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Predicting The Azimuth of Stress from Wellbore Breakouts in (X) Oil Field

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Abstract:

The current minimum and maximum horizontal stresses orientations are influential parameters in the development of any Geomechanical model; these models aim to reduce wellbore instability and non-productive time during drilling by selecting the best wellbore direction when drilling inclined or horizontal wells. Minimum horizontal stress orientations can be established by examining wellbore breakouts. Borehole breakouts result from a natural failure compression process in which the maximum hoop stress surrounding the hole exceeds the rock strength, which may be detected using an oriented caliper log tool. There is no data in the World Stress Map (WSM) in the research area. As a result, data from 10 wells in the (X) oilfield's Oriented caliper well logs were analyzed for this study. The breakouts azimuth is consistent with depth, and the minimum horizontal stress azimuth from the north is 140o - 150o and 320o - 330o, which is compatible with the regional maximum horizontal stress direction (Shmax). As a result, the recommended drilling direction of deviated, and horizontal wells in the (X) oil field area should parallel the maximum horizontal stress.

Keywords: Horizontal stress, Oil field, Well-bore Breakouts.

التنبؤ بأتجاه الإجهاد بأستخدام تحليل تهدمات جدار البئر في حقل (X) النفطي

الخلاصة

تعتبر الأتجاهات الحالية للأجهادات الأفقية (الأجهاد الأقصى والأدنى) عوامل مهمة في أعداد وتطوير أي موديل جيوميكانيكي؛ وتهدف هذه الموديلات إلى التقليل من مشكلة عدم استقرار جدار البئر أثناء الحفر وبالتالي تقليل الوقت غير الإنتاجي أثناء الحفر من خلال اختيار أفضل اتجاه لحفر الآبار المائلة أو الأفقية. يمكن تحديد اتجاهات الأجهادات الأفقية الدنيا من خلال تحليل ودراسة التهدمات التي تحدث اثناء الحفر ضمن تجويف البئر. تحدث التهدمات في الأبار كنتيجة طبيعية حين يتجاوز إجهاد الطوق الأقصى المحيط بالبئر قوة الصخور، والتي يمكن تحديدها باستخدام مجس قطر البئر الموجه. في منطقة الدراسة الحالية لا توجد بيانات لأتجاه الأجهادات في خريطة الإجهاد العالمية (WSM). لذلك، تم تحليل البيانات من 10 آبار في مجسات الآبار ذات قطر البئر الموجه لحقل (X) النفطي لهذه الدراسة. يتوافق اتجاه التهدمات مع العمق، ويتراوح أتجاه الإجهاد الأفقي الأدنى بين 140 درجة الى 150 درجة ومن 320 درجة الى 330 درجة من الشمال، وهو متوافق مع اتجاه الأجهاد الأفقي الأقصى الإقليمي. نتيجة لذلك، يجب أن يوازي اتجاه الحفر الموصى به للآبار المنحرفة والأفقية في حقل (X) النفطي الأجهاد الأفقي الأقصى.

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1. Introduction:

Orientation of horizontal stress (minimum and maximum) is an important input to recognize the current stress field and analyze the wellbore instability to optimize well planning, optimal hydraulic frac, and minimizing sand production throughout oriented perforations, the feasible method to determine stress orientation is through understanding the wellbore breakout trend during drilling, another method involves running acoustic or electric borehole image logs before and after mini-frac test to identify the direction of the induced fracs. Breakouts are one of the critical and costly problems and cause a major increase in non-productive time (NPT), It is connected to a compressive natural failure process that occurs when the rock strength becomes less than the hoop stress around the borehole (Figure 1).

