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Fracture density evaluation using well logs and oil production data in an onshore oil field

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ABSTRACT Conventional well logs cannot detect fractures in hydrocarbon reservoirs. Drilling core data are costly and this puts a significant limitation on data acquisition. The image logs, with their specific technology and by implementing electrical and sonic characteristics of the formation, can recognise various features in the borehole wall, including bedding, fracture, sedimentary structures, faults, condition of fractures, whether mineral-filled, etc. This investigation uses image logs (FMI, OBMI, and UBI) of five wells in different Iranian oil fields. The studied area is located in the central part of the northern Dezful embayment. The fracture values in each zone of the Asmari Formation of studied wells were calculated, and each zone's fracture density histogram was drawn. The maximum and the minimum number of fractures were recognised, and reservoir zones with a high production potential were defined. Mud loss and cumulative oil production data were converted to histograms and compared with fracture density histograms. The results showed that there was a good correlation between the three histograms. Based on these research results, well log image diagrams can determine the exact location and calculate the fractures density to determine the appropriate reservoir zones.

Key words: fractured reservoir, image log, fracture density, Dezful embayment, mud loss.

1. Introduction

Geological features, such as fractures and structures, can be described as more or less planar openings, where one dimension is smaller than the other two dimensions. Fractures are mechanical breaks in rocks involving discontinuities in displacement across surfaces or narrow zones (Khoshbakht *et al.*, 2009; Aghli *et al.*, 2016). Fracture networks in reservoirs provide additional flow pathways for hydrocarbons and other fluids, significantly influencing production performance and total recovery. Fracture networks are essential for assessing exploration wells and further production (Bates and Jackson, 1980; Zeeb *et al.*, 2013, Amirov, 2016). Fractures have a vital role in the production and migration of oil in the Zagros basin. Iranian fractured carbonate reservoirs are features that are renowned worldwide (Roehl and Choquette, 1985; Rajabi *et al.*, 2010). Due to the importance of fractures and their influence on reservoirs rock properties, several studies have been published on fractures in this region (McQuillan, 1973, 1974; Gholipour, 1998; Rezaie and Nogole-Sadat, 2004; Ahmadhadi *et al.*, 2007, 2008; Khoshbakht *et al.*, 2009; Rajabi *et al.*, 2010) and in other regions worldwide (e.g. Stearns, 1968; Price and Cosgrove, 1990; Van der Pluijm and Marshak, 2004; Fossen, 2010). Based on the past study, regional fractures in Asma**ri** Formation are mostly sub-vertical, indicating that their initiation was before the main Mid-Pliocene folding phase of the sedimentary cover (Ahmadhadi *et al*., 2007). The fracturing observed in the formation is thought to result from the reactivation of deep basement faults associated with the Arabian plate's continental collision with the central Iranian plate (Alavi, 2007). Fracture data analysis derives from various sources, such as drilling, construction, petrophysics, core, production data, and well dynamics data (Thompson, 2000; Flaig, 2016). Direct and indirect methods were used to determine reservoir parameters such as seismic section, petrophysical logs, well test, cores, and image logs (Thompson, 2000; Tingay *et al*., 2008; Rahimi and Riahi, 2020). Well logs and drilling core data are methods for reservoir parameters analysis. The drilling core data have marked limitations such as high cost, low recovery in the fractured interval, and core environment change during data acquisition (Khoshbakht *et al*., 2009; Rahimi and Riahi, 2020). Image logs have become the most important and advanced fracture analysis methods for reservoir evaluation (Shrivastva *et al.*, 2011; Khoshbakht *et al*., 2012). These methods have improved rapidly due to their excellent ability to characterise the borehole features such as fractures and bedding (Serra, 1989). Image log studies help lessen expenditure owing to the reduced coring measurement and perforate zone determination. This study identifies zones with higher fracture densities in the Asmari reservoir of the Parsi oil field and determines the sections with higher production potential. Due to the high cost of image logs, their use is limited to certain wells in the study area. This study sought to find the relationship between fracture density, drilling mud loss and oil production from the studied wells. The possibility of using any of this information as an alternative to estimate the fracture density was used.

2. Geological setting

The oil field study is located in the SW of Iran. This oil field lies 130 km SE of Ahvaz city and extends to about 40 km SE of Ramhormoz city (Fig. 1). The studied oil field is one of the large oil fields located in the southernmost part of northern Dezful from the Dezful embayment, and the area of this oil field is affected by a fault along with the N-S slip of the Izeh-Hindijan fault (Sherkati and Letuzey, 2004).

The Parsi anticline is an almost elliptical, elongated and asymmetrical fold, separated by adjacent faults at the northern and southern sections. This anticline is separated from the Mamatin anticline and is a part of its north-western cape by a thrust fault so that the Mamatin anticline is driven on the Parsi anticline.

The reservoir's longitudinal axis is located on the outcrops of Gachsaran, Mishan, Aghajari, and Bakhtiary formations, which is about 3.7 km relative to the building axis in the Asmari Formation in the SW direction. The maximum height of the area relative to sea level is 900 m. The structure of the Persian terrestrial surface is asymmetric so that the slope of the layers in the southern section on the outcrops of Mishan and Gachsaran formations reaches 30° to 60° and sometimes up to 70° (Fig. 2).

Asmari Formation in this field is composed of marine carbonate rocks with alternate shale layers. The lower part includes limestone and shale, and the upper part is mostly dolomite and limestone. A stratigraphic thickness of the Asmari Formation is equal to 395 m in most of the studied type sections. The studied stratigraphic sections in the SW of Iran were located in Khuzestan province (Fig. 3). The Asmari Formation is known as a giant hydrocarbon reservoir, and this reservoir has a thick carbonate sequence of the Oligocene-Miocene epochs in the Zagros foreland basin (Horn, 2003). The geological investigations, based on thin sections study, were prepared from the studied reservoir in wells A, B, C, D, and E, showing that stylolite related to the compression dissolution process was observed. The thin section studies in different zones show the various porosity types including melodic, vuggy, intercrystalline (dolomitisation), and intergranular porosity in limestones, mainly filled with anhydrite calcareous cement. This cementation indicates the effect of diagenetic processes on the reservoir after sedimentation, which can significantly affect permeability value (Aghli *et al.*, 2016; Soleimani *et al.*, 2016a, 2016b).

