EXPLORATION CHALLENGES IN TRIPURA FOLD BELT, ASSAM & ASSAM ARAKAN BASIN, INDIA

A.K.Jena*, EdithaMarydhan, V.L.N Avdhani & P.P Deo
CEWELL, ONGC, Makarpura Road, Baroda-390009, India
e-mail: jena_ak@ongc.co.in

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Summary
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. There are concealed structures like Agartala Dome, Kunjab an etc and exposed structures like Rokhia, Baramura, Gojalia Tulamura etc. The main producing formations are paysands belonging to Bokabil, Upper Bhuban, Middle Bhuban and Lower Bhuban formations. In this paper some of exploration challenges and play concepts are being discussed. The continuing exploration successes in Kunjab an, Konaban, Manikyanagar have rekindled our perception about the new plays in different paradigm. But the exploration challenges are Discrete sand bodies with rapid facies variation, Determination of axial region of the structures, Synclinal exploration, Exploration in Plunge parts of the structures, Difficulties in petrophysical evaluation are some of the areas which require more focussed approach in Tripura Fold Belt. Interpretation of Hydrocarbon bearing sands where resistivity contrast is poor with high resistivity shales is also an exploration challenge.

This paper discusses some answers to these problems with a contemporary approach. Only a logical thinking of the possible entrapment model is the answer. New discovery KUP-60 paysand in well KU-H which is a discrete sand, has been mapped precisely with RMS attribute studies where the sand pack thickness is about 22m and the entrapment is stratigraphic, narrow axial regions in some anticlines has been discussed with possible area of exploration, small culminations and relict features, in synclinal areas with argillaceous facies as drape is the entrapment condition. In the low contrast resistivity reservoir in a Baramura well has been addressed with suitable petrophysical model using proper mineralogical suit to identify presence of hydrocarbon which produces @ 1,30,000m3/d. These aspects are elaborated in this paper.

Introduction
The Tripura-Cachar Fold Belt of the Assam and Assam Arakan Basin (Figure 1) 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). Recent discovery of Gas in KUP-60 paysand of middle Bhuban Formation in well KU-H of Kunjaban structure has a different dimension in exploration which needs to understand proper entrapment condition in discrete sand bodies with rapid vertico-lateral facies variation. Axial exploration for mostly un-explored logistically difficult Tulamura Anticline for deeper Upper and Middle Bhuban formations is a new challenge where few new 2D seismic lines have been acquired. The broad flat synclines between anticlines have become target for stratigraphic traps and concealed structures. To fulfill the increasing demand of a steady supply of gas to Tripura...
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 massif. 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 Venkatraman,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 Bhuban (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 like Evans(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

**Exploration pursuits to tackle rapid facies variation and discrete sands**

The hydrocarbon plays of some recently discovered...
Kunjaban Structure

Kunjaban structure is a concealed structure in northern plunge part of Agartala Dome. Kunjaban structure got its prominence in the year 2007 with significant exploratory lead in well KU-B in KUP-35 pay sand belonging to Upper Bhuban Formation. Though earlier in first well KU-A, KUP-40 paysand belonging to Upper Bhuban Formation has produced about 1200m3/d gas with water, the major breakthrough was well KU-B in which KUP-35 paysand belonging to Upper Bhuban formation produced gas @ 2,25,000m3/d. But the same sand was not found in two updip wells. Gas producing KUP-56 paysand of Middle Bhuban formation found in KU-A found water bearing in KU-A. Similarly thick KUP-30 paysand (about 25m) could not be found in any of the nearby well. Peculiarity of this paysand is that it produced gas @ 53,664m3/d along with water @140m3/d. The top 1m of this paysand is Gas bearing and rest portion is water bearing. A new paysand KUP-60 belonging to middle Bhuban Formation was found producing gas @ 2,03,613m3/d through 10mm bean in recent discovery well KU-H. Equivalent of this sand is not found in nearby KU-A well. This type of rapid facies variation and discreteness of the sand bodies poses grave exploration challenges. (Figure No2a,3) But this discrete sand, has been mapped precisely with RMS attribute studies where the sand pack thickness is about 22m and the entrapment is stratigraphic (Figure 2a). This type of sand bodies are typical of tidal bars, channels and tidal flats. There are discrete sand bodies belonging to tidal bars or channels. Clay filled abandoned channels or drapes with argillaceous facies in tidal/mud flats. Sometimes the sand bodies are thinly laminated as in the case of KUP-56. The thicker sand bodies like KUP-30 (Figure No 4) could be possibly resolved with attribute analysis. But thin sand bodies like KUP-35 sand found in well KU-B is difficult to delineate with 3D attribute analysis. Understanding the depositional environment and sand geometry analysis is some answer to delineate these discrete sand bodies. For example a thick sand unit like KUP-30 could not be traced in adjacent areas, particularly in updip direction so that this sand unit which is mostly water bearing except the top 1m could be totally gas bearing. This sand extension with RMS attribute could not be mapped due to data gap in acquired 3D seismic data due to rapid urbanization in Agartala City.

