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Exploration Strategy in Tripura Fold Belt, Assam & Assam Arakan Basin, India - Some Contemporary Approach

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Summary

Tripura Fold Belt of Assam & Assam Arakan Basin is in news for a number of recent discoveries like Sundalbari, Kunjaban, Khubal, Tulamura, Gojalia, Baramura etc. These discoveries have also guided us to think a bit unconventional and adopt different strategies to understand the Hydrocarbon plays in the structures of Tripura Fold belt. Synclinal Exploration, Exploration in Plunge parts of the structures, Determination of axial region of the structures, Identifying the stress directions and pressure regimes, Challenges in petrophysical evaluation and overcoming drilling problems are some of the challenges. Success in tapping gas from sands belonging to a relict feature of Upper Bhuban formation in synclinal area of Sundalbari structure, discovery of gas in a lower Bhuban sand in Khubal structure in synclinal area has rekindled the hope to find out similar ones in other synclinal areas between the structures. The gas discovery in Kunjaban structure which is the northern plunge part of Agartala Dome has proved the potential of the plunge parts of different structures particularly the northern plunge parts. Identification of fault cuts from log motifs in Baramura structure has helped in understanding compartmentalization of structures where seismic coverage is poor. It is also observed that particularly in Baramura structure, finding out the axial region is a challenge and slightly away from the axial region, the wells fall to water bearing sands. The super charged aquifers present in the structures pose serious problem while drilling with water blow outs like what happened in Gojalia Structure. Interpretation of Hydrocarbon bearing sands where resistivity contrast is poor with high resistivity shales is also a problem in exploration.

This paper discusses some answers to these problems with a contemporary approach armed with high-tech logging tools and change in think tank patterns to address these challenges and come out with solutions for way ahead in exploration. Only a logical thinking of the possible entrapment model can solve and answer the key issues. The possible entrapments like small culminations, relict features, updip pinchouts in synclinal areas, fault closures in plunge parts, unconformity related entrapments are discussed in this paper. The petrophysical model to identify the low contrast hydrocarbon bearing sand units have been discussed in this paper.

***Keywords**: Synclinal Exploration, Petrophysical Challenges*

Introduction

The Tripura-Cachar Fold Belt of the Assam and Assam Arakan Basin (Figure 1a,b,c) has attracted the attention of Geoscientists for almost a century. The Discovery of gas in Mio-Pliocene sands in Rokhia, Agartala Dome, Gojalia, Tichna, Baramura, Kunjaban, Sundalbari and of late Tulamura and Khubal structures have proved the Hydrocarbon potential of Fold belt part of Tripura. The Tripura area has Hydrocarbon resources of about 600MMT(O+OEG). Synclinal exploration has got a new vista after success of Sundalbari and Khubal structures where stratigraphic traps in flanks/synclines have proved to be prolific gas producers which were considered risky earlier and mainly the anticlinal highs were being targeted. The broad flat synclines between anticlines have become target for stratigraphic traps and concealed structures. It can be observed in Figure No 1a that gas bearing concealed structuresof Bangladesh surround Tripura fold belt area in north south and west directions. In fact, discovery of gas in

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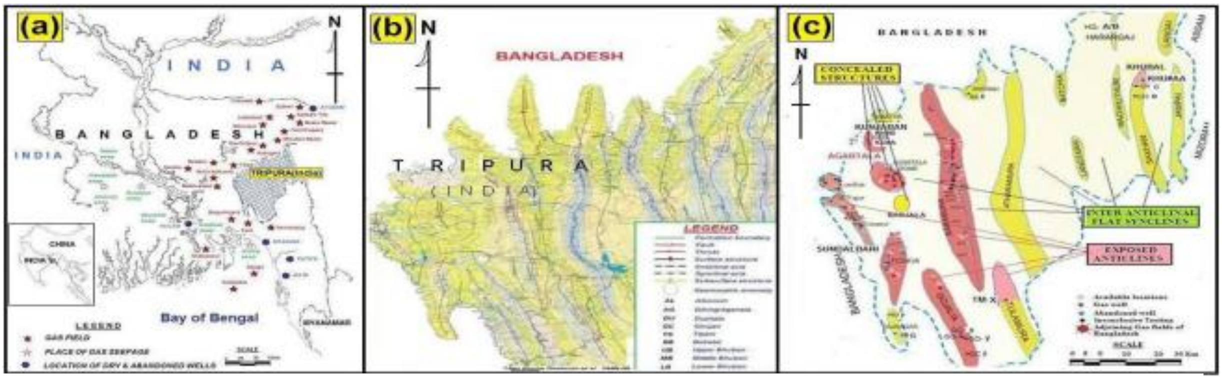