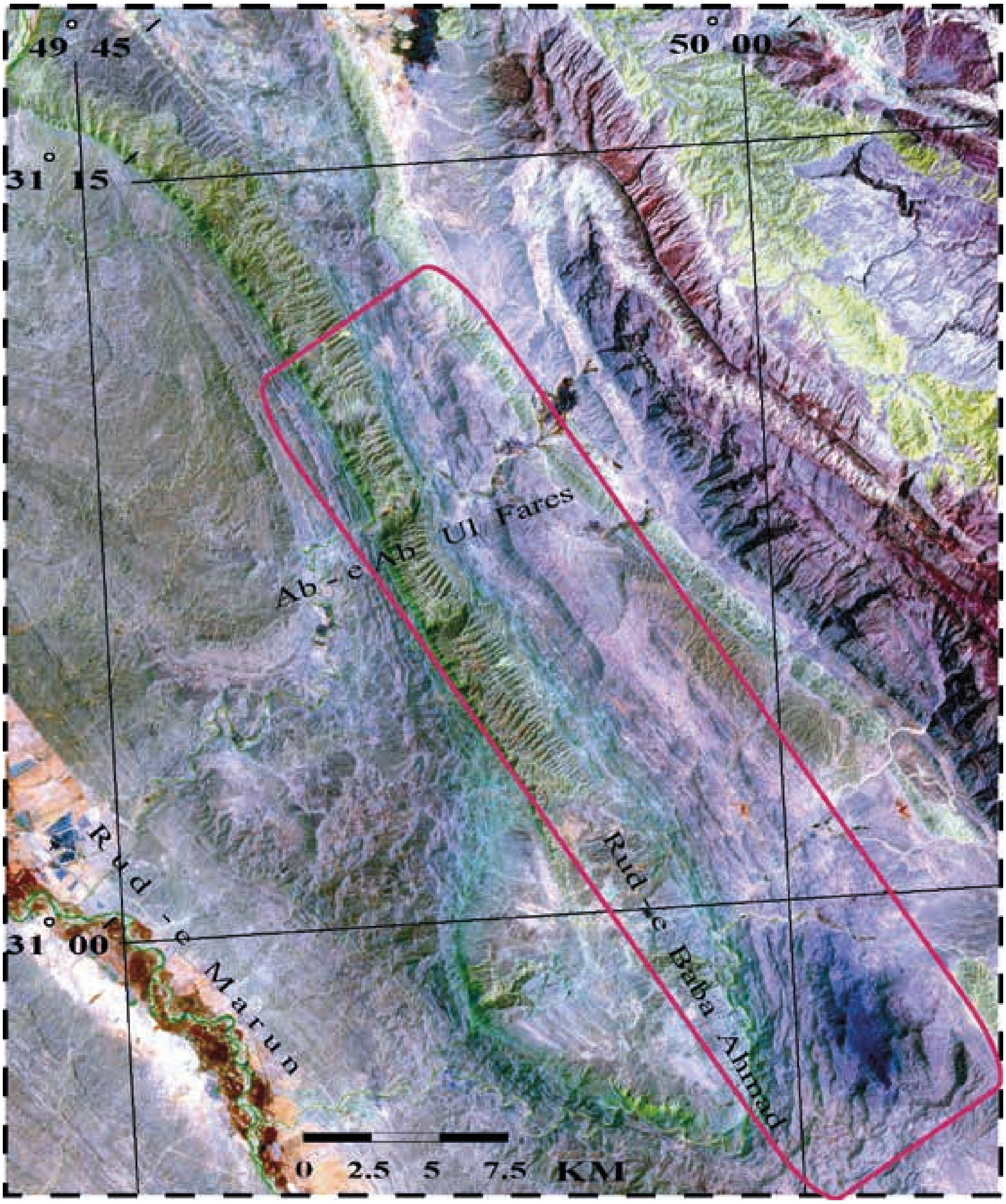


Fig. 1 - Schematic representation of studied oil fields in the Dezful embayment (Sherkati and Letuzey, 2004).

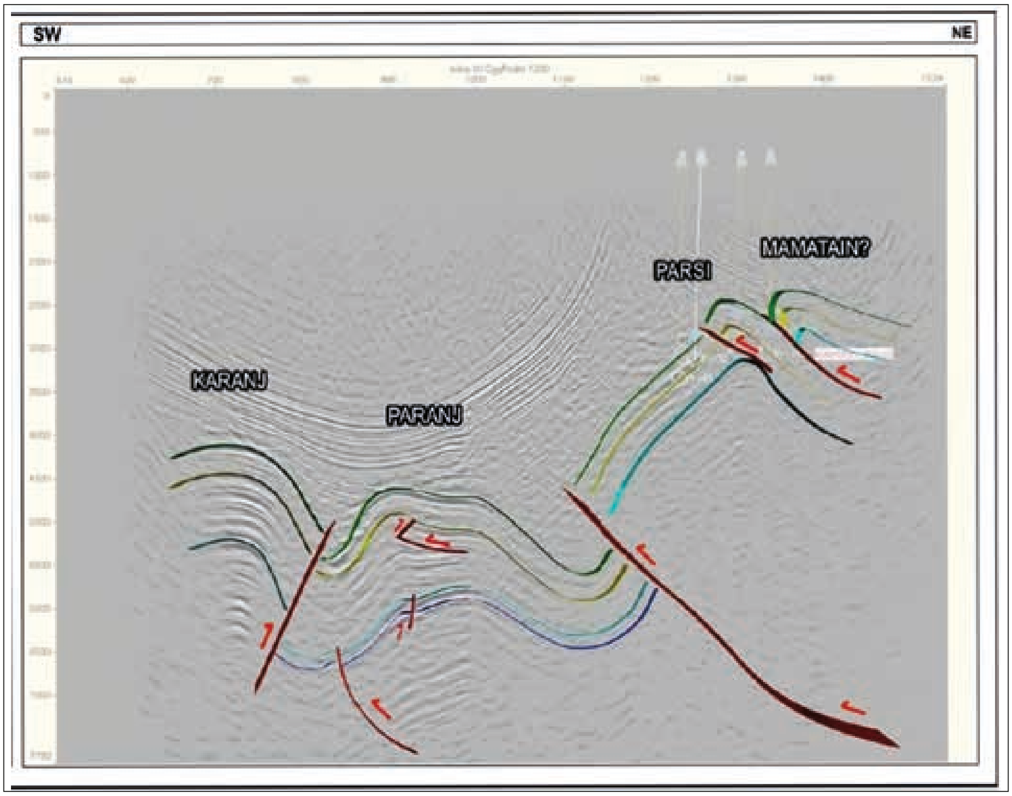


Fig. 2 - Structural relationship between Mamatin, Parsi, Paranj, and Kranj oil fields on the seismic section.

