Paper id: 2005479

Fracture and Breakout Analysis from Image Log in Krishna-Godavari Basin, India

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Abstract

Formation Micro-imager logs from borehole in the sedimentary formation is analyzed to identify natural fractures and constrain the stress field acting on the fractures proximal to the borehole. The selected depth intervals from four wells namely; KD, KS, KL and KA located at the Krishna-Godavari (K-G) onshore basin have been considered for fracture and breakout analysis. The breakouts are observed in these well in several depth intervals whereas drilling induced fractures (DIF) are noticed only in well KL. The orientation of maximum principal horizontal stress (S_H) varies from N14.30^{0}E to N20.34°E for four wells. The dip amount of fracture is 10.79° with standard deviation (s.d) 4.63° in well KS and 12.71° with s.d 7.41° in well KD. The orientation of S_H is agreement with the regional horst-graben trend i.e towards NNE in this K-G basin. A breakout phenomenon is modelled for well KA at depth of 2800m under differential stresses.

Introduction

Natural fracture systems not only control the performance and the state of depletion in reservoirs under primary, secondary or tertiary recovery, but also influence flow patterns for production, cementing and completion techniques and the trajectory and quality of the wellbore during drilling operations Borehole breakouts and drilling-induced fractures (DIFs) are important indicators of horizontal stress in petroleum and tectonic system. Fractures or fractures system by themselves do not normally constitute commercial reservoirs; they do however often provide to the mechanism necessary for commercial production from tight, low porosity, and low permeability reservoir rock (Plumb et al, 1985, Bell, 1990, Zoback et al., 1985). As such, there is great interest and value in fracture detection and evaluation. Here, Formation micro image log (FMI) has been used for identification of natural fracture, induced fracture and breakout from four wells namely, KD, KS, KL and KA located at the Krishna-Godavari (K-G) onshore basin.

K-G basin is a passive margin pericratonic basin situated on the Eastern Continental Margin of India (ECMI). K-G basin encompasses large areas both onland and off shore including those located in deep waters. The basin itself came into existence following rifting along ECMI craton during early Mesozoic. Both the onland part of the basin and its off shore host a large number of structural traps that have been mapped and a large number of them established through drilling (Rao, 2001).The basin was created as a result of tensional basement tectonics and is characterized by ENE-WSW to NE-SW trending horsts and sub-basins/grabens overlying a rifted basement structure. K-G basin is subdivided into three sub-basins namely; Krishna, West Godavari and East Godavari which are separated by Bapatla and Tanuku horsts respectively (Figure 1) (Sastri et al., 1973 and 1981, Gupta, 2006). The well KD has encountered the Mandapeta and Gollapalli Sandstone overlain by Raghavpuram Shale formation. The well KS and KL have penetrated the Narsapur Claystone, Matsyapuri Sand formation overlying the Vadapurru Shale. These three well are located at east-Godavari subbasin. The well KA located at the west-Godavari subbasin has encountered the Raghavpuram Shale formation.

In this study, the main focuses are (a) identification of fractures, (b) identification of breakout and induced fractures from the four wells and (c) 2D modelling of wellbore deformation under unequal compressive horizontal stresses.

