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Analytical Fractured Reservoir Characterization by using Geological and Petrophysical Logs

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Abstract: Due to structural complexities in some wells, higher than the expected thickness of the Asmari formation is found. Fracture intensity and deep-rooted fractures broadly increase the risk of unpredictable water production. The well-test analysis is not sufficient in describing fracture properties. Unfortunately, the core condition is poor in the fractured zones and cannot be used to provide reliable information. So, the objectives of this study are developing an accurate structural model for the Asmari reservoir, and fracture characterization in the borehole by interpreting image logs and comparing the log's image results with core data. Dip classification based on a geological log has the value of providing a direct demonstration of structural origin and detecting Asmari fault and fracture systems and their impact on production and answering structural issues. So, in this study, the borehole imaging tools were interpreted to find solutions for fracture systems and fracture attributes. Interpreting accurate structural dip determined the structural problem, thus bringing the precise location of the well within the Asmari reservoir. Fracture properties (open or closed), occurrence, orientation, spacing, and porosity were interpreted using an Image log. The high density of fractures seen on FMS image logs in the study well has been confirmed by inspection of the cores and the distinction between major and minor fracture types from the FMS image logs has been established following core review. As a result, this exercise has been confirmed to be very valuable, not only for indicating the value of the log data, but it has also emphasized some significant limitations of the core data. The amount of information extracted from the FMS image logs goes beyond that achieved from the core. This exercise has validated why image logs are the main source of fracture information in the oil fields of Iran.

Keywords: Structural Complexity, Fractures, Fractured Reservoir, FMS, Cores

Introduction

The structural style of the fields located in the southern basin of Iran is quite complex due to compression along the northern edge of the Arabian plate marked by the Zagros Mountain belt of 200-300 km width (Fig. 1 and 2) (Kalantari-Dahaghi *et al*., 2006).

Bibi hakimeh field, one of the biggest Iranian fields that has an important role in the daily production of oil and gas, was discovered in 1961 by drilling well no. 1 and in 1964 the well started producing oil. The strategic thickness of this field is 400 m and increases in the northern direction. And it has a relation with the Bangestan formation. Bibi Hakimeh oil field is a complex naturally fractured oil field that is located in the south of Iran (Fig. 3) (Khoshbakht *et al*., 2009).

Hence, keeping in view the complex nature of structures (like Gachsaran, Agha Jari, Bibi Hakimeh, etc.), comprising the Zagros Mountain belt, accurate information on the structural dip and fault pattern in the subsurface is compulsory to plan development/infill wells successfully. In some reservoirs, higher than the expected thickness of formations is found. The structural difficulty in crossing the reservoir is affected by deeper bedding dip and due reverse faults. In some cases, it is not very easy to work out the precise reason for unexpectedly higher thickness. In addition to the structural problems, it is similarly required to know whether productive fractures are present in a well (Movahed *et al*., 2014c). Subsequently, most reservoirs in this basin are comprised of carbonates and have a complex tectonics history, therefore the chances of finding good or bad fractures are quite high. Thus, the main objective is to find out where all the good fractures are more concentrated and what dip and azimuth these fractures have to the structural axis.

The Asmari fracture system is usually well connected and pressure reactions at the well are dissolute promptly over long distances. In addition, the fracture system often connects the Asmari reservoirs with those of the Bangestan Group reservoirs (from 500 to 1,000 m of shale). In the interconnected zones, the oils are of the same type and have an almost identical composition. Even in the Asmari relatively low-porosity zones, fractures have resulted in some wells producing over 80,000 barrels per day (bbl/day). The thick Gachsaran formation (anhydrite/salt) sequence (300-1,500 m) covering the Asmari reservoir rock provides an excellent seal. For that reason, the study of the fractures in the Asmari Reservoir has been a serious subject up to now (Zohreh *et al*., 2014). Commonly, in the fractured reservoir, the fractures control the reservoir behavior. If the fractures are open, they can be the conduits to petroleum migration and so result in developing a high production zone with a permeability of more than 10000 mD (Movahed *et al*., 2015). It appears that the complex interaction of fracture, matrix and fluids are adequately variable to reduce each fractured reservoir unique.

By using FMI logs, structural and reservoir geologists can detect fracture features and classify fracture types at the wellbore directly and in the absence of seismic data, they can provide critical information to find a consistent solution, for some major geological problems. In this research, FMI is used to develop an accurate structural model by interpreting dip attributes in input data and to characterize fractures in the borehole by interpreting image logs. Moreover, core investigation often emphasizes the poorer part of the reservoir. Core recovery has hardly done well in the fractured reservoir.

Materials and Methods

Study Area

The study was carried out at NIOC South and Schlumbeger. The well BH-90 is located in the eastern south part of the Bibi Hakimeh field (Khuzestan Province) between BH-30 and BH-60 (Fig. 4). It was drilled with an 8.500" bit 30-degree deviation towards the northeast over the image log interval.

Methodology

Field data files are first read into the computer using a module called Data Load (Geoframe Software). Normally both methods of speed correction are used in Bor Eid. Optionally, a program called BorScale is run to calibrate the image data response to that of a shallow log such as an ILM (resistivity curve). The BorNor is used to dynamically standardize the images to improve the image contrast. Interpretation typically started with hand-picking dips using sinusoid techniques on oriented images presented at 1:20 or 1:10 scale in Borview, so that the geological features are easily visualized. Once dips have been picked, they have to be classified into bed boundaries and fractures and based on structural dip data, a computer-based cross-section along the NNE-SSW plane was constructed in the strucview (Fig. 5).

Results and Discussion

Structural Analysis

Except for some short intervals, the whole logged section of the Asmari is layered/bedded as it consists of alternating beds/layers of dense and porous limestone of different thicknesses. Most bed/layer boundaries are not so sharp and planar. They generally are uneven due to diagenetic processes. Sharp boundaries, which are picked in this part of the log, are in places where there is contact between marly/shaly and anhydrite parts. They regularly have a planar surface that is a characteristic feature of bed boundaries in a succession of marl and anhydrite. Some thin dense and resistive streaks were identified over the logged interval, at places in the carbonates of Asmari. There are also some shaly/marly beds in these carbonates, causing some places to wash out in the Asmari part of the interval. As the accuracy of structural dip is dependent on the planarity and sharpness of bed boundaries, the layer/bed boundaries were then categorized into High Confidence and Low Confidence categories as far as their dips (Fig. 6).

55 bed/layer boundaries are sharp and planar, hence categorized as high confidence for bedding dip and there are 33 less sharp and relatively uneven layer/bed boundaries, classified as low confidence bedding. Both LC and HC beddings were used to determine the structural dip. Based on both dip types, an average dip magnitude of 75 degrees can be taken for structural dip computation for the whole interval. However, the structural dip is deduced to be 75 degrees towards S28W. These variations in the dip Azimuth could be attributed to several reasons. As mentioned above, the sedimentary structure of the Asmari formation is moderately complex due to diagenetic processes, which happen in carbonate sequences naturally and have the potential for variations in dip angle. There are major variations in bedding dip and strike trends. These variations sometimes make it difficult to recognize the major structural trends. The inclinations of dip are normally low and vary between 55-90 degrees. The large spread in the dip Azimuth within the structural zones

could be attributed to the existence of diagenetic variations in limestone (Fig. 7-10).

A computer-based cross-section along an NNE-SSW plane was built in Strucview based on this dip data. Strucview deals with geological dip data; displays and can automatically group dip data into sets representing geological structures. The cross-section computation is accessible in groups. The cross-section displays some irregular bedding planes possibly demonstrating diagenetic alterations.

As a result, the structural dip data is an input for permeability analysis software and helped in understanding the reservoir structure, identifying and evaluating sedimentary features and fractures, visualizing the rock texture and complementing coring programs (Fig. 10-12).

Natural Fracture Characterization (Calibration data)

It is vital to know, whether is the reservoir fractured or non-fractured. If it is fractured, then what is the kind of fracture (open or closed) and what is its intensity? Are those fractures single set or multiple sets and what are the fracture azimuth and strike? Solutions to questions like these support geologists and reservoir engineers to increase oil production (Tatar *et al*., 2004).

The well-test analysis is not sufficient in characterizing fracture properties. Fracture intensity and deep-rooted fractures widely grow the risk of unexpected water production. Fractured reservoirs are a special type of hydrocarbon reservoir. They are commonly thick, porosity is mainly secondary, the distribution of porosity and permeability is irregular, production varies greatly and they may or may not have a common hydrocarbon content. Fractured reservoirs show a great deal of difference in terms of (1) The pores of the host rock may or may not contain hydrocarbons and (2) reservoir potential may or may not be evaluated by conventional open hole logs (Movahed *et al*., 2014a).

Fracture analysis is a target of the FMS survey in the study well. To get the maximum knowledge of fractures, the images were interpreted in conjunction with open-hole logs. Discussion on various fracture attributes is given in the following paragraphs.

Fracture Morphology

In terms of morphology, fractures are classified into three categories; Major, Medium, Minor, open (continuous, discontinuous) and closed fractures. The traces of continuous open fractures are visible in all pads and have larger apertures compared to discontinuous open fractures. The others have discrete fracture traces, which are not visible in all pads and are in some cases vuggy. In closed fractures, the trace is completely healed and a resistive halo effect is present in many cases (Fig. 13).

