Natural fracture analysis and determination of fracture parameter using image log, Bangestan Reservoir, Gachsaran oil field, SW Iran

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Abstract

Fracture system in carbonate reservoirs is very complex. Understanding the features of fractures such as dip, strike and the other parameters can help to distinguish the behaviour of reservoir in any exploration and production plan. Image log is the best way to investigate feature planes like fracture and bedding. Image log in one of drilled well #10x393 of Bangestan reservoir in Gachsaran oilfield was used and interpreted by X-tended Range Micro Imager (XRMI). The study resulted to identify 333 fractures and 78 beddings in interval understudy. Based on stereo net and rose diagram of fracture and bedding, interpreting was made. In this area, according to the origin classification, the fractures divided into three sets: longitude, transverse and oblique. Fracture parameters such as fracture density (VDC), fracture aperture (VDA) and fracture length (VTL) were calculated. Velocity deviation log (VDL) from conventional log calculated and compared with fracture parameters. VDA and VDL data make in past a well agreement together while VDC and VTL are less correlated with VDL. It seems fracture aperture plays an important role than other fracture parameters in the reservoir quality due to their effects on permeability to be increased.

Keywords: Fracture, carbonate reservoir, image log, deviation log.

1- Introduction

Carbonate rocks are the main reservoirs in Middle East and Iran. The porosity of carbonate rocks can be grouped into three types: connected porosity, existing between the carbonate grains; vuggs which are unconnected pores resulting from fluid dissolution of calcite during diagenesis; and fracture porosity caused by stresses followed deposition. Diagenesis can create stylolite structures which form horizontal flow barriers, sometimes extending over kilometers within the reservoir, having a dramatic effect on field performance. Fractures can be responsible for water breakthrough, gas coning and drilling problems such as heavy mud losses and stuck pipe (Schlumberger, 2007). Most carbonate reservoirs are naturally fractured. The fractures exist at all scales, from microscopic fissures to kilometer sized structures called fracture swarms or corridors, creating complex flow networks in the reservoir (Schlumberger, 2007). Fractures are planar features with no apparent displacement of blocks along their planes (Fossen, 2010). Generally, they have a steep dip in tensional and wrench regimes. Until now the best method of detecting planar features like fracture is image log.

Characterization of fracture systems from electrical images includes: the identification of the fracture type as to vertical, polygonal, or mechanically induced; the definition of the fracture morphology as to open, mineral-filled, or vuggy; and the dip/strike orientation. Fractures may be open, mineral-filled, or vuggy (Schlumberger, 2005). Physical features noted in the core sample are very well revealed in imagery. This is because of contrast in resistivity values (Chakravorty *et al*., 2009). McQuillan (1973, 1974, 1977, 1985) studied the fracture systems, its relation to bed thickness and structural setting in Asmari and their role in production as well. Stearns and Friedman (1972) examined the fractures in terms of its direction along the axis of the anticline and presented segmentation data as: Transversal (Cross Axial); Longitudinal (Parallel Axial); and Oblique Fractures.

There are plenty of fractured reservoirs in the southwest of Iran (Khoshbakht *et al*., 2012). Fracture is the most features of carbonate oil fields (Rezaei, 2007). Most carbonate fractured reservoirs display complex behavior in the simulation and production stages of their development, and this complexity is thought to be the result of the different fracture distributions and intensities within the reservoir (Shaban *et al*., 2011). Also, fractures can help to understand the stress situation. Carbonate reservoir behavior extremely dependent on fracture features. Determination of fracture characteristics such as type, frequency, orientation and opening is very important in different aspects of development and management of these reservoirs (Khoshbakht *et al*., 2012).

Sometimes the fracture effect on reservoir rocks permeability and flow control is very high (Philip *et al*., 2005; Eichhub *et al*., 2009). The presence of fractures even very fine ones- has a considerable impact on the permeability (Rezaei and Chehrazi 2005). And knowledge about them and their scattered patterns are helping in determination of the best location for drilling and maximum exploration (Serra and Serra 2004). The fracture aperture effect have a great influence on fluid flow; for example the ability of flow on some fracture in Gachsaran oil field is about 17 km (Motiei, 2008). In the analysis of fractures on the carbonate reservoirs, a large amount of data is used from various sources such as structural data, drilling data, petrophysical logs, cores data, production wells data and dynamic wells data (Thompson, 2000).