Figure 1 (a) Map of Tripura showing Gas Fields of adjoining Bangladesh (b) Geological Map of Tripura (c) Structures of Tripura Fold Belt

Bangladesh in structures like Beani Bazar, Begumganj etc. started in the same year i.e.1972 of gas discovery in Baramura structure (Curiale J.A. et al 2002) To fulfill the demand of 6MMSCD gas to Tripura Power Plant, a major challenge lies ahead to step up exploration/exploitation efforts to accrete more and more reserves. This paper is an attempt to have a re-look about the contemporary exploration / exploitation strategy in Tripura Fold belt.

Regional Geological setting

The Tripura-Cachar fold belt represents the frontal fold-belt of Assam and Assam Arakan Basin. The belt comprises of long linear tight N-S trending anticlines separated by broad synclinal troughs. To the north the belt is bound by ENE-WSW to E-W trending fold belt associated with Dauki Transfer Fault which passes to the south of Shillong self. The intensity of folding increases from West to East and the tightly folded belt of Mizoram-Manipur, to the east separated from the Tripura-Cachar belt by Kaladan Fault. The Kaladan Fault is interpreted to be the eastern limit of the Surma Sub-basin (Ref Jokhan Ram and Venkat raman,1984).The folds decrease in intensity and amplitude towards the west and pass below the Ganges-Brahmaputra Alluvium in Bangladesh. In the southern part, the Chittagong Hill tracts in Bangladesh are contiguous to the fold belt part of Tripura in an en-echelon pattern. The major anticlinal structures in the area have associated thrusts on their flanks. Regionally it is thought that the thrust fold association has its roots to a decolment surface either within the topmost part of Barail Group or within the Lower Bhubans (Kale A.S.et al 2007).

Stratigraphy

The stratigraphy of Assam & Assam Arakan fold belt has been established and revised by a number of workers likeEvans(1932), Mathur and Evans(1964), Dasgupta et al (1977), Deshpande et al.(1993) etc. The Tripura Cachar Fold Belt exposes different sedimentary units mainly along the narrow linear ranges formed by the anticlines. The cores of the anticlines usually expose the Bokabil or Bhuban formations flanked by Bokabil and Tipam/Post Tipam formations exposures. The pre-Surma sediments have not been penetrated in the subsurface and are present beyond this depth. Details of generalized stratigraphy is given in Table-1

Plunge Part Exploration

The hydrocarbon plays of some recently discovered structures in plunge parts have been discussed below for a logical analysis and way forward for future exploration strategy.

Kunjaban Structure

Kunjaban structure got its prominence in the year 2007 with significant exploratory lead in KU#A. Kunjaban structure is a concealed structure in northern plunge of Agartala Dome. It is separated from Agartala Dome by a NE-SW trending cross fault F1 (Figure 2a,b,c) and cross fault F2 separates well KU#B from KU#A. A separate culmination in the same axial trend is observed around KU#B. It can be observed in the schematic diagram

Table 1: Generalised Stratigraphy of Tripura Fold Belt

CHRONOSTRATIGRAPHY		LITHO-STRATIGRAPHY		GENERALISED LITHOLOGY	THICKNESS (m)	DEPOSITIONAL ENVIRONMENT
	AGE	GROUP	FORMATION/ MEMBER			
QUARTERNARY	RECENT TO PLEISTOCENE		ALLUVIUM	Loose sands,silts and clays	400	Fluvial
			DIHING	Pebble beds,conglomerates and sandstones with thin beds of clay		
	UNCONFORMITY					
NEOGENE	PLIOCENE	DUPITALA	UPPER	Coarse, pebbly sanstone & mottled clays	1000	Fluvial
			LOWER			
	UNCONFORMITY					
	MIOPLIOCENE	TIPAM	GOBINDPUR	Varigated soft & sticky clays often silty with Sandstone	1500-1700	Fluvial
			JAIPUR	Mainly sandstone with clays and claystone.		Fluvial
	MIOCENE	SURMA	BOKABIL	Fine grained sandstone/ siltstone with intervening layers of claystone	700-1500	Brakish/Shallow Marine
			UPPER BHUBAN	Sandstone & sandy claystone/ shale layers	650-1200	
			MIDDLE BHUBAN	Shale & occasional Fine grained sandstone	650-1200	Outer shelf/Open Marine
			LOWER BHUBAN	Alterations of sandstone and shale	700-1000	Brakish/ Marginal Marine
	UNCONFORMITY					
PLAEOGENE	OLIGOCENE TO LATE EOCENE	BARAIL	RENJI	Dominantly sandstone with thin shale layers	700-1000	Brakish/ Marginal Marine
			JENAM	Shale and occasional sandstone	900-1500	
			LAISONG	Alternations of thin sandstone and shale beds	1500-2000	
	EOCENE	DISHANG	DISHANG	Dark grey shale with thin beds of sandstone	1750	

