International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 02 – Issue 10 || October 2017 || PP. 63-70

Determinationof Natural Fractures using FMI images: a Case study of the South Pars gas field in the Persian Gulf

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Abstract: The South Pars gas field in Persian Gulf is one of the world’s largest offshore fields. Its main reservoir units consist of Kangan and Dalaan carbonate sequences with upper Permian and lower Triassicage.
Natural fractures are planar features with no apparent displacement of blocks along their planes. Generally, they have a steep dip in tensional and wrench regimes. Whereas in compressional regimes, they may have high to low angle dips. Their apertures may be open, tight (closed) or filled with some minerals like clays, calcite, anhydrite, pyrite, etc. Data of this study are FMI static and dynamic normalized images from 3924.2-4929 m and Fullset data recorded by Schlumberger. The main objectives of FMI processing and interpretation were to evaluate structural dip, natural fractures and faults, if any. Based on the observations and interpretation of the FMI images, the highlights are as follows:

- Conductive / open fractures are well observed over certain zones. They are classified into three main categories. The major-open fractures (3 in total) dip at 80 degrees in average towards S30W. The medium open fractures (46 in number) dip at 75 degrees in average mainly towards S25W. Total of 639 minor open fractures dip at an average of 75 degrees towards S30W.
- High conductive fracture densities (>20/m) are computed at 3990-3993 m (Kangan), 4282-4289 (Upper Dalan), 4427-4437 m, 4455-4460 m, 4463-4470 m, 4559-4575 m, 4589-4595 m (Nar), 4647-4653 m (Lower Dalan).
- Conductive fractures apertures vary in value between 0.0002 cm and 0.006 cm. The highest aperture (slightly more than 0.006 cm) is seen at 4565 m (Nar). Highest fracture porosity can be observed at the same depth, where it is slightly more than 0.03%.
- A total number of 12 resistive fractures are observed only within Upper Dalan interval. They show dip azimuth dominantly towards S55W with an average inclination of 69 degrees.

Keywords: South Pars gas field, natural fractures, FMI images.

Introduction:

Discovering and developing Hydrocarbon in regions such as middle-east, South America and south east of Asia, beside presence of diagenetic and facies factors, is also because of the presence of natural fractures in reservoir deep and hard rocks. One challenge for the experts of oil industry in these regions is to identify the fracture systems, modeling and determine the fluid route along them. Existing reservoirs in the Middle East are among the most important naturally fractured reservoirs in the world, whose open and permeable fractures are attributed to the performance of factors such as nature, fold degree, faulting, the nature of situ tension and the change in some features of the stone such as porosity, bedding, lithology, and shale percentage [1]. Although in the first glance it seems that the convergence of two planes of central Iran and Saudi Arabia toward each other and their collision, is the underlying cause of Zagros Orogeny in Miocene and there is a significant relationship between the Zagros folds and natural fractures of limestone formations and of Zagros belt, but in 1974, McQuillanas the first person who examined Asmari fractures claimed that wide variation in the process of fractures, and lack of relationship between their density and the severity of folds, Indicates the emergence of fractures before in main folding phase in Mio-Pliocene. This conclusion is while many scholars before and after him have put emphases on the presence of North-South and linear trends and their importance in the formation and geologic history of Arabian platform[1]. Also, in 1992, Edgellnoted the existence of the rock-base faults, and attributed their origin to the Late Proterozoic and former Cambrian That during Mesozoic Era, especially Triassic and Cretaceous, have been reactivated. Salt domes distribution in Arabic platform and bent anticline axis in some parts of folded structures have been considered in relation to the position of rock base faults. Other studies have claimed that rock base faults, in the trends of driving the Arabia crust beneath central Iran, acted as weaknesses and their activity is a factor in the development of natural fractures in the region[2, 3]. The most recent studies on fractures in the anticlines ASMARI Formation of Khunriz, Dale, ASMARI, Sulac, Bangestan, Sefid and Razi in the heavily folded region of Zagros show that these fractures are dividable into two groups of fractures before and simultaneously with folds [2].

[1-]Heson,1951:falcon,1969&1974;koop&Stoneley1982;McQuillan,1991;Ameen,1992.