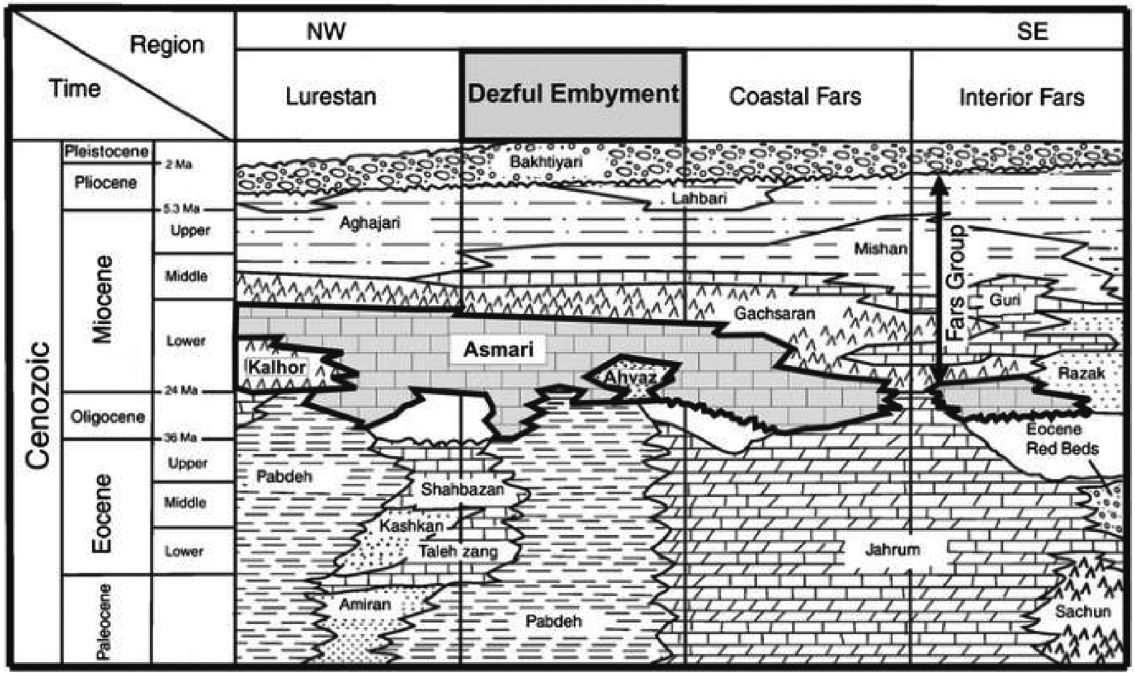


Fig. 3 - Cenozoic stratigraphy chart of the Zagros basin in the studied area (James and Wynd, 1965).

2.1. Image logs

Imaging techniques can be used in various geological and drilling environments, providing well log images of reservoir rocks, from the carbonates to soft thinly laminated sequences (Halliburton, 1996; Aghli *et al*., 2016). There is a consensus among geoscience researchers that image logs are the best method for fractures and geological structure studies. Fractures are planar geological features with no apparent displacement of blocks along with their plane's tension (Fossen, 2010; Soleimani *et al*., 2016a, 2016b). Frequently, fractures have steep dip tensional and wrench regimes. The fracture apertures may be open, closed, or filled with some minerals. Open fractures in a clay-free formation have a conductive appearance on the images due to the invasion of their aperture with the conductive drilling mud. The sealed fractures appear resistive if the filling material of their apertures is dense such as calcite or anhydrite (Tehrani *et al.*, 2001; Shahinpour, 2013).

Borehole imaging tools are routinely used to support detailed core analysis for various applications such as sequence stratigraphy, facies reconstruction and diagenetic analysis. The images appear to be sensitive to variations in mineralogy, porosity and fluid content, which highlight both natural fractures and fabrics of rock (Aghli *et al*., 2016; Soleimani *et al*., 2016a, 2016b). The acoustic image logs reveal a similar natural fracture population, but do not reveal rock fabrics due to their low resolution (Davatzes and Hickman, 2005). The Formation Micro-Imager (FMI) log has an azimuthal resolution of 192°, capable of radial micro-resistivity measurements. These two tools cannot be used in the oil-based mud where Oil Based Mud Imager (OBMI) and Ultrasound Borehole Imager (UBI) logs are applied.

3. Methodology

Raw data from well-logging are loaded in GeoFrame software. This study uses GeoFrame software to process and interpret the image logs. Geoframe is one of the practical tools in interpreting and processing geophysical, geological and petrophysical data. This software uses efficient algorithms and techniques by analysing input data (Schlumberger, 2005). After a few

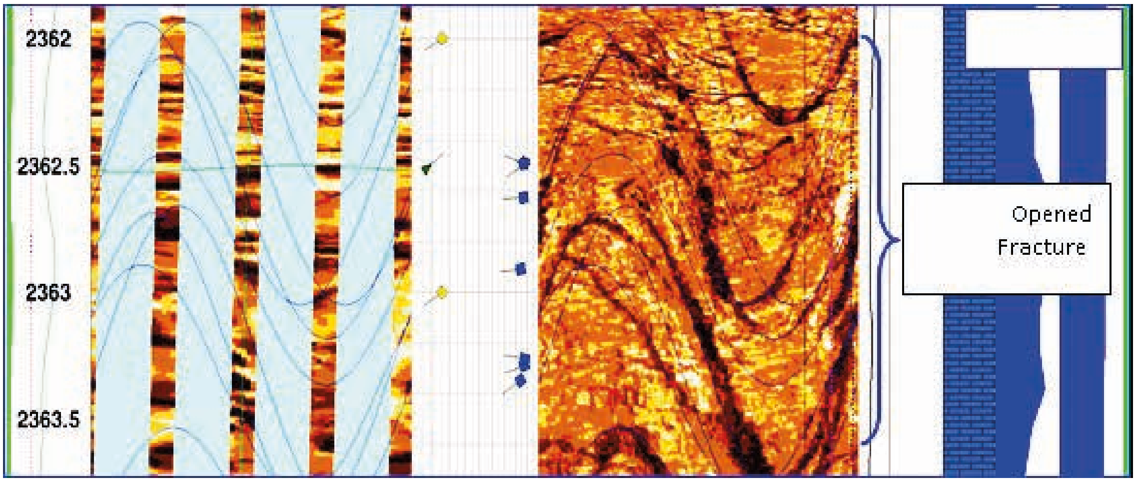


Fig. 4 - Open fracture illustration from image log in well A.

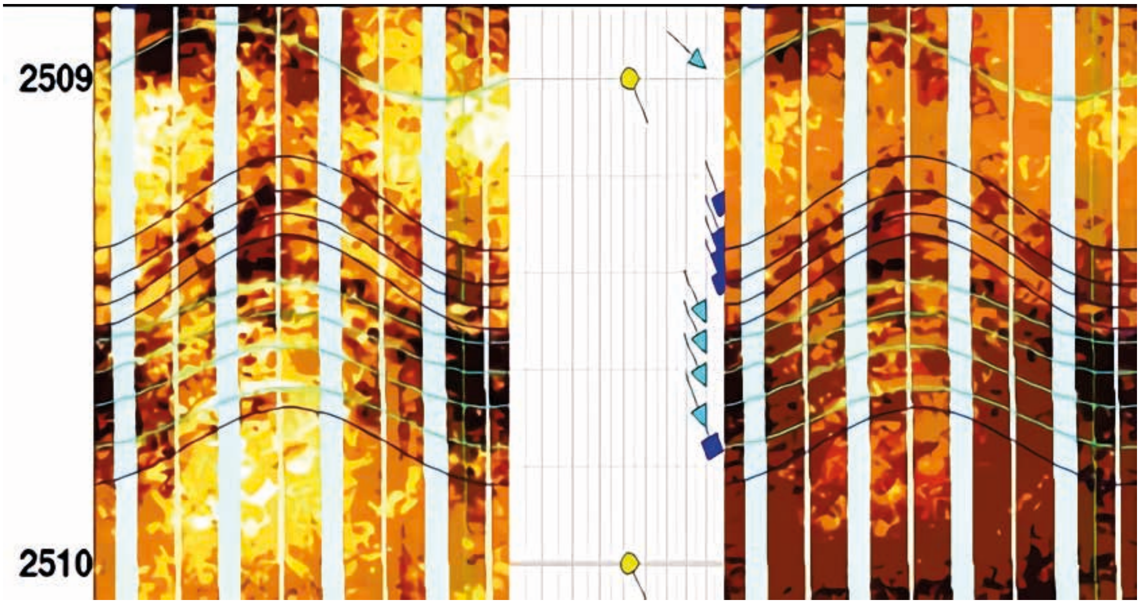


Fig. 5 - Close fracture illustration from image log in well A.

processing steps, a virtual image of the oil well wall is displayed. For wells drilled with water-based drilling mud, FMI should be used; for wells drilled with oil-based mud, OBMI, and UBI were used simultaneously.

