

A Re look into exploration strategy of Lower Bhuban play in Eastern Tripura, India. A Case study

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Abstract: Exploration for hydrocarbons in Western Tripura-Cachar, in India is about 37 years old. However, quest for hydrocarbon in Eastern Tripura began only in 1991. Drilling of few wells mainly over the crest has helped in establishing only hydrocarbon leads within Bhuban reservoirs. Complex geological conditions, prevalent high pressure regime and subjectivity in delineating exploratory targets from seismic data were significant hindrances in initial phase of exploration in Eastern Tripura. In the later years exploration was shifted towards the synclinal part between anticlines marked by geomorphic highs. Recent discovery of sandstone gas pay within Lower Bhuban formation in Agartala Dome in Western Tripura and a thick sandstone gas pay within Lower Bhuban formation 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.

Present paper attempts to develop a conceptual geological model for Lower Bhuban play in East Tripura, demarcate prospective areas for future exploration and delineation of potential reservoir facies. A comprehensive study was under taken, integrating surface geology, 2-D Seismic, drilled well, Petrophysical, Sedimentological, Geochemical and Palaeontological data of Tripura, Cachar & Mizoram to understand sedimentation history, distribution of reservoir facies and hydrocarbon accumulation pattern in the study area.

Different seismic attributes and AVO studies were undertaken to understand the distribution of pay sands around Khubal area. Based on this integrated study, seismo-geological cross sections, structure contour & lithofacies maps were generated. Detailed facies analysis was done to reconstruct suitable geological model. The suggested model is essentially a delta complex. This integrated study has helped in preparing a Tectono-Sedimentological model of Lower Bhuban play; identify lead areas and potential reservoir facies for exploration and delineation of Lower Bhuban reservoirs in Eastern Tripura.

1. Introduction: The Tripura-Cachar region forms a part of folded foredeep sedimentary prism of the Assam Arakan orogenic belt. The area comprises a series of sub parallel, long, narrow doubly plunging anticlines arranged in an echelon fashion (Fig-1). Degree of deformation increases due east with progressively older rocks exposed in the core. The sigmoidal shaped Assam-Arakan mountain belt belonging to the Indo-Burma ranges covers most of the northeastern states of India as well as Bangladesh and Myanmar. This province lies between Indian plate in the west and Burmese plate in the east. In the northwest, it abuts against Shillong Plateau and in the northeast it wedges towards Himalayan arc.

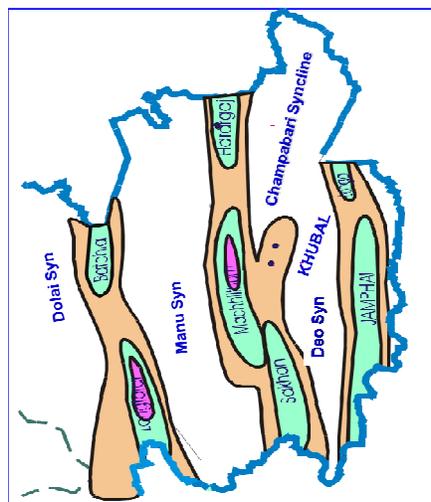


Fig-2. Structures in Eastern Tripura

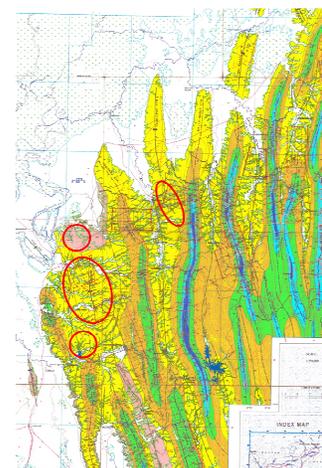


Fig-1. Geological Map of Tripura

Southward, the basin extends up to Tripura. The basin extends beyond Nagaland, Manipur and Mizoram into the Arakan coast of Myanmar. The basin extends southwestward under the alluvial cover of Bangladesh and is contiguous with Bengal basin. Eastern Tripura is situated in the eastern part of Tripura Fold Belt, India. The area comprises structures, viz. Batchia, Langtarai, Harargaj, Machhlithum, Khubal, Sakhon, Longai and Jampai (Fig-2). It is filled mainly by orogenic sediment derived from the eastern Himalayas to the north and the Indo-Burman ranges to the east. These deposits record uplift and exhumation of mountain belts formed by the

ongoing India–Eurasia collision. The bulk of the deltaic deposits are Miocene and younger.