Trustable method to analysis the reservoir and fractures is core data; but because of getting small scale of reservoir, low percent recovery no direction fracture and bedding and high cost, image logs prefer toward core. Imaging tools can be used in a wide variety of geological and drilling environments, providing borehole images of rock, from the karstic carbonates to soft thinly laminated sand/shale sequences (Aghli *et al*., 2014).

Image log is an oriented high-resolution pseudo-picture of the detects borehole wall such as fractures and other tiny features which give them a potential to be considered as a powerful alternative method than core analysis in fracture study (Khoshbakht *et al*., 2012). The velocity-deviation log, which is calculated by combining the sonic log with the neutron-porosity or density log, provides a tool to obtain downhole information on the predominant pore type in carbonates. The log can be used to trace the downhole distribution of diagenetic processes and to estimate trends in permeability. Different pore types in the carbonates cause significant scattering in the velocity-porosity diagram, so that most samples show deviations from an average velocity-porosity trend (Anselmetti and Eberli, 1999).

2- Geological setting

The Gachsaran anticline is situated in the Iranian section of the Zagros fold–thrust belt, a belt which stretches from the Anatolian fault in eastern Turkey to the Minab fault near the Makran region in the SE of Iran (Shaban *et al*., 2011) due to the collision between the Iranian and Arabian plates. Geologically, the belt forms the northeastern border of the Arabian plate;

geographically it is located in SW Iran. The Main Zagros Fault, which marks the northeastern margin of the belt, represents a suture zone (Fig. 1). This zone is now seismically inactive and the seismicity has migrated southwest wards towards the frontal part of the belt (Berberian, 1983). The Gachsaran anticline is located in the Dezful Embayment region and more accurately in Dezful South near the Zagros mountain front (Fig. 1).

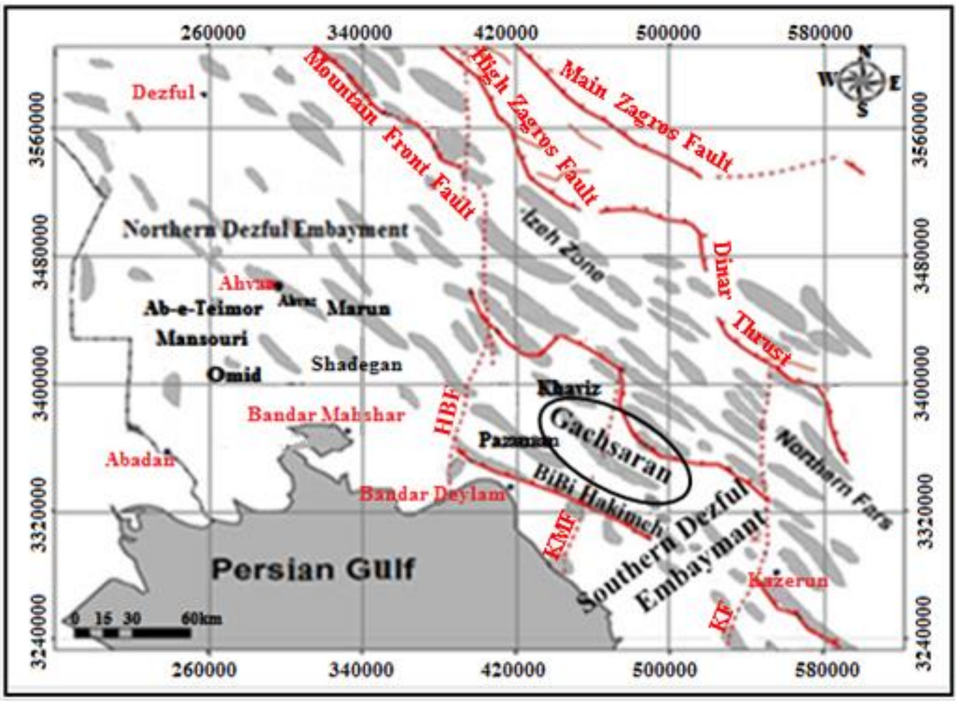

Figure 1) Main hydrocarbon oil fields and the location area understudy in Iranian Zagros range (Sherkati and Letouzey, 2004). Abbreviations are: HBF= Hendijan-Bahregansar Fault; KMF=Karg-Mish Fault;KF=Kazerun Fault .

