

Lithology effects on the fractures parameters using image log and petrophysical data

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Abstract. Fractures within a reservoir play an influential role in the porosity and permeability, therefore affect the fluid flow. By analyzing properties of fractures, such as fracture height, density and mutually spacing and compare them with different tectonic locations and different lithologies, one could gain insight in the mechanical behavior of a rock mass, when distorted by tectonic forces. The velocity deviation log (VDL) can be used for determination of effective porosity. The result indicated that there is a high fractures density in the Asmari Formation which shows high correlation with VDL. They are mainly strike N75E, S75W direction and are chiefly observed in the upper Asmari zones. Fractures and vuggy have been also observed in the well. Image log showed a range of bedding dip from 53–89 degree with strike N55W, S55E in the well indicating of reverse limb in the field. Image log

show two set fracture which azimuth 347 for discontinuous fracture and 220 with strike N55W, S55E for continuous fracture. Main type of lithology determined by petrophysical log showed that dolomite is dominant constituent. Induced fractures and breakouts haven't been observed in this well. After correlating image logs with VDL and lithology, zones with dominant pure dolomite presented higher aperture rather than zones with dolomite and anhydrite. Fracture density is more affected by bed thickness than mineralogy. Zones with negative deviation velocity have high fracture density or high fracture aperture.

Introduction

Fractures have a vital effect in production rate and migration of oil in Zagros basin [Alavi, 2004, 2007]. Fractures in carbonate reservoirs are important due to their high influence on reservoir rock properties that deal with porosity and permeability [Nelson, 2001; Rajabi et al., 2010]. Two main categories of factors controlled fracture generation in folded structures: (1) geomechanical properties such as lithology, porosity, grain size and fabric of beds and (2) geometrical factors such

as: bedding thickness and structural setting [*Nelson, 2001*]. Knowledge about fracture and their scattering patterns are helping in determination of the best location for drilling and maximum production rate [*Serra and Serra, 2004*]. There are several direct and indirect methods to determine fractures in reservoirs such as seismic, petrophysical logs, well test, mud loss data, cores and image logs analyses [*Thompson, 2000; Tingay et al., 2008*]. Image logs and cores are the best methods for the analysis of reservoir parameters. However, cores have serious limitations such as high cost, low recovery in fractured interval, and changing core orientation during coring [*Khoshbakht et al., 2009; Mohebbi et al., 2007*]. The Asmari Formation (Oligo-Miocene) is a main petroleum reservoir of Iran. Petroleum production potential of the Asmari reservoir is about 85% of the crude oil due to abnormal vuggy porosity type resulted from natural fractures [*Gholipour, 1998*]. Therefore the study of the fractures in the Asmari reservoir is a serious subject up to now [*Aghli, 2013; Khoshbakht et al., 2009, 2012*]. It is cleared that fracture study and evaluation in any oilfield can be helpful in the complementary stage of the well, the determination of perforating depth, field development, directional drilling well program, fluid injection zone

and fracture modeling. Image log studies reduce expenditure owing to the reducing coring depths and perforate zone determination. The presence of fractures has a considerable impact on permeability [*Rezaee and Chehrizi, 2005*]. Previous work indicated that lithological change and sedimentary heterogeneity such as grain composition, cementation relative to the stress field, can be influenced rock behavior and have a visible effect on the fracture density and distribution [*Massiot et al., 2015; McQuillan, 1973*]. Fracture spacing has also been related to the rock properties and bed thickness of the adjacent rock unit as well as the rock properties of fractured bed [*Bai and Pollard, 2000*]. The velocity deviation log, which is calculated by combining the sonic log with the neutron or density log, provides a tool to obtain well information on the predominant pore type in carbonates [*Anselmetti and Eberli, 1993*]. The present work is an attempt to indicate the role of fracture on the reservoir parameters and the role of lithology on the fracture parameters. For this aim petrophysical and image logs are used simultaneously.

Geological Setting

Zagros fold-thrust belt extends about 2000 km from southeastern Turkey through northern Syria and Iraq to western and southern Iran [Alavi, 2004]. Structurally, Zagros basin is placed in the north of the Arabian plate. The studied field is located in Dezful Embayment of Zagros basin in SW of Iran (Figure 1).

Geological history of this basin indicated a long time subsidence and deposition which interrupted by short time uplift. Folding process of this basin occurred in Miocene and Pliocene and continued until now which formed long anticlines [Ahmadhadi et al., 2008; Motie, 1995; Twerenbold and McQuillan, 1962]. These anticlines constitute most of oil traps in this basin. Dezful Embayment (SW Iran) is a part of Zagros fold and thrust belt [Alavi, 2004, 2007; McQuarrie, 2004].

The Asmari Formation (Oligo-Miocene) is composed of light gray (locally buff to white) shallow marine Hippurite bearing limestone (grainstone, pelletal packstone, dark bioclastic wackestone) with intercalations of black fissile shale and broken by several intraformational disconformities [Alavi, 2004]. The Gachsaran oil field is located at the south Dezful Embayment limited by many faults which has caused difficulty in structural

