Origin of lateral thrust in Mawat area, Kurdistan, NE-Iraq

K. H. Karim & S. H. Sulaiman
Department of Geology, University of Sulaimani, Iraq

Abstract

In the Kurdistan part of the Zagros Fold-Thrust belt, as whole Zagros, many deformation types and scales are described which all have effects on oil accumulation and preservation. One of these deformations is lateral thrust which must be encountered during a search for oil in the area. At present, the lateral thrusts are described and analyzed for the first time in the area.

The origin of the several lateral thrusts (oblique local thrust) are studied in Mawat area from Kurdistan Region of northeastern Iraq at about 30km to the north of Sulaimani city. The study is achieved in terms of the relation with both the Main Zagros Thrust Fault and the graben that exists in Chwarta-Mawat. These local thrusts are occurring in two groups, each group dips nearly 15º in opposite directions towards the northwest and southeast (about 340º and 155º respectively). The thrusts are associated with small reverse faults with nearly the same dip direction. These directions are nearly normal or oblique to dip direction of the Main Zagros Thrust Fault. The origin of these oblique thrusts is attributed to one of the following four possibilities:

1. Local thrusts may belong to the lateral boundaries of the Main Zagros Thrust Fault (MZTF). The lateral boundaries make up the lateral thrust of the main thrust fold thrust belts. Field evidence that aids this probability is that the Main Zagros Thrust Fault is located about 2km to the northeast of the location of the lateral thrusts. Other evidence is the angle of striations of the associated reverse faults surface which is about 15–20. These angles are close to the direction of the sigma one of the Main Zagros Thrust Fault which is about N38E degrees in the studied area. 2. The possibility is that these thrusts are generated by shortening associated with the graben that is bounded by two large normal faults which are mentioned in previous studies. The third possibly is that the thrusts are formed under the effect of two of the above factors which include horizontal stress of the local front of the main Zagros thrust and vertical stress

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associated with the graben. This notifying the apparent difference in imposed stress (σ1) that generated the local thrusts and main Zagros thrust faults. Moreover, the direction of the sigma one (σ1) of the local thrusts do not coincide with that of the Main Zagros Thrust Fault (MZTF), but they stand nearly normal to it. The last possibility is the poly-phase deformation of Zagros Orogenic Belt.

Keywords: lateral thrust, oblique thrust, Aqra Formation, Zagros Main thrust, Chwarta-Mawat area.

1 Introduction

The area located at 30km to the north of Sulaimaniyah city about 4km to the southeast of Mawat town on the both side of the valley stream of Mokaba (extreme upstream of Little Zab River in Iraq) (Fig. 1). The lateral thrusts are exposed along southwest facing erosional scarp of a ridge (Questa). The ridge is about 250m high and formed by lateral and vertical erosion of the above mentioned stream (Fig. 2). The dip slope of the ridge is facing toward northeast and has 25 degrees of slope. The ridge elongates from 6km southwest of Chuarta town (from Qishlagh village) towards northwest and terminated at 3km southeast of Mawat town, near Dere village. This ridge is called Qishlagh−Dere ridge. The lateral thrust faults can be seen in several locations along the scarp such as northeast of Mokaba, Dolbesh, Kareza, Konamassi and Mokaba Villages. The largest one can be distinguished from Google Earth at the latitude and longitude of N: 35 48 8.53 and E: 45 25 42.35.