Khubal Structure

Gas discovery in Khubal Structure in eastern Tripura was the biggest news in the year 2009. A 52m thick sand(KHL-
60) belonging to Lower Bhuban formation in well KH-D (the fourth well in this structure) produced gas @ 1,54,000 m³/d through 8mm bean. Already 9 wells have been drilled in this structure and the 10th one is under drilling. But except KH-A where KHL-60 paysand produced commercial gas @ 1,54,000 m³/d and KH-G where KHL-10 paysand produced sub commercial gas @ 40,000 m³/d, success has eluded us in other wells. In three wells HF was attempted in different sand units with geomechanical studies but to no avail. The sand units are found to be discrete in nature and look to be deposited as a complex system of stacked tidal bars/Channels with Mud flats. In well KH#D, the 52m producing Lower Bhuban sand pinches out towards KH#E and in KH#F, it becomes shaly. So a careful exploration strategy should be adopted to identify the vertico-lateral dispersal of discrete sands and their entrapment model. Petrophysical evaluation of sands is also a challenge due to bad hole conditions and paucity of good quality logs. So developing a proper petrophysical model will also guide in future for formation evaluation. 3D seismic data has been acquired in this area though the data quality is not upto mark. Attempt has been made to map the sand bodies by attribute analysis. But it is found that though there is no dearth of sand units in these wells, but there is no HC entrapment. So proper understanding the extent of these sands, sand orientation pattern and proper entrapment condition is a challenge. So this type of discrete sands which are stratigraphic nature can be explained with shale draping or in small culminations. We should remember that the sand units in Konaban and Agartala Dome area are extensive like KP-55 or KP-65etc found in Konaban structure. They are distributary mouth bars and channels. But same is not the case in Khubal or Kunjaban area.

Axial Exploration

Tulamura Structure

Tulamura structure was put on the gas map of Tripura Fold belt for the first time in 2009 when a shallow reservoir TS-20 of well TLM-X (the first well) produced gas @ 50,000m³/d in Northern plunge part of Tulamura anticline (Figure No5,6,7) in axial region. Tulamura Anticline is a linear, NNW-SSE trending doubly plunging, asymmetric anticline. The western limb of the anticline is gently dipping and relatively undisturbed. The eastern limb is steep and faulted with a major reverse fault. The anticline is also dissected by number of cross faults. Bokabil and Tipam formations are exposed in this anticline. Bokabil Formation is exposed in the core of the anticline, whereas the Tipams are exposed along the flanks. Exploration in this logistically difficult anticline started quite late in 2009 when the first well drilled in this structure TLM-X produced gas from a shallow reservoir TS-20 belonging to Upper Bhuban formation. Earlier with few 2D lines and geological map subsurface mapping was done. Recently after acquiring few 2D lines in the southern part of structure, subsurface mapping has been done to a greater extent. However 3D seismic data acquiring still remains a
difficult proposition because of logistics problem. Two released locations are there for deeper prospects. From the seismic sections the axial part looks to be promising from HC point of view. So axial exploration in the southern part of the anticline should be taken up for deeper prospects in Upper and Middle Bhuban formations. Prospectivity of Lower Bhuban formation cannot be ruled out in relatively shallower depth. The southern plunge part of Tulamura Anticline falls in Bangladesh. Some authors (Roychoudhary et al) believe that southern plunge part of Tulamura Anticline will be promising from HC point of view in proximity of small Hatibari Depression flanked by Gas Fields like Feni and Semutang of Bangladesh unlike southern plunge part of Baramura Anticline which proved dry.

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. It can be observed in structure contour maps at Upper Bhuban (Close to MFS) that most of the wells falling on the axial region are hydrocarbon producing. Similarly the southern culmination is prospective at both upper and Middle Bhuban levels.

Synclinal Exploration

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 8a). 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. It can be observed in the seismic section AA’ (Figure 8b) 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.

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). 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 9a that the sand of well BRM#Y which is producing @ 1,30,000 m³/d gas though 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
calcereous 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 9b). 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 with appropriate log derived petrophysical parameters integrating detailed core studies to avoid missing zones.

**Conclusions**

- Understanding the depositional environment and sand geometry analysis is some answer to delineate the discrete sand bodies found in Kunjaban Structure as well as Khubal structure.
- For thick sand packs RMS attribute study has enabled to map pay sands like KUP-60 of KU-H. Proper attribute analysis should be carried out to identify the HC bearing sand bodies and it’s equivalents where 3D seismic data is acquired.
- The sand bodies of Upper and Middle Bhuban Formations are discrete in nature sand bodies belonging to tidal bars/ channels or clay filled abandoned channels or drapes with argillaceous facies in tidal/mud flats in Kunjaban structure. The sand units in Khubal structure are found to be be deposited as a complex system of stacked tidal bars/Channels with Mud flats.
- Determination of axial region of the structures is very important particularly in the structures like Tulamura, Baramura, Gojalia etc to avoid wells falling to water bearing parts of the reservoirs.
- Synclinal exploration should be stepped up after success of Sundalbari and Khubal structures understanding the entrapment condition like small culminations relict features with shale drapes in synclinal areas.
- Proper petrophysical model enabled to identify low contrast HC bearing sand in Baramura-Y. So proper petrophysical model is the answer integrating with detailed core studies and mineralogical model to avoid missing zones where gas effect is not visible properly on logs.

**References**


Jena A.K., Das N.C., Saha G.C and Samanta Asim, 2011, Exploration in synclinal areas of Tripura fold belt, India : A re-found opportunity : Proceedings of AAPG Annual Conference & Exhibition at Houston,Texas,USA.


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