Drilling activity had started in western Tripura in 1972 with commercial production from 1975. However in Eastern Tripura drilling had started only in 1991 with few wells drilled in crestal part of Harargaj and Khubal structures. The major hydrocarbon producing reservoirs are the Upper & Middle Bhuban Formation; though drilling has indicated gas from Lower Bhuban in Agartala Dome and Baramura structure. In the light of discovery of hydrocarbons in the northern plunge in Western Tripura, viz. Kunjaban in northern part of Agartala Dome and Sundulbari in northern part of Tichna structure, it was felt worthwhile to explore the flank & plunge part in eastern Tripura as well for exploration of Lower Bhuban.

2. Problems encountered in Exploration: Hydrocarbon exploration in thrust fold belt is a risky proposition riddled with constraints, foremost being complex geological and tectonic conditions (Fig-3) and mapping of exploration targets from available seismic data. Our experience in of drilling in exposed anticlines shows that even anticlines are not always safe bet on account of structural disharmony well exemplified in number of structures drilled in Cachar and two structures drilled in East Tripura. Efforts are further compounded due to failure in understanding the distribution of quality reservoirs within Lower Bhuban.

3. Re look into Exploration strategy: The frontal folded belt of Tripura-Cachar-Mizoram area show a progressive east ward increase in structural complexity with wide synclines in between. Evaluation of seismic section across Tripura-Cachar area reveals that section across anticlines show chaotic /loss of reflection where as synclinal part display well defined/continuous reflection characters. It has been observed that many anticlinal crests are dissected

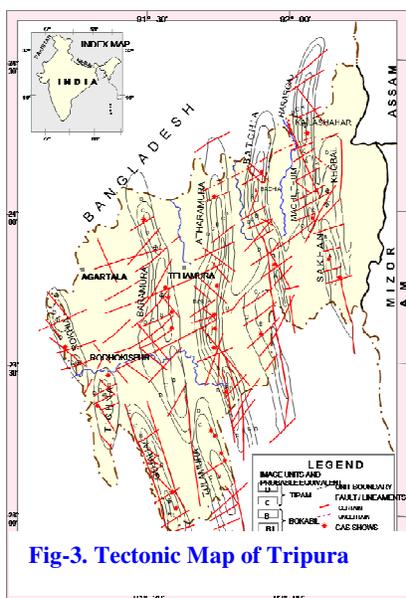


Fig-3. Tectonic Map of Tripura

by faults that cause drilling complication/ possible escape route for hydrocarbons. It is envisaged that down warping of synclinal flanks in response to tectonic loading may cause up warping of central portion & readjustments of hydrocarbons towards domal uparching. Though structural amplitude of these structures will be small, their large areal extent and absence of structural complexity make them good exploratory targets.

4. Objective and Focus area: The surface geological & land sat maps indicated presence of the seven exposed structures in Eastern Tripura, out of them, Khubal structure is tectonically the least disturbed and gentle structure. Also, proximity to the hydrocarbon bearing structures of Adamtila, Patharia of Cachar and those of Bangladesh makes this area prospective. Collating these facts, the focus of exploration was concentrated on the Khubal–Champabari-Manu area. Main objective was to formulate hydrocarbon lead areas for exploration of Lower Bhuban reservoirs.

5. Breakthrough: Two locations were generated based on integrated studies. Location KHC (Fig-4) was drilled on the eastern flank of Harargaj anticline. It produced feeble gas from Upper & Middle Bhuban formation, but Lower Bhuban could not be drilled due to complication. Taking lead from the results, another location KHD (Fig-5) was drilled in a fault closure to the NW plunge of Khubal structure. The well was drilled around 3000m and had encountered about 60m of pay sand in Lower Bhuban which on testing produced 1,25,000 SCMD of gas and has