Study Area:

South Pars gas field covering an area of 3,700 square kilometers in the south of the Persian Gulf, as the world's largest gas reservoir is of particular importance. The main carbonated reservoirs in this field are Dalan (upper Permian) and Kangan (Lower Triassic) carbonate - evaporating sequences. The field is in offshore of Iran, a part of the Fars-Qatar Arc[1] (Figure 1), which is formed in the eastern part of Arabian plate, and it seems that the collision of Ammar in 620-640 million years ago, is the main factor of emergence of this arc that in a north-south trend had cut the Arabian Peninsula in longitude E ° 45 [4]. Among tectonic factors influencing the shape and position of the Middle East, it seems that The original structure of Rock base, had the greatest influence on the emergence of South Pars structure with a north-south trend, And other factors such as the movement of salt and orogenic movements of Middle Miocene (Zagros orogenic) had acted weaker (Figure 2) [5]. The presence of shallow carbonate massive sequences which since facing the sea in the Permian, have been deposited on Lower Paleozoic rocks in northern border of Arabianplates[2][5, 6] Along with the favorable situation of region structure and a wide range of rich source rocks in the basin of Saudi with Silurianage, are the main causes of present of huge reservoirs of hydrocarbon in this region. Hydraulic Fittings of reservoir units of Kangan and Dalan made them be continually considered as a gas reservoirs and be separated into four member units of k1 to k4, only based on the characteristics of the reservoir and sequence biostratigraphy. Studies indicate that changes in the thickness and lithology of these of reservoir units in the horizental direction is insignificant and reservoir parameters are under strict control of diagenesis before burial, especially with leaching and dolomitization. On the other hand, pores and fractures anhydrite cementation also plays an important role in reducing the quality of reservoir units [5].

[1-]Fars-Qatar arc.
[2-]Stocklin 1974, Ruttner et al.,1968.

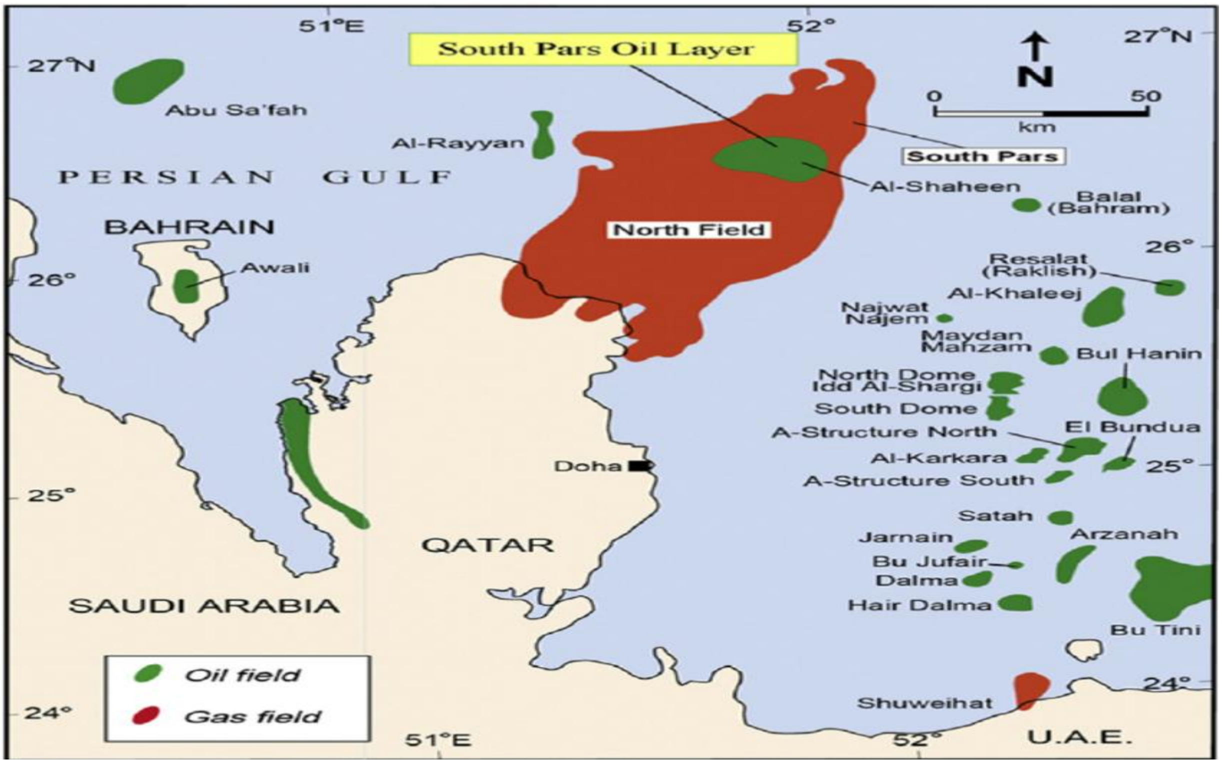


Figure1: Location of South Pars field in the Persian Gulf.