The Gachsaran oil field is an elongated doubly-plunging anticlinal structure with dimension of 65 km length and 4–8 km width, and it is considered one of the most important productive oil fields in the Oligocene–Lower Miocene carbonate horizons (Asmari Formation) and the Middle Cretaceous carbonate horizons (Sarvak Formation, Fig. 2, Motiei, 1994).

3- Methodology

In this study image log and conventional logs such as neutron-density log and sonic log as the main data were used. The images are carefully described to characterize fractures and other geological features (Zahmatkesh *et al*., 2015). In this study image log from XRMI tools was processed and interpreted by Ciflog software and compared with deviation log.

The X-tended Range Micro Imager (XRMI) tool, a wire line borehole imaging tool, is designed to obtain quality images even in environments with a high formation resistivity to mud resistivity (Rt : Rm) ratio. The expanded operating range of the XRMI tool over conventional electrical imaging services is achieved through its state-of-the-art 32-bit digital signal acquisition architecture combined with a large increase in available power for the excitation current (EMEX) (Halliburton, 2012). As a result, the signal-to-noise ratio of the raw measurements is improved by a factor of up to five, and the dynamic range is expanded by a factor of up to three. The resulting images offer superior fidelity, even in highly resistive formations (Rt > 2,000 ohm-m) or relatively salty borehole fluids (Rm < 0.1 ohm-m). Calculation and interpretation of deviation log was given in detail and available in published papers (e.g. Aghli *et al*., 2014, 2016).

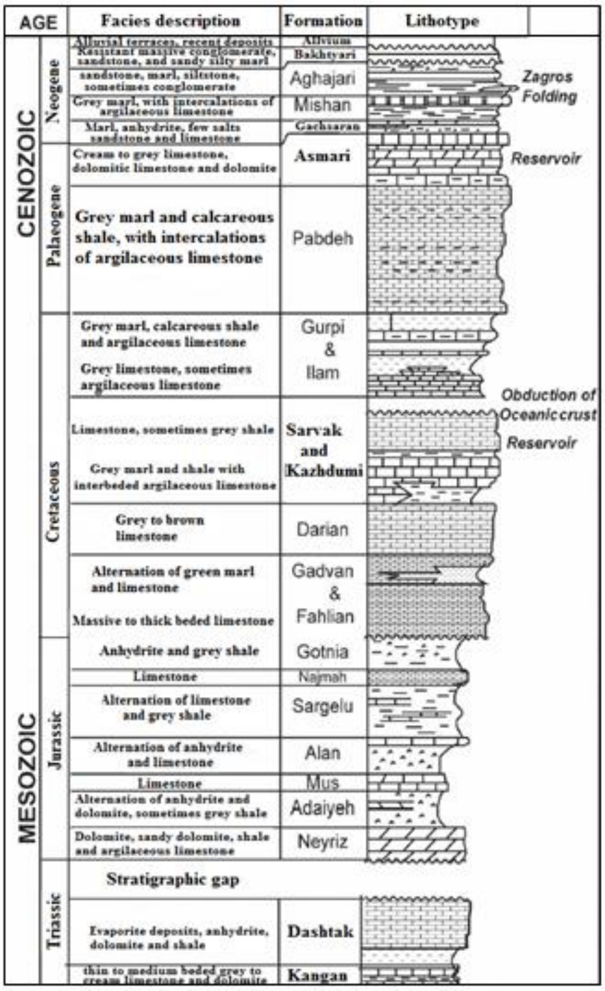

Figure 2) The Mesozoic–Cenozoic stratigraphic column of the Dezful Embayment area showing the position of the two major carbonate reservoirs in the Gachsaran oil field: Asmari and Sarvak formations.

3.1- Tool Design and Superior Image Quality

Pads mounted on six independently articulated arms help maintain pad contact in rugose, washed-out, elliptical, or highly deviated boreholes (Fig. 3). Further, a high sampling rate (120 samples per foot) and borehole coverage help obtain high-resolution pictures of the borehole walls.

4- Results and Discussion

The Sarvak reservoir is the second fractured reservoir in the Gachsaran oilfield. The formation (Albian-Cenoanian) as a part of Bangestan Group in the Gachsaran area was deposited as shallow deep sea to semi limited sediments (outer to inner ramp) which was indicating regression of the sea during Albian-Companian. Surgah was not deposited and the sedimentation of Ilam Formation is also in question. It is documented that the high portion of the top of Bangestan Group was removed by erosion in the end of Touronian (Shirzadeh, 1985).

