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NATURAL FRACTURES ANALYSIS OF RESERVOIR ROCK VIA FMI IMAGE LOGS IN BIBI- HAKIMEH OIL FIELD, SW OF IRAN

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Abstract

Fracture system in carbonate reservoirs is very complex. Understanding the features of fractures such as dip, strike and the other parameters can help to distinguish the behavior of reservoir in any exploration and production plan. Evaluation of fractures and their parameters, such as aperture and density, is necessary in the optimization of oil production and field development. Image log is the best way to investigate feature planes like fracture and bedding. This enables the petroleum geoscientists to describe in detail the structural fracture networks very essential for structural analysis and improved reservoir characterization. Their aperture may be open, tight (closed) or filled with some minerals such as calcite, anhydrite, clays and pyrite. The main objective of FMI log was to determine structural dip and characterize probable fractures intersected by the well. Discussion on various fracture attributes is given in the following: Based on observations and interpretation of the images logs from Asmari formation, the closed fracture, has N27°E-S27°W strike and 73 degrees inclination to S55°E and the open fractures in directions N83°E, S83°E and N7°W with dips of 14° to 90° (43°). Fracturing is observed strongly in the studied interval. The brittle nature of the formation could be the reason for development of fractures in the drilled section of Asmari formation. Thus permeability of reservoir rock is much and result production of hydrocarbon is high.

Keywords*: Fracture analysis, Image logs, Asmari formation, Bibi- Hakimeh oil field.*

1. Introduction

To identify small natural fractures around the well, most of the methods, such as geophysical logs, wells and drilling mud data, are not sufficiently precise due to their low resolution [1]. The FMS / FMI imaging logs provide high resolution images of well wall at millimeter scale, which are based on the physical properties of wells like electric resistances [2]. Imaging logs for reservoir geologists allow for the identification of small-scale phenomena within well wall boundaries. The most important application of imaging logs is to identify the types of fractures and their characteristics (type, orientation, and spacing) in oil and gas wells [3].

Natural fractures are caused by tectonic stresses. Zones that have natural fractures are important and are explored in reservoir rocks because of dramatic drainage and significant increases in permeability. Although fractures can have a major impact on the total permeability of the formation, they have very little effect on porosity, fluid saturation and other petrophysical properties of the rock. The features of the natural fractures are in [4].

Natural fractures are usually perpendicular to the slope of the layer. The extent and development of horizontal fractures is much less than that of vertical fractures. Their predominant direction is usually aligned with the orientation of regional faults. Natural fractures cause small amount of wellbore wall to fracture and collapse by drilling bit during drilling operation [5]. Fractures are usually seen in dense and tight rocks, which, in the absence of fracture during drilling, cause the diameters of drilling bit and wellbore to be the same. From the point of view of production, only open fractures are useful.

In the case of artificial fractures, the wellbore wall is always affected by horizontal tensions and damage caused by drilling. There are two types of artificial fractures which are as following: borehole breakout due to shear stresses and induced hydraulic fractures caused by damages during drilling [6], which is not discussed in this study.

2. Geological setting

Well No.91 of Bibi-Hakimeh oil field is located 25Km South-East of Gachsaran city in SW of Iran (Fig.1). This well was drilled in the Eastern part of the Bibi-Hakimeh oil field near the crest of anticline. Asmari formation was the target formation of the well, which was drilled with a 6.125 inch bit. The FMI and FMS logging with open well logs (neutron, density, gamma ray and electrical resistance) was carried out by National Iranian Oil Company to better understand the structural features. Dimensions of the Asmari reservoir at the water-oil interface are about 70 km in length and 7 km in width [7].

Figure 1. Located of Bibi- Hakimeh oil field in Dezful embayment, near the other oil fields, Southwest of Iran.

3. Methodology (FMI and FMS imaging logs)

In this study, the FMS and FMI image logs were used to identify the types of natural fractures of wellbore wall of well No.91 in Bibi-Hakimeh oil field and the results were compared with the studies of open well logs. Finally, the density, orientation and impact of fractures in the permeability of Asmari formation were investigated.