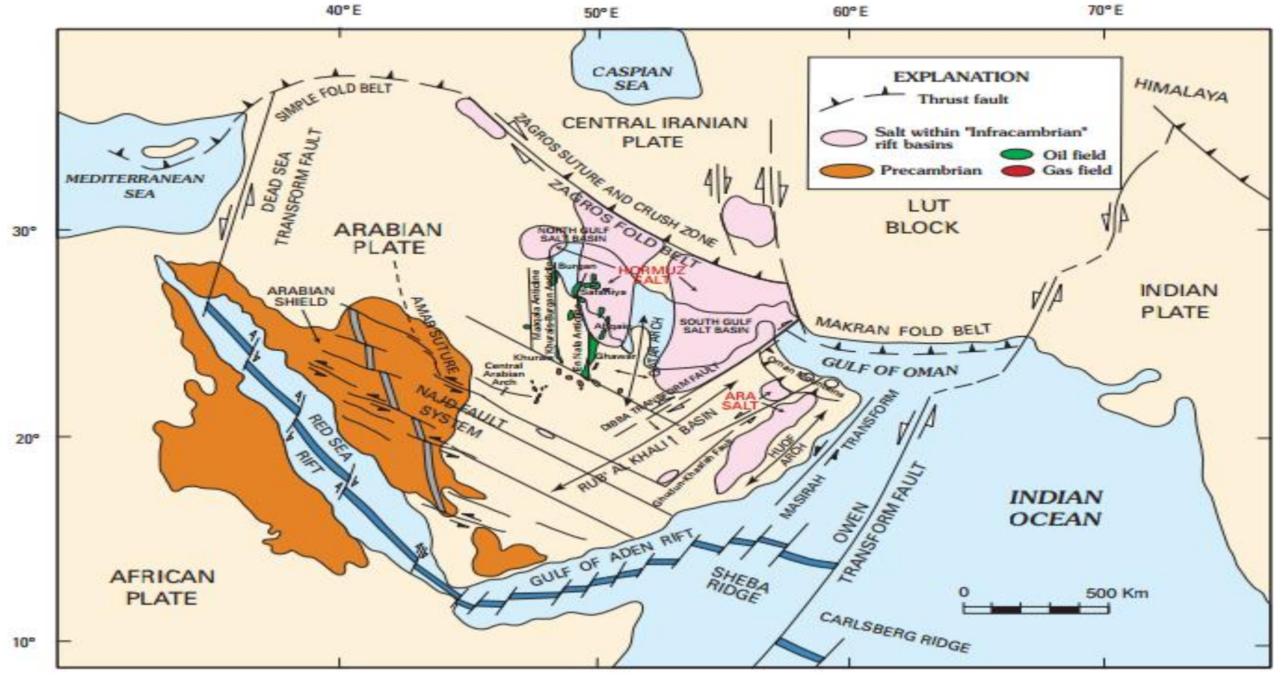


Figure 2: Fars- Qatar Arc, pre-Cambrian Salty basin in the Persian Gulf and region of basementfaults with North- Northeast trend in Middle East and around the South Parsgas Field (After Konert et al.,2001).

Methodology:

Image Processing

Prior to feature interpretation and formation evaluation from the images, the FMI data are processed for a number of factors that may affect the quality of the images. Such factors include: variation in tool speed relative to the drill-pipes (in case of conveyed pipe logging) or cable speed; sticking of the tool; and EMEX variation. Moreover, to enhance details of formation features, images are equalized and normalized. [9]

Image Resistivity Calibration

Because the kind of current that flows out from the FMI tool into the formation is a relative current and cannot be used for quantitative analysis of formation features, the FMI resistivity / conductivity is calibrated with the environmentally corrected shallow laterolog (LLS, HLLS or AT3) or spherically focused log (SFLU). In the present well, RLA2 has been used for image scaling.[8].

Depth Matching

As open hole logs and images are acquired at different sampling rates, logging speed and time (in case of multiple runs), and each log may be affected by different extent due to sticking of the tool, consequently, each set of logs may be off-depth with respect to other logs or set of logs by variable amount of shift. Therefore as a rule, all logs and images are depth matched to a reference log before actual analysis of image and log data starts. [9]

Structural Dip Analysis

Structural dip analysis is based on interpreted bed boundaries dip interpreted on image log. To obtain the best results for structural dip and visualize these results, dips picked interactively for bed boundaries in BorView* are input into different modules in GeoFrame. Stereonet* is used to show the statistical plot of all dips picked. StrucView* is used to visualize the dips on cross-section view to better understand the structural features. Dip Vector Plot shows the trend for structural dip variations across the given borehole.[9,10].

