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# Geometry of Khalakan Anticline, Northeastern Iraq

**Manal Shakir Al-Kubaisi , Ayyed Hussein Ward**
*Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq*

**Corresponding Author:**
**Name:**
**Ayyed Hussein Ward**
**E-mail:**
ayyedward@gmail.com
**Tel:** +9647701868475
**Affiliation:**

## Abstract

This research deals with the geometry of Khalakan Anticline by using field data. The anticline is located in NE Iraq, within the High Folded Zone of the Iraqi Western Zagros Fold – Thrust Belt where the southwestern limb of it represents the boundary between the Low and High folded zones. The age of the exposed rocks in the study area ranges from Cretaceous to Late Pliocene. Qamchuqa and Kometan formations expose in the two limbs as oldest rocks, while the youngest rocks in the northeastern limb are covered by Dokan Conglomerate. Consequently the fold geometry was determined by the measured field data of Qamchuqa and Kometan formations only. Khalakan anticline was described as asymmetrical and overturned fold, with northeastern vergency, where the mean attitude of the NE limb is $220°/89°$ and the mean attitude of the SW limb is $219°/55°$ in terms of dip direction and dip amount. The attitude the fold axis in terms of trend and plunge is $130°/1°$, the attitude of the axial plane is $220°/72°$ in terms of dip direction and dip amount, the interlimb angle is $34°$, consequently the fold was classified as Close Fold.

## Introduction

Geographically, the studied area is located in NE Iraq, it is extending between longitudes (44°41′35" - 45°00′00" E) and latitudes (35°55′10" - 36°08′40" N). Dokan Lake defines the northeastern boundary of the studied area, while Haibat Sultan Mountain defines the southwestern boundary of it (Fig. 1).

Tectonically, Khalakan Anticline is located in High Folded Zone of Iraqi Western Zagros Fold-Thrust Belt (Fig. 2), where the SW limb of the anticline forms the boundary between the Low and High folded zones [1].
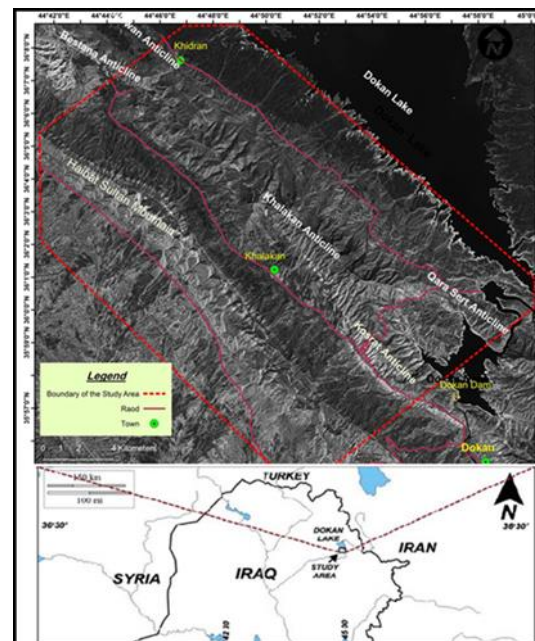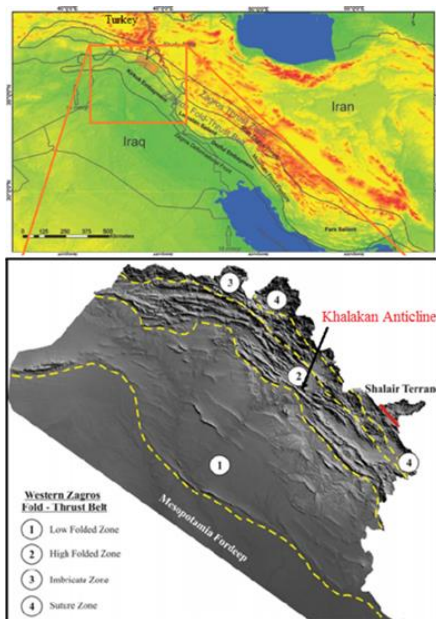