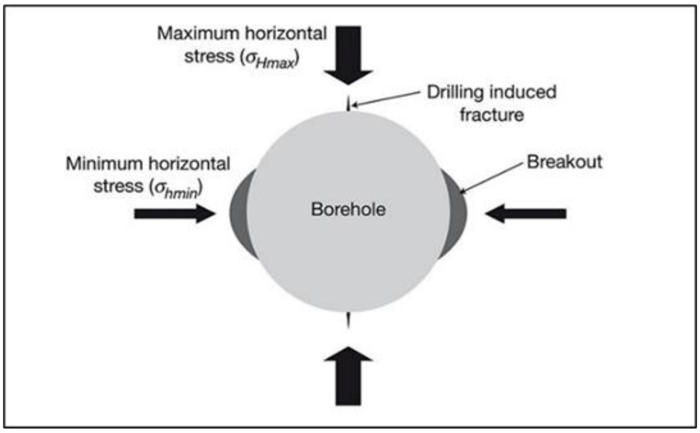

Fig. (1): Breakouts and fractures in the stress field. [1].

In vertical wells, the SHmax direction is parallel to the drilling-induced tensile failures, and perpendicular to the breakouts of the wellbore [1], this may cause many issues such as pipe stuck, bad cement job, issues with running wireline logs in the well, decrease the life of drilling bit [2]. The mean breakout axis may be proven to be parallel to Shmin and hence perpendicular to SHmax when accurate in-situ stress data are provided.

2. The area of study

The (X) oil field is one of the biggest oilfields in southern Iraq (Figure 2), it is located west of Basra city, south of Iraq, the field is made up of two anticlines and mainly produce from Zubair and Mishrif reservoirs [3].

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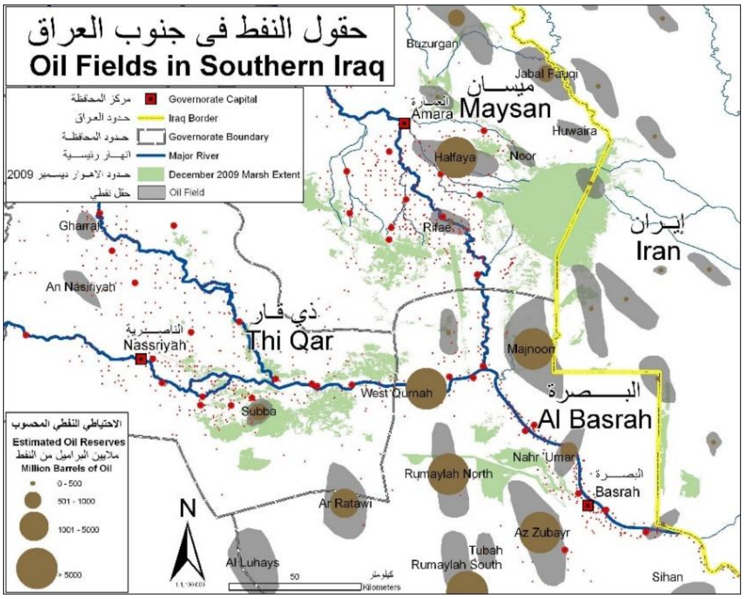

Fig. (2): Location of oil fields in the south of Iraq [4]

3. Background Geology

The Mesopotamian tectonic zone, which is part of the Arabian plate's north-east border with the Eurasian plate, comprises the (X) oilfield [5]. Two tectonic periods produced the Mesopotamian passive margin zone. [6]:

a) **Opening phase**: The Iranian and Turkish plates were split from the Arabian plate during the late Permian/early Triassic epoch as a result of extensional movements (Figure 3), which led to the Neo Tethys ocean opening [7], and Upper Permian carbonate or clastic overstepped earlier Paleozoic rocks. Thermal subsidence and decay generated a passive margin mega-sequence over the Arabian plate's north and east borders, forming the Mesopotamian basin [5]. During the Jurassic, the extensional movement continued, leading to enlarging of the Neo Tethys Ocean [8].

