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Folding Geometry Surveys of Asef Mountain, Northern Shiraz (Southwestern Folded Zagros Belt)

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Abstract

In this paper the geometrical relationship of the folds which exist in the Folded Zagros Mountains, including Asef Mountain (northern Iran), were studied. The southern and western zones of the Zagros Mountains are called the Folded Zagros. These zones extend approximately 1,375 km in length with a width ranging from 120 to 250 km. Asef Mountain is located in northern Shiraz (from northern Sarda to the vicinity of Zarghan) and is part of the southwestern zone of the Folded Zagros. In this area, Cenozoic formations are folded due to the effects of the tectonic process. This study was done in order to identify these folding features. The results of this research indicate that the axial surface of the folding has a dominant northwest-southeast trend which does not conform to the general trend of the Zagros. The folds are placed into the classes: upright gently plunging, steeply inclined gently plunging, steeply inclined moderately plunging, upright moderately plunging, upright sub horizontal, moderately inclined sub horizontal and moderately inclined gently plunging with respect to their geometry and floating divisions (Fluety,1964), on the basis of axial surface and hinge line trends of the Cenozoic formations. Additionally, these folds are categorized in close and open fold classes on the basis of limb inclination (Fluety, 1964).

Keywords: *Folded Zagros, Asef Mountain, folds*

1. Introduction

Asef Mountain is located in northern Shiraz in the southwestern portion of the Folded Zagros. The folds and faults of the Zagros Mountains show NW-SE trends. The pivot mount folds of Asef Mountain, in most cases, share these same NW-SE trends. The evolution of the Zagros and the beginning of the closure of the Neotethys is thought to have occurred during the late Cretaceous period [1,2].

The final closure and intersection of the Central Iranian and Arabian plates took place between 10 to 35 million years ago (Oligo-Miocene) [3]. The direction of force exerted on the Arabian plate has not changed significantly with respect to Central Iran for 19 million years [4]. The fracturing and falling of the Arabian takhtal lithosphere subduction page under Iran changed to plate convergence approximately 3 to 7 million years ago causing significant structural changes in this area regionally [5,6 and 7]. Since the folded Zagros Belt is of Zagros orogeny, studying the structures and their manner of development in this zone can help us understand the tectonic evolution. The folding can be described as anticline, syncline or exposure of single-dip layers of rock units of different ages.

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Given that the styles of the folds in rock units of various ages differ, folding was studied in the Sachoun formations, Qorban member, Jahrum, Pabedeh and Razak formations, (oldest to most recent respectively). Investigating the general trend of these folds can reveal the approximate direction and performance manner of the tectonic forces affecting the region. The distribution of these formations on a geological map of the region is shown in Fig.1.

2. Methodology

To date, studies carried out on the folds around Asef Mountain have not been surveyed in detail. The study of this area was done within the framework of a 1:100,000 scale map of Shiraz. In this paper analyses were done using geometrical parameters such as the position of the joint line, axial surface and the angle between the edges using stereographic methods.

3. General Geology of the Area

The studied area is part of the structural Folded Zagros zone in northern Shiraz between 52° 29́ E and 52˚ 35́ E longitudes and 29° 42' N and 29˚ 56́ N latitudes (Fig.2). With regard to the classification of the geological-structural zones of Iran [8], the considered area is located in a sedimentary structural zone in the southwestern portion of the Folded Zagros.

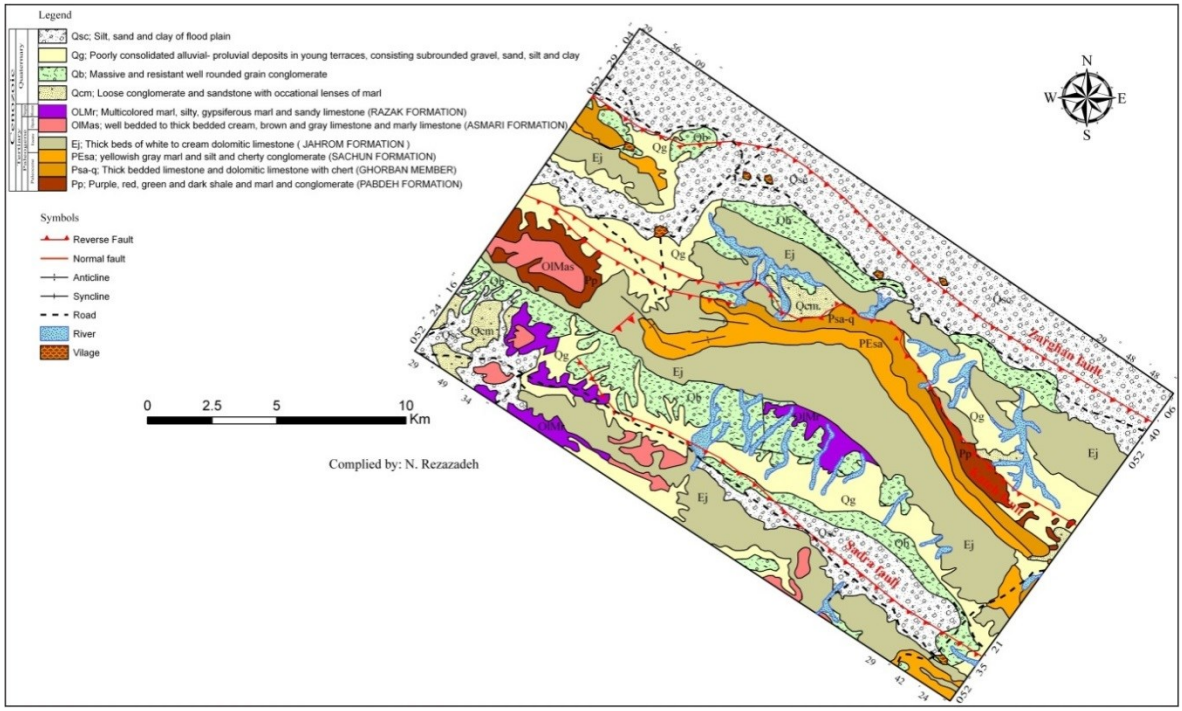

Fig.1 Geological map of the studied zone using 1:100,000 scale geological maps of Shiraz and Kalestan as well as satellite images.

