



Identification of Fractures from Conventional Wireline Logs and Integration with Sedimentological Core Samples – A Case Study of Western Offshore Basin, India

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Summary

In western offshore basin, some of the wells are producing hydrocarbon from fractured basement reservoir. The accurate identification of fractures is the critical part for evaluation of unconventional reservoirs like basement. In present technology, the fractures can be identified from wellbore imaging tools like Formation Micro-Imager and Dipole Shear Sonic, which is very expensive and time consuming. The objective of present study is to identify the fractures from conventional log like flushed zone resistivity (MSFL), density (RHOB), sonic log (DT), density correction (DRHO) and photoelectric factor (PEF). The fractures are identified based on the response of conventional logs recorded in fractured section in 6 nos. of wells in western offshore basin, India. The identified fractures are also confirmed with the sedimentological study carried out on core sample. This technique for identification of fractures from conventional Wireline logs integrated with core studies is very useful and cost effective.

Introduction

Western offshore Basin offshore is the largest producing asset of India. Some of the wells are producing hydrocarbons from fractured basement. The accurate identification of fractures is the critical part for evaluation of unconventional reservoir like basement. The technology used in present scenario for identification of fractures is generally based on the wellbore imaging tools like Formation Micro-Imager and Dipole Shear Sonic. These high-tech tools are very expensive and time consuming when all the cost associated with this data acquisition (including rig time and associated costs). Sometimes, high-tech logging tools may not be available. In all type of scenario, the identification of fractures from conventional Wireline tools is very much helpful and better approach. In this paper, an attempt is made to identify the fractures from the conventional well logs like flushed zone resistivity (MSFL), density (RHOB), sonic log (DT), density correction (DRHO) and photoelectric factor (PEF). These conventional Wireline logs generate some response in the presence of fractures. Fractures have been identified for six wells namely Well-A, Well-B, Well-C, Well-D, Well-E and Well-F. In all these wells, sedimentological study was also carried out in laboratory and fractures have been identified. This technique for identification of fractures from

conventional Wireline logs integrated with core studies is very useful and cost effective.

Well Log Response to Fractures

The conventional Wireline logs respond to natural fractures typically and are summarized as below:

• Gamma Ray Log (GR):

The GR log is a record of a formation's radioactivity. The GR log is principally used quantitatively to calculate shale volume. In fractured reservoirs an increase in the gamma ray without concurrently higher formation shaliness, is frequently observed. This increase has been explained by the deposition of uranium salts along the discontinuity surfaces of a fracture or within the crack itself (Fertl, 1980).

• Natural Gamma Ray Spectroscopy Log (NGS):

Natural Gamma Ray Spectroscopy records the individual mass concentrations of uranium, thorium and potassium. High uranium content may reflect the effect of organic shales or the deposition of uranium salts in fractures (Serra et al., 1980). The solubility of uranium compounds accounts for their transport and their frequent occurrence in fractures.

• Density (RHOB) & Density correction factor (DRHO) Log:

The density log is a continuous record of the formation's bulk density. The dual detector density tool recorded two values: a value of uncompensated density using a long-spaced detector response, and a value of density correction. The correction is added to the uncompensated values to obtain the compensated bulk density, b (Bassiouni, 1994):

$$b = I_s + \quad (1)$$

where I_s is the long-spaced detector, uncompensated density. The term is a measure of the correction made to the bulk density to compensate for mudcake and for the density tool not seating perfectly against the borehole wall. It will also respond to a fluid filled fracture. An active, erratic curve may therefore indicate fractures when the hole is in gauge. Since the density logs are a measure of total reservoir porosity, fractures filled with fluid will decrease the recorded bulk density, creating a sharp negative peak on the density curve, and a corresponding peak on the correction.

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- **Neutron Log (NPHI):**

The measurement principle of the neutron log is based on the fact that hydrogen is very efficient in slowing down fast neutrons. Similar to the density log, any neutron-type log is a measure of the total reservoir porosity in fluid saturated formations. Therefore, in the presence of fractures, the neutron log is expected to have a behavior similar to that of the density log i.e. it will read more porosity.