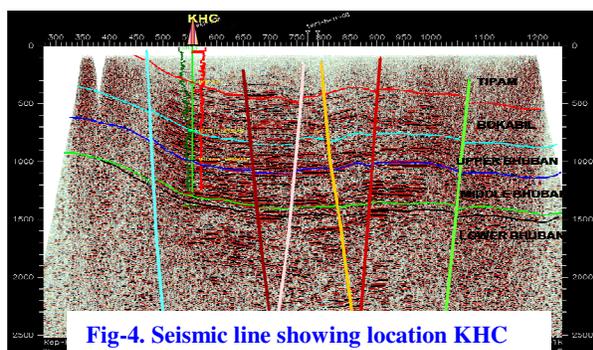


Fig-4. Seismic line showing location KHC

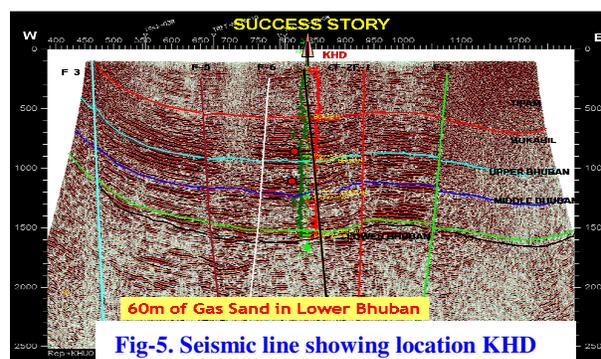


Fig-5. Seismic line showing location KHD

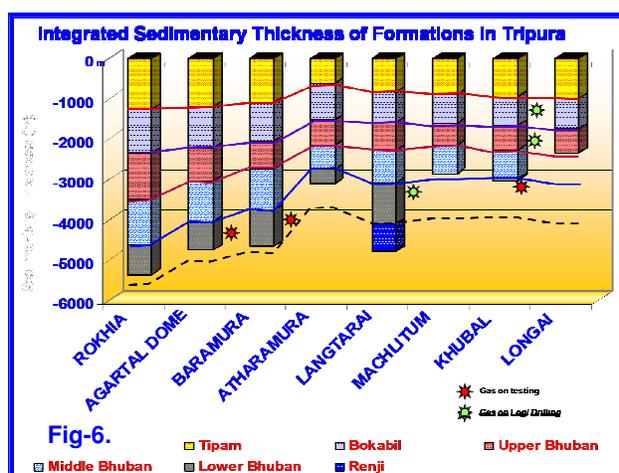
resulted in substantial reserve accretion.

Present Study: With the discovery of huge gas reserve in the plunge part of Khubal structure in Eastern Tripura, the focus has shifted for exploration in Lower Bhuban in adjoining structures. Since the data point were limited, as a first step, distribution of Lower Bhuban reservoir was studied, sedimentary structure, petrographic, floral and faunal assemblage study was carried out in the study area to ascertain the reservoir characteristic, sand distribution pattern and depositional environment. Pressure data available for the drilled well were studied to understand the pressure variation of Lower Bhuban sands in the study area. Surface geological and Landsat data was used to map the subtle structural features and cross faults, available seismic data, AVO was done to map the Lower Bhuban reservoirs around the study area.

6. Methodology: To chase up the discovery in Lower Bhuban reservoir, an integrated study has been carried out in selected wells of Western and Eastern Tripura, Cachar and Mizoram where Lower Bhuban is present, to assess the reservoir distribution pattern and sand characteristics. Attempt has been made to integrate lithology, sedimentary structure, petrography, Palaeo floral and faunal studies of Lower Bhuban drilled in the area. A detailed analysis was done to reconstruct a suitable model for the depositional environment resulting in reconstruction of paleogeography. In this study, subsurface lithofacies maps of Lower Bhuban formation have been constructed based on analysis of well logs. Finally the model was tested by drilling in one of the identified prospects.

7. Distribution of Lower Bhuban Formation:

Detailed analysis of Existence of Lower Bhuban sequence in Tripura-Cachar-Mizoram area has been confirmed by drilled wells in Baramura, Agartala Dome & Rokhia in western Tripura, Khubal and Harargaj in the Eastern Tripura & Adamtila, Badarpur, Hilara, Masimpur, Bhubandar, Chatachura, Chargola, Karalkandi, Patimara, Patharia, Nrayanchara in Cachar & Rengte in Mizoram. Lower Bhuban is also exposed in core of Ataramura structure. Analysis of thickness data compiled from drilled wells and field geological studies/traversing indicates sedimentary thickness pattern of Lower Bhuban formation (Fig.6).



8. Petrographic study: Results of studies of lithological characters and sedimentary structures of cores and samples indicates the rock composed of sub lithic quartz arenite to lithic quartz arenite of well-sorted grains of quartz, feldspar and lithic fragments (chert, schist and shell fragments) of angular to sub rounded grains. The sedimentological analysis, indicate the sands are dominated by silica with less feldspar content. Among the feldspar K₂O is dominant which indicates that the sediments were derived from granitic terrain. Increased thicknesses of Miocene strata and the composition of Miocene sandstones of the Surma Group yield a clear record of orogenic unroofing. The sediments were probably fed from eastern part from Burmese shield to the study area. The dominance of quartz with lithic fragments indicating it may also be recycled sedimentary rocks from the Himalayan orogenic belt and from Burmese plate.

