Faults in well trajectory; Sensitivity and impacts in successful well completion

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Keywords

Thrust faults, resistivity image, fault intersection, mud loss, break out

Summary

The well complications in the form of extreme mud loss in exploratory wells AT of Tripura Fold Belt and KS of Krishna Godavari Basin were subjected to detailed G&G analysis. Resistivity image log of well AT revealed the presence of two thrust faults and a severe break out zone which was not evident in the corresponding 2D seismic section due to poor sub surface image in the structure. Severe mud loss had encountered in Lower Bhuban Formation in well AT and which was analysed in resistivity image log and corroborates with the identified break out zone. Similarly in well KS the seismic sections were revisited post drilling and it was observed that the extreme mud loss sections were in proximity of zone of fault intersection. In the area where two faults would intersect, difference between two horizontal stresses would be maximum and more likely to induce break out.

Introduction

Operational constraints caused by mud loss and related downhole complications is one of the major challenges being faced during drilling of wells, especially common in areas of depleted reservoirs and structural complexities. The problem is compounded when zones of high pressures are also involved. While depleted reservoirs can be reasonably handled by the existing understanding of the field, areas of tectonic complexities are likely to cause expected complications. Therefore, it is crucial to identify presence of even minor faults and especially fault intersection which might be encountered through well trajectory. Appropriate well design ensuring a trajectory wherein fault intersection would be avoided is of paramount importance for successful achievement of exploratory targets through drilling the well. On this back gorund, two wells were chosen for detailed analysis. Well AT within Fold Belt of Assam & Assam Arakan Basin which is a terrain of strong compressionsl set up and the well KS on the other hand located in Krishna Godavari basin where dominant tectonic fabric is extensional are chosen for detailed analysis to bring out the root cause of severe mud loss and related well complications observed during drilling.

Geology of the area

Assam &Assam Arakan Basin, located in the north eastern part of Indian subcontinent (Fig.1) evolved in a passive margin set up and later it was modified by collision and subsequent subduction of Indian plate beneath Burmese plate (*Chakrabarti et al; 2011*). Tripura Fold Belt is a part of Assam Arakan Fold Belt of the A&AA Basin and is highly affected by compressional tectonism and resultant thrust faults. Fold Belt is characterized by a series of parallel doubly plunging anticlines separated by synclines along NNE-SSW to N-S directions. Structural complexity is found to be intense from west to east in the Fold Belt area *(Jena et al; 2012)*. Tulamura structure is a doubly plunging asymmetrical anticline with a steep faulted eastern limb and a gentle western limb. The anticline is about 40 km long and 18 km wide where the well AT was drilled.

Krishna Godavari basin, situated in the south eastern part of India is a passive margin basin comprising of a number of North East - South West trending horsts and grabens. It was an intracratonic rift within the Gondwanaland until Early Jurassic period. After the break up of Australian plate from Indian plate during the break up of Gondwanaland, KG Basin attained the form of a pericratonic basin *(Rao. 2002).* Structuration of Tertiary sediments in the basin is due to the heavy sediment load and subsequent collapse of the shelf edge which formed series of growth faults. The present study has been done on well KS located in KG Offshore (Fig.2), where the major tectonic elements are Kottalanka- Yanam basement high and K-T high. The well KS is located in a basement tilted block.