- **Photoelectric factor log (PEF):**

The litho-density tool reports the measurement of the effective photoelectric absorption cross-section index for the formation, Pe. The Pe index will report anomalously high values near mud invaded open fractures. Therefore, a high reading of Pe, with good tool-borehole contact established by the caliper curve, may be a good indicator of fractures (Ellis, 1987).

- **Acoustic Log (DT):**

Acoustic logging for formation evaluation can be defined as the recording of one or more parameters of acoustic wave trains for use in estimating fundamental rock properties. Acoustic logging includes the measurement of both interval transit time and amplitude/attenuation logging mainly for compressional and shear waves. Sonic interval transit time logging records the time required for an acoustic wave to transverse a given length of formation. Most acoustic logging tools are designed to detect the first arriving compressional wave only when the energy level reaches a certain threshold. If the energy level does not reach the threshold value, cycle skipping occurs. Cycle skipping may occur when the attenuation in a formation is abnormally high (due to under-compaction, light hydrocarbons, or fractures) or when the mud is gas-cut. In hard rock (i.e. fast formations), cycle skipping may be a good indicator of fractures (Fertl, 1980).

Acoustic amplitude logging records the energy level of an acoustic wave while acoustic attenuation logging records the decrease in amplitude across a specified distance in the medium. The acoustic amplitude log delineates fractures by measuring the energy loss caused by the mode conversion that occurs when an acoustic wave reaches a fluid filled fracture. The signal amplitude is affected by the dip angle of the fracture, the number of fractures, the shape of the fracture faces and the nature of the material within the fracture (Guyod, et al, 1969). However, considerable care is necessary in the interpretation of the amplitude log because changes in lithology or porosity can produce effects that are similar to the response from fractures (Aguilera, 1976).

- **Caliper Log (CALI):**

Caliper tools measure hole size and shape. Fractured zones may exhibit one of two basic patterns on a caliper log. The caliper log may indicate a slightly reduced borehole size due to the presence of a thick mud cake especially against micro fractured zone. Alternatively,

borehole enlargement may be observed which occurs preferentially in the dip direction of fractures due to crumbling of the fractured zone during drilling (Fertl, 1980). Neither of these log response patterns can be taken as a conclusive evidence of the presence of fractures. Highly permeable and under-pressured formations can also cause mud cake build-up, which would result in the caliper log recording a hole size smaller than the bit size. Unconsolidated formations can also show borehole enlargement effects.

- **Flushed Zone Resistivity Log (MSFL):**

Resistivity logs are measurements of the ability of the fluids in a formation to conduct electricity. The dual laterlog generally provides three resistivity measures: the deep laterlog (which investigates about 10 ft. into the formation), the shallow laterlog (which investigates 3 to 6 ft. into the formation), and the micro-spherically focused log (Micro-SFL) which measures resistivity in the invaded zone i.e. 6-8 inch. The effect of fractures on resistivity logs will depend primarily on the fracture direction, size (aperture size and height), length, and the fluid inside the fracture. A fractured zone should appear as a very conductive anomaly to the micro-resistivity tools because they see the fractures as entirely filled with mud filtrate with out any tortuosity.

Tool	Log Name	Response	Description
GR	Gamma-Ray log	Anomalous	Low background readings
DT	Sonic log	Apparent value change	Using porosity to compare with DEN/NEU porosity
RHOB	Formation density log	A sharp drop	Combined with PEF for an open fracture.
MSFL	Flushed zone Resistivity log	Decreases	Low
PEF	Photo-electric factor log	High value with sharp drop	PEF and DRHO in a similar way
DRHO	Density correction log	High value	CALI no variation and Rxo has a low value for fracture
CALI	Caliper log	Size change	Sudden variations indicate a discrete feature

Table 1: Response of conventional logs in fractures zone

Since conventional well logs are readily available, it is of great importance to understand the effects of fractures on them and try to use the information they provide to attempt a better characterization of naturally fractured reservoirs.

