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Structural Analysis of Hemrin North Structure, North of Iraq

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Abstract

The study focused on the results of first paleostress from thrust fault slip data on Tertiary age of Hemrin North Structure, Northern Iraq. In the study area, the nature of the rock type is one of the most important parameters determining the style of deformation. Some beds have behaved as incompetent horizons in the stratigraphic column and the thrust plans in some instances follow the individual beds, so that bedding act as detachment surfaces. The stress inversion for fault slip data was achieved using a developed right dihedral model, and then followed by rotational optimization (Georient Software). The trend of major stress axes (σ1, σ2 and σ3) and the ratio of the principal stress differences (R) show the main paleostress field is NE-SW compression regime. As well as using Mohr diagram and Lisle graph to determine the magnitudes of paleostress. The values of the paleostress in the study area were σ1=1430 bars, σ2=632 bars and σ3=166 bar. The large magnitudes of the primary stress axes could be attributed to active tectonic processes that caused pre-Tertiary deformation. It is suggested that the study area was affected by continuous thrust faults of tectonic deformation and this area is unstable and the striated faults were reactivated by inhomogeneous stresses.

Keywords: Fault slip, Hemrin North Structure, Lisle graph, Mohr diagram, Paleostress.

التحليل التركيبي لتركيب حمرين الشمالي، شمالي العراق

الخلاصة:

ركزت الدراسة على نتائج الاجهاد القديم الاول من بيانات الصدوع الزاحفة لعمر العصر الثلاثي لتركيب حمرين الشمالي، شمالي العراق. ان طبيعة الصخور هي واحدة من أهم العوامل التي حددت هيأة التشويه في منطقة الدراسة، حيث أن بعض الطبقات تصرفت على أنها مستويات غير صلدة في العمود الطباقي وان مستويات الصدوع الزاحفة تبعت هذه المستويات ولهذا فإن هذه الطبقات كونت ما يسمى بسطوح الفصل.

تم تحليل الاجهاد لمستويات الصدوع باستخدام طريقة التعامد الثنائي و استخدم برنامج الجيورينت لتمثيل البيانات. اوضحت الدراسة ان اتجاه محاور الاجهاد الرئيسة (σ1, σ2, σ3) ونسبة فروق الاجهاد الرئيسة (R). ان الاجهاد القديم الحقلي

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الرئيسي هو شمال شرق – جنوب غرب هو نظام تضاغطي. فضلا عن استخدام مخطط لايل و برنامج موهر لتحديد قيم الاجهاد القديم. قيم الاجهاد القديم في منطقة الدراسة كانت قيمة الاجهاد الرئيسي الاعظم (σ 1) هي 1430 بار، كانت قيمة الاجهاد الرئيسي المتوسط (σ2) (632) بار وكانت قيمة الاجهاد الرئيسي الاصغر (σ3) (166) بار.
اوضحت الدراسة ان القيم العالية لمحاور الاجهادات الرئيسة ربما تعود الى الاحداث التكتونية التي سبقت فترة العصر الثلاثي. أن منطقة الدراسة قد تأثرت بتتابع عمليات التصدع المستمرة أثناء التشويه التكتوني وان هذه المنطقة تعد غير مستقرة وان الصدوع المحززة قد اعيد نشاطها بسبب اجهادات غير متجانسة.