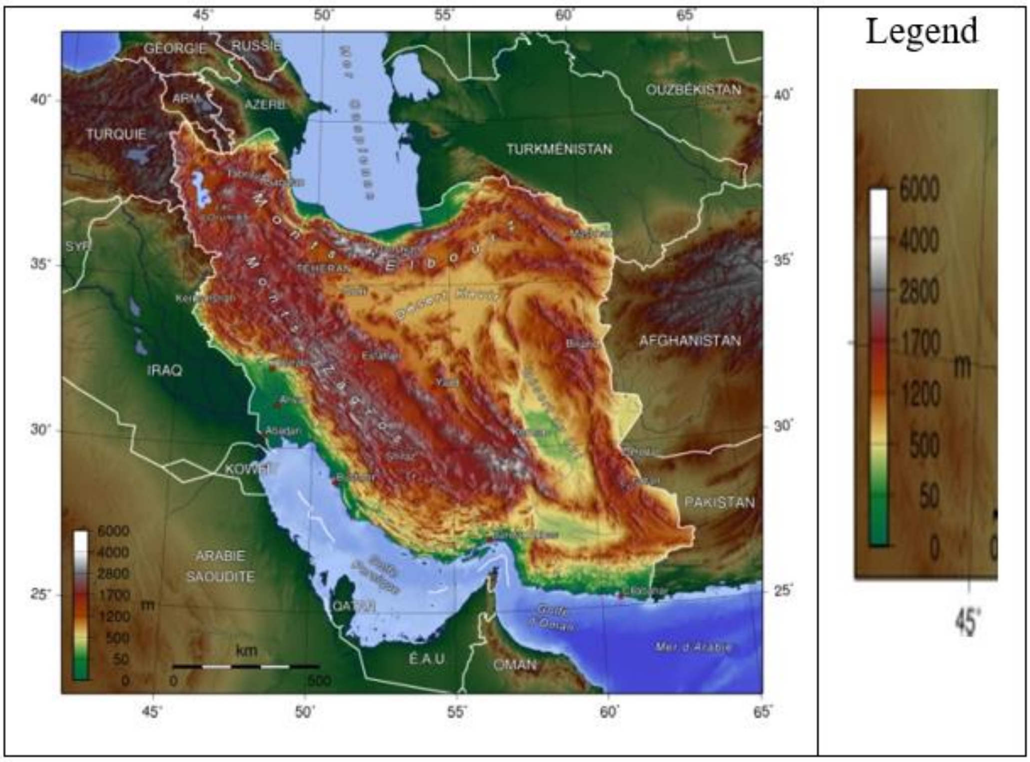

Fig. 1: Satellite image of Iran and part of the Arabian plate highlighting intense folding in the southwest part of Iran and right (Zohreh *et al*., 2016)

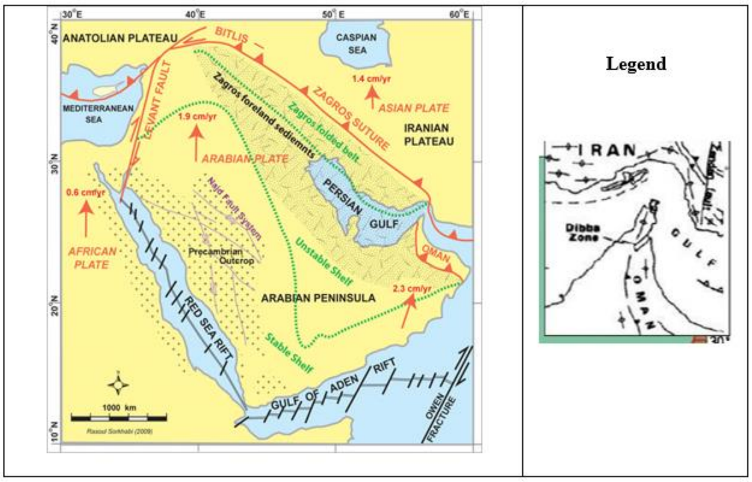

Fig. 2: Tectonics map showing the location of Iran between the Eurasian and Arabian tectonic. Foreland folding in the southwest of Zagros convergence and large-scale strike-slip faults are indicated in Iran (Statoil and RIPI, 2003)

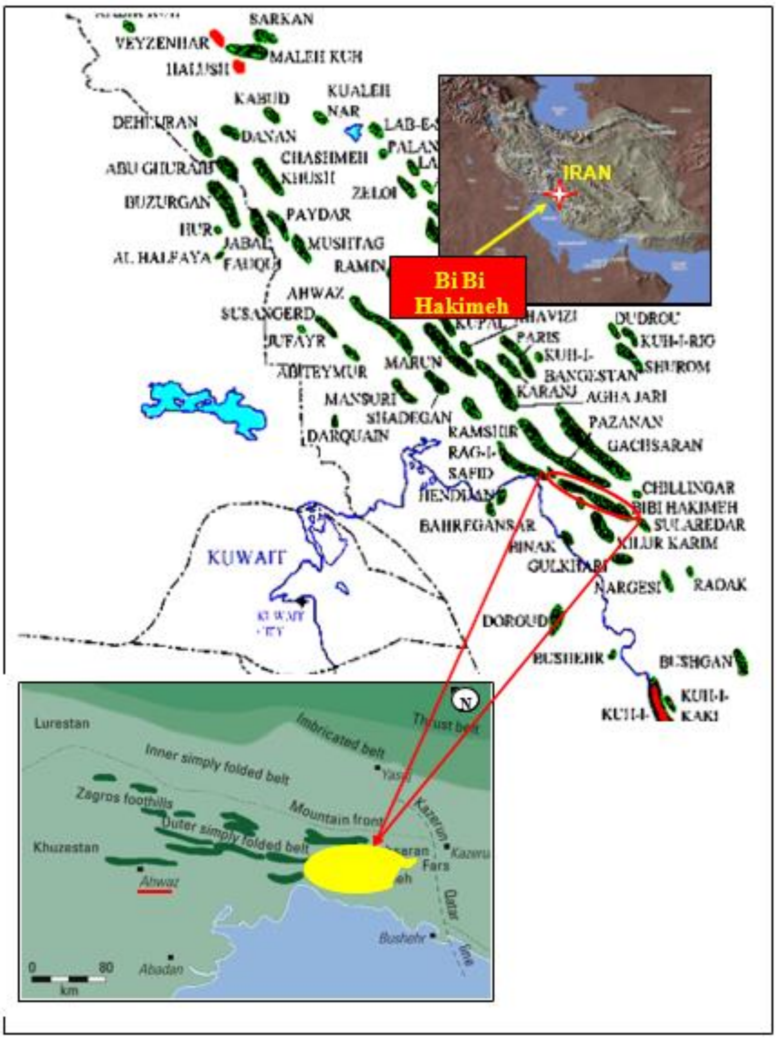

Fig. 3: The location of Bibi hakimeh field near-fault area (Rezaeei, 2006)

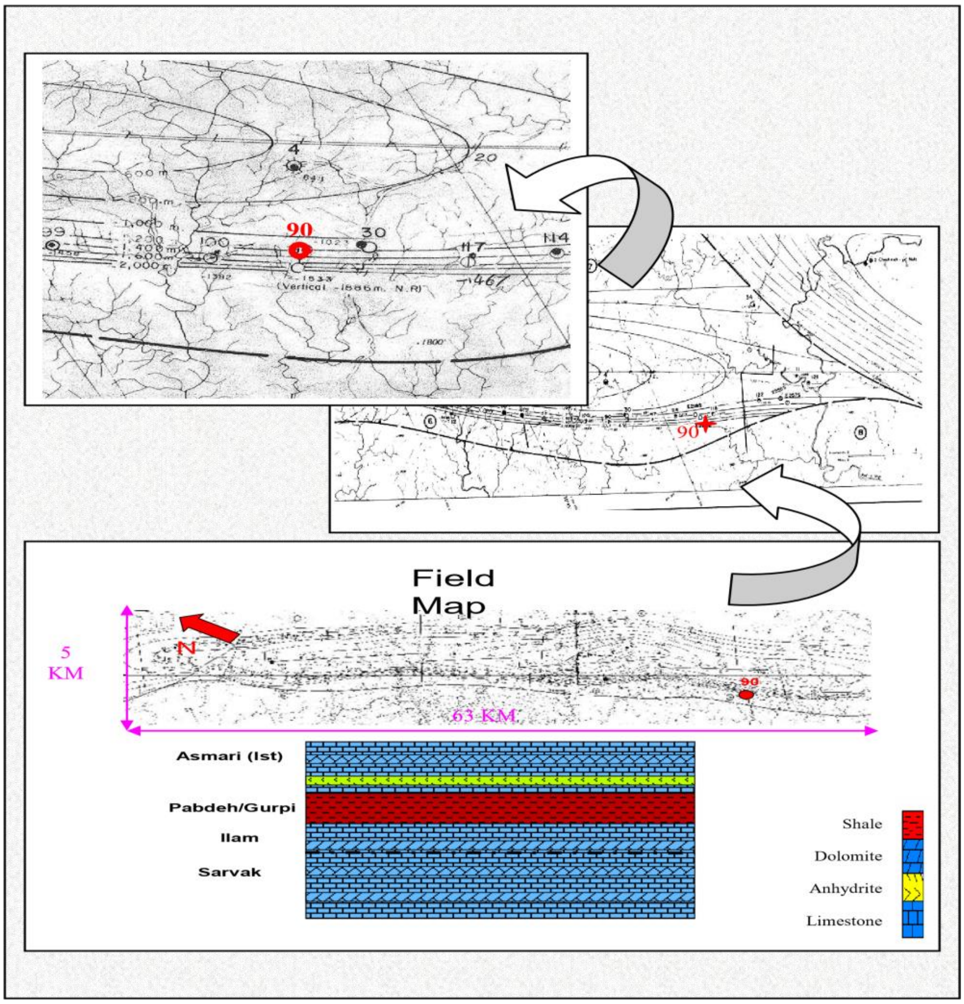

Fig. 4: The location map of well # 90 in the Bibi Hakimeh field (Shariatinia *et al*., 2013)

