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# THRUST FAULT IN THE MAASTRICHTIAN SEQUENCES OF MAWAT AREA, NE IRAQ

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Key words: Thrust fault, Tanjero Formation, Aqra Formation, lateral thrust, Mawat area, Iraq

## ABSTRACT

Stratigraphic studies of Maastrichtian Tanjero and Aqra formations and compression of microtectonic faults in Khewata – Dolbeshk valley constrains new geological setting of the Mawat area northeast Iraq. During Middle – Late Maastrichtian a carbonate-siliciclastic succession deposited in front of the subducted ophiolite and accretionary prism. These successions are well developed in the area. This study concentrates on the overthrust sequence and identifies the geometry of the thrust fault. The reefal limestone/ shallow clays succession are thrusted over reefal limestone/ marl-sandstone succession. This thrust fault illustrates (1) these two successions were initially deposited laterally beside each other during the Maastrichtian and (2) the limestone/ clay sequences belong to the Tanjero/ Aqra formations and not to the Red bed Suwais. The fault initiated during the last stages of collision, formed duplexes-imbricated thrusting fault and it brought the shallow facies over the deeper one. The thrusting can also be identified on Google Earth image manifested by vertical repetition of Aqra Formation and it changes to reverse fault when it laterally meet the thicker and massive limestone of Aqra Formation. The displacement of the thrust fault is accommodated by a fault-propagation folds in its southeastern tip. In addition to the studied thrust fault, the valley contains many well developed relatively smaller compression faults which might form in a relation to the main thrust fault.

# فالق إندفاعي في تتبعات عصر الماستريختي في منطقة ماوت، شمال شرق العراق

**كمال حاجي كريم، سيروان حما أحمد و هوار فاضل اسماعيل**

**المستخلص**

أدت دراسة الطباقية للتكاوين تانجيرو وعقره (ماستريختي) ودراسة ماكروتكتونية الفوالق في وادي خيواتا – دولبيشك إلى تقييد وضع جيولوجي جديد لمنطقة ماوت في شمال شرق العراق. فخلال وسط وأواخر الماستريختي تتابعات الحجرية الجيرية – الفتاتية السلكية ترسبت أمام الأوفيولايت. وهذه التتابعات الرسوبيه تطورت بشكل جيد في المنطقة. تركز هذه الدراسة على تحديد فالق الإندفاع وشكله. وبسبب هذا الفالق فان تتابعات الحجر الجيري والطين الضحلة تتواجد فوق تتابعات الحجر المرجاني الجيري. وقد تكون الفالق خلال المراحل الأخيرة من اصطدام الصحيفة العربيه والصحيفة الثوراسيه. شكل الفالق هو الدوبلكس-متقلب الإندفاع وجلبت التتابعات الضحله فوق التتابعات العميقه. ويمكن أيضا التعرف

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على الفالق من خلال صورة الجيري والمارل أو الحجر الرملي. يوضح هذا الفالق: **1)** هذه التواليتين ترسبت في البداية أفقيا بجانب بعضها البعض خلال الماستريختي، **2)** وتنتمي تتابعات الحجر الجيري والطين الضحلة لتكوين التانجيرو وليس لتكوين ريدبيد سويس ويمكن ملاحظتها على غوغل إيرث بسبب التكرار لتكوين العقره. مع إزاحة فالق الصدع تتواجد طيات تكونت بسبب الفوالق في الطرف الجنوبي الشرقي. بالإضافة إلى فالق الصدع المدروس، يحتوي الوادي على العديد من الفوالق المعكوسه الأصغر نسبيا والتي نشئت مع وبسبب هذا الفالق الرئيسي.

**INTRODUCTION**

The area is located in the northeastern part of the Arabian plate in the Zagros Fold and Thrust belt-Iraq (Fig.1A). The area is locate 4 Km to the southeast of Mawat town on both sides of the valley of Little Zab River upstream (Fig.1). The studied structures are expressed on the surface and can be observed in many locations along the ridge scarps such as northeast of Dolbeshk, Mokaba, Konamassi and Kareza Villages.