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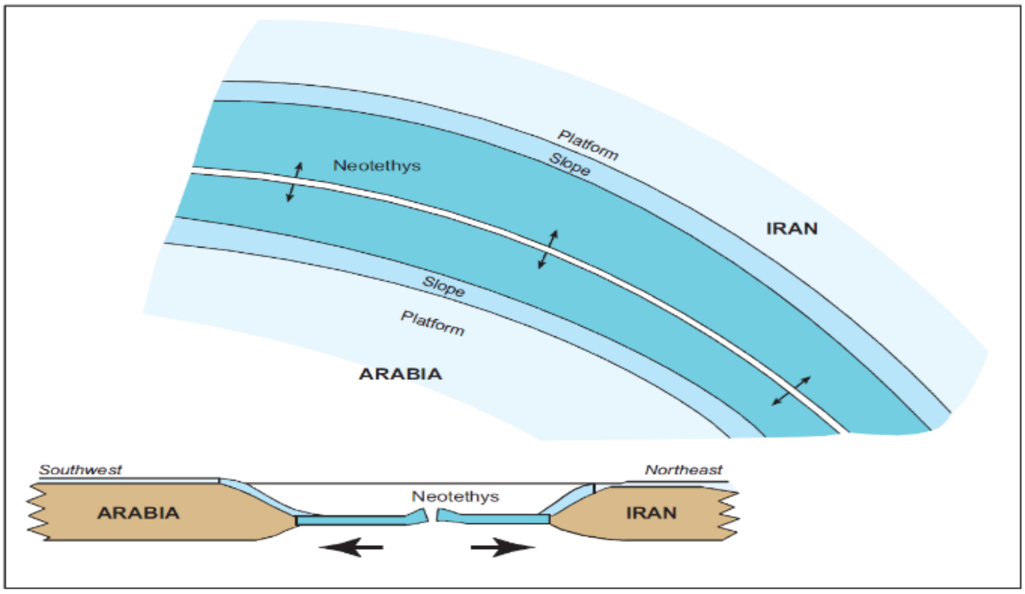

Fig. (3) Neo Tethys ocean through the Late Permian [9].

b) **Closing phase**: The tectonic activity changed from extension to compression during the Cretaceous, resulting in subduction along the active continental borders of the Turkish and Iranian plates. Later, during the Eocene-Oligocene, the continental Arabian plate met with the Eurasian plate, rising and deforming structural oil traps in southern Iraq [6]. Because of this lift, no Oligocene deposits occur in that location. The Neo Tethy Ocean was closed during this era, leaving shallow epicontinental seas and lagoons. During the Cretaceous epoch, the regional tectonic regime transformed from extension to compression, resulting in subduction along the active continental borders of the Turkish and Iranian plates. Later, during the Eocene-Oligocene, the continental Arabian plate met with the Eurasian plate, rising and deforming structural oil traps in southern Iraq [6]. As a result of this lift, no Oligocene deposits occur in that location. The Neo Tethys Ocean was isolated during this period, leaving shallow epicontinental seas and lagoons [7].

Finally, the Arabian plate converged and subducted under the Eurasian plate during the period from Miocene to recent (Figure 4), forming anticlines and thrusts in Zagros Mountain [9]. In the studied area, the impact of the Arabian and Eurasian plates created an NW-SE strike-slip regime [10].

