Assessment of B-VII-III pay within Middle Bhuban Formation in Baramura Anticline, Tripura: Implications of Structural Modeling and Sand Connectivity on Exploration and Development strategy

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Keywords

Structural modeling, Pack/Paywise Correlation, GWC movement, B-VII-III pay, Middle Bhuban, Exploration and Exploitation challenges

Summary

Exploration remains a challenge in Baramura anticline due to scarce seismic data owing to tough terrain. A total thirty six wells have been drilled and few surprises from northern part of central Baramura have been encountered. In this structure, thirteen pay sands have given gas production in Baramura anticline out of which five pays are within Upper Bhuban Formation (B-I-I. B-I-II, B-I-III, B-II-I and B-V-I) and eight pays are within Middle Bhuban Formation (B-VI, B-VI-I, B-VI-II, B-VII-I, B-VII-II, B-VII-IIA, B-VII-IIB and B-VII-III). Recently, in Central Baramura, five development wells did not yield hydrocarbons from their objective B-VII-III pay. To resolve this problem, review of geological model was carried out integrating surface geological data, seismic studies, pack/pay wise electrolog correlation, structural modeling, lab studies, pay wise pressure and production data to understand pay dynamics.

Seismic based structural modeling and pay level electrolog correlation suggests deepening in the northern part of Central Baramura. These dataset also suggest overall narrowing of the structure. Integration of G&G data brought out geological model that suggests sand input direction for most pays are from northeast to southwest in a fluctuating progradational and retrogradational deltaic depositional setup. Exploitation of B-VII-III pay needs review as movement of GWC after production suggests that new development wells need to be shifted in southern area where up dip structure is expected.

Introduction

In present exploration scenario of India and abroad, early monetization of reserve has become a crucial step for oil industries to realize the true potential of a basin. Integration of G&G has always been the industry standard for utilization of any exploration or exploitation goal. However, in area where we have limited data, for example, in rugged anticlines of Assam & Assam Arakan fold belt, integration is the only option to succeed.

General Geology

The Assam and Assam Arakan Basin is an onshore basin situated in the north-eastern part of India and has been categorized as a Category-I basin. On the basis of morphological characteristics, the Assam & Assam-Arakan Basin (A&AA Basin) is subdivided into a Foreland and a Fold belt. The foreland comprises of area including the Brahmaputra arch and it’s southern and northern slopes and is commonly known as Upper Assam Shelf North (UAN); the area encompassing the south eastern slope of Shillong and Mikir Massifs is commonly known as Upper Assam Shelf South (UAS). The A&AA Fold Belt comprises the Naga Schuppen Belt and sigmoidal en-echelon folds of Tripura-Cachar-Fold Belt.

The geomorphology of Fold Belt is typified by a succession of hill ranges and valleys of meridonial and sub meridonial trends (Dasgupta 1977). The height of these ranges varies from 200 to 500 m. The general elevation increases to the east in the region. Fold-belt has complex evolution history and characterized by series of parallel, elongated and doubly plunging, asymmetric anticlines arranged in en-echelon pattern and separated by wide synclines with the general trend of the anticlines being NNW to SSE to N-S with slight convexity towards west and longitudinal faults bounding the flanks. The intensity of folding increases towards east with progressively older rocks being exposed in the cores of the anticlines. Within these our focus of study lies in Baramura Anticline which lies in western Tripura Fold Belt (Fig. 1).