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Field Examples

Well: A

The composite of basic log curves are shown in the fig(1). The interval 1904 -1910 m is having many fractures, which may be interpreted by lowering the values of log curves e.g. MSFL, RHOB and increasing value of DT. The overlay (track - 4) of RHOB with PEF also indicates that increase in PEF value may be due to entry of barite mud in fractured portion. The sedimentology core studies were carried out in laboratory as shown in fig(1). Five open fractures with 45 degree are seen at 1907.24 m in core samples. Few micro fractures are also observed in the interval. Identified fractures from logs are confirmed from study on core samples in the well.

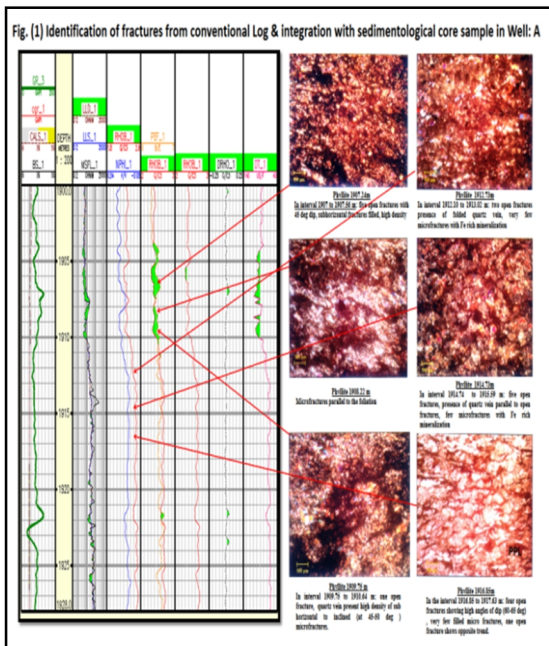


Figure 1: Identification of fractures from conventional log & integration with sedimentological core samples in Well: A

Well: B

The composite log of well-B drilled with barite mud is shown in the fig (2). The interval 1917-1920.5 m is having many types of fractures. The values of MSFL and RHOB are decreasing whereas value of DT increases compared to the bottom part that may be due to presence of fractures. The overlay RHOB with PEF also indicates that increase in PEF value may be due to entry of barite mud in fractured portion.

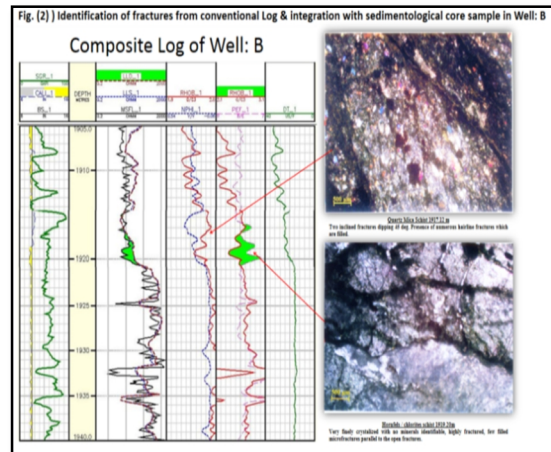


Figure 2: Identification of fractures from conventional log & integration with sedimentological core samples in Well: B

The sedimentological core studies were done at depth 1917.12 m showing two inclined fractures with many hairline fractures. Open fractures and micro-fractures are observed on core samples in sedimentological lab at depth 1919.20 m. Identified fractures from logs are confirmed from study on core samples in the well.

Well-C

The composite log of well C is shown in the fig.(3). The interval 2039-2039 m is having many fractures. The values of MSFL and RHOB are decreasing whereas value of DT is increases compare to the bottom part that indicates the presence of fractures. The high value of DRHO (density correction) with no change in caliper at depth 2035.8-2036.5m may also indicate the fractures. The sedimentological core studies carried out at depth 2036.15 m, 2037.14 & 2038.69 m also confirms the open fractures and micro fractures and seen in fig (3). Identified fractures from conventional logs are confirmed from sedimentological core studies in the well.