1. Introduction

Hemrin North Structure is one of the important structures in Iraq, due to the possibility of existing hydrocarbon in it. Hemrin North Structure is asymmetrical anticline has NW-SE trend. It is located between latitudes (34° 40′ - 35° 10′ North) and longitudes (43° 35′ - 44° 20′ East) (Figure 1). Average of the dip of the northeastern limb is gentle (20°) and dip of the south western limb is steep (75°). Thus, the structure is vergency toward south western limb. Paleostress analysis refers to several methods which attempt to estimate regional stress tensors that have existed in the geological structures. Many different techniques for determination stress tensors have been proposed. The principal stress trends and relative values have been estimated from fault populations [1]. These methods are based on Bott-[2] assumption suggesting that slip orientation is parallel to the resolved shear stress on the faults plane [3; 4; 5; 6; 7; and 8]. The reactivated fault slip model has been applied by several researches to estimate the magnitudes of the paleostress [5; 9; 10; 11 and 12]. Mohr circles representation of the states of stress in three dimensions can be tested to represent the reactivation of the faults. This paper done using structural analysis of Hemrin North Structure depends on ten measurements that were taken in the field. The data was plotted in the sterograpgic projection using Georient Software. Determining the stress magnitudes connected with the tectonic history of rock masses is dependent on establishing a close association between the state of stress and the development of a noticeable parameter in the rock itself. However, this study includes determination structural of the paleostress (orientations, magnitudes and stress ratio), and understanding the dynamics of the study area.

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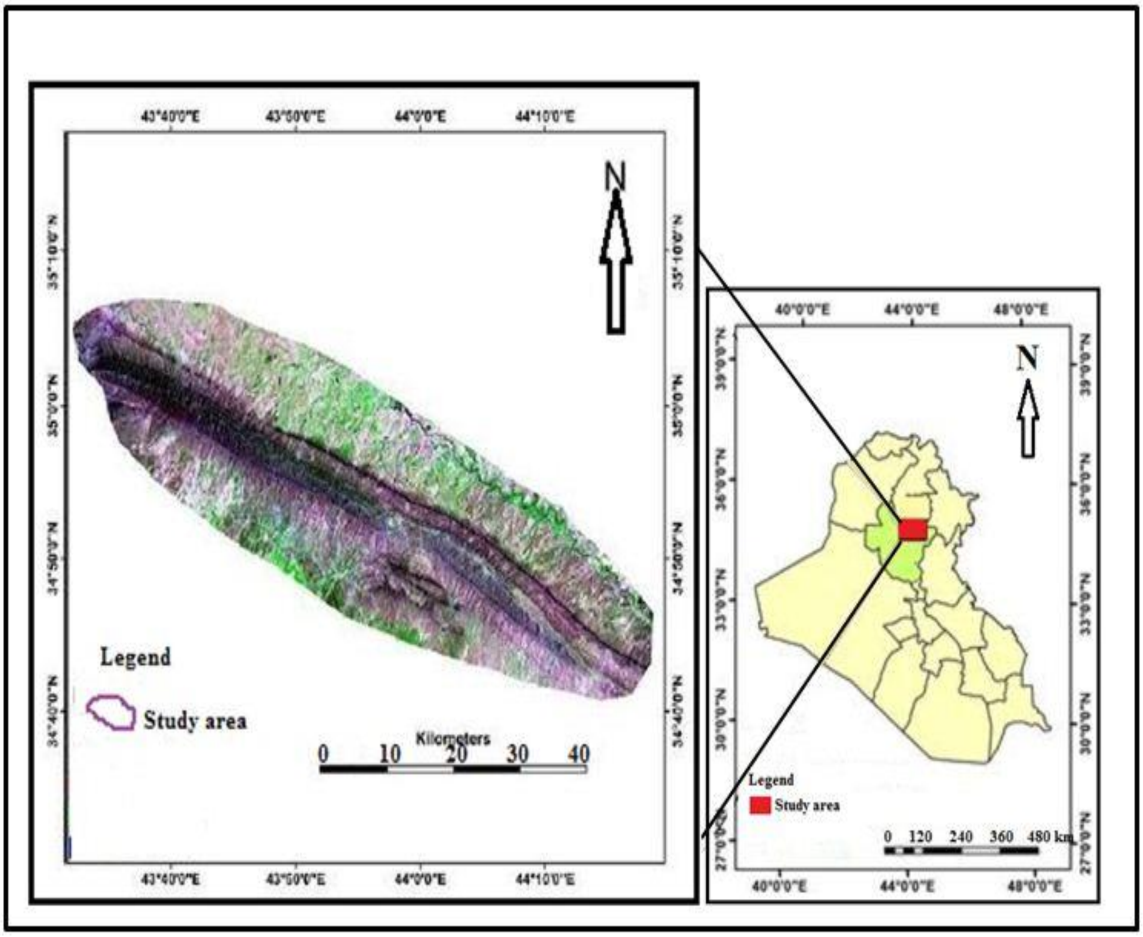

Fig. (1) Satellite image showing the study area [13].

