JJEES
Jordan Journal of Earth and Environmental Sciences

Volume 8, (Number 2), Dec, 2017
ISSN 1995-6681
Pages 55 - 60

Structural Evolution of the Area North of Ajloun Dome, Jordan

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Received 24 January, 2017; Accepted 10 October, 2017

Abstract

The detailed mapping of the area north of Ajloun dome proved the existence of conglomerate beds (equivalent to Dana Conglomerate) of post Eocene (Post Umm Rijam). Other outcrops in the area range from Turonian to Miocene. The structures in the present study area consist of one Syncline (Ausara Syncline), a group of normal faults, one strike slip fault, and a group of systematic joint sets. The Ausara symmetric syncline is trending S65ºW, plunging 17º. It was formed during the second stage of the Syrian Arc Stress field (SAS), after the formation of Ajloun dome, which was formed in the Upper Cretaceous, during the first phase of the Syrian Arc folding. Normal faults, grabens and horsts trend NNW. They are parallel to the general Dead Sea Stress field (DSS) which trends NNW-SSE compression and ENE-WSW tension. They formed after the Ausara syncline because one of these fault truncated the syncline. Horizontal fault block rotation is indicated from the change in the general strike of the joint sets. The area close to the Jordan valley was tilting to the west as indicated from the general westward dipping of the Tertiary and the underlying Upper Cretaceous beds. The general structure of the area can be described as faulted flexure.

Keywords: Ausara syncline, Ajloun dome, Syrian Arc Stress (SAS), Dead Sea Stress (DSS).

1. Introduction

Most of the geological structures in Jordan are related either to the formation of the Dead Sea Transform (DST) or to the Syrian Arc Fold Belt (SAB). Example of the structures related to the DST is the fault system in east Jordan (Atallah, 1992; Diabat and Masri, 2005) (Figure 1). Examples of the structures related to the SAB are Ajloun Dome, Koura Basin, Amman-Hallabat structures and some fold structures east of DST (Abed, 2000). The formation of some folds can be related to the formation of the DST (Atallah, 1992) (Figure 1).

The Dead Sea Transform (DST) is a major sinistral strike slip fault. It extends more than 1000 km from the Gulf of Aqaba in the south to Taurus Mountains in the north. It separates the Arabian plate to the east from Sinai sub-plate to the west (Figure 2). In Jordan, the DST consists of three segments: Wadi Araba fault in the south, the Dead Sea basin in the middle and Jordan valley fault in the north (Figure 1). Jordan valley extends from the Dead Sea to the Lake Tiberias; it is crossed by the sinistral active Jordan Valley Fault (JVF) (Figure 1).

SAB is one of the most important geological systems in the Middle East. It controls the topography of the area to form heights and depressions. SAB extends in S shape from northern Sinai to Lebanon and southern Syria (Figure 2).Some fold structures in Jordan were considered as part of SAB (Abed, 2000). It was formed in two phases; the first phase was in the Late Cretaceous (Turonian to Masstrichtian) and the second phase in the Paleogene (Oligocene), where it was formed as a result of the closing of Neo-Tethys due to the northward movement of African-Arabian plate. The Levant was part of the plate which led to the Folding (Abed, 2000). Abed El Mota'al and Kusky (2003) suggested that the intensity of the folding and thrusting increased from Oligocene to Miocene with separation of the Arabian plate from the African plate.

Two main stress fields were identified in the Middle East since the Late Cretaceous (Eyal and Reches, 1983; Diabat et al., 2004). The Syrian Arc Stress field (SAS) trending ESE-WNW compressional stress, followed by the Dead Sea Stress field (DSS) trending SSE- NNW.

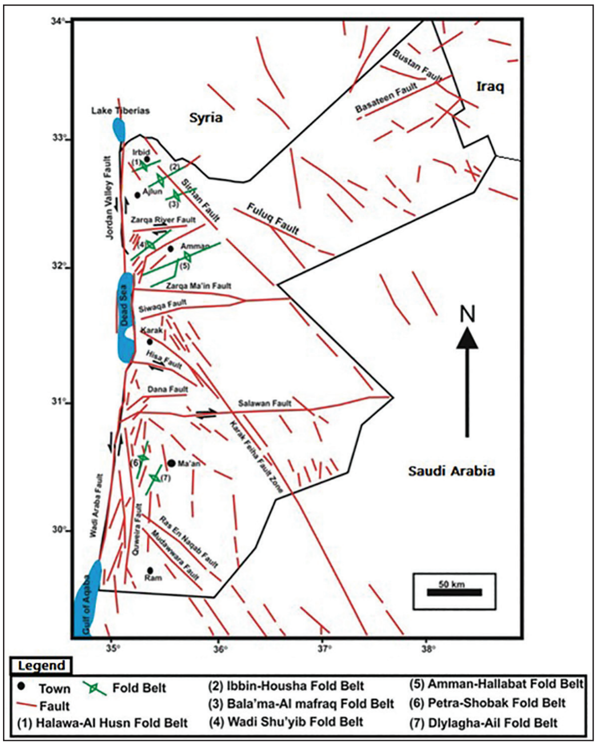

Figure 1. Fault system east of the DST (Modified after Atallah, 1992; Diabat and Masri, 2005)

