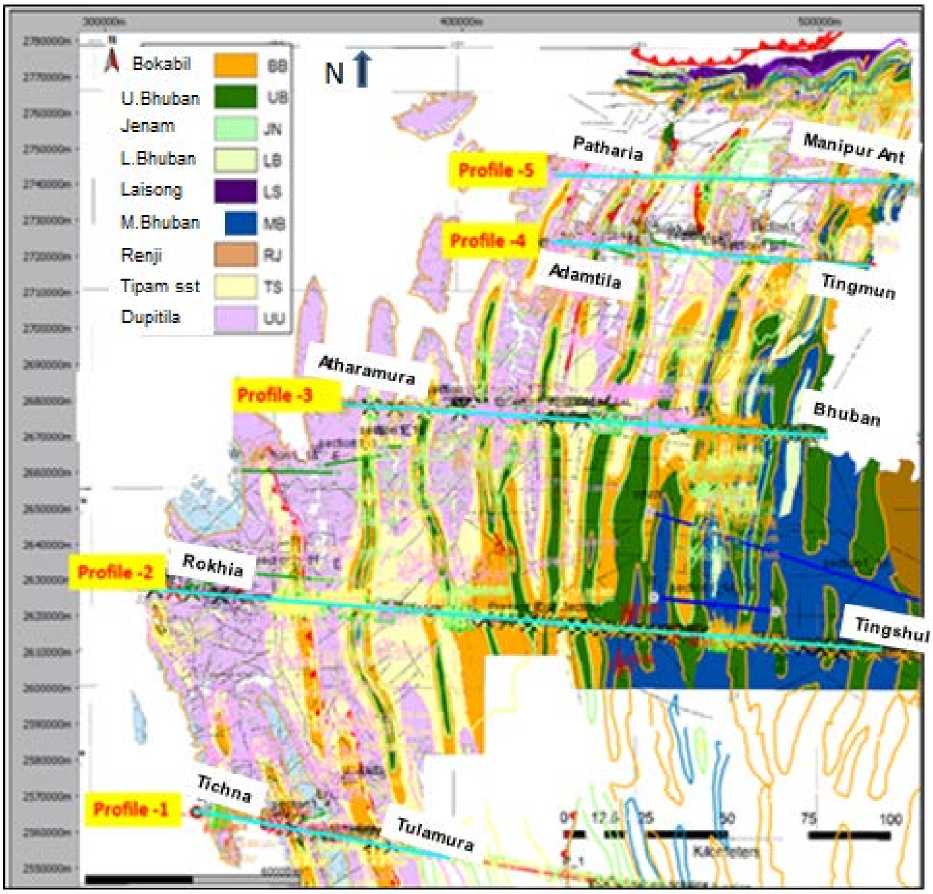

Fig.1: Composite Geological Map of the Area Showing the Five Profiles

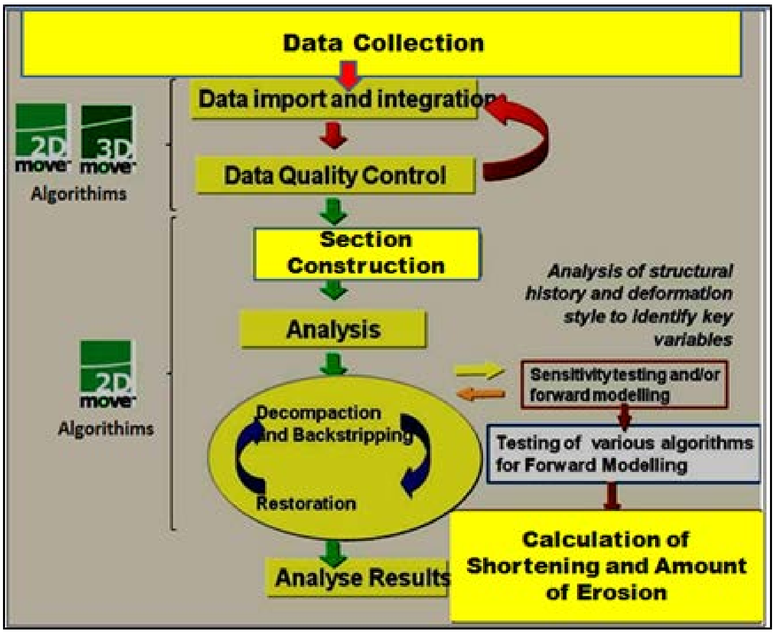

Fig.2. Cross-section restoration procedure in Move Software

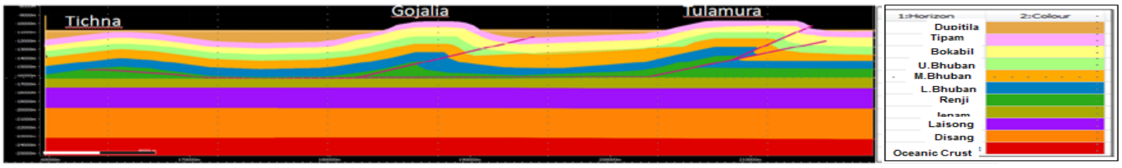

Fig.3: Present Day Section along Profile-1 with Erosion Reconstructed