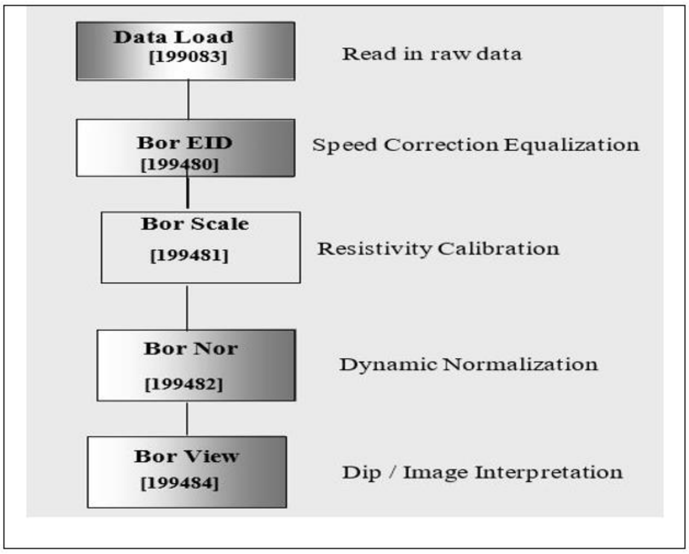

Fig. 5: Flowchart of structural and fracture analysis from FMS

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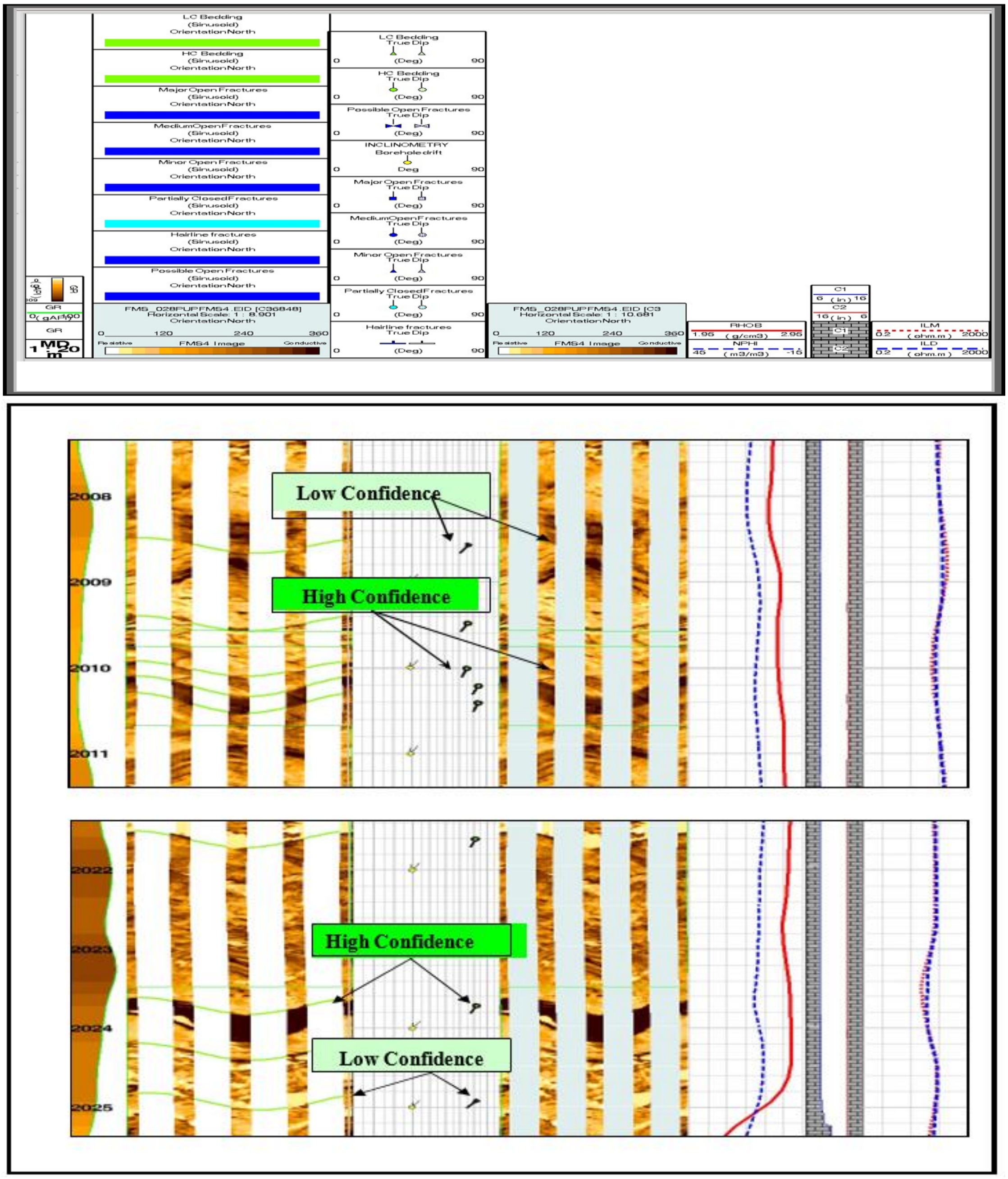

Fig. 6: The dips corresponding to layer/bed boundaries are shown as low and high confidence based on their sharpness and planarity for computation of structural dip

Fracture Classification

All the fractures that have continuous or discontinuous conductive traces are termed open (conductive) fractures (Movahed *et al*., 2016). Such fractures are found throughout the entire interval and are clustered in some places. These fractures have a discrepancy in their aperture look and trace continuousness across the wellbore. So, they are classified into three categories; major-open fractures, minor-open and medium-open fractures. Major open fractures have large apertures and are continuous across the wellbore. The minor-open fracture apertures are not as large as major open fractures, but their traces are still continuous. Several discontinuous-open fractures have a vuggy appearance, which is what is commonly expected in carbonates due to the dissolution of the host rock along the fracture plane as a result of crossing fluid (Fig. 13).

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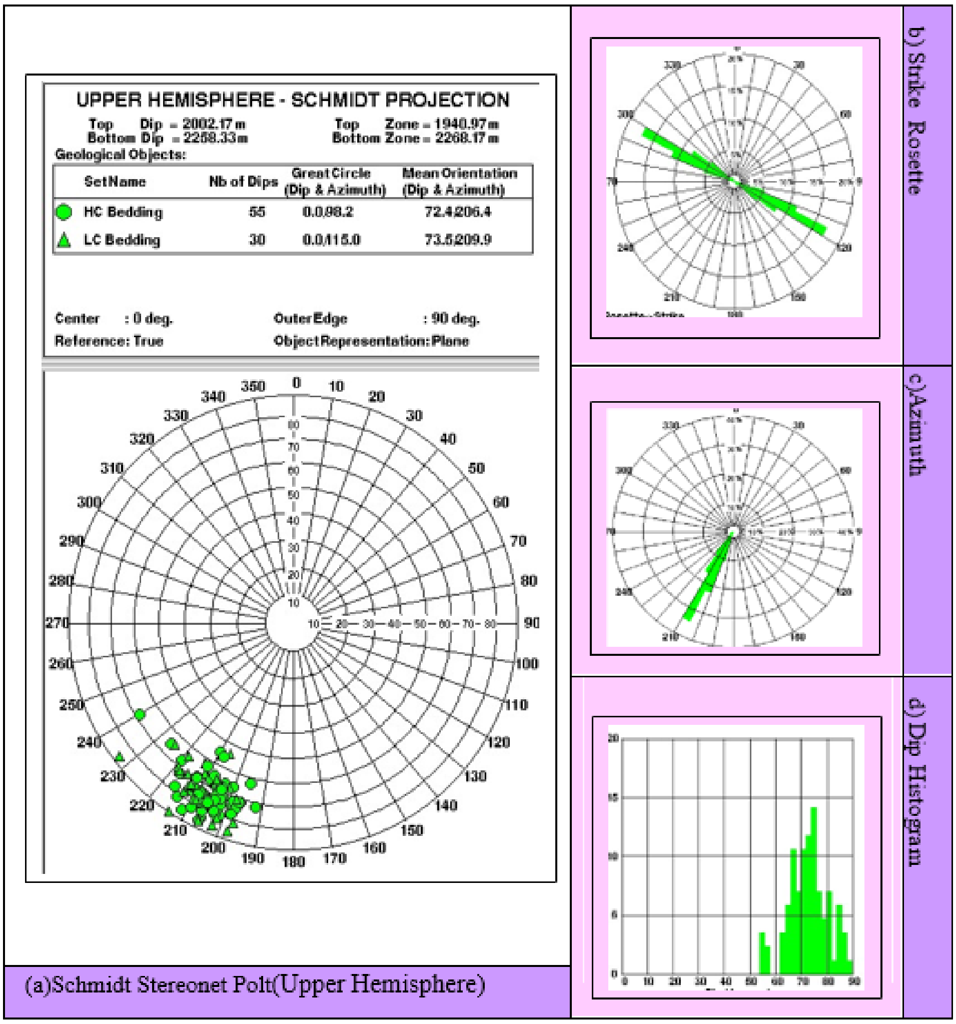

Fig. 7: Statistical plots of bedding dips are indicating an average dip of 75 degrees S28W and strike N62W-S62E. The average dip inclination of 75 degrees is the most representative of the whole interval of the Asmari formation