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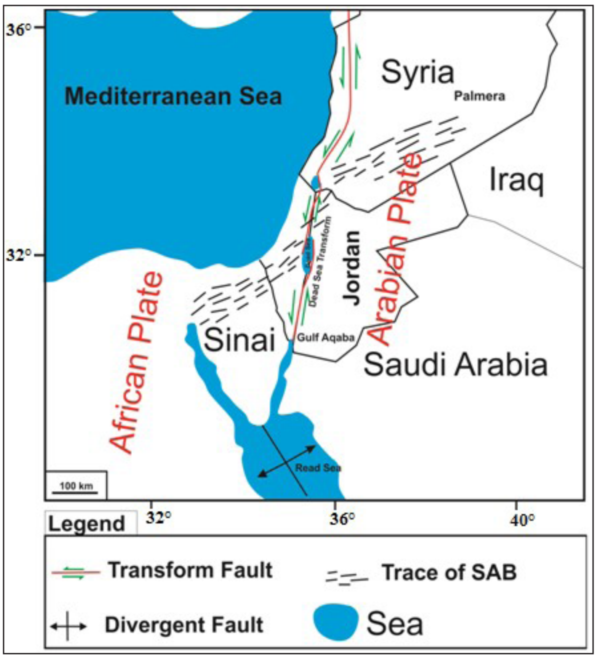


Figure 2. Tectonic setting of the Dead Sea Transform and the Syrian Arc Fold Belt (Modified after Garfunkel, 1981)

The present study area is located east of the Jordan valley fault, about 25 km southwest of Irbid (Figure 3). It extends from Ausara area (NW of Ajlun) passing through Halawa village to the Jordan valley (Figure 3).

The present study aims to map and analyze the structural elements in the area of investigation; in addition to understand the relationship between these structures and both the Syrian Arc System and the Dead Sea Transform. One of the interested features in the present study area is the folded Dana conglomerate. This study will describe this structure and find its relation with the Ajloun dome.

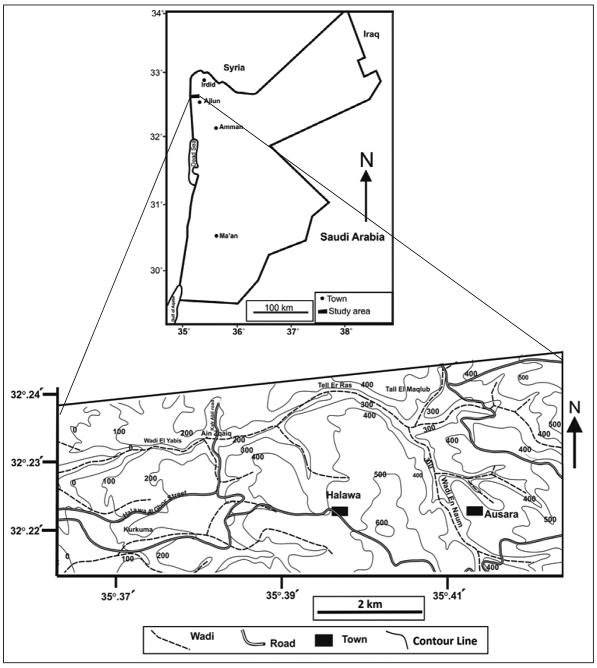


Figure 3. Location and topographic map of the study area.

2. Stratigraphy

The major outcrops in the present study area are Ajloun Group, Belqa Group and Jordan Group. Their age ranges from Late Cretaceous to Miocene (Figure 4). Ajloun Group consists basically of carbonate rocks. Belqa Group is composed mainly of chalk, chert, phosphate, limestone and marl. Jordan Group is composed mainly of conglomerate. Figure (4) is a geological map of the study area.

In the study area, the only outcropping formation of the Ajloun Group is the Wadi As Sir Limestone. It is of Turonian age and composed mainly of limestone, dolomite, and marly limestone. The thickness of this formation is 120 m (Abu Qudaira, 2005).