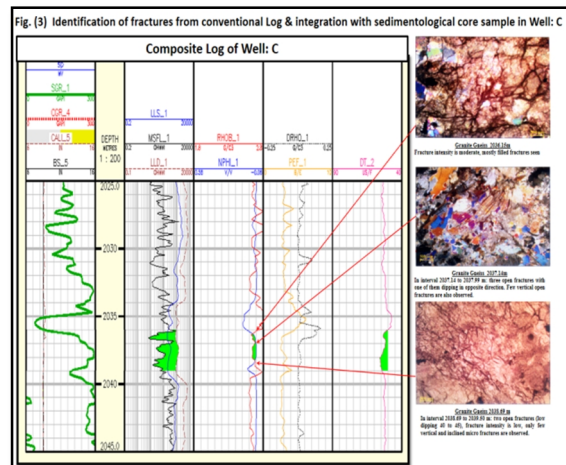


Figure 3: Identification of fractures from conventional log & integration with sedimentological core samples in Well: C

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Well: D

The composite log of well D is shown in the fig.(4). The interval 1890.7-1895.5 m in the well is showing many types of fractures. The values of MSFL and RHOB are decreasing whereas value of DT increases compare to the bottom part that may be due to presence of fractures. The sedimentological studies carried out on core samples are shown in fig (4). The lithology is weathered Granite / Granite. Four inclined fractures are seen in interval 1891.7 to 1892.5 m. At depth 1894.78 m, topmost segment highly weathered and fragmented with multiple parallel inclined fractures mostly thereby enhancing the porosity in the segment. Many micro-fractures and randomly oriented hairline fracture also seen in the well. Identified fractures from logs are confirmed from study on core samples in the well.

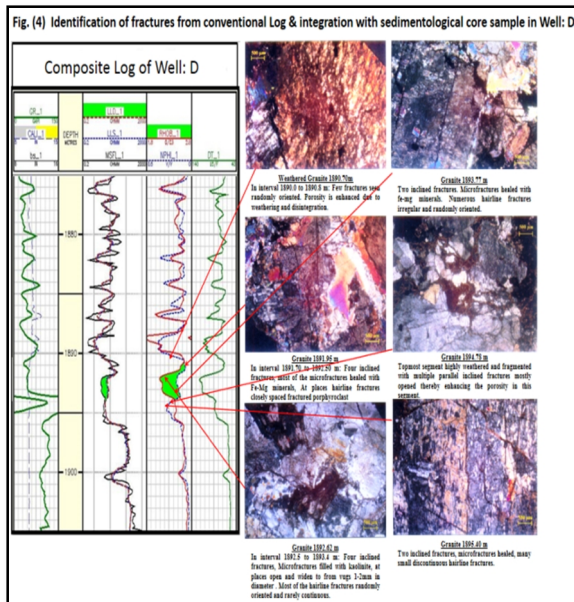


Figure 4: Identification of fractures from conventional log & integration with sedimentological core samples in well: D

Well: E

The composite of well E is shown in fig (5). The interval 2044 to 2053.3 is having variety of fractures. The MSFL and RHOB log values are decreasing against the fractured zone whereas the value of PEF and DT log are increasing. The sedimentological study carried on core samples are also shown in fig (5). The lithology is mostly Quartz Mica Schist. Mostly inclined fractures with a dip of 35 degree are seen at depth 2045.05 m in core samples. Many filled micro fractures and are also present in the 2048.8-2053.27 as seen in fig.(5). The value of DT log is showing very high value at places against fractures compared to adjoining places. Identified fractures from conventional logs are confirmed from sedimentological core studies in the well.