**Fig. 1: Geomorphic location of the studied area**

**Fig. 2: Tectonic location of Khalakan Anticline [1]**

## Geology of the study area

Based on the field data and by comparison with [2] and [3] as previous studies, the geological map of the studied area was carred out (Fig. 3). The age of the exposed rocks ranged from Cretaceous to Late Pliocene. Qamchuqa (Valanginian – Hautrovian) and Kometan (Turonian) formations represent the oldest rocks that exposed in the two limbs of Khalakan Anticline, while Shiranish (Late Cretaceous), Tanjero (Late Cretaceous), Kolosh (Paleocene – Early Eocene), Sinjar (Early Eocene) Gercus (Middle Eocene), Pila Spi (Middle - Late Eocene), Fatha (Middle Miocene) and Injana (Late Miocene) formations represent youngest rocks that exposed in the southwestern limb only, as well as Dokan Conglomerate that covers the anticline with angular unconformity (Figure 3). Dokan Conglomerate was considered as equivalent to the Late Pliocene Bai Hassan Formation by [2].
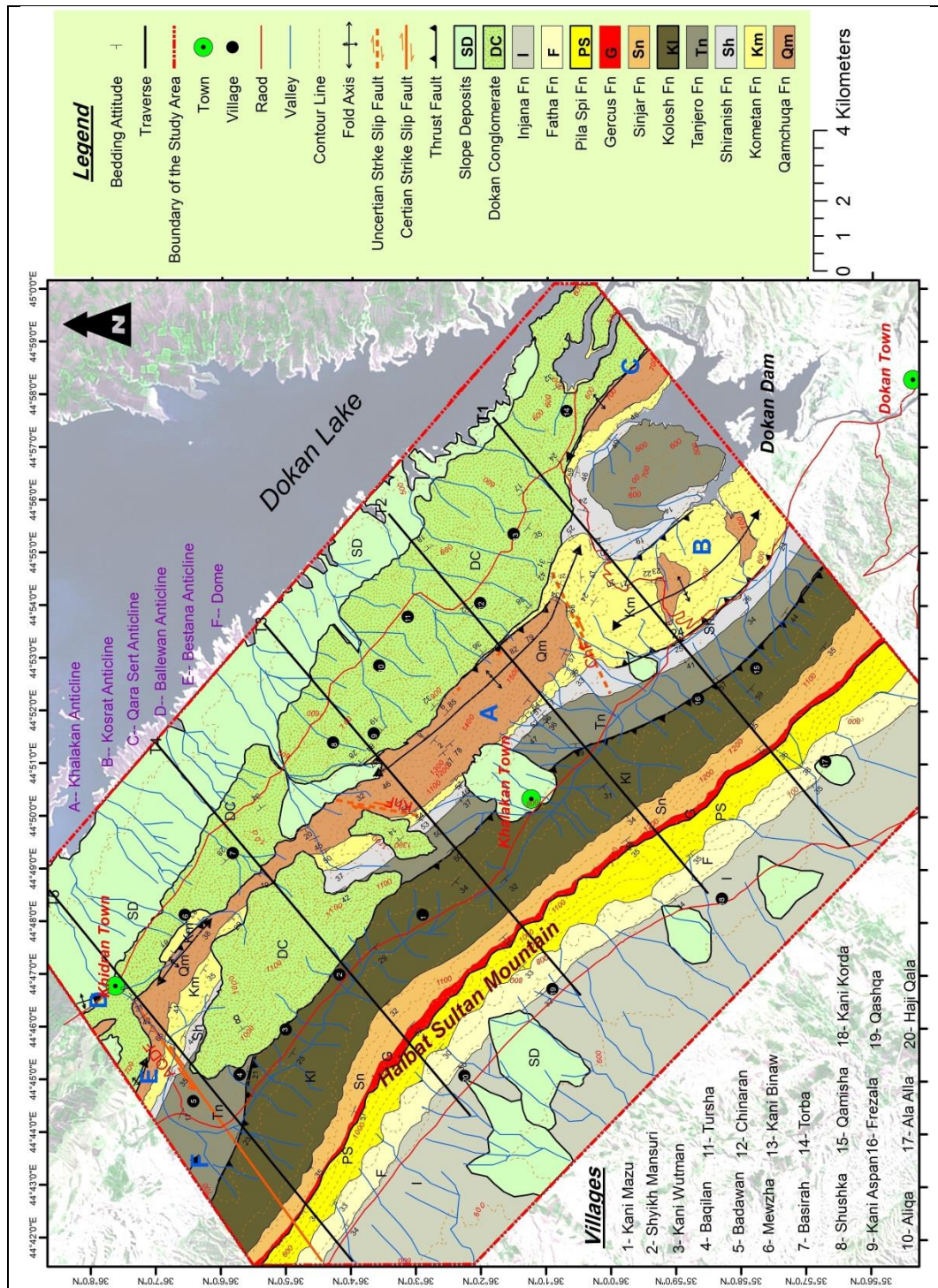
**Fig. 3: Geological map of the studied area**

**Description of Folds**

Generally, the fold grows in three dimensions and recognized by the changing attitude of the bedding planes for a folded sequence [4]. The elements (fold axis, axial plane and interlimb angle in Fig. 4) of the fold determine the geometry of it [5]. The fold axis is a straight line if moves parallel to itself generates the shape of a fold surface and the axial plane contains all the generated fold axes [6,7], interlimb angle is the angle between two limbs of fold measured in a cross section [8].
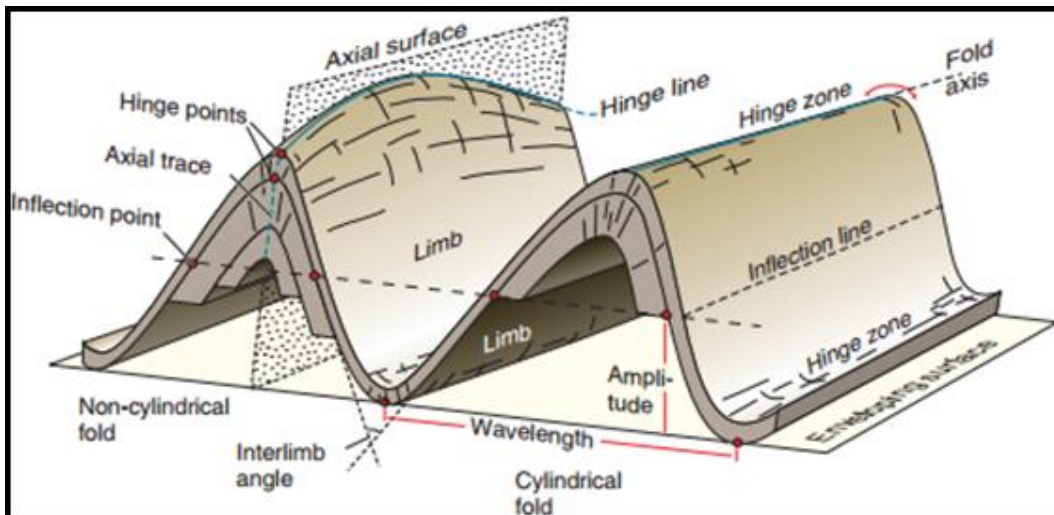
**Fig. 4: Fold elememnts that used to determine the fold geometry with some terminologies [5]**

An axial trace is the intersection line that result from the meeting between the axial surface and any other surface, consequently the axial surface of the fold may be planar or curviplanar and its orientation is determined in terms of strike and dip. When a fold have straight axis it is descriped as a cylindrical fold, but when it have curved hinge line is descriped as non-cylindrical fold [6 , 7]. In some situations, the fold is described as box fold when it have two hinges and broad crestal area, or desriped as overturned fold when one limb becomes overturned [5].

According to [9], the symmetry of the fold is determined by difference length of the two limbs where the dip angle of the short limb is the steeper than the long limb, depending on this base, the symmetrical fold is having the same length of the two limbs with axial plane while asymmetrical folds are ones with different limb lengths. In addition to the symmetry, the steeper limbs of folds in northeastern Iraq define the vergency of them, where the fold have hinterland vergency when the northeastern limb of it is the steeper, and have foreland vergency when the southwestern limb of it is the steeper [10].