2. Tectonic and Geological Setting

The study area is located in the low Folded Zone in the Unstable Shelf of Iraq (Figure 2).The stratigraphy sequence of the study area represents many sedimentary rocks that are exposed with age ranged from middle Miocene to Recent as shown in the geological map (Figure 3). The formations are described, from oldest to youngest as following:

Fatha Formation

The formation is exposed on the surface; the maximum thickness of it reaches 288 m and occupies the core of Hemrin North Structure. It comprises anhydrite, gypsum and salt, interbedded with limestone and marl. The age of the formation is middle Miocene and its depositional environment was dominated by shallow marine (lagoon) [16].

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Injana Formation

The thickness of formation is 132 m in the study area and composes of three members. The transition member, lower claystone member, and upper sandstone member. The latter two members are differentiated according to the prevalence of claystone and sandstone, respectively [17]. The environment of sedimentation is mostly continental and its age is late Miocene. This formation prevails on both limbs of Hemrin North Structure. The appearance of gravel layer above Injana Formation marks the beginning of Muqdadiya Formation.

Muqdadiya Formation

The thickness of formation is 180 m in the study area and is exposed continuously on both limbs of Hemrin North Structure. It consists of medium to coarse sandstone with pebbly sandstone in the lower part. The age of the formation is early Pliocene and its sedimentary environment represented by a fluvio-lacustrine [16 and 18].

Bai Hussan Formation

It consists of coarser grain size than Muqdadiya Formation and is younger in age. Bai Hussan Formation consists of two members: the conglomerate member and the claystone member with thickness of 137 m. The Bai Hussan Formation formed and deposited in a fluvio-lacustrine setting. Terrace gravels and/or alluvial deposits cover the formation, which is occasionally covered by Quaternary fine grain sediments [18].

3. Aim of the Study

The main goal of this research is to detect the structural model and determine the trend and magnitudes of the paleostress that affected the study area. In this study, the structural and tectonic model was done in order to determine and estimate the stability of the study area and petroleum exploration methods.

4. Methodology

The fault slip data was utilized by several authors such as Al-Obaidi [10]; Al- Diabat [19]; Al-Obaidi, and Al-Kotbah [11]; Al-Hachem, and Al-Obaidi [12] and Al- Shwaily and Al-Obaidi [20] to calculate trends of the paleostress field. The right dihedral approach was used to identify the trend of the study area's principle stresses axes (1, 2, and 3).The maximum principal stress ($\sigma 1$) and the intermediate principal stress ($\sigma 2$) were horizontal, while the minimum principal stress ($\sigma 3$) was sub-vertical. The dips of these faults were to the east direction in the study area

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as shown in Figures (4) and (5). The orientations of principal stress axis were determined as earlier described (Georient, Ver. 9.5).

