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Variation of the Anticlines Vergency in the Iraqi Zagros Folds Belt and Its Tectonic Indications

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ABSTRACT

Folds of northern Iraq are considered integral part for the Western Zagros Fold – Thrust Belt. The growth of these folds was due to inversion displacement on inherited listric faults. This research deal with the relationship between the folds vergency and the faults that propagated folds, where that the dip of the back limb (gentle limb) for the fold is parallel to the thrust fault surface that propagated the fold, and the vergency of the fold determined by the forelimb (steep limb) situation. As a results, the folds of the high folded zone and of the western part of the low folded zone showed suture (N and NE) vergency and foreland (S and SW) vergency, while the eastern part of the low fold zone showed foreland (S and SW) vergency only. The appearance of the suture and foreland vergency within the high folds considered as indication to the high tectonic development conformable with the location of these folds in the Iraqi Zagros Fold Belt, while the appearance of the suture and foreland vergency in the western part of the low folded zone attributed to the more tectonic development of this part in comparison with the eastern part of the zone that there folds appeared foreland vergencies only, or to the influence of the evaporite beds for Fatha formation in this part.

Introduction

Most of folds that located within the fold – thrust belts and that they resulted from the collision between the tectonic plates represent distinctive deformation for the sedimentary cover. This deformation involves faults (fractures) that effect on the folds shape and the fold vergency, therefore these folds called folds related faults [1].

Generally, folds related faults are formed by bending and buckling mechanism and classified in three types [2]; detachment folds, faults propagation folds and fault bend folds (Fig. 1).

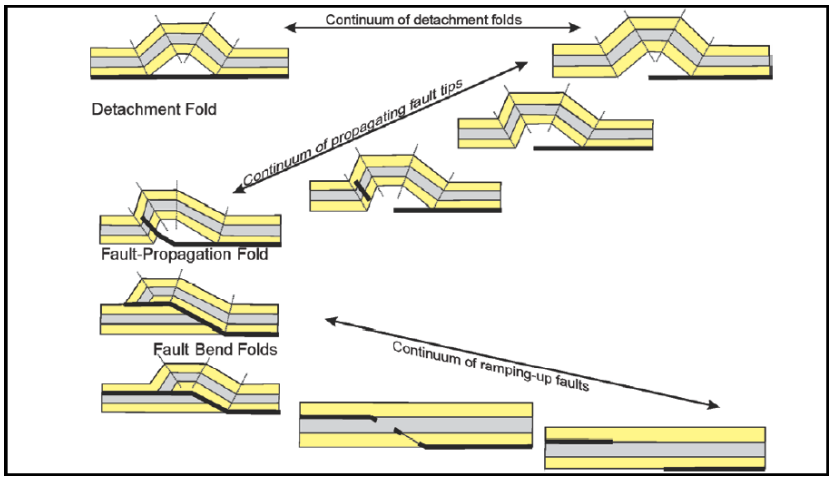

Fig.1: Shows the three types of folds related faults mechanism in the cross section [3].

Mostly, folds of northern Iraq (high and low folds) attributed to the fault – propagation fold [4], where this a special geometric relation between ductile (folds) and brittle (faults) behavior of rocks that formed together during the same deformation events [5], and can be summarized as the following: when the beds of a sedimentary rocks are submitted to the horizontal tectonic stress, the beds move parallel to the fault surface and form fold above the tip point, and therefore the fault surface that propagate the fold is parallel to the back limb (Fig. 2). Generally, the fold described as asymmetrical fold where the angle of the back limb is less than the dip angle of the forelimb [5] and [2].

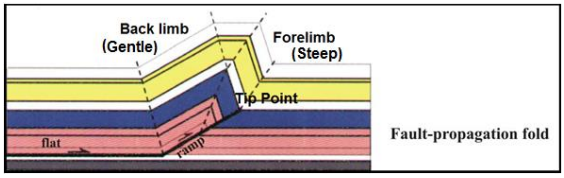

Fig. 2: Cross section shows fold growth by fault propagation fold mechanism [5].