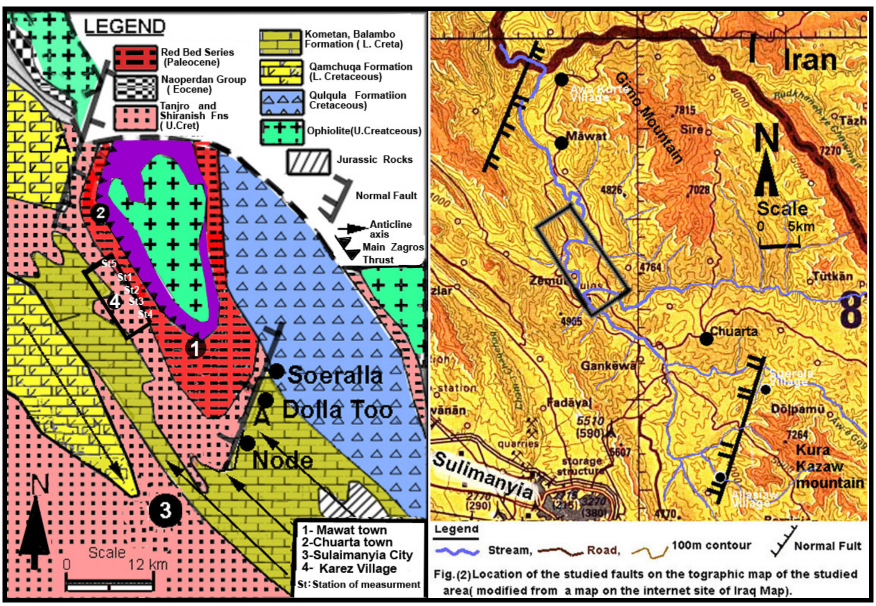

Figure 1: Left) geological map of the studied area (modified from [1]). Right) topographic map of the studied area (taken from *Iraq map* internet site).

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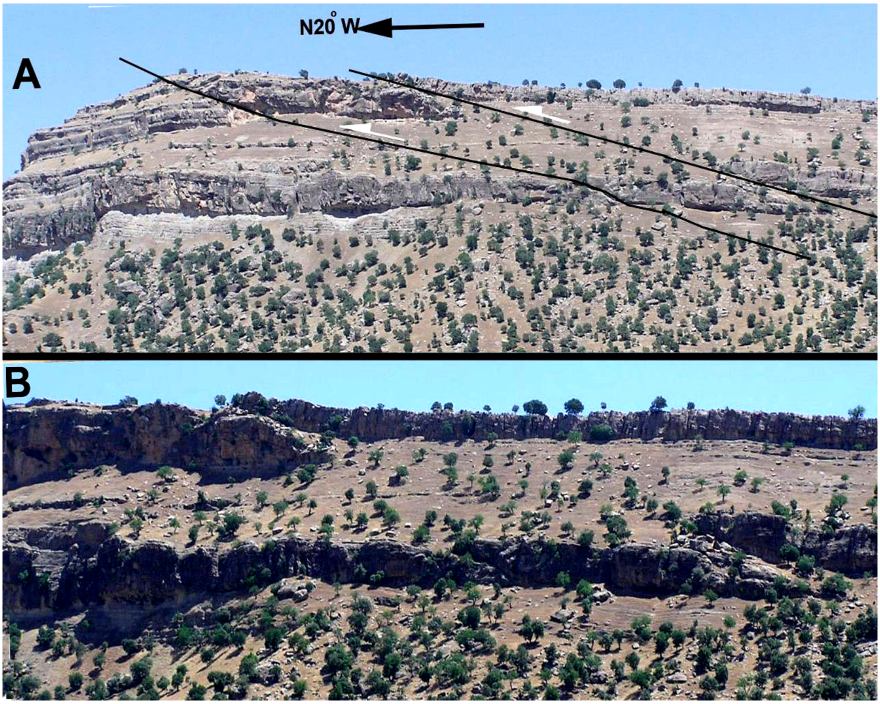

Figure 2: A) an erosional scarp northeast of Kareza village showing southeast dipping lateral thrust cutting two limestone beds of the Aqra Formation, each about 7m thick at station five (St5). B) close up view of the upper fault.

The aim of this study is recording and analysis of the occurrence of lateral thrusts in the Imbricated Zone into which the exploration works of the oil companies are expanded recently. Accordingly, this study is useful for these companies for understanding of the structural setting of the area especially; it is possible that they occur at depth too.

2 Geological setting of the area

The studied area has complex geological setting which manifested by exposing of highly deformed mixtures of all type of rocks, sedimentary, metamorphic and igneous at the northern boundary part of area to the north of Chwarta and Mawat towns. In the southern part, only sedimentary rocks are exposed in which the lateral thrusts are observed. The geological complexity of the area is attributed to the fact that the area located in the Imbricated Zone of Buday [2], Buday and Jassim [3] and Jassim and Goff [4]. According to Karim [5], the studied area is located between two large normal faults that transformed the area to a graben (Fig. 1). On the other side, the area represents part of the area where the continental part of Iranian and Arabian plates occurred during Miocene [6] or at Eocene [7] or during Upper Cretaceous [8].