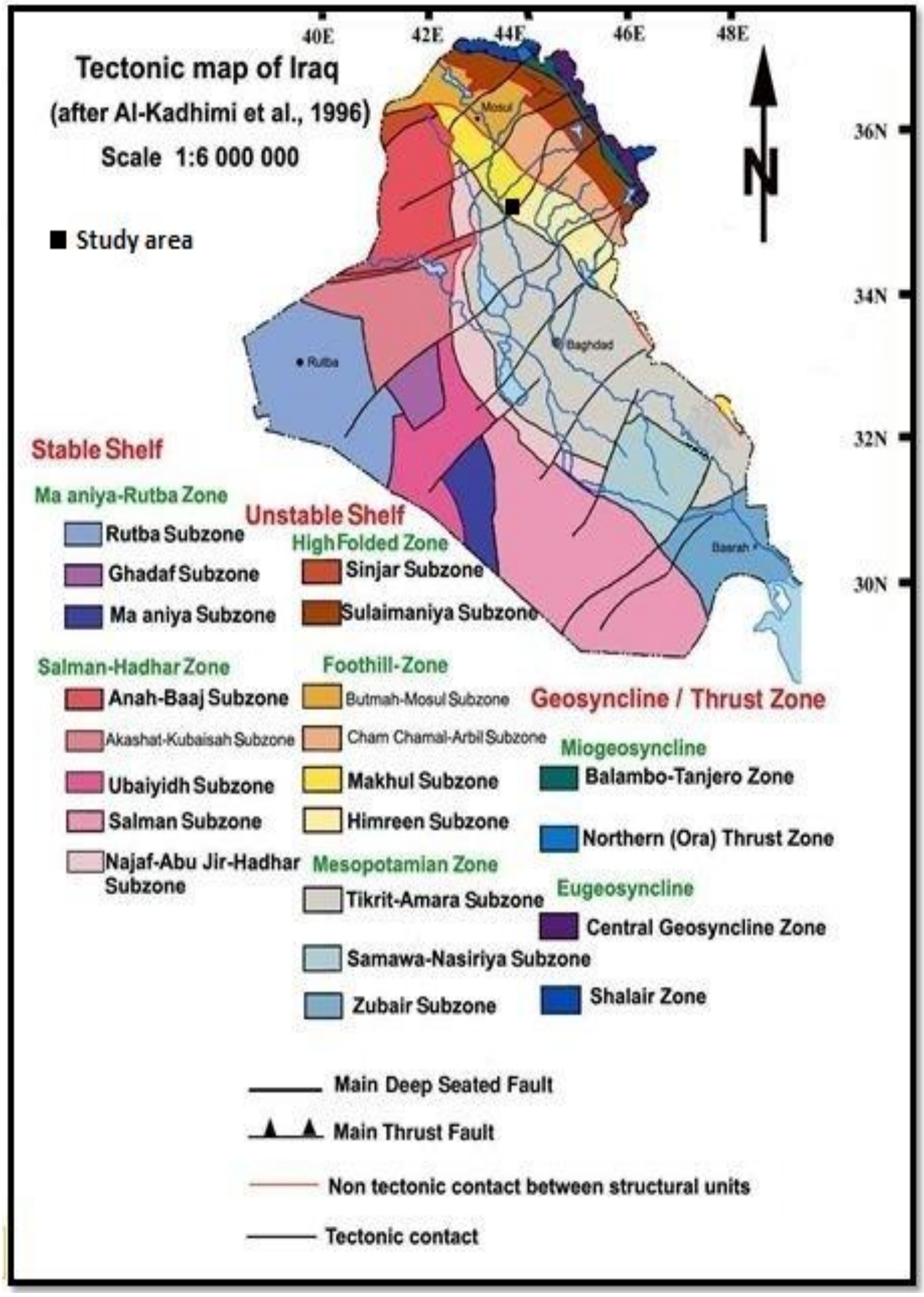

Fig. (2): Tectonic map of Iraq [13].