**Classification of Folds**

According to [9], the fold elements determine the class of fold. Based on the attitude of the axial plane and hinge line, the fold can be classified to vertical, reclined, horizontal inclined, plunging inclined, recumbent, upright or plunging upright fold (Fig. 5 a). Whereas based on the interlimb angle, can be classified to gentle, open, tight or isoclinal fold (Fig. 5 b).
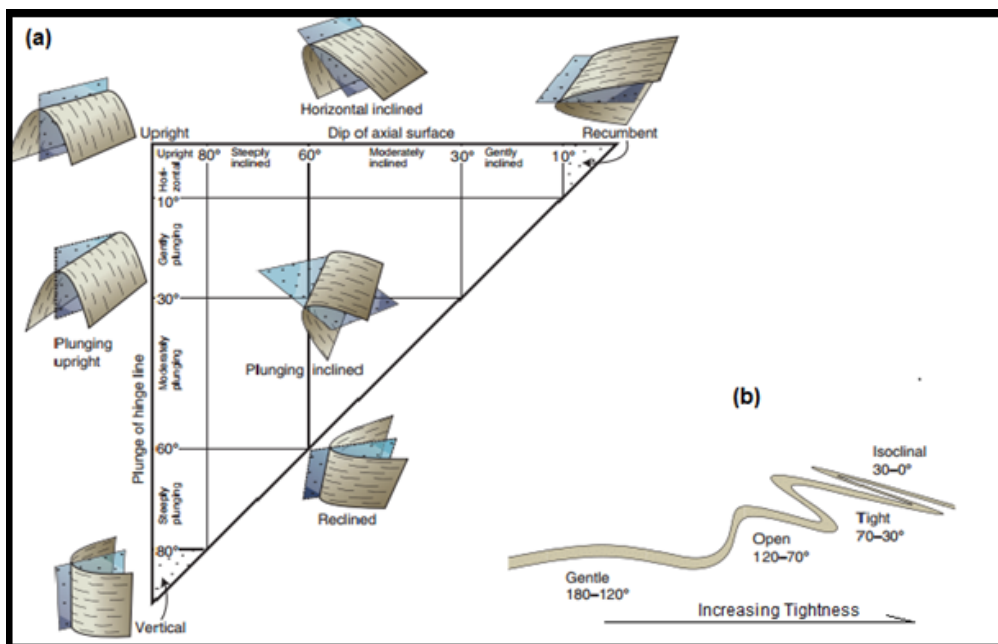


**Fig. 5: Classification of folds. (a) Based on attitudes of axial plane and hinge line,
(b) Based on interlimb angle [9]**

On other hand, [5] used the shape of hinge area in the cross section as base for the classification of folds, he classified the fold which have sharp hinge as kink band (monocline) or chevron, whereas the fold with rounded hinge as concentric fold (Fig. 6).
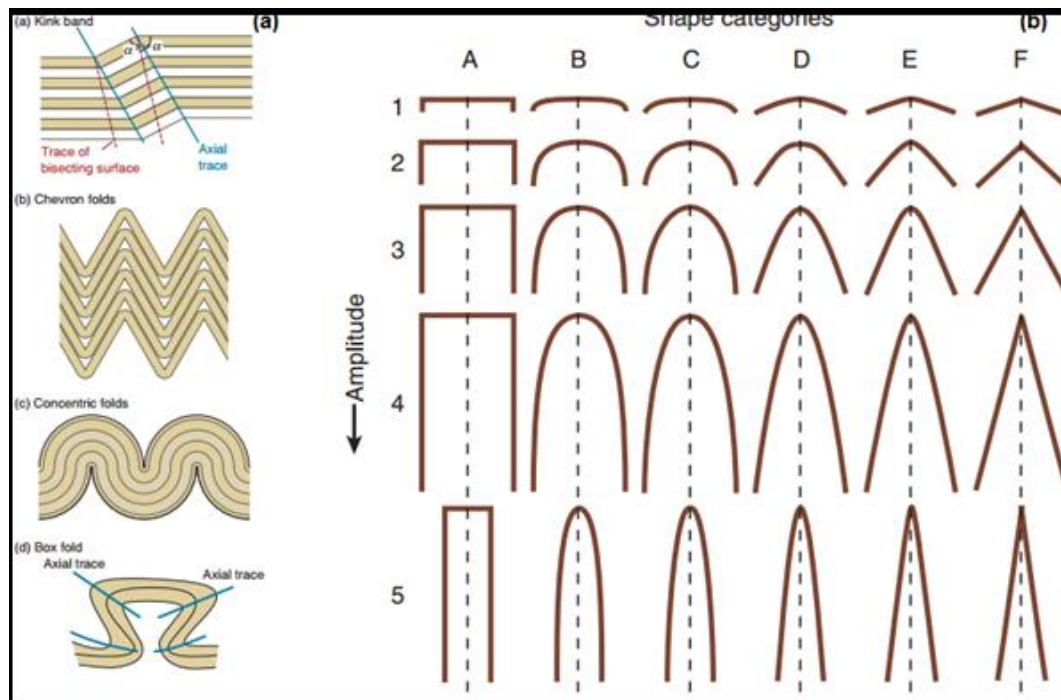
**Fig. 6: Classification of folds based on the shape, according to [5].**

**Field Description of Khalakan Anticline**

Khalakan Structure is northwest trending double plunging, asymmetrical anticline, runs parallel to the southwestern side of Dokan Lake. The length of the structure is about 19 km. The NE limb is relatively very steep to overturned and considerably shorter than the SW limb. The core of anticline shows the maximum elevation (about 1550 m), while the SW limb reachs Haibat Sultan Mountain (about 1250 m) if compared with the NE limb that shows Dokan Depression (about 500 m) (Fig. 3).