One of the lateral thrusts has attitude of 25º/35º and cut the fossiliferous limestone of Aqra Formation that is exposed at the top of the scarp slope of a homocline (or questa) while Tanjero Formation is exposed at the base and middle of the scarp (Fig. 2). The thrusts also appear in the conglomerate of the lower part of the Tanjero Formation but they are badly developed and they mostly appear as zone of deformation. At few kms to the north and northeast, the Red Bed series, ophiolite and Walash-Naoperdan series are exposed. The relations between these units are tectonic as concerned to the stratigraphic boundaries.

3 Discussions

Lateral ramps (lateral thrusts) are a natural part of the architecture of fold-and-thrust belts as a zones where décollements change stratigraphic level along strike; they differ from frontal ramps, where the décollements change stratigraphic level perpendicular to strike [9]. According to same author, the term “lateral ramp” was used by Boyer *et al.* [10], Butler [11], and Hossack [12] to describe a tectonic ramp that is parallel to the transport direction of regional thrust sheets.

3.1 Main Zagros thrust

In Iraq, the lateral thrusts are not found although important part of Western Zagros Fold-Thrust belt is located in side this country. On contrary to lateral thrust, frontal thrust (frontal ramp) is well documented in Iraq by Stocklin [13] Buday [2], Buday and Jassim [3], McQuarrie [14] and Jassim and Goff [4]. These authors are described the frontal thrust under the name of “Main Zagros thrust” or “Main Zagros suture Zone” and “Main Zagros reverse Fault” which elongate nearly parallel to Iraq-Iran border in the direction northwest-southwest. The field study, by the authors, in the northeastern Iraq revealed that the main thrust (frontal thrust has the dip between 10º and 35º. The shallow dip angle is between 10º and 20º and exists in the low lands such as Mawat-Chuarta area while the high angle (20º−35º) exist where the thrust climbs the elevated anticlines in the Avroman–Surren and Kaolos–Chwarta areas, in the latter cases the thrust can be called reverse fault .

3.2 Lateral thrusts (lateral ramps)

As mentioned before the lateral thrusts are not found in Iraq before, therefore the present study is the first one that record and describe these structures in the Mawat area. The thrusts exist in the fossiliferous limestone of the upper part of Tanjero Formation (Aqra lens). The attitudes of the lateral thrusts are consisting of two types which are existing in the same succession (or beds). The first ones are dipping northwest and the other ones dipping southeast with the attitude of 10º−25º/330º–355º and 10º−25º/145º−160º respectively (Figs. 2, 3 and 7).

Figure 3: A) northwest dipping lateral thrust (St 6) at south of Sura Qalat village cutting a limestone beds about 4m thick. B) close up view of the upper fault at station (St 4). The bed is 3m thick.

In the two cases (stations 5L and 6L), the thrusts have the displacement of more than 25m and cut across the thickness of the formation for about 50m as can be seen northeast of Kuna Massi, Dolbesk villages and southwest of Kele Village. In between the two large thrust, there are many small reverse faults in the same direction of displacement of the thrusts (Figs. 4 and 7C). These reverse faults are occurring in decimetric scale and associated with mineralization and striation at the station (St1, St2, and St3) at the southwest of Sura Qalat Village. In the thrust and reverse faults, the strikes of the faults surface are nearly parallel to the shorting direction of the Zagros Fold-Thrust Belt. In literature, lateral thrusts (lateral ramps) are recorded in the many lab and field studies. Among these studies it worthy to mention that of Schreurs *et al*. [15].

3.2.1 Reasons for the lateral thrust

Lateral thrust and oblique ramp allow oblique migration of the thrust front [16]. The dip of the lateral ramp decreased along strike toward the frontal ramp in the brittle-viscous domain, from about 30º to less than 10º [17]. Pohn [9] mentioned that no major thrust fault (frontal ramp) can continue indefinitely along strike, therefore the presence of lateral ramps in fold-and-thrust belts is the result of one of the two possibilities. The first is that the thrust die out by diminishing displacement and then the lateral boundary is developed as a lateral thrust. The second is that thrust sheets transfer their displacement to some cross-strike fault via a lateral ramp.

