5th Conference & Exposition on Petroleum Geophysics, Hyderabad-2004, India PP 767-771

Geodata Integration Leads To Reserve Accretion In Baramura Gas Field of Tripura, Assam-Arakan Fold Belt – A Case Study

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ABSTRACT : Subsurface maps prepared during the 1980s for the reservoir sands of the North-South trending Baramura gas field in Tripura had steeper flanks and plunge with a low angle eastern bounding reverse fault and a number of NW-SE oblique normal faults. As the production from the main pay sand A72 in the block of well BG exceeded its ultimate reserves, a total re-assessment of the field was undertaken. First step of the study was an in-depth analysis of the subsurface maps, geological cross sections, parameters of reserve estimation and the surface and subsurface data that were the basis of earlier model. As a next step, interpretation of the available 2D seismic data was done by tying up with the well data, as well as, with the VSP data and an isochron map was prepared for a reflector close to the Middle Bhuban Formation top. Qualitative analysis of the well logs was done with a clear understanding of well data viz., cores/cutting lithology, drilling rate, pay sand correlation and testing details. Re-evaluation of the logs was carried out with latest software and realistic petrophysical values were obtained by using recently worked out *a, m, n* parameters. Integration of the VSP and seismic data with surface geological, remote sensing, log re-evaluation, dipmeter, production and reservoir data resulted in a major revision of the geological model. The Baramura Anticline, as brought out by this study, has gentler flanks and plunge. The angle of reverse fault is comparatively higher and the orientation of cross faults conforms to regional ENE-WSW trend. Broadening of the structure and increase in the thickness of the main pay sands has brought about remarkable increase in the rock volume at the crestal part, leading to substantial accretion of gas reserves.

INTRODUCTION

The Tripura Sub-Basin, covering about 11,000 km^2 area, in the western frontal part of the Assam-Arakan Fold Belt is bounded by Chittagong hills in the south and Sylhet Depression of Surma Basin in the north, the latter two fall in Bangladesh. Tripura Fold Belt comprises of a series of N-S trending elongated, arcuate, folded anticlines and synclines, formed during Pleistocene period (Ganguly, 1993). The Surma Basin with over 20,000 km^2 thick sediments with fair amount of predominantly terrestrial organic matter, has served as a vast kitchen (Curiale et al., 2002). The generalised stratigraphy and elements of petroleum system of Tripura are given in Figure 1.

Baramura structure, falling in western Tripura, is a N-S trending, about 100 km long, doubly plunging, asymmetric anticline, with gently dipping western limb and steep and reverse faulted eastern limb (Figure 2). Baramura gas field is the first discovery in Tripura. So far 24 wells have been drilled and 13 wells are gas bearing with ten pay sands. A72 and A73 gas sands (2250-2600m) within Middle Bhuban Formation are fairly extensive and together constitute about 90 % of total ultimate reserves.

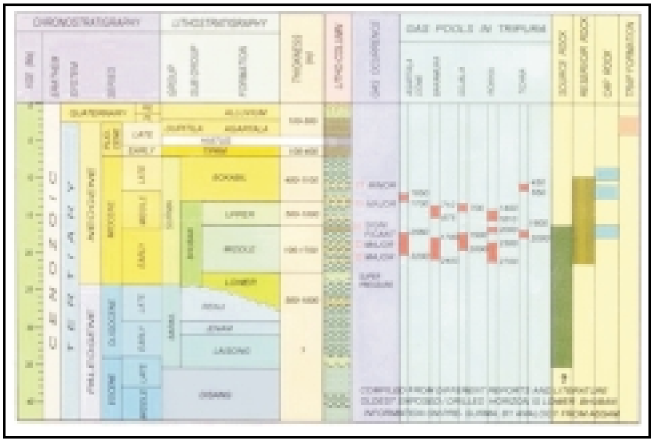

Figure 1: Generalised Stratigraphy and Petroleum System chart of Tripura.

Sustained water free gas production with a steady reservoir pressure from the pay sand A72 through the well BG indicated presence of a far higher volume of hydrocarbons than estimated. The present study, undertaken to refine the model, includes the analysis and integration of data acquired in Baramura Structure pertaining to, seismic, VSP, well logs,

Figure 2: Geological map of Baramura showing exposed stratigraphy, major structural features and the area of study.

dipmeter, field geology, photogeology, wellsite geology, testing, production, reservoir and laboratory studies.