**Khalakan Anticline in Coss Sectional View**

The geological map for this study included five traverses perpendicular to the fold axis of Khalakan Anticline (Fig 2), these travereses were used to drawn five cross sections (Fig 7, 8, 9,10 and 11). Traverses no.1, no.2 and no.3 were used to determine the geometry of the anticline, while traverses no.4 and no.5 were excepted because the presence of Dokan Conglomerate above the NE limb of the anticline.
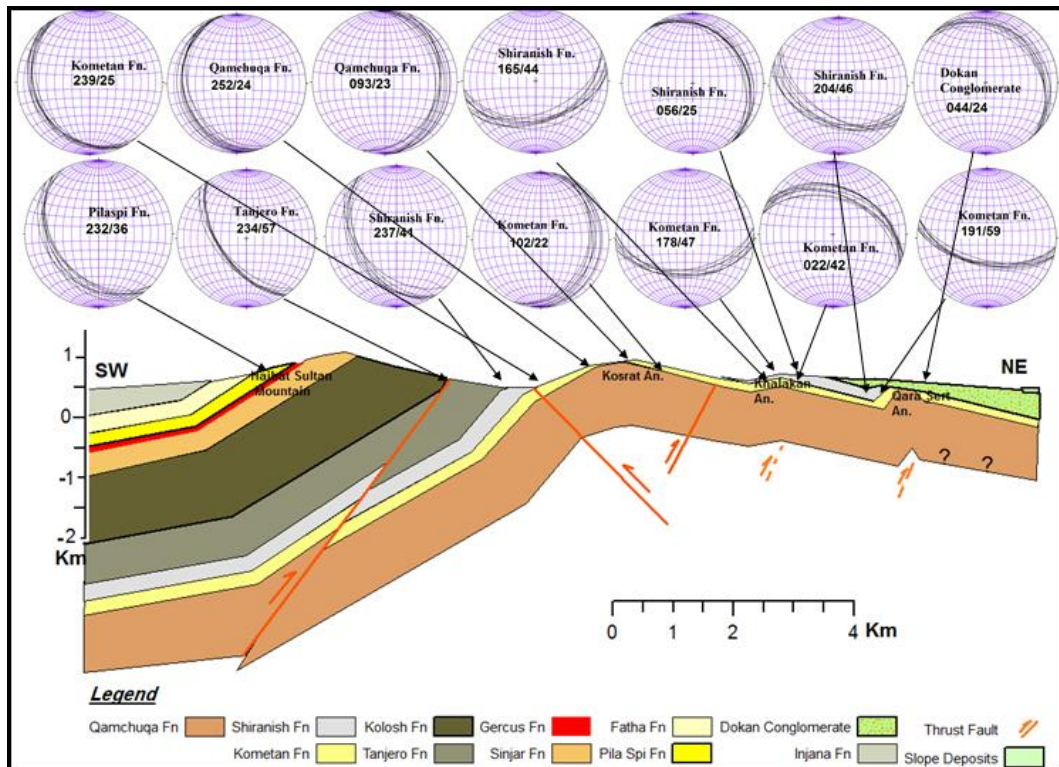
**Fig. 7: Geological cross section shows Khalakan Anticline in traverse no. 1**
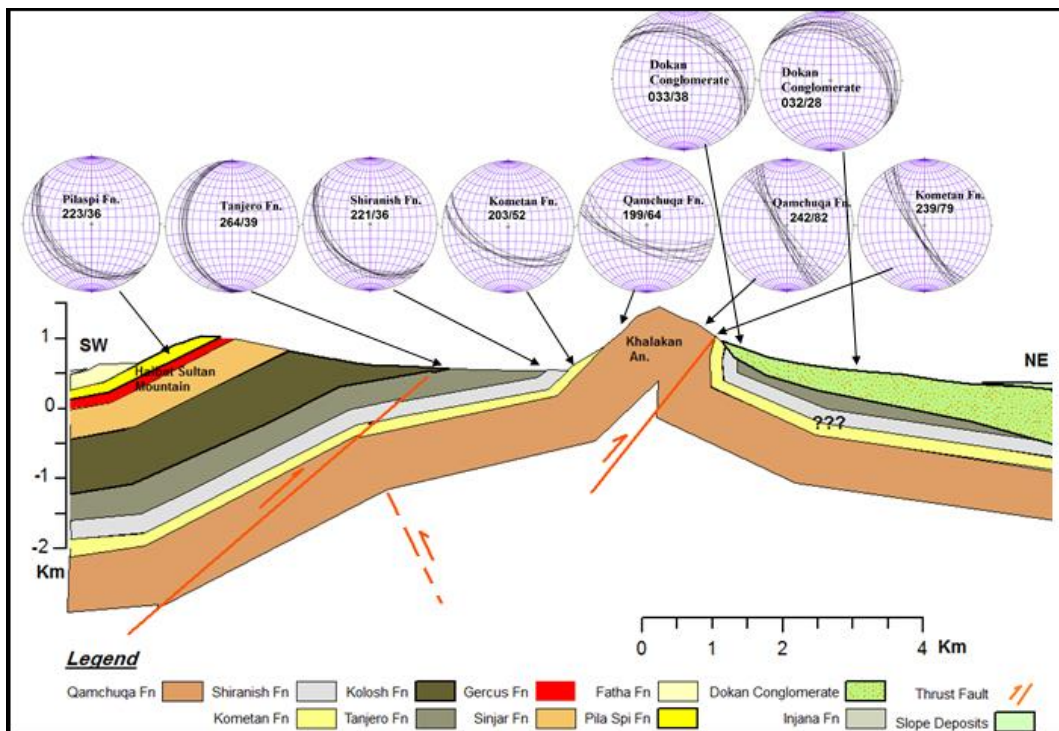