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Figure 4: A and B) fault surface showing striation and mineralization. These features exist only on the surface of small reverse faults between the lateral faults. Both the compass and hammer are pointing toward north. The Hammer head is pointing to north.

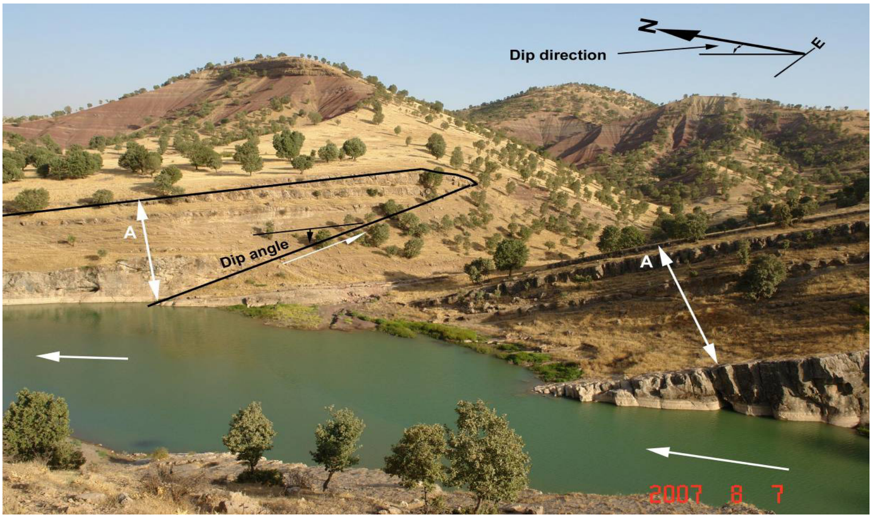

Figure 5: Northwest dipping lateral thrust ion the Aqra Formation (or Lens) at 2km south of Kele village, on the right bank of Dolbeshk stream. The limestone succession (A) is repeated by thrusting which is about 20m thick. The longitude and latitude reading of GPS of this location is (N: 35 48 17.55 and E: 45 26 99.

In the present study, it is not known exactly if these lateral thrusts are associated with a local front of Main Zagros Thrust Fault or not. This is because the main thrust is about 2km far from the position of lateral thrust to the northwest. Therefore, there are four possibilities for origin of these lateral thrusts. The first: it is possible that the main thrust has more southwest advance front (local front) than that previously indicated. In this connection, there are some signs of small frontal thrust or reverse fault along the Qishlagh–Dere ridge and along Amir–Goiza anticlines at 10km to the south. The second is that the local lateral thrust is representing shortening (of the upper part of the succession) due to graben that described by Karim [5]. The graben is located between two large normal faults at east and west of the studied area. This shortening is true when the graben assumed to be generated by subsidence due to excessive loading of Mawat area due to accumulation of huge pile of sediment and or by tectonic loading due to accumulation of accretionary prisms mentioned by Karim [18, 19], Karim and Surdashy [8]. The third possibility is that the shortening is activated by both vertical subsidence of the graben and horizontal advance of the local front of the main thrust.

The forth possibility is that the stress state in direction NW-SE. This stress was mentioned by the following workers. Al-Fadhli *et al*. [20, 21] studied polyphase deformation and superimposed folding in Piramagroon, Surdash and Sayed-Sadek folds. They have pointed to the compressive tectonic phase in the direction NW-SE. Al-Jumaily [22] studied tectonic investigation of the brittle failure structures in the foreland fold belt in northern Iraq and he deduced the compressive tectonic stress in the direction NW-SE. Al-Hakari [23] studied paleostress analysis from minor structures indicated that the investigated area was subjected throughout its geological history to the stress states in the direction NW-SE parallel to sub parallel to the major structure axes.

Table 1: Data recording and type of the faults in the five different stations (St1, St2, St3, St4 and St5) of the studied area (see figure 1 for location of stations).