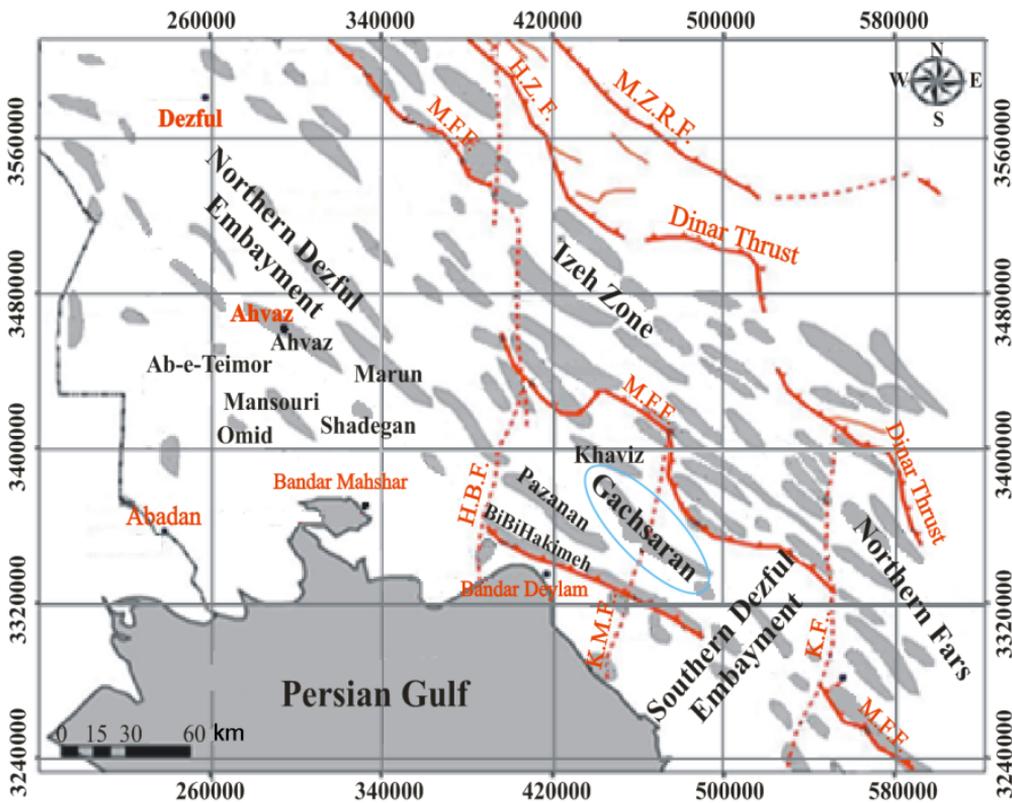


Figure 1. Main hydrocarbon oil fields position in Iranian Zagros range [Sherkati and Letouzey, 2004]. Abbreviations are: M.Z.R.F.: Main Zagros reverse Fault, M.F.F.: Mountain Front Fault, H.Z.F.: High Zagros Fault, K.F.: Kazerun fault, K.M.F.: Karg-Mish fault, H.B.F.: Hendijan-Bahregansar fault.

analyses. The studied oil field characterized by 50 miles long and 6 miles wide (80 km \times 9.6 km). Understudy drilled well in this field is in the south limb in the anti-cline which has higher dip rather north and this limb is reversed (Figure 1b).

Methods and Materials

Electrical images are produced by placing pads with arrays of electrodes maintained at a constant electrical potential against the borehole wall, and measuring the current drop as the electrodes travel along the borehole wall [Ekstrom et al., 1987; Ye and Rabiller, 1998]. Data from multiple electrodes are combined to produce electrical conductivity images. Because a current is being passed into the borehole wall, this technique actually measures the properties of a volume of rock within a few inches out of the borehole. The azimuthal coverage of the image and its resolution is determined by the size and number of electrodes, their arrangement, the pad dimensions, and the borehole diameter. When the image is “unrolled” and displayed from 0° to 360°, linear features intersecting the borehole appear as sinusoids [Rider, 1996] Assuming that the images are properly oriented to geographic north, the amplitude

Dip Computation

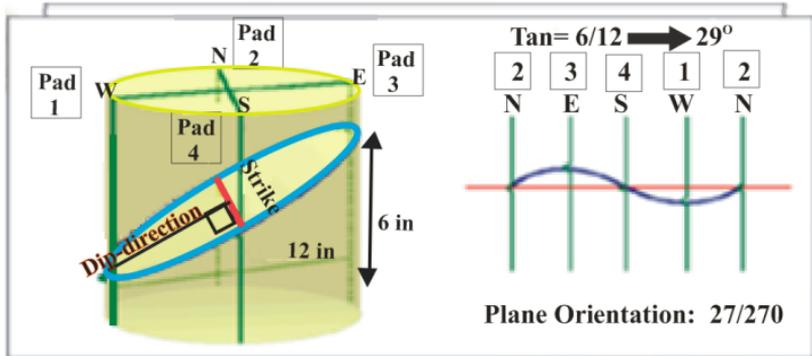


Figure 2. Schematic illustration of fracture plane intersecting a cylindrical borehole, indicating how the strike and dip of the fracture is interpreted from televiewer log images of the intersection between the fracture plane and the borehole wall.

and minimum of the sinusoids can be related to the dip and azimuth of the associated feature, respectively, and consequently provide fundamental information regarding the encountered formation (Figure 2).

In this study, FMI image log as the main data and VDL is complementary data were used. Image log is a “pseudo-picture” of borehole wall which image the physical property of borehole wall such as electrical resistivity or acoustic impedance. In the first method resistivity of borehole wall is converted into high resolution resistivity image of wall. There are 2, 4, 5 or

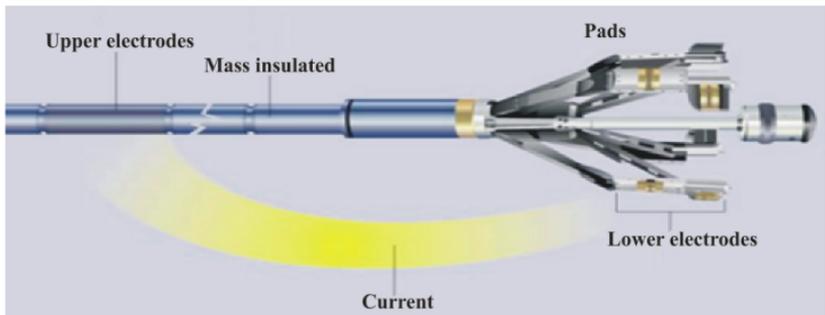


Figure 3. FMI tool and pads on the tool.

8 pads on an imaging tool (Figure 3). Each pad covers limited part of borehole wall [Serra, 1989]. The FMI tools have an azimuthal resolution of 192° capable of radial micro resistivity measurements (vertical resolution: 0.2", vertical sampling: 0.1", depth of investigation: 30") [Schlumberger, 1994]. The images are carefully described to characterize fractures and other geological features and finally the image results were correlated with other data. In this study, image logs were processed and interpreted by the CIFLOG GEOMATRIX software. CIFLog-GeoMatrix integrated logging data interpretation and processing software uses Java's self balancing technology to realize cross-platform and multi-operating system processing without need to convert logging data [Dawei et al., 2013; Zhen, 2013]. Based on the key special projects

of the State and China National Petroleum Corporation (CNPC), CIFLog-GeoMatrix, integrated software for log processing and interpretation, is available for Windows, Linux, and Unix operating systems and with multiple languages. This software exclusively adopts a plug-in design that integrates conventional logging, imaging logging, special logging, and LEAP800 logging interpretation. Also, it features a user-friendly graphical user interface (GUI), powerful interactivity, and accurate and reliable interpretation methods while supporting multi-language secondary development.

Velocity Deviation Log

The velocity deviation log, which is calculated by combining the sonic log with the neutron or density log, provides a tool to obtain well information on the predominant pore type in carbonates [*Wang and Nur, 1990*]. Velocity deviation characterizes with three zones.

(a) Positive deviations – It indicates relatively high velocities in regard to porosity, and are caused mainly by porosity that is integrated in a frame like fabric of where the pores commonly are not connected. A positive deviation thus also may indicate low permeability.

