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Fracture Characterization using Image Log in Bengal Basin, India

Abstract

Globally there is an increasing gap between demand and availability of the conventional energy sources. Natural and induced fractures play an important role in permeability of coal bed methane (CBM) and basement reservoirs. Here types of fractures and in-situ stress direction from a well using formation micro imager (FMI) and circumferential acoustic borehole image (CBIL) logs in basement of Contai area, Bengal basin are identified. The fractures in the basement of Contai area, Bengal Basin provides a means of characterizing fractures in granitic rock. The study of image logs from a well through basement concentrates upon closed and open fractures, drilling induced fractures as well as bedding planes. Rosette diagram are used to differentiate present day S_H indicator from natural fractures. Very few open fractures are observed in acoustic image log such as CBIL. Low amplitude open fractures show total loss of energy on travel time image. Fractured basement of Bengal basin is devoid of hydrocarbon as most of the fractures in basement are mineralized and as a result they are closed as noticed from CBIL tool.

Introduction

Commercial production of hydrocarbon has begun from fractured crystalline basement across globe since decades. Basement reservoir typically comprises of lithologies like granite, granodiorite and gneiss with secondary lithologies including dolerite and basalt. The permeability of this reservoir is provided by fractures ranging in scale from faults detectable from seismic data to those fractures that can be detected and quantified from the evaluation of core (Jolly and Cosgrove, 2003, Nguyen et al., 2014). Basement reservoirs may tend to have complex geological histories with fracture properties resulting from a combination of tectonic, hydrothermal and epithermal processes. Production wells are usually drilled perpendicular to the dominant fracture system. Wells should be deviated rather than vertical in order to optimally intersect the dominant fracture systems. Borehole image logs will provide information of the fractures with sufficient accuracy at well location (Datta Gupta et al., 2012, Ali et al., 2017). Many seismic techniques have been developed recently for providing fracture information between wells or exploring fractured basement before drilling a well (Nguyen et al., 2014). Open facture identification in basement will help in search of hydrocarbon exploration activities. This study focusses on identification of fractures and estimation of horizontal stress orientation using microresistivity and acoustic image logs from a well in Contai area of Bengal basin.

Geology of Bengal Basin

The Bengal Basin is one of the major sedimentary basins in Indian Sub-continent. The area is bounded by Indian Shield to the northwest, Surma Basin to the east, deeper part of Bay of Bengal to the south-southeast and Mahanadi Basin to the southwest (Curray et al., 1993, Alam et al, 2003).The Ganga-Brahmaputra rivers and their tributary/distributary system transport sediments from the Himalayas and surrounding Indian cratonic part to pour into the basin, forming one of the biggest modern delta system of the World (Roy and Chatterjee, 2015).

The major tectonic zones identified in the Bengal Basin are stable shelf, hinge zone and deeper Basin. The stable shelf is further divided into the structural elements viz, the Radha monocline, the Baidapur depression and Contai terrace from North to South. The area was affected by ENE-WSW to NW-SE trending basement faults. The Pre-Trappean sediments were deposited in continental and Post-Trappean sediments in marine environments. Stratigraphically, Jalangi Formation with thickness ranging between 150-700m in the basin is characterized by coarse to medium grained sandstone in the basin margin and sandstone to limestone in hinge zone deposited under fresh water to warm shallow water environment and deposited during Paleocene to Upper Cretaceous period. Similarly, Ghatal Formation with thickness ranging between 0-150m is characterised by inter-bedded black calcareous shale and pink to grey shaly limestone with sand, silt & oolite etc deposited under lagoonal to littoral environment during Upper Cretaceous period (Dasgupta, 1997, Gangaiah et al., 2006).

Tectonically Contai block is located in the stable shelf area in the southern part of onland Bengal (Figure 1).