The Belqa Group consists of the following formations: Wadi Umm Ghudran Formation. It ranges from Coniacian to Santonian. Its thickness ranges from 25-40 m and comprises of white-gray massive chalk and chalky limestone. Amman Silicified Limestone and Al Hisa Phosphorite. They are of Campanian to Maastrichtian age and they are composed mainly of chert, limestone, and some phosphates. Their thickness is 70m. Muwaqqar Formation is of Maastrichtian to Paleocene age. It is composed of chalky limestone and marly limestone, its thickness reaches 150 m. Umm Rijam Chert Limestone is of Eocene age. It is 45 m thick and consists mainly of alternating of chalky and marly limestone and chert.

The Ausara conglomerate layers are exposed along the road from Ba'un to Judeta, Another outcrop of conglomerate exposed west of Ausara village, Here, the conglomerates are folded in a well-formed syncline. They lie on the Umm Rijam Formation (Figure 5). The age of Ausara Conglomerate is post Umm Rijam Formation (Post Eocene), which is equivalent to Dana Conglomerate. The thickness of the Ausara conglomerate reaches 40-60 m. It can be considered as part of the Jordan Group.

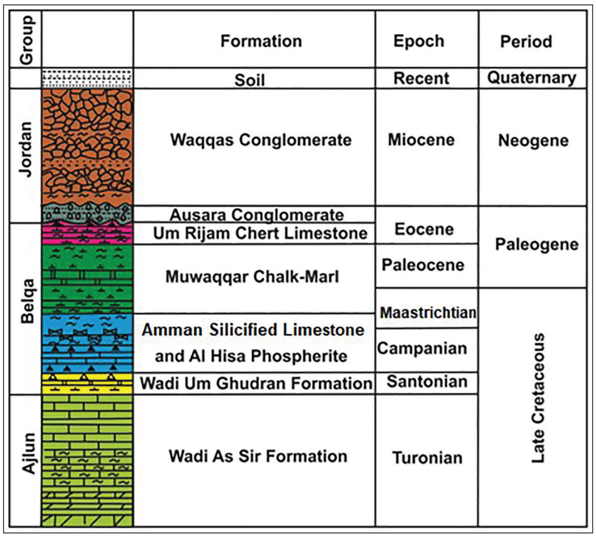


Figure 4. A general geologic column of the study area. (Modified after Abu Qudaira, 2005)

Waqqas Conglomerate as part of the Jordan Group is of Miocene age. It is composed mainly of gravel, silt and limestone (Abu Qudaira, 2005). The thickness of this unit reaches 150 m.

3. Structural Elements

3.1. Ausara Syncline

The Ausara Syncline locates northwest of Ausara village andeast of Halawa village along Wadi En Naum (Figure 5). The fold axis extends more than 4.5 km. The width of the syncline is about 4 km. The folded beds are Late Cretaceous-Paleogene. They are Muwaggar Formation, Umm Rijam Formation and the Ausara Conglomerate.

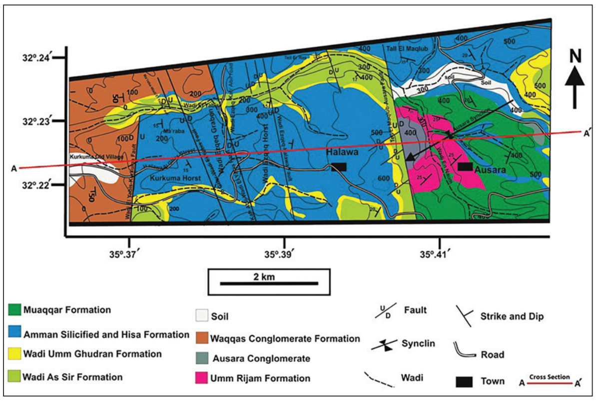


Figure 5. Geological map of the study area

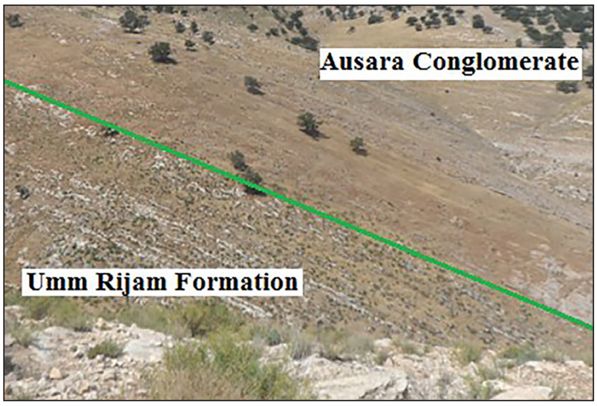


Figure 6. Conglomerate layers lie on the beds of the Umm Rijam Formation

Ausara Conglomerate form the core of the syncline (Figure 7). The Ausara Syncline is symmetric. The fold axis plunges17º and trends S65W. The inter limb angle is 64º, which means that it is an open fold (Figure 8) (Pluijm andMarshak, 2004).