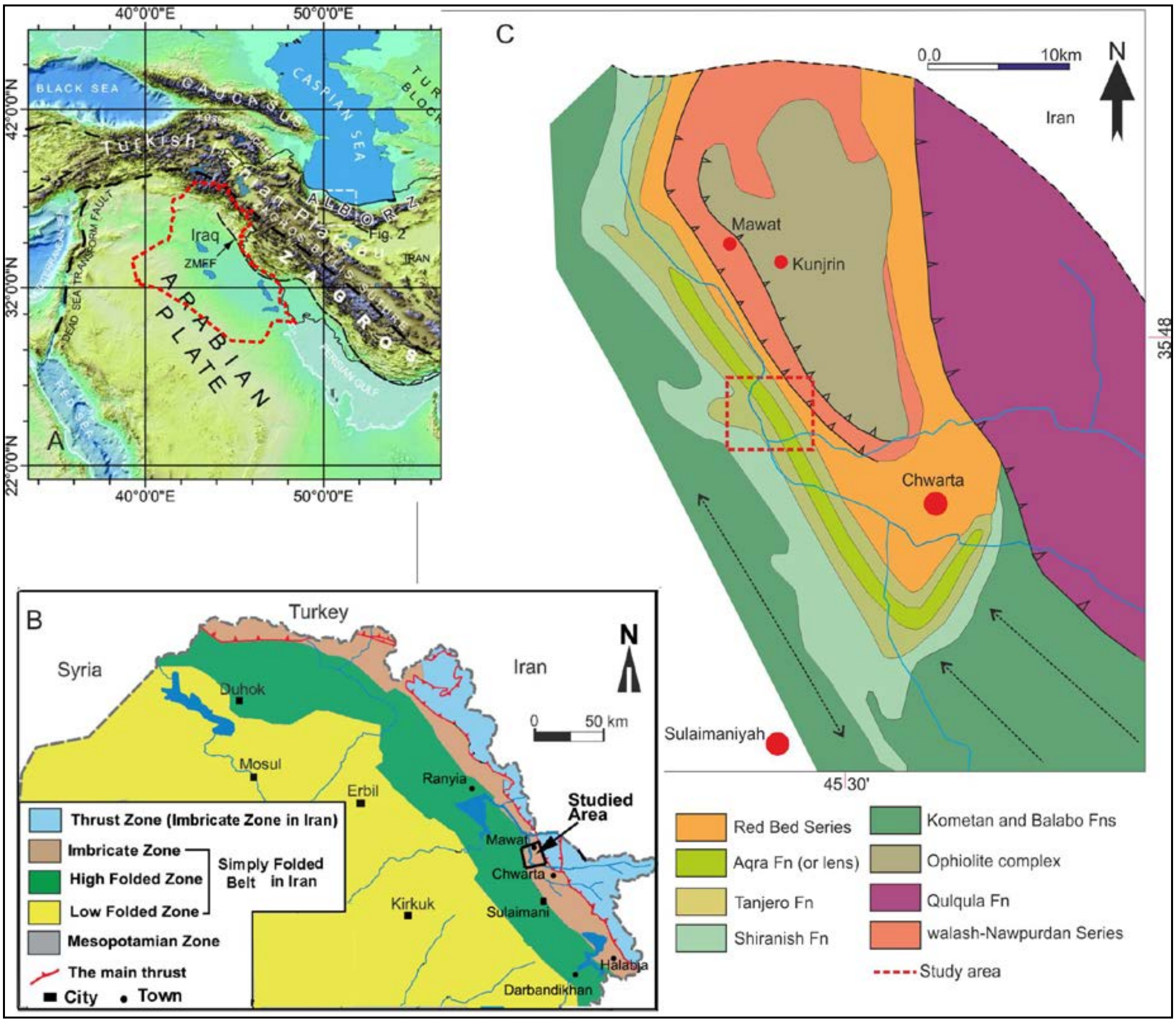


Fig.1: **A)** location of Iraq within the Middle East, **B)** Map of tectonic subdivisions of northern Iraq (Jassim and Goff, 2006) on which the studied area is indicated, **C)** Geological map of Mawat area (modified from Sissakian, 2000), on which the location of the studied area and three thrusts are indicated

The northern part of the area is occupied by the ophiolite nappe (Al-Mehaidi, 1975) and Eocene Naoperdan Series (Jassim and Goff, 2006). The northeastern part is covered by the Early Cretaceous sequence of Qulqula Radiolarian Formation (Karim, 2009) (Fig.1). Tectonically, the studied area represents the northeastern margin of the Arabian Plate, where the previous Early Cretaceous platform has transformed to a Foreland basin during the Late Cretaceous (Karim, 2004). The studied area is located in the Imbricated Zone (Buday, 1980) and is also recognized as Balambo – Tanjero Zone (Jassim and Goff, 2006). The studied area is very close to the boundary between Imbricated and Thrust Zones. Two main thrusts exist in the nappe area (Fig.1C). First thrust is located between ophiolite and Walash Naoperdan series while the second is located between Walash Naoperdan and Red Bed Suwais. The rocks of the area are subjected to intense deformations which can be seen from intense fracturing and thrusting due to stresses that are imposed by the collision of Eurasian and Arabian plates (Karim and Sulaiman, 2012).

The major structure of the area is the Main Zagros Thrust Fault (MZTF) which is located about 4 Km to the north of the studied area. The MZTF extends nearly along Iraq – Iran border. In Iraq, the thrust or frontal thrust (frontal ramp) is well documented by Jassim and Goff (2006), and others. These authors have described the frontal thrust under the name of "Main Zagros suture Zone", "Main Zagros thrust" and "main Zagros reverse Fault".

## ▪ General Geological Setting

The main area is covered by two types of sequences. One is the nappe sequence that is overthrusted to the area due to the Arabian – Eurasian collision; they are Qulqula group, Walash Naopurdan and Mawat Ophiolite. The Walash Naopurdan Series is thought to be transported to its present location from the northeast. For this reason, the Walash Naopurdan Series is completely crushed and show intense fracturing and faulting. This series consists of two main units, the first consists of alternating thin beds of sandstone, shale and marl which is about 100 m thick (Jassim and Goff, 2006). However, there might be repetition by faulting and thrusting that lead to thicker succession. The second unit consists of limestone (about 50 m thick) at the northwestern part near Mawat Town (Fig.1C). The Mawat ophiolite complex consists of many igneous rocks such as Peridolite, Dunite, Serpentinite, Gabbro and Basalt. The Gabbro is relatively thick and its thickness is more than 400 m and most of the Gimo Mountain iscomposed of this type of rock. This rock is completely brecciated and crashed due to tectonic stress generated from the Arabian and Iranian plate collusion (Fig.3). Due to the shearing and crushing, the rock is being disintegrated into more friable rock that can be easily weathered. Its color shows bluish gray soil around Mirawa and Kuradawe villages. According to Karim (2005) this ophiolite is the most southwest limited of the thrusted sheet in northern Iraq; it is attributed to the presence of large graben in Chwarta – Mawat area.

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The second sequence type of the Cretaceous and Paleocene – Eocene sequences deposited in the area are Shiranish, Tanjero, Aqra and Red Bed Suwais formations. The sequence overlying the Maastrichtian formations in the area is the Red bed Suwais (Fig.1C).

This formation belongs to the Paleocene – Eocene (Jassim and Guff, 2006) and is about 2000 m thick consisting of red claystones, sandstones and conglomerates. The conglomerate consists of consolidated and cemented gravels and sands which contain a mixture of different types of clasts (pebbles) of limestone (5%), Gabbro (35%) and both cherts (60%). It contains rare dunite and basalt clasts too. The chert clasts are of different colors such as gray, brown and red green, black while the limestone clasts are fine grained and have milky color. Most of Gabbro particles are weathered while chert and limestone look fresh. At the base of the series, alternation of claystone and sandstone occur above Aqra Formation and about 200 m thick. The thick conglomerate is characterized by the high internal friction angle in addition to the stiffness and massiveness which resist deformation such as faulting and fracturing. Therefore, the faulting may be related to the conglomerate by transferring the tectonic stress from north to south across the area.