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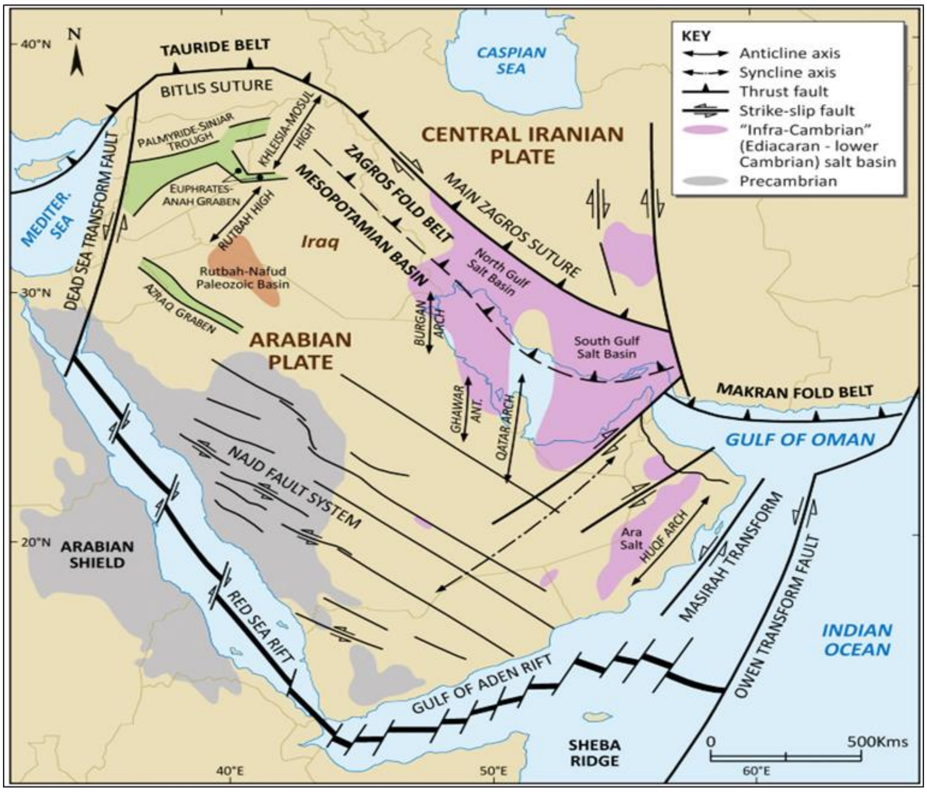

Fig. (4): Along the Bitliz-Zagros fault, the Arabian plate collides and subducts [11].

4. Stress Orientation

Stress orientation depends generally on SHmax and Shmin where vertical stress (SV) is regarded as vertical. Wellbore failures such as drilling borehole breakouts and induced tensile fractures were employed to assess the orientation of principal stress. Dependable in situ stress results indicated that the common axes of breakouts are mostly parallel to the S_{hmin} direction. Thus, it would be perpendicular to the S_{Hmax} direction. Breakouts in wellbores are created by a natural failure compression mechanism that happens when the maximal hoop stress surrounds the hole more than the strength of the rock (Figure 5).

Borehole Image logs and oriented multi arms Calipers are often used to gather the majority of stress direction data [12]. Caliper 1 (C1) denotes pads 1 and 3 of the four-arm caliper, whereas Caliper 2 (C2) denotes pads 2 and 4 of the four-arm caliper (C2). Those two calipers can be used to determine the hole's diameter. When C1 and C2 have the same readings as bit size, Figure 5a shows an in-gauge hole. On the other hand, a borehole washout is depicted in (Fig. 5b). C1 and C2 readings differences identify this washout. Caliper logs tend to spin while pulled from the wellbore due to cable twisting. When any Caliper arms pair (C1 or C2) becomes 'jammed' in the direction of extension, the tool will not spin in those zones where the wellbore is expanding (Fig.

Open Access
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5c.). The analyst would be able to distinguish zones of breakouts produced by stress from additional borehole expansions, such as key seats and washouts, using a combination of Caliper pad azimuth and diameter values [13].