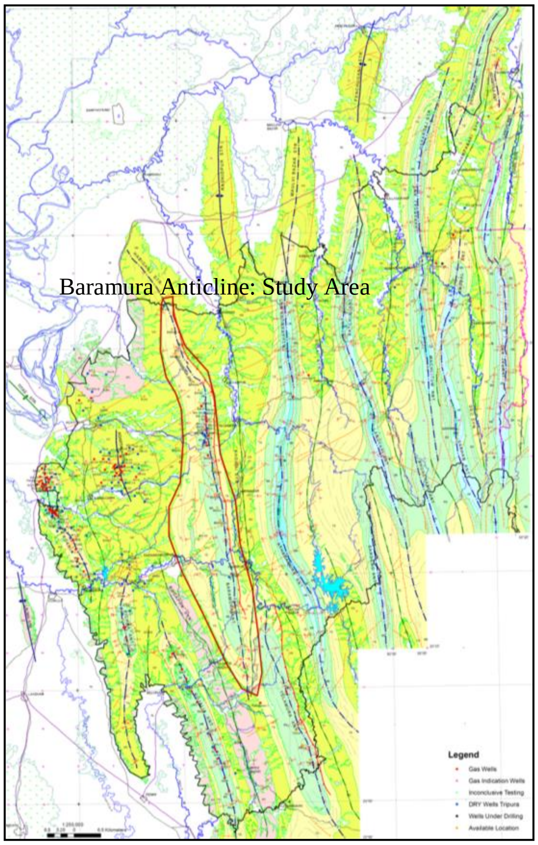


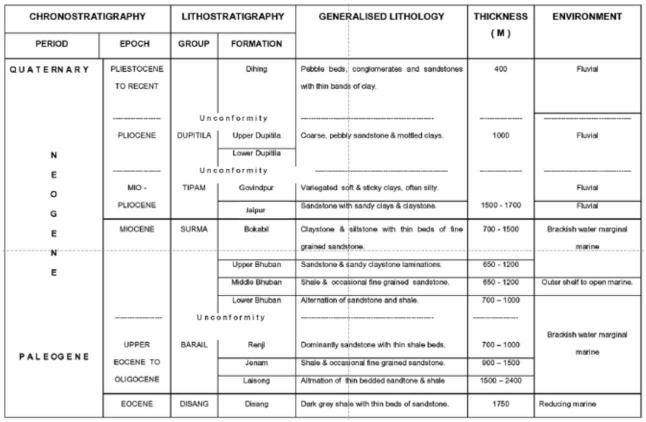
Figure 1: Geological map of Tripura Fold Belt

The stratigraphy of Assam & Assam Arakan fold belt (Table 1) has been established and revised by a number of workers like Evans(1932), Mathur and Evans(1964), Dasgupta et al (1977), Despande et al.(1993) etc.

The pre-Surma sediments have been penetrated in the sub-surface and are encountered only in few wells. Disang Formation of Eocene age is the oldest unit recorded in the region which is dominantly argillaceous. These are followed by tidal deltaic to shallow marine Barail equivalent sediments of Oligocene age namely Liasong, Jenam and Renji respectively. These are overlain by the Surma Group of rocks of Mio-Pliocene age, deposited in an unstable, rapidly subsiding tectonic basin under mainly deltaic conditions with at least three major intervals representing transgressive marine cycles.

The Surma group has been further sub-divided into a lower, more arenaceous Lower Bhuban unit overlain by relatively argillaceous Middle Bhuban which is again overlain by arenaceous Upper Bhuban. The Bhubans are overlain by mainly argillaceous Bokabil unit. The available field, laboratory and well data indicate that the younger Plio-Pliestocene sequences of Tipam and Dupitila groups were deposited under subaqueous to sub aerial, fluvial to lacustrine conditions.

Tipam Group is divided into Jaipur and Gobindpur formations. Gobindpur Formation also known as Girujan clay is a 1350m thick sequence of claystones with intercalated silts and encountered only in synclinal areas. Unconformably overlying the Tipams are the Dupitila, Dihing and the Alluvium ranging from Plio-Pliestocene to Recent age. These are exposed in the synclinal areas of Tripura and Cachar (Table 1).