(b) \pm Zero deviations – Zones with small deviations

(± 500 m/s or less) represent sections that follow the predictions by the time-average equation. These zones are dominated by interparticle, intercrystalline, or high micro porosity. All of these pore types are particularly predominant in a sediment just after deposition, when original grains or micrite are simply packed together.

(c) Negative deviations – The larger scale fractures can be detected with the logging tools and yield lower velocities than the undisturbed rock. In addition, buried fractures are normally closed or, in regard to total porosity, are relatively insignificant, so that the neutron porosity is not significantly reduced. As a result, fracturing produces negative deviations [*Anselmetti and Eberli, 1999*].

Discussion

After analyzing image logs in the well (Figure 4) software has this facility to show the data in stereo nets, rose diagrams and histograms. Because of the importance of open fractures (about 700) and bedding in this study (based on this study purpose), they were determined on image logs. Fracture density and fracture aperture was calculated for the well. After the analysis of electric image logs in the studied wells sev-

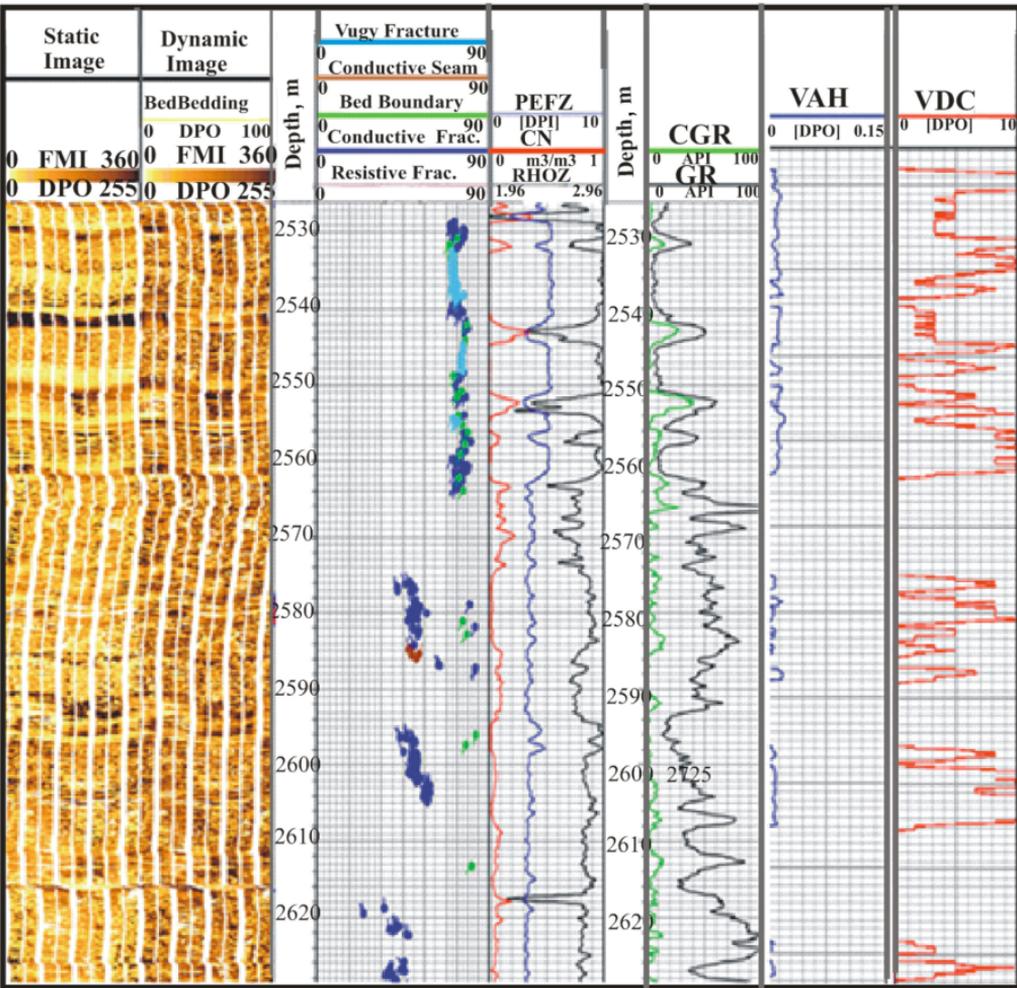


Figure 4. Image log and petrophysical logs in the understudy well. Abbreviations are: FMI: formation micro image, PEFZ: photoelectric factor, CN: compensate neutron, RHOZ: density log, CGR: compensate gamma ray, GR: gamma ray, VAH: apparent hydrologic fracture aperture, VDC: fracture density.

eral feature such as open fracture, resistive fracture, conductive seam and bedding identified in this well. Fracture and bedding identified in the image log because is important in this research. After identifying the fracture, fracture density and aperture correlated with image log. To determine of lithology, petrophysical logs such as DT (acoustic log), NPHI (neutron porosity), PEF (photoelectric factor), RHOB (density porosity) were used. To find the effect of lithology on the fracture generation and fracture parameters, image log correlated with lithology and VDL (Figure 5). The correlation showed that in depth, within thin bedded dolomite layers, fracture density is higher and velocity deviation is more negative.

Structural analyses in the Gachsaran oilfield indicated that Asmari Formation is a fracture reservoir. Fracture has two sets with two directions in the well: discontinuous fracture has dip within $8 - 49^\circ$ with azimuth $10-20$ and $330-360$, continuous fracture has higher dip rather discontinuous and are between $53 - 82^\circ$ with azimuth $200-230$ (Figure 6). Two sets identified for the resistive fracture are scattered in dip, strike and azimuth. In this set, azimuths are 120 and 319 , dips are 62 and 19 (Figure 7). Most fracture existing in the upper zone of the Asmari Formation. in this field,