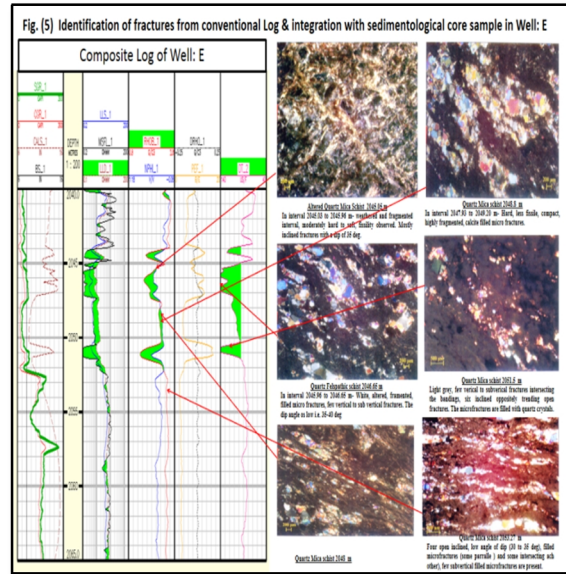


Figure 5: Identification of fractures from conventional log & integration with sedimentological core samples in well: E

Well: F

The composite of well F is shown in fig (6). The interval 1878 to 1882.5 is having variety of fractures. The MSFL and RHOB log values are decreasing against the fractured zone whereas the value of DT log value is increasing. The sedimentological study carried on core samples are also shown in fig (6). From core studies, two open fractures with inclined micro-fractured are observed and shown in fig.(6). The very high value of DT and low value of RHOB is also observed against the same fracture. Parallel micro-fractures along with numerous hairline fractures are observed in core samples and shown in fig.(6), but no change in DT are observed which may be due to parallel fracture. However, identified fractures from conventional logs are confirmed from sedimentological core studies in the well.

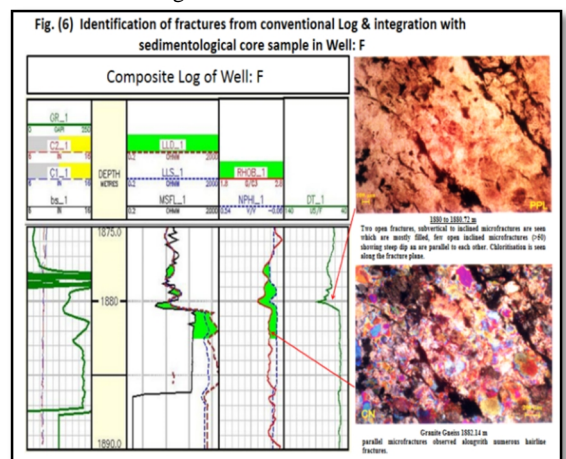


Figure 6: Identification of fractures from conventional log & integration with sedimentological core samples in well: F

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Conclusions

No single conventional well log provides reliable characterization of fractured formations, however all logs are affected in one or another way by the presence of fractures. Decreasing values of RHOB and MSFL with increasing value of DT may be one of the indicators of the presence of fractures as observed in the present study. PEF and DRHO also respond in the presence of fractures. The study provides the identification of fractures from conventional logs in the absence of high-tech log data. Identified fractures from well logs are confirmed by the sedimentological study carried out on core samples.

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References:

- Fertl, W. H.: "Evaluation of Fractured Reservoirs Using Geophysical Well Logs", SPE paper 8938 presented at the 1980 SPE/DOE Symposium on Unconventional Gas Recovery held in Pittsburgh, Pennsylvania, 18-21 May, 1980.
- Serra, O., Balwin, J. and Quirein, J.: "Theory, Interpretation and Practical Application of Natural Gamma Ray Spectroscopy", Paper F presented at the 21st Society of Professional Well Log Analysts Logging Symposium. 1980.
- Ellis, D. V. "Well Logging For Earth Scientists", Elsevier Science Publishing Co., New York, 1987.
- Guyod, H. and Shane, L. E., "Geophysical Well Logging", Houston, TX., 1969.
- Aguilera, R.: "Analysis of Naturally Fractured Reservoirs From Conventional Well Logs", Journal of Petroleum Technology, p. 764-772, July 1976.
- Bassiouni, Z., Theory, Measurement, and Interpretation of Well Logs. Society of Petroleum Engineers, SPE Textbook Series Vol. 4, 1994.
- SP Singh et. al, "Petrography and fracture characterization of basement complex rocks of Mumbai high" an unpublished ONGC report, 2014