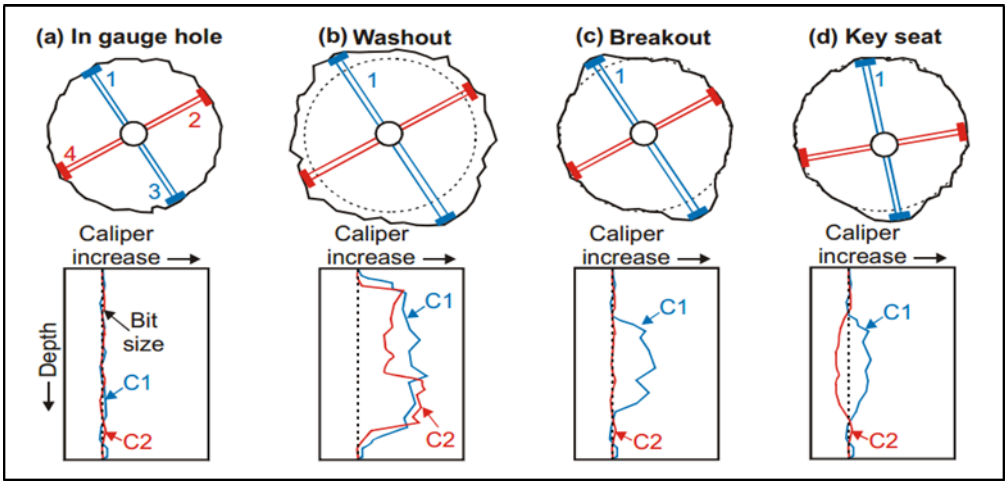

Fig. (5): Different types of borehole enlargements and the caliper log's response [1]

5. Materials and Methods

Wellbore breakouts are usually caused by stress concentrations surrounding the wellbore; this concentration occurs as a result of drilling a well into an existing stressed rock mass. [14].

The six-arm or four-arm oriented caliper log is widely used to identify the direction of horizontal stress generated from the orientation of the breakouts; this log also provides two or three measurements for the borehole cross-section as their orientations. [12].

The following procedures were used to interpret the breakouts from four-arm caliper data in the (X) field:

a) Collect data from the four and six-arm caliper logs in ten wells (A, B, C, D E, F, G, H, I, J) along the (X) oilfield, that logs cover the section from thetop of Sadi to the bottom of Zubair Formations.

b) Identify the presence of breakouts when there is more than 0.85 inch difference between the maximum and minimum caliper readings, following Plumb and Hickman's (1985) criteria to define breakouts, where they stated that caliper difference has to surpass bit size by 10 % (bit size is 8.5 inch).

c) Define the orientation of the breakout wherever the long caliper log axis azimuth indicates the breakout direction and no tool rotation within the enlarged zone. Also, breakouts are

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identified from theImage log (Figure 6) where the two zones that are out of focus on opposite well edges relate to breakouts due to the bad contact between the Image log pad and wellbore wall [1].

d) The last step is to map the breakouts azimuth against their depth. (Figure 7).

6. Results and Discussions

6.1. Orientation of the S_{Hmax}

In the (X) oilfield, the breakouts have a direction of NW-SE (130^o to 150^o) (orientation of Shmin). As a result of being perpendicular to the minimum horizontal stress, the SHmax orientation will be around NE-SW (40^o to 60^o).