PREVIOUS WORK

Mitra et al. (1968) described the surface geology and discussed the subsurface stratigraphy, petroleum geology and prospects of discovering hydrocarbons in Tripura. After gas was struck in 1975, estimation of reserves was done using geological models that did not consider seismic data owing to poor data quality at the crest of the anticline. However the attempts to interpret the subsurface by integrating the seismic, VSP and well data (Kharak Singh et al. 1996) were useful for successful drilling in some structures of Tripura.

In the earlier models the Baramura anticline appeared to be tightly folded with lesser area and rock volume in the crest; the longitudinal Baramura fault was considered as a low angle reverse fault with steep limbs and plunge, and was affected by NW-SE oriented oblique normal faults. Wireline logs were interpreted by using certain initial assumptions such that in the pay sand A72 the Gas Water Contact (GWC) was taken in the middle of the sand.

PRESENT STUDY

The geoscientific information obtained during the last 13 years aided by the refinement in techniques has helped to improve the understanding of this structure. Six wells were drilled in Baramura; one in Khowai-Kalyanpur (KA) and VSP was recorded in four wells BV, BW, BX and in KA. Seismic data of TR 18 and 19 series was acquired in the eastern flank and Khowai syncline. High-resolution satellite imagery was integrated with the photogeology and field geology maps using the latest GIS software by Dotiwala et al. 2000. Recently published Seismo-tectonic atlas of India, by the Geological Survey of India (2000) has added to the understanding of the regional structural style of Tripura, particularly to the ENE-WSW orientation of the cross faults.

MODIFIED GEOMETRY OF BARAMURA STRUCTURE

VSP and 2D seismic data of different vintages correlated and tied up from Agartala Dome on the west to Khowai syncline on the east is the most important input in revising the model of Baramura structure. Interpretation of two east-west dip lines GA and GD, in addition to the other lines available, have enabled to refine the fault geometry of the main longitudinal reverse fault. Angle of the fault is higher in comparison to the earlier interpretation shown as dashed line in Figure 3. By incorporating VSP and well data an isochron map was made for a horizon close to middle Bhuban top (Figure 4). The map enabled identification of major cross fault ENE-WSW oriented cross faults CF1, CF2 and CF3. The northern and central culminations are separated by a sinistral strike-

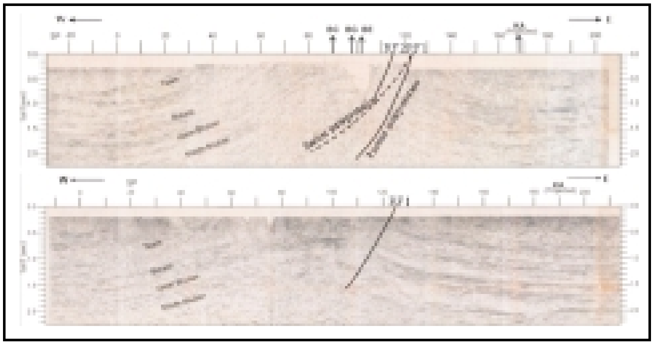

Figure 3: Seismic sections across Baramura anticline; section GA passing close to the well BG at the structurally highest part has poor quality data while the section GD on the northern plunge has better resolution. Re-interpreted fault position is shown as dashed line on the line GA.

slip fault CF1. Another major sinistral strike slip fault CF3 causes a sharp westward swing of the structure. CF2 is a dextral fault between wells BE and BG inferred on the basis of surface geological information and pay sand distribution.

By integration of seismic data with surface geology information, well data, dip meter of several wells, and pay sand correlation, geological cross sections in the dip direction were prepared. Figure 5 and 6 clearly bring out the differences between the earlier model and the revised model. It is brought out that the main longitudinal fault of Baramura is a high angle reverse fault, RF1 traceable from surface to Middle Bhuban. About 500 -700 m west of the main fault is another reverse fault RF2 which dies out in Upper Bhuban formation. Between these two faults a zone of intense deformation is interpreted. High dip values near the fault zone at surface but gentler dips at deeper levels as per the dipmeter logs indicate a higher effect of deformation closer to surface that diminishes with depth.