CHRONOSTRATIGRAPHY		LITHOSTRATIGRAPHY		GENERALISED LITHOLOGY	THICKNESS (M)	ENVIRONMENT
PERIOD	EPOCH	GROUP	FORMATION			
QUATERNARY	PLIESTOCENE TO RECENT		Dihing	Pebble beds, conglomerates and sandstones with thin bands of clay.	400	Fluvial
	----------	Unconformity		----------	----------	----------
NEOGENE	PLIOCENE	DUPITILA	Upper Dupitila	Coarse, pebbly sandstone & mottled clays.	1000	Fluvial
			Lower Dupitila			
	----------	Unconformity		----------	----------	----------
	MIO - PLIOCENE	TIPAM	Govindpur	Variegated soft & sticky clays, often silty.	1500 - 1700	Fluvial
			Jaipur	Sandstone with sandy clays & claystone.		Fluvial
	MIOCENE	SURMA	Bokabil	Claystone & siltstone with thin beds of fine grained sandstone.	700 - 1500	Brackish water marginal marine
			Upper Bhuban	Sandstone & sandy claystone laminations.	650 - 1200	
			Middle Bhuban	Shale & occasional fine grained sandstone.	650 - 1200	Outer shelf to open marine.
			Lower Bhuban	Alternation of sandstone and shale.	700 – 1000	
	----------	Unconformity		----------	----------	
PALEOGENE	UPPER EOCENE TO OLIGOCENE	BARAIL	Renji	Dominantly sandstone with thin shale beds.	700 – 1000	Brackish water marginal marine
			Jenam	Shale & occasional fine grained sandstone.	900 – 1500	
			Laisong	Altrnation of thin bedded sandtone & shale	1500 – 2400	
	EOCENE	DISANG	Disang	Dark grey shale with thin beds of sandstone.	1750	Reducing marine

Table 1. Generalized stratigraphy of Tripura Fold Belt

Input Data

Surface Geological Map, Electrolog Correlation, Seismic 2D lines, Structural modeling and Reservoir pressure and production data was primarily integrated to understand the dynamics of this reservoir.

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Interpretation

To evaluate pay dynamics, pack and pay wise electrolog correlation was carried out keeping in mind the surface disposition of geological elements. The available 2D seismic line was reprocessed and used for structural modeling to evaluate the structural framework of the Baramura Anticline. Well based isolith and structure maps were then prepared and existing faults/thrust on geological map were used to understand the entrapment conditions for all pays within Middle Bhuban Formation.

Structural Framework

Based on observations made in geological map, electrolog and structural modeling, a structural framework was created.

Observations in Surface Geological Map:

Surface geological map suggests two important observations. Firstly, well BM-E is placed at a structural higher position with respect to well BM-G (Fig. 2) with respect to anticlinal axis. As a result, well BM-G is expected to be shallower in subsurface at all levels provided well has not passed through a fault in the sub-surface and all conformable sequences are encountered. Secondly, the surface position of well BM-G lies close to exposed geological boundary of Bokabil and Tipam formations as compared to surface position of well BM-E which lies on the top of the eroded surface of Bokabil Formation. The basic inference made from this observation is that the thickness of Bokabil Formation in well BM-E is expected to be less (due to erosion) as compared to well BM-G.

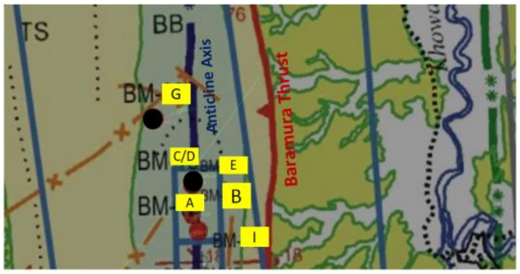

Figure 2. Zoomed part of geological map in northern part of central Baramura showing surface positions of well BM-E and BM-G

Observations from Electrolog Correlation

Electrolog correlation was a challenging task in this area as it lacks major markers below Upper Bhuban Formation and packwise correlation was attempted to compare facies variation in terms of different pays that are established in this structure.

Bokabil Shale Marker (Fig. 3) was taken as first major shale that could be correlated on electrologs and is separated from an overlying high resistivity sandstone that are typical within Bokabil Formation. This shale is followed by a sand rich signature on electrologs and taken as Upper Bhuban (UB) top followed by UB unit 2 pack (a shale rich pack) and UB unit 3 which consists of alternating shale and sandstone.

Similarly, Middle Bhuban Formation is divided into four units i.e. MB Unit-1 (between MB Top and MB Unit 2), MB Unit-2, MB Unit-3 and MB Unit-4 (between B-VI-II and B-VII-III bottom) (Fig.3) based on sand percentages as interpreted on electro logs.

MB top is taken as a shale rich pack which often show bad hole on logs due to excess cavings during drilling. MB unit 2 is sand rich pack. MB unit 3 is shale top and is followed by alternating sandstone and shale as we go deeper.