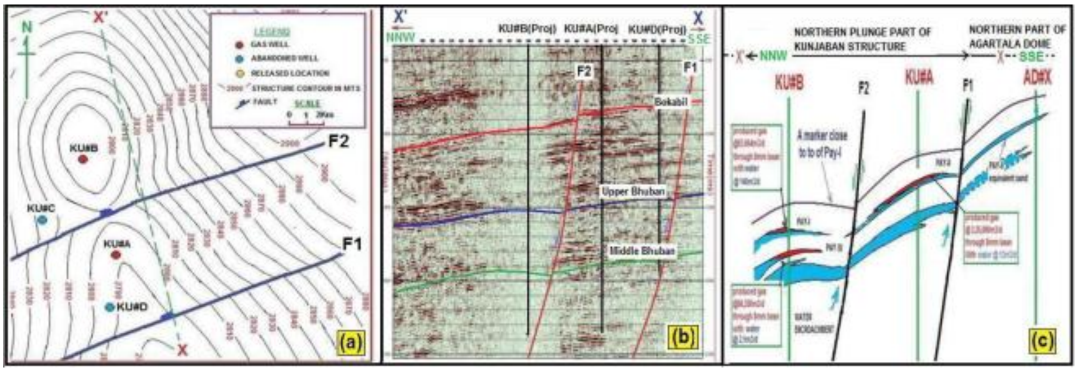

Figure 2 (a) Structure Contour Map close to Middle Bhubn top (b) Seismic section X'X showing plunge part of Kunjaban Structure (c) Schematic diagram showing entrapment of gas in plunge part of Kunjaban structure in Figure 2b that in NNW direction of Agartala Dome, there are three culminations separated by F1 and F2. The structurally lowest culmination around KU#B is gas bearing where as in the structurally highest northern plunge part, the equivalent sands in AD#X are water bearing. Similarly the culmination around KU#A is gas bearing which is below GWC of AD#X. The preferential charging of the sands through fault conduits/permeable layers has controlled the entrapment where top part of the structurally lower culminations upto spill point has been charged with gas where as structurally higher sands in AD#X are water bearing with very gentle dip without any culmination.

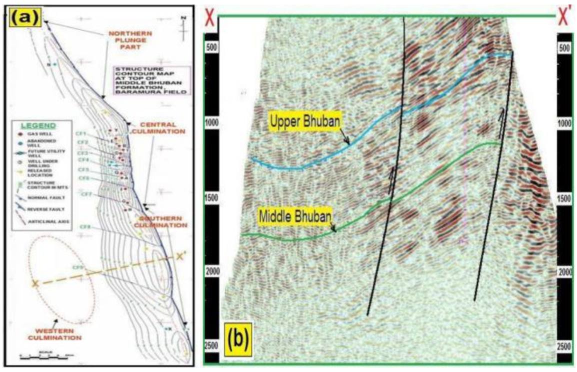

Figure 3: (a) Structure contour map at top of Middle Bhuban Formation, Baramura Structure (b) Seismic section X - X' showing Southern culmination of Baramura Structure

Baramura Structure

The Baramura Anticline is an elongated doubly plunging asymmetric anticline, trending NNW-SSE with slight convexity to west near the central culmination (Figure 3a,b). Again there is a bulge in NE direction of well BRM#Y with axial trend becoming slightly convex towards NE direction. Recently a Middle Bhuban sand between B-VII-III and B-VII-II produced gas @ 1,30,000 m3/d of gas in BRM#Y in northern part of central culmination. The southern culmination found to be relatively higher unlike the earlier version, and hence it becomes prospective. The northern concealed plunge part close to the anticlinal axis is prospective. The western culmination, which is a concealed structure looks to be prospective. With scanty seismic data it is some times very difficult to find out the axial part just based on Geological maps, so slightly away from the axial part of the anticline the well falls in water bearing parts. So a careful strategy to be adopted to probe the anticlinal areaclose to axis in this logistically and environmentally difficult structure.