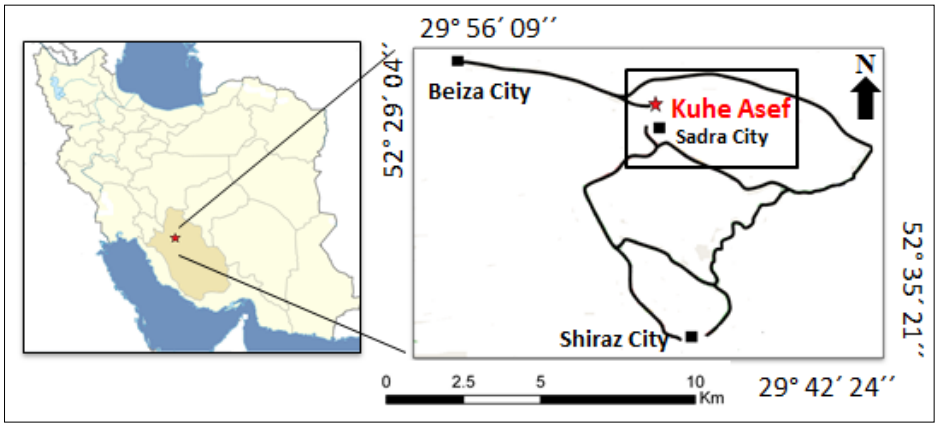

Fig.2 Geographical location of the studied zone.

Using the geological 1:1,000,000 scale map of Shiraz [9] and the geological 1:100,000 scale map of Kalestan [10], field observations of the area showed that Sachun (late Cretaceous Paleocene), Ghorban member (lower Paleocene),Jahrum (Paleocene middle Eocene) ,Pabdeh (Paleocene Miocene), and Razak (lower Miocene) formations and Quaternary deposits were folded by tectonic processes during a range of geological times.

4.Discussion

In the Asef Mountain area, Sachun (late Cretaceous-Paleocene), Ghorban member (lower Paleocene), Jahrum (Paleocene-middle Eocene), Pabdeh (Paleocene-Miocene), and Razak (lower Miocene),the formations and Quaternary deposits were folded by tectonic processes during a range of geological times. Studying the folds and related information can help us understand the tectonic evolution of the area. Generally, effects caused by tectonic movements (orogenic) include the deformation of layered rocks as well as smooth surfaces being changed to curve surfaces or folds. Great folds are the major structures of the fold-driven Zagros Belt and are the most obvious structures of the Folded Zagros Mountains. The folds surrounding Asef Mountain were investigated using field surveys. These studies led to the identification of 18 major folds. Using Google Earth satellite images the location of the studied folds

along with their axial surfaces can be seen in Fig.3. The structural data related to each fold and geometrical findings of the stereographic studies are given in Tables 1 and 2. Following is an explanation of the folds surrounding the Asef Mountains:

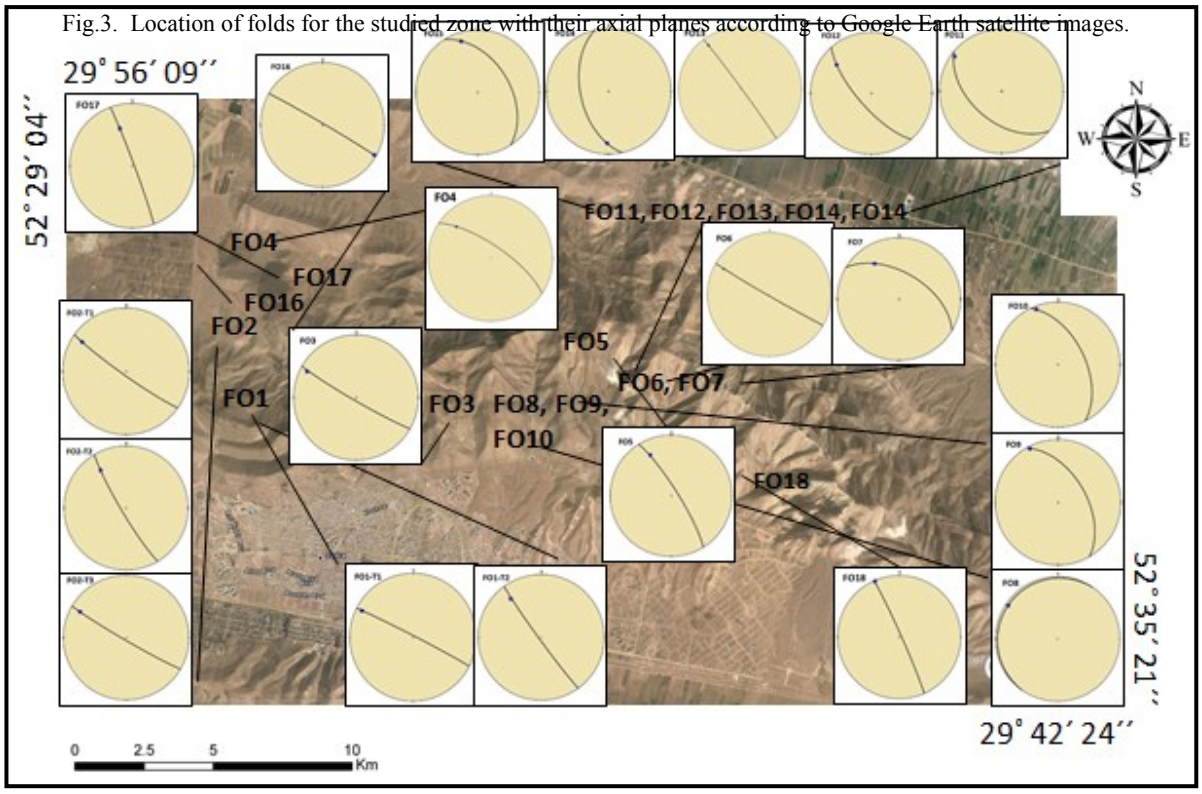

Fig.3. Location of folds for the studied zone with their axial planes according to Google Earth satellite images.

Table.1 The axial plane, joint line and intra-sides angle location for folds.

Angle Between the Two Edges	Position of the Hinge	Pivot Position	Name of Structure
90	17/294	88/027	FO1-T1
88	26/324	87/234	FO1-T2
81	22/305	85/035	FO2-T1
97	27/326	89/055	FO2-T2
89	20/239	88/028	FO2-T3
87	17/229	86/207	FO3
64	26/312	73/031	FO4
123	26/333	81/058	FO5
102	16/299	88/209	FO6
61	31/326	62/036	FO7
149	5/304	89/033	FO8
89	4/322	53/060	FO9
93	5/339	54/064	FO10
86	6/307	50/220	FO11
51	27/309	72/226	FO12
92	13/324	86/053	FO13
77	18/182	76/037	FO14
86	14/342	72/067	FO15
84	4/120	210/89	FO16
91	36/341	87/068	FO17
57	7/337	87/066	FO18

Table.2 Fold classifications

Classification Fluety, 1964 By Tilt and Pivot Shaft Hinge Line	Classification Fluety, 1964, Based on the Angle Between the Edge	Name of Structure
Upright- Gently Plunging	Open	Fo1
Upright- Gently Plunging	Open	Fo2
Upright- Gently Plunging	Open	Fo3
Steeply Inclined- Gently Plunging	Close	Fo4
Upright- Gently Plunging	Open	Fo5
Upright- Gently Plunging	Open	Fo6
Steeply Inclined- Moderately Plunging	Close	Fo7
Upright- Sub Horizontal	Open	FO8
Moderately Inclined- Sub Horizontal	Open	FO9
Moderately Inclined- Sub Horizontal	Open	FO10
Moderately Inclined- Sub Horizontal	Open	FO11
Steeply Inclined- Gently Plunging	Close	FO12
Moderately Inclined- Gently Plunging	Open	FO13
Steeply Inclined- Gently Plunging	Open	Fo14
Steeply Inclined- Gently Plunging	Open	Fo15
Upright- Sub Horizontal	Open	Fo16
Upright- Moderately Plunging	Open	Fo17
Upright- Gently Plunging	Close	Fo18

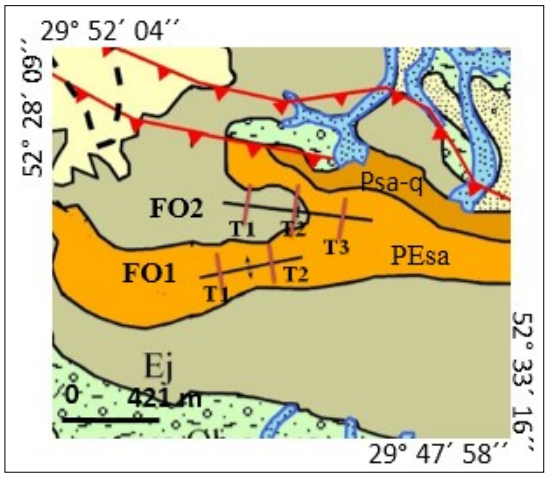

Fig.4 Location of the navigation paths for Anticline FO1and Syncline FO2 on a geological map of the zone.

4-1- Anticline FO1

Anticline FO1 is located on the northwestern portion of Asef Mountain, Sachoun formation, at 52˚ 30' 08" E longitude and 29˚49' 50" N latitude (Fig.5). The geometric features of the Sachoun formation anticline were studied in both T1 and T2 navigation paths (Fig. 4). Figures 6 and 7 represent the stereogram of this anticline.

4-1-1-Field Surveys for Anticline FO1 in T1 Path

The position of the joint line of Anticline FO1 in T1 navigation path is17°/294. The position of the axial plane of the anticline is 88/027.The angle between fold sides is 90˚. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-gently plunging class.

4-1-2-Field Surveys for Anticline FO1 in T2 Path

The position of the joint line of Anticline FO1 in T2 navigation path is 26°/324. The position of the axial plane of the anticline is 87/234.The angle between fold sides is 88˚. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-gently plunging class (upstanding axial plane and joint line with gentle trend).

4-2-Syncline FO2

Syncline FO2 is located at 52˚ 31' 20" and 52˚ 30' 04" E longitudes and 29˚ 50' 29" and 29˚ 50' 18" N latitudes (Fig.8). It was formed due to the folding of the Jahrum and Sachoun formations. The geometric characteristics of the syncline were considered in the navigation paths of T1, T2 and T3 (Figure 4). Figures 9, 10 and 11 represent the stereogram depicted in the syncline scrolling T1, T2 and T3 paths.

4-2-1-Field Surveys for Syncline FO2 in T1 Path

The position of the joint line of syncline FO2 in T1 navigation path is 22°/305..