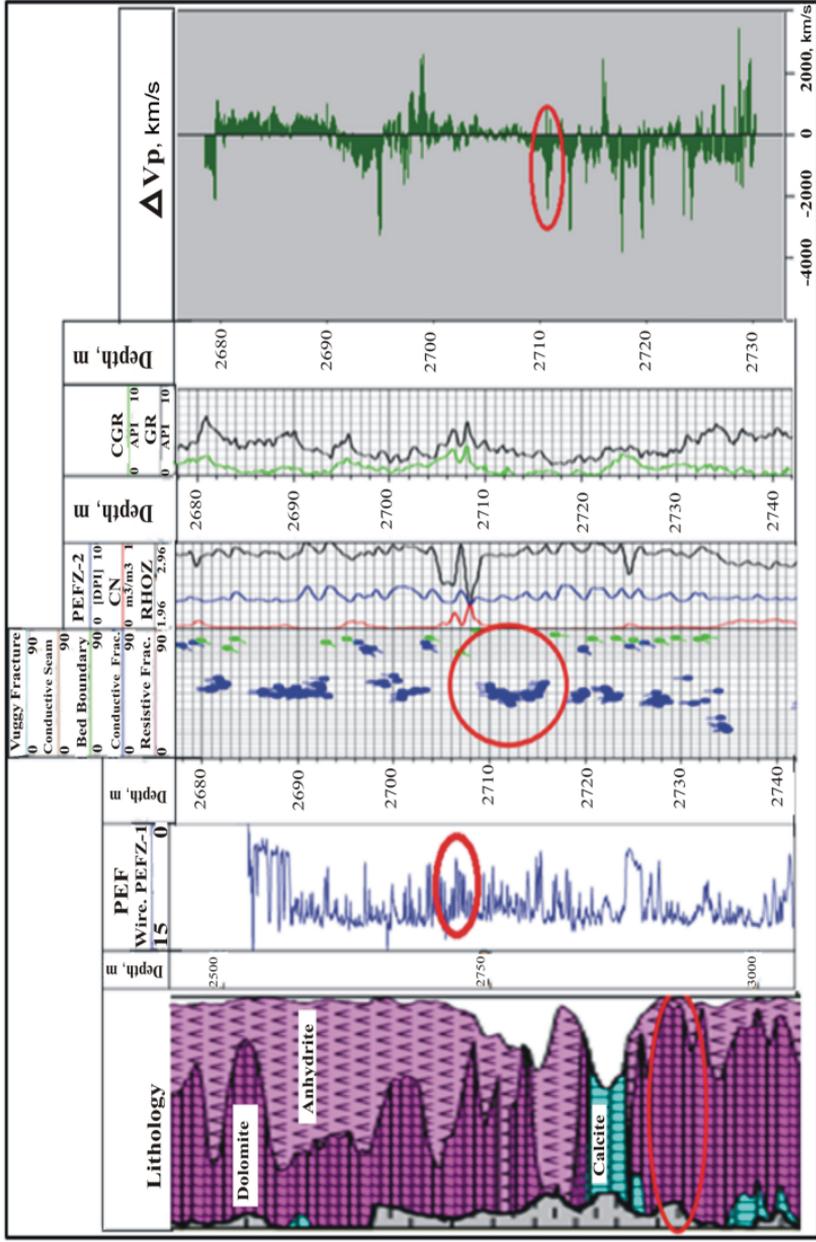


Figure 5: Comparison between lithology, image log and VDL showing negative values of VDL in zone with thin bedded dolomite layer. Abbreviations: PEF: photo electric factor, ΔVp : variation of velocity deviation.

Well name= 7-35-FMI- 035PUC Top zone= 2525.7278 m
 Top= 2525.725098 m Bottom zone= 3033.2173 m
 Bottom= 3033.2197265625 m

Set Number	Number of Dip
● Conductive fracture	729

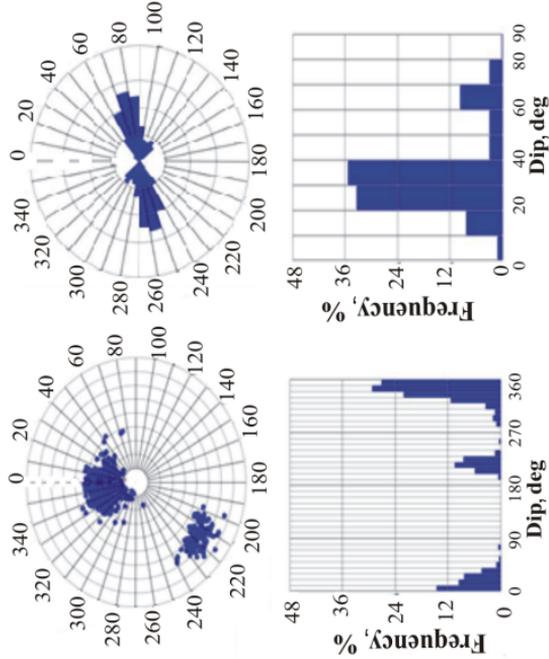
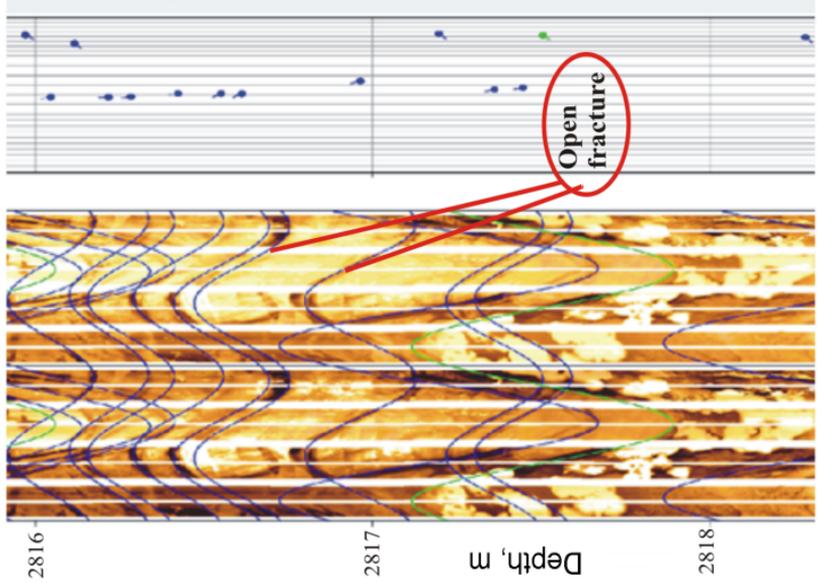


Figure 6: Open fracture on the image log, Stereonet rose diagrams and histograms.