**Fig. 8: Geological cross section shows Khalakan Anticline in traverse no. 2**
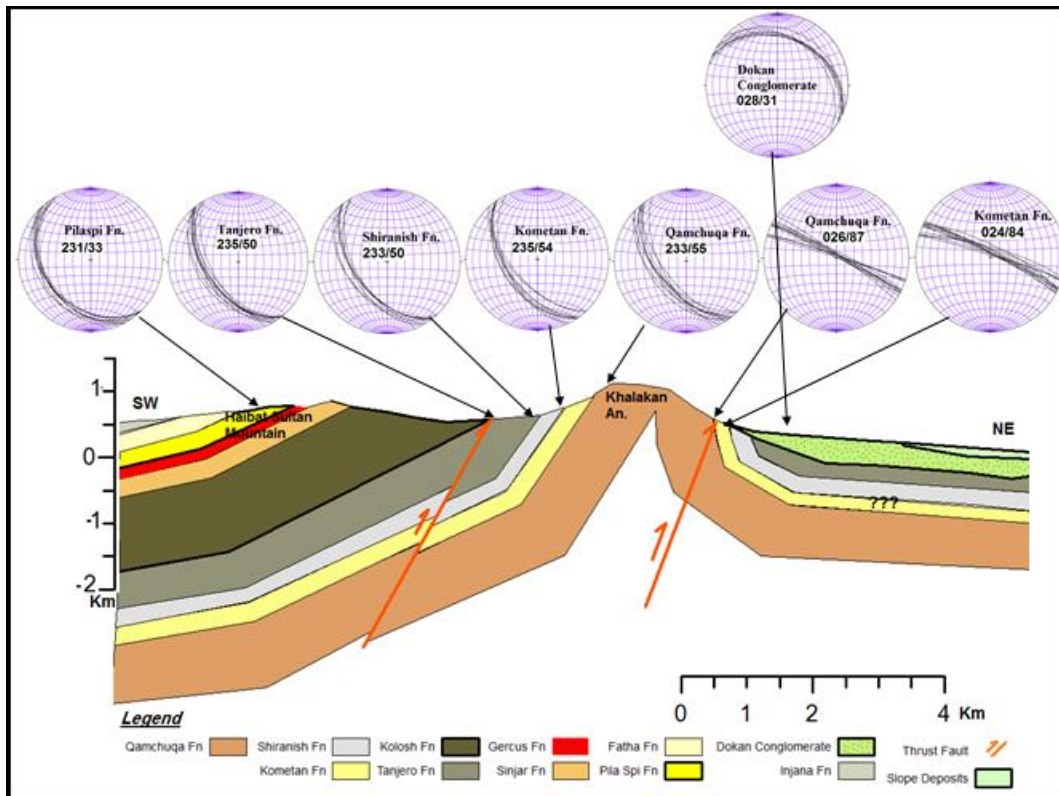
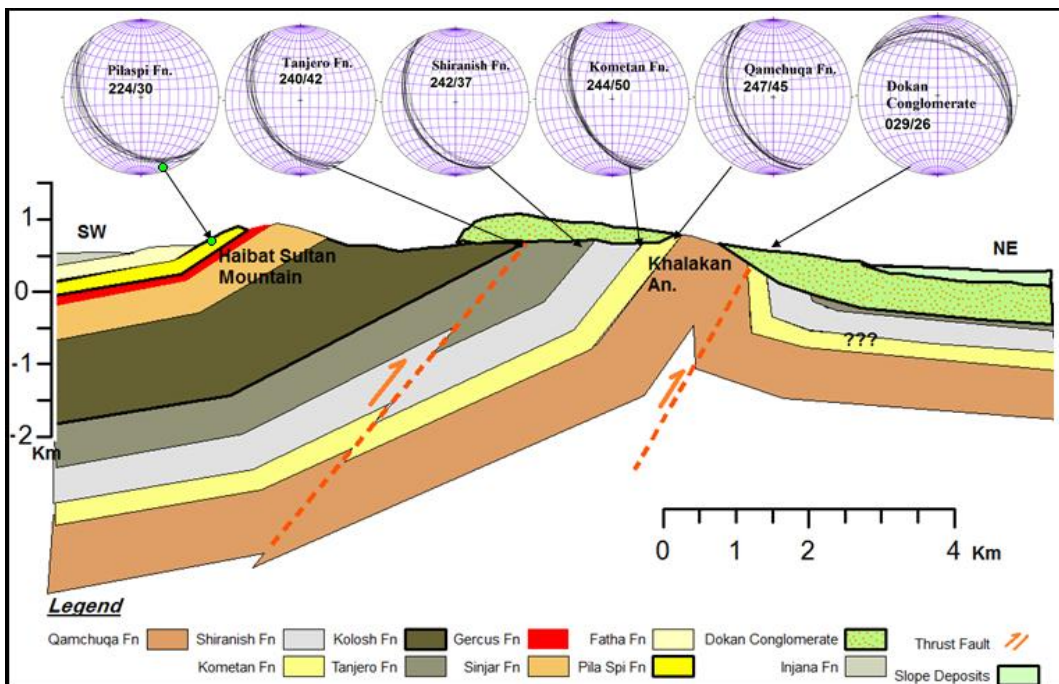**Fig. 9: Geological cross section shows Khalakan Anticline in travese no. 3**



**Fig. 10: Geological cross section shows Khalakan Anticline in travese no. 4**
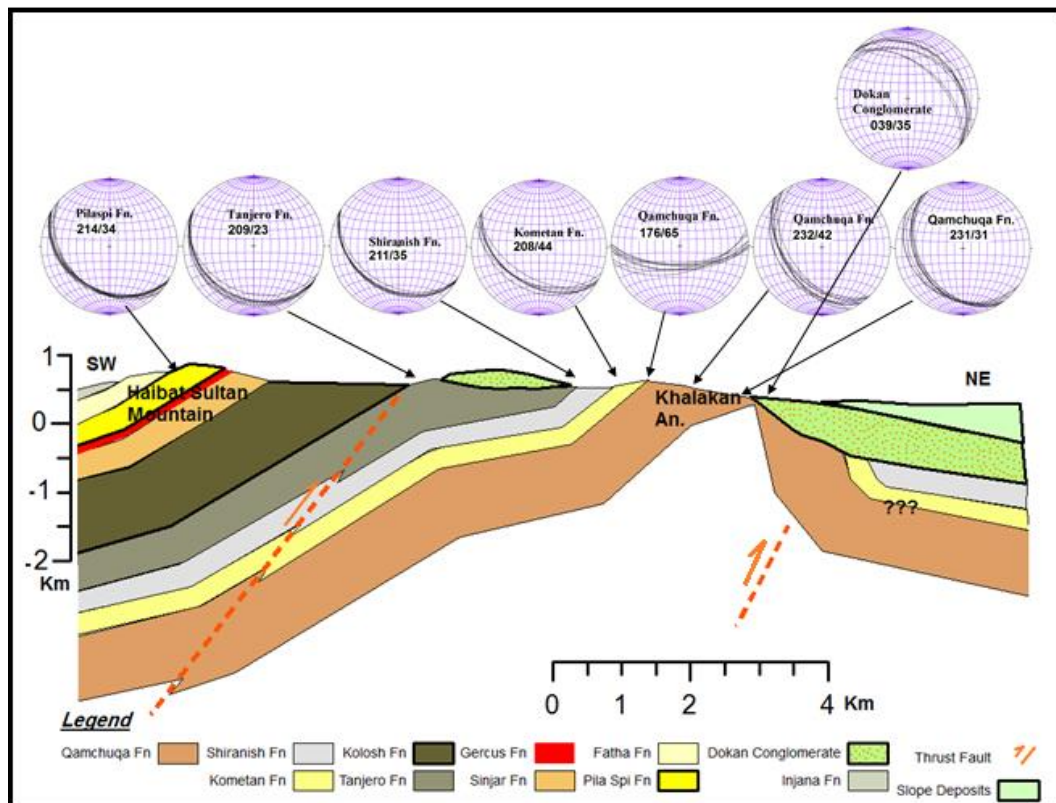
**Fig. 11: Geological cross section shows Khalakan Anticline in travese no. 5**

**Geometry of Khalakan Anticline**

The field data were processed by using GEOrient version 9.5.0 and Stereonet version 9.0.1 Software to determine the fold elements (axial plane, fold axis and interlimb angle), which subsequently determine the geometry and the class of the fold.