9. Facies Analysis: Based on lithological study, sedimentary structures, faunal & floral assemblages few major facies were identified.

Facies X: The most dominant lithology is sandstone, shale/Clay stone with silt stone layers. Sandstone in the northern part is light to dark grey, mainly quartzose wacke and with micaceous matrix as observed in Hilara, Karalkandi and Badarpur. It is lithic wacke in Narayan chara. Further south the sandstone is medium grained with improved sorting. Moving further south in Harargaj, Khubal, Baramura, sandstone is mature fine grained and silty in nature. Sedimentary structures are ripple laminations, trough cross stratification, slump structures, lenticular bedding. Based on these, it is interpreted to be deposited in lower delta plain with subfacies of distributary channel-levee complex super posed over eroded bar complex.

Facies Y: Lithology is sandstone with minor shale and the environment of deposition is interpreted to be delta fringe with subfacies of distributary mouth bar. It is observed in Bhubandar, Badarpur, Kanchanpur and East Tripura area.

Facies Z: Lithology is shale with minor silt stone and sand stone. Sedimentary structures are current ripple, flaser beds, herring bone structures. Mainly observed in Mizoram. It is interpreted to be deposited in coastal inter deltaic environment.

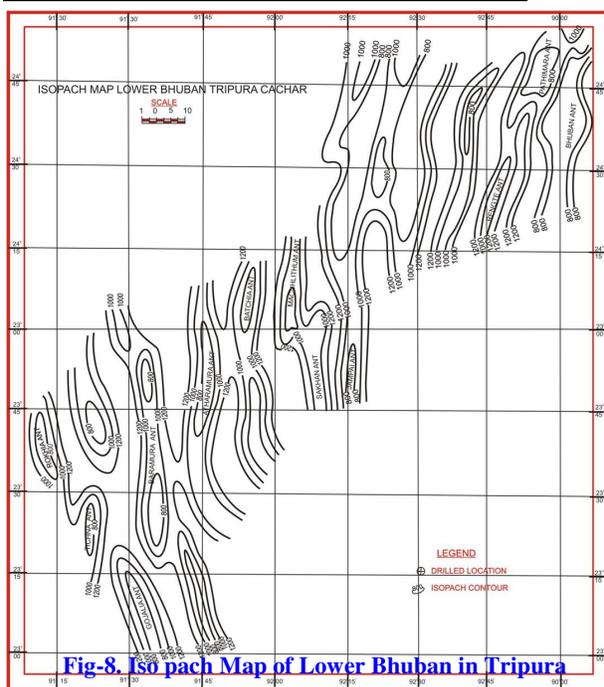
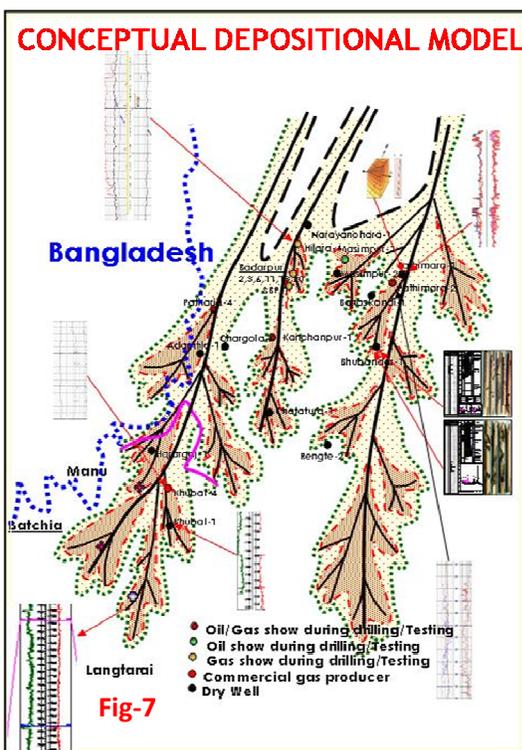
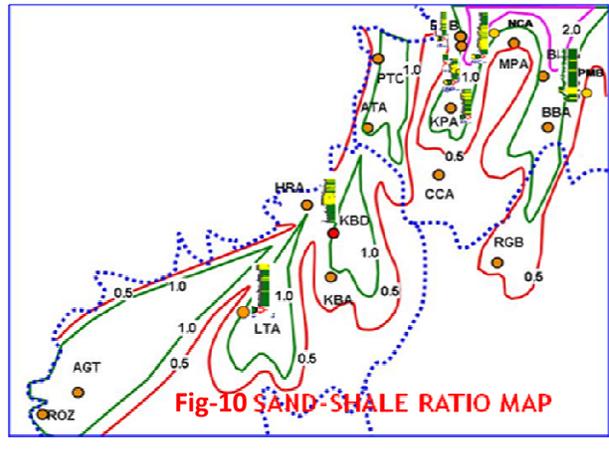
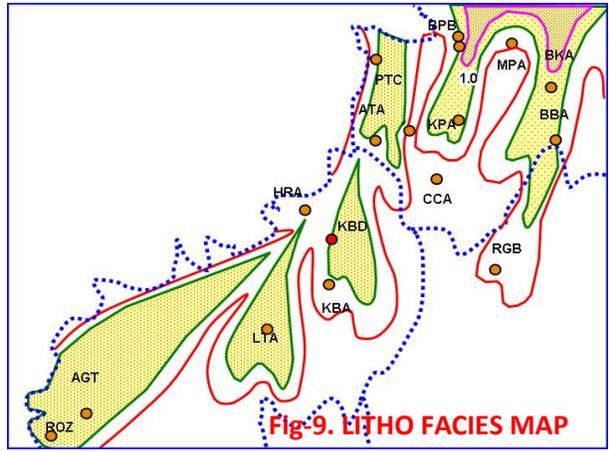