The hinge of the thrust fault is in the Aqra and Tanjero formations. The Aqra Formation consists mainly of coarse grained detrital and biogenic limestones, which in many places contains terrigenous clastics. Its thickness rapidly varies from 20 to 150 m and has a prismatic depositional form. It is characterized by abundant rudists, benthic foraminifers, gastropods and non-rudist bivalves, the echinoderms and solitary corals occur too (Karim, 2004).

The Aqra Formation crops out as a narrow L-shaped strip and have the length of about 35 Km which extends along both sides of Mokaba – Mawat stream from south of Chwarta to south of Mawat (northwest of the study area). The thick successions of the coherent and stiff limestone of this formation is from the ridge of Dolbesk – Mokaba ridge (Qishlagh – Dere) ridge. This formation is exposed in three different stratigraphic positions which may be attributed to faulting.

The first outcrop of the Aqra Formation contains red clastics and is located to the north near the Main Thrust Zone between Tanjero Formation (Maastrichtian) at its base, and the Red Bed Suwais at its top (Karim and Khanaqa, 2014) (Fig.2). The second outcrop consists mainly of well bedded reworked bioclast limestones and marl which is located inside Tanjero Formation at the southern side of the Mokaba – Mawat stream while the third unit is located at the middle of the studied area and consists of reefal and shoal limestone about 150 m thick in some places and its thickness changes rapidly (Fig.2). The Tanjero Formation consists mainly of thick successions of gravely conglomerate with a thickness of 20 – 500 m in the northern and eastern part of the studied area (in the proximal part of the Cretaceous Foreland basin), whereas it consists of calcareous shale and channelized sandstone and pebbly sandstone.

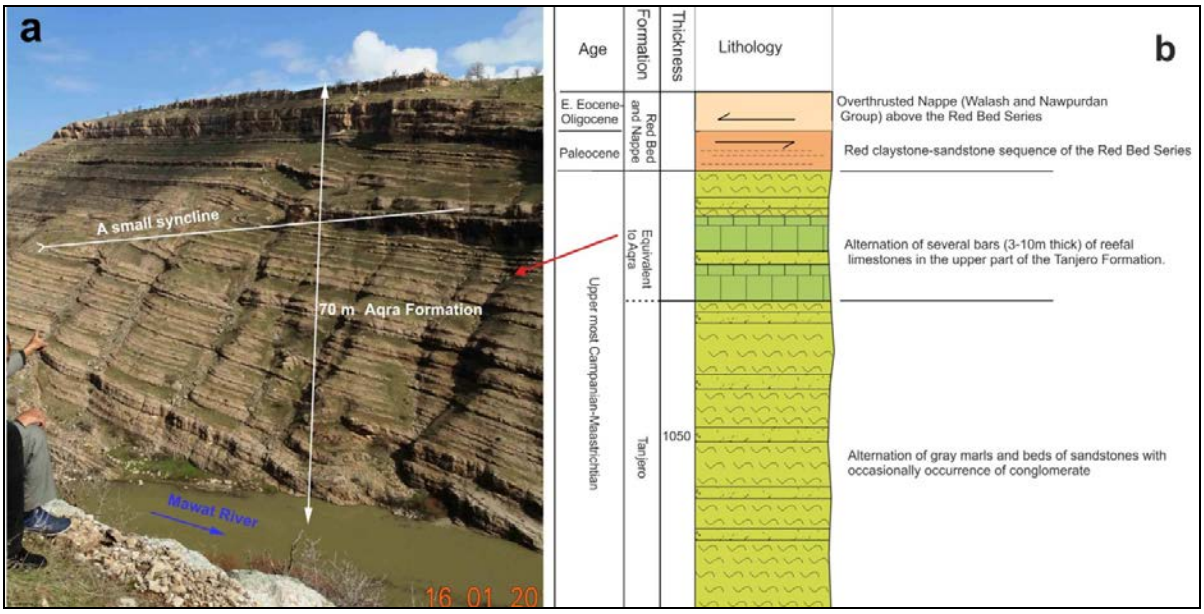


Fig.2: **A)** Outcrop of Aqra Formation 3 Km to the south of Kele village consisting of 150 m of massive rudist bearing limestone. **B)** Stratigraphic column of the study area shows the Aqra Formation stratigraphically overlain by Red Bed Series (Ahmed, 2013)

## FIELDWORK AND MAIN TOOLS USED

The thrust fault in the Dolbeshk Valley is not easily recognized because the fault thrusts the same lithiofacies over each other. In founding the geometry of this thrust fault three main approaches are used:

- **Brittle tectonic analysis**

One part of this study deals with the compression brittle tectonic analysis in order to reconstruct the paleostress and orientation of thrusting. We studied 6 sites. Analyses of brittle deformations were performed in the area close to the hinge of the thrust fault (Fig.8). We selected the sites for measure men according the following principle: **1)** the bedding plane must be clear, **2)** the fault planes are not weathered (i.e. slickenside lineations are preserved), **3)** the site must have enough fault planes to measure a reasonably consistent fault population (fault population must contain at least 4 measurements for paleostress reconstruction). The purpose of these methods is to rebuild systems from paleostress analysis in the field populations of faults streaks. The *Anderson* models (1942), based on the results of rock mechanics, allow in the case of newly formed combined position of σ1, σ2 and σ3 axes, and define a dihedral angle faults. Other simple models proposed by of Wallace (1951) and Bott (1959), allowed to examine the case of non-conjugate faults and their compatibility with the combined systems. The Carey and Brunier (1974) proposed one method for calculating the average stress tensor using computer resources. Their idea is based on the inversion of reasoning Wallace (1951) and Bott (1959). With the evolution of computer technology, the idea of solving the inverse problem has given rise to many numerical methods (Angelier, 1975; Carey, 1976; Armijo and Cisternas, 1978; Etchecopar *et al*., 1981; Angelier *et al*., 1982; Angelier, 1983; Angelier 1984; Michael; 1984; Reches, 1987 and Angelier, 1990). For the determination of the stress tensor we use the Direct Inversion method, named INVD (Angelier, 1990). It was made for analysis and computation of the stress axes. The inversion is based on the slip-shear angle (α) between the real strata (s) and the calculated relative shear stress (τ) (Angelier, 2002). The method and the software that we used for stress tensor computation were developed under the *Angelier* (1975, 1977, 1979, 1982, 1984, 1989 and 1990).