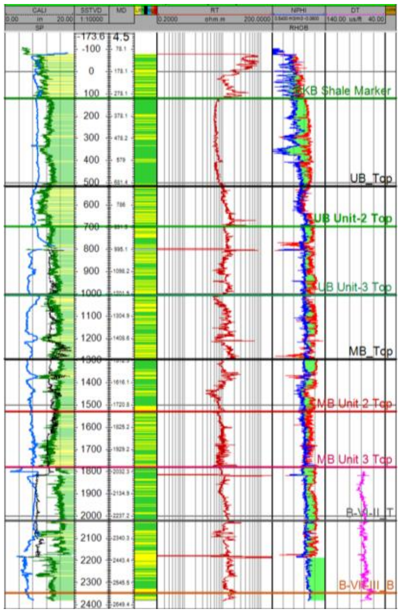

Figure 3. Log motif of key units in well BM-E

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The Electrolog correlation between well BM-C, BM-E, BM-G and BM-H suggests deepening in the northern part of central Baramura (as also suggested by preliminary study of surface geological map). In this part of the Baramura structure, most surprises were encountered especially around cluster wells near BM-C and BM-G. None of the recently drilled development wells have given hydrocarbons from B-VII-III (objective pay sand). Well BM-C was drilled in 2017 as substitute well of BM-D (drilled in 90s) which was tested gas bearing, however, BM-C on testing produced water.

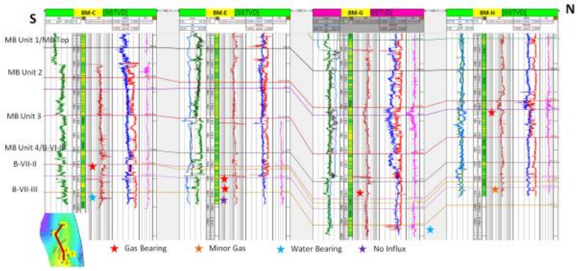

Figure 4. Electrolog Correlation between key wells BM-C, BM-E, BM-G and BM-H (Structural)

Based on the pack wise correlation BM-G cluster is found to be deeper w.r.t BM-C/E cluster in the south (Fig. 4) at all levels (~160m at UB Top and ~225m deeper w.r.t B-VII-III Top). The lithofacies variations along wells (Stratigraphic) hanged at B-VI-II Top are brought out in Fig. 5. Producing sand in well BM-G from the interval 2490-2494m MD was taken as B-VII-III pay in earlier model. However, present study suggests that B-VII-III sand in well BM-G is developed at deeper depth i.e 2523-2565m (Fig. 11) and is below initial GWC of 2367m MSL established for this pay. Testing of this sand gave water with feeble gas (Salinity: 8.7-10.4 gpl). Therefore present study suggests that producing pay in well BM-G may now be correlated with B-VI-II equivalent pack.

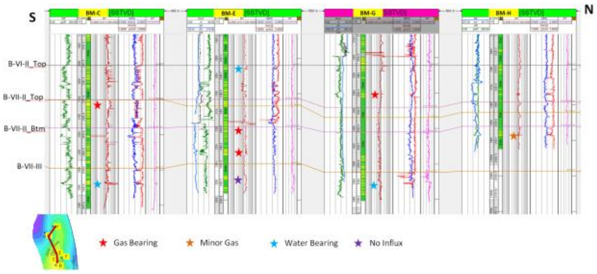

Figure 5. Stratigraphic Correlation between BM-C, BM-E, BM-G and BM-H(Stratigraphic)

Observations from Structural Modeling

One balance cross section was prepared along the recently reprocessed 2D seismic line, passing through the Baramura structure close to well BM-X (Fig. 6).

