Addressing the Challenges of Wellbore Stability in Complex & Tectonically Active Area of Tripura Fold Belt through Integrated Geo-mechanical Studies

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Overpressure, Unloading, Wellbore failures, Horizontal stresses, Leak of Test (LOT)

Summary

Tripura Fold belt has huge amount of natural gas reserves. The uplifted Tripura fold belt has undergone severe folding, faulting and thrusting during the different phases of post collision events. The study area has complexity in terms of overpressure, high stress and lithology. ONGC has drilled several wells in the region with encouraging result, but the main challenges faced during drilling were various well control and instability issues like: kicks, tight pull, and stuck pipe, lost in hole (LIH) etc. Past drilling experience indicated the existence of overpressure in middle and lower Bhuban formations. Drilling through these high stressed and overpressure formation led to excessive non-productive time (NPT), thereby increasing the drilling cost. Borehole instability and severe hole enlargement led to poor log data acquisition thereby affecting the reservoir characterization.

In this paper, based on advanced logs, drilling and other geo-scientific data integrated Geo Mechanical Earth Model for Upper, Middle & lower Bhuban formations of Rokhia, Agartala Dome & Baramurah fields has been prepared. The study has led to reduction in drilling NPT, understanding of the fact that unloading mechanism being one of the main reason for overpressure generation in middle and lower Bhuban of these fields. The suggested mud weight window and drilling direction can greatly help in improving drilling performance, reduce drilling NPT and aid in quality log data acquisition, thereby assisting in better log based reservoir characterization.

Introduction

Tripura fold belt is a part of Neogene Surma Basin (Assam-Arakan Basin). The complexity of the Tripura Cachar Fold Belt arises due to collision of the Indian plate with Burmese plate at the east and subsequent collision with the Eurasian plate at the North. The uplifted Tripura fold belt has undergone severe folding, faulting and thrusting during the different phases of post collision events leading to further regional complexity in litho-facies. Exploration in this region (Fig. 1) has been very challenging due to complexity of structures and lithology.

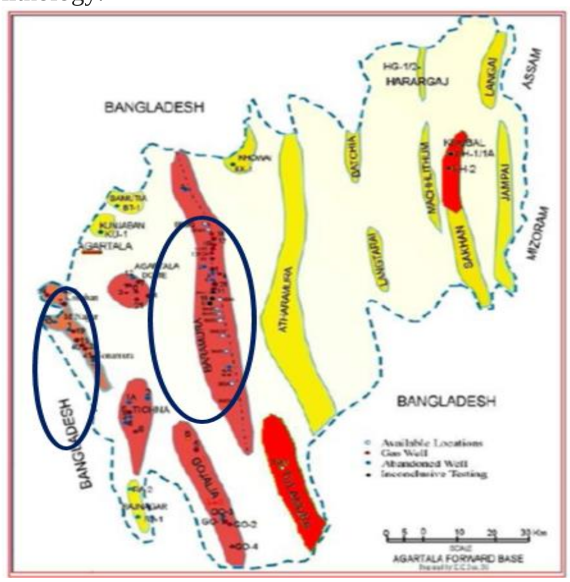

Fig. 1 Map of the study area

ONGC has drilled several wells in the region with encouraging result, but the main challenges faced during drilling were various well control and instability issues. Past drilling experience indicated the existence of overpressure in middle and lower Bhuban formations of Rokhia, Baramurah & Agartala dome structures. Due to enlarged and rugose hole conditions against these formations, logging was limited and recorded logs were of poor quality in many wells. Non-availability of advance logs like full wave form sonic, image & formation pressure

measurements in Middle & Lower Bhuban gave rise to poor understating of reservoirs and led to uncertainty in formation evaluation. A need was felt for understanding the mechanism of overpressure generation in these formations, develop comprehensive 1D mechanical earth model for these complex and tectonically active region, thereby addressing challenges of wellbore stability and minimize drilling NPT.
Depending on the availability of advance logs, total ten numbers of wells distributed over Rokhia, Baramura & Agartala Dome was considered for the study.