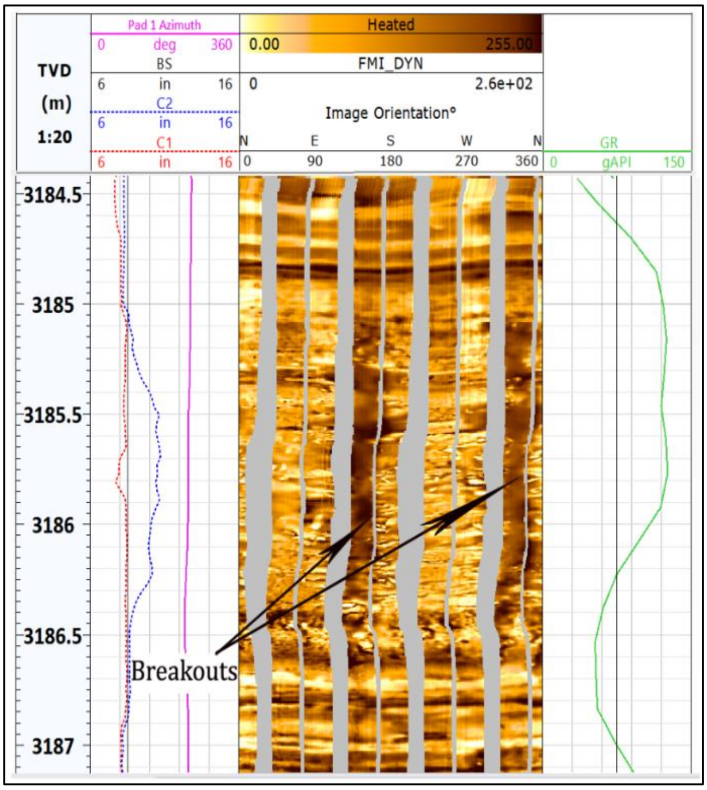

Fig. (6): Breakouts in the Zubair Formation are depicted in the image log in well-C.

Open Access
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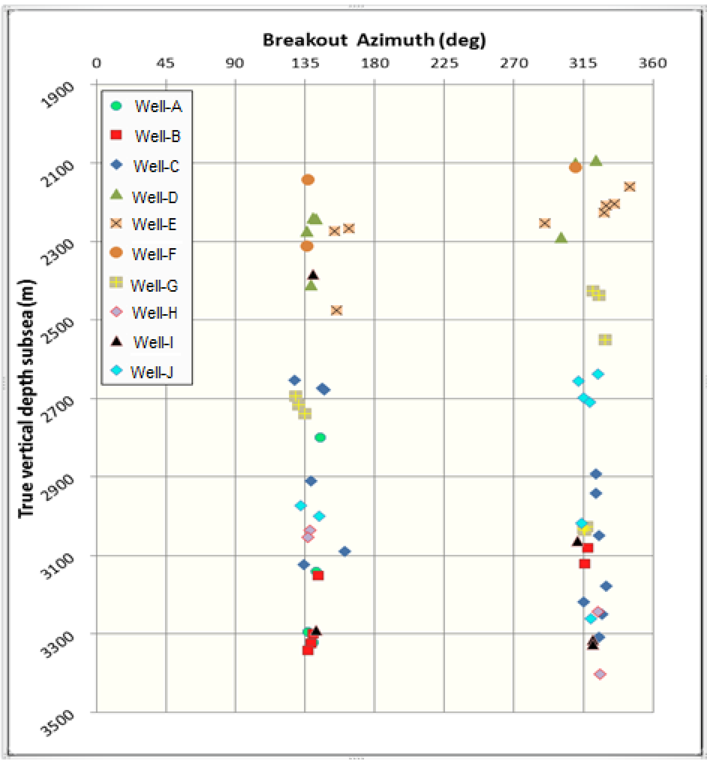

Fig. (7): Breakouts azimuth was analyzed from ten wells in the (X) oilfield.

Stereonet plots show the azimuth of maximum Caliper readings, which indicate breakout orientation, these plots were marked on the Zubair Formation's contour map at the top of the upper sandstone member (Figure 8).

Open Access
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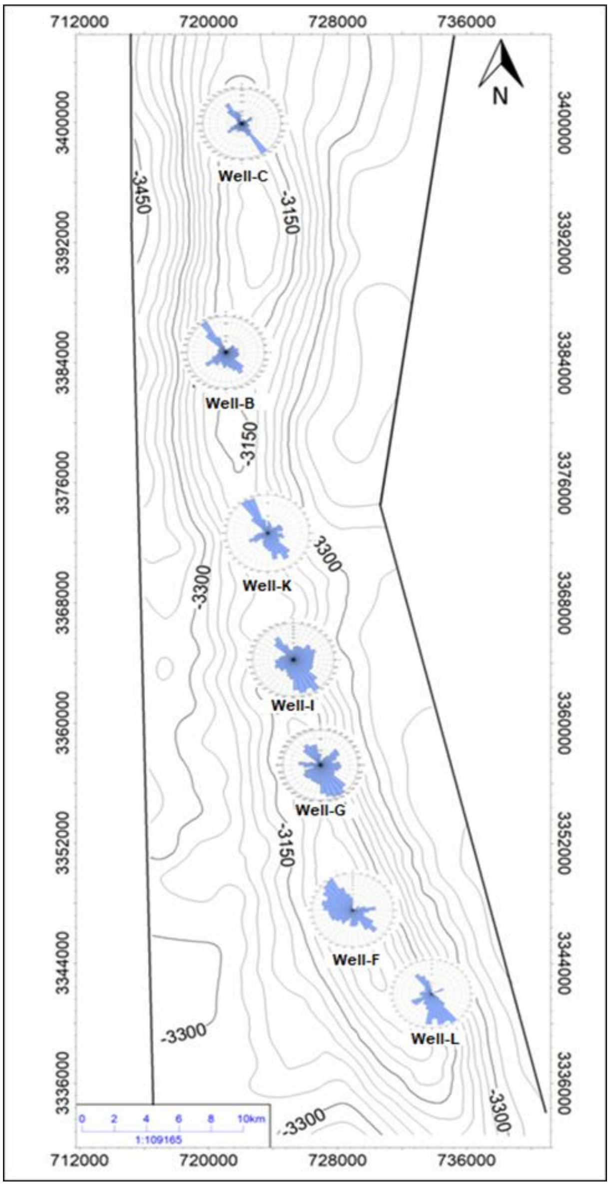