In traverse no.1, the mean attitude of the SW limb and NE limb of the anticline are $171^{o}/45^{o}$ and $034^{o}/33^{o}$ respectively (Fig. 12), the attitude of the fold axis in terms of trend and plunge is $098°/16°$, the attitude of the axial plane is $010°/84°$ in terms of dip direction and dip amount, the interlimb angle is $72°$. Consequently the fold can be described as assymmetrical fold with foreland vergency, and classified as open fold according to [9] classification.

In traverse no.2, the mean attitude of the SW limb and NE limb of the anticline is $201^{o}/58^{o}$ and $241^{o}/81^{o}$

respectively (Fig. 13), the fold axis attitude in terms of trend and plunge is $165°/52°$, the attitude of the axial plane is $224^{o}/68°$ in terms of dip direction and dip amount, the interlimb angle is $44°$. Consequently the fold can be described as assymmetrical fold with hinterland vergency, and classified as close fold according to [9] classification.

The mean attitude of the SW limb and NE limb in traverse no.3 is $234^{o}/55^{o}$ and $025^{o}/85^{o}$ respectively (Fig. 14), the attitude of the fold axis in terms of trend and plunge is $299^{o}/39°$, the attitude of the axial plane is $232^{o}/74^{o}$ in terms of dip direction and dip amount, the interlimb angle is $54°$. Consequently the fold can be described as assymmetrical, overturned fold with hinterland vergency, and classified as close fold according to [9] classification.

Traverse No.1

SW Limb Attitude = 171 $^\circ$/45 $^\circ$

NE Limb Attitude = 034 $^\circ$ /33 $^\circ$

Interlimb Angle = 72 $^\circ$

Fold Axis Attitude = 098 $^\circ$/ 16 $^\circ$

Axial Plane Attitude = 010 $^\circ$ /84$^\circ$

Fold Classification : Open

**Fig. 12: Stereogram shows the geometry of Khalakan Anticline in traverse no.1**



Traverse No.2

SW Limb Attitude = 201$^\circ$/58$^\circ$

NE Limb Attitude = 241$^\circ$/81$^\circ$

Interlimb Angle = 44 $^\circ$

Fold Axis Attitude = 165$^\circ$/52$^\circ$

Axial Plane Attitude = 134$^\circ$/68$^\circ$
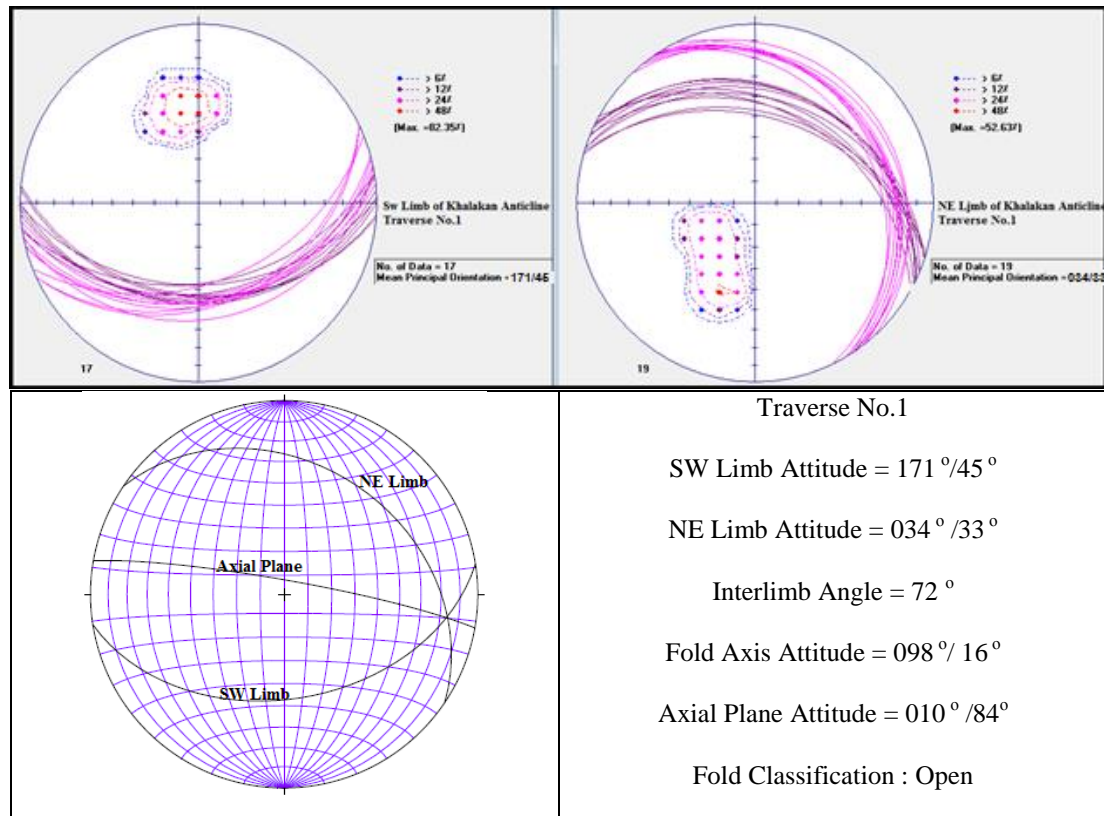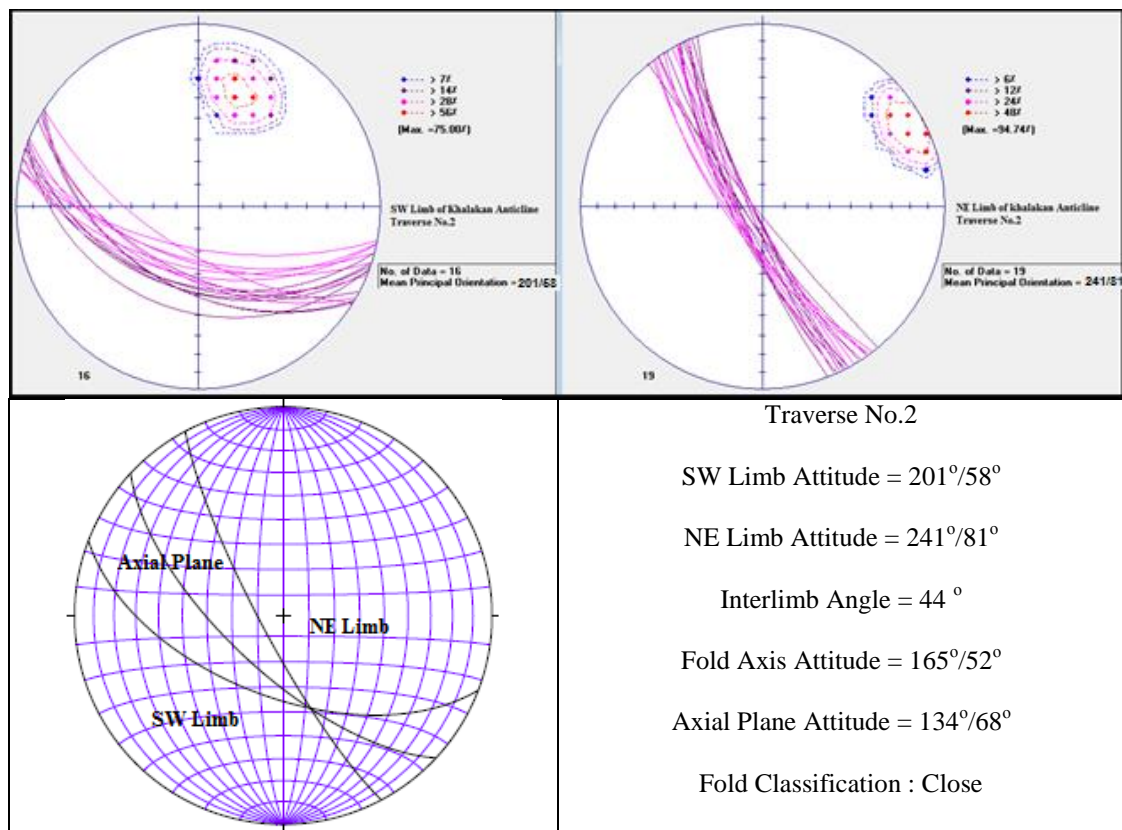
Fold Classification : Close