Methodology

A tailor made workflow(Fig.2) consisting of integrated petrophysics , geomechanics and drilling data was adopted to characterize the overpressure in Middle & Lower Bhuban formation, generate wellbore stability models and optimize mud weight for drilling the wells in the area. Borehole image analysis was done to pick compressive and tensile failures. Geomechanical zones were created based on breakout widths. This data was used to model the magnitude of horizontal stresses and calibrated with available Leak-off Test (LOT). Image and full wave form sonic data was used to obtain the direction of maximum horizontal stresses.1D Geomechanical model was calibrated by simulating borehole failures for given pore pressure, rock strength and earth stresses and matching them with actual wellbore failures seen on image and caliper logs.

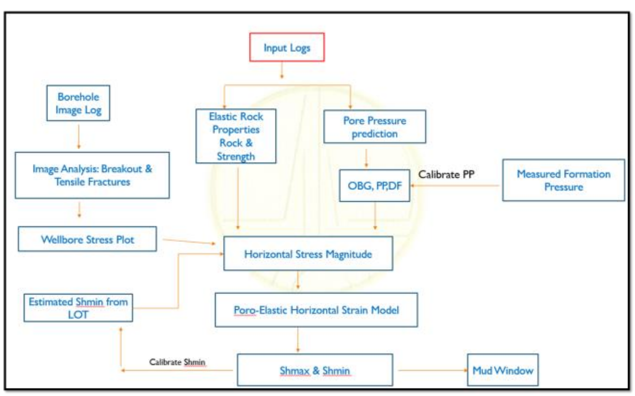

Fig. 2 Workflow adopted during study

1D mechanical earth model comprises of pore pressure, elastic properties, rock strength and earth stresses. Pore pressure was computed using Eaton's trend line method for type-I (overpressure due to under compaction) and Bower's method for type-II (over pressure due to unloading, clay diagenesis, thermal cracking of Kerogen etc.)

Image Log Analysis was done to pick borehole breakout and drilling induced tensile fractures (Fig 3). Based on the breakout width (Fig.4), Geomechanical zones were created and was further used to model the magnitude of maximum horizontal stress. Poro-Elastic Horizontal strain model was used to compute SHmax & Shmin and calibrated with available LOT data.

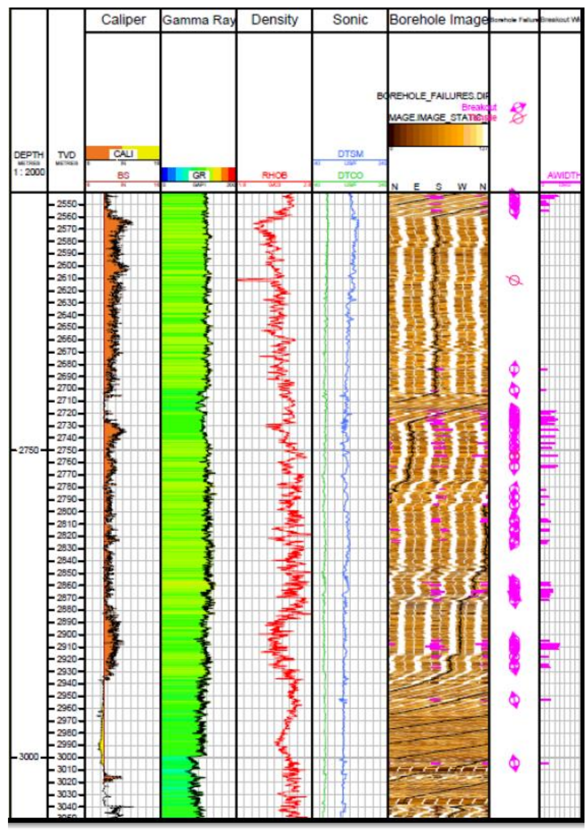

Fig.3 Breakout picked on image log of well R-1

Cross-Dipole full wave form sonic data has been processed to obtain the direction of Shmax(Fig.6 &7).Shmax direction obtained from failure analysis of Resistivity Image log & anisotropy analysis of

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advance sonic log of well R-1 (Fig.8) are in good agreement with each other.

