



Study of Joints in Baba Dome - NE Iraq

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ABSTRACT

The present work involves detailed study for joints in Baba dome within the foreland fold belt of north Iraq. It aims to identification and classification of various joint sets and systems, extraction predominant directions of joint sets and systems and estimation stress direction in the study area. The study includes only Injana (Miocene) and Mukdadiya (Pliocene) formations. The field work has been executed by means of nine traverses, each of them includes mainly two stations, as a result, 719 measurements of joint planes were extracted. The study comprises several categories: carefully scanning the joint plane for any shear movement, measuring the attitude, classification of joints according to tectonic axes a, b and c, determining the predominant direction, calculation of causative stress, estimation the structural history of Baba Dome .The types of joint which distinguished are (ab, bc, ac, hko system acute about a, hko set acute about b, hol system acute about a and hkl set).All measured joints have no visible shear displacement on their planes. The hko system and hol system appeared as single set and as conjugate system. The predominant direction of the joints is determined to be nearly along the strike of exposed beds. The mean causative stress direction is calculated to be: 046° from hko system and 315° from hol system. Trend of measured joints (ab = 315° , ac = 045° , bc = 315° , hko₁>a = 058° , hko₂>a = 033° , hko₃>b = 336° , hol₁>a = 316° , hol₂>a = 312° and hkl = 257°). An attempt to put the measured joints in order according to timing sequence and from older to younger: hko system acute about a & ac set, hol system acute about a and hko system acute about b & bc set.

Keyword: Paleostress, Joints, Stress, Set, System .

دراسة الفواصل في قبة بابا – شمال شرق العراق

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الملخص

يتضمن العمل الحالي دراسة تفصيلية للفواصل في قبة بابا الواقعة ضمن حزام طيات الفورلاندي في شمال العراق. تهدف الدراسة الى تحديد الفواصل وتصنيفها الى مجاميع وانظمة وتحديد الاتجاهات السائدة لها ثم تخمين اتجاه الجهد المسبب في تكوينها في منطقة الدراسة. تتكشف في منطقة الدراسة التكوينات الجيولوجية التي امتدت اعمارها من عصر المايوسين الى البلايوسين وهي من الاقدم الى الاحداث: الفتحة، انجانة، المقدادية وياي حسن. انجز العمل الحقلية من خلال اختيار تسعة مسارات و كل مسار يتضمن محطتين. تم قياس ٧١٩ قراءة لمستويات الفواصل. اشتملت الدراسة الحقلية للفواصل على التحري عن اي حركة قصية على مستويات الفواصل و قياس وضعية مستويات الفواصل و تصنيف الفواصل اعتمادا على المحاور التكتونية (a, b, c). تم تحديد الاتجاهات السائدة وحساب اتجاه الجهد المسبب وتخمين التاريخ التركيبي لقبة بابا. ان النتائج التي افرزتها الدراسة الحالية تتمثل بعدم وجود اي ازالة قصية على مستويات الفواصل المقاسة. سجلت مجاميع الفواصل (ac, bc, ab) ونظام (hko) الحاد حول المحور a نسبة عالية مقارنة بنظام (hol) الحاد حول المحور a ونظام (hko) الحاد حول المحور b ، اما فواصل (hkl) فقد سجلت بنسبة قليلة جدا . يظهر نظامي (hol و hko) بشكل مقترن او بشكل مجموعة منفردة. ان الاتجاه السائد للفواصل يحاذي تقريبا اتجاه مضرب الطبقات المتكشفة . ان اتجاه الجهد الرئيسي المحسوب من نظام hko المقترن هو 46.15° ، والاتجاه المحسوب من نظام hol المقترن هو 315° . كانت اتجاهات الفواصل المدروسة

كالاتي ($ab = 315^\circ$, $ac = 045^\circ$, $bc = 315^\circ$, $hko_1 > a = 058^\circ$, $hko_2 > a = 033^\circ$, $hko_3 > b$)

صنفت الفواصل اعتمادا على ($= 336^\circ$, $hol_1 > a = 316^\circ$, $hol_2 > a = 312^\circ$ and $hkl = 257^\circ$) .

التسلسل الزمني وهي من الاقدم الى الاحداث: نظام hko الحاد حول a ومجموعة ac ، نظام hol الحاد حول a ، نظام hko الحاد حول b ومجموعة bc .

الكلمات الدالة : الاجهاد القديم، الفواصل، الاجهاد، مجموعة ، نظام .