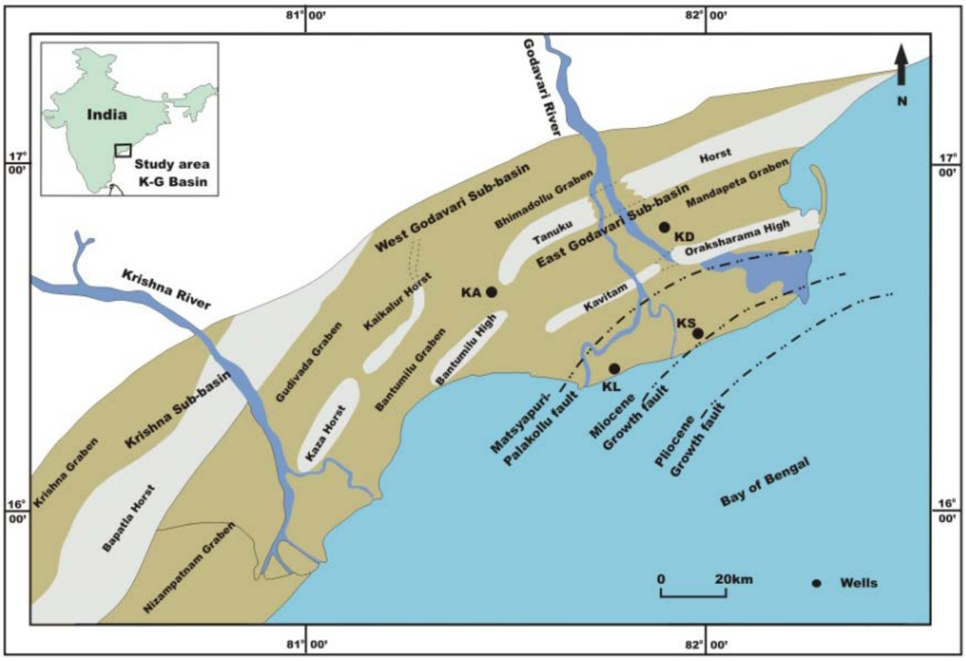

Figure 1: Krishna-Godavari (K-G) basin is showing NNE-SSW trending horst and grabens. Three numbers of growth faults are shown and the four well KD, KS, KL and KA are distributed over this basin.

Fracture identification from FMI Logs

Two main types of processed resistivity image logs are available in static and dynamic image format. Static images are those which have had one contrast setting applied to the entire well. They provide useful views of relative changes in rock resistivity throughout the borehole. Dynamic images, which have had variable contrast applied in a moving window, provide enhanced views of features such as fractures, bed boundaries. The electrical images are made by applying a gray scale to the resistivity wiggle-traces produced from the electrodes on the tool. In this way, low resistivity zones appear dark and high resistivity, low resistivity intervals appear white. Since the array on each pad is two and a half inches wide, irregular features, such as vugs and fractures, show up as dark spots, lines, sinusoid on the images.

Dip amount of the fracture = $\tan^{-1}(h/d)$

Where h = length from crest to trough, d = diameter of borehole

Strike = dip direction+90^0 (dip direction is calculated from the position of the trough)

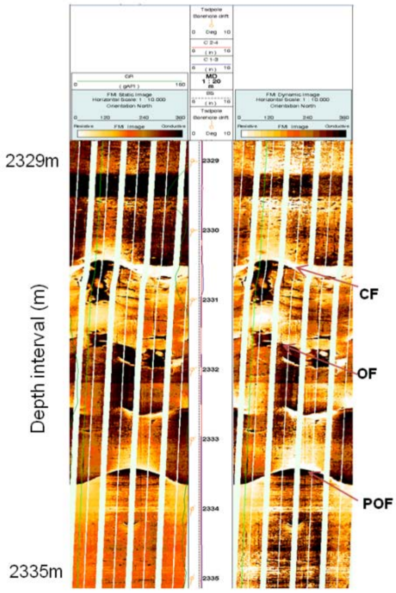

Figure 2: Fracture identification in depth interval 2329-2335m in well KD. CF- closed fracture, OF-open fracture and POF-partial open fracture.