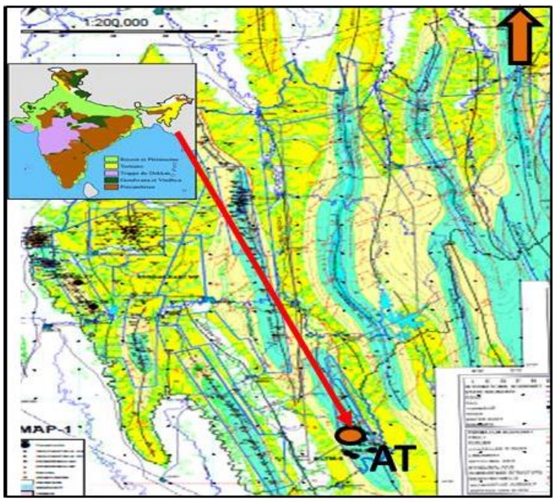

Fig.1 Geological map of Tripura Fold Belt showing well AT

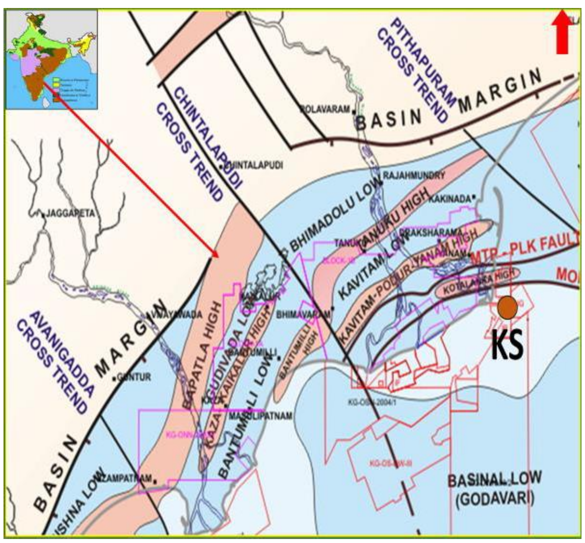

Fig.2 Tectonic map of KG Basin showing well KS

(i) Case study; Well-AT, Assam & Assam Arakan Basin

The exploratory well AT located on the crestal part of the upthrust block of Tulamura structure (Fig.3) was planned to drill upto 2835m with an objective to explore the hydro carbon prospectivity of Middle and Lower Bhuban sands. An E-W schematic geological cross section with the well AT and associated thrust faults is shown in Fig.4 which clearly depicts the geological formations and the major thrust faults developed in the structure.

Prior to drilling the well AT, a major thrust fault (F1) located towards the east of the well had been clearly demarcated in the 2D seismic section. While drilling 8 ½'' hole cumulative mud loss of about 267m^3 was observed at 2475m. After repeated attempts, mud loss was brought down to approximately 1m^3/hr. Further repeated dynamic mud loss along with tight pull and held up was observed upto 2583m. Eventually the well could not be drilled further to the exploratory targets of Lower Bhuban.

Detailed analysis of resistivity image logs recorded in the well AT revealed presence of two sets of thrust faults at 2288m and 2344m respectively (Fig.5). Severe break outs were identified in the interval 2466-2490m which is depicted by the hole irregularity (Fig.6). Based on the resistivity image log data, re-interpretation of the 2D seismic section was carried out which revealed the presence of a minor thrust fault intersecting the well trajectory at 2287m (F2). Antithetic faults viz., F3, F4 and F5 are also found to be developed in the structure in which fault F3 cut across the well (Fig.3&4). The cause of sudden mud loss occurred around 2475m is likely to have been caused by the break out zone in the interval 2466-2490m (Fig.6).

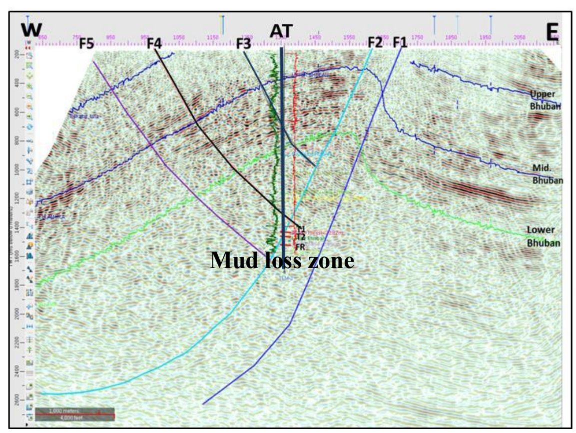

Fig.3 Interpreted 2D section showing well AT; F1 indicates major thrust fault which was evident prior to drilling (*After A & AA Basin*).
T1. Thrust-1 (2287m), T2: Thrust-2 (2344m)
FR: Fractured/break out zone (2466- 2490m)