Fig-8. Iso pach Map of Lower Bhuban in Tripura

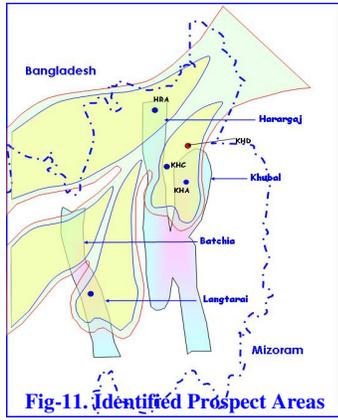
10. Style of sedimentation: Surma sediments are believed to be only 2400m thick in Sylhet-Chatak area of Bangladesh, 2800m in North Cachar, 4500m in Tripura while it is progressively thickening towards SE up to 8500m in Mizoram, where the depocentre of sedimentation is believed to lie. The Oligocene Barail Formation was deposited during a major marine regression that exposed most of the 'Indian platform' of the Bengal basin. The Barail Formation comprises a thick sequence of medium- to coarse-grained sandstone intercalated with siltstone & shale. By Early Miocene time, a major phase of sedimentation started and huge amounts of clastic sediment were funneled into the basin from the northeast & were deposited in a rapidly fluctuating condition of deltaic to marginal marine environment that was followed by a major transgression during Early to Mid Miocene resulting in deposition of Lower Bhuban sediments. In the study area during Lower Bhuban time delta system was prevailing from Oligocene time resulting in deposition of increased sand supply. Major delta system was prograding towards South & SW, with sediment supply from Rising Himalaya and from Indo-Burman Ranges; sedimentation was in deltaic and open-shelf environments along the basin margins. Proto-Brahmaputra River may be oriented NE-SW and N-S and the current course was only configured following Pleistocene uplift of Shillong plateau. A considerable amount of sediment was also coming into the basin from the northwest and small deltas were building on the western side of the basin (Fig-7).

11. Depositional patterns: Sand thickness derived from field traverse & the drilled wells suggest the following depositional patterns for the sediments of the Lower Bhuban formations. The deposits in the NE part are only 500-600m around Badar pur, Hilara presumably due to limited subsidence in this area. The exposed Indian shield is located not far from here, the thickness in the Mizoram part in the east and Rokhia part towards west shows increase in thickness as these part of the basin was affected by tectonic loading, both from the east (Indo-Burman ranges) and the northeast (eastern Himalayas) which caused it to subside further, helping to accommodate huge thicknesses of Miocene sediments of the Surma Group (Fig-8). Trends from the lithofacies maps suggest that deltaic deposits filled the