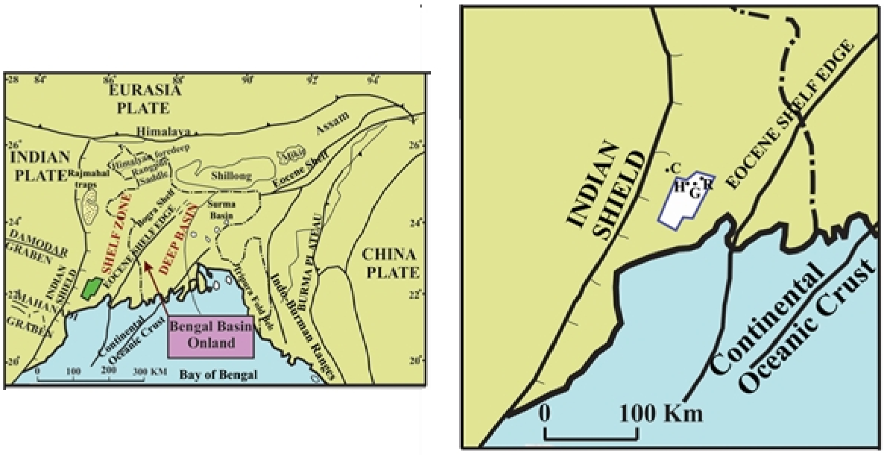


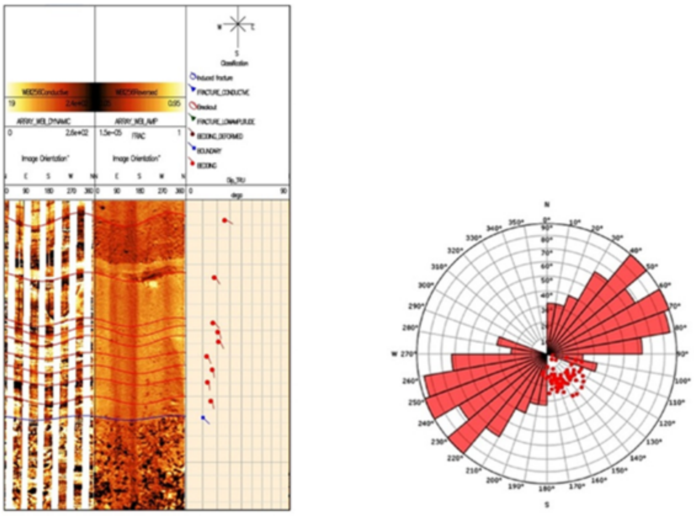
Figure 1: Tectonic Map of Bengal basin showing Contai block with wells (after Mukherjee et al., 2009, Banerjee et al., 2013).

In Contai area, four wells, namely; C, G, H and R have been drilled by ONGC. The well C was drilled in upper part of Gondwana sequence down to 3862 m and was terminated within Lower Gondwana (Talchir Formation). The well G reached till 3330 m and was bottomed within Upper Gondwana sequence.

Analysis of Image log

The image log data such as: formation micro imager (FMI) and Circumferential borehole acoustic image (CBIL) logs are only available for well R to study the basement fractures under the study area. Main objectives are to characterize the fractures from the image logs and to integrate microresistivity and acoustic image log for estimation of maximum horizontal stress (S_H) direction. These logs are able to find out dip of the fractures, bedding plane and lithological boundaries.

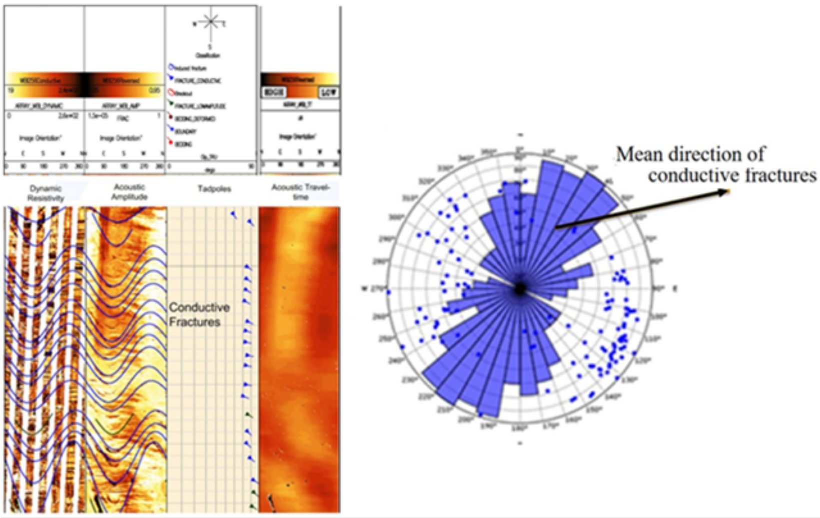
Bedding plane identification in the interval 3650-3655 m: This depth interval 3650-3655m displays FMI and CBIL logs to identify bedding planes and its orientation. Bedding planes are marked in this figure (Figure 2a). Resistive image log (FMI) is much more resolved vertically than acoustic image log (CBIL) for delineation of bed boundary (Figure 2a). Tadpole plot shows the dip amount and azimuth of the bedding plane. Figure 2b shows the Rosette (Rose) diagram of bedding plane within basement striking NE-SW direction for depth interval 3650-3950m.