- **Stratigraphy and Dating (biostratigraphy)**

Extensive field investigation to identify the lithofacies of the Maastrichtian flysch and reefal lithofacies (Tanjero and Aqra formations), as well as the reputation of the sequences. For biostratigraphy, amphasis is made on the existing rudist fossils in the reefal beds of area formation.

- **Satellite mapping**

The Google earth maps used to understand the changing thickness of the Maastrichtian sequence in the study area.

## RESULT

In the upper part of the Tanjero Formation thick-bedded reefal limestones exist as intercalated bars. These reefal limestone beds are intercalated inside the Upper part of the Tanjero Formation are 3 – 5 m thick. We observed the repetition of 10 or 15 bars. The thickness and repetition of the reefal limestone lenses inside the Tanjero Formation increase northwest of Qalachwalan Town (before Kunamasi village). In the east of the area, in Kato Mountain, the Upper part of the Tanjero Formation lithologically changes with the occurrence of clastics represented mainly by a thick sequence of conglomerate without any inter-bedded reefal carbonates.

Two Maastrichtian lithofacies are identified in the Qalachwalan – Mawat area:

1- Sandy Marlstone/ reefal limestone lithofacies: This sequence is widely distributed in the study area. The thickness is variable, ranging between 50 to 100 m thick. In the bottom, the each marl/limestone bundle is thick where the marl bed thickness exceeds 3 m (Fig.3A). However, toward the top of this lithofacies the thickness of marl decreases (1 – 0.2 m), therefore the repetition of marl/limestone increase (Fig.3B).

2- Claystone/ reefal limestone lithofacies: this lithofacies has a restricted distribution as compared to the first lithofacies. The total thickness exceeds 100 m thick. Each claystone/ limestone bundle is thick where the terrigenous claystone bed thickness ranges between 7 – 20 m (Fig.3C and D). Therefore the repetition of claystone/ limestone is less compared to the marl/ limestone lithofacies. All the limestone beds in this succession are of shallow reefal type containing Maastrichtian rudist species (Fig.4). These Maastrichtian Macrofossils insure this lithofacies to belong to the Aqra Formation and not to the Red Bed Formation.

The red conglomerate beds stratigraphically overly the marl/ limestone lithofacies in different localities such that close to the Banale village. However the same red conglomerate stratigraphically overlies the clay/ limestone lithofacies in other localities such as that close to the Suraqalat Village. According to Budy (1980) it is identified that the conglomerate parts with shales above the Aqra Formation in Mawat area belong to the Paleogene Red Bed Suwais. That means that the marl/ limestone facies in the study area structurally overlain by the claystone/ limestone beds or stratigraphically overlain by the Red Bed Suwais.

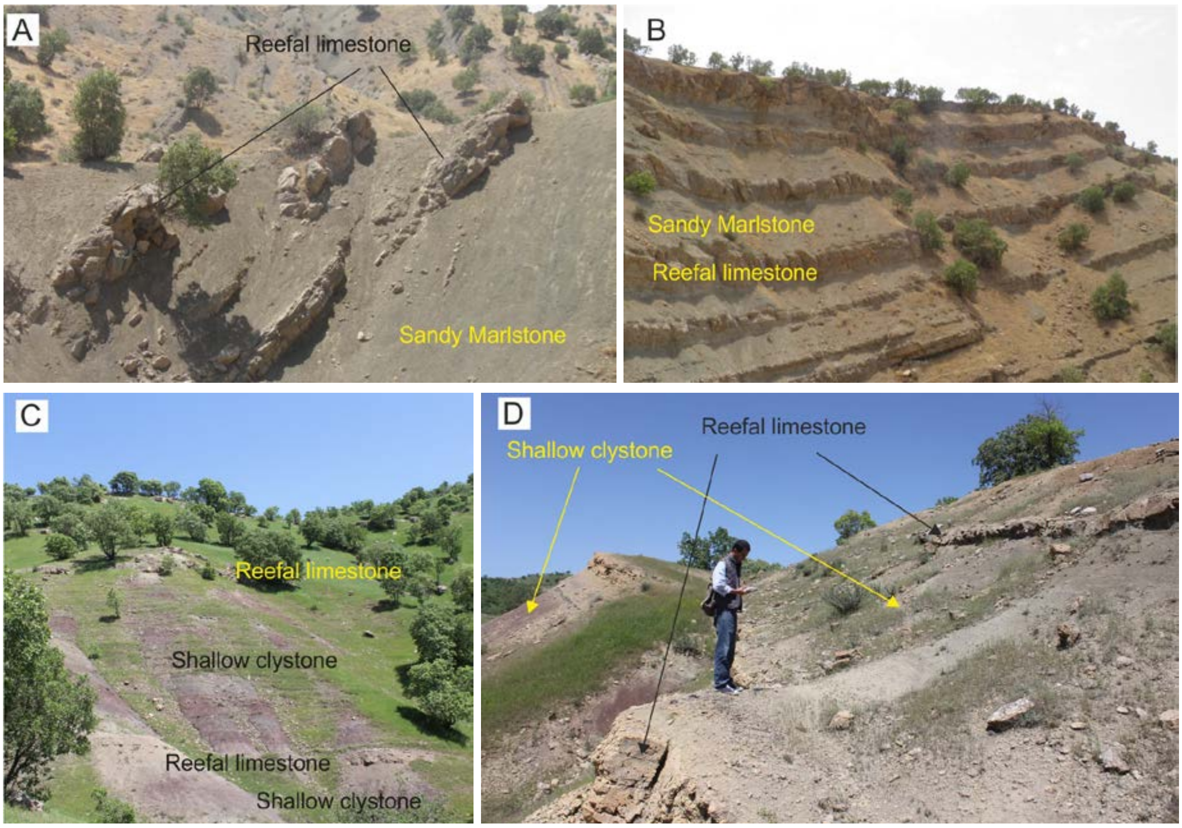


Fig.3: **A)** Lower part of the Marl/ Limestone lithofacies show thick marl and thin limestone, **B)** repetition of the Marl/ Thick reefal limestone bundles (Upper part of Marl/ Limestone lithofacies), **C** and **D)** show part of the Shallow Claystone/ Reefal Limestone lithofacies