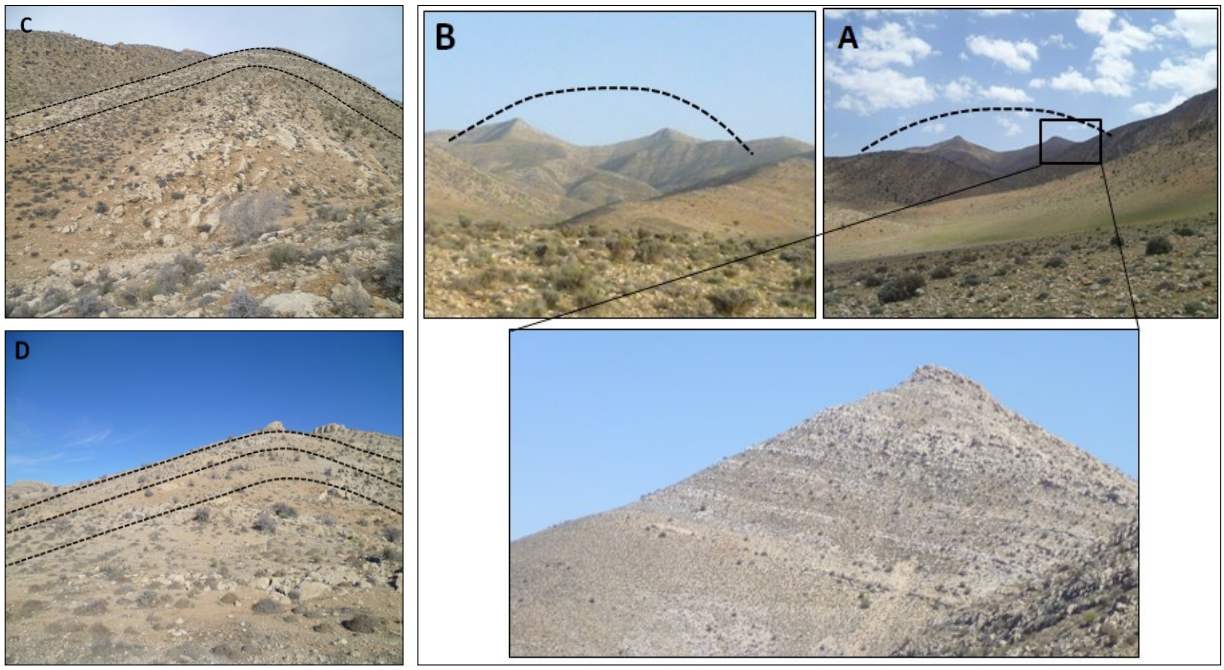

Fig.5 (a, b, c) Field outcrop of Anticline FO1, (d) Anticline FO2 in T1 path, (e) Anticline FO2 in T2 path.

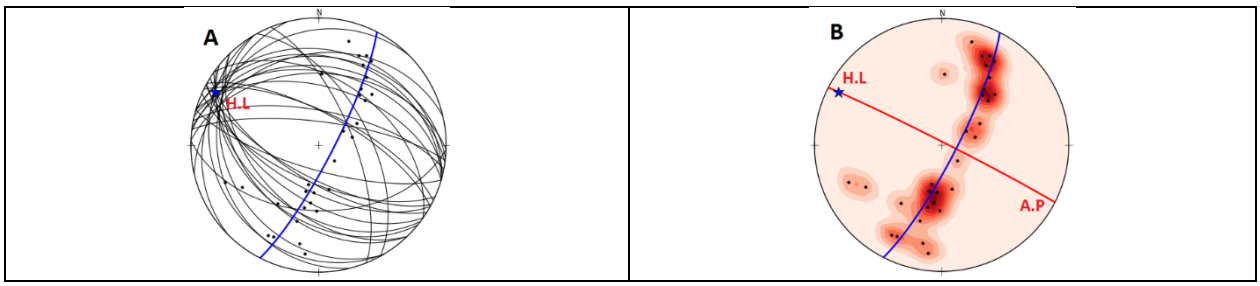

Fig.6 (a) βand π diagrams and determination of the joint line location for Anticline FO1 in T1 path (17°/294), (b) counter plot of the sides of the fold in order to determine the intra-sides angle (90°) and obtain the axial plane position (88/027).

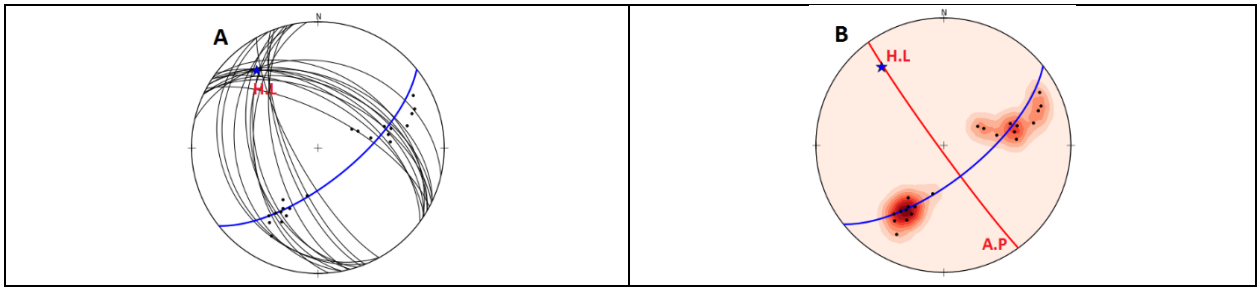

Fig.7 (a) βand π diagrams and determination of the joint line location for Anticline FO1 in T2 path (26°/323), (b) counter plot of the sides of the fold in order to determine the intra-sides angle (88°) and obtain the axial plane position (87/234).