1. INTRODUCTION

The NW and SW ends of Baba Dome (Study area) lie on the Lesser Zab River and Tarjil Village respectively (Figure 1.A). It covers 250km^2 . The length and width of the study area attain 52km and 4-6km respectively.

The study area appears on the surface, i.e on the geological map as a trace of reverse fault, passes roughly through hinge line of the subsurface anticline (Figure 1.B). The mentioned fault causes the NE limb overrides the SW limb causing the latter obscure.

The present study comprises classification and extraction of stress from the measured joints. The classification depends mainly on [1 and 2]. Numerous studies concerning joints in Iraq for an instant [3and 4] from NE Iraq. Other studies outside Iraq treat joints from different view like [5, 6, 7, 8 and 9].

The aim of the present study is to study joints from different view: classifying joints, estimating the stress orientation and deduce the tectonic history of the study area.

2. Location and geological setting of the study area

The study area is located between Longitudes ($44^\circ 03' 29.2591'' - 44^\circ 35' 44.4315''\text{E}$) and latitudes ($35^\circ 20' 27.1644'' - 35^\circ 43' 18.178''\text{N}$) Fig. (1) .

Tectonically, the study area lies within low folded zone of Zagros Fold-Thrust Belt ,that consists of a series of widely spaced, low amplitude gentle folds trending NW – SE but change gradually to E – W as they extend northwestwards [4] . This zone is characterized by the presence of regional detachment consists of Middle Miocene salt layers of Fat'ha Formation, that have caused decoupling of the surface structures from their subsurface counterparts [4] .

Structurally, the study area is a part of Kirkuk Structure, that is an anticline trending NW-SE, divided by two prominent saddles into three major structural domes, Amsha saddle

separate Baba Dome from Avanah Dome while Dibagah saddle separate Avanah Dome from Khurmala Dom **Fig. (2)** . Kirkuk Structure is overthrust from the NE in the exposed beds ,due to sliding on the Fat'ha salt, but the fold at medium depth , below the salt zone of the Fat'ha , is simple and almost symmetrical [10]. The study area, on the surface, represented by NE limb of the anticline with inclined bed (31° - 60°) toward NE , which resulted from the intersection of the thrust fault plane with the surface.

The lithology of rock units exposed in the study area is built up of alternating beds of gypsum, marl, claystone , sandstone and conglomerate represented by Miocene and Pliocene formations: Fatha (Middle Miocene, 370 m. thick), Injana (Upper Miocene, 1266 thick), Mukdadiya (Pliocene, 840m. thick)) and Bia-Hassan (Pliocene, 906.5m. thick) **Fig. (1.B)** .

3. Methodology

Nine traverses have been chosen to cover the study area. The method of work depends upon [2 and 11] .Joint planes were measured by compass in the pre-located and accessible stations oriented along nearly straight line (traverses) perpendicular to strike of bed. The field data are plotted on Schmidt net using Stereonet program. Then the joints were classified depending on tectonic axes a, b and c. The mentioned program also calculates the orientation of bisector of the acute angle between planes of joint system representing the orientation of stress.

4. Classification and Description of Joints in the study area

1- Bedding joints (ab)

The planes of this set are parallel to tectonic axes a and b, and perpendicular to c **Fig. (3)**. Therefore, they are parallel to the bedding plane. Their strikes are NW-SE direction with bearing ranges from 306° to 324° . The mean strike is 315° and the mean dip angle is 044° toward NE. It appears in all stations. It has 13.7% of the measured joints **Fig. (4)** (Plate 1.A).

2- Strike Joints (bc)

The planes of this set is parallel to tectonic axes b and c and perpendicular to axis a, so it is perpendicular to the bedding plane along strike of beds **Fig. (3)**. It has NW-SE direction with bearing range from 306° to 318° . Its mean strike is 315° and mean dip angle is 46° toward SW. It appears in all stations, having 15.4% of the total measured joints **Fig. (4)** (Plate 1.C).