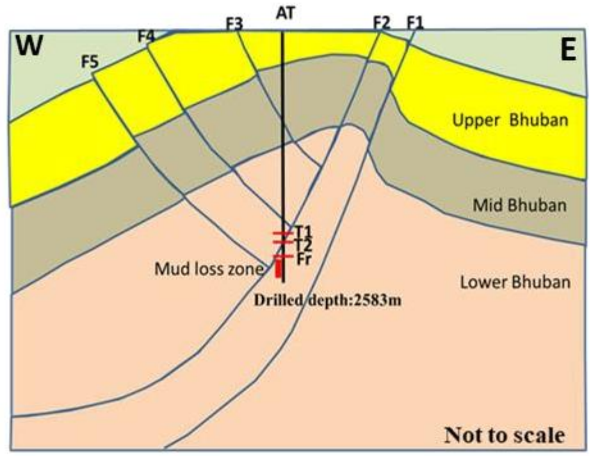

Fig.4 Schematic geological section showing well AT and associated faults T1. Thrust-1 (2287m), T2: Thrust-2 (2345m) FR: Fractured/break out zone (2466- 2490m)

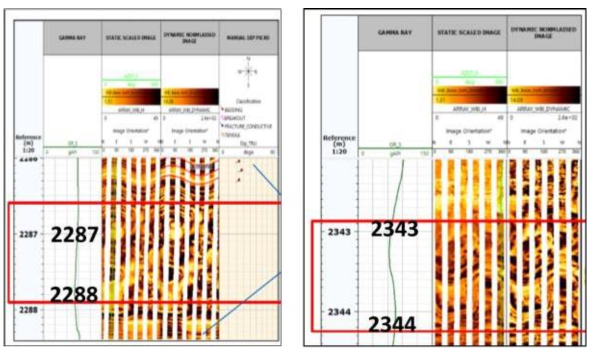

Fig.5 Two different bedding directions observed. Possible thrust fault zone as marked by red box.

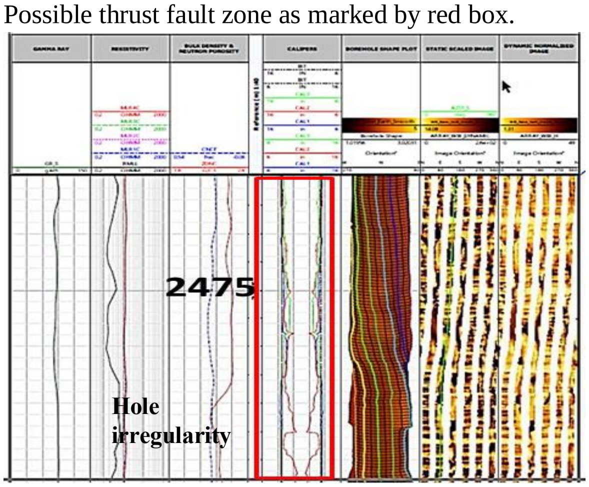

Fig.6 Resistivity image log showing hole anisotropy due to severe break out in the interval 2466-2490m. Mud loss zone corresponds to the same interval

(ii) Case study; Well KS, Krishna Godavari Basin

The well KS located in GS structure of KG basin was targeted to explore the HC prospectivity of Miocene sands with a target depth of 2560m. After completing 17 ½'' section at 1650m, initial static mud loss of 16 bbl was reported in the well. However, after several attempts to control the mud loss intermediate casing (13 3/8'') was lowered in the well with loss condition. Subsequently, while drilling 12 ¼'' hole at 2467m both loss and gain situation was observed (total mud loss: 1317 bbls SOBM & mud returns: 764 bbls) and the phase target depth could not be completed. However, 12 ¼'' hole was logged and a cement plug was placed in the interval 2320-2200m and the hole was side tracked. After lowering 9 5/8'' casing 8 ½'' Sidetracked hole was drilled down to 2475m and again gain/loss situation was observed and the repeated attempts to control the situation were unsuccessful. Subsequently, three cement plugs had to be placed to arrest the loss and gain situation. After short landing 7" liner at 2400m, instead of planned depth of 2560m; 6" slim hole, which was not planned had to be drilled to 2585m with continued Loss/Gain trend.