Fig. (8): Maximum caliper readings azimuth projected on Zubair Formation contour map.

6.2 Orientation of the S_{Hmax}

The direction of maximum horizontal stress (SHmax) in the study area is NE-SW (40^o-60^o and 220^o-240^o from the north), according to the predicted orientation of minimum horizontal stress (Shmin) retrieved from drill breakouts that are NW-SE, that stress trend aligned with the regional maximum horizontal stress direction similarly (Figure 9).

The current state of regional stress is determined by a variety of physical data, such as wellbore breakouts, earthquake focal mechanisms, and fault-slip studies [15].

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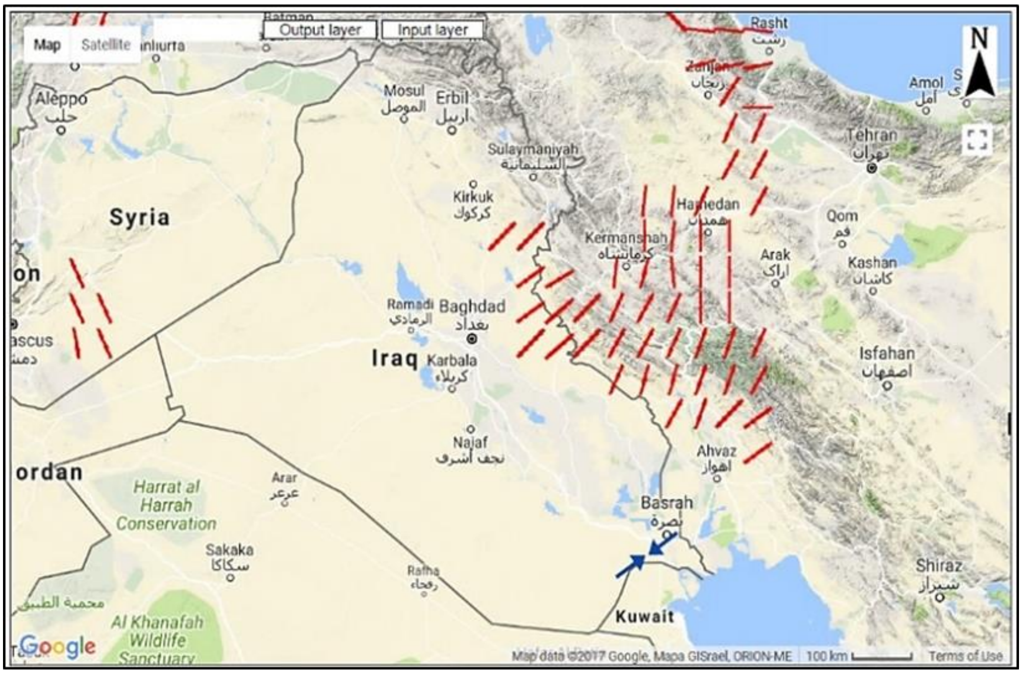

Fig. (9): The (X) oilfield's maximum horizontal stress direction (NE-SW) with regional stress directions [15].