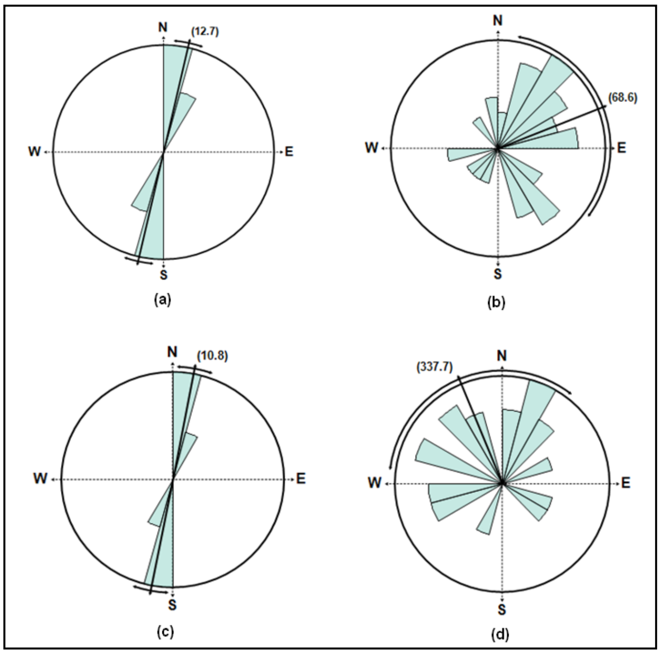

Figure 3: Rose diagram plot: (a) dip amount and (b) strike for KD well and (c) dip amount and (d) strike for KS well.

Total 50 and 24 numbers of fractures are observed in KD and KS wells respectively. Fractures mostly have been noticed in Mandapeta and Gollapalli Sandstone Formation in KD well. The dip amount of this fracture is 12.7^0 with s.d 7.41^0 and the strike is 68.8^0 with s.d 58.19^0. The all the fracture have been found in Matsyapuri Sandstone in KS well. The dip amount of this fracture is 10.79^0 with s.d 4.63^0 and the strike is 377.3^0 with s.d 60.69^0.

Breakout and Drill Induced Fracture (DIF)

Borehole breakouts are broad parallel grooves separated by 180^0 and parallel to borehole axis. They are generated by shear failure fractures orthogonal to the main in-situ stress direction and therefore useful for in-situ stress determination. Minimum in-situ horizontal stress direction is perpendicular to maximum in-situ horizontal stress direction (Bell, 1990, Zoback et al., 1985 and Tingay et al., 2008).

DIFs are created when the stresses concentrated around a borehole exceed that required to cause tensile failure of the wellbore wall (Aadnoy, 1990). DIFs typically develop as narrow sharply defined features that are sub-parallel or slightly inclined to the borehole axis in vertical wells and are generally not associated with significant borehole enlargement in the fracture direction (note that DIFs and breakouts can form at the same depth in orthogonal directions) (Bell, 1996). The stress concentration around a vertical borehole is at a minimum in the S_H direction. Hence, DIFs develop approximately parallel to the S_H orientation.

Breakout is observed for 30m length in KA wells from depth interval 2800-2830m in the Raghavpuram Shale. Breakout has been observed in depth interval of 1300-1311m in KS well. Breakouts in well KD have also been noticed from depth interval 2396-2625 m discontinuously. The induced fractures have appeared in several depth intervals such as: 1101-1105 m, 1445-1448 m and 1558-1565 m from Narsapur Claystone to Matsyapur Sandstone in KL well. The orientation of S_H is sub-parallel to direction of regional horst-graben trending towards NNE direction. The breakout feature is shown in for only KA well (Figure 4). Induced fracture orientation is shown in figure 5 for a well KL (Figure 5).

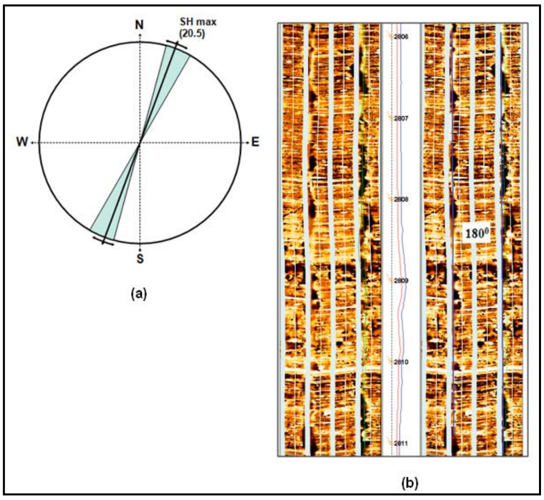

Figure 4: (a) rose diagram plot of orientation of S_H obtained from breakout data and (b) breakout in depth interval 2806-2811 m for KA well.