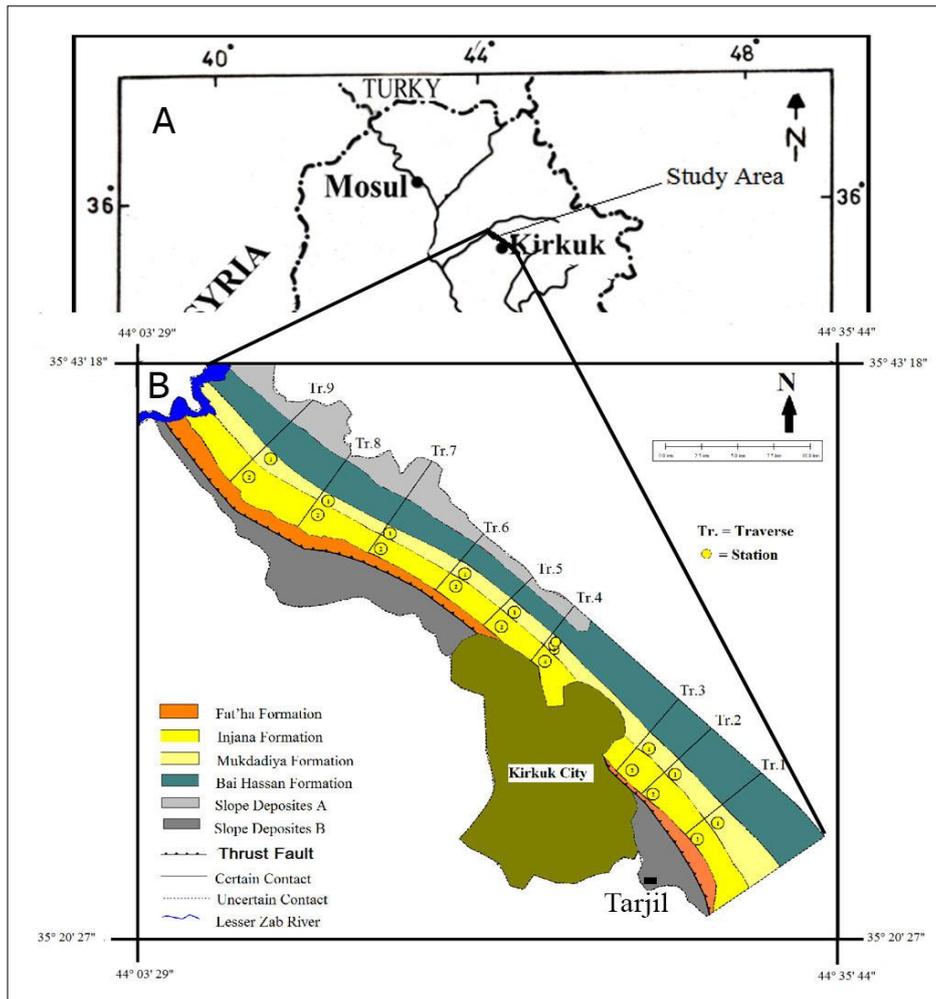


Fig. (1) : (A) Location map of studied area. (B) Geological map of the study area compiled in this study.

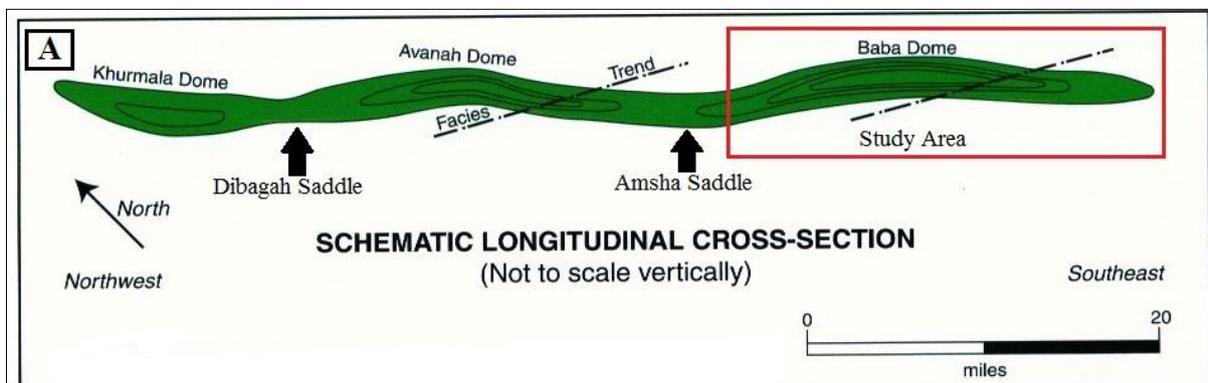


Fig. (2) : Schematic longitudinal cross – section of Kirkuk Structure including study area (after Dunnington, 1958).