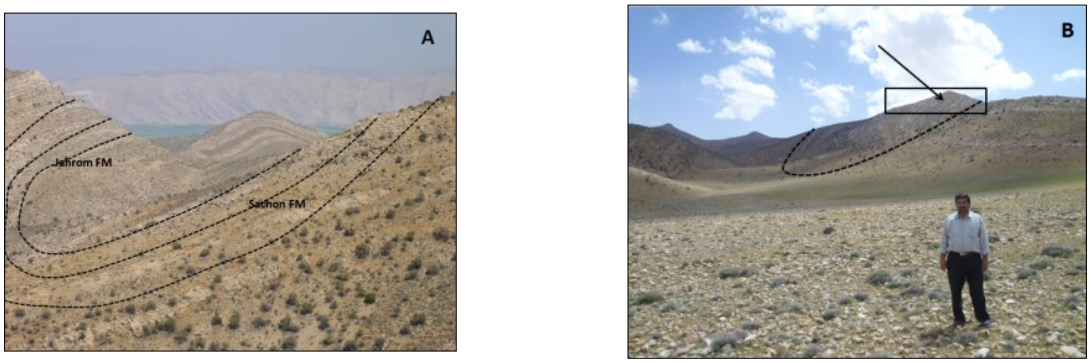

Fig.8 (a) Outcrop of Syncline FO2 in T1 path (viewed toward southwest), (b) outcrop of Syncline FO2 in T2 path (viewed toward southwest) and (c) outcrop of Syncline FO2 in T3 path (viewed toward southwest).

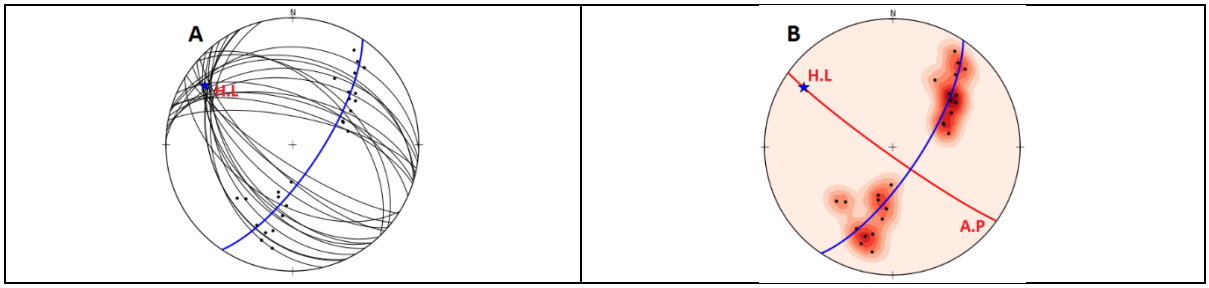

Fig.9 (a) βand π diagrams and determination of the joint line location for Syncline FO2 in T1 path (22°/305), (b) counter plot of the sides of the fold in order to determine the intra-sides angle (81°) and obtain the axial plane position (85/035).

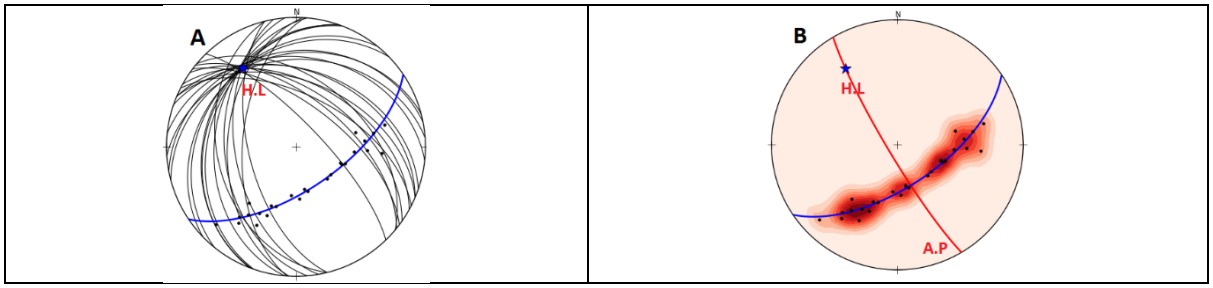

Fig.10 (a) βand π diagrams and determination of the joint line location for Syncline FO2 in T2 path (35°/329), (b) counter plot of the sides of the syncline in order to determine the intra-sides angle (83°) and obtain the axial plane position (86/056).

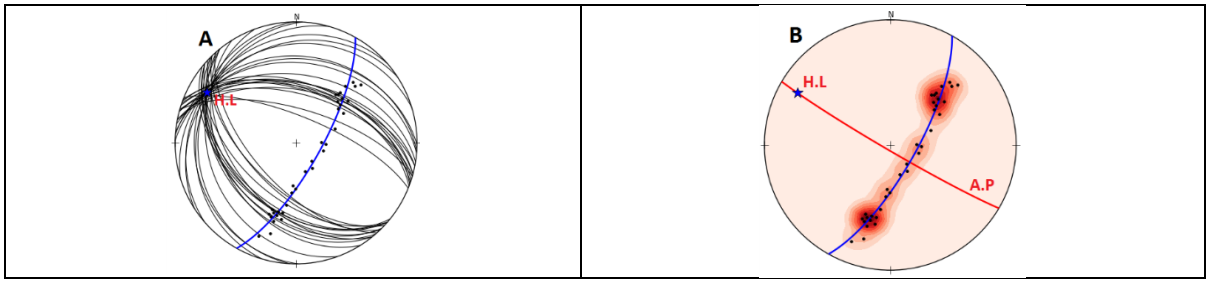

Fig.11 (a) βand π diagrams and determination of the joint line location for Syncline FO2 in T3 path (20°/329), (b) counter plot of the sides of the syncline in order to determine the intra-sides angle (89°) and obtain the axial plane position (88/028).