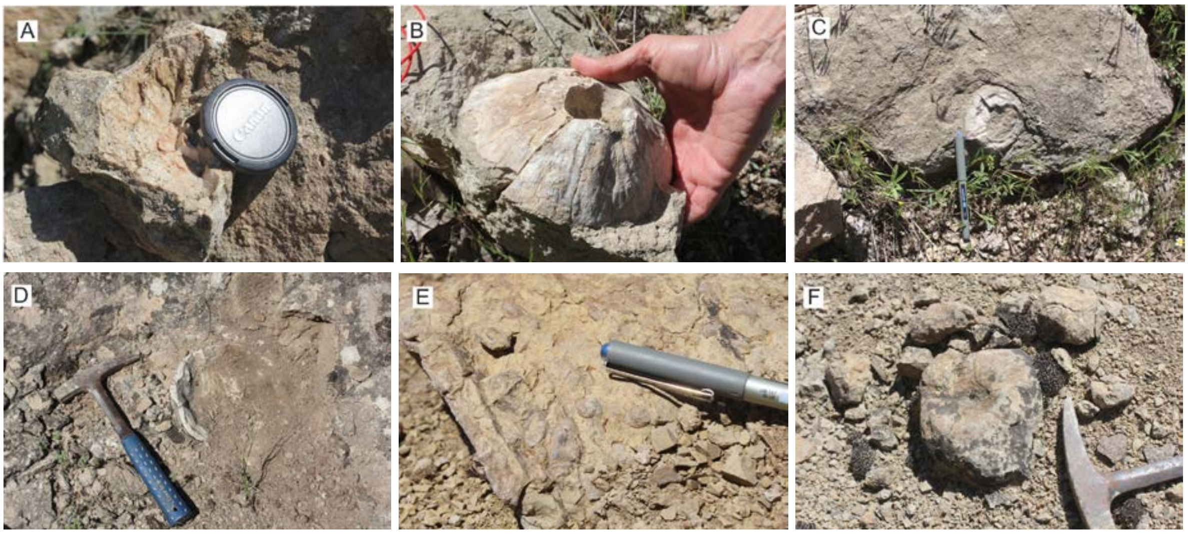


Fig.4: Macro fossil species of Maastrichtian Coral (*lapeirousia jouanneti* and *hippurites cornucopiae* species) in the Aqra Formation

To identify the orientation and hinge of the thrust fault we try to find several compressional microtectonic fault sites. For that reason, we select 6 sites (Fig.5 and Table 1) in the study area. All the sites contain compressional reverse fault formed during the same event and with stress (σ1) of the main thrust fault. Descriptions and result of these microtectonic fault sites are:

1. **Site-1:** This site is located on the Suraqalat – Kunamasi main road (Fig.8). The faults are in the limestone of Aqra Formation. The compressional regime of the Site-1 is reconstructed from a post-tilting reverse faults. The orientation of the σ1 axis is ENE – WSW (240°) (Fig.5 and Table 1).
2. **Site-2:** Is located on the Qalachualan – Kareza main road (Fig.8). The microtectonic fault population is post-tilting conjugate regimes of reverse faults system. The orientation of the σ1 axis is ENE – WSW (249°) (Fig.5 and Table 1).
3. **Site-3:** Is located on the Qalachualan – Kareza main road near the river (Fig.8). It contains two compressional populations and is in the upper part of Tanjero Formation. The first fault population is post-tilting one set of reverse fault system. Unfortunately, the conjugate fault sets could not be found. The orientation of the σ1 axis is EN – SW (239°) (Fig.5 and Table 1). The second population is oblique post-tilting conjugate strike-slip fault population. The σ1 orientation is ENE – WSW (256°) (Fig.6 and Table 1).
4. **Site-4:** Occurs on the reefal bar of Aqra Formation. The site contains faults of two populations of reverse and right lateral strike-slip faults (Fig.5 and Table 1). Both populations show compression in NE – SW direction.
5. **Site-5:** Is the site in front of the major thrust fault. The striation of the compression fault well appears in the limestone beds (Fig.5). The fault population constrains conjugate reverse fault system. The σ1 orientation is toward NNE – SSW (Fig.5 and Table 1).
6. **Site-6:** Is located on the main road to Kunamasi Village (close to the Kunamasi village) (Fig.9). The fault populations are in the Tanjero Formation. The fault constrains compression conjugate reverse fault system and the analysis shows that the σ1 is oriented to NE – SW (Fig.6 and Table 1).

In the study area, several lateral thrusts can be identified that exist in the fossiliferous limestone of Aqra Formation (Karim and Sulaiman, 2012). These lateral thrust faults are related to the main thrust fault. According to their attitudes, they consist of two types. The first is dipping northwest and the other is dipping southeast (Fig.7).