Attitude of the fault plane	Pitch angle	Type of fault	**Attitude of the fault plane**	Pitch angle	Type of fault
St1: 240/45	60 from SW	Reverse	St3: 015/70	20 from NE	Reverse
St1: 251/40	58 from SW	Reverse	St3: 020/60	30 from NE	Reverse
St1: 220/48	50 from SW	Reverse	St4L: 150/20	20 from SE	Thrust
St1: 255/50	48 from SW	Reverse	St4L: 166/16	18 from SE	Thrust
St1: 245/45	55 from SW	Reverse	St4L: 156/22	20 from SE	Thrust
St1: 230/42	60 from NE	Reverse	St4L: 160/18	18 from SE	Thrust
St1: 225/48	50 from SW	Reverse	St4L: 140/20	20 from SE	Thrust
St2: 325/60	15 from NW	Reverse	**St5L:** 315/18	22 from NW	Thrust
St2: 330/70	20 from NW	Reverse	**St5L:** 340/22	18 from NW	Thrust
St2: 340/60	18 from NW	Reverse	**St5L:** 330/20	20 from NW	Thrust
St2: 315/65	22 from NW	Reverse	**St5L:** 156/22	20 from NW	Thrust
St3: 005/60	26 from NE	Reverse	**St5L:** 325/20	16 from NW	Thrust

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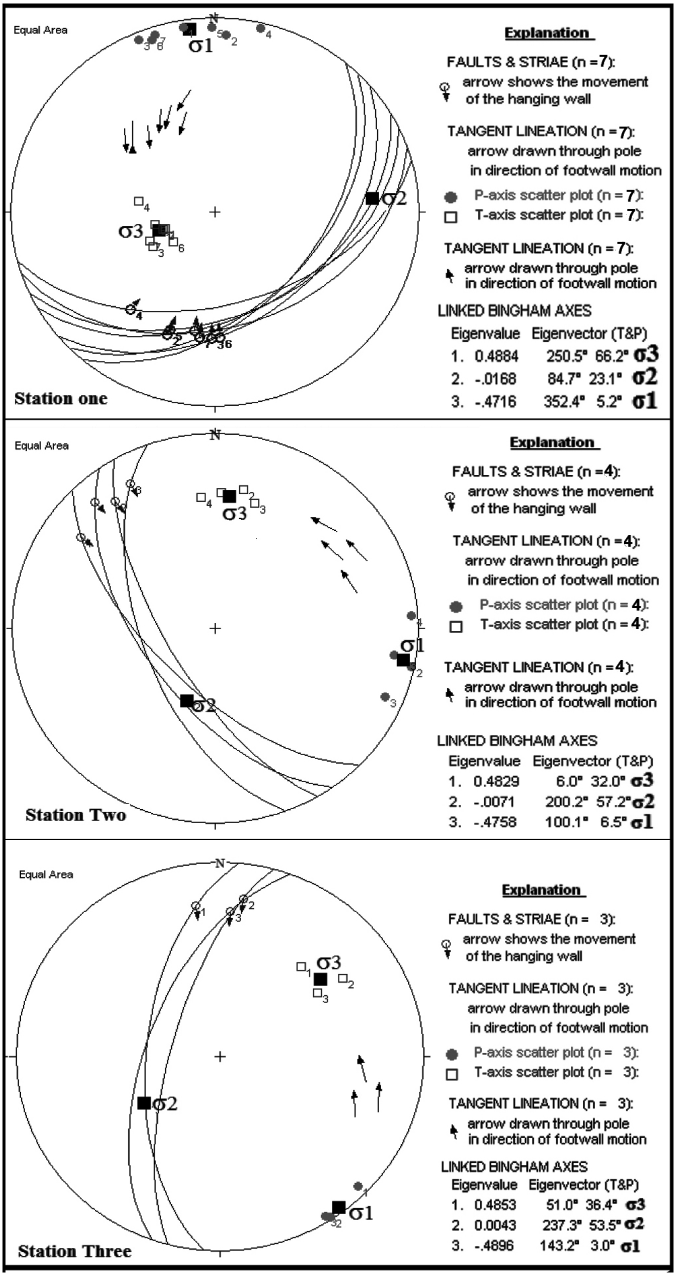

Figure 6: Stereonets analysis of the attitude and stress (σ1, σ2 and σ3) distribution of the small reverse faults at station St1, St2 and St3 that associated with lateral thrusts. St: station, p: pole.