Synclinal Exploration

Khubal Structure

Gas discovery in Khubal Structure in eastern Tripura was the biggest news in the year 2009. A 40m thick sand

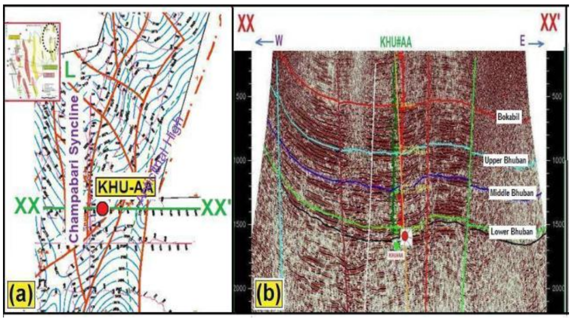

Figure 4: (a) Time structure map at top of Lower Bhuban Formation, Khubal stucture (b) Seismic section XX -X X' showing KHU#AA showing Hydrocarbon entrapment in Synclinal area.

belonging to Lower Bhuban formation in well KHU#AA produced gas @ 1,54,000 m3/d through 8mm bean. It resulted in accretion of about 23BCM GIIP for the structure and gave a boost to exploratory efforts after failure in three wells.

Khubal structure lies east of the Champabari Syncline (Figure 4a) in eastern part of Tripura east of Machlitum Anticline and Hararganj structure is NNW part of it. It is a gentle, doubly plunging structure trending NNE–SSW. It is a structural culmination with Upper Bhuban exposed towards south whereas Bokabils are exposed in north. The cross faults have shifted the anticlinal axis. The northern plunge of the anticline is well defined, whereas the southern plunge is short and abruptly truncated by the transverse Kanchanchara fault. The western limb of the structure is affected by a major longitudinal fault which runs along the Tipam/Bokabil contact. Eastern limb of the structure is affected by a minor fault running NNW – SSE. It can be observed in seismic section XX-XX'(Figure 4b) that the entrapment is in the synclinal part west of the anticlinal high truncated with a reverse fault to the east.

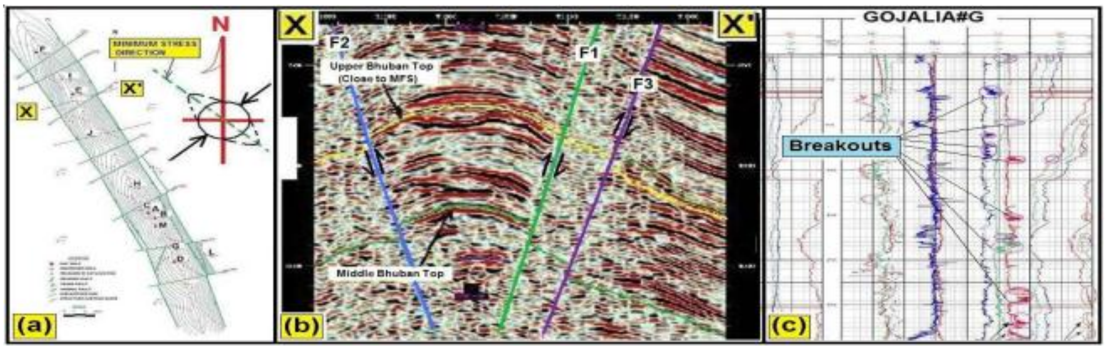

Figure 6 (a) Structure contour map at top of Upper Bhuban formation , Gojalia Structure showing the prospective areas and minimum and maximum stress directions (b) Seismic section X-X' showing Northern culmination of Gojalia Structure (c) Break out features in Gojalia #G showing the minimum stress direction in 310-130 deg. direction.

Sundalbari Structure

Sundalbari structure got its discovery in the year 2007 with well SD#BB. Sundalbari Structure is a separate fault closure in northern plunge of Tichna Anticline(Figure 5a). Though Sundalbari structure is in the northern plunge of Tichna field and is structurally down w.r.to nearby main Tichna anticline, the commercial gas production from SD#BB has proved that the structurally lowest fault blocks of Sundalbari structure have suitable HC entrapment condition in northern most plunge part of structure.