Fig. 6 shows the FMI logs of well A in the studied oil field with a scale of 1:1000. This figure shows the plate phenomena in the well wall, including bedding and fractures, and the direction, aspect, and slope can be calculated (Fig. 6). If the drilling mud is water-based (conductive), the FMI imaging data were used. The filled fractures with this type of drilling mud appear in dark visual logs (Serra, 1989; Davarpanah *et al.*, 2016). The matrix resistance is greater than that of drilling mud, and open fractures in FMI image logs appear as continuous sinusoidal waves. The processing of the FMI images from well A shows that the sinusoidal curves of the closed fractures are clear lines and open fractures as dark lines, while induced fractures due to drilling operations as perpendicular to the layering. Although fracture detection is very important in image logs, this phenomenon is rarely identifiable due to the low diameter of the well. Figs. 4 and 5 show that fracture planes are seen in the image (dark and light sine lines). The arrows select them in the image as an open fracture (dark lines) or a closed fracture (light lines). The observed fracture densities are blue, red, and green arrows curves with their dip and azimuth. The obtained result from image logs interpretation shows the average structural slope of the Asmari Formation in well A is 22° towards E65°N and the dominant strike is E25°S and W25°N. The average structural slope of the Asmari Formation in well E, identified from the interpretation of OBMI and UBI logs, is about 25° towards W60°S, the dominant strike being E30°S and W30°N. The average structural slope of the Amari Formation in well D, obtained from the interpretation of OBMI-UBI logs, is 61° towards W62°S. Based on the interpretation of OBMI-UBI logs, the average structural slope of Asmari Formation in well C is about 26° W69°S with a dominant strike E21°S and W21°N. The average construction slope of the Asmari Formation in well B was identified from the interpretation of the OBMI-UBI logs about 6° towards E45°N, with the dominant strike E45°S and W45°N.

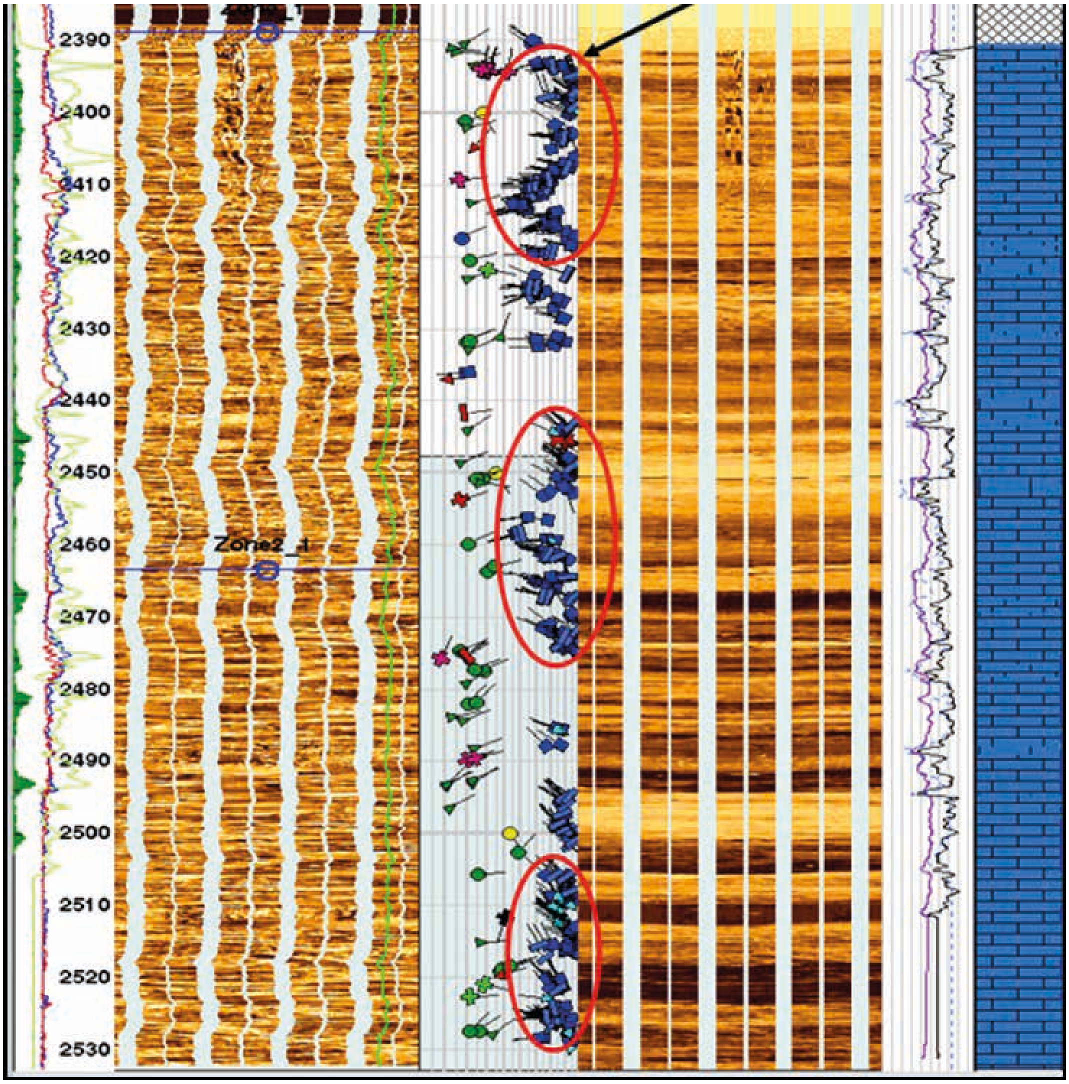
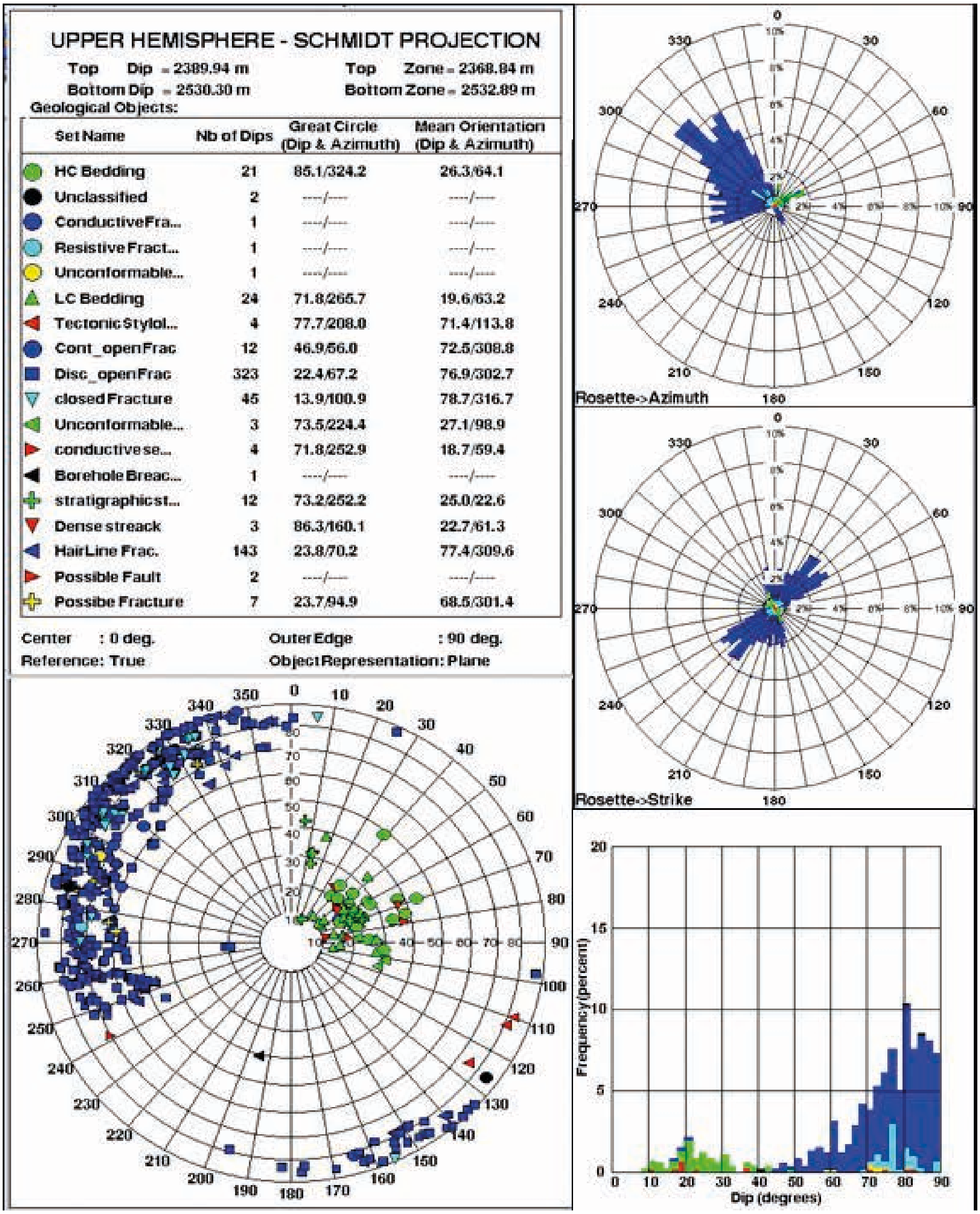