The asymmetrical folds considered vergenced folds, where the direction of the fold vergncy is determined by the location of the forelimb fold [6]. According to this idea, there are two types of the folds vergency in northern Iraq, suture and foreland vergency. The suture folds vergency have dip angles of NE or W limbs more than the dip angles of their SW or S limbs, contrary with the foreland folds vergency that have dip angles of NE or W limbs less than the dip angles of their SW or S limbs [4].

Location, Nature and Aims of the Study

Some researchers (such as [7], [8] and [9]) give fold – thrust belts nomination to the mountains that results from the collision between the convergent plates, these folds belts represent thrusts related folds. Zagros Fold – Thrust Belt is considered good example to these belts, where the belt resulted from the collision between the Arabian an Eurasian plates in Early Tertiary [10].

Tectonically, Zagros Fold – Thrust Belt is partitioned into three segments, east Zagros, West Zagros, and the central Zagros [8]. [9] considered the northern part of Iraq (folded part) as integral part for the Western Zagros Fold – Thrust Belt, and he divided it into four zones, Suture Zone, Imbricated Zone, high folded zone and low folded zone (Fig. 3).

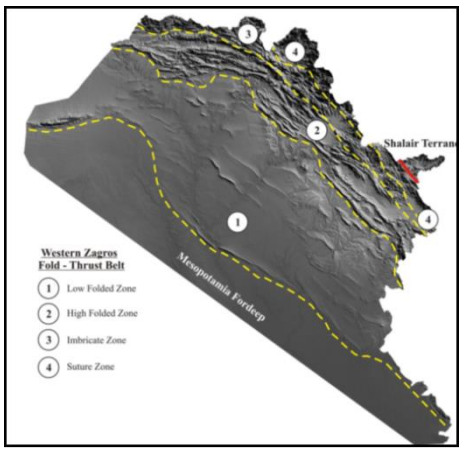

Fig. 3: The tectonic divisions of the Iraqi Western Zagros Fold – Thrust Belt [9].

Depending on the back limb is parallel to the fault surface that propagated the fold and the type of the fold vergency is determined by the forelimb direction idea, this research aims to determination of the folds vergency within the Iraq Zagros Fold – Thrust Belt, and interpretation of the changing in the fold vergency in the belt.

Relationship of Listric Faults with Folds

Some structural studies considered the faults that effected on the folds within fold – thrust belts as listric faults, but the other studies considered them as thrust faults. Generally, faults whose dip decreases progressively with depth have been given the special name listric faults. where the surfaces of these faults have concave or spoon shape [11]. The listric faults form during the divergent phase as listric normal faults within the passive plate margin, the dip direction of the some faults is conformable with the slope direction of the passive plate margin, but are not. The conformable faults are called synthetic while the other are called antithetic faults (Fig. 4).

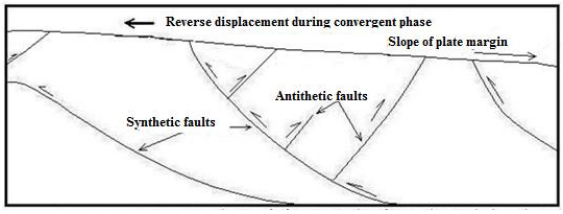

Fig. 4: Synthetic and antithetic faults with the plate margin [12].

The listric normal (synthetic and antithetic) faults change to reverse (thrust) faults during the compressive (convergent) phase that occur in subsequent time, leading to the collision between the plates, and growth of the folds finally [12].

The faults that propagated the high and low folds in northern Iraq are inherited from the listric normal faults. That is logical interpretation to the more development of the high folds in comparison with the low folds in northern Iraq [13] and [4].

There are seven suggested models show the relationship between the listric faults and asymmetrical folds shape in northern Iraq [13], (Fig. 5). From these models, can be understand that the folds of northern Iraq have suture and foreland vergency.