3- Dip Joints (ac)

The planes of this set are parallel to tectonic axes a and c and perpendicular to tectonic axis b Fig. (3), so they are nearly perpendicular to the bedding plane. It has NE-SW direction with bearing ranges from 36° to 54 °. The mean strike is 045° and perpendicular to the bedding. This set appears in all stations. It has, 16.1% of the total measured joints Fig. (4) (Plate 1.B).

4- Oblique Joints

4-1 hko joints

The hko joints, in the study area, appear as set and system. They are of two types represented by hko set acute about b and hko system acute about a. The hko system acute about a intersects the tectonic axes a and b and parallel to c tectonic axis. This system occurs in the form of two sets : hko1 and hko2, Fig. (3) .The hko1 has a mean strike and dip angle attaining 058°and 64° toward NW respectively while the hko2 has a mean strike and dip angle attaining 033°and 81° toward NE respectively. This system appears as conjugate planes in traverse / stations(1/1,2/1,2/2,3/1,3/2,4/1.1,4/2,5/1,5/2,6/ 1, 6/2, 7/1, 7/2, 8/1, 8/2, 9/1and 9/2), Fig. (1.B) .This system consists of two intersected sets making an acute angle 2Θ ranging (28.2°-50.7°) about a axis. The intersection line of conjugates planes is parallel to c tectonic axis and perpendicular to bedding plane. This system has 28.1% of the measured joints Fig. (4) (Plates 1.D and 1.E). The hko set acute about b intersects tectonic axes a and b and parallel to c Fig. (3). It has NW-SE direction with bearing ranges from 330° to 359 ° .It's mean strike and dip angle attains 336° and 60° toward NE respectively. This set is detected in traverse / stations(1/1, 2/1,2/2,3/2, 4/2,5/1,5/2,6/2,7/1,7/2,8/2,9/1and 9/2) Fig. (1.B). It has 10.15% of the measured joints Fig. (4) (Plate 1.F).

4-2 hol System acute about a

This system appears as single set and conjugate system in the study area. The mention joints are of hol > a type. The planes of this system intersects tectonic axes a &c and parallel to b Fig. (3).This system consists of two intersected sets (hol1 and hol2) making an acute angle (2Θ) ranging (66.7°-88.2°) bisected by tectonic axis a and obtuse angle bisected by tectonic axis c. The hol1 has NW-SE direction. Its mean strike and dip angle are 316° and 51° toward NE respectively. It has 5.7 % of the measured joints. This set appears in traverse / stations (1/1, 3/2,4/1.1,4/1.2,4/1.3,4/2,7/1, 7/2, 8/2 and 9/1) Fig. (1.B).

The hol2 has NW-SE direction. Its mean strike and dip angle are 312° and 41° toward SW respectively. This set appears in traverse / stations (1/1, 1/2, 2/1, 2/2, 3/1, 3/2, 5/1, 5/2, 6/1, 6/2, 7/1, 7/2, 8/1 and 8/2). It has 9.5 % of the measured joints, Fig. (4.2) .The other characters of this set are on Table (4.1) .

4-3 hkl Joints

This set intersects the tectonic axes a,b and c Fig. (3) .Its appears in travers / station (1/1, 1/2, 2/2, 4/1.1, 4/1.2, 4/1.3, 6/2, and 7/1).This type has mean strike and dip angle 257° and 73° respectively .It's percent 1.6% of the measured joints Fig. (4) .