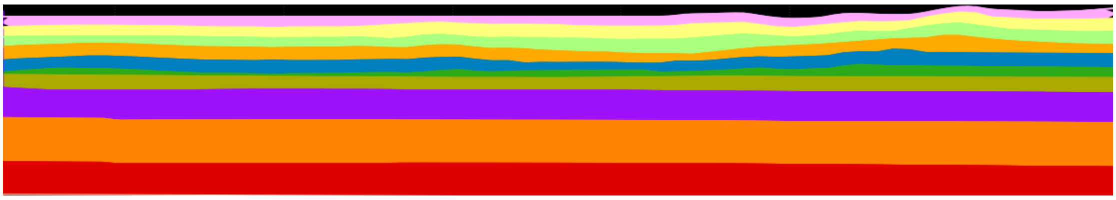

Fig. 4: Sequential Restoration Along Profile - 1 : Anticlines are Restored.

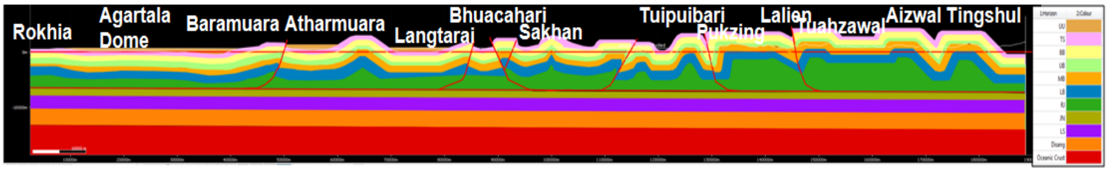

Fig.5: Present Day Section along Profile-2 with Erosion Reconstructed

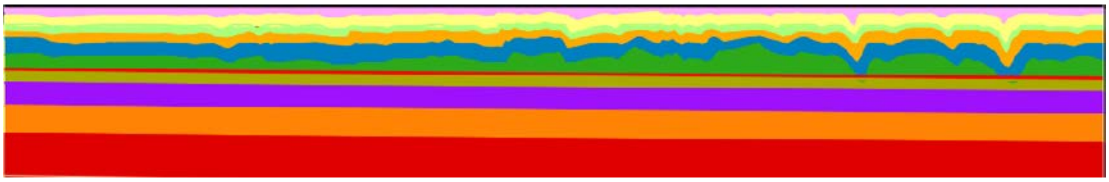

Fig. 6: Sequential Restoration Along Profile - 2 : Anticlines are Restored.