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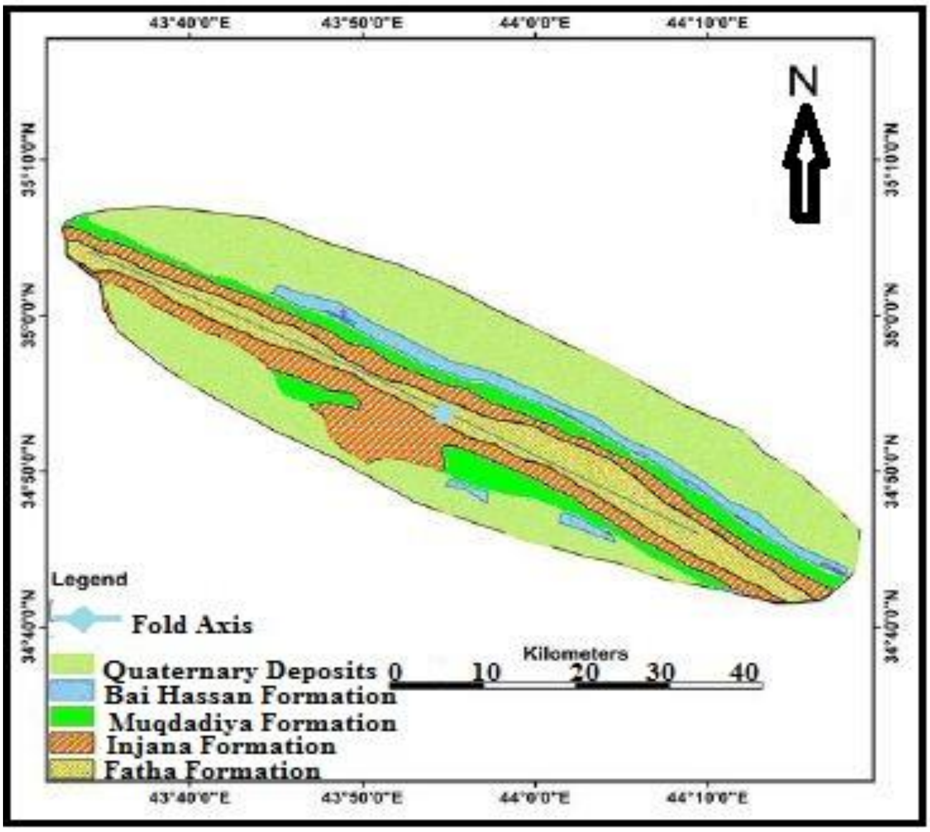

Fig. (3): Geological map of study area (modified from Al Naqib [14]).

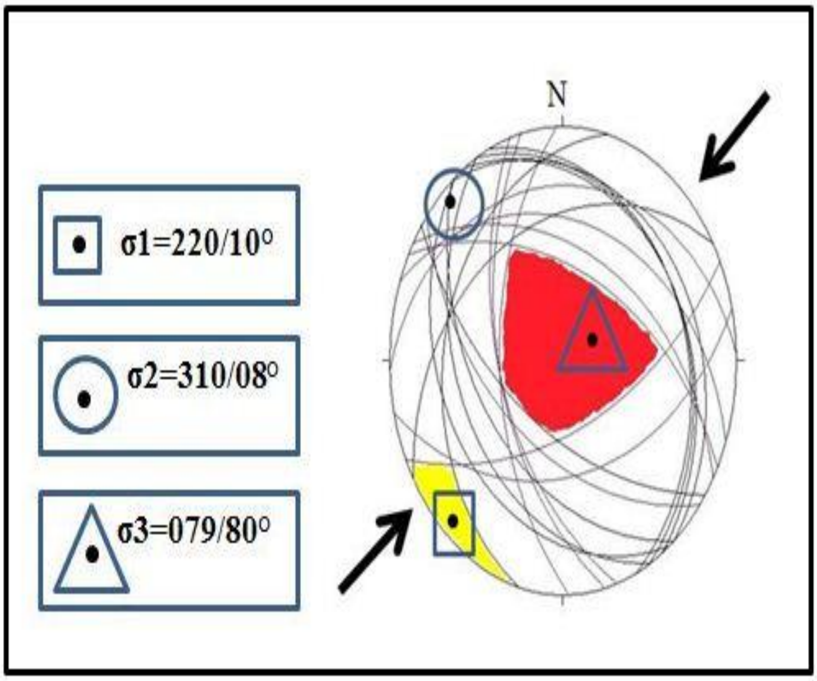

Fig. (4): Right dihedral method showing the distribution orientation of the principal stress axes in the study area.

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The lithostatic load and one of the principle stress axes can be used to estimate the value of the vertical stress (v). The depth and average density of overlying rock beds may be known at the time of tectonic events, and additional information on the value of one principle stress can be acquired using the following equation:

$\sigma v = \rho gz$ ……………… (1)

Where:

ρ: is average density of the rocks (kg/m^3) .

g: is the acceleration of gravity (m/s^2).

z: is the depth (m).