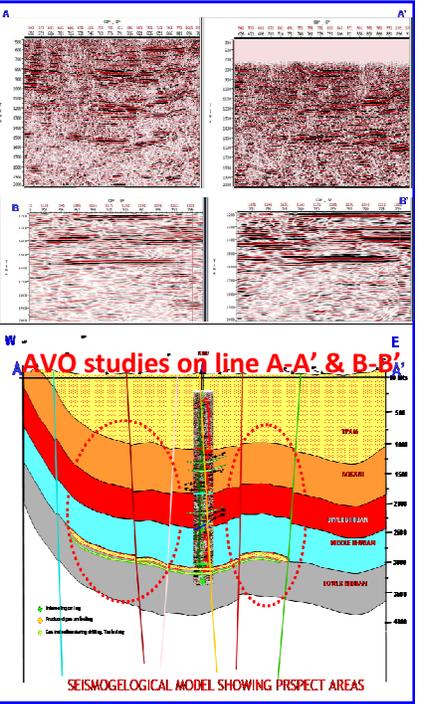
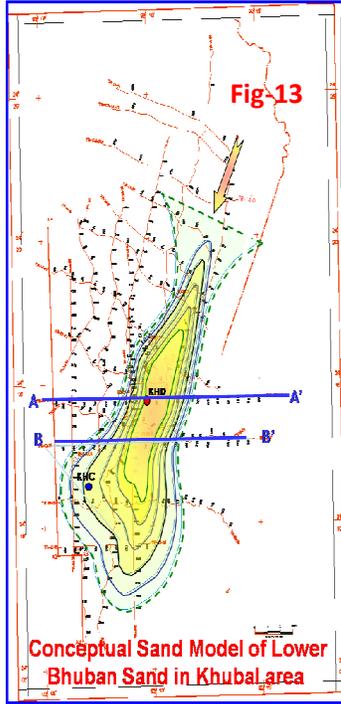
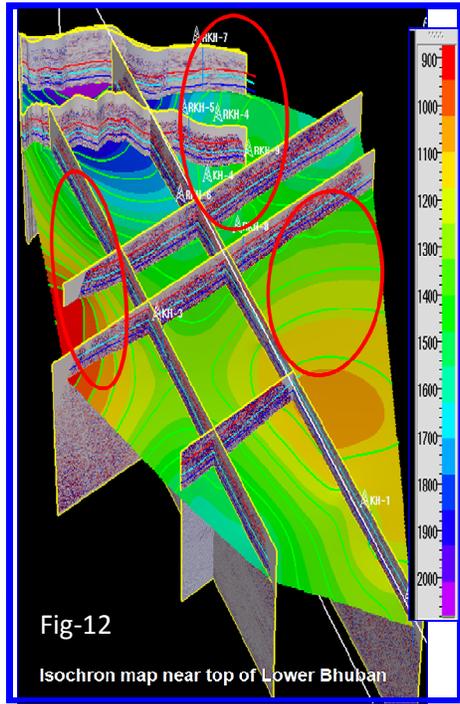
area from the east, and that the source of this sediment included the north-trending Indo-Burman ranges directly adjacent to the east and the eastern Himalayas. The sand/shale ratio has been estimated from various field traverse & drilled well data. The highest sand/shale ratio for the Lower Bhuban Formation (2.0) is at the Narayanchara & Masimpur area in the north east, gradually decreasing to towards south in Chatachura and Mizoram area. In Eastern Tripura, the ratio is higher in KBA which decreases to 0.33 in LA, further west in RKA it is again 1.33, clearly indicating different sand lobes, which is also confirmed by pressure data recorded in few well (Fig-9 & 10).



On the basis of integrated studies, different sand lobes has been worked out for Lower Bhuban sands and after super imposing sand maps over structures following areas are identified as potential exploration areas (Fig-11).



12. Khubal Anticline: To chase up the lead of the discovery well D, the area was studied in detail. Seismic data were tied up at well locations and with outcrop data. Seismic reflection events corresponding close to the tops of Lower Bhuban Formations have been correlated. Time structure map at Lower Bhuban level (Fig.12, 13) indicate a NW-SE trending prominent cross fault which dissects the northern plunge of the structure into two parts, and an up dip fault closure to the west of the structure. The NW-SE trending fault closure mapped to the west of the Khubal anticline lies in the vicinity of Machhmara and Champabari Synclines. The 2D seismic data acquired over Line XX4 & XX1 is processed for Pre-stack Time migration. AVO has been used to map the possible extent of the gas producing pay sand. As the subsurface dip recorded is low about 60m sand is expected to extend



lead area. Drilling has proved occurrence of Lower Bhuban sand in the area and also existence of hydrocarbon in the structure.