Table 1: Microtectonic fault sites and their stress attitudes in the study area

| Site No. | Lat. | Long. | σ1 | | σ2 | | σ3 | |
|---|---|---|---|---|---|---|---|---|
| | | | strike | dip | strike | dip | strike | dip |
| 1 | 35:46:31.0 | 45:26:40.1 | 240 | 10 | 024 | 6 | 098 | 81 |
| 2 | 35:45:49.0 | 45:27:07.9 | 249 | 11 | 157 | 06 | 040 | 78 |
| 3 | 35:45:49 | 45:27:07.9 | 235 | 08 | 143 | 08 | 006 | 78 |
| | | | 256 | 23 | 037 | 62 | 159 | 16 |
| 4 | 35:46:08.9 | 45:26:42.1 | 237 | 11 | 328 | 04 | 076 | 79 |
| 5 | 35:47:00.8 | 45:26:19.2 | 015 | 11 | 107 | 8 | 230 | 76 |
| 6 | 35:47:14.3 | 45:25:45.1 | 236 | 07 | 327 | 07 | 102 | 80 |

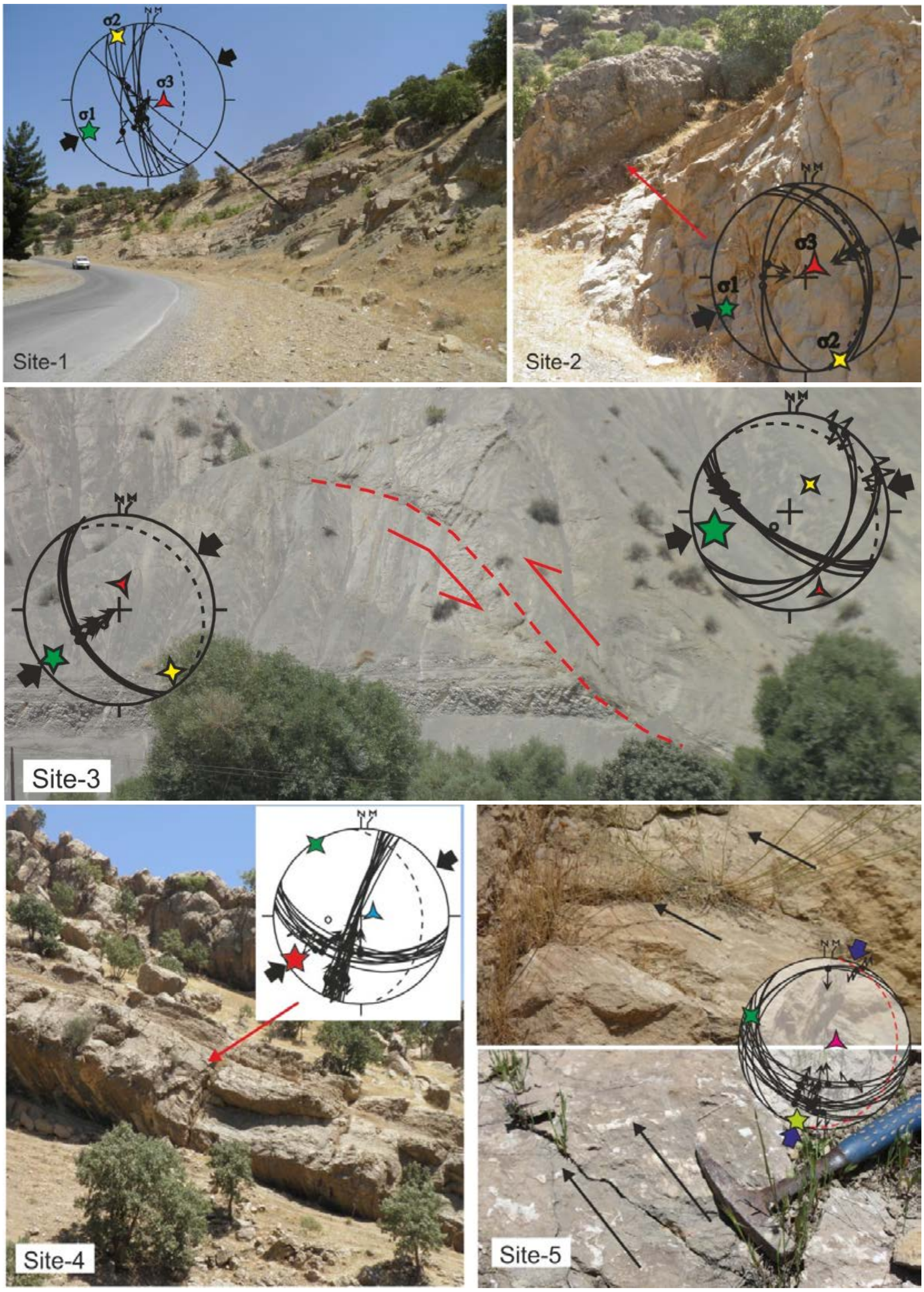


Fig.5: **Site-1)** Post-tilting reverse and right-lateral faults in the limestone of Aqra Formation; **Site-2)** Post-tilting conjugate reverse fault system in the thick limestone (Aqra Formation); **Site-3)** compression right and left lateral faults and compression reverse faults in the upper part of Tanjero Formation; **Site-4)** two set of post-tilting reverse and right lateral strike-slip faults constrain NE – SW σ1 orientation; **Site-5)** post-tilting conjugate reverse fault systems in thick limestone of Aqra Formation

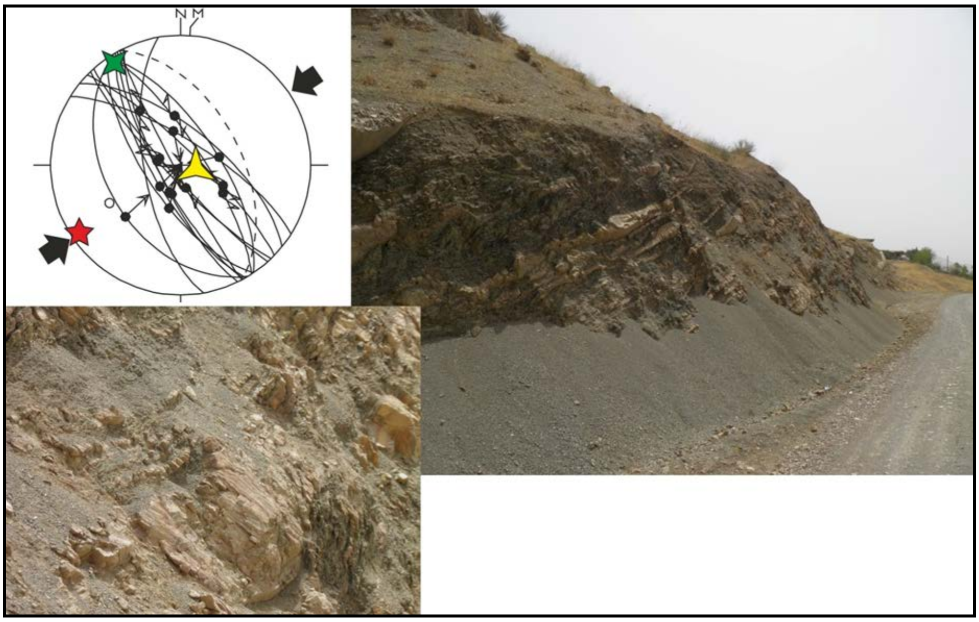


Fig.6: **Site-6)** post-tilting conjugate reverse fault systems in Upper part of Tanjero Formation