Result and Discussion:

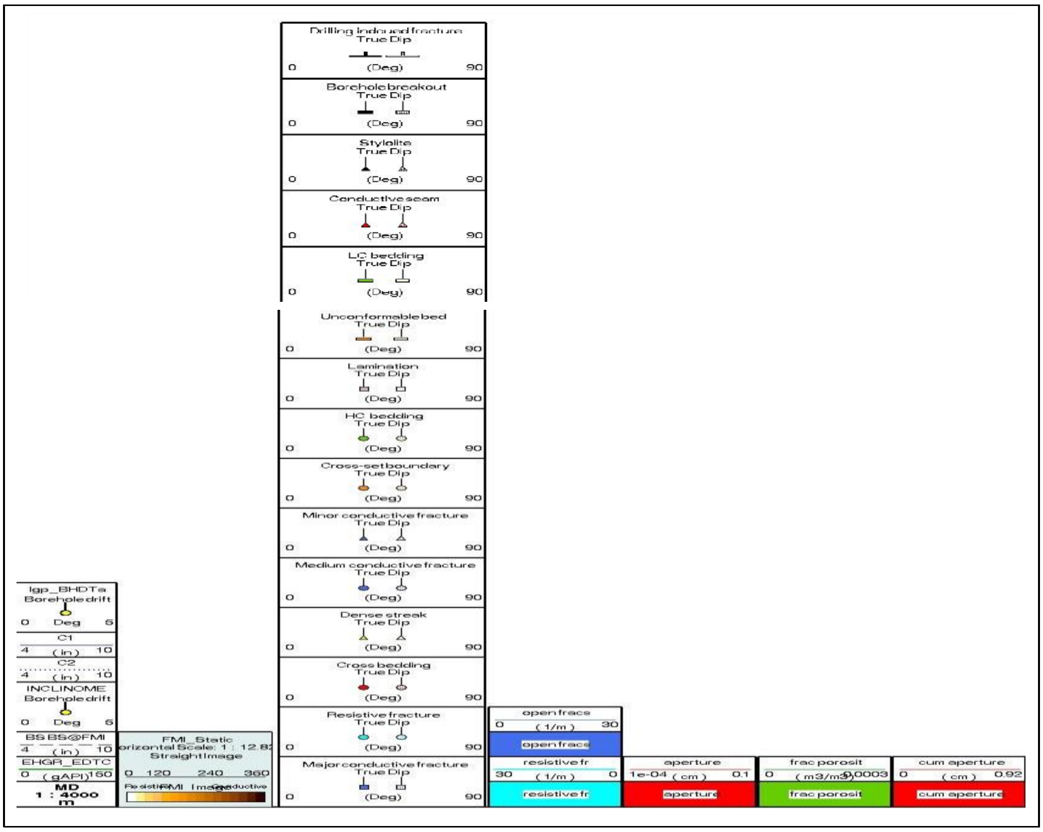
Natural fractures are planar features with no apparent displacement of blocks along their planes. Generally, they have a steep dip in tensional and wrench regimes. Whereas in compressional regimes, they may have high to low angle dips. Their apertures may be open, tight (closed) or filled with some minerals like clays, calcite, anhydrite, pyrite, etc. [9].On the FMI images, natural fractures tend to occur as linear features that generally have dips steeper than the structural dip. Open fractures, in a clay free formation, have a conductive appearance on the images due to invasion of their aperture with the conductive drilling mud [9]. While the mineralized or sealed fractures appear resistive if the filling material of their apertures is dense like calcite or anhydrite. However, the natural fractures filled with clay or pyrite, have a conductive response. To differentiate between the drilling-mud filled and clay / pyrite filled conductive fractures, knowledge of the depositional and stratigraphic setting of the study area is imperative. Additionally, core data over the same interval can help in defining the exact nature of fractures. In some cases, fullsetopenhole logs (pef, rhob, neutron, …) can also be very helpful for such kind of differentiation. [11].

Natural Fractures Analysis

Natural fracture analysis is one of the main objectives of the FMI survey in the study well. To get additional information on open fracture attributes (i.e. aperture and porosity) the image log was scaled with a shallow resistivity log, RLA2 (acquired by Schlumberger). Discussions on various natural fracture attributes are given in the following paragraphs.