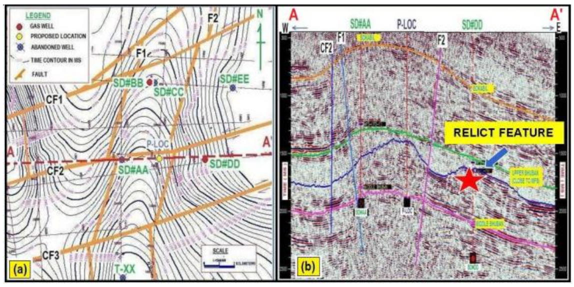

Figure 5 (a) Structure map at top of Upper Bhuban Formation, (close to MFS), Sundalbari Structure (b) Seismic section A- A' showing hydro carbon bearing Relict feature in eastern syncline of Sundalbari Structure

Tichna anticline, the commercial gas production from SD#BB has proved that the structurally lowest fault blocks of Sundalbari structure have suitable HC entrapment condition in northern most plunge part of structure. It can be observed in the seismic section AA' (Figure 5b) that the erosional relict feature in well SD#DD has arenaceous bands with claystone/shale drapes which act as an effective seal in the eastern synclinal part of Sundalbari Structure (Jena A.K. et al 2011) and has trapped hydrocarbon. So exploration haunt should be for similar stratigraphic traps in the flat inter-structural synclines.

Anticlinal Closures

Gojalia Structure

Gojalia is one of the major structures in South Western Tripura. Part of the anticline falls in adjoining Bangladesh where as major part of the NNW part of anticline falls in India. It is a doubly plunging anticline trending NNW-SSE direction(Figure 6a,b,c) it can be observed in structure contour maps at Upper Bhuban (Close to MFS) ,GO # M falls in the culmination, south of GO # B, which is a prospective area as per the study. This has been proved by gas production from GS-I-I sand (849-854m) @ 45,960m^3/d through 8mm bean in well GO#M. Similarly the southern culmination is prospective at both upper and Middle Bhuban levels.

Petrophysical Challenges

Realistic estimation of shale volume and water saturations is a challenge in structures of Tripura fold belt like Baramura, Sundalbari etc because of complex lithology. Challenges are related to low contrast of resistivity in gas bearing sands and shale. Shale resistivity (≈ 10-12 Ωm) is observed to be higher than that of the adjacent water bearing sands (≈ 6-8 Ωm).

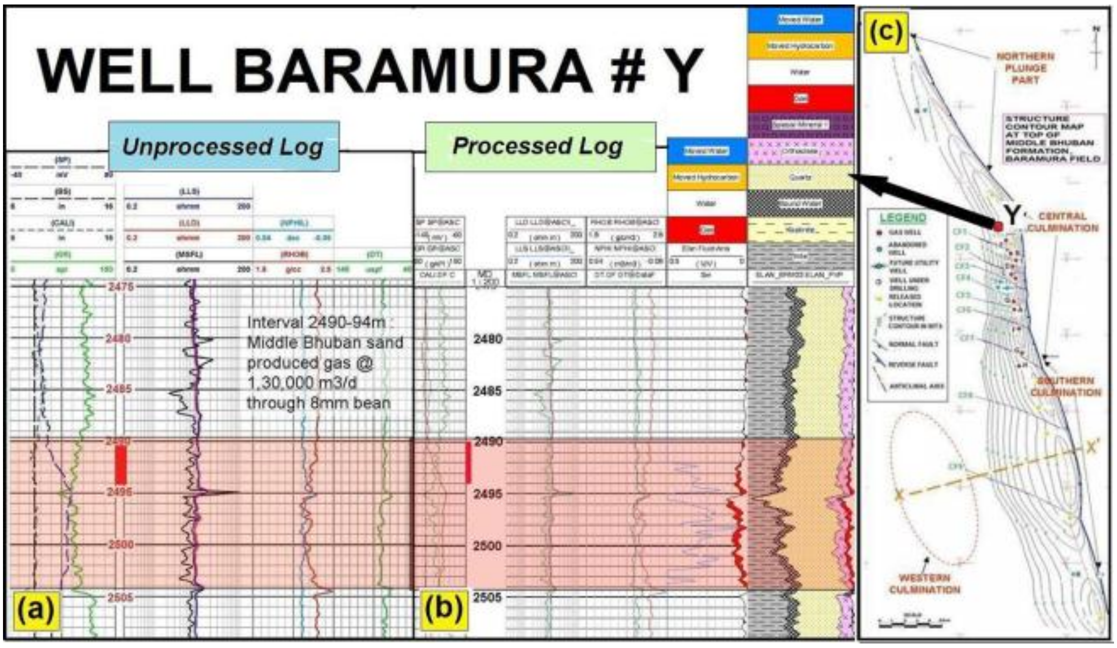

Figure 7 (a) Unprocessed log of a Middle Bhuban Sand showing low resistivity contrast (b) Processed log with appropriate petro physical model shows hydrocarbon bearing nature of sand. (c) Baramura Structure showing location of Well Baramura # Y