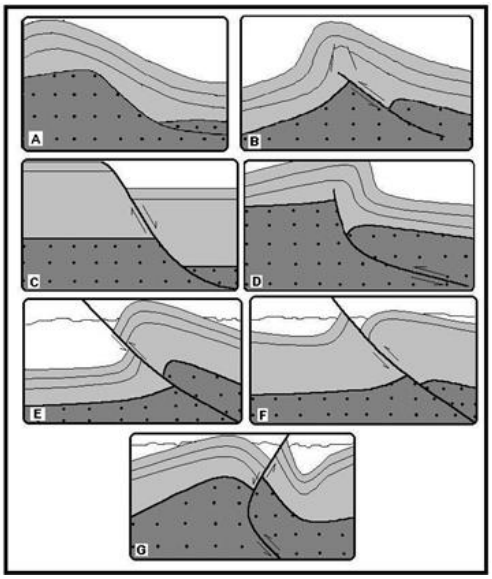

Fig. 5: Suggested models show the relationship between the listric faults and folds shape [13].

The Origin and History of the Listric Faults in northern Iraq

During the Triassic, the Turkey and Iranian plates separated from the Afro-Arabian plate [10], the separation lead to the appearance of New – Tethys ocean and listric normal faults associated with the extensional phase (Fig 6). The separation between plates continued until the Late Tithonian – Cenomanian (late Cretaceous), where the Late Cretaceous showed tectonic inversion from the extensional phase to the compressional phase. The tectonic inversion caused subduction of New – Tethys oceanic crust beneath the Turkey and Iranian plates (Iranian and Turkey plates). As a results, the normal slips hampered on that listric faults. The continental collision between the Arabian plate (passive margin) and Eurasian plate (active margin) started in the Early Tertiary and continued to the Recent. The paroxysmal phase of alpine folding started in the Pliocene, where the reactivation of reverse movement on the listric faults effective role on configuration of the folds shape and vergency [10] and [14].

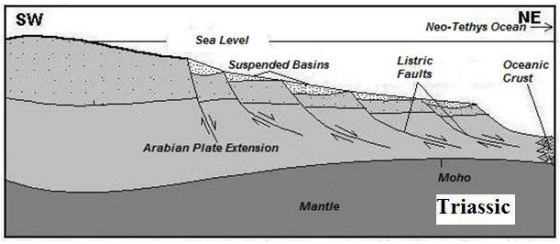

Fig. 6: Regional cross section in the NE margin of Arabian Plate shows listric [13].

The faulted basement rocks of northern and northeastern Iraq were covered by about 8 km of sedimentary units in the high folded zone and more than thickness in the low folded zone. This sedimentary cover involves carbonate competent units (as Qamchuqa, Bakhme and Pila Spi formations) and clastic incompetent units (as Kolosh, Gercus formations), as well as the two ductile evaporite units (Hormuz unit and evaporite of Fatha formation) [15].

Hormuz evaporites (Cambrian) and evaporite beds of Fatha formation (Middle Miocene) considered as lower and upper detachment surfaces in the sedimentary cover of the high and low folded zones [16], where the evaporites caused thrusting in beds and effected on the fold shape in northern Iraq (Fig.7).

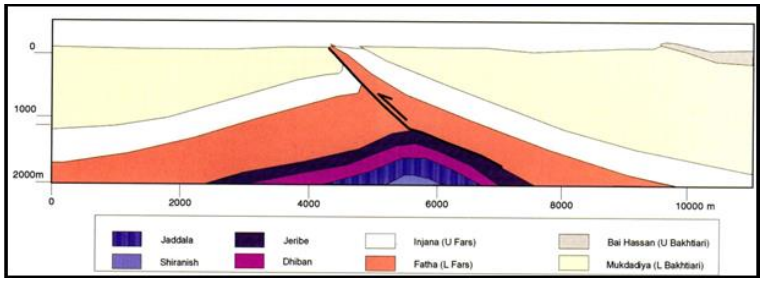

Fig. 7: Geological cross section in Hemrin anticline shows thrusting of northeastern limb on the southwestern limb because the evaporite beds of Fatha formation [15].

The Relationship Between Faults and Folds Vergency

When the fault propagates fold, the surface of fault is parallel to the back limb (gentle limb) of the fold that related it (Fig. 2). The fold vergency is determined by the forelimb situation, and the foreland vergency is common in folded belts (foreland area) in comparison with the suture vergency [1].