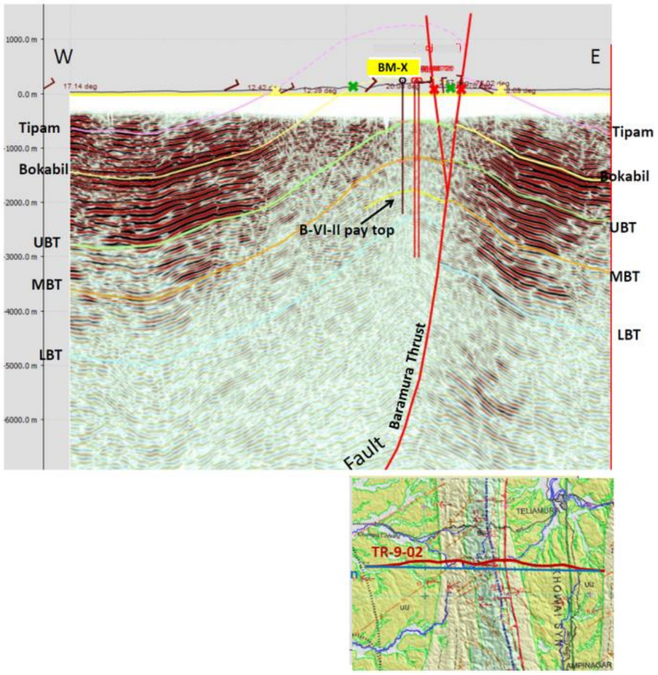

Fig 6. Structural Model across reprocessed 2D line

Present day 2D structural model of Baramura anticline has been generated through integration of surface geological, well and seismic data.

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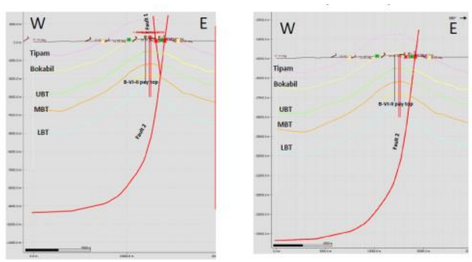
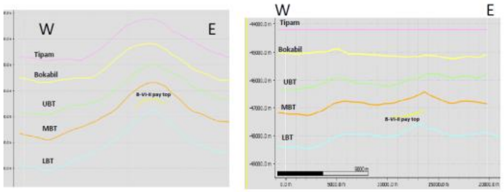


A) Original Model B) Fault 1 restored



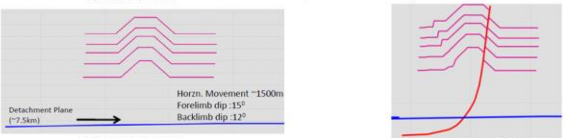
c) Fault 2 Restored B) Flattended at Tipam

Figure 7. Restoration along 2D seismic line

The model was validated through restoration and forward modeling. Restoration involved removal of displacement along the fault and unfolding of horizons (Fig. 7A-D). No major issues related to horizon length and stratal thicknesses across the fault blocks were observed. B-VI-II top marker is a trace of an intersection between well based structure map and 2D seismic line.

Forward modeling indicates, Baramura anticline is initially developed by a detachment fold mechanism followed by break through thrust at the forelimb resulting into present day structure (Fig. 8A-D).

A) Initial deposition C) Forward Model and Original model after fault restoration validates geometry



B) Detachment Folding D) Break through fault

Figure 8. Forward modeling along 2D seismic line

Structure and Isolith Maps

Key differences have been observed with respect to earlier geological model (Fig. 9). While, northern part of central Baramura is shown flat in earlier model but integration of G&G data in present study reveals plunging in the north and narrowing in overall structure (Fig. 9).