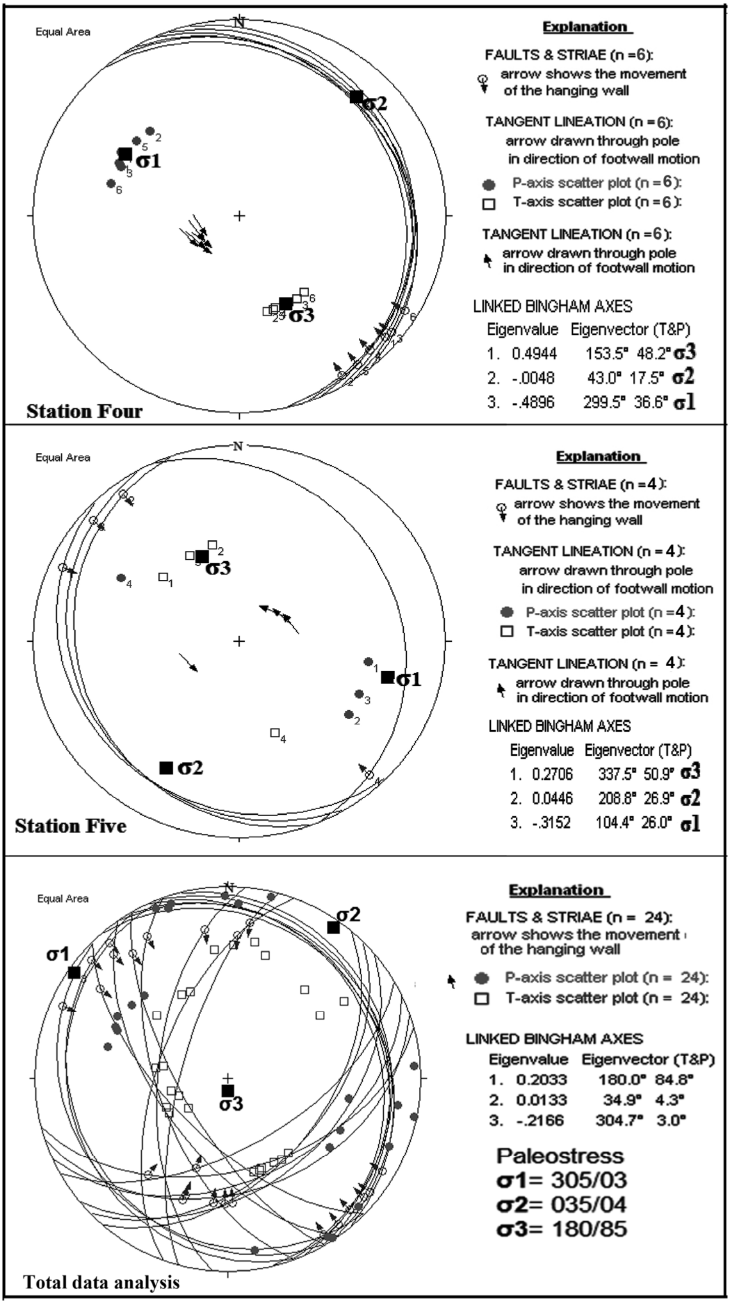

Figure 7: Streonets show the analysis of the attitude and stress (σ1, σ2 and σ3) distribution of the large lateral thrusts at station St4, St5 and comparison with the main Zagros thrust. St: station, p: pole.