Well name= 7-35-FMI- 035PUC Top zone= 2525.7278 m
 Top= 2525.725098 m Bottom zone= 3033.2173 m
 Bottom= 3033.2197265625 m

Set Number	Conductive seam (unclassified)	Number of Dips
●		5

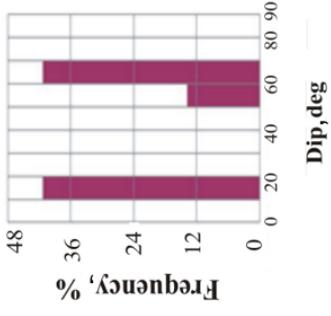
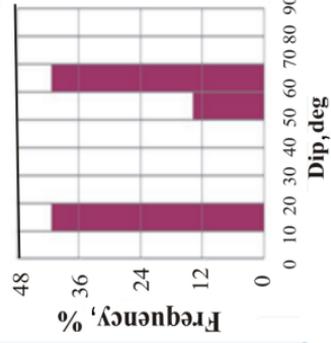
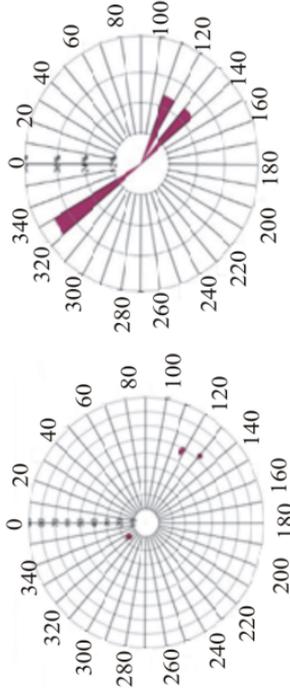
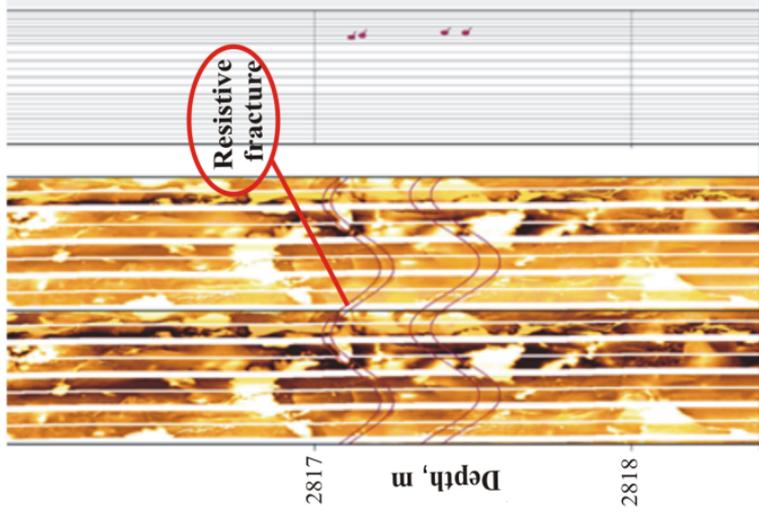


Figure 7: Resistive fractures on the image log, Stereonet rose diagrams and histograms.

considering the general pattern of fractures, it is evident that they are related to the folding and are mainly classified as longitudinal, transverse, and oblique. The main fracture set has different orientation as the bedding. Strike in this set is almost N75E. The other fracture set is same oriented relative to the bedding and is considered as a longitude set. Dominant strike in this set is S55E. Continuous fracture has a same strike with bedding and type of fracture in this is longitudinal and fractures with strike of N65W are dominant in this well and are transvers.

The full-bore micro imager clearly indicate layering/bedding throughout the logged interval In the image log, bedding boundary is defined as a plane which two dimensions of it show different resistivity or acoustic impedance; therefore in image log bedding appears as abrupt change in image color which usually could be seen in all pads. These lines are easily correlated from pad to pad and are visible on static images and correspond to the surface or boundaries separating two beds of different lithology [*Serra*, 1989]. So the dips computed from the first type of layer/bed boundaries are classified into high confidence (HC) bedding dips, and those from the uneven and vague boundaries are classified as low confidence (LC) bedding dips. In

the upper Asmari, very thin shaly layers and anhydrite/limestone are abundant. Very thin lamination in upper Asmari carbonate and dense streak were indicators of bed boundary. In the middle part of Asmari, the quantity of bed boundaries was very limited and formation changes to massive limestone with anhydrite nodules. In this zone, variation of texture formed vague bed boundaries. Dips of bedding are very high between $53 - 89^\circ$ with azimuth 180–240 but dominant azimuth is 218 (Figure 8). In spite of high dip bedding it must be considered that this feature indicates the role of reverse limb.

The Lithology can be one of important factor in controlling fracture distribution. Dolomite reservoirs are important sources of hydrocarbons, and their fluid flow pattern is commonly influenced by fractures. Fracture architecture depends on the rock properties at the time of fracturing (particularly subcritical crack index). Lithology and bed thickness are primary controls the fracture density, fracture aperture and orientation, reflecting the fact that different rock unit are mechanically distinct. Fracture density has been correlated with the mineralogical composition of the matrix grain, porosity and bed thickness. More brittle rocks will have more density fracture rather less brittle rocks. The

Well name= 7-35-FMI-035PUC Top zone= 2525.7278 m
 Top= 2525.725098 m Bottom zone= 3033.2173 m
 Bottom= 3033.2197265625 m

Set Number	Number of Dips
● Bed Boundary	73

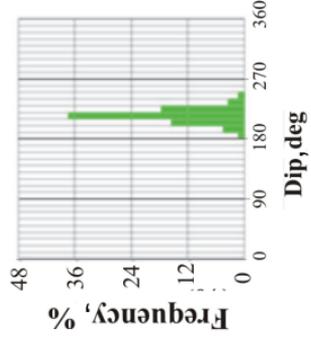
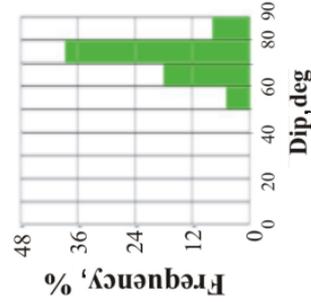
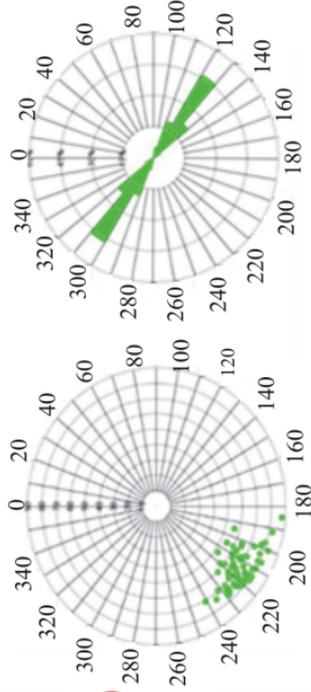
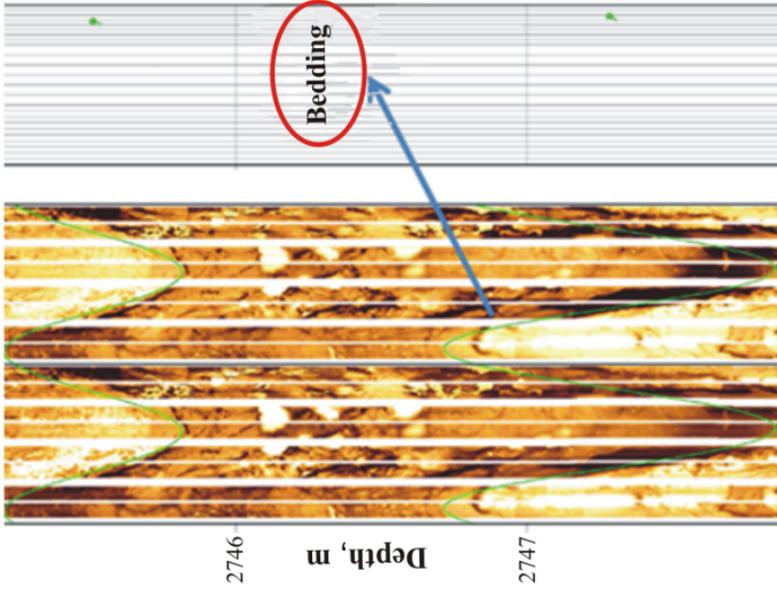