The listric faults that effected on the folds shape in foreland area (northern and northeastern Iraq) have two types of vergence, foreland-vergent listric faults and suture-vergent listric faults. The dip direction of the foreland faults vergency is north and north – east, while the dip direction of the suture faults vergency is south and south – west. The foreland faults vergency nomination conformable with the synthetic faults that formed during the extensional phase in northern Iraq (northeast margin of Arabian plate), and the suture faults vergency nomination conformable with the antithetic faults [4].

General Description of Folds in Northern Iraq

Foreland of Iraq includes large number of folds, these folds are distributed within the high and low folded zones. Generally, the folds that located within northeastern part of Iraq have NW-SE trending of fold axes while the folds that located within northern part of Iraq is E – W trending (Fig. 8, and 9).

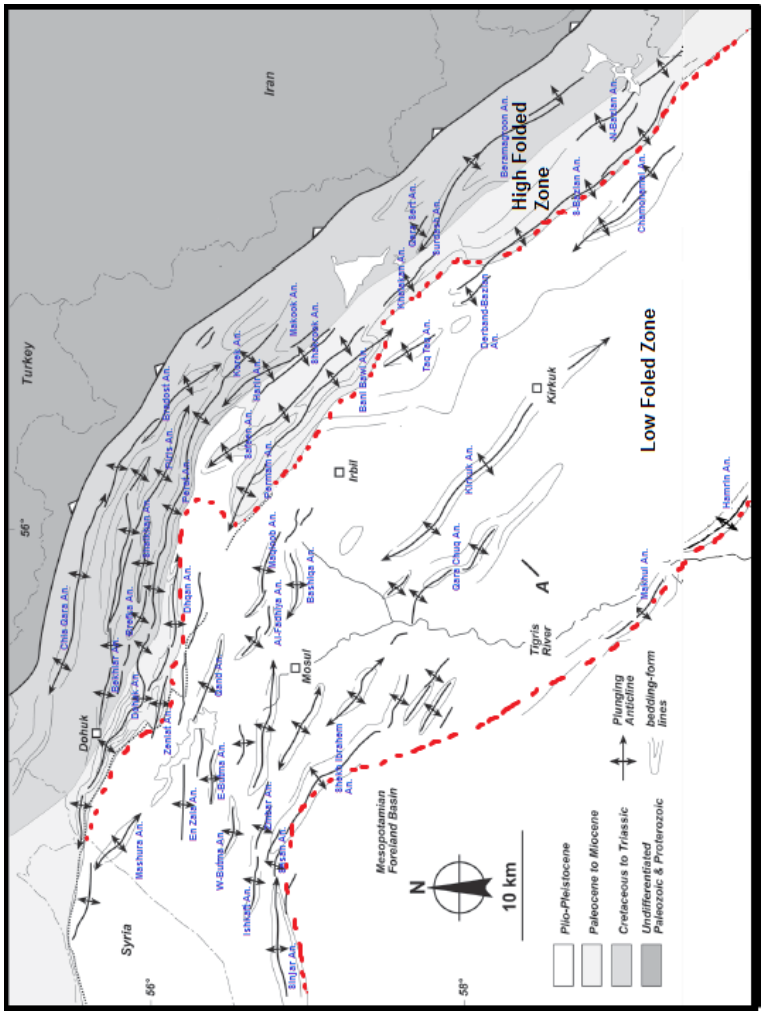

Fig. 8: Structural map of the Iraqi Zagros Fold – Thrust Belt shows locations and names of anticlines, modified from [16].

The high and low folded zones separated by high topographic boundary. Mostly, the folds of the high folded zone show high anticlinal mountains separated by deep and narrow synclines, with exposing of the Triassic-Cretaceous rocks that form the carapace of their cores in mostly [9].

Folds of the low folded zone show low anticlinal mountains separated by shallow and wide synclines. However, the exposed rocks in cores of these anticlines is attributed to Miocene, Eocene rocks were exposed in same cores of anticlines for the western part [15].