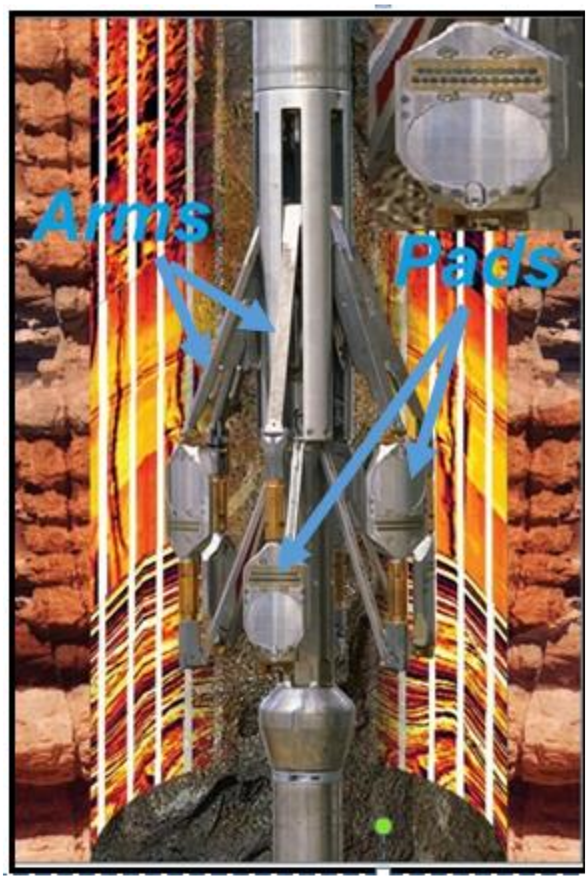

Figure 3) XRMI tools obtain six independent arms and six pads with 25 buttons on each pad.

The thickness is varied from 200-440 m from east to west. Therefor the thickness of the formation is showing variations through the field (Amirbahador *et al*., 2014). The Sarvak Formation deposited on the Kazhdumi Formation as gradational type. Determined microfacies are (1) Benthic Foraminifer Packstone to Wakstone Grain-Dominated, (2) Rudist Wackstone to Packstone Grain-Dominated, (3) Rudist Packstone to Grainstone, (4) Planktonic Oligostegina Wackstone to Packstone Mud-Dominated (Maldar Cheshmeh Goli, 2008). The last one is dominant microfacies. Microfacies 1, and 4 showing low porosity (less than 3%) as intra particle type, 7% in microfacies 2 as inter-intra particles and vuggy, 20% in microfacies 3 as inter and intra particles and vuggy types. Mehrabi and Rahimpour-Bonab (2014) were discussed the roles of paleoclimate conditions and tectonic controls on the depositional and diagenetic history of the Sarvak Formation in this area but the frcture distribution were not in their field. Hydrocarbon gravity is 42°API which was determined by drill stem test (DST). In the present study image log data were loaded as input in the software.

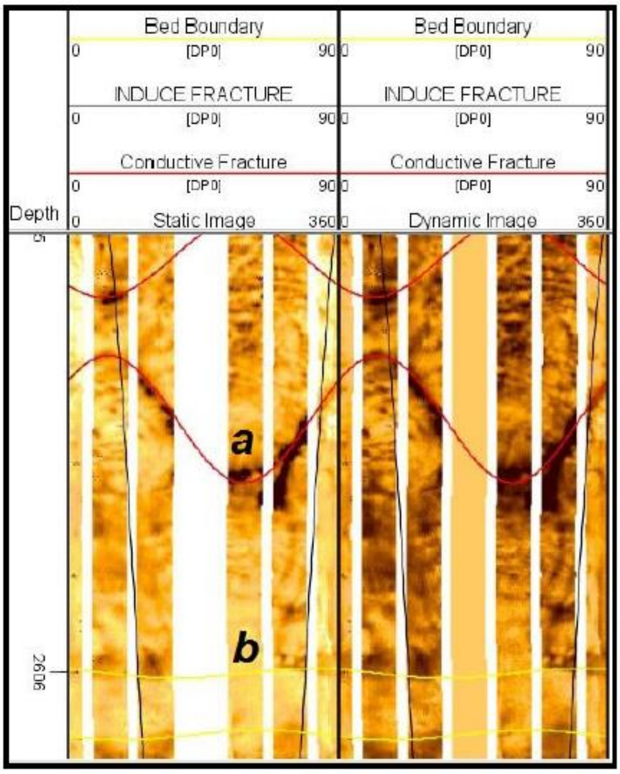

Figure 4) The Static and dynamic images from XRMI. Line- a shows a conductive feature that's seems to be open fracture, and line- b is bedding. Fractures tend to occur as linear features that generally have a dip steeper than the structural dip.