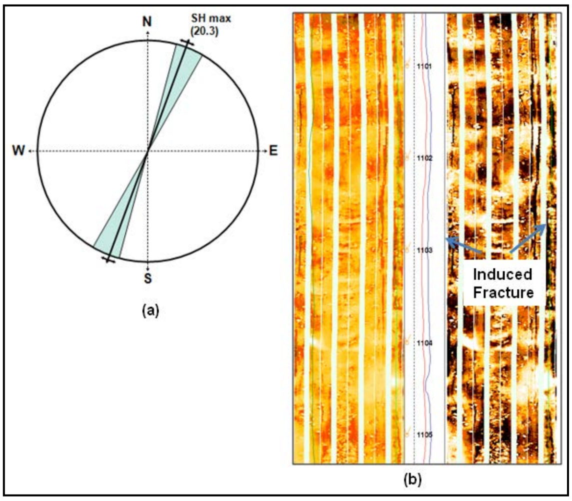

Figure 5: (a) Rose diagram plot of orientation of S_H from induced fracture and (b) induced fracture in depth interval 1101-1105 for KL well.

Wellbore deformation under unequal compressive horizontal stresses

The horizontal section of well KA at depth of 2800m has been modelled under unequal compressive horizontal stresses. The vertical stress (Sv) is calculated at 2800m depth using vertical stress gradient of 22 MPa/km. Pore pressure is estimated from hydrostatic pressure gradient assuming 0.433 psi/ft (equivalent to 9.33 MPa/km) and it becomes 26.12 MPa at the depth of 2800m (Chatterjee et al., 2013). The length of the boundary is about 2m length in each side. The diameter of the well bore has been assumed 0.5m. Using finite element modelling (FEM) the mesh has been generated to get the solution for deformation around the wellbore shown in figure 5a. Boundary constraints for these FEMs represent a key element in understanding the modeling results. These include a far-field stresses ($S_H = S_V = 62$MPa and $S_h = 0.7S_V = 44$MPa) at the model boundary (Figure 6a). Drilling mud pressure of 28 MPa is applied at the well boundary. It is observed that the well bore is enlarged along the perpendicular direction of S_H in figure 6b. The local stress vectors are accumulated in dense around the well bore but it becomes lesser from away of well bore in figure 6c (Figure 6).

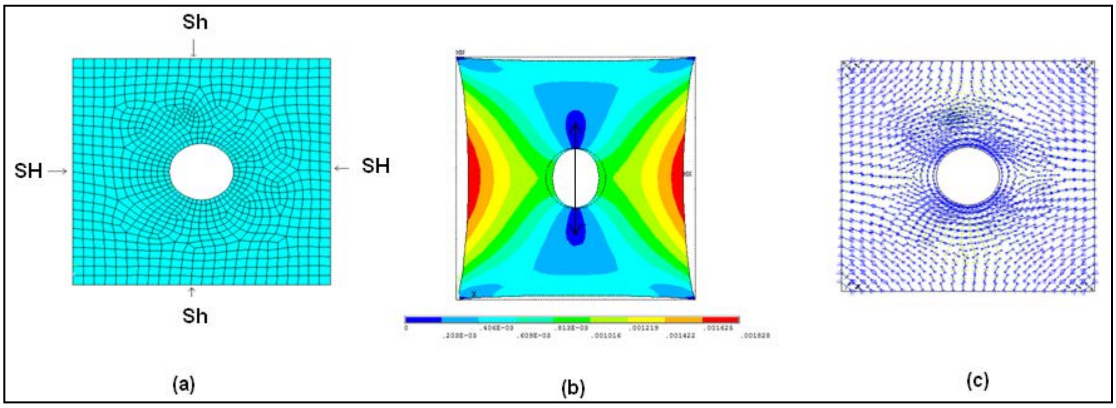

Figure 6: (a) meshing around the wellbore using FEM technique, (b) deformation of well bore due to far-field stress and (c) stress accumulation around the well bore (after Chatterjee et, al 2013).