Figure 8. Bedding on the image log, stereonet rose diagrams and histograms.

primary brittle constituent within a rock are quartz, dolomite and calcite. However, it should be noted that the elastic properties of a given rock unit which have a direct influence upon fracture density need not always associate with the amount of brittle constitute. According our results, it has been observed that when condition and all other rock parameters are equal, thin beds will higher fracture density rather thicker bed in the reservoir. In the present study, dominated mineral is dolomite and anhydrite, calcite and shale are little. It was evident that high density and high aperture fracture are correlated well (Figure 9). It showed that the fracture occurred in areas with thin bed and pure dolomite layers has high aperture (Figure 10) and fracture density is more dependent to bed thickness to lithology (Figure 11).

To evaluating the dominant pores pattern and fractures detection, VDL log was drawn using Sonic and Neutron digital data for the Asmari reservoir. In this well, generally, there is an inverse relationship between porosity and velocity, so velocity decreases with increasing porosity [Wyllie *et al.*, 1956]. Velocity deviation log (VDL) is a correlated method which is drawn with sigma plot 12 software and correlated with image log and lithology. The correlation of high fracture density,

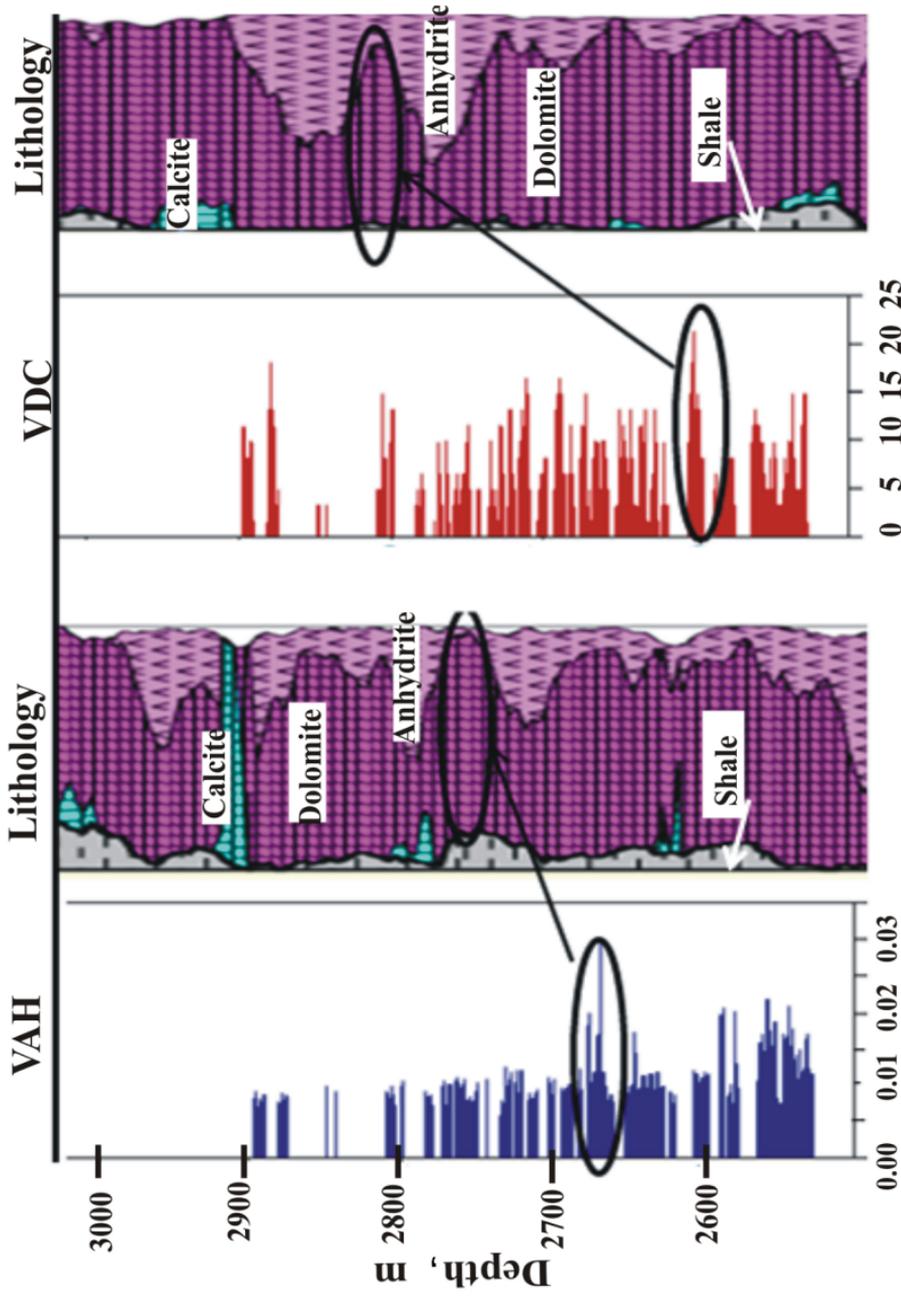


Figure 9. Role of lithology on fracture density (VDC) and fracture aperture (VAH).