**Fig. 13: Stereogram shows the geometry of Khalakan Anticline in traverse no.2**
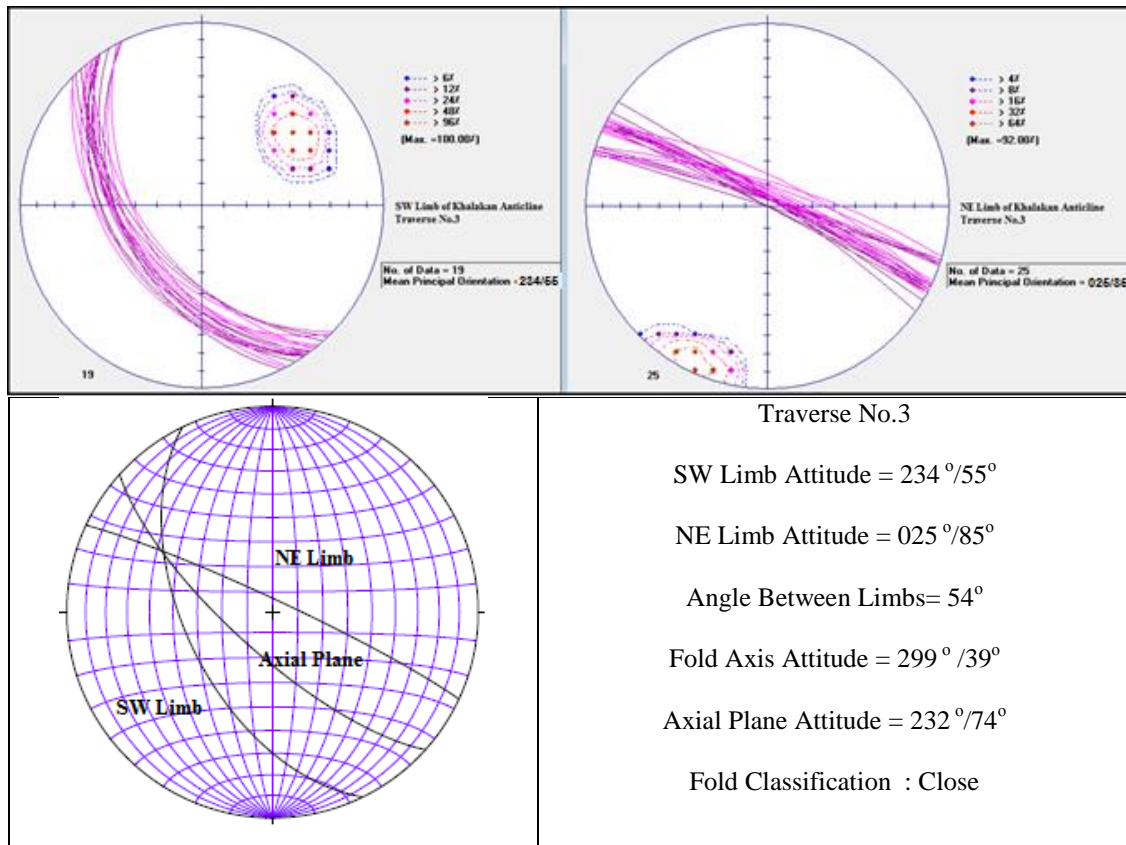
Fig. 14: Stereogram shows the geometry of Khalakan Anticline in traverse no.3

From stereograms above, it can be seen that the fold axis of Khalakan Anticline have NW-SE trending in traverses no.2 and no.3 (Fig. 13 and 14), while it is rotated to proximally E-W trending in the traverse no.1 that cross the southeastern plunge of the anticline (Fig. 12). Still the vergency of the anticline is to hinterland (NE) direction in traverses no.2 and no.3, and changed to foreland (SW) direction in the traverse no.1. The rotation may be interpreted by presence of NE-SW trending strike slip fault, where this fault called Chinaran Fault (Ch in Fig. 3).