3.2. Normal Faults

The study area was divided into three structural domains. Each domain contains a group of normal faults; they are: Kurkuma structural domain, Wadi Ezqeq-Tell ErRas structural domain, and Tell El Maqlub-Ausara structural domain.

3.2.1. Kurkuma Structural Domain

It is located in the western part of the study area, northeast of Kurkuma old village (Figure 3). The major faults in this structural domain are: Wadi El Yabis-Kurkuma Fault, Al Ghor-Wadi El Yabis Fault, KafrAbil-Wadi El Yabis Fault and Ma'raba-Wadi El Yabis Fault (Figures 5 and 9).

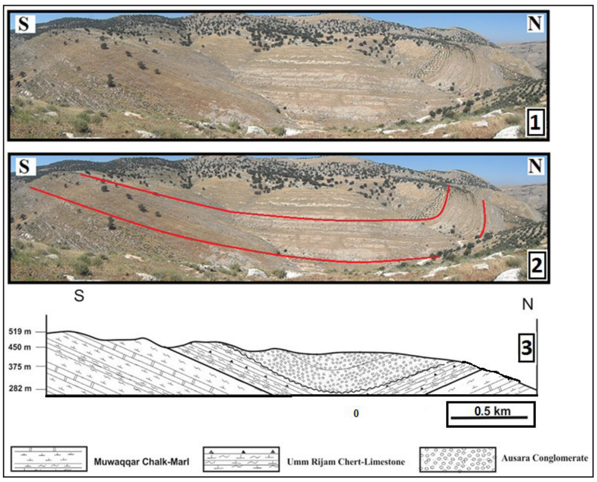


Figure 7. Part of Ausara Syncline (1, 2) and Cross section of Ausara Syncline (3)

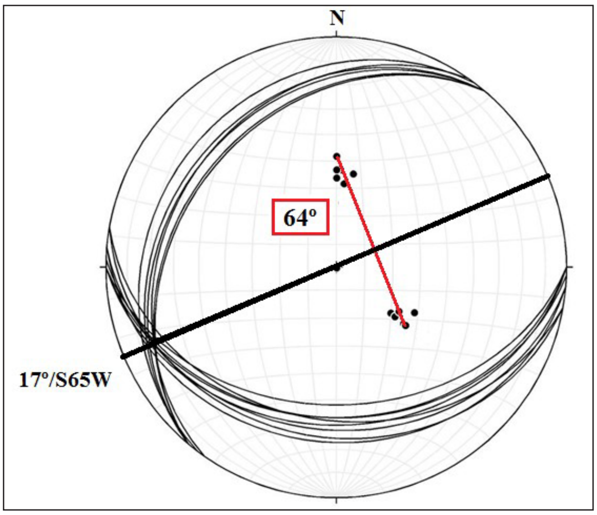


Figure 8. Stereonet diagram of Ausara Syncline. The fold axis trends S65W and plunges17º. The inter limb angle is 64º.

► *3.2.1.1. Wadi El Yabis-Kurkuma Fault*

This fault is located in the western side of the domain; it extends about 2.5 km (Figure 9). The strike of the fault plane is N5E with 140-180 m down throw to the west. This fault juxtaposes the Amman Silicified and Al Hisa Formations to the east against Waqqas Conglomerate to the west.

► *3.2.1.2. Al Ghor-Wadi El Yabis Fault*

It extends about 4 km. The strike of the fault plane is N20W (Figure 9); the downthrow is 70-90 m to the east. The Wadi Umm Ghudran Formation is downthrow relative to the Wadi As Sir Formation. It shows normal drag close to the fault plane (Figure 10).

► *3.2.1.3. Ma'raba-Wadi El Yabis Fault*

It is a small-scale normal fault and it is part of the Kurkuma Structural domain. The strike of fault plane is N20W. The downthrow is about 40-60 m. It juxtaposes Umm Ghudran Formation against Wadi As Sir Formation. Ma'raba-Wadi El Ybis Fault and Al Ghor-Wadi El Yabis Fault formed a horst between them (Figure 10).