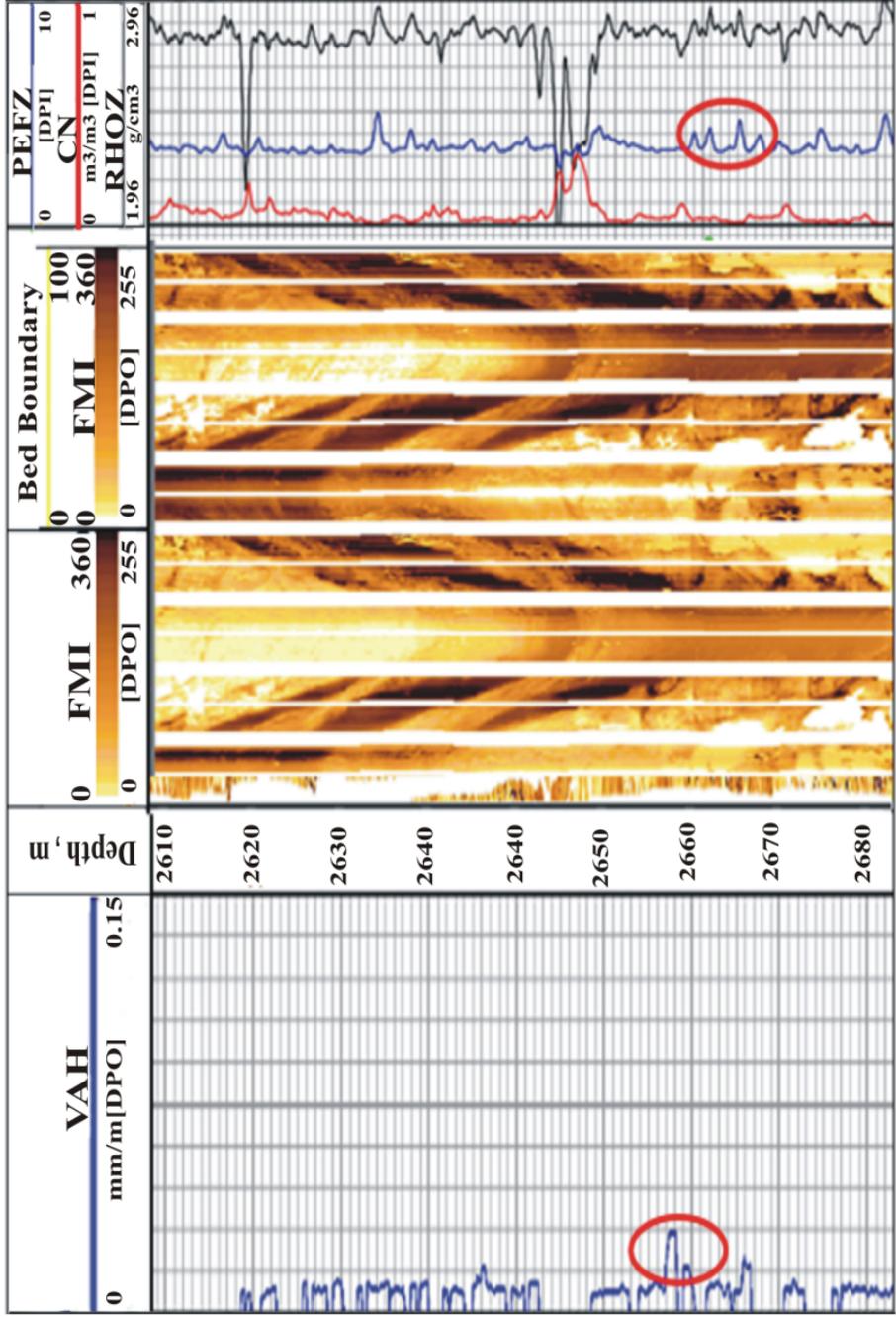


Figure 10. Comparison between the zone responses having fractures with higher aperture (VAH) and petrophysical log (PEF).

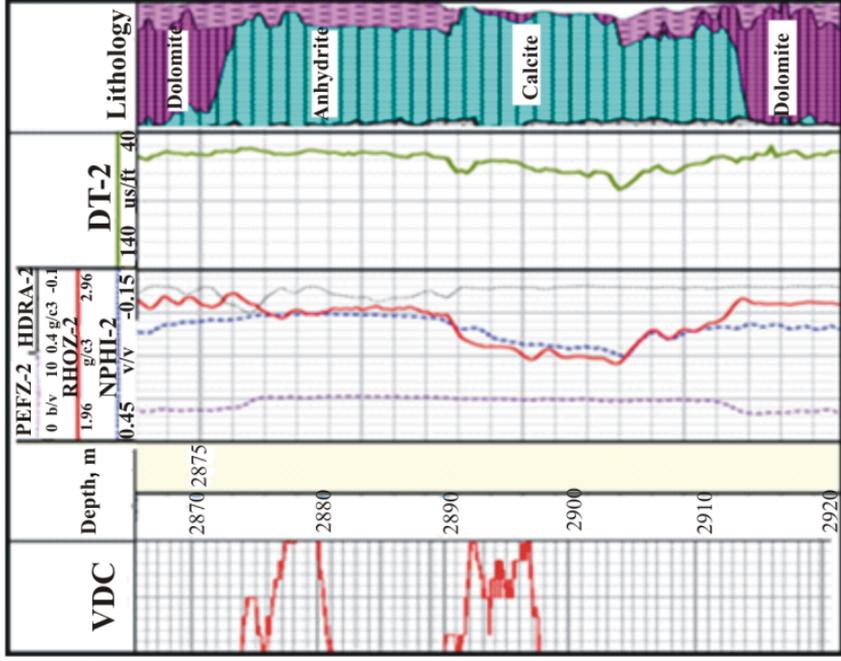
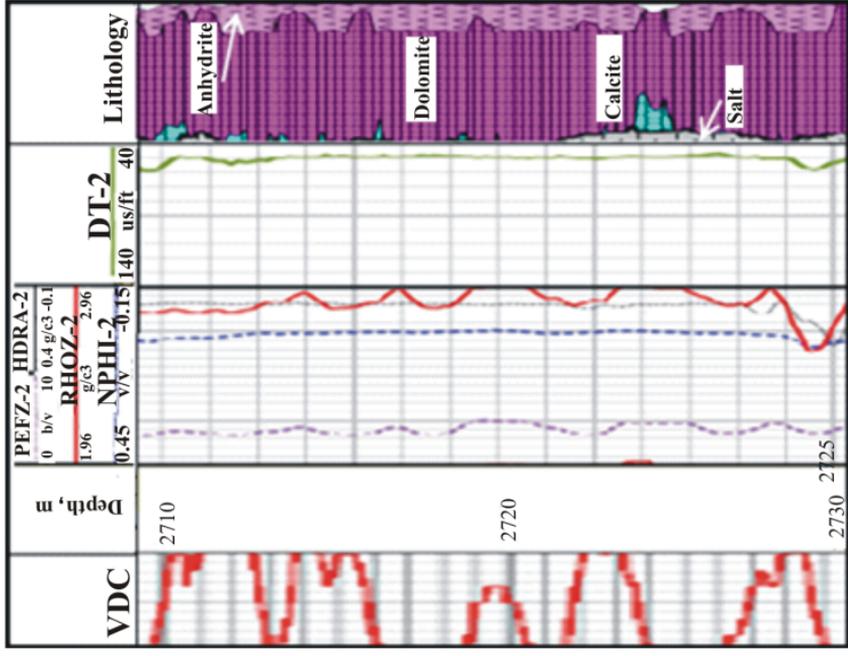


Figure 11. The plot indicates the effect of mineralogy on the fracture density. Abbreviations: NPHI: neutron porosity, DT-2: sonic log.

fracture aperture and negative deviation in this zone showed that fracture is higher correlated to VDL (Figure 12).