Natural Fractures Classification

All the natural fractures that have continuous or discontinuous conductive traces are termed as conductive / openfractures[12]. A total of 688 such fractures are encountered on FMI images in the present section of well(Figure3). These fractures have a variation in their aperture appearance and trace continuity across the wellbore. They are further classified, depending on their appearance and continuity on the images, into three categories: major-conductive, medium-conductive and minor-conductivefractures. There are only 3 major open fractures, which apparently have large apertures and better continuity across the wellbore. Mediumopen fractures are 46 in number over the entire interval. Their traces are less sharp compared to major conductive / open fractures, but more in extent compared to the minor ones. A majority of the open fractures appear to be minor. A total of 639 such fractures are picked up on the image. Their traces do not look very sharp and only occur on one or two pads of the FMI images. In addition, 12 resistive fractures have also been observed over the interpreted interval all occurred within the Kangan zone, classified as closed / resistive fractures based on their resistive appearance on image logs.



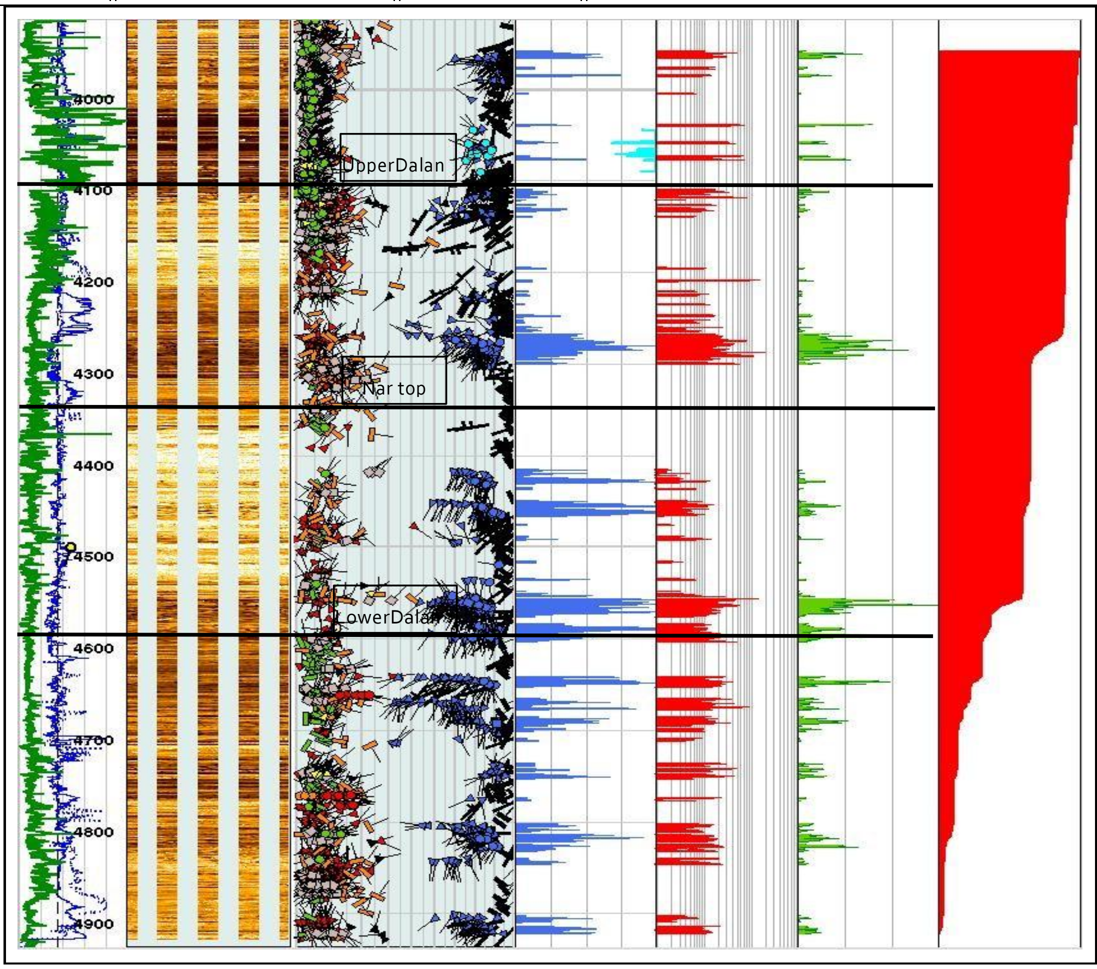


Figure 3: Summary of natural fractures, analysis and results.