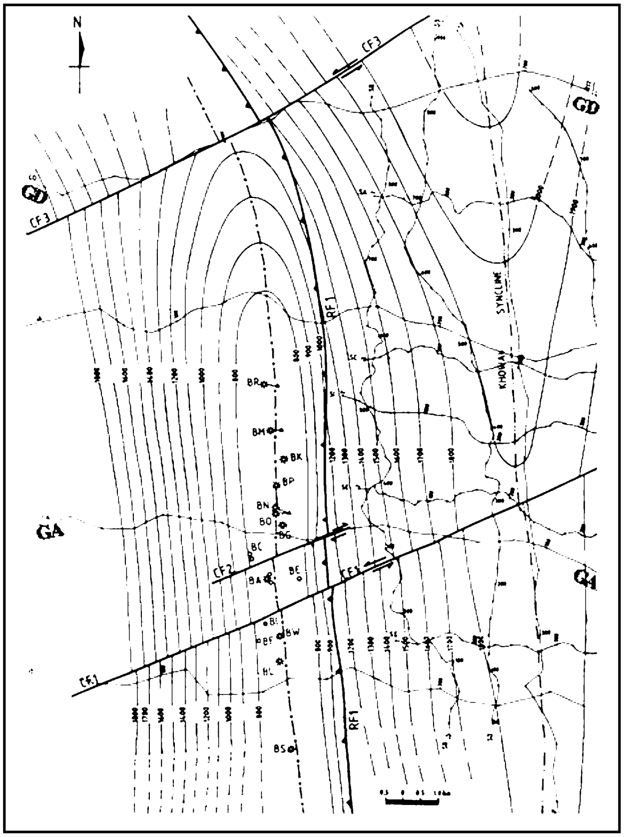

Figure 4: Isochron map for a horizon close to Middle Bhuban top prepared by incorporating VSP and well data tied up with the seismic data of different vintages and correlated from Agartala Dome on the west to Khowai syncline on the east of Baramura anticline.

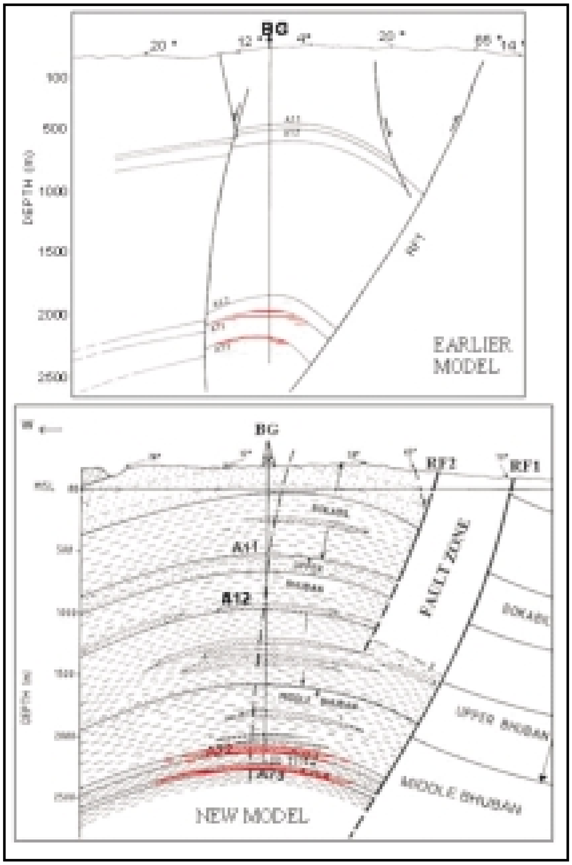

Figure 5: Geological cross sections along the same profile passing through well BG for comparing the previous and new models. The new one prepared by integrating seismic data of line GA, surface geology information, well data, dip meter and pay sand correlation shows more lateral extension of the gas pools.