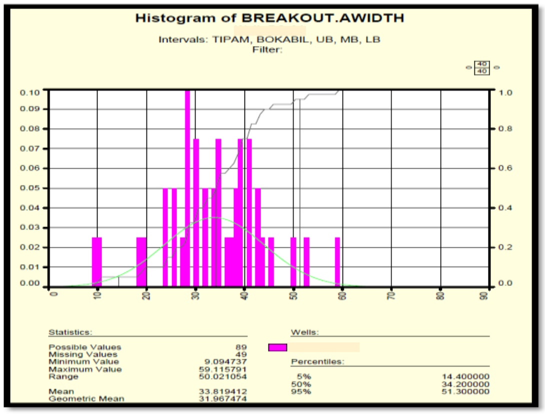

Fig.4 Breakout width histogram of well R-1

The direction of Shmax was obtained from image log, caliper and advance sonic data processing.

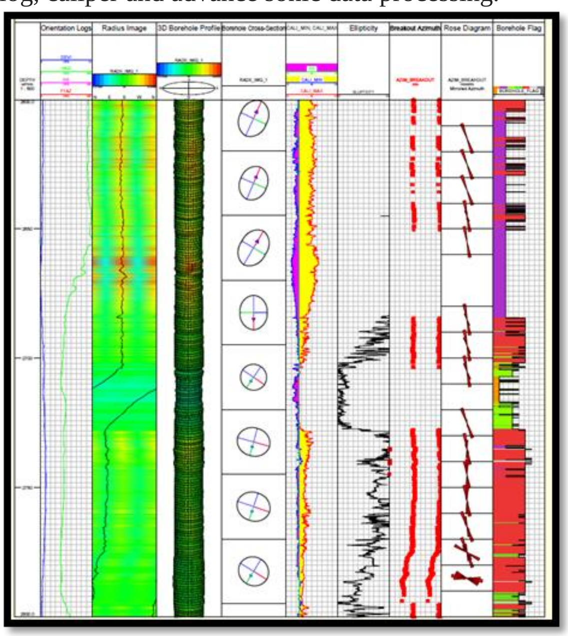

Fig.5 Caliper log analysis to the direction of Shmax of well R-1

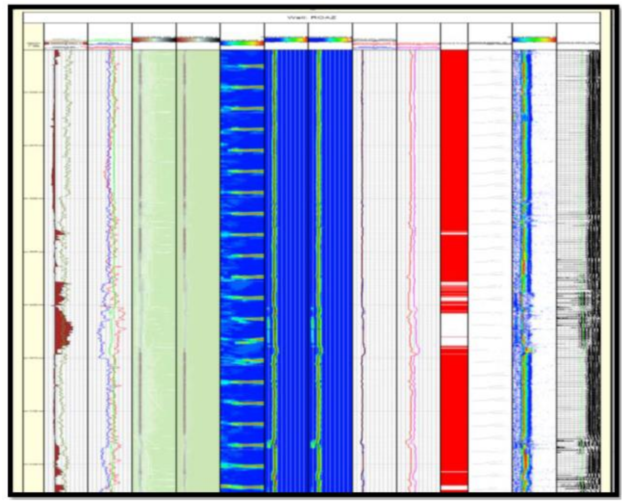

Fig.6 Dipole full wave form data for anisotropy processing of well R-1

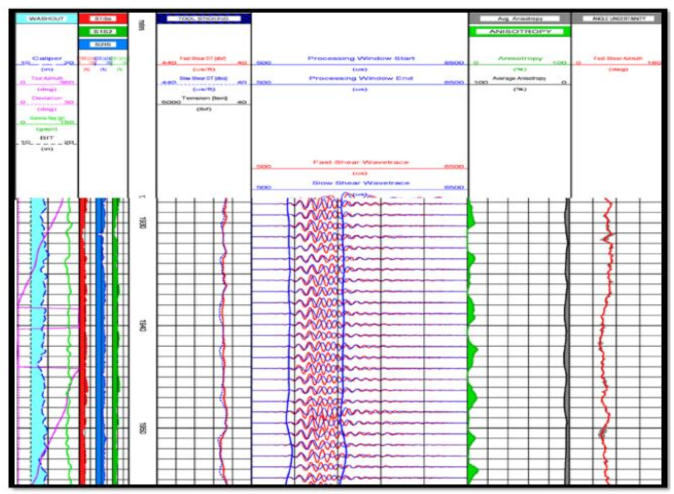

Fig. 7 Advance sonic log showing the direciton of Shmax in Well R-1

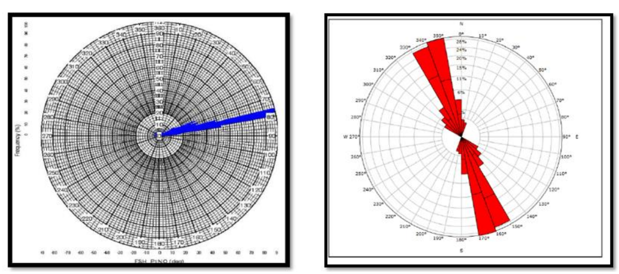

Fig. 8 Shmax direciton from Sonic log & Shmin direciton from Image log of well R-1

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Understanding Overpressure Mechanism & Wellbore Stability

Understanding the reason for Pore pressure generation is the key to accurate pore pressure prediction in the area. Velocity vs Density cross plot (Fig. 9) is known as Hoeseni's plot .It is a helpful technique used to differentiate between different mechanisms of overpressure generation in the study area. In Fig.9, data points lying on trend A represents over pressure due to Normal Compaction, that on trend B represents due to Unloading and trend C represents that due to diagenesis plus unloading.

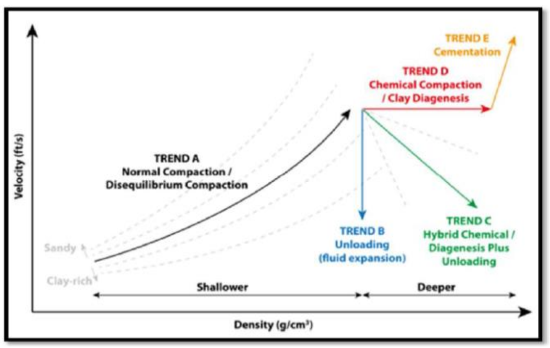

Fig.9 Velocity Vs Density plot

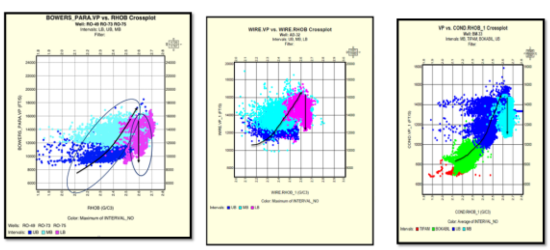

Fig.10 Hoeseni's plot showing unloading against MB & LB of wells R-1,R-2, A-1 & B-3

Fig. 10 shows that against UB in all the wells, the trend is A .i.e the cause of over pressure is due to disequilibrium compaction; where as a clear trend B is seen against Middle and Lower Bhuban representing the cause of overpressure to be unloading. Tipam, Bokabil & upper Bhuban is normally pressured (hydrostatic) in Rokhia, Agartala Dome & Baramurah area, whereas as Middle and lower Bhubanis over pressured.