3.2.2. Wadi Ezqeq-Tell Er Ras Structural Domain

It is located northwest of Halawa village. It extends from Tell Er Ras to Wadi Ezqeq (Figure 5). The major fault in this domain is the Wadi Ezqeq-Halawa fault; it extends about 3.5 km (Figures 5 and 11). The strike of the fault plane is N15ºW. The downthrow of the fault is about 70-100 m to the east. It juxtaposes Wadi As Sir Limestone against Amman Silicified Limestone.

Other small-scale normal faults trending NNW, they form small-scale horsts and grabens (Figure 12). They extend for about 80-100 m with downthrow about 30-40 m.

3.2.3. Tell El Maqlub-Ausara Structural Domain

This structure is located west of Ausara. It consists of one major normal fault and three subsidiary faults (Figures 5 and 13). Tell El Maqlub-Ausara fault represents the major fault. It strikes N15W. It crosses the study area from north to south. The downthrow of this fault is to the east, it reaches about 470 m. The maximum displacement occurred when the Ausara Conglomerate to the east were displacement against the Wadi As Sir Formation to the west (Figure 14).

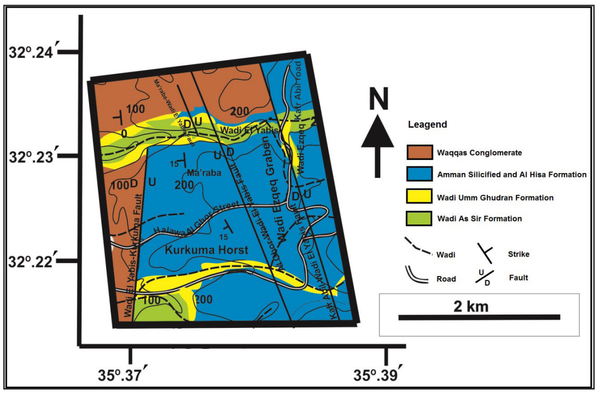


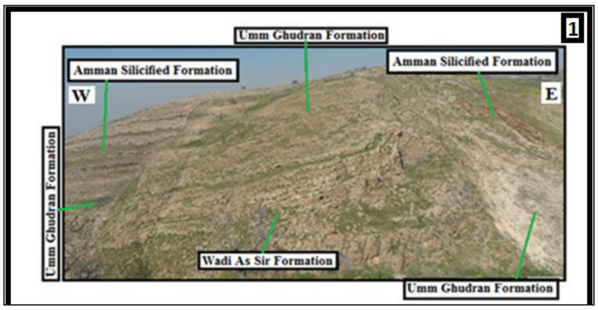
Figure 9. Kurkuma structural domain.

3.3. Strike Slip Fault

Located in the western part of Wadi El Yabis, north of the wadi, as a group of reverse and thrust faults dissecting the Wadi As Sir Formation (Figure 15). They form a positive flower structure. Positive flower structures are formed as bending of a strike slip fault. This fault can be traced in aerial photographs and in the field south of Wadi El Yabis. It strikes N60W (Figure 15). The horizontal displacement of this fault is not clear.

3.4. Joints

The study area is divided into three stations for interpretation of joints (Figure 16). The measured joints are represented in rose diagrams. All of the joints in the field were measured depending on the selection of the systematic joints. Stations were selected depending on the good exposure of systematic joints to cover the study area.



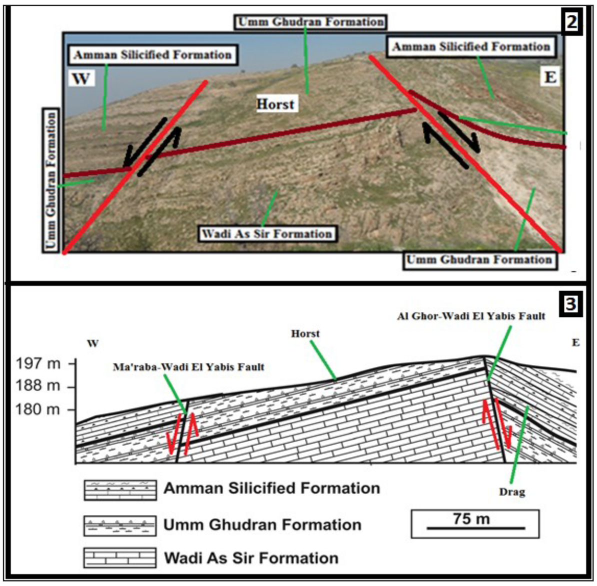


Figure 10. Al Ghor-Wadi El Yabis Fault to the right and Ma'raba-Wadi El Yabis Fault to the left, where they form a horst. The normal drag is close to the fault plane (1, 2). No. 3 is Cross section