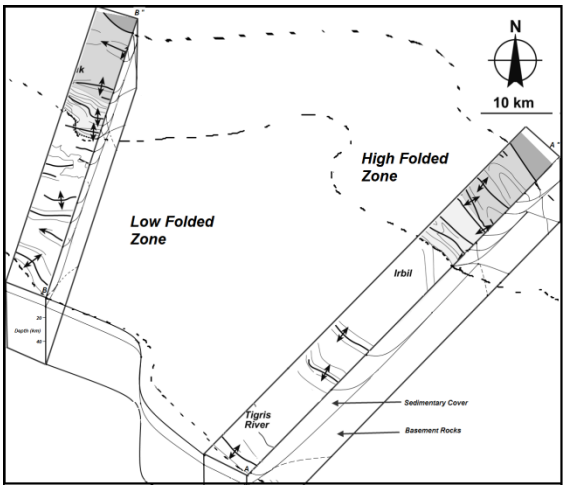

Fig. 9: 3 dimension model related fig. 8, shows the relationship between faults and folds distribution of the east and west parts for high and low folded zones that located within Iraqi Zagros Fold – Thrust Belt.

Field Description of the High Folds

N-Bazian, S-Bazian, Beramagroon, Sordash, Kosrat, Khalakan, Bani Bawi, Safeen, Makook, Korek, Harir, Permam, Bradost, Perat, Piris, Shaikhan, Prefka, Duhok, Bekhiar, Chia Gara and Qara Serd anticlines are located within the high folded zone and mostly they have NW-SE fold axes trending (Fig. 8). [17] described N-Bazian and Beramagroon as asymmetrical anticlines have dip amount of NE limbs more than dip amount of their SW limbs, and subsequently [18], [19], [20], [21], [22], [23] and [24] described Permam, Bani Bawi, Bekhair, Brefka, Makook, Kosrat , and korek with Bradost as asymmetrical anticlines have dip amount of NE limbs less than the dip amount of their SW limbs respectively, while [25], [19], [26], [27], [22], [24], [28] and [29] described Perat, Shakrook and Safeen, Dohuk, Shaikhan, Piris, Harir, Khalakan, and Qara Serd as asymmetrical anticlines have dip amount of NE limbs more than the dip amount of their SW limbs respectively.

Field Description of the Low Folds

The eastern part of the low folded zone includes Makhul, Hamrin, Kirkuk, Chamchamal, Derband-Bazian, Taq Taq and Qara Chuq anticlines that have NW – SE fold axes trending only (Fig. 8). [17] described Chamchamal, Kirkuk, Derband-Bazian, Taq Taq and Qara Chuq as asymmetrical anticlines have dip amount of NE limbs less than dip amount of their SW limbs respectively, and subsequently [30], [31] and [32] described Qara Chuq, Makhul, and Hamrin as asymmetrical anticlines have dip amount of NE limbs less than dip amount of their SW limbs respectively.

The west part of the low folded zone involves Sijar, Sasan, Zmbar, Shaikh Ibrahem, Maqloob, Bashiqa, Al-Fadhlya, Qand, W-Butma, E-Butma, En Zala, Ashkft, Mashura, Dhqan, and Zeniat anticlines that have E – W fold axes trending as well as the NW – SE fold axes trending (Fig. 8). Mashura, En Zala and Zeniat were described as asymmetrical anticlines have dip amount of NE limbs more than dip amount of their SW limbs by [33], Sinjar, Sasan, Maqloob, and Ashkft were described as asymmetrical anticlines have dip amount of NE limbs more than dip amount of their SW limbs by [34], [35], [36] and [37] respectively while Dhqan and Qand, E- Butma, and W- Butma, Zmbar and Shaikh Ibrahem, Bashiqa and Al-Fadhlya described as asymmetrical anticlines have dip amount of NE limbs less than dip amount of their SW limbs by [17], [18], [35] and [38] respectively.

Results and discussion

Generally, folds of northern Iraq (high and low folds) have two types of vergency, Foreland and suture. The suture folds vergency have dip amount of NE or N limbs more than dip amount of their SW or W limbs, while the foreland folds vergency have dip amount of NE or N limbs less than dip amount of their SW or W limbs [4]. That means the fold vergency for the folds in northern Iraq can be determined by the forelimb (steep) location.

The eastern part of the low folded zone involves Hamrin, Makhul, Chamchamal, Kirkuk, Qara Chuq, Taq Taq, and Derband-Bazian anticlines that show foreland vergency, where these anticlines have dip amount of NE limbs less than the dip amount of SW limbs. In addition to foreland vergency, the average distance between these anticline is about 15 km and the age of the exposed rocks in the core of these folds is not exceed the Miocene.