The position of the axial plane of the anticline is 84/035.The angle between fold sides is 81˚. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-gently plunging class.

4-2-2-Field Surveys for Syncline FO2 in T2 Path

The position of the joint line of Syncline FO2 in T2 navigation path is 27°/326. The position of the axial plane of the anticline is 89/055.The angle between fold sides is 97. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-moderately plunging class.

4-2-3-Field Surveys for Syncline FO2 in T3 Path

The position of the joint line of Syncline FO2 in T3 navigation path is 20°/229. The position of the axial plane of the anticline is 88/028. The angle between fold sides is 89˚. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based of the axial surface slippage and joint line trend places this fold in the upright-gently plunging class. Figure 11depicts the stereograms of the syncline in the T3 path. Figure 12 shows a symbolic section of Anticline FO1 and Syncline FO2 along the NW-SE.

4-3-Anticline FO3

Anticline FO3 was studied at the geographical coordinates 52° 31' E longitude and 29° 48' N latitude. At the outcrop of this fold, a valley is present in the western portion of Asef Mountain, Jahrom formation (Fig.13-a). To evaluate the geometric features of this fold, the slope and strike of the layering of the fold's sides were measured (Tables1and 2).The position of this anticline is marked in Fig.3.

The stereograms related to the measurement of this fold in the lower hemisphere of the Schmidt Net are shown in Fig.13: b-c. The π diagram in this figure shows 17°/229 positions for the joint line of the fold. The position of the axial surface is 86/207. The angles between the sides of the fold are 87˚. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-gently plunging class.

4-4-Syncline FO4

Syncline FO4 is located at 52˚ 30' 11" N latitude and 29˚ 52' 23" E longitude (Fig.14-a). Figure14-b shows the stereograms of this syncline; the position of this syncline is illustrated in Fig. 3. As shown in the π diagram, the position of the joint line is 26°/312 and the axial plane position is 73/031. The intra-sides angle is 64°. This, according to intra-sides angle classification, places it in the closed fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the steeply inclined-gently plunging class.

4-4–Anticline FO5

Anticline FO5 is located at 52˚ 33' 02" E longitude and 29˚48' 51" N latitude (Fig.15-a). Figure15-b shows a drawing of the stereograms of this anticline. The position of Anticline FO5 is illustrated in Fig. 3. These stereograms show the position of the joint line to be 333°/26 and the axial plane position to be 81/058. The intra-sides angle is 123°. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold is in the upright-gently plunging class.

4-5- Western Outcrop of Asef Mountain

Anticline FO6 and Syncline FO7 are located in the Jahrum formations (Figure16-a) at 52˚ 32' 59" E longitude and 29˚ 48' 27" N latitude respectively. The positions of Anticline FO6 and Syncline FO7 can be found in Fig. 3.

4-5-1-Anticline FO6

The stereograms shown in Fig.16, show the position of the joint line of Anticline FO6 to be 16°/299. The position of the axial plane of the anticline is 88/209.The angle between fold sides is 102°. This, according to intra-sides angle) classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-gently plunging class.

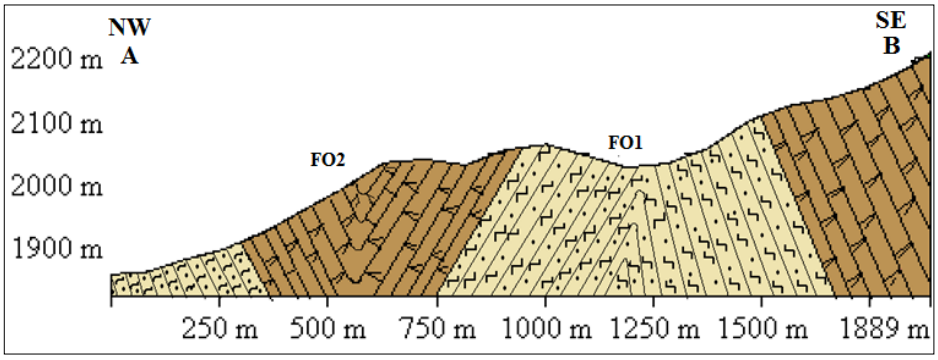

Fig.12 Symbolic section from Anticline FO1 to Syncline FO2 in a NW-SE direction.

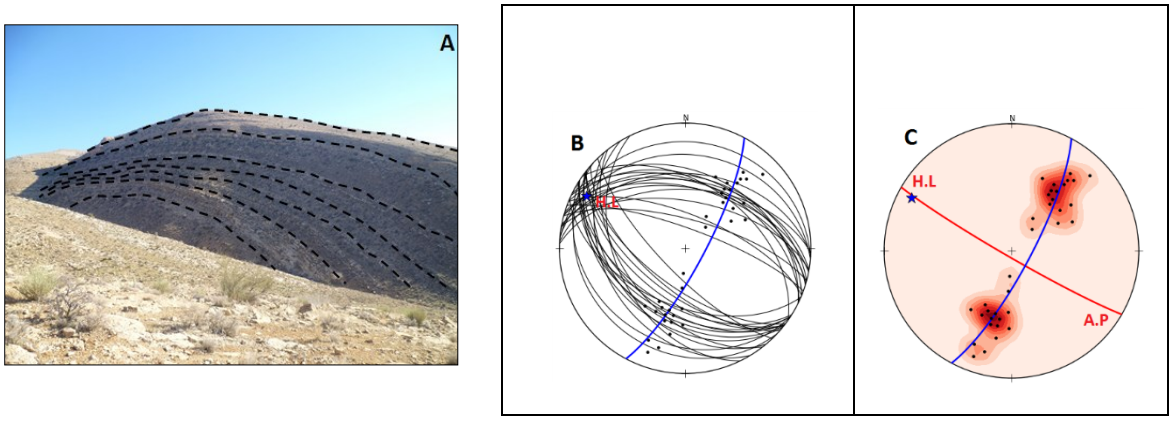

Fig.13 (a) Field outcrop of Anticline FO3 (viewed toward northwest), stereograms of surveyed positions of the fold's layering. (b) βand π diagrams and determination of the joint line location (17°/229), (c) counter plot of the fold's sides in order to determine the intra-sides angle (87°) and obtain the axial plane position (86/207).