Wellbore deformation is displayed in (figure 6b) with maximum horizontal stress orientation perpendicular to the breakout orientation as observed in well KA.

Conclusions

The fractures at various depth intervals are estimated from FMI log in well KD and KS. The breakouts have been identified in well KA, KL and KD and induced fracture is also noticed in well KS. The average orientation of maximum horizontal stress is about N18.6^{0}E which is a close agreement with that orientation calculated by dip-meter log previously (Chatterjee and Mukhopadhyay, 2002). The fracture analysis enhances the understanding the reservoir modelling and the migration of the reservoir in Mandapeta and Gollapalli Sand reservoirs. The enlargement of wellbore has been discussed in well KA at depth 2800m under differential stress field application and it exhibits the accumulation local stress vector around the wellbore.

Acknowledgment

Authors are very thankful to ONGC, Dehradun for providing us the well log and geologic information. Authors also acknowledge the financial support from the Ministry of Earth Science through the R&D project MoES /P.O./(Seismo)/1(138) 2011 dated 9.11.12.

References

Aadnoy, B.S., 1990, Inversion technique to determine the in-situ stress field from fracturing data, Journal of Petroleum Science and Engineering, 4, 127-141.

Bell, J.S., 1990, The stress regime of the Scotian Shelf offshore eastern Canada to 6 kilometres depth and implications for rock mechanics and hydrocarbon migration. - In: Maury, V. and D. Fourmaintraux, eds., Rock at Great Depth, Rotterdam, Balkema, 1243-1265.

Bell, J.S., 1996, Petro Geoscience 1. In situ stresses in sedimentary rocks (part 1): measurement techniques, Geoscience Canada, 23, 85-100.

Chatterjee.R, Singha**,** .D.K. and Sanghvai, P., 2013, Deformation modeling around A Wellbore using Finite Element Technique, Extended Abstract, 10th Biennial Int. Conf. & Exp. Organised by SPG India, Nov. 23-25, Kochi.

Chatterjee, R and Mukhopdhyay, M., 2002, In-situ stress determination using well log data for the oil fields of the Krishna-Godavari basin, Petrophysics, 43, 26-27.

Gupta, S.K, , 2006, Basin architecture and petroleum system of Krishna Godavari Basin, East coast of India, the Leading Edge, 25, 830-837.

Plumb, R.A. and S.H. Hickman, 1985, Stress-induced borehole elongation: A comparison between the Four-Arm Dipmeter and the Borehole Televiewer in the Auburn Geothermal Well, Journal of Geophysical Research, 90, 5513-5521.

Rao, G.N., 2001,Sedimentation, stratigraphy and petroleum potential of Krishna-Godavari basin, East Coast of India, AAPG Bulletin, 85, 1623-1043**.**

Sastri, V. V., Sinha, R. N., Singh, G., and Murti, K. V. S., 1973, Stratigraphy and tectonics of sedimentary basins on the East coast of penninsular India, AAPG Bulletin, 57, 655-678.

Sastri, V. V., Venkatachala, B. S. and Narayanan,V**.,** 1981, The evolution of East coast of India, Palaeogeography, Palaeoclimatology, Palaeoecology*,* 36, 23-54.

Tingay, M., Reinecker, J. and Müller, B., 2008, Borehole breakout and drilling-induced fracture analysis from image logs, World Stress Map Project.

Zoback, M.D., D. Moos, L.G. Mastin and R.N. Anderson, 1985, Well bore breakouts and in situ stress, Journal of Geophysical Research, 90, 5523-5530.