Fig. 6 - Schematic representation of all the identified features in the total charting distance of well A based on the caliper, gamma rays, FMI imaging logs, porosity, and density.

The result shows that the Asmari reservoir characteristics are different in different parts of the studied oil field. This oil field is divided into four northern parts based on lithological characteristics, porosity, permeability, reservoir pressure history, production rate from each section, and other reservoir features. The cumulative oil production of the studied oil field was evaluated from 2005 to 2011 and Fig. 8 shows the average result of the cumulative oil production of well A.

4. Results and discussion

This investigation uses five wellbore data as input data, and several features such as fracture type and densities were identified. Fracture evaluation has been performed using the



UPPER HEMISPHERE - SCHMIDT PROJECTION

Top Dip = 2389.94 m
Bottom Dip = 2530.30 m
Top Zone = 2368.84 m
Bottom Zone = 2532.89 m

Geological Objects:

	Set Name	Nb of Dips	Great Circle (Dip & Azimuth)	Mean Orientation (Dip & Azimuth)
●	HC Bedding	21	85.1/324.2	26.3/64.1
●	Unclassified	2	----/----	----/----
●	ConductiveFra...	1	----/----	----/----
○	Resistive Fract...	1	----/----	----/----
○	Unconformable...	1	----/----	----/----
▲	LC Bedding	24	71.8/265.7	19.6/63.2
◀	Tectonic Stylol...	4	77.7/208.0	71.4/113.8
●	Cont_openFrac	12	46.9/56.0	72.5/308.8
■	Disc_openFrac	323	22.4/67.2	76.9/302.7
▽	closed Fracture	45	13.9/100.9	78.7/316.7
◀	Unconformable...	3	73.5/224.4	27.1/98.9
▶	conductive se...	4	71.8/252.9	18.7/59.4
◀	Borehole Breac...	1	----/----	----/----
✚	stratigraphicst...	12	73.2/252.2	25.0/22.6
▼	Dense streack	3	86.3/160.1	22.7/61.3
◀	HairLine Frac.	143	23.8/70.2	77.4/309.6
▶	Possible Fault	2	----/----	----/----
✚	Possibe Fracture	7	23.7/94.9	68.5/301.4

Center : 0 deg.
Reference: True
Outer Edge : 90 deg.
Object Representation: Plane

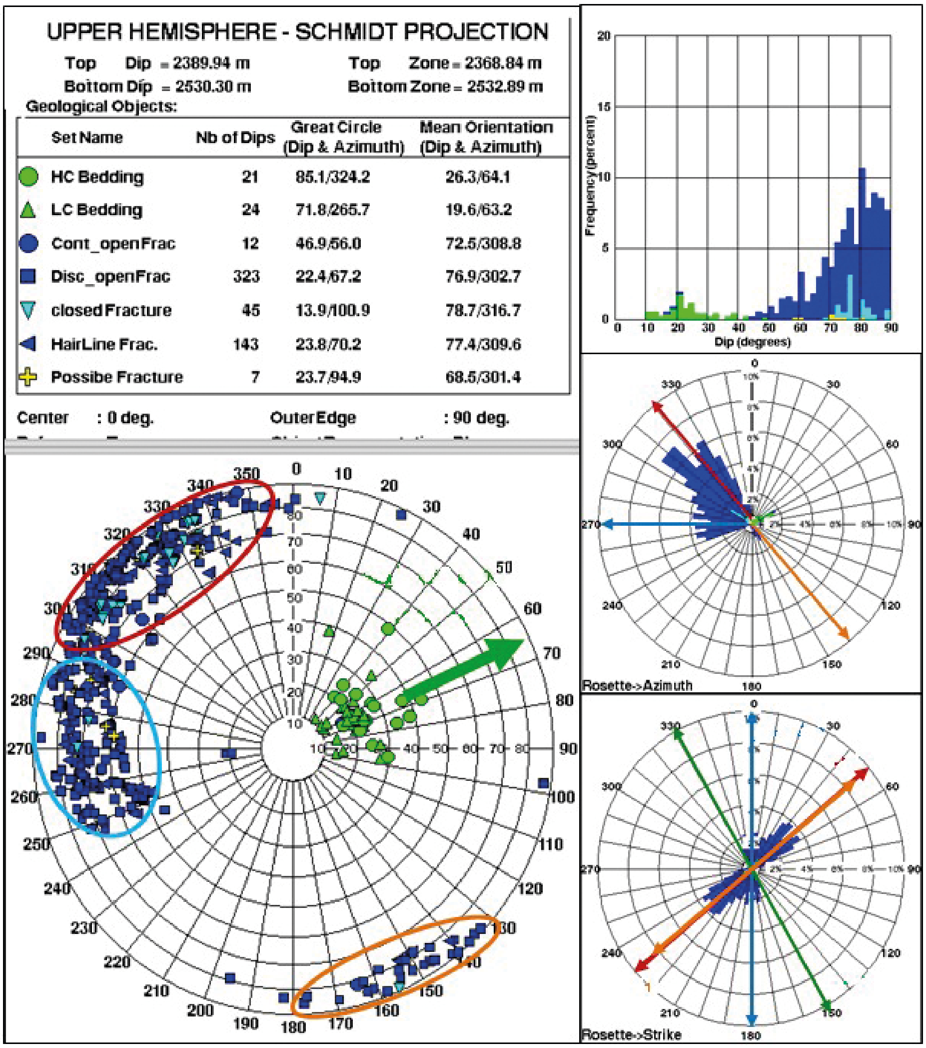
Fig. 7 - Representative status (slope, azimuth, and aspect) of all the features determined from the interpretation of the FMI log of well A.