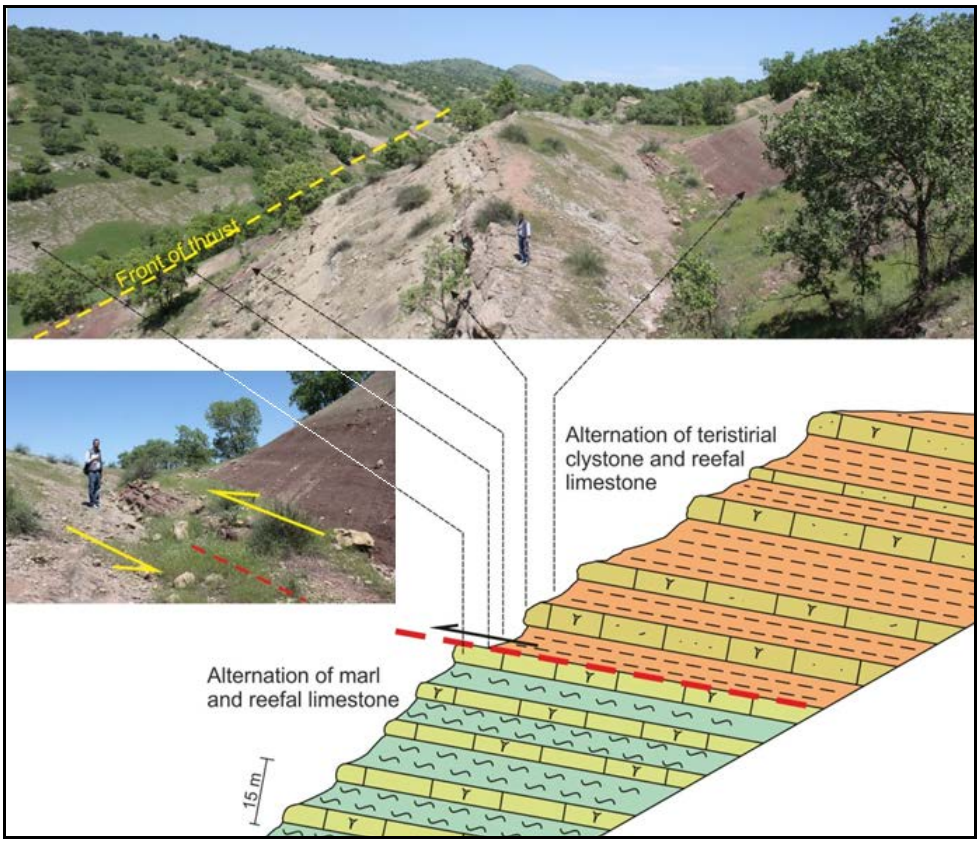


Fig.7: Geological cross section shows the limestone/ claystone Aqra Formation overthrusted over the limestone/ marl of Aqra – Tanjero Formation. The thrust fault is parallel to the bedding plane (bedding thrust). Existence of large rudist in the limestone indicates that this sequence belong to the Aqra Formation and not to the Red Bed Suwais Formation. The figure in the left up also shows the claystone is a detached layer from the thrusting