Imaging logs are cylindrical and virtual images of a high-resolution wellbore wall that can display the delicate phenomena of the wellbore wall. Each plate-shaped construction, such as stratification and fracturing that interrupts the wells vertically and horizontally, can be seen in the ellipsoidal in wellbore cylinder. If the cylinder is cut and opened along its axis, the same shape as shown in the imaging log, will illustrate the fracturing or stratification as a sine wave. Also in the imaging log, the vertical fracture (parallel to the well axis) is represented by vertical straight lines and horizontal fractures (perpendicular to the well axis) will appear as horizontal straight lines.

The FMI tool is a new generation of electrical imaging devices that has double wall coverage as compared to FMS. The FMI is equipped with four vertical caliper arms. At the end of each arm, a pad and flap are attached. Pads and flaps contain a number of electrical resistive sensors (usually 24 sensors for each pad and flap), which results in a high resolution level of about 0.3 inches. The data from sensors are used to process and create an image that is based on the difference in electrical resistance of the wellbore wall [8]. In this study, the FMS log has 4 pads as well as 16 sensors on each pad.

The FMS and FMI tools collect information about wells cross-section and geometry as well as electrical resistive image information. In general, imagers are used to determine natural fractures and artificial fractures, and can be used to calculate gradient and fracture length and stratification levels.

The crude data extracted from the oil wells is interpreted after processing and correction on them. The processing of image graphs involves processes that eliminate some of the errors and increase the quality. The processes performed on the images are divided into two categories: a) fundamental corrections that are necessary for electrical imaging diagrams, including depth correction, speed correction, correction of broken and disabled pads, etc.; b) Process of image quality improvement which includes equalization and normalization of the correction [9].

In image diagrams, sometimes, image strips have different brightness and darkness due to the curvature of the pad. Normalization is used to correct the buttons response. Similarly, in order to highlight geological elements and structures in graphic diagrams, the correction equalization option is used. At the end of this step, two static and dynamic images are created; the static image is often used to identify stratification and lithology changes, and the dynamic image is usually used to identify natural and artificial fractures [9].

4. Analysis of fractures via Image logs

FMI logs are used to interpret the geometry of natural fractures. Natural fractures are observed on the logs as sinusoidal regions, which may have electrical resistance or electrical conductivity [10]. Based on the appearance of the fractures, two types of fractures on the FMI log are identified: Open fractures that easily allow the fluid to pass and closed fractures that inhibit fluid to pass quickly.

The opening of the fractures may be open, closed or filled with minerals such as clays, calcite, anhydrite, pyrite, and the like. On FMI / FMS images, fractures tend to occur linearly, which generally has a steeper slope than the stratification slope. Open fractures in a clean clay-free clay structure have a conductive look on the images. This is due to the penetration of the conductive drilling mud into the opening of the fractures. If the fractures are closed or filled with calcite and anhydrite minerals, it will have an electrical resistive appearance. However, fractures filled with clay and pyrite will have conductive responses [11]. Sedimentation and stratigraphic data of the study area are essential to distinguish the electrical conductivity resulted from filling by mud and filling by clay and pyrite. Of course well logs can be used in some cases to detect such differences [12].

FMS and FMI images showed any fractures in Asmari formation. The fractures did not have the same appearance, some were resistant and some were conductive. There was a tight fracture with resistive presentation that was grouped as a closed fracture (Fig.2 and 3), and all fractures with continuous or discontinuous conduction effects were considered as open fractures. The reason for the conduction of these fractures is due to the infiltration of the drilling mud into the open regions. In the next stage, open fractures were divided into further groups based on the appearance and lateral continuity in the wellbore (Fig.2 and 3). The characteristics of open and closed fractures and subgroups are presented in Table.1 and the spatial position of the types of fractures, both closed and open, in terms of slope, tensile angle and slope angle are given in Table.1.