The stress ratio can be calculated when the trend of the principal stress axes are known, for all faults individually, using Bott law [2] in equation (2). As well as Lisle graph and Mohr circles were used to represent the stress state (Figure 5).

$R = \tan\theta\ Im - I^2 n / n\text{-}n^3$ ……………........…………(2)

where:

R: is ratio of the principal stress

θ: is the pitch angle.

(I, m, n): are cosine of the angles (α, β, γ) respectively as shown in Table (1).

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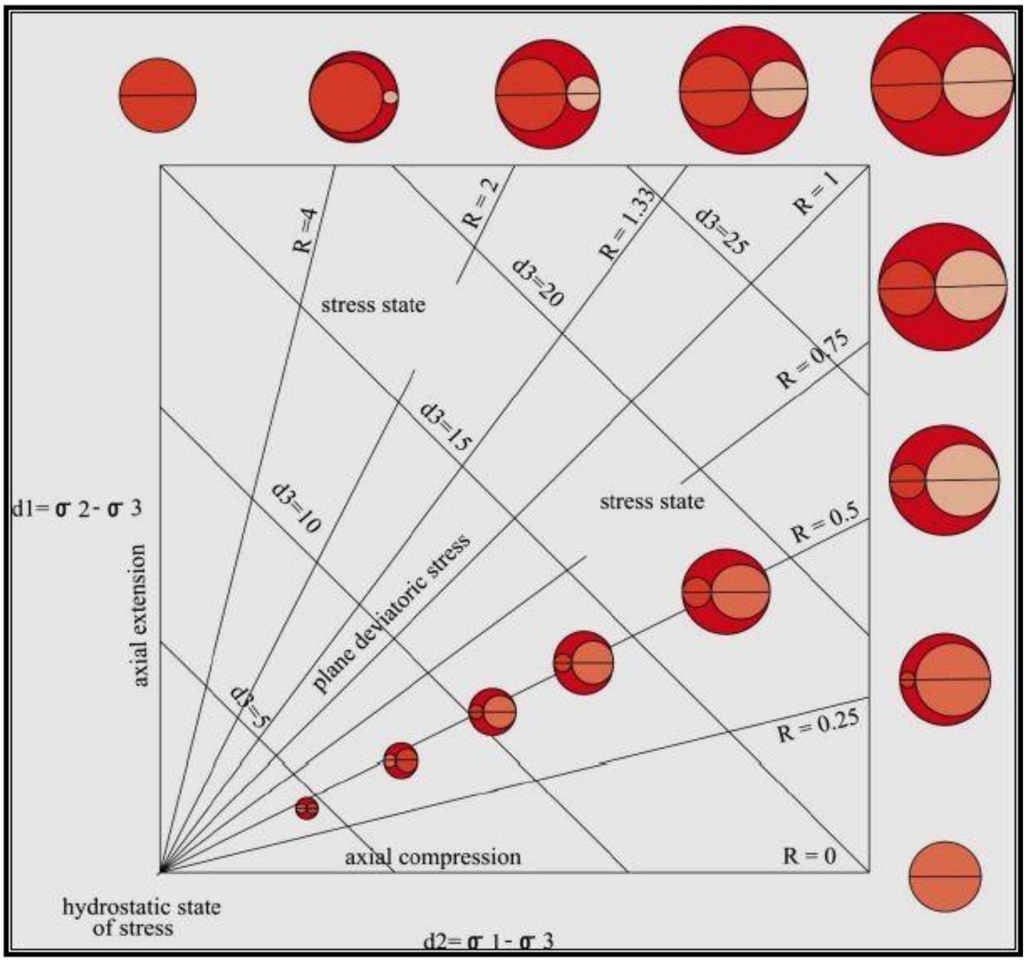

Fig. (5): Lisle graph of the stress states representation [7].

Table (1) Magnitude of the stress ratios (R) for thrust faults in the area.