Bower's plot (velocity vs effective stress) is used to compute loading & unloading parameters. Loading curve denotes overpressure mechanism due to under-compaction (rapid burial) and is classified as Type-I. Unloading curve denotes overpressure generation due to uplift, clay digenesis, fluid migration etc. and is classified as Type-II. The root cause of overpressure mechanism was investigated by integrating advance sonic and formation pressure measurements, and borehole images. Plotting velocity and effective stress (Bower's plot) clearly indicated that in top part of Middle Bhuban overpressure points lie on the loading curve while data from lower part of Middle Bhuban lie on the unloading curve. (Fig. 11)

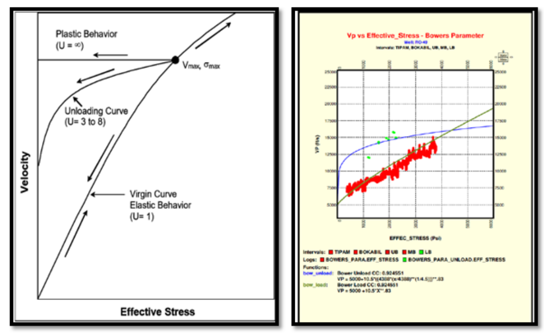

Fig. 11 Bower's Loading & Unloading parameter of well R-2

Analysis of image log and advance sonic data shows crossover of fast and slow shear as seen on slowness

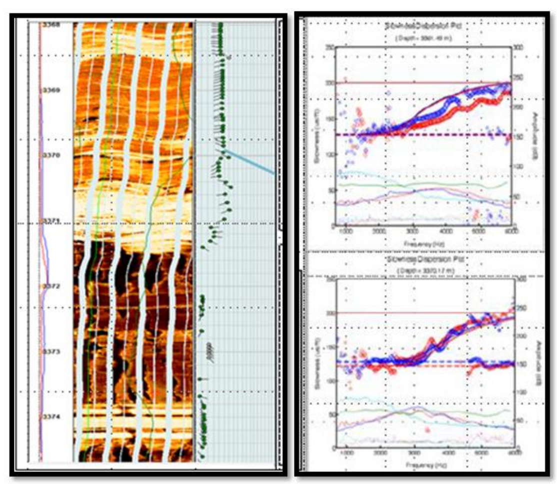

Fig. 12 Slowness dispersion plot of well R-1

dispersion plot (Fig. 12) and change in stress direction as inferred from breakouts. This indicates presence of thrust in the vicinity. This shows that overpressure due to tectonic upliftment cause by thrusting can be a possible reason.

Fig. 13 shows the pore pressure analysis of well R-2 against UB, MB & LB formations. Eaton's method was used to compute pore pressure against Upper and Middle Bhuban whereas against LB formation the method under estimated pore pressure. Bower's method was used to compute pore pressure against LB and good match was seen between the predicted pore pressure and the one measured by formation tester. Fig. 14 shows the wellbore stability analysis of well R-1. The methodology adopted during the study is capable of taking tectonic factor into account for computing pore pressure and wellbore stability analysis.

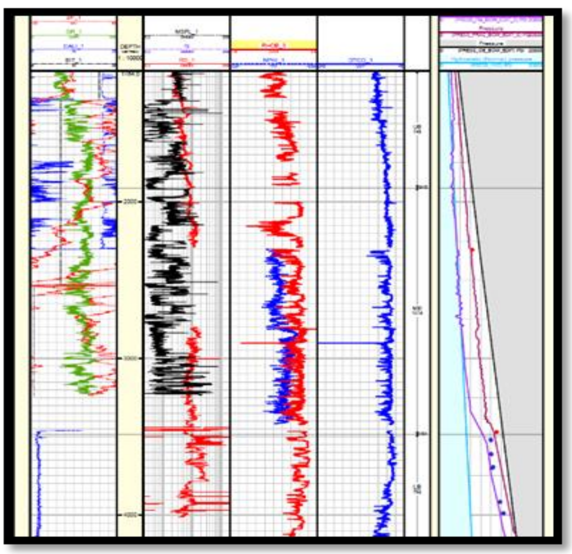

Fig.13 Porepressure computation using Bower's method well R-2

Based on image and advance sonic analysis, the most stable drilling direction for Middle & Lower Bhuban have been suggested .Fig. 15 shows the most stable trajectory against MB for well R-1.