Fracture having zone on the image log and VDL shows high correlation with the mineralogy determined with petrophysical log in Geolog.7.1 software. All data revealed that the Asmari reservoir consisted lithologically of dolomite, limestone. Anhydrite is also detected as a minor element (20–30%) but decreased towards the base of Asmari Formation and formed Kalhor member. All data revealed that fractures can be effected the reservoir properties and for this aim image log, lithology and VDL were used. It was found that fractures are the most important features in the reservoir especially in the upper Asmari zones. In this field, production is controlled by a combination of fractures and vugy pores. Also reservoir zones with high rate of production characterized with continuous fractures with high aperture rather than discontinuous fractures. Correlated with density fracture (VDC) and aperture fracture with VDL showed that in the areas with high aperture and high fracture density velocity deviation, there is the highest negative deviation values which is indirectly indicated the association of aperture and fracture density in controlling the permeability. In view of the effect of

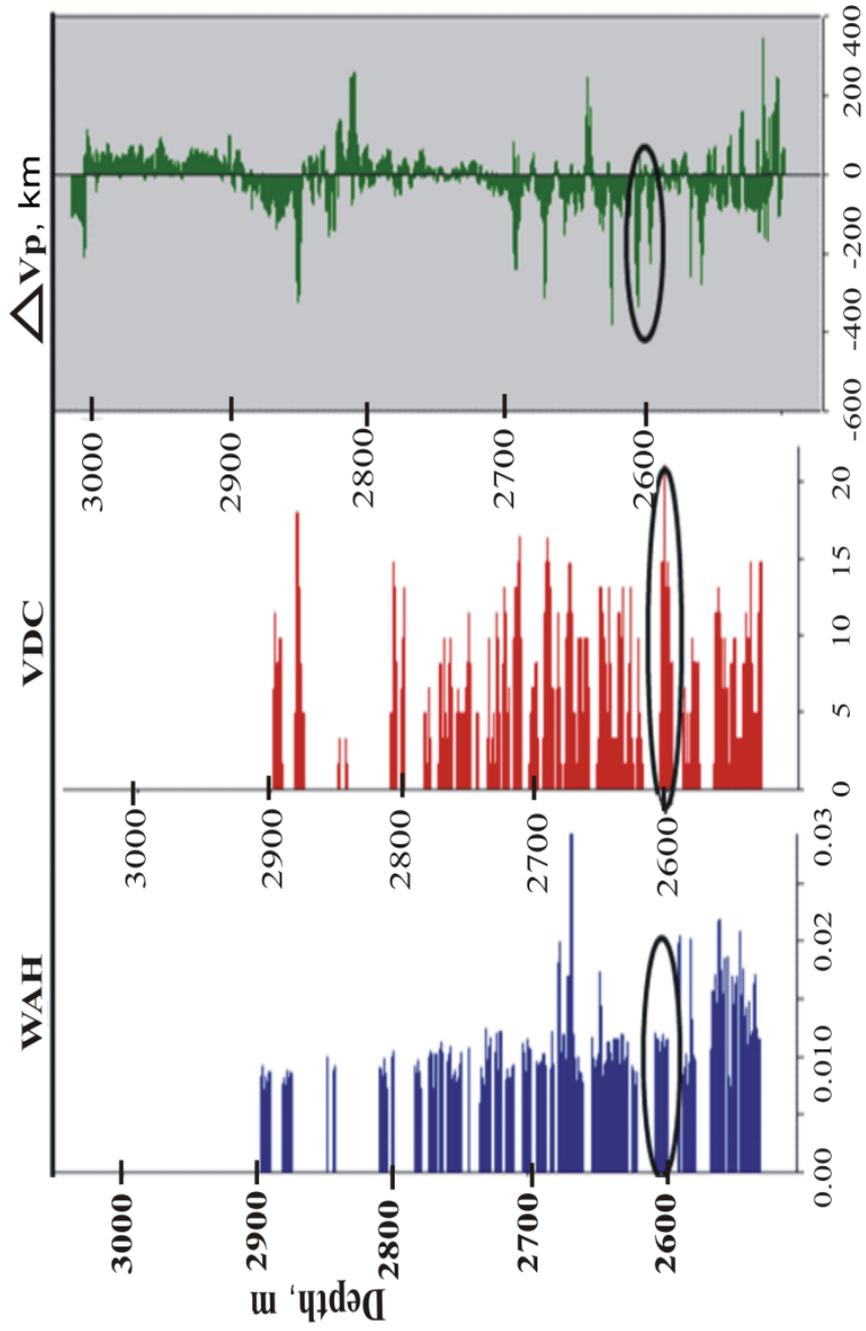


Figure 12. The plot shows more negative values of VDC in zones with high fracture aperture and so high fracture density velocity deviation. VAH controlled deviation of VDL values.

lithology in fracture parameters such as density and aperture, VDL and mineralogy are correlated well, and they show the zones with pure dolomite, fracture apertures are higher than zones with dolomite and anhydrite, and the fracture density in thin bedded dolomites is higher (shown on the image log and VDL).

Conclusion

The Asmari reservoir consisted of dolomite, limestone and anhydrite. To determine the lithology impacts on the fracture parameters and carbonate reservoir properties of Asmari Formation in Gachsaran oilfield, SW Iran, image logs, VDL and lithology results were compared. Image logs interpretation showed that fracturing was occurred in different horizons. There are more than 700 open fractures and so the Asmari Formation can be considered as a fractured reservoir. N75E fracture set as transverse pattern is dominant. They are characterized by strike N75E and are discontinuous. The other set as longitude has strike S55E, and showing a same strike with bedding, and are to be contemporaneous fractures with folding. Bedding with strike N55W has a high dip between 53–89° which indicate reverse limb in the anticline. Due to well correlation between all

data and fracture parameters it can be concluded that the fracture parameters are controlled by lithology and tectonic activity. VDL as a method for the detection of fracture zones showed high correlation of fracture density log (VDC) and fracture aperture (VAH). The last factor is higher in the zones consisted of pure dolomite. Zones having thin bedded pure dolomite are presenting better reservoir quality as well.

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