NO.	Fault plane D.D/D.A	Pitch (ɵ)	tan (ɵ)	(α)	(β)	(ɣ)	R= tanɵIm - I^2 n / n-n^3
1	015/32°	70° E	2.74°	84°	36°	60°	0.5
2	145/30°	75° E	3.73°	84°	30°	66°	0.2
3	060/41°	75° E	3.73°	85°	35°	60°	0.5
4	140/25°	70° E	2.74°	81°	39°	60°	0.4
5	305/64°	70° E	2.74°	80°	38°	62°	0.5
6	150/30°	75° E	3.73°	80°	36°	64°	0.8
7	322/32°	70° E	2.74°	82°	38°	60°	0.6
8	330/39°	70° E	2.74°	81°	39°	60°	0.4
9	155/30°	70° E	2.74°	84°	30°	67°	0.3
10	320/50°	75° E	3.73°	82°	36°	64°	0.8

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5. Results

The friction angles of fault planes were measured for different lithology's based on practical sliding and field data. The smooth surface is predicted to be around 25°, whereas the rough surface is assessed to be around 35°. The average density of the sedimentary beds is estimated to be 2300 kg/m^3. The depth of the bed rocks was measured at the field equal 737 m, the acceleration of gravity (g) equal 9.8 m/ s^2, and the average depth of the bed rocks was measured at the field equal 737 m. As a result, vertical stress (v = 3) can be calculated. Finally, the rock cohesion magnitudes (0-100) bars were selected because published cohesion values typically fell within this range.

Mohr circles were drawn based on the stress ratio (R), magnitude (R=0.5), and the spots (fault poles) on these circles were plotted based on the angles. Above the sliding line and beneath the failure envelope, plot points in Mohr circles should be detected. The results of this method's use are summarized in Figures (6) and (7) and Table (2).

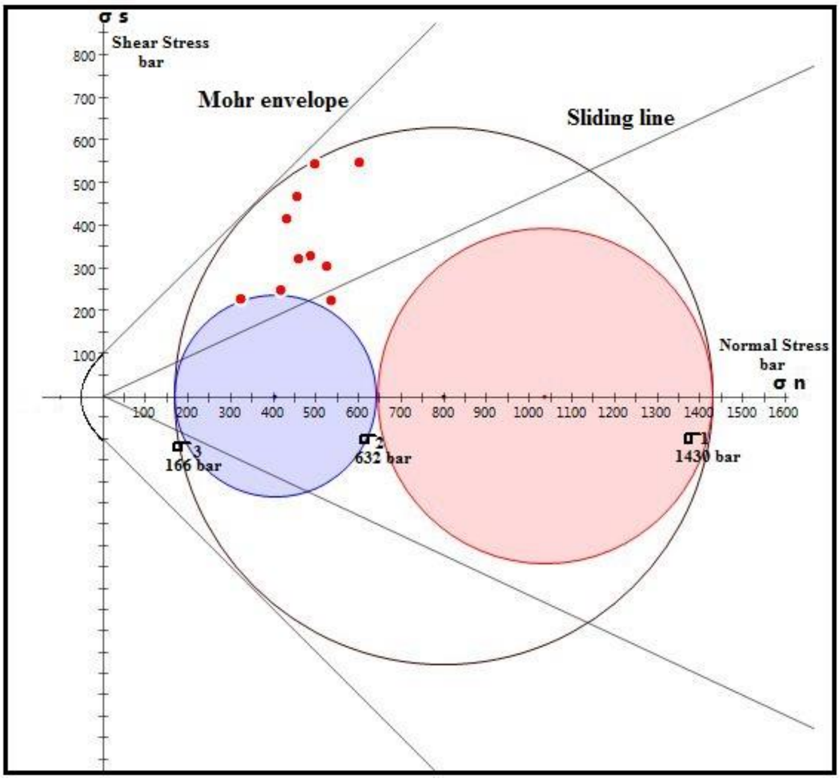

Fig. (6): Mohr Circles to calculate the magnitudes of the principal paleostresses of the study area, when the friction sliding line 25°.