Compared to the earlier maps for the deeper sand A72, the Baramura reverse fault RF1 is further east, the dip of eastern flank is gentler and the structure is broader. The isochron map as well as surface data indicates that the anticlinal axis runs N–S from the well BG to about 4 Km north of the well BP with a very gentle plunge without much westward curvature. Therefore the fluid contacts of the main pay sands have extended significantly thereby creating more reservoir volume due to broadening of the structure.

RE-EVALUATION OF WIRELINE LOGS

In the log interpretation reports for wells of BG, BN and BO the Vshale estimated for the entire A72 pay sand was same assuming uniform lithology as there was no shift in

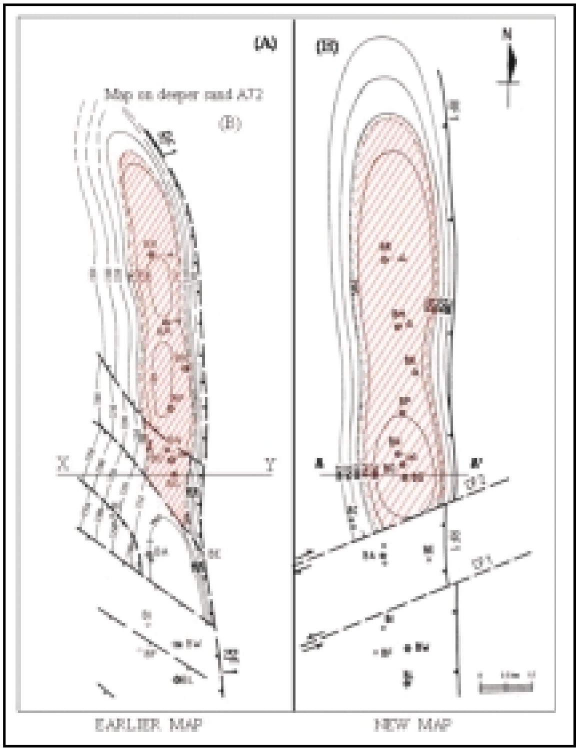

Figure 6: Comparison of the earlier and new structure contour maps prepared on top of the pay sand A72. The earlier model had a narrow structure with a smaller gas pool while the revised map shows significantly bigger area of the gas pool resulting from re-interpretation of data particularly the seismic, dipmeter and wireline logs.

Gamma ray log for whole of the sand. Therefore the drop in resistivity in the middle of this sand was attributed to water and the GWC was marked at that depth 2325m log depth in well BN. Figure 7 illustrates the complete set of logs of well BN, interpreted logs showing porosity (%), matrix density (gm/cc), water saturation (Sw %) and shale volume (Vshale %). In addition to the GR, SP, Caliper and bit size in the first track, the drilling rate (Rate of Penetration, in minutes per meter) is shown.

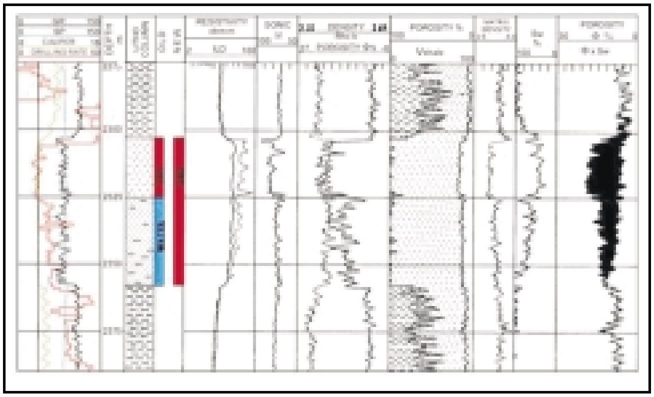

Figure 7: Log responses of the pay sand A72 in the well BN of Baramura showing earlier interpretation of GWC at 2325m and constant Vshale for the entire sand. Note the present interpretation of the entire sand as gas bearing and change in log responses as well as drilling rate correspond to clean sand above and silty sand below 2325m.