Table 1. Classification of fractures

Main types of fracture	Subgroups of fracture	Number of fractures	Dominant Strike	Dominant Dip Azimuth	Dominant Dip Inclination (deg.)
Closed fractures	Discontinues closed	34	N27E-S27W	S55E	73
Open fractures	Discontinues Continues	37 54	N83E-S83W	N7W	43 (Range 14-90)

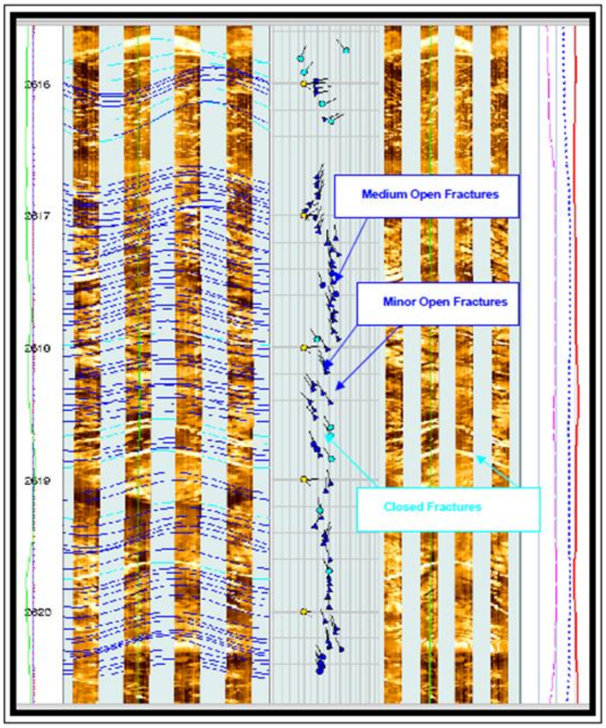

Figure 2. Minor open fractures (blue triangle dips), Medium open fractures (blue circular dips) and Closed fractures (Cyan circular dips) shown by FMI image in Asmari Formation

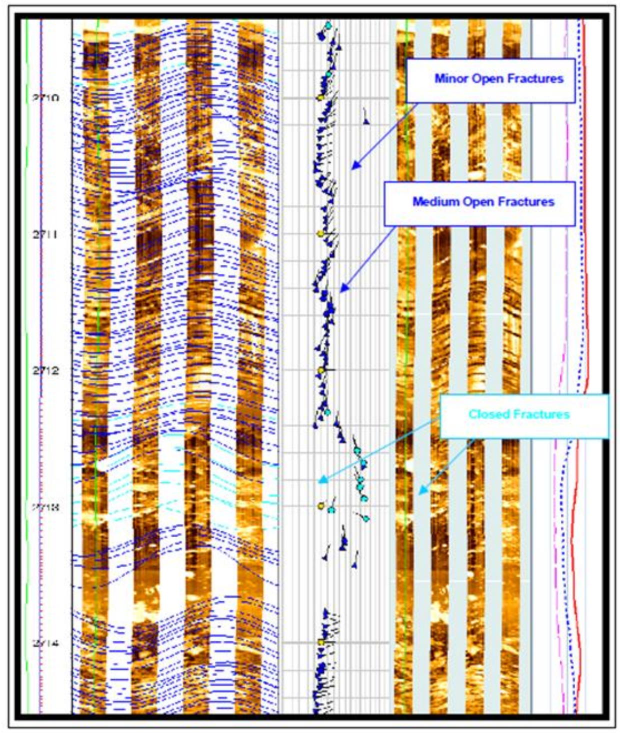

Figure 3. Minor open fractures (blue triangle dips), Medium open fractures (blue circular dips) and Closed fractures (Cyan circular dips) shown by FMI image in Asmari Formation

Open-well log data showed that the main lithology of the reservoir is limestone or marl. The drilled region of the Asmari formation has the most developed fracture, due to the brittle nature of this formation against tectonic stresses. Therefore, fractures in this region are significant and even they are considered as fractured.

5. Conclusions

Based on observation and interpretation of images log from Asmari formation, the following important conclusions are as follows:

Open-well log data indicates that the main lithology of the reservoir rock is limestone or marl. In the study region, fracture is strongly seen. 34 Number of closed fracture, 37 discontinues open fractures and 54 continues open fracture were detected from FMI image logs. Closed fracture was identified with slope direction of S55°E slope and slope angle of 73°. Open fractures were detected with slope directions N83E-S83W and slope angle ranging from 14° to 90°. The statistical survey of this region from Asmari formation shows that fractures are high developed and this is probably due to the brittle nature of the reservoir rock, so the evaluation shows that the reservoir has a good permeability and will have a positive effect on the production of hydrocarbon from the well.

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