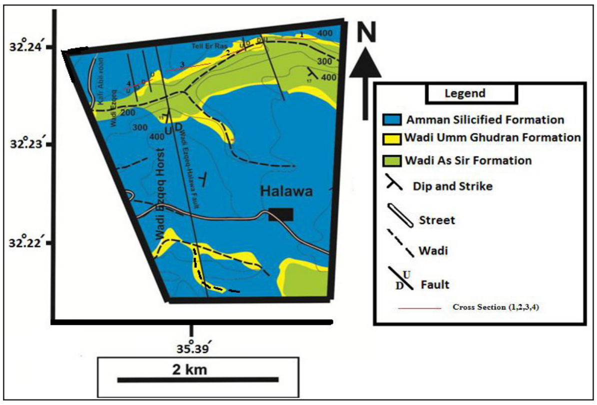


Figure 11. Wadi Ezqeq-Tell Er Ras structural domain.

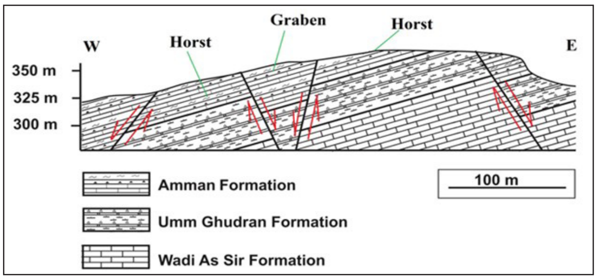


Figure 12. Cross section showing normal faults, horsts and grabensinWadiEzqeq–Tell ErRas structural domain

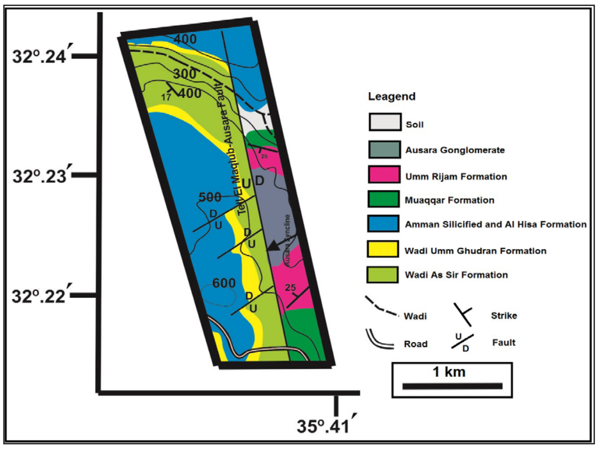


Figure 13. Tell El Maqlub-Ausara structural domain

3.4.1. Station 1

It is located around Ausara village east of study area (Figure 16). Joints were measured in Umm Rijam and Muwagger Formations. More than sixty joints were measured. The major trends are N60E and N30W (Figure 16). They are orthogonal sets of joints and the dihedral angle between the major joint trends is 90º (Figure 17).

3.4.2. Station 2

It is located in the middle part of study area (Figure 16). Joints were measured in Wadi Umm Ghudran Formation. Around sixty joints were measured. The measured joints show two major trends; N60W and N45E (Figure 16).

3.4.3. Station 3

It is located west of study area (Figure 16). Sixty joints were measured in the WadiAs Sir and Wadi Umm Ghudran Formations. The major trends are N60W and N30E (Figure 16). The dihedral angle between them is 90º (Figure 17).

The general trends of the total joints are S60W and N30E (Figure 18) other minor trends are also recorded.

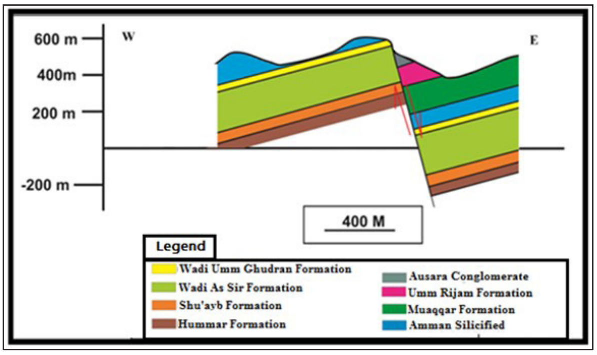


Figure 14. Cross section of Tell El Maqlub-Ausara Fault (Modified after Abu Qudaira, 2005)