Formation MicroScanner tool from all wells in the oil field study, which has image logs. Finally, fracture evaluation and production data in the Asmari Formation have been compared, and the stereonets, rose diagrams and histograms have been used to facilitate the display of GeoFrame results.

4.1. Fracture data analysis

In the analysis of fracture evaluation of the oil and gas reservoirs, a large amount of data is used from various data sources such as wellbore data, drilling data and production data. Image log interpretation aims to identify the geological properties and fractures and their spatial position and support drilling operations to assist geologists and petroleum engineers (Roehl and Choquette, 1985; Nie *et al.*, 2013; Shalafi *et al.*, 2016). This investigation, using image logs, includes FMI, OBMI, and UBI to evaluate the reservoir fracture study.

Several fracture types were identified after analysing the image logs in the five wells of the studied oil field. 485 fractures were observed in the image logs of well A: 323 non-continuous open fractures, 12 continuous open fractures, 143 capillaries, 7 possible open fractures, and 45 closed fractures. Most fractures in this formation vary from 45° to 90° (Figs. 8 and 9). Three major fractures can be identified based on the relationship between fracture length and bedding and fracture pattern (Fig. 8). The first and second groups of fractures with the same length oriented



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✚	Possibe Fracture	7	23.7/94.9	68.5/301.4

Center : 0 deg. Outer Edge : 90 deg.

Fig. 8 - Open fractures relative to the bedding in the Asmari Formation of well A.

W50°S E-50°N and the slopes of W40°N and E40°S are located perpendicular to the layering and are considered cross-axial fractures. It should be noted that along with this category of transverse fractures, a significant number of conjugate shear fractures have been formed. The third group of fractures has a dominant N-S aspect and a W90°N slope direction, and their direction to the strike-slip and N-S Izeh-Hindijan faults is the same as the length of the R-fractures in the Riddle fault system associated with strike-slip faults. Therefore, it can be concluded that these fractures are the same as R-fractures related to the Izeh-Hindijan fault and indicate the effect of this fault on fractures in the studied oil field.

After drawing image logs for each of the studied wells in the oil field, fractures, bedding, and other plate phenomena were identified. The data of the image logs were used for density fractures evaluation in the Asma**ri** Formation. The obtained result shows all open fractures in the specific Asmari reservoir zone and then divides these fractures using the depth related to each zone (Fig. 8). The open fracture densities of the zones in well A were calculated. According to the obtained result, Zone 1 and Sub-zone 1-2 have fracture densities of 3.41 and 3.37 (number of fratures/metre) respectively, which indicates the high fracture density in both zones (Fig. 8).

The open fracture density in well C indicated a very high fracture of this well at all depths. The results include Zone 1 and Sub-Zone 1-2, both with a fracture density of 4.75, Zone 2-2 with a fracture density of 2.71, and Zone 3 with a fracture density of 5.4, and this well has a full production potential (Fig. 9). Table 1 shows the qualitative comparison of open fractures in the studied wells from the studied oil field. The wells A, B, and C are on the northern section, and D and E are on the southern section. Well D is located in a steep area of a building from the southern section. Fig. 7 shows that all the wells on the northern sector of the field have significant open fractures. However, the two wells were studied in the southern ridge.

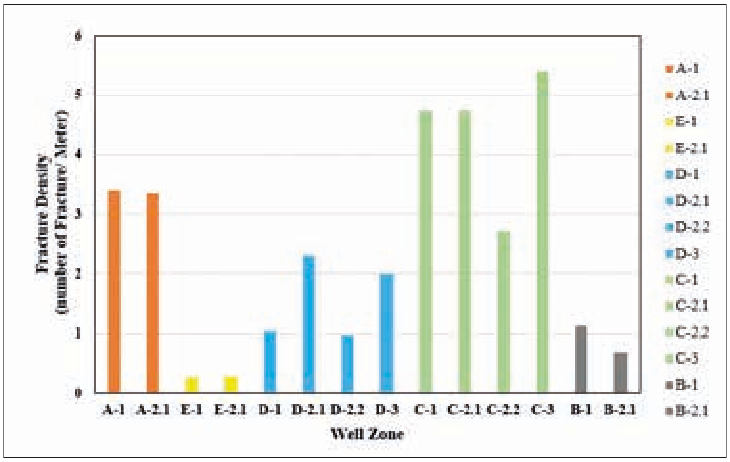

Fig. 9 - Relative frequency of open fractures in different zones of Asma**ri** Formation in the studied wells.

Table 1 - Qualitative comparison of open fractures in the studied wells. **This table is not clear: olease improve it.**

Minimum fracture				Maximum fracture	Correlation fractures
E	B	D	A	C	Num of wells
South	North	South	North	North	Well location

4.2. Mud loss data evaluation

Mud loss evaluation is a valuable method for fracture studies and data available for this from drilled are wells in the oil fields study. The mud loss data can be reliable for determining fractures and fault zones correlated with other geophysical and geological data. The drilling fluid losses flowing from the wellbore to the surrounding target geological formations have been used to recognise the fracture zones. The comparison of the diagrams of Fig. 9 (fracture density) and Fig. 10 (drilling mud loss) shows the relationship between fracture density and drilling mud loss. Comparing this with other information related to fractures can lead us to conclude that it is possible to use mud loss data to identify fractured zones. The lowest amount of mud loss is related to well E, located in the reservoir's western sector, and the fracture density is very low. Wells A, B, and D have a relatively high average fracture density at all depths and show good agreement with the drilling mud loss result. Well C has the highest fracture density among all the studied wells, and drilling mud loss has been prevented due to the underbalanced drilling method. The results show that the higher the number of fractures in a well, the more mud can escape through them in the formation. This factor causes damage to the formation, environmental pollution and can also cause problems for drilling operations. Well A, C, and D are located in the studied oil field, and those wells have the highest oil average production. The correlation between those wells can be seen in the fracture density and drilling mud loss diagrams. The average oil production of well D has a good correlation between the fracture density and drilling mud loss diagram (Figs. 10 and 11). Well E is located in the studied oil field, and this well has the lowest oil average production. The fracture density and drilling mud loss diagrams are also proof of this fact.