Feature Type	of No. Samples	Symbol	Dominant Dip Azimuth	Dominant Strike	Dominant Dip	Average Dip
High Quality Bedding	55	●	S28W	N62W S62E	75	75
Low Quality Bedding	30	▲	S30W	N60W S60E	71	71
Structural Dip Based on All Bedding Types	85		S28W	N62W S62E	75	75

Fig. 8: Bedding dips are indicating an average dip of 75 degrees S28W and strike N62W-S62E. An average dip inclination of 75 degrees is the most typical of the whole interval of the Asmari formation

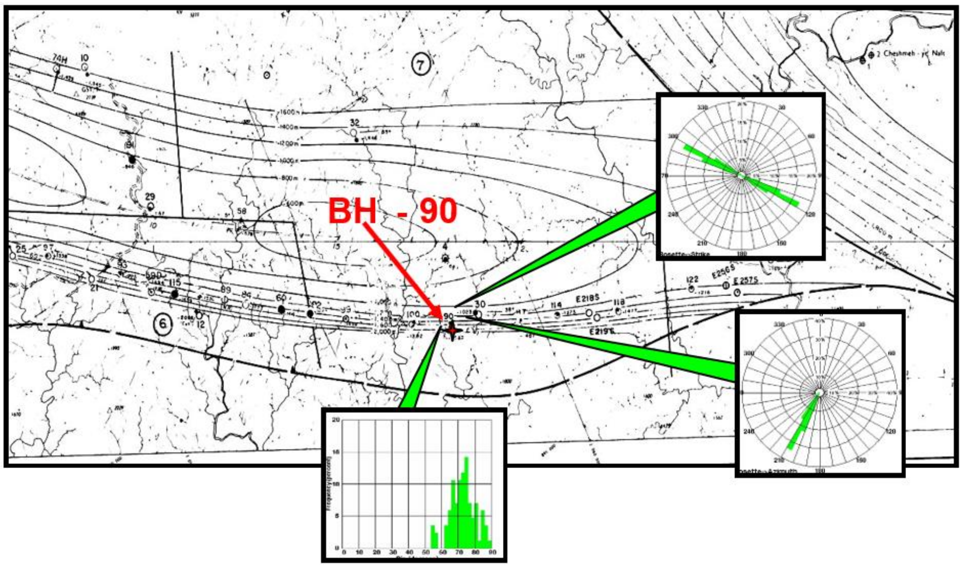

Fig. 9: Bedding dips, Azimuth and Strike indicating an average dip of 75 degrees S28W and strike N62W-S62E in the Eastern South flank

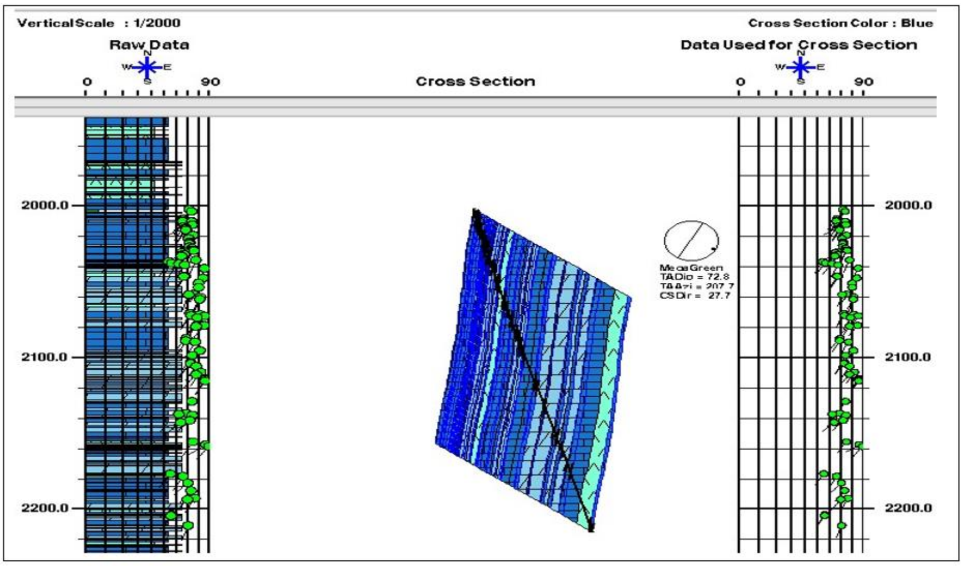

Fig. 10: Bedding dips indicating an average dip of 75 degrees S28W and strike N62W-S62E. Schematic computer-generated model using dip data

Fracture Strike and Dip

The FMI images discovered fractures in most zones of the Asmari reservoir. Altogether, 698 fractures were identified. Most of the fractures are plotted within the 20- and 50-degrees inclination circles of the stereonet. The open fractures with a 40-dip inclination toward N48W. The open fractures show a dominant, striking trend of N42E-S42W. Once studied concerning the bedding dip data, it is found that open fractures tend to strike oblique, parallel and perpendicular to the bedding strike. It indicates that open fractures are oblique, longitudinal and transverse types (Fig. 14-16).

Fracture Occurrence

Three open-fracture zones can be roughly distinguished in the interval based on some factors, including fracture density and the distribution of these fractures in the form of clusters. Statistical plots for the dips of open fractures in the Asmari formation fracture zones show a wide range of dips and dip azimuths, which can be considered a sign of the presence of a fault near the well (Fig. 17 and 18).

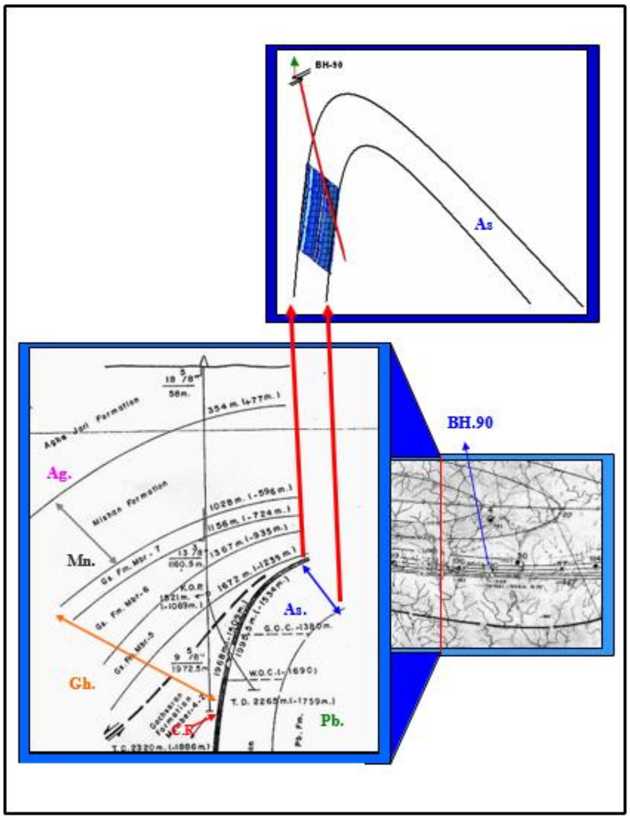

Fig. 11: Bedding dips indicating an average dip of 75 degrees S28W and strike N62W-S62E. A computer-based cross-section along an NNE-SSW plane in Strucview based on this dip data matches well with NISOC structural model

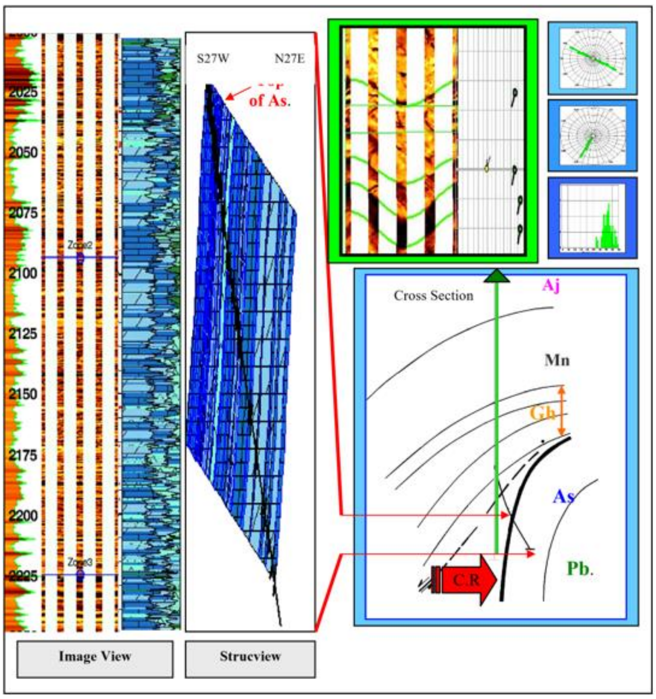

Fig. 12: Composite plot of orthogonal calipers (C1 and C2), GR, FMS static normalized images, dips, well deviation, bedding dip, and lithology in Asmari formation. Bedding dips indicate an average dip of 75 degrees S28W and strike N62W-S62E. A computer-based cross-section along an NNE-SSW plane in Strucview based on this dip data matches well with NISOC structural model