The geometry of Khalakan Anticline was carried out from traverses no.2 and no.3 only, while the traverse no.1 was expected because it give different results. From the stereogram (Pi-diagram) of the anticline (Fig. 15), it can be seen that the mean attitude of the NE limb is 220 $^{o}$/89 $^{o}$ and the mean attitude of the SW limb is 219 $^{o}$/55 $^{o}$ in terms of dip direction and dip amount. The attitude of the fold axis in terms of trend and plunge is 130°/1°, the attitude of the axial plane is 220 $^{o}$/72° in terms of dip direction and dip amount, the interlimb angle is 34°. Consequently the anticline can be described as assymmetrical, overturned with hinterland vergency, and classified as close fold according to [9] classification.
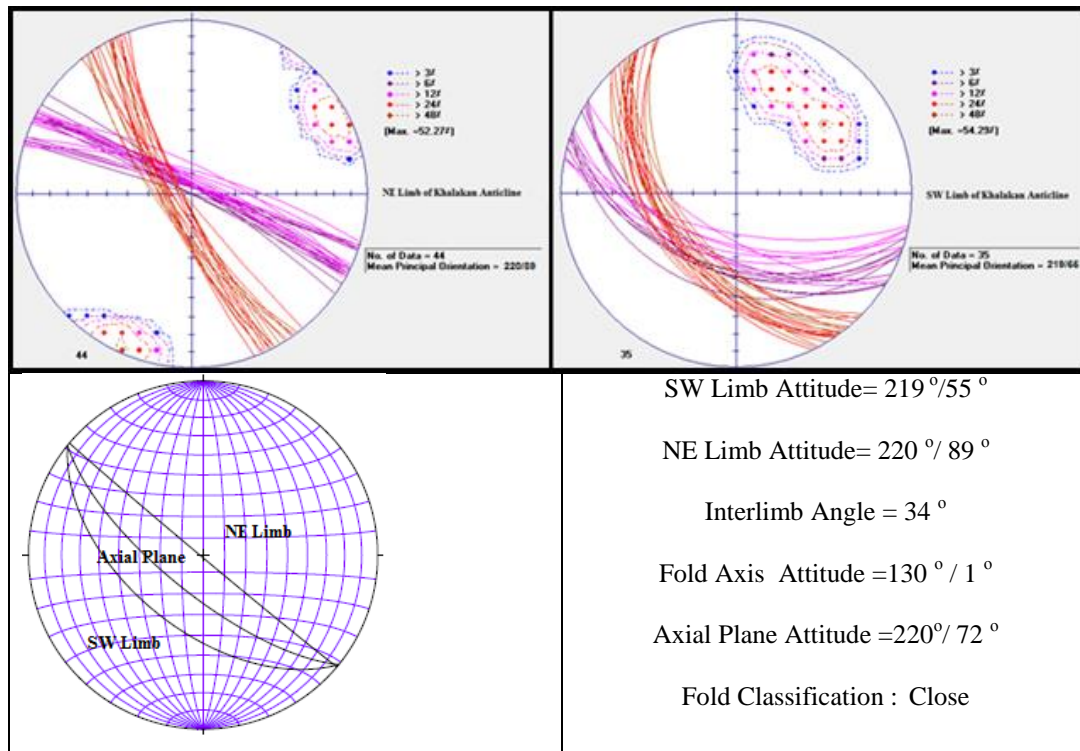
SW Limb Attitude= 219 $^{o}$/55 $^{o}$

NE Limb Attitude= 220 $^{o}$/ 89 $^{o}$

Interlimb Angle = 34 $^{o}$

Fold Axis  Attitude =130 $^{o}$ / 1 $^{o}$

Axial Plane Attitude =220$^{o}$/ 72 $^{o}$

Fold Classification :  Close

**Fig. 15: Stereogram  shows the geometry of Khalakan Anticline**

## Conclusions

1- Khalakan Structure is large anticline, runs parallel to the western side of Dokan Lake, in NE Iraq where the southwestern limb of the anticline represents the boundary between the Low and High Low folded zones.

2- The age of the exposed rocks in the studied area ranges from Cretaceous to late Pliocene, represented by Qamchuqa, Kometan, Shiranish, Tanjero, Kolosh, Sinjar, Gercus, Pila Spi, Fatha, Injana formations and Dokan Conglomerate as expected equivalent to Bai Hassan Formation.

3- Dokan Conglomerate covers the northeastern limb of the anticline, therefore the geometry of it was determined by the field data that obtained from Qamchuqa and Kometan formations only.

4- The mean attitude of the northeastern limb is 220 °/89 ° and the mean attitude of the southwestern limb is 219°/55° as dip direction and dip amount, consequently the anticline can be described as asymmetrical and overturned fold with northeastern (hinterland) vergency.

5- The  attitude of  fold axis is 130°/1° in terms of trend and plunge, the attitude of the axial plane is 220 $^{o}$ /72 ° in terms of dip direction and dip amount, the interlimb angle is 34°, consequently the anticline can be classified as close fold.

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# هندسية طية خلكان المحدبة, شمال شرقي العراق

منال شاكر الكبيسي , عايد حسين ورد

*قسم علم الارض ، كلية العلوم ، جامعة بغداد ، بغداد ، العراق*

## الملخص

يتناول البحث هندسية طية خلكان المحدبة باستخدام البيانات الحقلية. تقع الطية في شمال شرقي العراق, ضمن نطاق الطيات العالية لحزام طي وتصدع زاكروس الغربية العراقية حيث جناحها الجنوبي الغربي يمثل الحد  بين نطاقي  الطيات الواطئة والعالية. عمر الصخور المنكشفة في منطقة الدراسة  يتدرج  من الكريتاسي الى البلايوسين المتأخر. ينكشف تكويني قمجوقة وكوميتان في جناحي الطية كصخور اقدم, بينما تغطى التكوينات الاحدث في الجناح الشمالي الشرقي بمدملكات دوكان, بناءا على ذلك حددت هندسية الطية بالبيانات الحقلية المقاسة لتكويني قمجوقة وكوميتان فقط.   وصفت طية خلكان المحدبة كطية غير  متناظرة ومقلوبة مع اتكاء شمالي شرقي, حيث وضعية الجناح الشمالي الشرقي  ° 89°/ 220 ووضعية الجناح الجنوبي الغربي °55% ° 219   كاتجاه ميل/قيمة ميل. وضعية محور الطية °1°/130 كاتجاه / غطس, وضعية المستوى المحوري °72°/220 كاتجاه ميل / قيمة ميل, الزاوية بين الجناحين °34, وبناءا على ذلك صنفت الطية مغلقة.