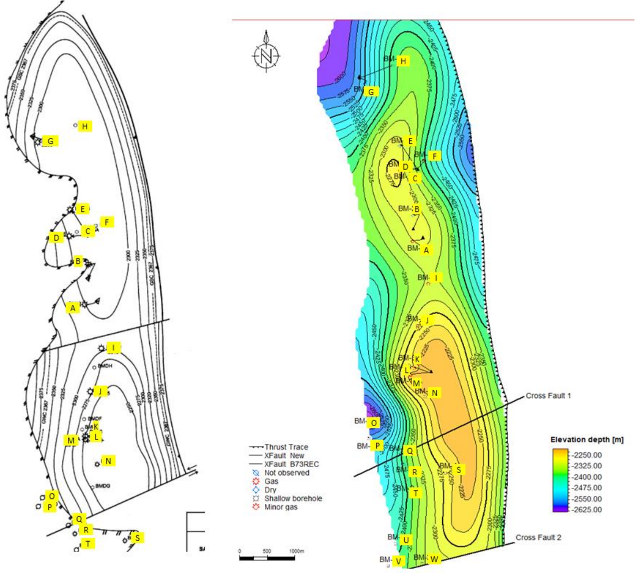


Figure 9. Earlier sand relief map vis-a-vis present sand relief map

As a result of this, BM-H which was drilled upto 2628m MD did not penetrated B-VII-III and explains why this well did not give expected results. In BM-D cluster, BM-D was initially tested in B-VII-III sand (lower part) and gave 180834m3/d gas during initial testing but due to fish could not be completed in this pay. Therefore, a substitute well BM-C was drilled (27 years later) which on testing produced water. It is important to note the year of testing of BM-C and BM-D i.e 1990 and 2017 (a gap of 27 years) as it has implication on envisaged geological model.

This sand is being exploited from shallower part of the structure from wells BM-J and BM-I since 1989 and has given a cumulative production of ~700 MMm3 (1.1.2019). BM-I got sick in 2006 and all attempts to its revival failed and well got abandoned in 2014 (Fig 11).

In present study, it is shown that all sands of B-VII-III are hydro dynamically connected (Fig. 10) and due to exploitation from shallower part of the structure, GWC has moved from initial 2367 (BM-I) to 2333m (BM-C). This new GWC explains the reason for water flooding in BM-I and presence of water in a substitute well BM-C (Fig. 11).

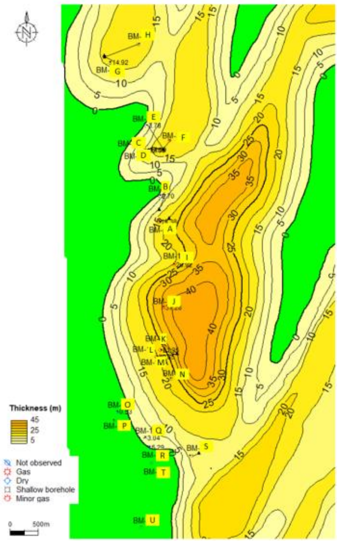


Figure 10. Isolith map of B-VII-III pay

Geological Cross Section

An intersection across the structure maps of B-VII-III, and B-VII-II in NNW-SSE direction passing through BM-N, BM-L, BM-J, BM-I, BM-A, BM-B, BM-D and BM-H (Fig. 11) shows the structure configuration and explains sand behaviour based on reservoir production and GWC movement associated with it. Production from shallow wells has resulted in movement of GWC in B-VII-III pay and have drained the structure around BM-C/D and BM-A. Shallower part of the structure i.e. around BM-N holds remaining reserve and venturing further south is advisable.

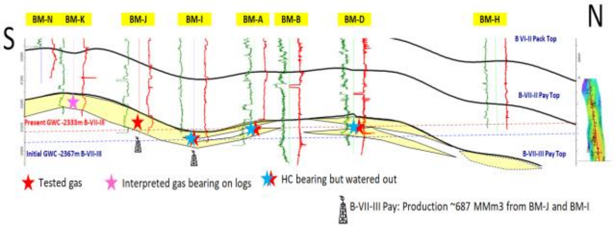


Figure 11. Geological cross section showing B-VII-III pay dynamics

Conclusions

Main objective was to evaluate the pay dynamics of the B-VII-III pay within Middle Bhuban in northern part of Central Baramura. The present model shows that due to 1) deepening in the north (plunging of structure) as brought out by electrolog correlation and observations obtained from surface geological map and 2) upward movement of GWC due to ~700 MMm3 of gas production has resulted into the water encroachment in well BM-C (suggesting hydrodynamic continuity of sands). Therefore, exploration and exploitation of B-VII-III pay should be targeted in up dip at shallower structures in the south.

Deeper sands in similar setup are expected to be present in this area and their exploration will open up a new frontier.

Present article also highlights the methodology adopted for geological evaluation of a pay in a scarce data set by integrating structural modeling and reservoir production data.

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