4.3. Cumulative oil production

The Asmari reservoir in the oil field study has different reservoir properties in each direction. The lithological characteristics, porosity and permeability, history of reservoir pressure,

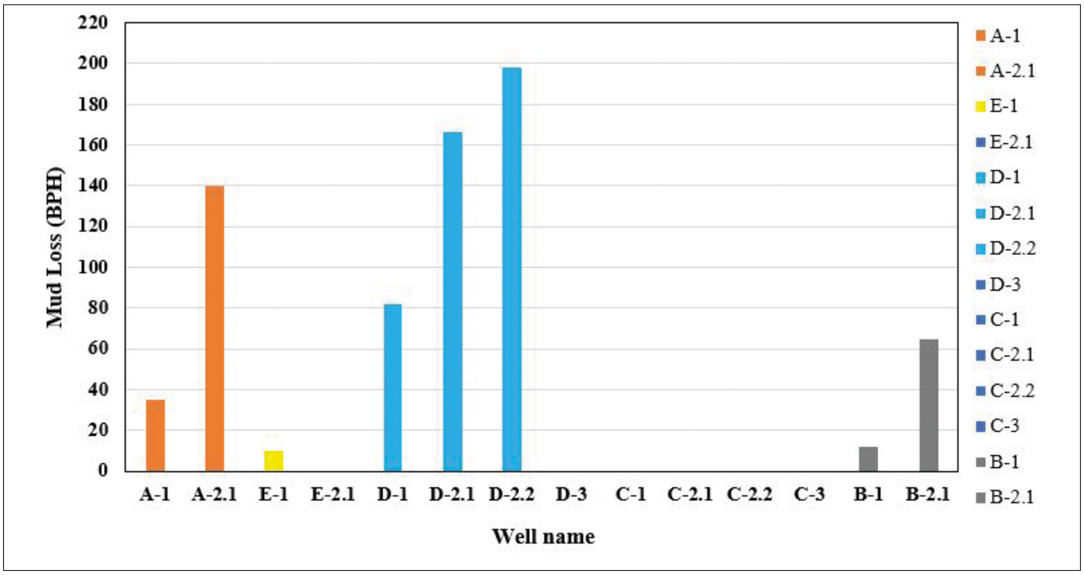

Fig. 10 - Mean of drilling mud loss value in different Asmari Formation zones in the studied wells.

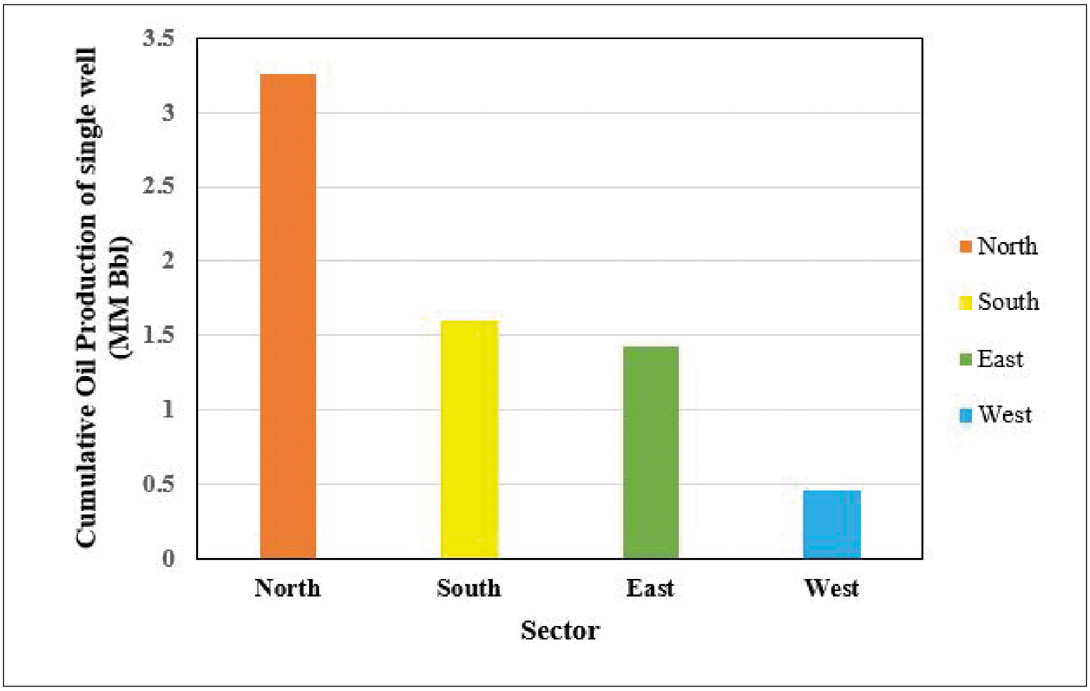

Fig. 11 - Average cumulative oil production for a well from each sector of the studied oil field.

production rate from each section, and other reservoir features were divided into four parts (north, east, south, and west). Fig. 11 shows the high value of oil production from 2005 to 2011 in the northern part of the studied oil field. The eastern and southern parts have a slight difference in oil production's second and third ranks. The western part of the field also has a low value of oil production.

5. Conclusions

This study aimed to investigate the analysis of fractures and determine their role in the reservoir production of a carbonate Asmari Formation. This investigation shows the average cumulative oil production of the Parsi anticline formed by an asymmetrical fold separated by adjacent faults in the western cape and the northern and southern ridges. The fracture study showed that the field's northern edge has more open fractures than the southern edge. The fracture density in the southern ridge eastern cape, compared to the southern ridge western cape and the Izeh-Hindijan (Bahrgansar) fault in this formation, is apparent. The trend of reducing the fractures frequency in Zone 3, Sub-zone 2-1, and Zone 1 were determined. The northern part has higher production than other parts. This point can confirm the assumption of a basement geological feature in the southern edge, which another dominating fracture set could create. According to the other methods, the mud loss data in this oil field demonstrates that the central and eastern parts were fractured. Comparison of fracture density, flower waste and production data in Asmari reservoir showed good agreement. In the absence of image logs, drilling mud waste data and oil production can predict fracture density in the oil reservoir.

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REFERENCES

Aghli G., Soleimani B., Mousavi R. and Mohammadian R.; 2016: *Fractured zones detection using conventional petrophysical logs by differentiation method and its correlation with image logs*. J. Pet. Sci. Eng., 142, 152-162.

Ahmadhadi F., Lacombe O. and Daniel J.-M.; 2007: *Early reactivation of basement faults in Central Zagros (SW Iran): evidence from pre-folding fracture populations in the Asmari Formation and Lower Tertiary paleogeography.* In: Lacombe O., Lavé J., Vergés J. and Roure F. (eds), Thrust Belts and Foreland Basins; From Fold Kinematics to Hydrocarbon Systems, Frontiers in Earth Sciences, Springer Berlin, Heidelberg, pp. 205– 208, doi: 10.1007/978-3-540-69426-7_11.

Ahmadhadi F., Daniel J.-M., Azzizadeh M. and Lacombe O.; 2008: *Evidence for pre-folding vein development in the Oligo-Miocene Asma**ri** Formation in the central Zagros fold belt, Iran*. Tectonics, 27, 1-22.

Alavi M.; 2007: *Structures of the Zagros fold-thrust belt in Iran*. Am. J. Sci., 307, 1064-1095.