Open fractures are more conductive than the surrounding matrix. The degree of conductivity depends on the resistivity of the mud and the flushed-zone, and the fracture geometry. Their aperture may be open, tight (closed), or filled with some minerals (Schlumberger, 2005). On the image logs, fractures tend to occur as linear features that generally have a dip steeper than the structural dip (Fig. 4). While drilling, mud drilling fill the open fracture and because of low resistivity of mud, open fracture shows darker than the matrix (Fig. 4). If open fracture filled by crystal minerals, because of high resistivity, color of their area on image will be pastel. Vuggy fractures exhibit irregular enlargements along the fracture plane Fault is a type of fracture that displacement occurred along the fault plane. These characteristics may be applied to analysis the fracture in image logs.

After the analysis of image log in the studied drilled well, several features such as fractures and beddings were identified. Because of the importance of open fractures and bedding in this study (based on this study purpose), they were determined on the image logs and fracture density was calculated for well. After process and interpreted 333 conductive fracture and 78 bedding was detected (Fig. 5). Fractured dip inclination varied from 20˚ to 80˚ degree, azimuth (dip direction) varies from 20˚ to 60˚ and from 120˚-330˚, dip bedding varied from 0 to 50˚ degree and azimuth varied from 0-80˚ degree (Fig. 5). Three sets of fractures were detected, first set of the fractures has a dip from 30-40 degree with azimuth 20-60, second set has a range of dip between 20° -70° with azimuth 120-160 and the last set has fracture dip between 10°-45° with azimuth 170-220 (Fig. 5).

For to determine the fractures origin it needs to be analysed and interpreted some information such as dip and strike, shape, frequency and angle relation (Nelson, 2001). Based on azimuth, angle, aperture and length of fractures, detected fractures were classified as: the first set of fractures has most apertures and length fracture is parallel to bedding (Fig. 6). According to the fold axis which is in line with the NW-SE, first set created during tensile of fold axis which considering in longitudinal fractures. The most frequency of fracture belongs to the second set (Fig. 6) with least aperture. These two sets built 90° angle with each other which shows that the second set is transversal fractures, the third set of fractures has angle between the two other sets which is the origin of oblique fractures.