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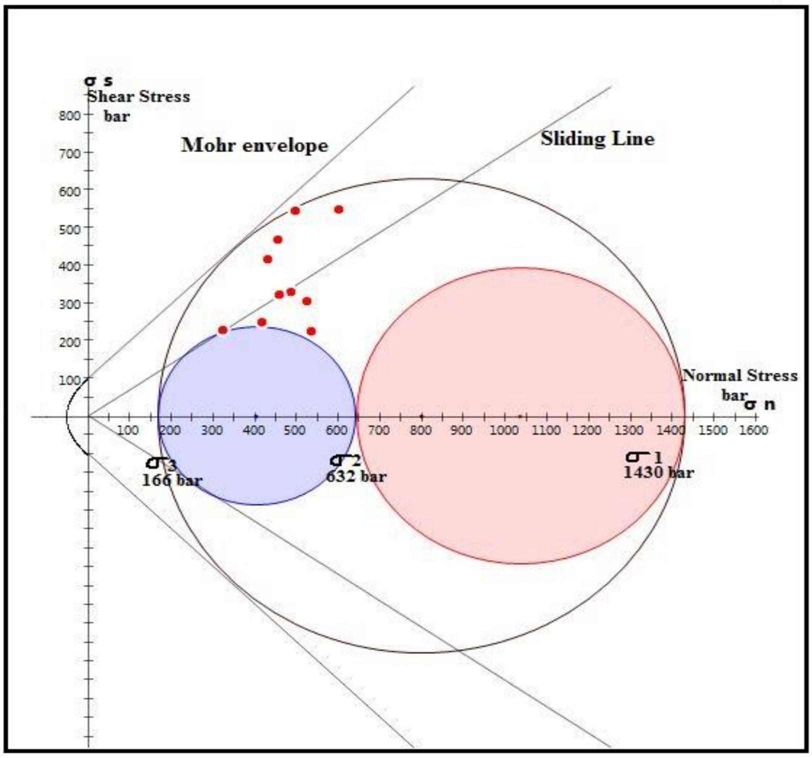

Fig. (7): Mohr Circles to calculate the magnitudes of the principal paleostresses of the study area, when the friction sliding line 35°.

Table (2) Magnitudes of the principal stress (σ1, σ2, σ3) of the study area.

σ1 bar	σ2 bar	σ3=σv bar	Depth (m).	Density Kg/m³	Hydrostatic Pressure bar = (σ 1+ σ 2+σ 3) /3	Cohesion Strength= (σ 1- σ 3) bar	d2 bar (σ 1- σ 2)	d1 bar = (σ 2- σ 3)
1430	632	166	737	2300	742.6	1264	798	466

Thrust faulting in Hemrin North Structure involved a compression regime (σ1) which was almost horizontal, (σ3) was sub vertical extensional axes, and an intermediate axis (σ2) which was horizontal.

6. Discussion

The field data, Mohr circles, Bott's [2] equation, and Lisle diagram were used to evaluate the magnitudes of the paleostresses in Cenozoic Eara sedimentary rocks. The poles of the thrust faults are located between the sliding lines and the Mohr envelope, as shown by Mohr circles. Mohr circles depict the relationship between shear stress and the effective normal on fault

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planes, as well as the proportional relationship between shear stress and fault reactivation. The stress ellipsoid was varied, and the magnitudes of the stress were not constant. This difference could reflect to the fact that the stress fields, depth variation, and stress magnitudes have altered throughout time. The large magnitudes of normal stresses could point to a vigorous tectonic event that caused the land to deform during the Cenozoic Era.

7. Conclusion

The displacement on thrust faults surfaces is one of the important parameters that were affected on the mechanism of the final deformation in the study area. Magnitudes of the principal stress were calculated depending on rupture friction law, depth of the rock units and stress ratio. Value of the paleostress ranges (166 – 1430) bars. These stresses magnitude are enough to produce or to reactivate faults in the study area.The stress ratio mean (R= 0.5) that indicates state of the stress was flattening stress, in other words, axial compression of stress ($\sigma1 > \sigma2 > \sigma 3$). These faults could be formed at the early stage of the folding. These values are important in study stability of the area and petroleum exploration processes which can use to increases porosity and formation permeability that represent hydrocarbon reservoirs characteristics.

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