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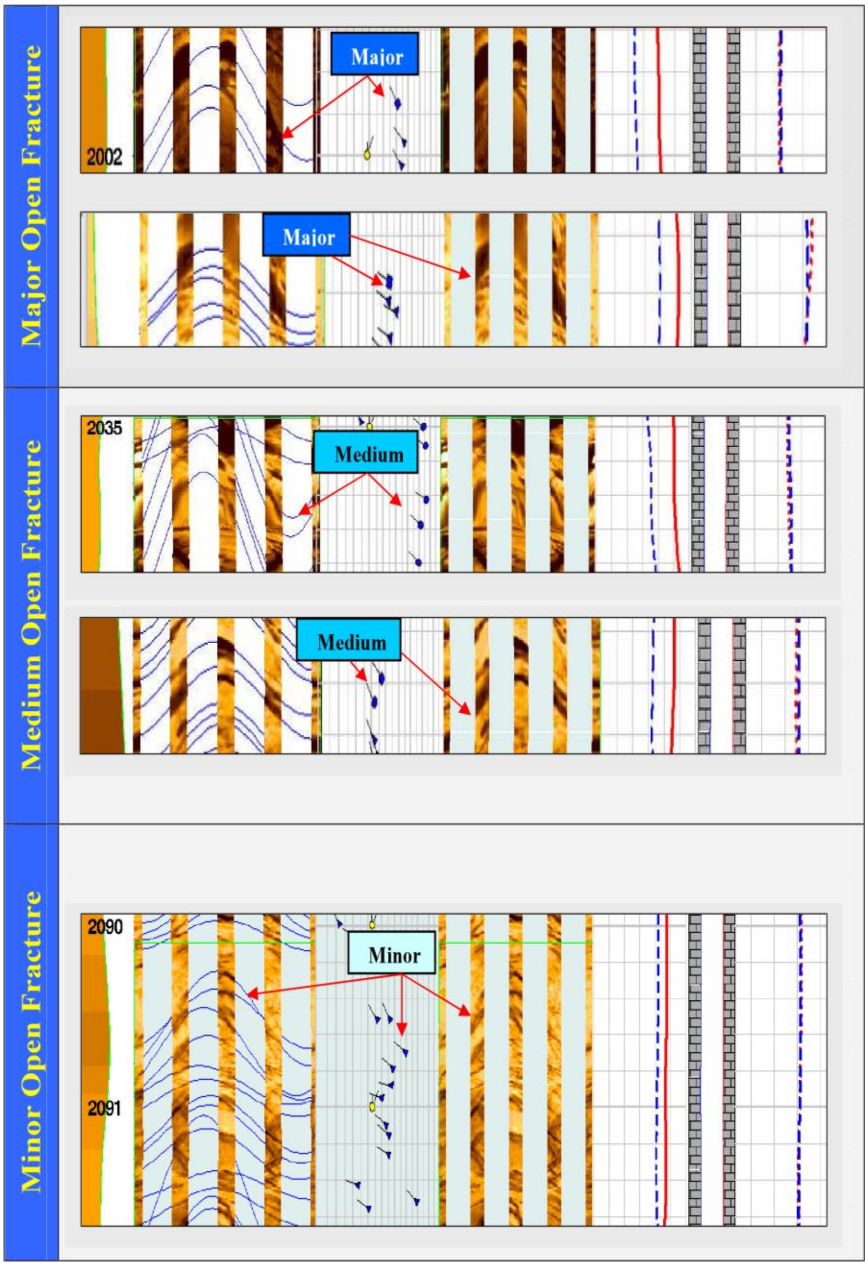

Fig. 13: Minor open fractures (blue triangle dips), Medium open fractures (blue circular dips) and Major open fractures (blue square dips) are shown by the FMS image in the Asmari formation

Comparison between FMS and Thin Section Data from Cores

Image logs are recorded over more extended depth intervals and can be used to achieve structural, stratigraphic and sedimentary dip profiles. There are four intervals where the fracture attributes FMS are compared with the thin section data. Minor and medium open fractures partially cemented with calcite and anhydrite have good confirmation with fractures in thin section data at some intervals.

Image logs have provided oriented fracture data in in-situ reservoir conditions. Unfortunately, the core condition during core sampling is incredibly poor within the fractured zones and cannot be used to deliver consistent information. Lowly core retrieval resulting from the existence of fractures has made the straight core to log match tough in places. Thin sections of the cores are usually only taken in reservoir formations where, due to lithology type, there may be only uncommon bedding planes that provide the structural dip trend (Fig. 19-22).

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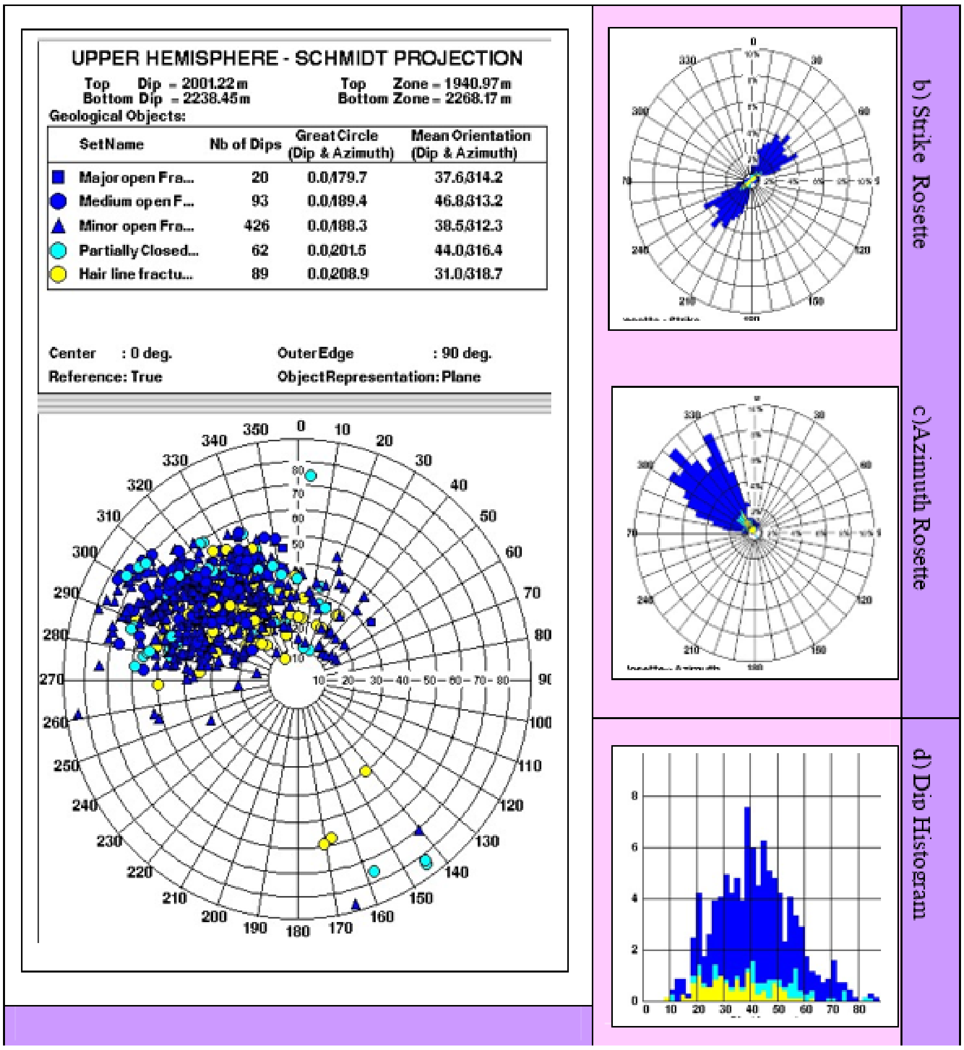
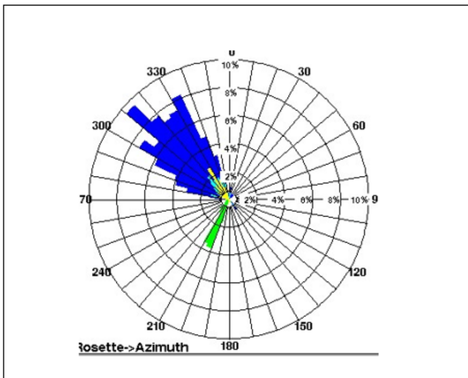
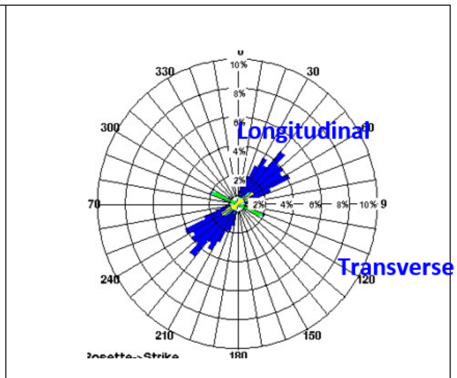


Fig. 14: Statistical plots for dips of all open fractures in the Asmari formation



A) Fracture and bedding dip Azimuth rosette.



B) Fracture and bedding strike rosette.