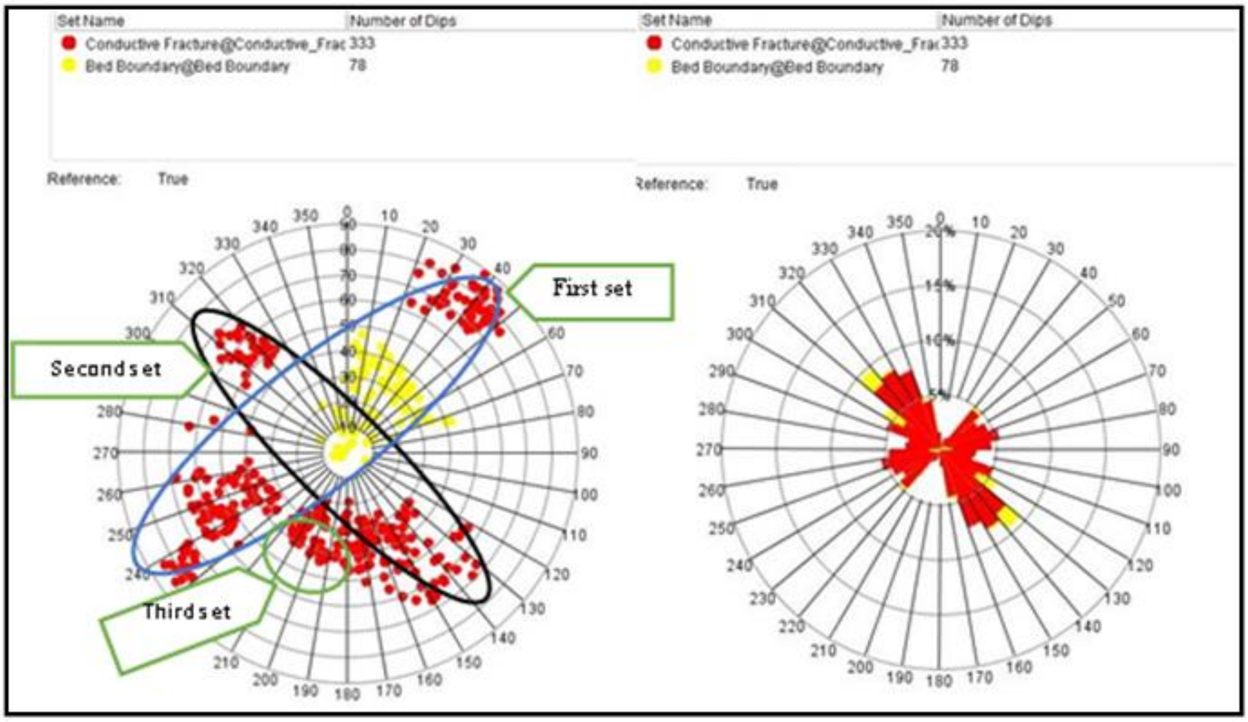

Figure 5) Result of interpreted fracture and bedding on image log, fracture (red) and bedding (yellow) stereo net and strike in well understudy.

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Considering important of fracture density, length and aperture parameters, their charts were plotted (Fig. 7). Velocity deviation log (VDL) was built based on petrophysical log data for this well. Fracture density (VDC), apparent fracture aperture (VDA) and fracture trace length (VTL) on this image log were put together in the same depth and compared with VDL (Fig. 7). Velocity deviation log showed good relation with aperture fracture (VDA). VTL and VDC in depth of 2594-2610 and 2670 meters are presenting high values. By comparing of these two charts with VDL, it is indicated that there is lower relations between them rather than VDA plot.

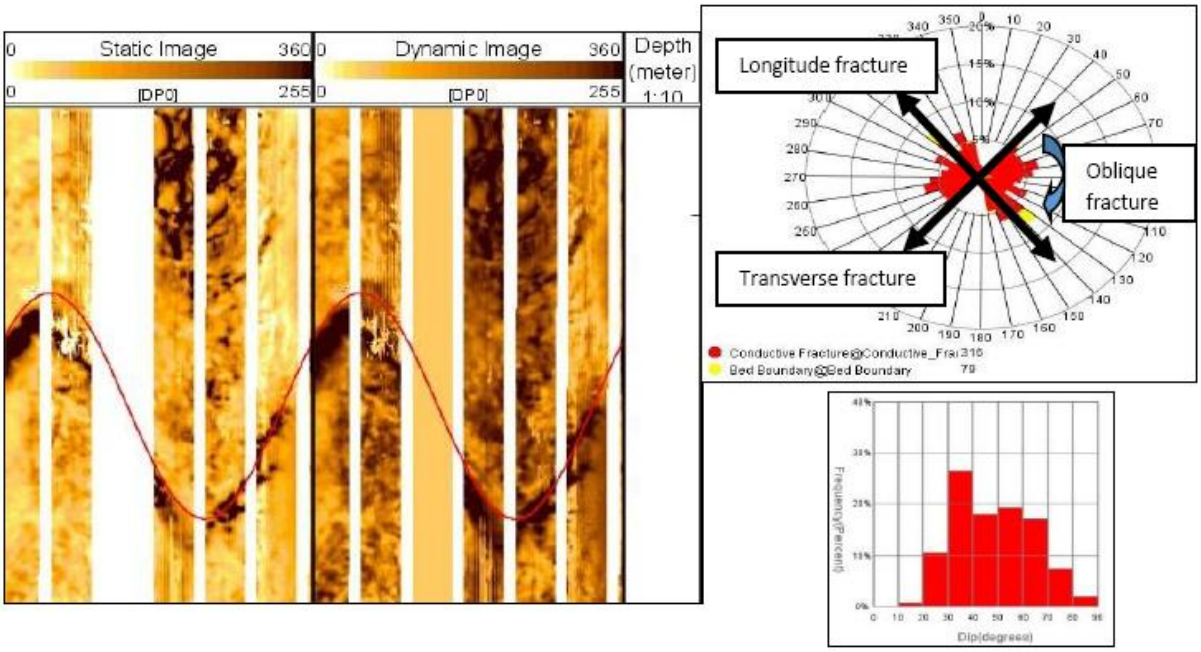

Figure 6) Display conductive zone in image log (means open fracture), and velocity deviation log indicated readings near -500 amount in conductive zone.