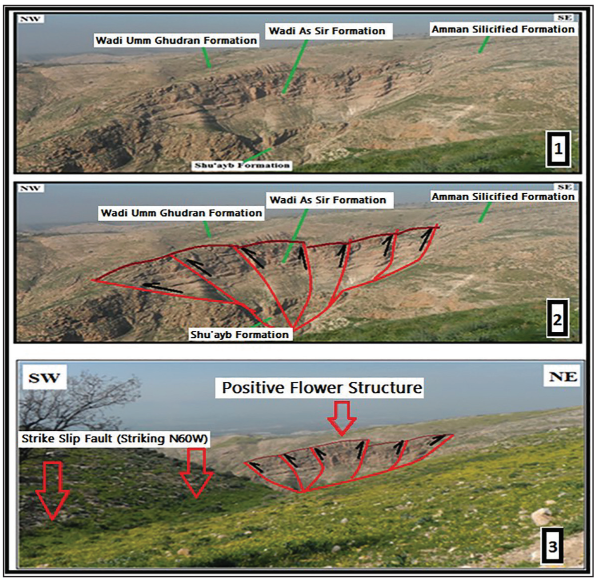


Figure 15. positive flower structure in the western part of study area (1, 2). The trace of the strike slip fault which causes the positive flower structure (3)

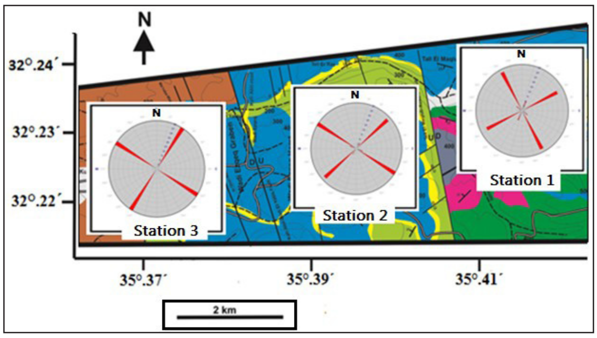


Figure 16. Joint trends in the different measured stations

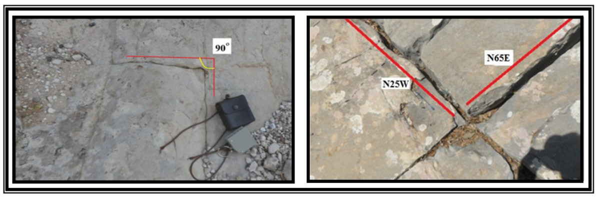


Figure 17. Orthogonal joint sets in the study area

4. Discussion

The major outcrops in the present study area are Ajloun Group, Belqa Group and Jordan Group. Their ages range from Late Cretaceous to Miocene. Ausara conglomerate is Post Eocene Age (which is equivalent to Dana Conglomerate).

The study area is located east of the Jordan Valley Fault and north of Ajloun Dome. The area is located on the northwestern flank of Ajloun Dome. The strata are gently dipping to the NW, but closer to the Jordan Valley; they are steeply dipping to the west. According to Abed (2000), Ajloun Dome and Koura Basin are part of the Syrian Arc Fold Belt.

The study area includes: one syncline, a group of normal faults, one strike slip fault and a group of systematic join sets. The folded beds of Ausara syncline are Late Cretaceous-Paleogene. The core of fold is Ausara Conglomerate. The fold axis trends S65ºW and plunges17º. The fold is symmetric and open. The fold is located on the northwestern flank of Ajloun dome. The general strike of the normal faults is S15ºE (Figure 19). The extension of the fault planes varies from tens of meters to few kilometers. The throw of these faults varies also from few meters to tens of meters and, in some cases, a hundred of meters were recorded. Some of the fault planes dip to the east and others dip to the west; therefore, different sizes of horst and grabens are formed between these faults. One of the prominent faults in the study area is the Tell El Maqlub-Ausara fault; it represents the maximum downthrow in the study area, which is 470 m. This fault is truncating the Ausara syncline (Figure 20). It means that these normal faults were formed after the formation of the folding. The major trend of the normal faults is 165º, which is parallel to the Dead Sea Stress field (DSS). Figure (21) shows a general W-E cross section in the study area. The general structure of the area can be considered as faulted flexure.

Comparing the major trends of joints in the rose diagrams in station (1) and station (2), it is noted that there is a block rotation of 30º. The rotation took place along Tell El Maqlub-Ausara fault domain (Figure 16).