2(a) 2(b)

Figure 2 (a):Shows the bedding plane of FMI and CBIL Log in the interval 3650 -3655m. (b): Shows the strike direction of bedding plane in the interval 3650m-3950m

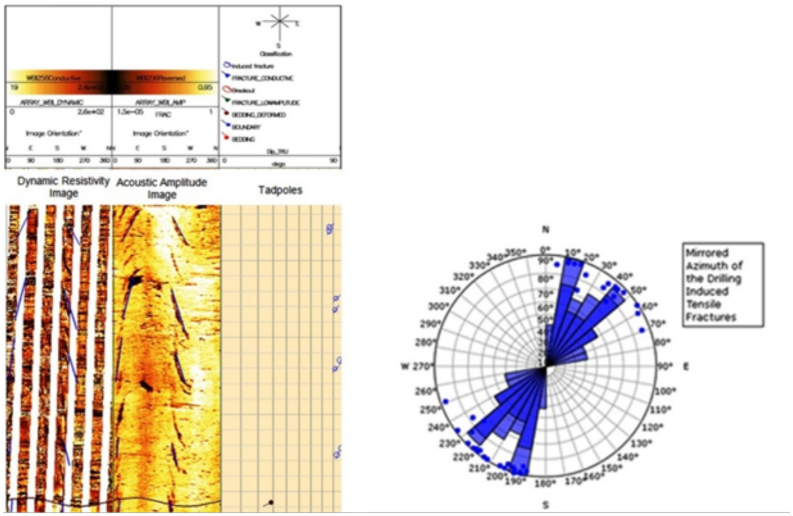
Conductive fractures: The low amplitudes fractures are identified from 3650 to 3950m of basement of Contai area. Figure 3a typically shows few low amplitude conductive fractures in both resistive and acoustic images**.** The acoustic amplitude and microresistivity image logs indicate sinusoidal shaped fractures but acoustic travel time image log does not indicate any such types of features. Since these fractures are mineralized, there is no dissipation of acoustic energy. Travel Time image does not show any sinusoidal features due to the mineralised fractures. Microresistivity image show dark colored sinusoidal features due to presence of low resistive/ conductive mineral in the fractures. The closed fractures in basement are devoid of hydrocarbon. Therefore the depth interval of 300m may not be useful for hydrocarbon exploration. Figure 3b indicates the mean strike direction of N45ºE of mineralized fractures for 300m depth interval. The strike direction shows the paleo-stress direction of the basement fractures.



3(a) 3(b)

Figure 3 (a): Showing conductive fractures (mineralised) in depth 3695-3700 m. (b) Strike of conductive fractures in the interval 3650-3950 m

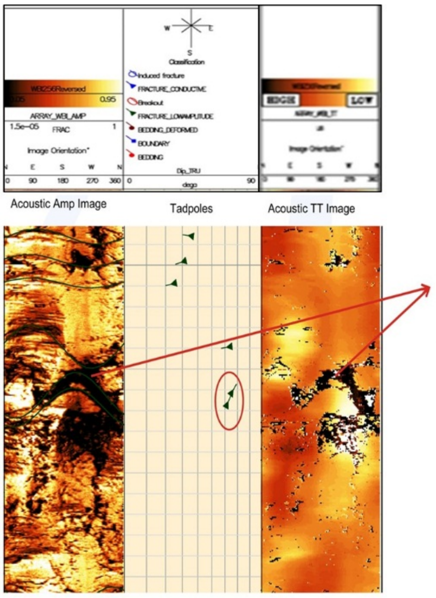
Drilling Induced Tensile Fracture in the depth interval 3746-3750 m: Figure 4a represents the drillings induced fractures (DIF) which are observed very distinctly in acoustic borehole image log in the interval 3746-3750 m in basement. The orientation of DIF is aligned with the orientation of maximum horizontal stress (S_H).Strike direction of DIFs is NE-SW indicating that the orientation of S_H is NE-SW (Figure 4b).