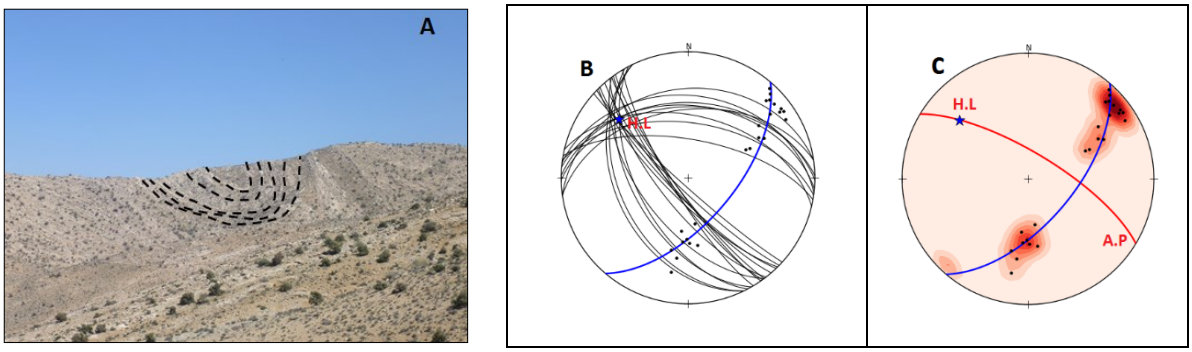

Fig.14 (a) Field view of Syncline FO4 (viewed toward northwest), (b) βand π diagrams and determination of the joint line location (26°/312), (c) counter plot of the fold's sides in order to determine the intra-sides angle (64°) and obtain the axial plane position (73/031).

4-5-2-Syncline FO7

The position of the joint line of Syncline FO4 is 31°/326. The position of the axial plane of the syncline is 62/036. The angle between fold sides is 61°.This, according to intra-sides angle) classification [11], places it in the close fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the steeply inclined-moderately plunging class. Figure 17 shows all geometrical characteristics related to this fold.

4-6- Eastern Outcrop of Asef Mountain

This outcrop is located on the eastern portion of Asef Mountain at 52˚ 31' 03" E longitude and 29˚ 48' 53" N latitude (Fig.18).

4-6-1- Anticline FO8

The stereograms shown in Fig.18-b,c show the position of the joint line of Anticline FO8 to be 5°/304. The position of the axial plane of the anticline is 89/033. The angle between fold sides is 149. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-sub horizontal class.

4-6-2- Anticline FO9

The stereograms shown in Fig.19-a,b show the position of the joint line of Anticline FO9 to be 4°/322.The position of the axial plane of the anticline is 53/060. The angle between fold sides is 89˚. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the moderately inclined-sub horizontal class.

4-6-3- Syncline FO10

The position of the joint line of Anticline FO10 is 5°/339. The position of the axial plane of the syncline is 54/064. The angle between fold sides is 93. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the moderately inclined-sub horizontal class.

4-7- Northwestern Outcrop of Asef Mountain

This outcrop is located at 29˚ 50' 30" E longitude and 52˚ 34' 49" N latitude (Fig.21-a).

4-7-1- Anticline FO11

The stereograms shown in Fig.21 show the position of the joint line of Anticline FO11 to be 6°/307. The position of the axial plane of the anticline is 50/220.The angle between fold sides is 86˚. This, according to intra-sides angle) classification [11], place it in the close fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the moderately inclined-sub horizontal class.

4-7-2-Syncline FO12

The stereograms shown in Fig. 22 show the position of the joint line of Syncline FO12 to be 27°/309. The position of the axial plane of the syncline is 72˚/226. The angle between fold sides is 51˚. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the steeply inclined- gently plunging class.

4-7-3- Anticline FO13

The position of the joint line of Anticline FO13 is 13°/324. The position of axial plane of the anticline is 86/053.The angle between fold sides is 92˚. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the moderately inclined-gently plunging class (Fig.23-a, b).

4-7-4- Anticline FO14

The position of the joint line of Anticline FO14 is 18°/182. The position of the axial plane of the anticline is 76/037. The angle between fold sides is 77˚. This, according to intra-sides angle classification [11], places it in the close fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the steeply inclined-gently plunging class (Fig.24-a, b).

4-7-5- Anticline FO15

The position of the joint line of Anticline FO15 is 14°/342. The position of the axial plane of the anticline is 72˚/067. The angle between fold sides is 86˚. This, according to intra-sides angle classification [11], places it in the close fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the steeply inclined-gently plunging class (Fig.25-a, b).