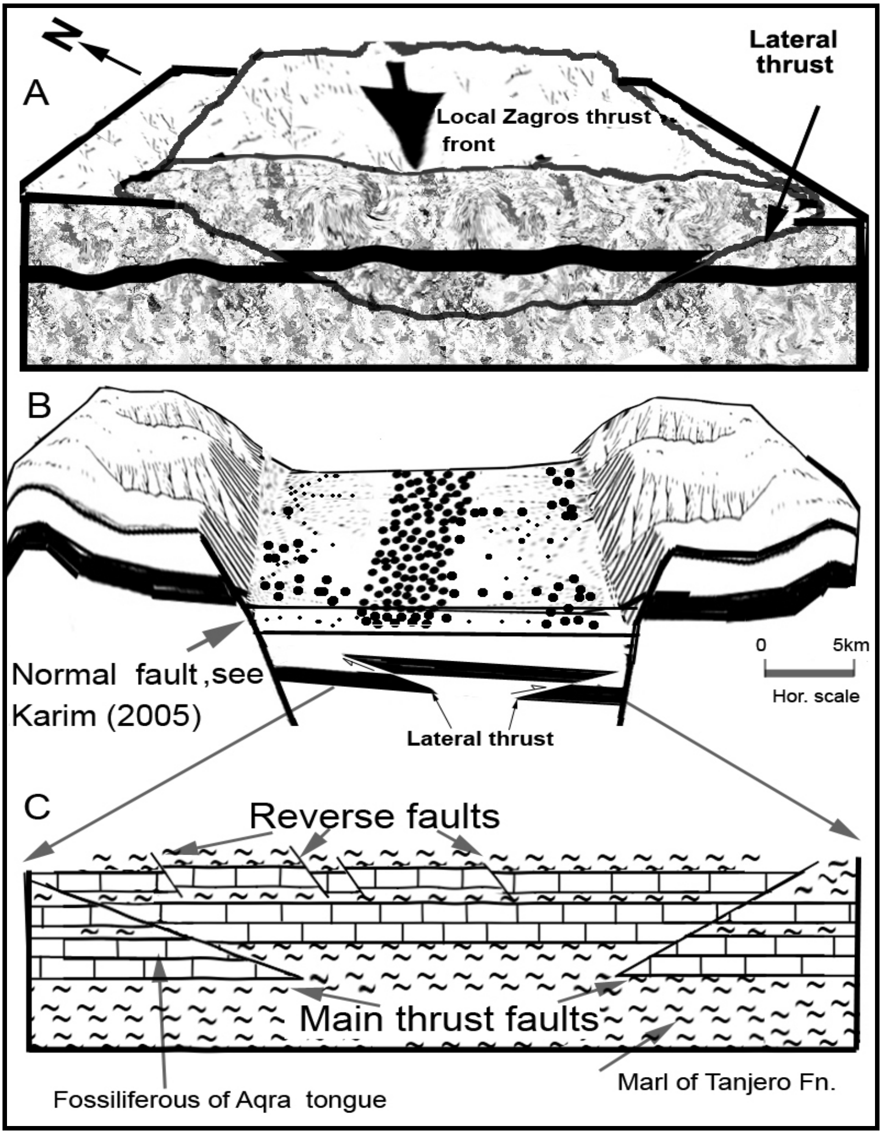

Figure 8: Field based sketches to show the possible origins of both the large lateral thrust faults and e small reverse faults. A) lateral thrusts as a boundary of the local front of Main Zagros Thrust Fault. B) lateral thrusts as due to a shortening that associated with graben subsidence (see [5]). C) lithologic detail of the.

3.3 Paleo-stress analysis from fault-slip data

The paleostress is analyzed using FaultKinWin 1.2.2 Program, 2001 (Richard W. Allmendinger). The software relies on Lisle [24] A-B dihedral method extension to the P&T dihedral method by Angelier and Mechler [25]. The minimum data required for FaultKinWin to work are the entries of: Fault plane orientation; strike, dip and dip direction in addition to striations or slickenside's orientation. For the striations, either trend and plunge or rake is required.

The data are represented stereographically in which the software plots the faults and the striations and calculates the attitude of (σ1, σ2 and σ3) and indicates the direction of the footwall and hanging wall movement by arrows. The paleostress which resulted from mesolateral thrust and reverse faults are compared with that of the main Zagros thrust fault to see angular relation between them.

Two of the stations are located on the local lateral thrusts while the rest are located on the small reverse faults that situated in between the two lateral thrusts (Figs. 4 and 8c). According to this method, the data of the lateral thrust and reverse faults are compared with that of the main Zagros thrust fault to see angular relation between them.

4 Conclusions

This paper has the following conclusions.

1. Two types of local lateral thrusts are found in the fossiliferous limestone of Upper Part of Tanjero Formation (Aqra formation) in Mawat area, about 2km to the south of Main Zagros Thrust.
2. The first one dipping toward southwest and the other one toward northwest.
3. In between the two thrust several small reverse faults are recorded that have dip direction nearly coincide with that of the thrusts.
4. The development of the reverse and thrust are attributed to possible occurrence of the local front of the main Zagros thrust fault or to shortening resulted by a graben that mentioned to occur in the studied area in previous studies.

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