The reason for unexpected severe mud loss in the well KS was analysed in detail. The corresponding seismic sections (IL15326 & XL 3754 of well KS were revisited and which clearly show the presence of several normal faults cutting across the well trajectory (Fig.7&8). Severe mud loss occurred at depth 2384-2467m in the parent hole and at 2374-2584m in the side tracked hole. Seismic sections passing through the wel KS showed intersection of two faults in the proximity of mud loss zone (2475m) and which is likely to be the reason for severe mud loss/gain.

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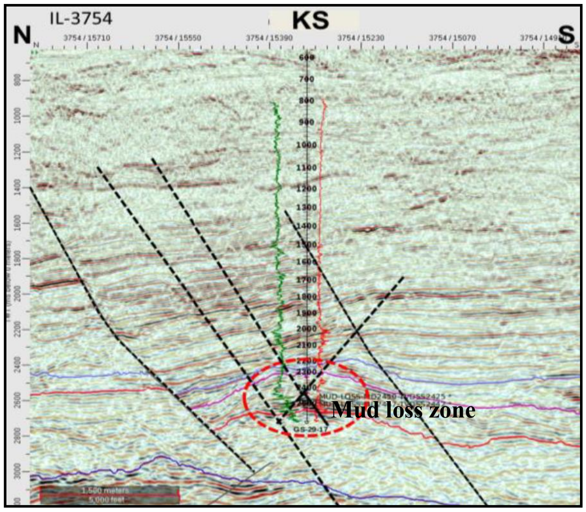

Fig.7 Inline-3754 showing cross cutting of faults in well trajectory (*modified after KG Basin, unpublished ONGC work)*

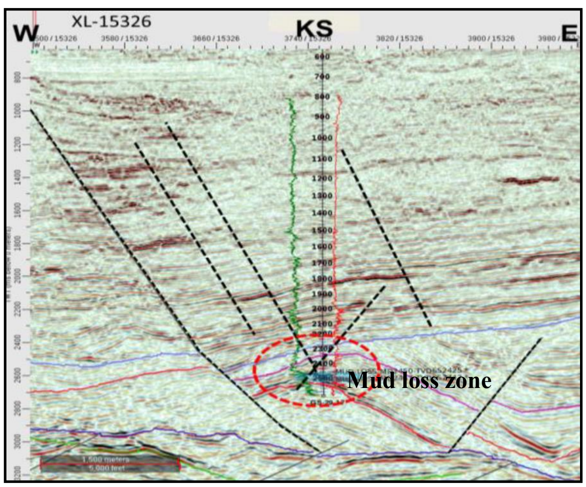

Fig.8 Interpreted Crossline-15326 showing cross cutting of faults in well trajectory (*modified after KG Basin)*

Conclusion

The down hole complications like mud loss and related well problems in the wells AT and KS of Tripura Fold Belt and KG basin could be explained very well with the help of analyzing resistivity image data and correlating with seismic data. Bore hole image data reveals the presence of thrust faults and break out zones in the well trajectory of well AT which corroborates the observed downhole complications. Similarly, in well KS, intersection of faults along the well trajectory resulted in severe loss/gain situations.

Based on the present study it is recommended that well design should ensure trajectory avoiding the zones of fault intersection. Bore hole image logs can effectively be used to calibrate the seismic data for pre drill unidentified faults in the area for optimization of subsequent well placements.

References

A.K.Jena, B.S.Haldia, R.Solomon, A.K.Sahoo, A.K.Bhanja & Asim Samanta, 2012, Exploration Strategy in Tripura Fold Belt, Assam & Assam Arakan Basin, Biennial International Conference and exposition on petroleum geophysics.

Chakrabarti. A.K, H. J. Singh. H.J., Akhtar. MDS, Singh.R.K., Dominique Silox, Tohon & Rosa E. Polanco, Ferrer, 2011, Structural Style of the Assam Shelf and Schuppen Belt, A &AA Basin, India., The 2nd South Asain Geoscience Conference and Exhibition, GEOIndia, 12-14th Jan,2011,Gearter Noida, New Delhi,India

Rao, G. N., 2001, Sedimentation, stratigraphy and petroleum potential of Krishna-Godavari basin, East Coast of India, Bull. AAPG, v. 85, no. 9, p. 1623-1643.

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The views expressed in this paper are those of the authors and not necessarily of the organization.