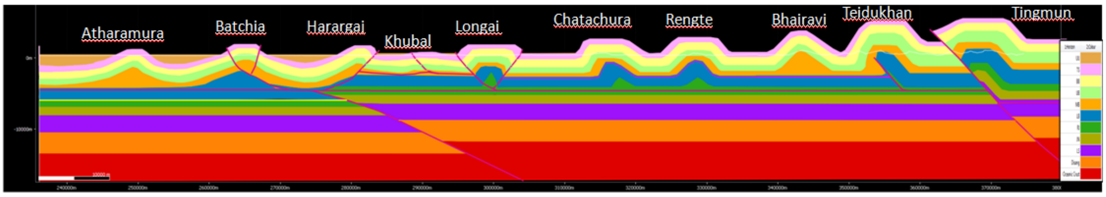

Fig.7: Present Day Section along Profile-3 with Erosion Reconstructed

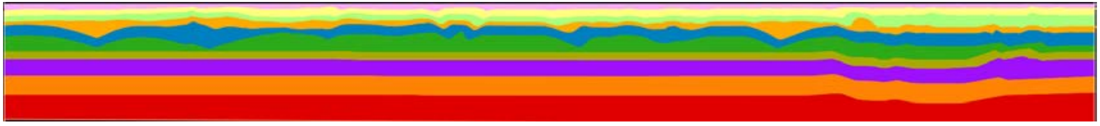

Fig. 8: Sequential Restoration Along Profile - 3 : Anticlines are Restored.

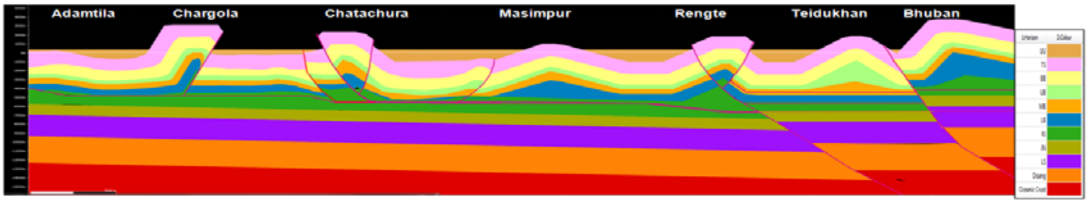

Fig.9: Present Day Section along Profile-4 with Erosion Reconstructed

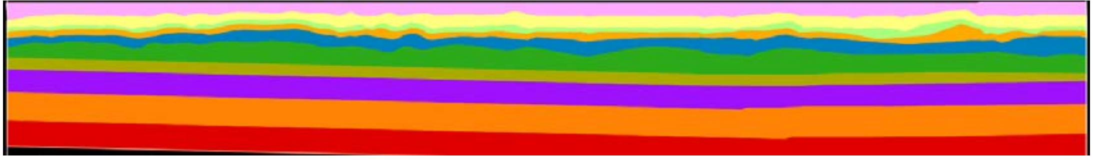

Fig. 10: Sequential Restoration Along Profile - 4 : Anticlines are Restored.

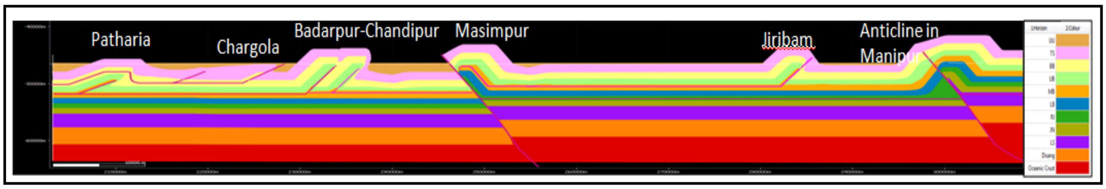

Fig.11: Present Day Section along Profile-5 with Erosion Reconstructed

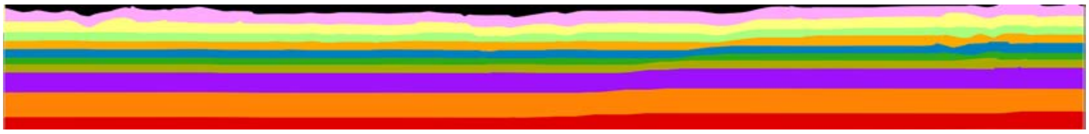

Fig. 12: Sequential Restoration Along Profile - 5 : Anticlines are Restored.