Qualitative log analysis with a clear understanding of cores/cutting samples lithology, drilling rate, pay sand correlation, initial testing, production and reservoir data has demonstrated that the drop in resistivity in the middle of the pay sand is due to a sharp change in the lithology from clean sandstone above to silty sandstone below and not because of change in the nature of fluid. Figure 7 also shows that the upper half of the A72 sand is clean, while the lower half is silty and more consolidated. This is clear from the density and sonic logs as well as the drilling rate plot. Therefore, the entire A72 sand is interpreted to be gas bearing with a shale contact, the drop in resistivity reflects variation in lithology and the Gamma ray log does not vary with lithology in this case.

Well logs of six wells BG, BM, BN, BO, BP and BR were re-evaluated using advanced software and latest *a*, *m* and *n* parameters for pay sands A72, A73 and para-logs were prepared. The para-log for well BN showing Gas Shale Contact (GSC) is depicted in the Figure 8. It confirmed the qualitative interpretations that wells of BG, BN and BO do not have a GWC in the middle of the A72 pay sand. Hence a common GWC encountered in the well BJ was taken for the entire block with a higher pay thickness again resulting in a higher volume of reservoir.

CONCLUSION

- The geological model for reserve estimation of Baramura structure used during 1980s relied mainly on the sub-surface conceptualisation of the surface geological data, without the help of the available seismic data. It has been revised to account for the excellent production performance of A72 reservoir.
- Integrating the VSP and seismic data interpretation with other surface and sub-surface data, the geological model of Baramura anticline was revised. It shows gentler flanks and plunge of the structure with a higher angle of the main reverse fault (RF1) and ENE-WSW orientated strike slip faults.

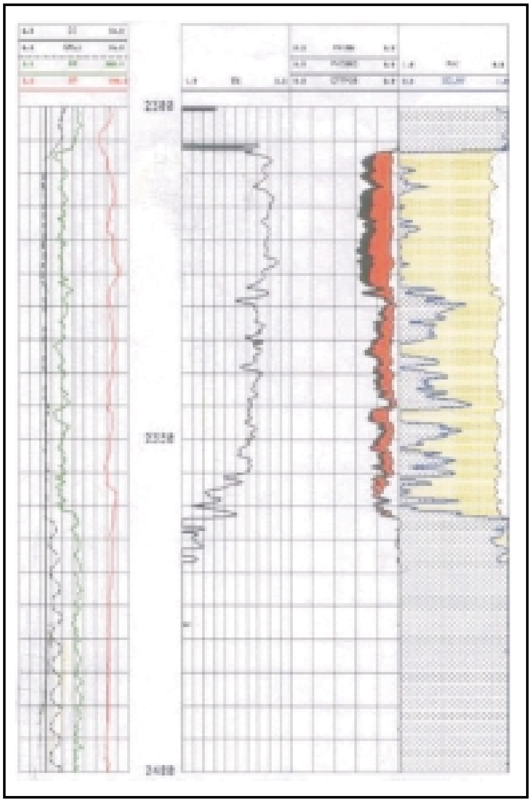

Figure 8: Result of log re-evaluation of well BN of Baramura gas field showing entire sand as gas bearing. The drop in resistivity corresponds to change from clean sand above to silty and tight sand having higher Vshale. Compare with Figure 7 for earlier interpretation.

- Effective utilization of seismic data, due diligence in examining the data and concepts used in previous models, honoring the regional structural style, systematic approach to data integration and careful qualitative log interpretation led to the development of a new model that resulted in substantial accretion of reserves in Baramura gas field in 2003.

- This study also demonstrates that an integrated approach to seismic, VSP and wireline log data interpretation is absolutely necessary in view of the heterogenous nature of the reservoir sands and the first order structures of Tripura.

ACKNOWLEDGEMENTS

The authors are highly indebted to Shri S.K. Majumdar, ED-Basin Manager, A&AA basin for constant guidance and motivation during the course of this study. The value addition done by Shri S.Choudhury DGM-Block Manager, AAFB in improving the fault geometry is gratefully acknowledged. Without the invaluable support of the colleagues of the Agartala Forward Base, particularly Dr.K.K.Das, SG, this task could not have been accomplished. Special thanks are due to Shri P.P.Deo SG(W), Jorhat for re-evaluating the logs. The views expressed are of the authors and do not necessarily reflect the views of the organization they belong to.

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