Therefore, the computed volume of shale using the resistivity log appears to be higher. Both the Gamma Ray and SP logs are quite erratic at several places. Apparent Neutron shale porosity is observed to be in the range of 24-30 p.u. and close to that of sandstone reservoir. Gas effect is not visible on density-neutron log. Very low contrast between shale density and sand matrix density is observed. Sonic porosity is low and gas effect is not identifiable on sonic log. It can be observed in Figure 7a that the sand of well BRM#Y which is producing @ 1,30,000 m3/d gas, there is poor gas effect on the logs and poor contrast in shale resistivity and producing sand. In our study based on Lab reports Sandstone has calcareous cement, feldspar & mica. Heavy minerals like Garnet, Tourmaline, Epidote and main clay minerals Illite & Kaolinite present in the formation. Working petrophysical model has been framed up with Quartz, Orthoclase and a special mineral which can represent gross log properties of heavy minerals and also high radioactive effect of some tracer elements. Illite & Kaolinite have been incorporated as clay minerals while Gas and water is introduced as fluids in the model. Dual water model has been used for saturation computation and accordingly petrophysical parameters a=1, n=2 and 'm' is related to average porosity which turned out to be mDWA=1.99. With this petrophysical model, the low resistivity contrast sands have been interpreted as hydrocarbon bearing(Figure 7b). But it is recommended to closely monitor the gas shows/activity during drilling and take number of SFTs to ascertain the hydrocarbon potential of these type of sands. A proper petrophysical model should be formulated integration with detailed core studies to avoid missing zones.

Technological Challenges

In structures like Gojalia, large breakout sections extending over several hundred meters of the bore hole. The analyzed data of SED (six-arm dipmeter) tool and the new generation XRMI (Extended Reach Micro Imager), the principal azimuth of well-bore breakouts matches perfectly with the strike direction of the axis of anticlinal structures in the direction of 310^0-130^0. This shows the minimum and maximum stress direction (Figure 6a,c).These observations can be used to plan the well trajectories in high angle wells which should be in minimum stress direction.

The high pressure sands in lower part of Upper Bhuban and in Middle Bhuban formation pose problem so far as drilling is concerned. The recent water blow out situation at depth 2004m in GO#J is a hard reminder of the grave situation and technological challenge. So careful planning of the drilling fluid balance with pore pressure has to be made. It can be noted that the well GO # M has been successfully drilled and is a producer in the same anticline.

Another technological challenge is that we are not able to complete the deep wells meant for lower Bhuban formation because of super charged aquifers/reservoirs. The examples are in Rokhia and Agartala Dome wells. Because of high mud weight, the cementation is poor and testing of potential reservoirs remain inconclusive. So a technological challenge lies with us to tap the hydrocarbon potential of Lower Bhuban reservoirs in structures of Western Tripura.

It is also another observation that wells drilled in synclinal parts like SD#DD, GO#L could be completed with lesser mud weight than the counterparts in the anticlinal highs. This may be due to the reason that the culminations are pressurized with tectonic stress. So care should be taken about drilling fluids while drilling synclinal part or anticlinal highs.

Conclusions

- Northern plunge portion of the structures should be probed for stratigraphic and fault closure traps.
- Updip pinch-outs, fault closures in the rising flank of anticlines, relict features in the synclinal part of structures of Tripura should be the target of exploration after success of Kunjaban and Sundalbari structures. The synclines between Rokhia Anticline (Konaban- Maniyakanagar-Sonamura) and Agartala Dome, Gojalia and Tulamura, Tichna-Gojalia and Baramura etc. should be probed for similar features with aggressive 3D seismic studies.
- Concealed structures should be identified in flat synclines with aggressive 3D campaigns for exploration.
- Determination of axial region of the structures is very important particularly in the structures where there is a paucity of seismic coverage like Baramura Structure to avoid wells falling to water bearing parts of the reservoirs.
- Proper petrophysical model should be formulated integration with detailed core studies to avoid missing zones where gas effect is not visible properly on logs.
- It is the time to overcome the technological challenges to drill successfully the wells meant for Lower Bhuban sands in western part of Tripura to tap its Hydrocarbon potential.

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