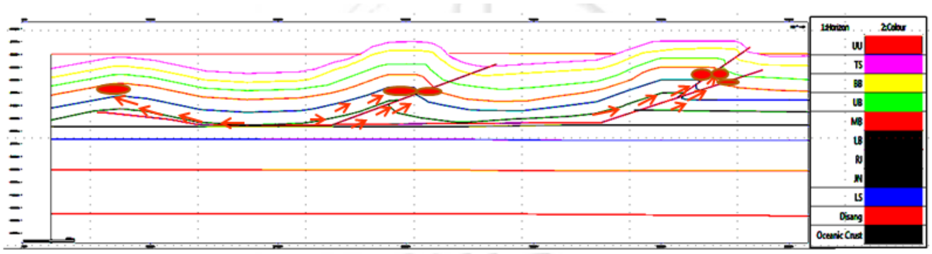

Fig.13: Showing short distance migration and hydrocarbon accumulation

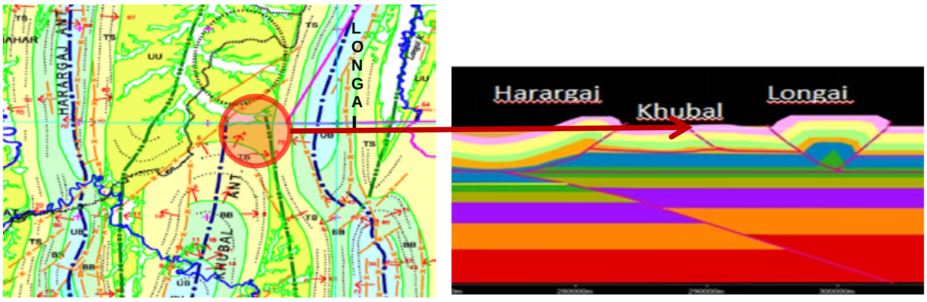

Fig. 14: Showing prospective area where anticlinal axis abut against Syncline

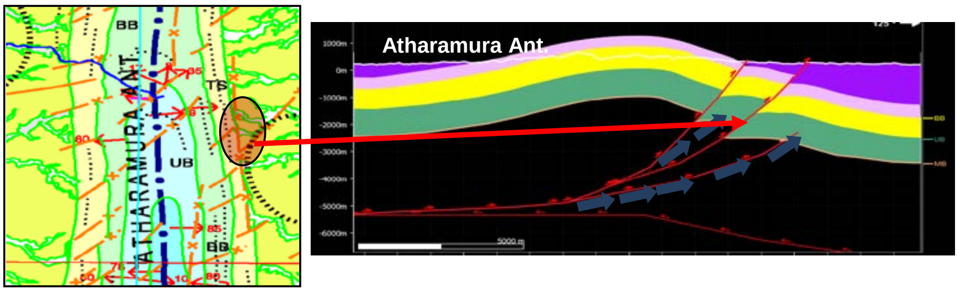

Fig. 15: Showing prospectivity in the subthrust area

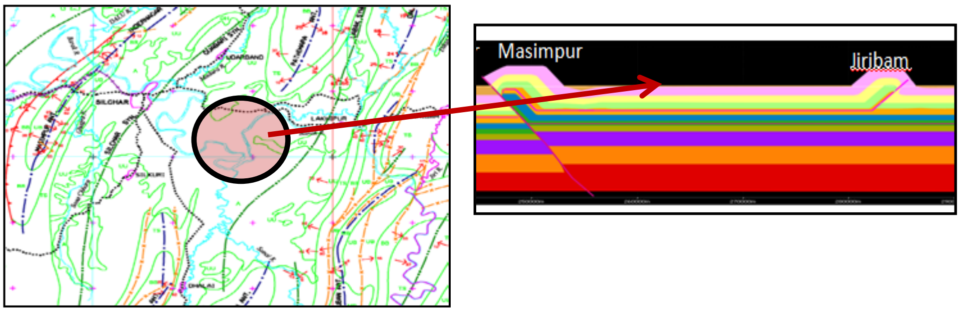

Fig. 16: Showing prospectivity in the saddle between two plunging anticlines