Fracture attributes tracks definitions:
-4th track: conductive/open (blue) and resistive/closed (cyan) fractures density
-5th track: conductive/open fractures aperture
-6th track: conductive/open fractures porosity
-7th track: cumulative fracture aperture

Natural Fractures and Dip Attributes

Entire Interval (4677-5253 m)

The statistical analysis of the conductive fractures indicates that most of these fractures dip towards southwest with relatively low azimuthal dispersion. The dominant dip azimuth for these fractures is computed to be S30W with corresponding strike of N60W-S60E. Dip inclination of conductive fractures varies from 32 degrees to 85 degrees with an average being 75, which indicates that they include both low and high angle fractures, while high angle fractures are much more frequent. The major-open fractures (3 in number) predominantly dip towards S30W with a dominant strike direction of N60W-S60E with an average inclination of 80 degrees. Medium open fractures dip mainly towards S25W at an average of 75 degrees magnitude with a dominant strike direction of N65W-S65E respectively. Minor open fractures dip mainly towards S30W with a corresponding strike of N60W-S60E and an average of 75 degrees inclination. The resistive fractures (12 in number) show dip azimuth towards S55W. The dip magnitudes of these fractures range mainly from 63 to 80 degrees with an average being 68 degrees. These shows resistive fracture have comparable dip attributes with conductive ones.

Kangan (3924.2-4107 m)

In Kangan, none major, 3 medium and 38 minor conductive fractures are identified. These fractures show a major dip azimuth towards S80W and a minor dip azimuth towards south. Their dominant strike directions are therefore N10W-S10E as the major trend and E-W as the minor strike direction. These fracture altogether compute an average dip inclination of 79 degrees. Strike relationship between conductive (Figure 4).

Upper Dalan (4107-4351 m)

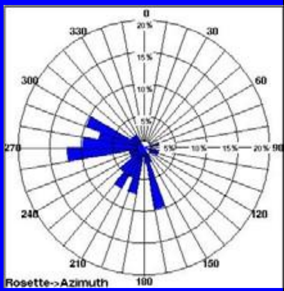
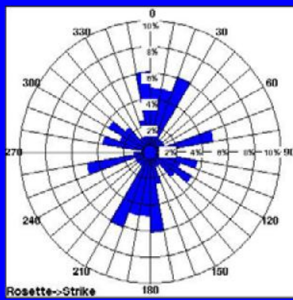
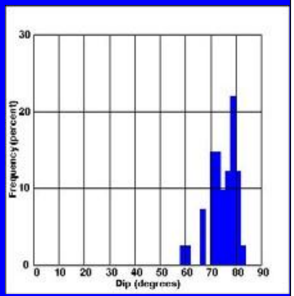
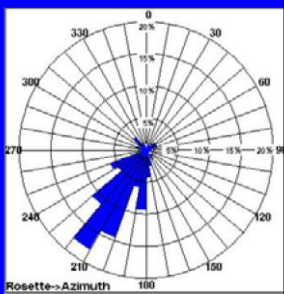
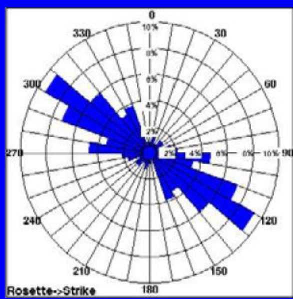
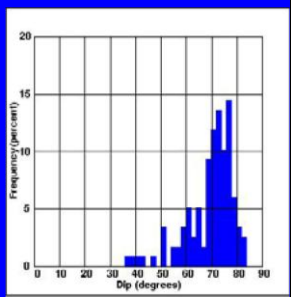
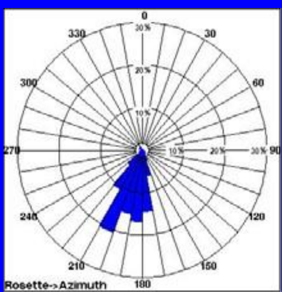
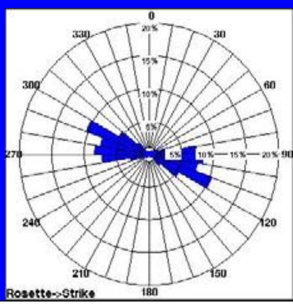
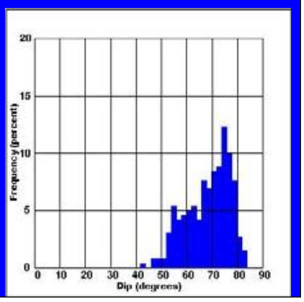
None major, 7 medium and 111 minor conductive fractures are observed within this zone. They show a dominant azimuth towards S35W with N55W-S55E strike trend and 75 degrees average dip inclination (Figure 4).