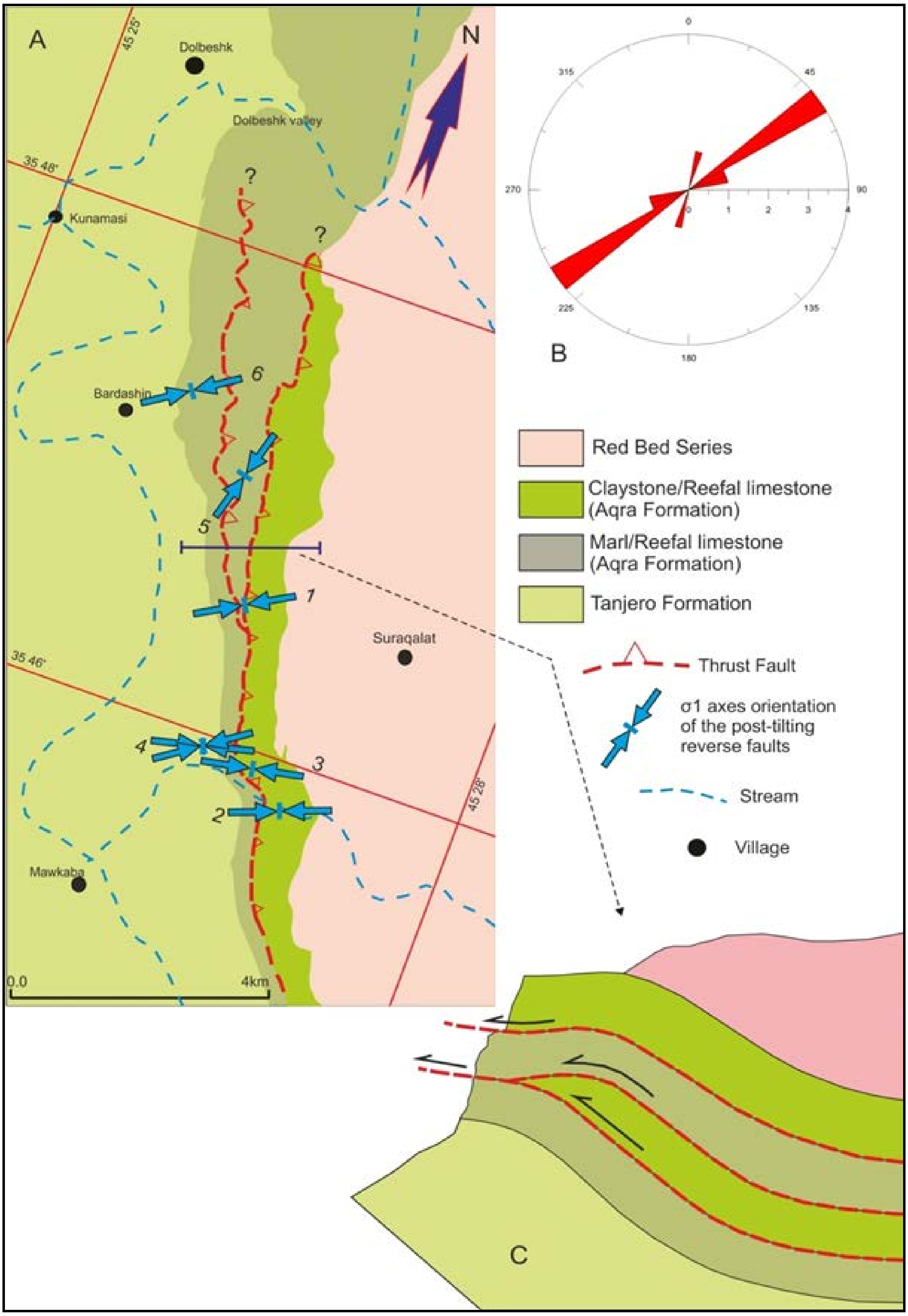


Fig.8: **A)** Geological map of the studied area shows the studied thrust and miceotectonic sites and its compression (σ1) orientation; **B)** Rose diagram of reconstructed σ1 axis orientations from post-tilting compression faults **C)** Schematic cross section model shows the duplex thrust fault

## DISCUSSION AND ANALYSIS OF THE THRUST FAULT

The main result of this study is the identification of a large thrust fault. This fault has affected the beds of Aqra Formation in such a way that clay/ limestone succession has overlapped Marl/ limestone succession. The trace of the thrust fault disappeares in the south of Kele village suddenly, but the thrust is most possibly continuous toward Mawat town.

From the analysis of the field data three main points can be discussed:

1- The two lithofacies that we identify (clay/ limestone and marl/ limestone lithofacies) in the Upper part of Tanjero and Aqra formations deposited during same period (Upper Maastrichtian) because both facies contain fossils of the Late Maastrichtian. Both facies were deposited in the shallow part of the trench. The clay/ limestone lithofacies deposited in the shallower part of the Foreland basin very close to the shoreline, while the marl/ limestone lithofacies deposited in the deeper part as compared to the first facies. The shallower facies due to the thrust fault exists above the marl/ limestone lithofacies at present (Fig.7).

2- Both marl/ limestone and clay/ limestone lithofacies are overlain, by the Red Bed Suwais. This is explained by the two facies being deposited in the same basin and same period.

3- All the microtectonic fault sites show the movement trend of the main thrust (Fig.8). Furthermore, the compression fault is post-tilting indicating that the thrust fault is formed during the last stage of the collision. The reconstruction of σ1 orientation from the results of the compression faults indicates that the displacement of the thrust fault is toward SW (Fig.8).

The studied area structurally is highly complex since it contain large graben (Karim and Surdashy, 2006), lateral thrusts (Karim and Sulaiman, 2012) and Main Thrust Zone (MTZ) (Jassim and Goff, 2006). This complexity is due to rapid facies change of Aqra Formation in all directions (Sadiq, 2010).

The interfingering of fossiliferous limestone with red clastic was a problem for geologists since it was not known if the red clastic belongs the Cretaceous or the Paleocene. Recently Karim and Khanaqa (2014) suggested that the red clastics belong to Maastrichtian on the basis of the content of in situ rudists. The red clastics are deposited more to the north as a coastal facies during the Upper Maastrichtian. This complexity is further extended to the south to Surdash and Azmir anticlines (Al-Hakari, 2011; Omer, 2011 and Omer *et al*., 2016).

The thrust fault is mainly composed of two continuous large scale faults and generally strikes NW – SE, with SW dipping feature with a dip angle of less than 15° and is parallel to sub-parallel to the foliation and bedding (Fig.8). Structurally, this thrust originated as a thrust duplex system that passed the ductile-brittle transition. This period of crustal shortening and forming the thrust fault formed during the extensive collision and after folding.

The propagation and movement of the thrust faults is not in a straight line, but is slightly irregularly changing direction (Fig.8). The reverse fault formed after folding (post-tilting) indicates the fault was formed during main thrust of Zagros. From analysis of these reverse faults NE – SW orientation of the σ1 is obtained (Fig.8B). This orientation shows the same orientation of the Arabian-Eurasian collision direction.

The thrust has generally the same trend of the faults fold, and thrust belt of the region, which is characterized by NW – SE-trending and SW-verging fault related folds (De Vera *et al*., 2009). These types of thrust faults are most possibly, at least in part, controlled by basement faults. Same observations are observed in the Zagros fold and thrust belt in Iran

(Berberian, 1995; Sepher and Cosgrove, 2004, Sepher and Cosgrove, 2004; and Alavi, 2007). Outstanding problems in Kurdistan include the deep structure and the nature of the basal detachment layer. The Zagros fold and thrust belt in contiguous Iran is widely interpreted as being detached on the Cambrian Hormuz Salt (Sepher and Cosgrove, 2004; and Alavi, 2004 and 2007).

## CONCLUSIONS

This research concludes that a large Foreland-vergent thrust fault is recognized in the Mawat area. This fault overthrust the terrestrial clay/ reefal limestone lithofacies over the marl/ reefal limestone lithofacies of Maastrichtian Aqra Formation. Many post-tilting compression faults recorded inside the Maastrichtian beds of Aqra and Tanjero Formation accompany the main thrust fault. These compressions, give the result of σ1 orientation toward NE – SW which ensure the main compression direction of Eurasian-Arabian collision.

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