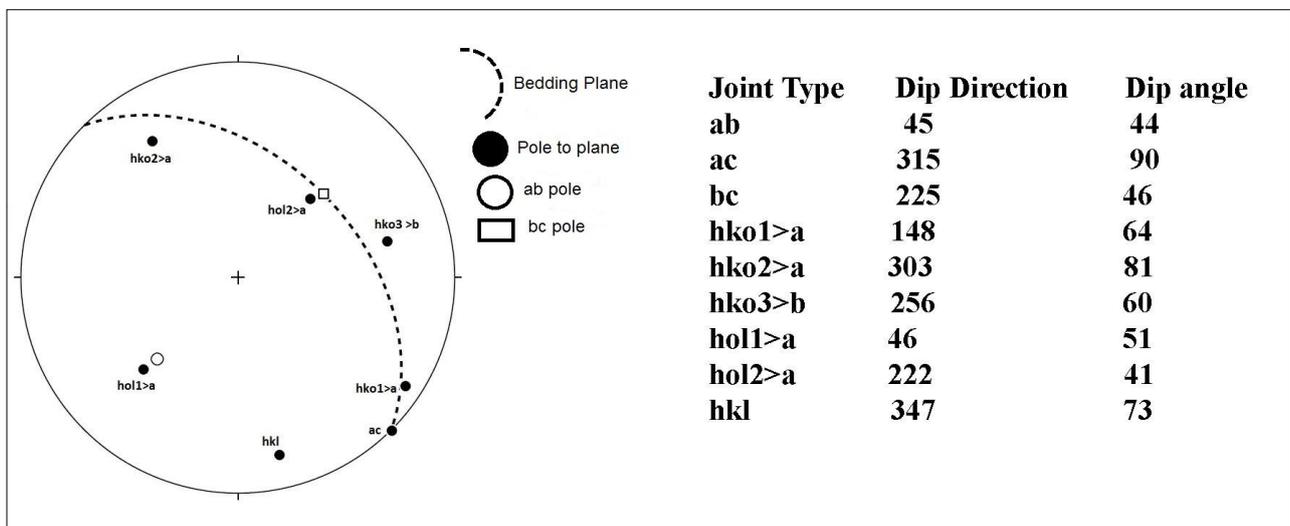


Fig. (3) : Mean poles for each type of joints in the study area.

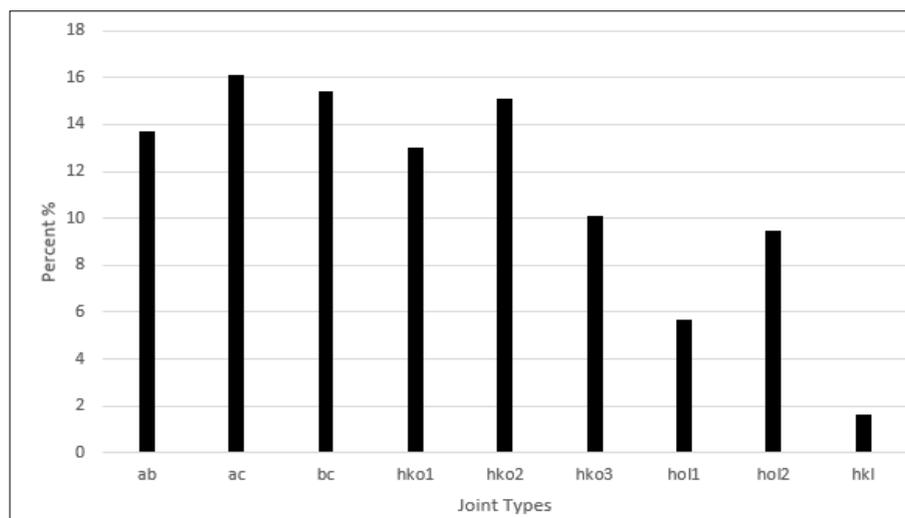


Fig. (4) : Histogram shows the percent of joint types in the study area.

During field work some notes were recorded. These are: the high weathered and eroded claystone and gypsum reflect lack of joint while brittle sandstone has relatively abundant joints, clayey and loam recent deposits fill the joint planes and the frequencies of the measured joints reveal an inverse proportion to the thickness of beds.