Nar (4351-4597 m)

In this interval, only 1 major along with 21 major and 240 minor conductive fractures are picked on image logs. These fractures indicate dominant dip azimuth towards S25W with 75 degrees average dip inclination (Figure 4).

Lower Dalan (4597-4929 m)

In this interval, altogether 2 major, 15 medium and 250 minor conductive fractures are identified. This fracture system shows dip azimuth dominantly towards S35W with a corresponding strike of N55W-S55E and 73 degrees average dip inclination (Figure 4).

Fracture type	Azimuth	Strike	Dip Inclination
Kangan Major(0) Medium(3) Minor(38)			
Upper Dalan Major(0) Medium(7) Minor(111)			
Nar Major(1) Medium(21) Minor(240)			

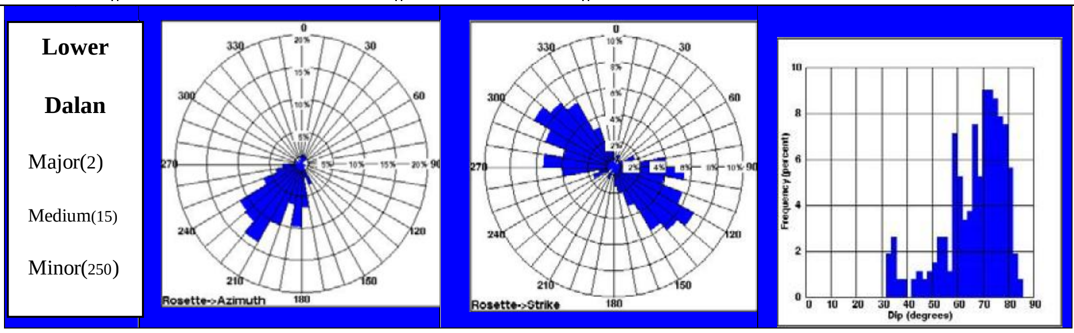


Figure4: Statistical plots for dips of conductive/open fractures in Kangan, Upper Dalan, Nar and Lower Dalan zones. Number of conductive / open fractures in the corresponding zones is also provided. All resistive fractures have been identified within this zone, which show dominant dip azimuth towards S55W with 68 degrees average dip inclination.

Occurrence of Natural Fractures and Density

Conductive / open fractures build a relatively extensive network across the study formations. These fractures are developed over certain areas within the entire interval. However, it seems that they are more developed in lower part of Upper Dalan, middle and lower parts of Nar and few zones in upper, middle and lower portions of Lower Dalan. Kangan formation shows less intense fracturing compare to the rest of the interval. The highest density of conductive / open fractures can be seen at 4454-4466, where the fracture density is slightly more than 30 / m (Figure3). Resistive/closed fractures all occurred in Kangan formation in a zone from 4058 m to 4092 m mainly at 4753 (Figure3).

Natural Fractures Pattern

According to Stearns and Friedman (1972), relationship between natural fractures and the strike of structural bedding determines the pattern of fracturing in a foldrelated fracture system. In current study, natural conductive/open fractures strikes tend to be more or less parallel with the dominant strike of the bedding planes across the entire interval. This implies that majority of these fractures can be attributed to type II of Stearns and Friedman and are longitudinal in nature. Nevertheless, it can be observed that conductive fractures strike is slightly deviates from being dominantly parallel with structural dip strike over Nar member, which is due to more complex system of fracturing in this zone with thick anhydrite layers.

Conductive / Open Natural Fractures Aperture

The majority of natural conductive fractures show aperture generally less than 0.002 cm (Figure 5). Fracture apertures with values more than 0.002 cm can be observed at 3965-3972 m, 4045 m, 4062-4065 m and 4079-4083 m (Kangan), 4115-4118, 4124 m, 4214 m, 4265 m and 4271-4304 m (Upper Dalan), 4560-4570 m (Nar), 4600 m, 4641-4655 m, 4662-4680 m, 4686-4695 m and 4736-4750 m (Lower Dalan). The highest value of fracture aperture with a value of more than 0.006 cm can be observed at 4565 m in Nar member interval(Figure3). F igure 5:Illustrates the histogram of fracture aperture of the entire study interval.