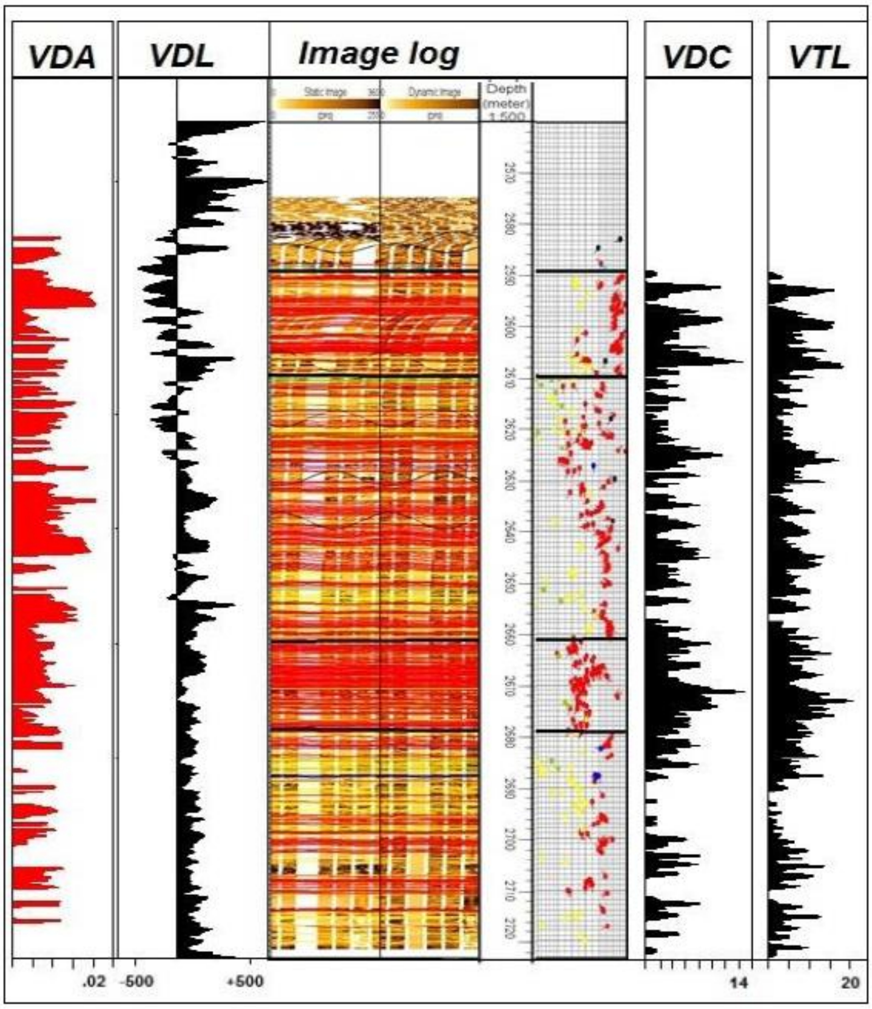

Figure 7) Velocity deviation showing a negative amount in depth of 2594 to 2610 meters and aperture fracture has a pick on this depth. Fracture length and density have two picks on 2605-2660 meters.