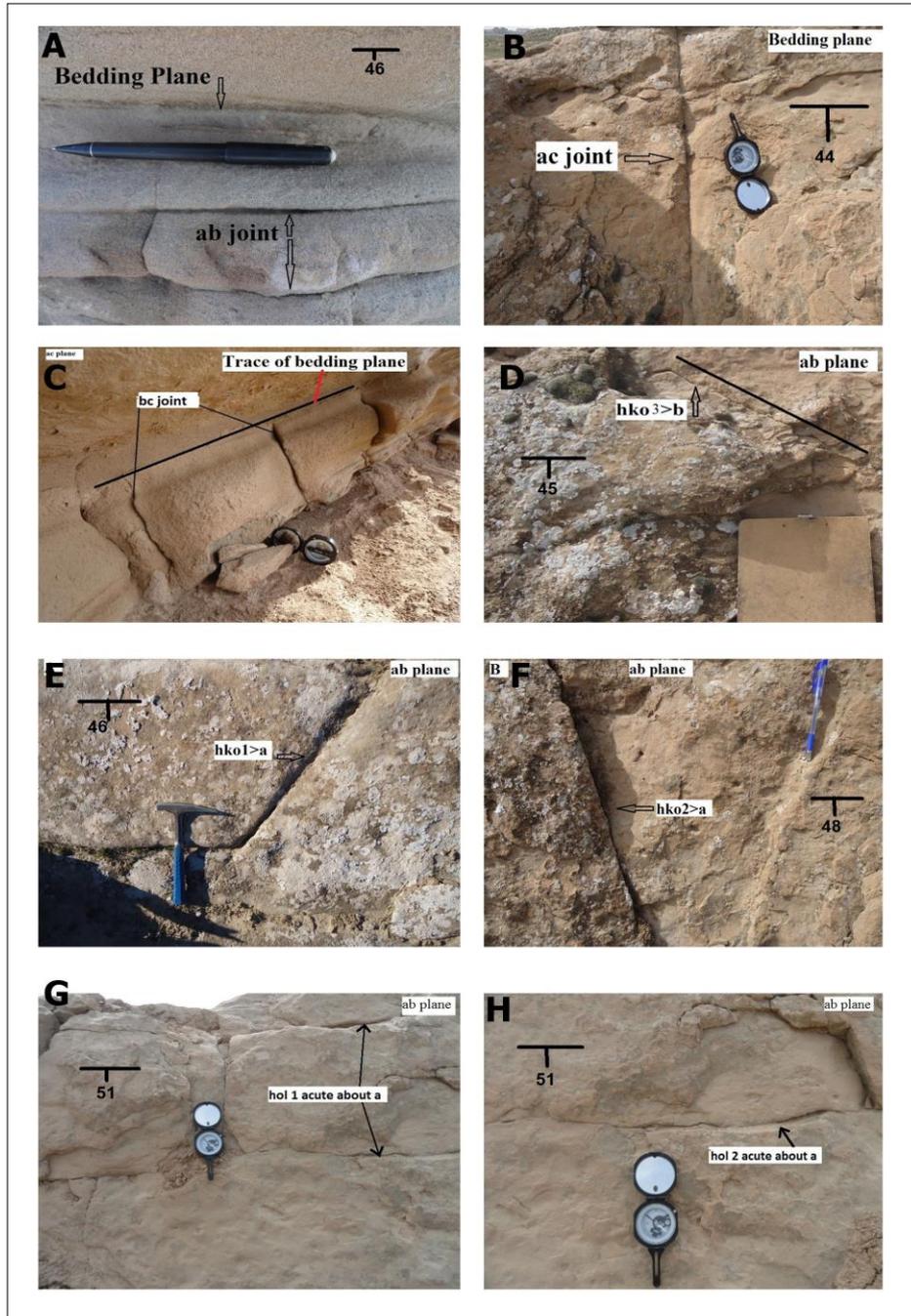


Plate (1) : A- ab joints , B- ac joint , C- bc joint , D- hko>b , E- hko1>a , F- hko2>a , G- hol1>a and H- hol2>a .

5. Discussion

Kinematic analysis shows the relationship between the joints (sets and systems) and the stages of the study area formation. The hko system acute about a and ac set are formed under the same stress regime in which the greatest principal stress (σ_1) is parallel to tectonic axis a, least principal stress (σ_3) is parallel to tectonic axis b (both σ_1 and σ_3 lies within the bedding plane) and the intermediate principal stress (σ_2) is perpendicular to the bedding plane. Under this stress regime the rock units suffer a relative elongation in the direction parallel to the strike of bed during the formation of these joints. This stress has a direction NE-SW. The acute angle 2θ between the planes of hko conjugate system acute about a appears in four mean values (28.5° , 38° , 44° , 50°). This means that effective stress ($\sigma_1 - \sigma_3$) and pressure solution vary during the formation of this system [3, 12 and 13]. In addition, this system formed in multi stages is separated by a time span. The mean direction of the bisector of the acute angle between the planes of this system is calculated to be (046.15°).

The hko set acute about b axis and bc set are formed under same stress regime, the greatest principal stress (σ_1) is parallel to tectonic axis b (strike of bed) and least principal stress (σ_3) is parallel to tectonic axis a (both σ_1 and σ_3 lie within bedding plane) while the intermediate principal stress (σ_2) is parallel to c axis (perpendicular to bedding plane). This stress regime leads to form a relation extension of the bed in the direction perpendicular to the strike of bed. It has direction NW- SE.