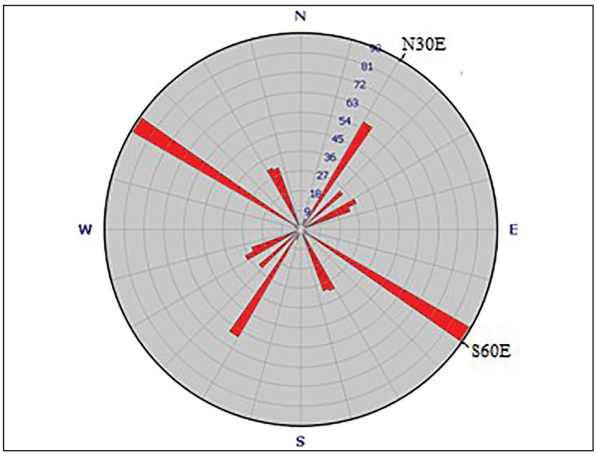


Figure 18. Rose diagram for joints in study area

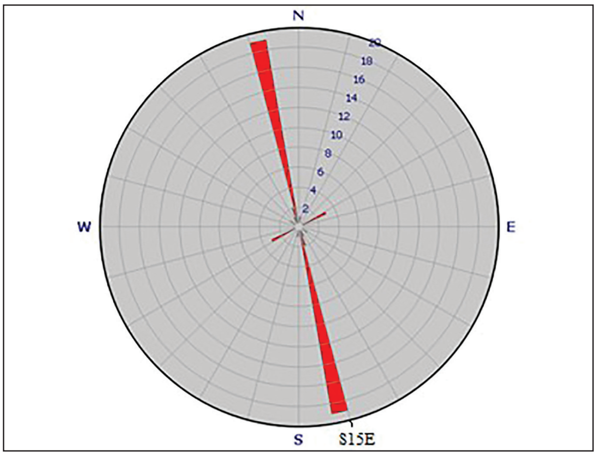


Figure 19. Rose diagram showing the main strike of normal faults in the study area

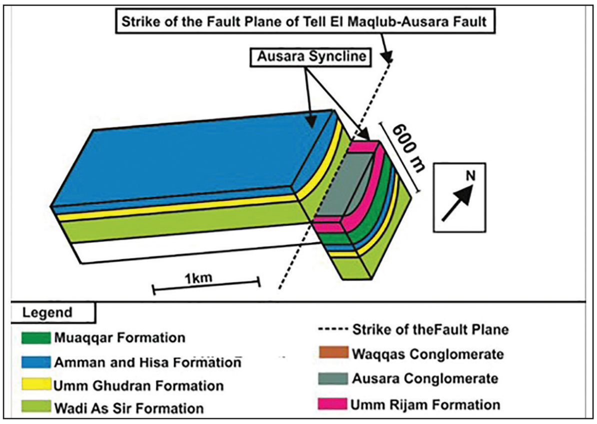


Figure 20. Block diagram showing the relation between Ausara syncline and Tell El Maglub-Ausara fault

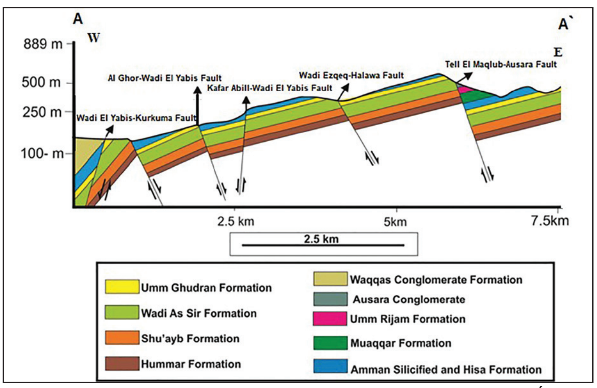


Figure 21. General E-W cross section of the study area (A-A´). For location see Figure (5)

5. Structural Evolution of the Study Area

The major structural features in north Jordan are the Ajloun Dome and the Koura Basin, in addition to other fold belts and faults. In the Late Cretaceous Ajlun Dome and Al-Koura Basin were formed during the first stage of the SAS. The Ausara conglomerate was deposited in certain basins that formed probably as a result of uplift of Ajloun area.

The area was subjected to compressional stresses forming the fold belts in north Jordan and forming the Ausara Syncline. The age of this folding is Post Eocene (the age of the Umm Rijam Formation). This folding could be associated with the second phase of the SAS (Abed, 2000; Abd El-Mota'al and Kusky, 2003).

A system of normal faults was formed after the Ausara Syncline. One of these faults truncated the syncline (Figure 20). The major strike of these faults is NNW-SSE, which is parallel to the trend of the DSS. The trend of faults, horsts and grabens is perpendicular to the main extension (ENE-WSW). The area close to the Jordan valley was tilted during the taphrogenesis associated with the formation of the Jordan Valley. The beds are generally dipping to the west (Figure 21).

Acknowledgment

The present study was supported by the Deanship of Scientific Research and Graduate Studies at Yarmouk University, under Grant Number (2014/23).

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