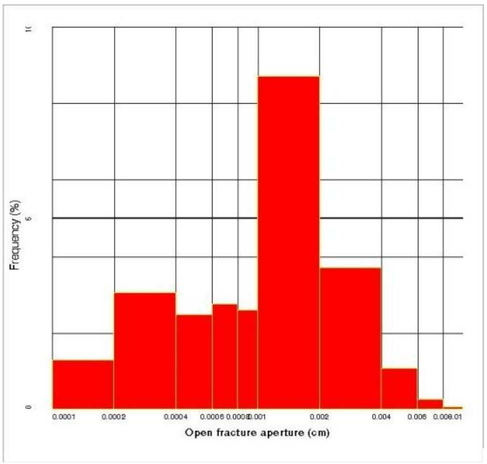


Figure 5: Conductive/open fractures apertures histogram

Conductive / Open Fractures Porosity

Open fracture porosity is the ratio of the fracture area (fracture length × fracture aperture) to the borehole area scanned by FMI images. The fracture porosity is given as a fraction (Figure 3). The range of fracture porosity from conductive fractures is computed to be 0-0.01 % in general. Fractures with porosity range of 0.01% to 0.02% are computed at 4967 m, 4045 m and 4083 m (Kangan), 42734300 m (Upper Dalan), 4560-4575 (Nar) and 4600 m, 4649-4651 m and 4823 (Lower Dalan). The highest fracture porosity can be observed at 4565 m with a value of 0.03%.

Conclutions:

- A total of 688 conductive / open fractures have been identified over the entire interval. They are classified based on their aperture and continuity into three categories. 3 major, 46 medium and 639 minor conductive fractures.
- Main fractured zone with highest conductive/open fracture occurrences are 3965-3972 m (Kangan), 4270-4300 m (Upper Dalan), 4420-4435 m, 4452-4470 m and 4560-4575 m (Nar), 4585-4605 (Nar-Lower Dalan), 4642-4655 m, 4687-4695 m, 48054830 m and 4809-4923 m (Lower Dalan).
- Conductive/open fractures dip dominantly towards S30W with corresponding strike of N60W-S60E and average dip inclination of 75 degrees.
- The resistive/closed fractures (12 in number) are observed only in Kangan formation and show dip azimuth towards S55W with 68 degrees dip inclination.
- Fracture apertures with values more than 0.002 cm can be observed at 3965-3972 m, 4045 m, 4062-4065 m and 4079-4083 m (Kangan), 4115-4118, 4124 m, 4214 m, 4265 m and 4271-4304 m (Upper Dalan), 4560-4570 m (Nar), 4600 m, 4641-4655 m, 4662-4680 m, 4686-4695 m and 4736-4750 m (Lower Dalan).

References:

[1]. Akbar, M., Nurml, R., Standan, E., Sharma, S., Panwar, P., Chaturvedl, J.G. &Dennls, B., (1993), Middle East well evaluation review, N. 14.
[2]. Ahmadhadi, F., Lacombe, O. & Daniel, J.M.,) 2007), Early Re activation of Basement Faults in Central Zagros (SW Iran): Evidence from Pre-folding Fracture Patterns in Asmari Formation and Lower Tertiary Paleogeography, in Trust Belts and Foreland Basins, Springer, Chapter 11,Pages: 205-228.
[3]. Cooper, M.A. &Williams,G.D.,(1989), Inversion Tectonics, Geol. Soc. London Spec. Publ, 44, 375PP.
[4]. Al-Husseini, M.I., (2000), Origin of the Arabian Plate Structures; Amar Collision and najd Rift, GeoArabia, V.5, N ..4, Pages:527-541.
[5]. Konert, G., Affifi, A.M., Al-Hajiri, S.A. &Droste, H.J., (2001), Paleozoic Stratigraphy and Hydrocarbon Habitat of the Arabian Plate, GeoArabia, V.6, N.3, Pages: 407-442.
[6]. Kashfi, M.S.,(1984), Source Bed Study of the Oligo-Miocene Asmari Limestone, SW Iran, Journ.Petrol.Geol.,V.7, P ages: 419428.
[7]. Tschopp, R.H., (1967), Development of the Fahud Field, 7th World Petrol. Congr. Mexico, Proc.,2, Pages:.243-250.
[8]. Suhlmberger. (2002). *Advanced Borehole Imaging Independent Of Mud type-UBI.*www.connect.slb.com.
[9]. Ghassem-Alaskari, M.K, 2012, Advanced well logging, Institute of Setayesh, Tehran, Iran.
[10]. Suhlmberger. (2009). *Fmi geological Analysis Reports.* Pars Oil and Gas Company.
[11]. kamyab.m,parchekhari.sh,2015,well logging principles,tools and petrophysical interpretation of data,Ahvaz,Tarava publisher.
[12]. Suhlumberger. (1992). Fullbore Formation Microimager. Suhlumberger Education Services.