The hol system acute about a axis is formed under stress regime in which greatest principal stress (σ_1) parallel to tectonic axis a and the intermediate principal stress (σ_2) is parallel to b axis (both σ_1 and σ_2 lie within the bedding plane) while the least principal stress (σ_3) parallel to the tectonic axis c (perpendicular to the bedding plane) .This system appears asymmetrical about tectonic axis a. The (σ_1) bisect the acute angle between conjugate joints while σ_3 bisects the obtuse angle. The mean acute angle between this type attain (82°), this means that the effective stress ($\sigma_1 - \sigma_3$) is relatively low during the formation of this type of joints.

The relatively constant relation between the angles of the planes of this type and bedding plane ($10^\circ - 15^\circ$) indicates that σ_1 varies with the dip of beds and being parallel to the bedding plane during the formation of this type. The stress direction of this type is calculated to be 315° .

During the end of Late Upper Miocene and mainly during the Pliocene the Folded Zone was progressively involved in to Orogenic uplift [14]. This phase include the collision of



Arabian and Eurasian Plates causing an effective compressional stress of NE-SW direction. Stress mentioned started to grow to commence shortening in the sedimentary pile. This shortening made by folding and later on thrusting on the folded beds. This scenario (tectonic model) is best put forward by [15].

In the study area, incompetent salty beds of Fat'ha Formation ruptured along shallow décollement (Imbricate fan in a thrust system with a basal décollement). Moreover, the earlier buckled beds are now serving as an obstacle or ramp structure which forces the propagated thrust sheet to rise and become shallower as it is furtherly pushed along the lubricant surface until finely crops out at the surface. This condition provided an ideal condition to develop a fault-fold geometry .The latter geometry has a typical asymmetrical foreland-verging characteristic of the folded zone associated with major Zagros thrust fault.

The timing mentioned and mechanism can be translated or linked to the joint and stress directions that are detected in this study and as follows:

- The NE-SW stress orientation: The flexural fold process of the preexisted ductile rocks of Fat' ha and Injana formations has been prevailed while Mukdadiya and Bia Hassan Formations deposited contemporaneously. The temperature and pressure decreased and the rock mass became semi brittle to brittle enough (after folding) to form hko system acute about a and ac joint related to the folding process. The hko acute about a and ac joints had resulted in shortening in the rock beds in the direction perpendicular to the strike of beds and elongation parallel to the strike of beds.

Later on, under the same stress regime the stress has continued causing a rupture (thrust fault) along the hinge line of already developed fold. In this time, the Mukdadiya and Bai-Hassn Formation had deposited and affected by the mentioned stress regime causing a slip along the two detected fault and related joints of hol asymmetrical about a in the study area.

- The NW-SE stress orientation: As the stress direction mentioned has continued and more joints hko system acute about a and ac formed, a new stress regime is formed parallel to the strike of beds. This phase was named by [4 and 16] the elastic recovery phase represented by hko acute about b and bc joints. It is worth mentioning that the NE-SW stress orientation can be described as a dynamo for all other stress orientation and their consequences in the study area.

6. CONCLUSIONS

- 1- The study of joints has been carried out in Miocene (Injana Formation) and Pliocene (Mukdadiya & Bai Hassan Formations). The joints are classified into sets and systems. Generally the orientation of joint planes has occurred parallel, perpendicular and oblique to the strike of the beds.
- 2- Joint planes were judged in the field by the naked eye. Neither microstructures nor evidence of shear movements are recorded, i.e no plumose marking and striations are observed on the walls of the measured joints..
- 3- The main trend of measured joints are calculated to be : $ab = 315^\circ$, $ac = 045^\circ$, $bc = 315^\circ$, $hko1>a = 058^\circ$, $hko2>a = 033^\circ$, $hko3>b = 336^\circ$, $hol1>a = 316^\circ$, $hol2>a = 312^\circ$ and $hkl = 257^\circ$.
- 4- Stress directions are calculated throughout conjugate joints, especially hko system. The mean directions are hko acute about $a= 046.15^\circ$ and hol acute about $a = 315^\circ$.
- 5- The Sulfurous bed of Fat'ha Formation, perhaps, has prevented or isolated the joints in the upper part of the lower part of the mentioned bed .Therefore, the detected joints probably have no relation to joints that developed beneath the sulfurous bed .On the contrary, if the mentioned possibility isn't true, the joints beneath the sulfurous bed could coincide with the joints in the upper part.

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