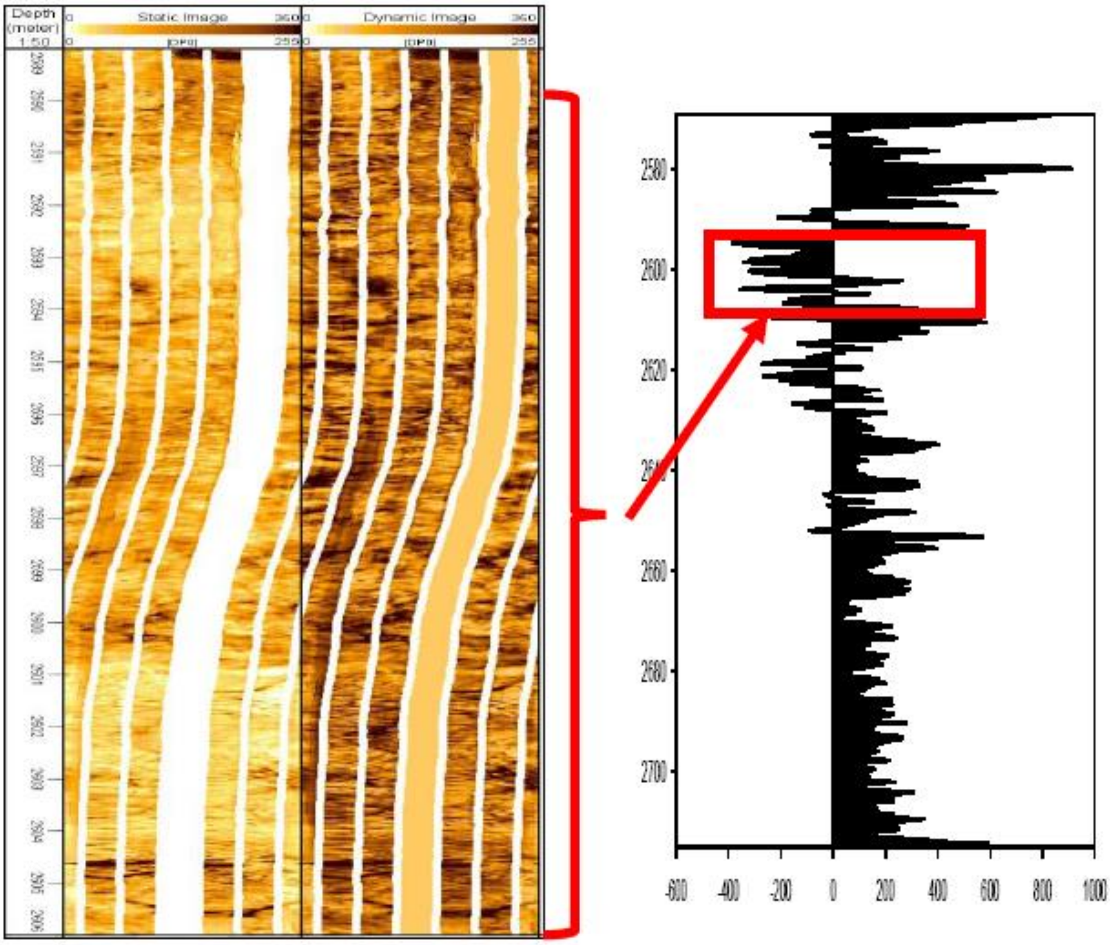

Figure 8) Display conductive zone in image log (means open fracture), and velocity deviation log indicated readings near -500 amount in conductive zone.

The most negative amount on velocity deviation log belongs to depth of 2594-2610 meters. Also image log on this depth shows open fracture with high aperture (Fig. 8). Considering this relation, aperture plays more effective on fracture porosity and permeability on this well. Therefor the reservoir can be classified as type 3 of Nelson classification that in this category the fractures provide a permeability assist to the reservoir.

5- Conclusions

The study of image log of the borehole drilled in the Sarvak reservoir of Gachsaran oil field indicated that three sets of fractures can be detected on the image log: longitude, transverse and oblique. First set classified as tensile fracture while anticline created from folding and they have the most aperture fracture. Fracture density, length and aperture were estimated. Aperture parameter plays more effective role on fracture porosity and permeability of the reservoir. Therefore the reservoir quality increased and can be considered a high role for the fracture in this tight reservoir. This paper is an attempt to show a comparison between Fracture density (VDC), apparent fracture aperture (VDA), and fracture trace length (VTL) on the image log were compared with velocity deviation log (VDL) in the same depth. Velocity deviation log showed a good agreement with VDA. VTL and VDC in depth of 2594-2610 and 2670 meters are presenting high values and lower relation rather than VDA plot. According to deviation log data, the role of fracture aperture is more important than density of fracture. VDL variation appeared to be high in depth of 2594-2610 and negative.

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Abbreviations

Fracture density (VDC), Apparent fracture aperture (VDA), Fracture trace length (VTL), American Petroleum Institute (API) Drill stem test (DST), X-tended Range Micro Image (XRMI).

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