Fig. 15: Statistical plots of dips of all fractures and bedding dip attributes showing most transverse fractures in the Asmari interval

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Main Fractures Type	Symbol	Number of Fractures	Average/Dominant Strike	Average/Dominant Dip Azimuth	Average/Dominant Dip(deg)
Major Open Fractures		20	N18E-S18W	N72W	51
Medium Open Fractures		93	N42E-S42W	N48W	46
Minor Open Fractures		426	N45E-S45W N62W-S62E	N45W N28E	38
Hairline Open Fractures		89	N57E-S57W	N33W	38
Possible Open Fractures		8	N36E-S36W	N54W	52
Partially Closed Fractures		62	N38E-S38W	N52W	57
All Fractures Types		698	N42E-S42W	N48W	40

Fig. 16: Dips data of all open fractures in the Asmari formation

	Depth	Major Open Fracture	Medium Open Fracture	Minor Open Fracture	Hairline Open Fracture	Partially Closed Fracture	Average Dominant Strike	Average Dominant Azimuth	Average Dominant Dip
Zone I	1996-2094m	13	51	243	37	65	N42E S42W	N48W	39
Zone II	2094-2225m	7	36	168	24	23	N32 E S32W	N58W	45
Zone III	2225-2265m	0	6	15	0	2	N62E S62W	N28W	43

Fig. 17: Fractured zones in Asmari formation

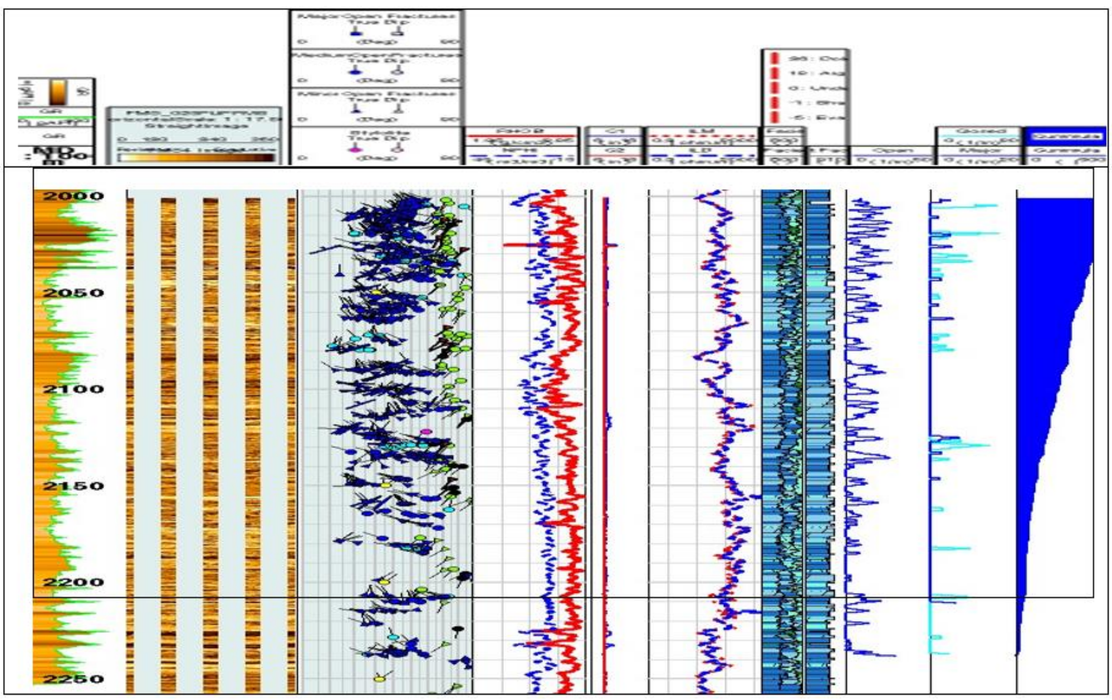

Fig. 18: Summary of structural and fracture analysis results in BH-90. Apart from some short sections, open fractures are present in most intervals

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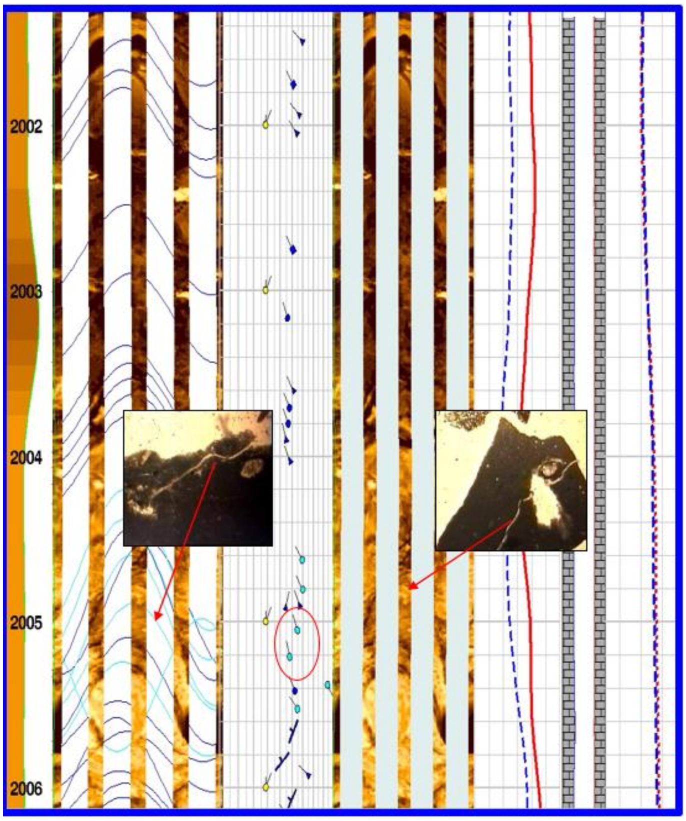

Fig. 19: Minor open fractures (partially cemented) with calcite showing in a thin section of 2005 m depth

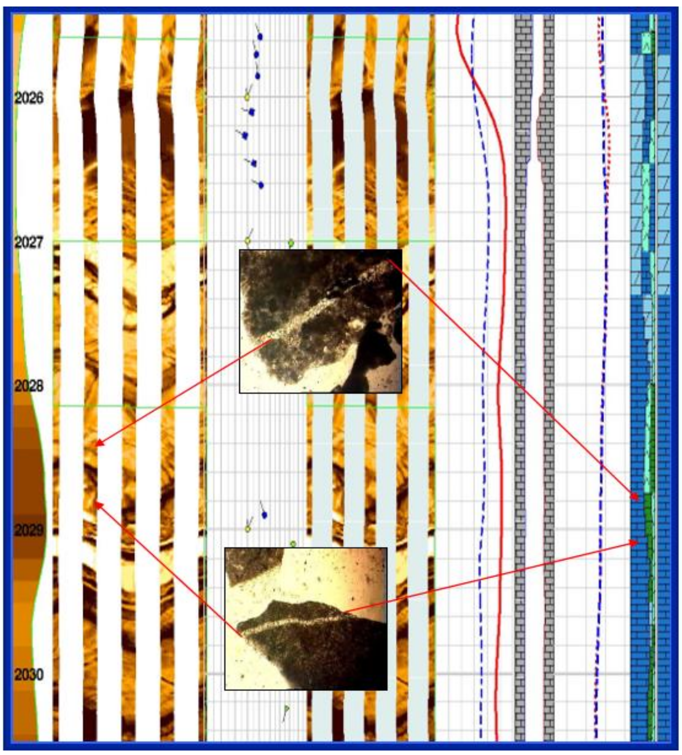

Fig. 20: Medium open fractures cemented with calcite showing in a thin section of 2029 m depth and it has a good match with FMS Image in shaly limestone layers

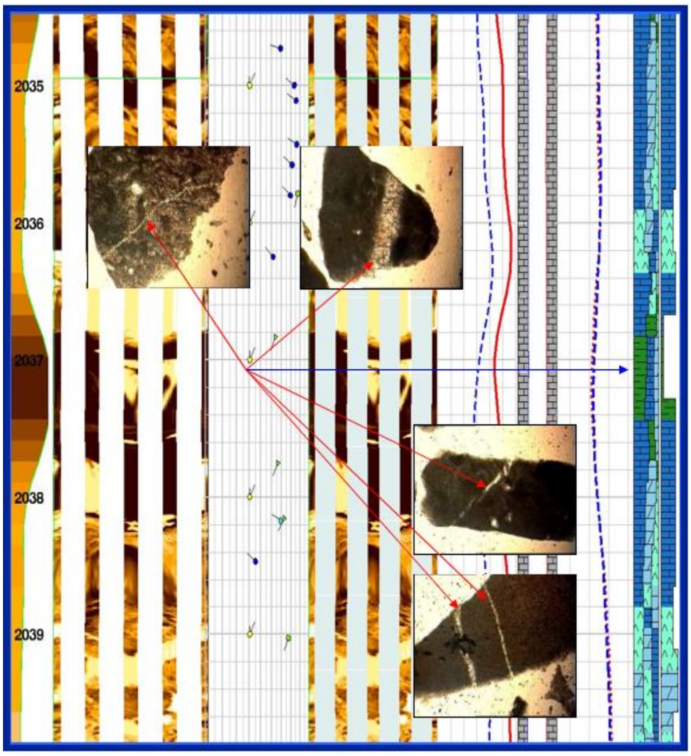

Fig. 21: Medium open fractures cemented with calcite showing in a thin section of 2037 m depth, but it cannot see in the FMS image