Amirov E.; 2016: *Application of ALD images and Caliper data for the breakout analysis from the wells which were drilled in the Caspian Sea of the Azerbaijan Republic.* Geophys. Res. Abstr., 18, EGU2016-1621.

Bates R.L. and Jackson, J.A.; 1980: *Glossary of Geology, 2nd ed*. American Geological Institute, Falls Church, VA, USA, 751 pp.

Davarpanah A., Kakoli M. and Ahmadi M.H.; 2016: *Analysis of fractured reservoir structure by interpretation of FMI and VSP logs.* J. Marine Sci. Res. Dev., 6, 216, doi: 10.4172/2155-9910.1000216.

Davatzes N.C. and Hickman S.; 2005: *Comparison of acoustic and electrical image logs from the COSO geothermal field, CA.* In: Proc. 30th Workshop on Geothermal Reservoir Engineering, Stanford, CA, USA, SGP-TR-176, 11 pp.

Flaig E.B.; 2016: *Image log and core analysis: increasing interpretation accuracy with descriptions in concert.* In: Proc. GeoConvention 2016, Optimizing Resources, Calgary, AB, Canada, 2 pp.

Fossen H.; 2010: *Structural Geology*. Cambridge University Press, Cambridge, UK, 479 pp., doi: 10.1017/CBO9780511777806.

Gholipour A.M.; 1998: *Patterns and structural positions of productive fractures in the Asmari reservoirs, southwest Iran*. J. Can. Pet. Technol., 37, 44-50.

Halliburton; 1996: *Electrical micro imaging service (Sales Kit).* Houston, TX, USA, 71 pp.

Horn M.K.; 2003: *Giant fields 1868-2003.* In: Halbouty M.K. (ed), Giant oil and gas fields of the decade 1990-1999, AAPG Memoir 78, Houston, TX, USA, 340 pp., Cd-Rom.

James G.A. and Wynd J.G.; 1965: *Stratigraphic nomenclature of Iranian oil consortium agreement area*. Am. Assoc. Pet. Geol. Bull., 49, 2182-2245.

Khoshbakht F., Memarian H. and Mohammadnia M.; 2009: *Comparison of Asmari, Pabdeh and Gurpi formation's fractures, derived from image log*. J. Pet. Sci. Eng., 67, 65-74.

Khoshbakht F., Azizzadeh,M., Memarian H., Nourozi G.H. and Moallemi S.A.; 2012: *Comparison of electrical image log with core in a fractured carbonate reservoir.* Journal of Petroleum Science and Engineering, 86-87, 289-296.

McQuillan H.; 1973: *Small-scale fracture density in Asmari Formation of southwest Iran and its relation to bed thickness and structural setting.* AAPG Bull., 57, 2367-2385.

McQuillan H.; 1974: *Fracture patterns on Kuh-e Asmari anticline, southwest Iran*. AAPG Bull., 58, 236-246.

Nie X., Zou C., Pan L., Huang Z. and Liu D.; 2013: *Fracture analysis and determination of in-situ stress direction from resistivity and acoustic image logs and core data in the Wenchuan earthquake fault scientific drilling borehole-2 (50-1370 m).* Tectonophys., 593, 161-171.

Price N.J. and Cosgrove J.W.; 1990: *Analysis of geological structures*. Cambridge University Press, Cambridge, UK, 502, pp.

Rahimi M. and Riahi M.A.; 2020: *Static reservoir modeling using geostatistics method: a case study of the Sarvak Formation in an offshore oilfield.* Carbonates Evaporites, 35, 1-13, doi: 10.1007/s13146-020-00598-1.

Rajabi M., Sherkati S., Bohloli B. and Tingay M.; 2010: *Subsurface fracture analysis and determination of in-situ stress direction using FMI logs: an example from the Santonian carbonates (Ilam Formation) in the Abadan Plain, Iran.* Tectonophys., 492, 192-200.

Rezaie A.H. and Nogole-Sadat M.A.; 2004: *Fracture modeling in Asmari reservoir of Rag-e Sefid oil-field by using Multiwell Image Log (FMS/FMI)*. Iran. Int. J. Sci., 5, 107-121.

Roehl P.O. and Choquette P.W.; 1985: *Carbonate petroleum reservoirs*. Springer Verlag, Berlin-Heidelberg, Germany, 644 pp.

Schlumberger; 2005: *GeoFrame 4.2, BorView user's guide*. Schlumberger Ltd, Houston, TX, USA.

Serra O.; 1989: *Formation micro scanner image interpretation, 2nd ed.* Schlumberger educational services, Houston, TX, USA, 117 pp.

Shahinpour A.; 2013: *Borehole image log analysis for sedimentary environment and clay volume interpretation.* MSc Thesis in Geology, Norwegian University of Science and Technology, Department of Petroleum Engineering and Applied Geophysics, Trondheim, Norway, 84 pp.

Shalafi M., Kazemi M.S., Moradi S. and Ghassem Alaskar M.K.; 2016: *Drilling fluid loss control via implementing the FMI and DSI logs to protect environment.* Model. Earth Syst. Environ., 2, 183-193, doi: 10.1007/s40808-016-0241-4.

Sherkati S. and Letouzey J.; 2004: *Variation of structural style and basin evolution in the central Zagros (Izeh zone and Dezful embayment), Iran.* Mar. Pet. Geol., 21, 535-554.

Shrivastva C., Muslem K., Girinathan S., Djamila B., Sikdar K. and Parashar S.; 2011: *Integration of image logs in brown field management.* In: Proc. 3rd Annual Logging Symposium, SPWLA-INDIA, Mumbai, India, 7 pp.

Soleimani B., Amiri K., Samani B. and Shaban L.; 2016a: *Lithology effects on the fractures parameters using image log and petrophysical data.* Russian J. Earth Sci., 16, ES5005, doi: 10.2205/2016ES000581.

Soleimani B., Mousavi R. and Shaaban L.; 2016b: *Natural fracture analysis and determination of fracture parameter using image log, Bangestan reservoir, Gachsaran oil field, SW Iran.* J. Tethys, 4, 124-133.

Stearns D.W.; 1968: *Certain aspects of fracture in naturally deformed rocks.* In: Riecker R.E. (ed), NSF Advanced Science Seminar in Rock Mechanics, Air Force Cambridge Research Laboratories Special Report, Bedford, MA, pp. 97-118.

Tehrani M.A., Sawdon C.A. and Levey S.J.M.; 2001: *Electrically conductive oil based mud.* In: Chemistry in the oil industry VII, RSC Publishing, London, UK, pp. 84-95.

Thompson L.B.; 2000: *Fractured reservoirs: integration is the key to optimization.* J. Pet. Technol., 52, 52-54.

Tingay M., Reinecker J. and Müller B.; 2008: *Borehole breakout and drilling-induced fracture analysis from image logs.* World Stress Map Project, 8 pp.

Van Der Pluijm B.A. and Marshak S.; 2004: *Earth structure: an introduction to structural geology and tectonics, 2nd ed.* WW Norton, New York, NY, USA, 672 pp.

Zeeb C., Gomez-Rivas E., Bons P.D. and Blum P.: 2013: *Evaluation of sampling methods for fracture network characterization using outcrops.* AAPG Bulletin, 97, 1545-1566.

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