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Determination of fractures distribution and horizontal in-situ stress in one of the Persian Gulf oil fields using FMI image log

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Abstract

In hydrocarbon reservoirs of hard formations, hydrocarbon extraction and field development are strongly dependent on the geomechanical conditions of the reservoir, such as fractures and faults status and in-situ stress conditions. Image logs are powerful tools used to evaluate geomechanical conditions of hydrocarbon reservoirs in recent decades. In this study, using the FMI image log, which has a high resolution, coverage percentage and accuracy, the status of fractures, faults, and in-situ stress conditions of the upper Arab Formation in one of the Persian Gulf oil fields were investigated. Accordingly, 206 open fractures in 10 crashed zone with N60E-S60W domain trend and 96 closed fractures with two N45W-S45E and N50E-S50W trends in the Upper Arab Formation of well A were detected and based on the orientation, they mainly were categorized in longitudinal tensile fracture. Also, based on the observed induced fractures and breakouts, maximum and minimum horizontal stresses are oriented in N50E-S50W and N40W-S40E directions, respectively.

Keywords: *Fractures, FMI image log, in situ stresses, induced fractures, breakout*

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Extended Abstract:

1. Introduction

Due to the significant impact of fractures on the better and more effective production and harvesting, identifying this phenomenon is vital (McCoss, 1986). Drilling with coring is a valuable way to get direct underground information, such as detecting fractured areas, bedding surfaces, and so on. Since the coring process is time-consuming and more expensive, most the oil-gas wells have been drilled in a wash-boring state without coring. On the other hand, in crashed zone core recovery percentage is deficient, and therefore, direct inspection by the core is not possible. Consequently, alternative methods for core inspection were strongly needed to assess the geomechanical characteristics of the reservoirs. Thus, high-resolution image logs from the well wall have entered the field to cover the gap and revolutionized the evaluation of oil reservoirs (Prensky, 1999). The FMI log is one of the most modern and ubiquitous imaging logs that have a high resolution, coverage percentage, and accuracy. It is widely used in cracked reservoirs to assess fractures. FMI resolution is 0.2 inches (5 mm) and can detect details up to 50 microns (Shahinpour, 2013). Many studies have been conducted to identify fractures using image logs (Khoshbakht et al., 2012; Ezati et al., 2014). Momeni et al. (2019) have used UBI and OBMI image logs to evaluate fracture characteristics in one of the Persian Gulf oil fields.

The used data for this study is obtained from one of the Persian Gulf oil fields. The studied field is located the south of the Persian Gulf, and it is also structurally situated in the southern boundary of the Zagros fold-thrust belt, one of the most famous hydrocarbon belts in the world. The repetition of hard and soft formations same as the formations of the anticline, have led to the development of many oil and gas fields in this belt. In this field, the Upper Surmeh Formation, with late Oxfordin to Tithunin in age, act an oil reservoir. The Upper part of the Surmeh Formation in the central and eastern regions of the Persian Gulf and coastal Persian zone and the countries bordering the southern Persian Gulf is known as the Arab Formation. The studied oil field has generally formed a relatively symmetrical anticline as a structural trap, characterized by two faults in the north with a west-southeast trend and two other faults with an east-west trend in the south of the anticline. The oil field anticline has extended with an approximate size of 11 km by 14 km.

2. Materials and methods

In this study, the used data have been taken from two wells of the oil field. Image log data is not a standard set of log data, and usually requires specialized software to process and interpret the image. In this study, FMI imaging log data were processed in GEOLOG software. Processing involves depth correction, speed correction, image creation, image enhancement, and data equalization and normalization. After preparing the image log, image analysis was categorized into two strategies, including 1) analysis of discontinuities such as fractures, faults, and stylolite and 2) analysis of horizontal in-situ stress direction using detection of drilling-induced fracture and breakout features.

Open fractures are usually filled by drilling mud, If the mud be conductive, recorded resistance in this part by the image log is less than the background of the rock, and the open fracture appears as a complete or continuous dark sinusoidal wave in the image logs. Closed fractures are usually filled with calcite crystals or other crystalline minerals that are highly resistant and appear on the image logs as a light sine wave. The halo effect is an ordinary mark for detecting filled fractures in carbonates (Khoshbakht, 2009). Stylolite is a common diagenetic phenomenon in limestone, dolomite, and sandstone rocks, which is seen in conductive, dark-colored, wavy, zigzag, and sometimes smooth lines in images (Ebner, 2009). A fault is generally defined as any surface or narrow zone with visible shear displacement along the zone (Fossen, 2010). One of the critical applications of image logs is the identification and description of faults.

During drilling, two main problems in borehole stability will have emerged. Breakout (BO) and drilling induced tensile fracture (DITF) that may lead to fishing, stuck pipe, sidetracking, reaming, and fluid loss. In this study, both of them have been used to determine the direction of horizontal stresses. Drilling-induced fractures extend in the form of straight lines or a long wave at a distance of 180 degrees from each other along the axis of the well and show maximum horizontal stress alignment. These fractures are always dark in color due to their openness and filling with drilling mud.

3. Results

The number of open fractures identified in well A is relatively large, but most of them are non-persistent fractures and cover some parts of a hypothetical sine wave. 206 open fractures with N60E-S60W domain trend and 96 closed fractures with two trends, including N45W-S45E, and N50E-S50W, were identified in the Upper Arab Formation of well A, while no open fracture was observed in the Upper Arab Formation in well B. The open fractures have a high dip angle and oriented parallel to fold axes trending of the anticline. Therefore is a longitudinal fracture and will be classified as a tensile fracture. Among subdivision zones, U3, which has 3075-3090 m interval, is detected as a crashed zone with 108 open fractures. Generally, ten zones were detected with relatively high fracture density, which are located in 2895-2900; 2280-2285; 2975-2980'; 2960-2965; 3025- 3035;360-370;3075-3080; 3085-3090; 3105-3110; 3165-3170 m intervals of well A. Furthermore, a fault with N65W-S65E strike and S25W dip direction, was detected at a depth of 2841.5 m.

The absence of fractures at some depths of well A can be related to the presence of anhydrite layers. Anhydrite is a ductile rock, and therefore fractures rarely will develop in this type of rock. That is why, in most reservoirs, anhydrite ac as caprock. For detection of Anhydrite layers, not only fracture density will be used, but also petrographical logs such as gamma-ray and density logs will be employed. In the studied logs, the anhydrite layer is associated with a sharp drop in gamma-ray and an increase in density logs. Nevertheless, breakout and induced-fractures were identified in well B. Based on the DIFs and breakout geometry, the orientation of maximum and minimum horizontal stresses in well B are N50E-S50W and N40E-S40W, respectively. The result has a good convergence with obtained results of other research on in-situ stress in the Persian Gulf region.

4. Conclusion

Image logs provide a virtual image of the well wall, which is one of the proper techniques for studying fractures in the well wall. Based on the image analysis and log description, the following results were obtained:

-The significant fractures developed in well A have a NE-SW trend with the geometry of N60E, 75SW. These fractures have appeared in both open and closed types. From a structural geology standpoint, the fractures are longitudinal fractures.

- 10 zones with high fracture density were detected in well A, and the subzone u3 was identified as the most fractured zone.
- based on the image log of well B, drilling-induced fractures appear in the N55E –S55W direction, whereas the breakouts show N45W-S45E as the dominant trend. Therefore, we can conclude that in this area, maximum horizontal stress is orientated N50E –S50W, whereas the minimum horizontal stress direction is N40W-S40E.

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