4(a) 4(b)

Figure 4 (a): Shows drilling induced fracture in the interval 3746m to 3750m in basement. (b) shows in-situ Maximum Horizontal Stress (S_H) direction

Open fractures in the depth interval 3710 – 3713 m: The fracture observed in acoustic image log in the interval 3710-3713m (Figure 5) is low amplitude open fracture. Acoustic travel time (TT) image characterizes total loss of energy indicating black sinusoidal features and striking parallel to S_H direction.



Low amplitude fracture showing total loss of energy on travel time image (black) and striking parallel to direction S_H.

Figure 5: Shows the open fracture in interval 3710 -3713 m

Discussion

Fractured basement of Bengal basin of one well is studied through microresistivity and circumferential borehole acoustic image logs. From the above image log studies, it is inferred that few natural fractures in the basement are open and they are oriented parallel to the maximum horizontal stress direction. Acoustic travel time image in the basement shows that most of the fractures are mineralized and closed. This closed mineralized fracture characterizes with low amplitude acoustic information due to presence of energy on travel time image. Low amplitude open fracture shows total loss of energy on travel time. Fractured basement of Bengal basin is devoid of hydrocarbon as most of the fractures in basement are mineralized and as a result they are closed observed from CBIL tool**.** Low amplitude sub-vertical fracture orientation is varying from 10°N to 40°N. The orientation of S_H at depth interval 3746- 3750m in basement is towards NNE in this well.

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References

Alam, M., Curray, J. R., Chowdhury, M. L. R. and Gani, M. R., 2003, An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin fill history, Sedimentary Geololgy, 155, 179–208.

Ali, M., Paul, S. and Chatterjee, R., 2017, Cleat Orientation from Ground Mapping and Image Log Studies for In-Situ Stress Analysis: Coal Bed Methane Exploration in South Karanpura Coalfield, India, Energy& Fuels, 31(7), 6812-6824

Curray, J. R., Emmel, F. J. and Moore, D. G., 1993, The Bengal Fan: Morphology, Geometry, Stratigraphy, history and processes, Maine and Petroleum Geology, 19, 1191–1223.

Das Gupta, A. B., 1997, Geology of Bengal Basin. Q. J. Geol., Min. Metall. Soc. India, 69, 161–176.

Datta Gupta, S., Chatterjee, R. and Farooqui, M. Y., 2012, Formation evaluation of fractured basement, Cambay basin, India, Journal of Geophysics and Engineering, 9, 162-175.

Gangaiah, A., Kumar, R., Gupta, M. P., Baruah, D. C., Sharma, P. B., Singh S. K. and Das, P. K., 2006, 3-D Seismic Survey in Gobindpur Area of Bengal Basin: A Paradigm Shift in Approach to Data Quality and Inter-regional Crew Mobilization in ONGC, 6th Exploration Conference & Exposition on Petroleum Geophysics, Kolkata, India, Paper id. 41.

Jolly, R. J. H. and Cosgrove, J. W., 2003, Geological evidence of patterns of fluid flow through fracture networks: examination using random realizations and connectivity analysis in Fracture and In-situ Stress Characterization of Hydrocarbon Reservoirs, Geological Society, London, Special Publication, ed Ameen M. S. 209, 177–187.

Nguyen H. N., Sahalan B. A and Nguyen, A. D., 2014, The application of seismic attributes for reservoir characterization in Pre-Tertiary fractured basement, Vietnam-Malaysia offshore, Interpretation, 2(1), SA57-SA66.

Roy, A. B. and Chatterjee, A., 2015, Tectonic framework and evolutionary history of the Bengal Basin in the Indian subcontinent, Current Science, 109(2), 271-279.