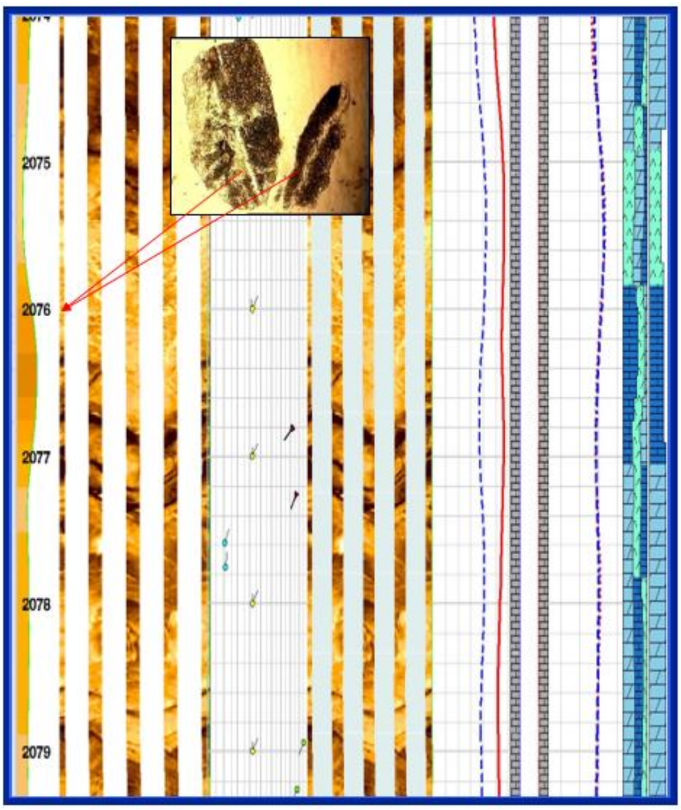

Fig. 22: Fractures cemented with Anhydrite showing in a thin section of 2076 m depth and it cannot see in the FMS image

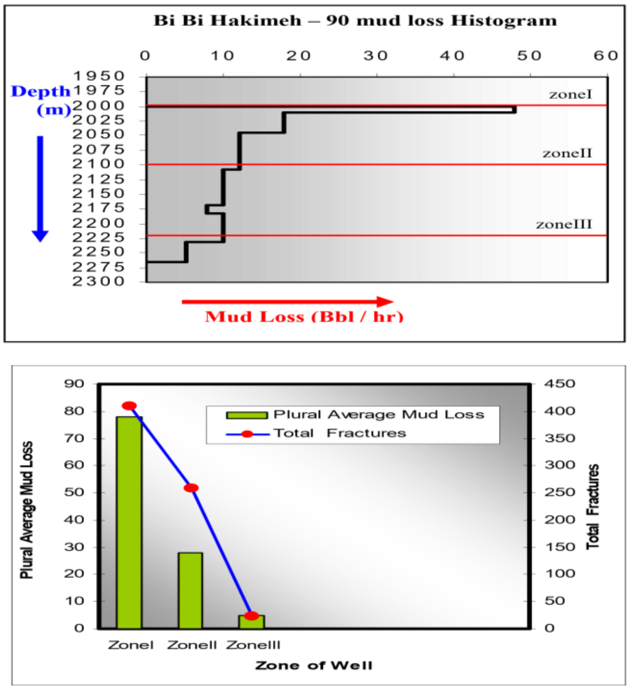

Fig. 23: Calibration of FMS fracture density data with mud loss data in the highly fractured reservoir. The red color is mud loss data and the blue color is fracture density data

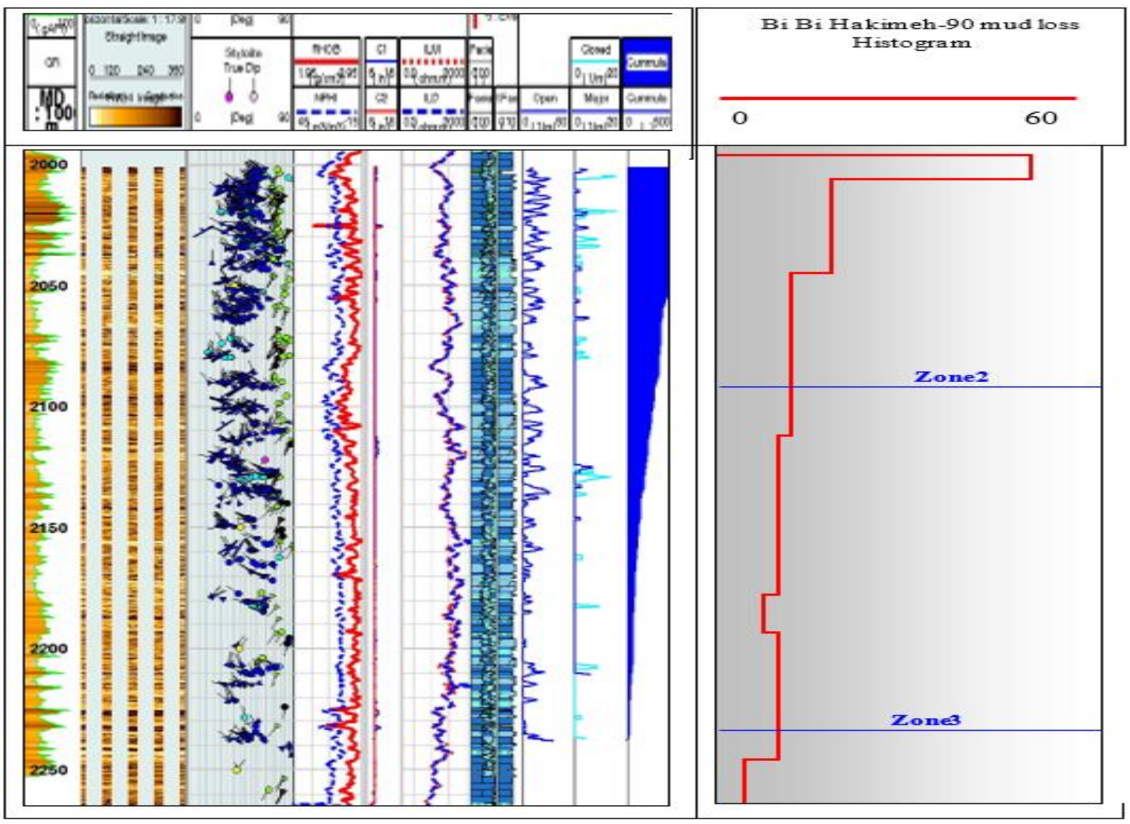

Fig. 24: Calibration of FMS fracture density data with mud loss data in Asmari reservoir. The red color is cumulative mud loss data and the blue color is cumulative fracture density data

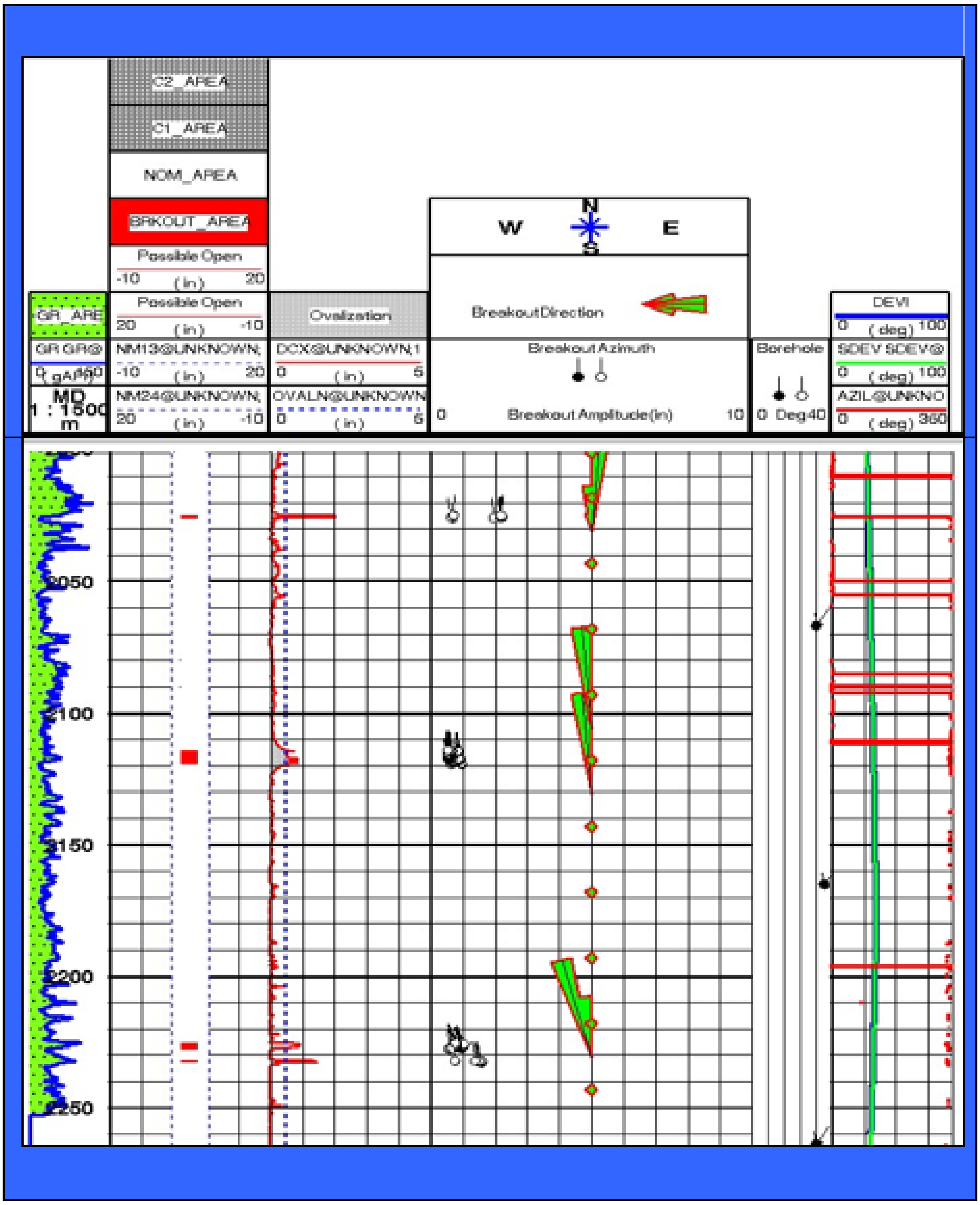

Fig. 25: In-situ stress orientations determined based on borehole breakouts identified in well BH-90. FMS images and caliper data show borehole breakouts oriented on the average NW-SE which is parallel to the minimum horizontal stress orientation

The image logs show that there is a strong NE-SW alignment of fractures which is 'transverse' to the Bibi Hakimeh field structure. Drilling fractures and borehole breakouts visible on image logs confirm the present-day in-situ stress directions. Due to the poor core recovery, there was some uncertainty in the distinction between natural and induced features.