6.3 Employment of the horizontal stress orientation

Knowledge of the horizontal stress orientation can be utilized in planning inclined wells trajectories to reduce the wellbore instability in any fault regime. In the normal fault basin, drilling deviated wells in the direction with the minimum horizontal tension is favoured [16]. On other hand, in a thrust fault or strike-slip fault regime, the deviated and horizontal wells are expected to be more stable if drilled analogous to the SHmax direction [17].

The strike-slip fault regime in the study area is a result of the impact of the Arabian and Eurasian plates [3, 10], indicating that drilling deviated wells in the direction of maximal horizontal stress is more stable than drilling in other directions, That is also evident in the interpretation of the caliper log in wells M and N (Figure 10), which reveal that Tanuma and Khasib are more stable parallel to the maximum horizontal stress direction (well M) than in the minimum horizontal stress direction (well N).

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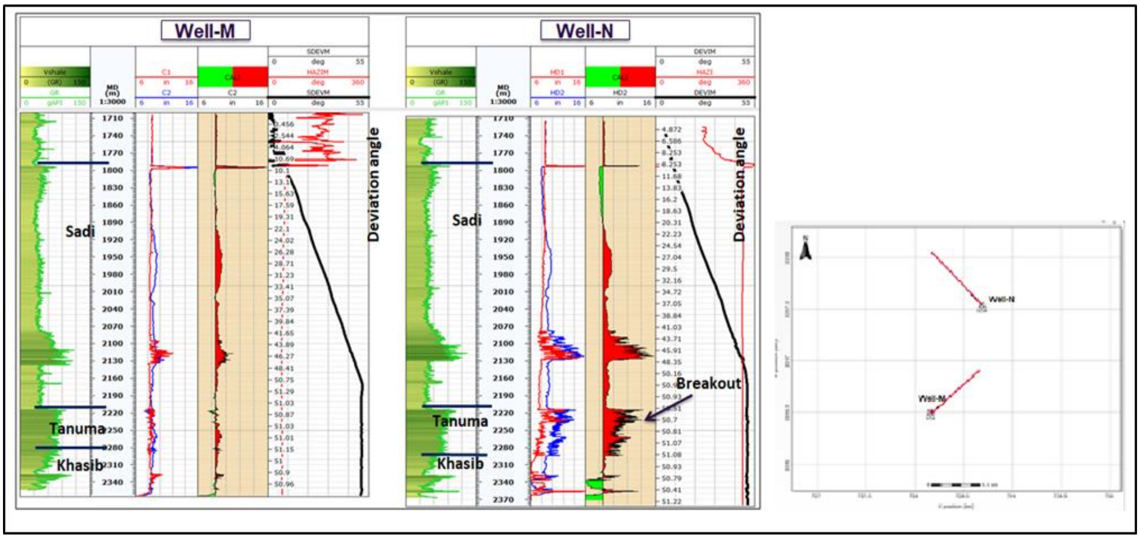

Fig. (10): Comparison between two deviated wells drilled in directions of minimum and maximum horizontal stress and the observed breakouts

7. Conclusions:

The following conclusions can be made:

1- Borehole breakouts orientation patterns that occur when the stresses around the borehole exceed rock strength are good indicators for the orientation of minimum horizontal stress, these breakouts can be identified using the multi-arm oriented caliper

2- The estimated orientation of Shmin was 140^o-150^o (SE) and 310^o-330^o (NW)

3- Maximum horizontal stress is about 40^o-60^o (NE) and 220^o-240^o (SW).

4- In the (X) oil field, it is preferable to drill high-angle and horizontal wells parallel to the maximum horizontal stress direction to reduce wellbore breakouts and non-productive time.

Open Access
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