The western part of the low folded zone involves Mashura, En Zala, Zeniat, Sinjar, Sasan, Maqloob and Ashkft anticlines that show suture vergency and Tertiary exposed rocks in cores, as well as Dhqan, Qand, E- Butma, W- Butma, Zmbar, Shaikh Ibrahem, Bashiqa and Fadhlya anticlines that show foreland vergency and Tertiary exposed rocks in cores.

N- Bazian, Beramagroon, Perat, Shakrook, Safeen, Dohuk, Shaikhan, Piris, Harir folds that are located within the high folded zone and considered as suture anticlines vergency, where these anticlines have dip amount of NE limbs (forelimbs) more than the SW limbs (back limb). In addition to the suture anticlines vergency, the high folded zone involves foreland anticlines vergency (as S- Bazian, Surdash, Chia Gara, Permam, Bani Bawi, Bekhiar, Brefka, Makook, Korek and Bradost) that have dip amount of SW limbs (forelimbs) more than the NE limbs (back limb).

The development for the anticlines increasing from north to south progressively [4] and antithetic (suture) listric faults can be formed as result for increasing in the tectonic deformation [13], therefore the suture vergency for the anticlines in the high folded zone can be attributed to the increasing in the tectonic deformation while the suture vergency for the anticlines in the western part of the low folded zone may by attributed to the influence of the evaporate beds for Fatha formation that considered as

detachment surface can be effect on the fold shape and give it vergent not conformable with the listric vergent that formed.

Conclusions

1- The presence of the suture and foreland vergency in the anticlines of the high folded zone and exposing of the Triassic-Cretaceous rocks in their cores can be considered as indication for the presence of antithetic faults associated with high tectonic development.

2- The presence of the foreland vergency only in the eastern part of the low folded zone and the exposing for the Miocene rocks can be considered as indication to the absence of the antithetic (suture) listric faults in this part or probably their influence vanished in the depth.

3- The presence of the suture vergency (as well as the foreland vergency) within the western part of the low folded zone may be indicate to the more tectonic development of this part in comparison with the eastern part of the zone, or may be indicate to the influence for evaporite bed of Fatha formation that considered detachment surface.

Recommendations

1- Structural development study for anticlines in the low folded zone and its relationship with the inherited faults by using seismic sections.

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تغير اتكاء الطيات المحدبة في حزام طيات زاكروس العراقية ومدلولاته التكتونية

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الملخص

تعتبر الطيات في شمال العراق جزء" مكملا لحزام طي – تصدع زاكروس الغربية العراقية. نمو هؤلاء الطيات كان نتيجة لإزاحة عكسية على صدوع لستيرية موروثة. يتناول هذا البحث العلاقة بين اتكاء الطيات وبين الصدوع التي أنشأتها, حيث أن ميل الجاح الخلفي (الجناح الاقل ميلا) للطية يكون موازيا لسطح الصدع الزاحف الذي أنشئ الطية, وان اتكاء الطية يتحدد بموقع الجناح الامامي (الجناح الاشد ميلا). كنتائج, أظهرت طيات نطاق الطيات العالية وطيات الجزء الغربي من نطاق الطيات الواطئة اتكاء درزي (شمالي – شمالي شرقي) وفورلاندي (جنوبي – جنوبي غربي), بينما أظهرت طيات الجزء الشرقي من نطاق الطيات الواطئة اتكاء فورلاندي فقط. اعتبر ظهور الاتكاء الدرزي والفورلاندي للطيات في نطاق الطيات العالية كدليل تطور تكتوني يتفق مع موقها ضمن حزام طي زاكروس الغربية العراقية. بينما نسب ظهور الاتكاء الدرزي والفورلاندي في طيات الجزء الغربي من نطاق الطيات الواطئة الى التطور التكتوني الاكثر في هذا النطاق بالمقارنة مع طيات الجزء الشرقي من النطاق الذين اظهروا اتكاءات فورلاندية فقط, أو الى تأثير صخور المتبخرات لتكوين الفتحة في هذا الجزء.