Calibration of FMS Fracture Data with Mud Loss Data in Highly Fractured Reservoir

The fracture data from FMS is calibrated with mud loss data. The high density of fractures seen on FMS image logs in zone I has been confirmed by inspection of the mud loss data. The mud loss and fracture density of the image is accurately matched in the Asmari reservoir. Accordingly, there is a strong match between cumulative fracture density and cumulative mud loss data. (Fig. 23-25).

In-Situ Stresses Analysis

The subsurface of the continental crust infrequently stays at hydrostatic stress conditions, the strain state under which all points within the crust are exposed from all directions to equal stresses (s1 = s2 = s3). Conversely, such stress conditions are infrequently met in the earth's subsurface as many structural movements keep taking place in it. The bigger portion of the disturbance in the equilibrium in the stress state is contributed by the plates' movements that eventually result in the formation of a regional stress system for the area confined by them. Nevertheless, sometimes the regional stress is overprinted because of stresses limited to a particular area. The cause of the local stress system could be also related to faults, folding, diapirism and then forth. The orientation of such local stresses could also be changed suddenly over small distances in any area.

The wells drilled in areas exposed to such sorts of unbalanced stress systems often display two styles of borehole failures, shear failure and tensile failure, after the rocks drilled by them are swapped with the drilling mud. The rocks can tolerate both compressive and shear stresses but the fluid filling the borehole can stand only compressive stress and not shear stress. Accordingly, the concentration of stresses takes place around the borehole within the types of hoop stress or tangential stress. Once the mud weight is simply too low (i.e., radial stress = mud weight minus pore pressure), the hoop stress becomes much on top of the radial stress. Subsequently, a shear failure of rocks exposed to the borehole takes place, which is revealed within the variety of borehole elongation on the orthogonal calipers of FMS and as extended dim areas on the FMS images that are 180 degrees separately. On the opposing, when the mud weight is just too high, the radial stress rises and therefore the hoop stress decreases; so, rock nearby the borehole comes under tension and flops in tension; the fractures so formed are called drilling-induced fractures. It is shown within the style of a fracture seen by the borehole images oriented at 180 degrees from another (Movahed *et al*., 2014b).

Commonly, in vertical wells and those with minor deviations, the orientation of borehole elongation is united with the tendency of minimum horizontal stress. Likewise, the strike drilling-induced is ranged with the drift of maximum horizontal stress. On the other hand, it should not be the case with the deviated wells and particularly those wells that are not aligned with either of the two horizontal stresses. In such wells, orientations of borehole breakouts and drilled-induced fractures may not represent the true orientation of the two horizontal stresses. It is because all three principal stresses (vertical and two horizontal) act obliquely on the borehole. Schlumberger developed a methodology by which borehole breakouts and drilling-induced fractures from deviated wells, in particular, can be inverted to stress tensors responsible for their formation. Borehole breakouts were observed in the well. The great commonality of these oval breakouts has their extensive axis oriented in a practically NW-SE direction. This indicates that the orientation of minimum horizontal stress around the BH-90 well is almost NW-SE and the orientation of maximum horizontal stress is NE-SW. This orientation of in-situ stress matches with the regional orientation of Zagros stresses (Fig. 25).

Subsequently, this reservoir consists of carbonates (limestone, dolomite and anhydrite) and rarely clastics (sand and shale). Bed boundaries are almost uniformly distributed throughout the logged interval. The layering in the lower part of cap rock logged by the FMS tool is mainly due to the concentration of conductive spots parallel to the bedding which forms conductive seams and the existence of marly/shaly interbeds between anhydrite beds characterized by high rates of CGR. These marly interbeds have also affected the borehole condition by causing some major and minor washouts which are reflected in caliper readings. The occurrence of these shaly and/or marly seams and layers can be a result of impermanent variation in sedimentary environment conditions, which has led to the domination of clastic particle accumulation in a sequence of anhydritic beds (Fig. 25).

Conclusion

This study helped to recognize the Asmari structural and fracture systems and their effect on production. It resolved structural complications and provided the precise location of the well in the reservoir. Dip classification based on geological logs has the benefit of providing a straight illustration of the structural source. Enhanced understanding of the Asmari structure contributed to the operator "s reservoir model and allowed scientists to evaluate reservoir potential more perfectly.

Fracture density data and mud loss data from this well were matched to verify the log measurements. Most fractures are open and can affect the production or/and injection profiles of the well. Most open fractures appear to be conjugate and transverse in nature. As a result, this exercise has proven to be very valuable, not only for demonstrating the value of the log data, but it has also highlighted some significant limitations of the core data. This workout has established why image logs are the main source of fracture data within the oil fields of Iran

Significant Statement

This study will be used as a standard workflow for other fractured carbonate reservoirs and the National Iranian South Oil Company will use this method in cases where no coring data is available. Image logs will help in optimizing coring and saving project drilling costs and at the same time allow more wells to be drilled in the field. NISOC has a better understanding of FMS data usage in cases where low-quality 3D seismic data is available.

Recommendation

A very beneficial tool for textural and pore system studies of carbonate formations is the combination of FMS and CMR tools. Better characterization of the Asmari formation in such fields as Bibi Hakimeh, in which the most production is coming from matrix and fractures, could be very effective using the above-mentioned high-technology tools.

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Author's Contributions

All authors equally contributed in this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

References

Kalantari-Dahaghi, A. M., Moghadasi, J., & Gholami, V. (2006, December). Applicability of Horizontal Drilling Techniques in Iran: A Field Case Study in Bibi hakimeh Field, Southwest Iran. In *International Oil & Gas Conference and Exhibition in China*. OnePetro. https://doi.org/10.2118/100784-MS

Khoshbakht, F., Memarian, H., & Mohammadnia, M. (2009). Comparison of Asmari, Pabdeh and Gurpi formation's fractures, derived from image log. *Journal of Petroleum Science and Engineering*, *67*(1-2), 65-74. https://doi.org/10.1016/j.petrol.2009.02.011

Movahed, Z., Junin, R., Amiri Bakhtiari, H., Safarkhanlou, Z., Movahed, A. A., & Alizadeh, M. (2015). Introduction of sealing fault in Asmari reservoir by using FMI and RFT in one of the Iranian naturally fractured oil fields. *Arabian Journal of Geosciences*, *8*(12), 10919-10936. https://link.springer.com/article/10.1007/s12517-015-1951-z

Movahed, Z., Junin, R., Amiri Bakhtiary, H., Taghavi Poor, S., Mohamadian, R. (2016). The evaluation of borehole imaging result comparing with cores in Sarvak fractured and non-fractured reservoir, Arabian Journal of Geosciences.

Movahed, Z., Junin, R., & Jeffreys, P. (2014a). Evaluate the Borehole Condition to Reduce Drilling Risk and Avoid Potential Well bore Damages by using Image Logs, Journal of Petroleum Science and Engineering 122 (2014), 318-330.

Movahed, Z., Junin, R., Safarkhanlou, Z., & Akbar, M. (2014b). Formation evaluation in Dezful embayment of Iran using oil-based-mud imaging techniques. *Journal of Petroleum Science and Engineering*, *121*, 23-37. https://doi.org/10.1016/j.petrol.2014.05.019

Movahed, Z., Junin, R., Safarkhanlou, Z., Akbar, M. (2014c). Formation evaluation in Dezful embayment of Iran using oil-based-mud imaging techniques, Journal of Petroleum Science and Engineering121 (2014)23–37 37.

Statoil, N.I.S.O.C., & RIPI. (2003). Sedimentology and stratigraphy and reservoir quality of the Asmari Formation in the Marun field.

Rezaeei, M. R. (2006). the book of petroleum Geology. *Alavi propagation*, *472*.

Shariatinia, Z., Haghighi, M., Feiznia, S., Hall, D., Levresse, G., Dehghani, A. M., & Rashidi, M. (2013). Paleofluid analysis from fracture-fill cement in the Asmari limestones of the Kuh-I-Mond field, SW Zagros, Iran. *Arabian Journal of Geosciences*, *6*(7), 2539-2556. https://link.springer.com/article/10.1007/s12517-012-0522-9

Tatar, M., Hatzfeld, D., & Ghafory-Ashtiany, M. (2004). Tectonics of the Central Zagros (Iran) deduced from microearthquake seismicity. *Geophysical Journal International*, *156*(2), 255-266. https://doi.org/10.1111/j.1365-246X.2003.02145.x

Zohreh, M., Junin, R., & Jeffreys, P. (2014). Evaluate the borehole condition to reduce drilling risk and avoid potential well bore damage by using image logs. *Journal of Petroleum Science and Engineering*, *122*, 318-330. https://doi.org/10.1016/j.petrol.2014.07.027

Zohreh, M., Junin, R., Bakhtiary, H. A., Poor, S. T., Mohamadian, R., & Movahed, A. A. (2016). The evaluation of borehole imaging results comparing with cores in Sarvak fractured and non-fractured reservoir. *Arabian Journal of Geosciences*, *9*(3), 1-12. https://link.springer.com/article/10.1007/s12517-015-2091-1