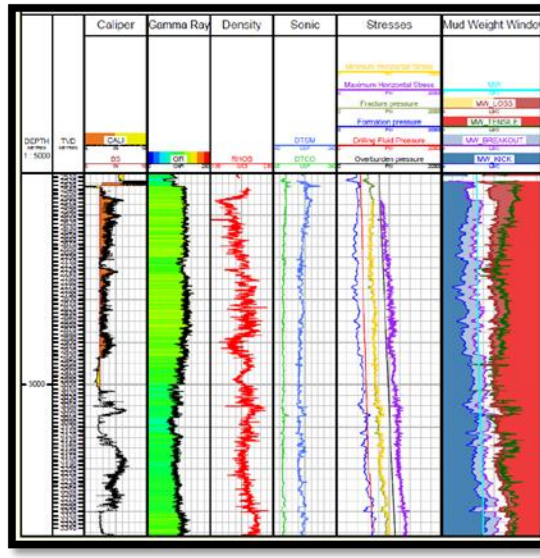

Fig. 14 Wellbore stability Analysis of well R-1

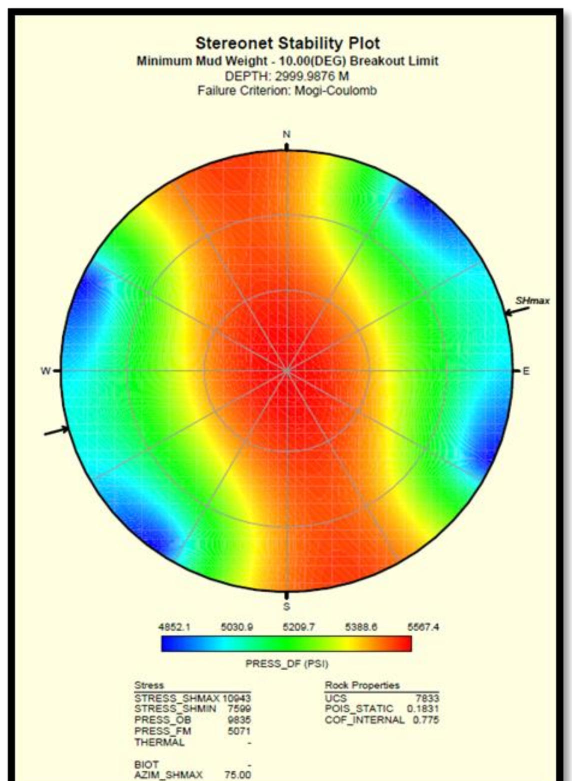

Fig. 15 Stereonet shwoing the most stable drilling trajectory of well R-1

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Conclusions

- Normal faulting is observed against Upper Bhuban formation whereas Strike slip & Reverse faulting is observed in lower part of Middle Bhuban and Lower Bhuban formation in Rokhia & Agartala Dome.
- Pore pressure has been estimated using Eaton's trend line method in Upper and Middle Bhuban in most of the wells where the reason for overpressure is due to Compaction Disequilibrium. However, in some wells the Hoseni plot and measured pore pressure suggests that the overpressure is due to tectonic uplift (Type-II overpressure). In those wells Bower's method has been used to compute the pore pressure.
- Various cross plots clearly indicate the existence of Type-II overpressure in the deeper depth. Drilling events encountered in the region also support this fact.
- An understanding of pore pressure generating mechanism in Rokhia, Baramurah & Agartala Dome has been made. The final pore pressure profile has been generated by taking into account both types of over pressure mechanism.
- The direction of SHmax in Middle Bhuban is 55-75 deg North. Deviated wells should be drilled along this azimuth to minimize the shear failure in the field.
- High pressure water zones have been encountered in some wells of Rokhia against the Middle Bhuban. The pressure gradient for the high pressure water bearing zones are about ~0.69-0.73 psi/ft.
- The complexity of well bore stability issues increases as one moves from Rokhia to Baramurah field. This is due to increase in intensity of folding as we move from west to east.
- The suggested mud weight window should be followed while drilling future wells in the area for minimizing the shear failure and have better and stable wellbore thereby aiding in acquisition of quality log data.

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