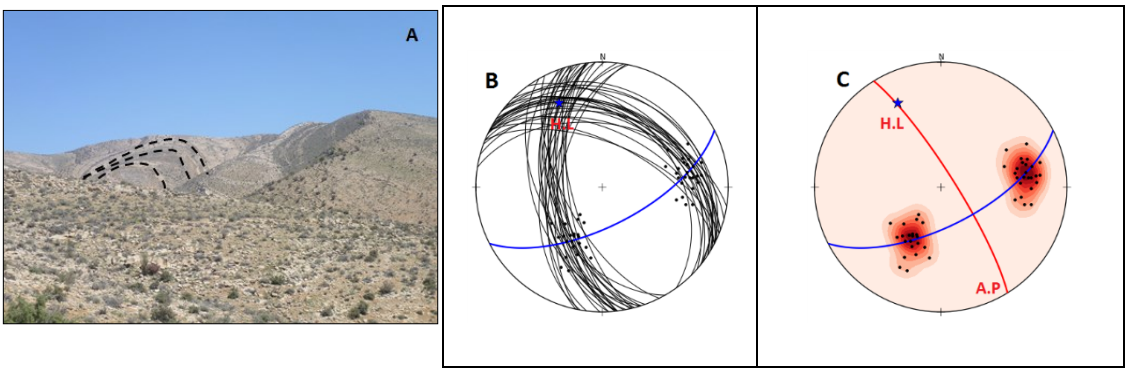

Fig.15 (a) Field outcrop of Anticline FO5 (viewed toward west), stereograms of surveyed positions of the fold's layering, (b) βand π diagrams and determination of the joint line location (26°/333), (c) counter plot of the fold's sides in order to determine the intra-sides angle (123°) and obtain the axial plane position (81/058).

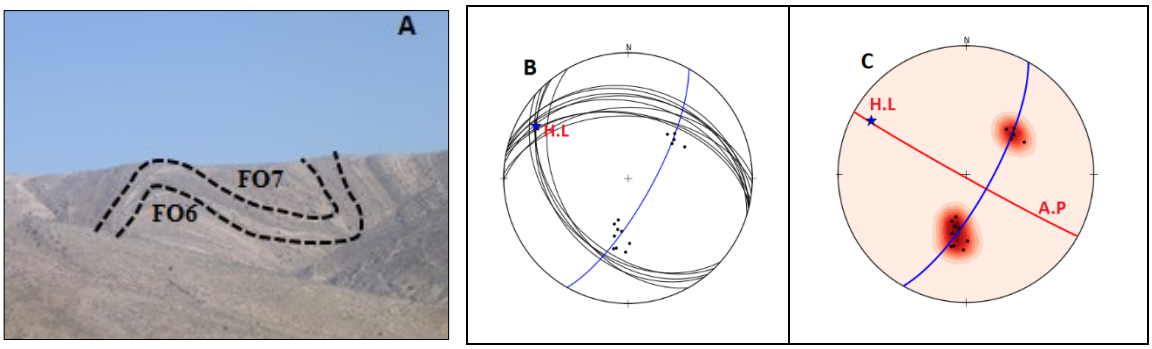

Fig.16 (a) Overall view of folding (FO6 and FO7) (viewed toward northwest), (b) βand π diagrams and determination of the joint line location for Anticline FO6 (16°/299), (c) counter plot of the sides of Anticline FO6 in order to determine the intra-sides angle (102°) and obtain the axial plane position of Anticline FO6 (88/209).

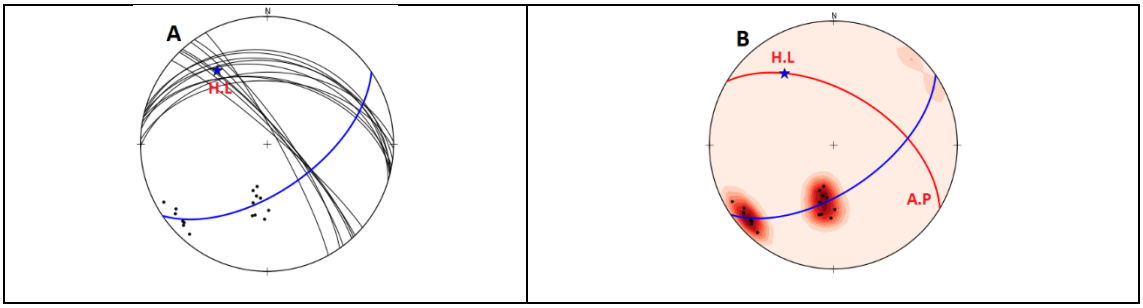

Fig.17 (a) βand π diagrams and determination of the joint line location for Syncline FO7 (31°/326), (b) counter plot of the sides of Syncline FO7 in order to determine the intra-sides angle (61°) and obtain the axial plane position of Syncline FO7 (036/62).

4-8-FO16

The stereograms shown in Fig.26 show the position of the joint line of Fold FO16 to be 4°/120. The position of the axial plane of the anticline is 89/210.The angle between fold sides is 84°. This, according to intra-sides angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-sub horizontal class.

4-9-FO17

The stereograms shown in Fig.27 show the position of the joint line of Fold FO17 to be 36°/341. The position of the axial plane of the anticline is 87/068. The angle between fold sides is 91°. This, according to intra-sides

angle classification [11], places it in the open fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright- moderately inclined class.

4-10- FO18

This outcrop is located at 52˚ 32' 57.57" E longitude and 29˚ 47' 52.07" N latitude. It is known as a chevron fold (chevron fold: when two folds' slopes are placed with a sharp angle relative to each other, the formed fold is called a chevron fold) (Fig.28-a). The stereograms, found in Fig. 28-a and b, show the position of the joint line of Fold FO18 to be 15°/335. The position of the axial plane of the fold is 66˚/87.The angle between fold sides is 57˚. This, according to intra-sides angle classification [11], places it in the close fold class. Additionally, classification based on the axial surface slippage and joint line trend places this fold in the upright-gently plunging class. Table 1 shows the axial plane position, joint lines and intra-sides angles for all 18 folds. In Table 2 the fold classifications are presented.

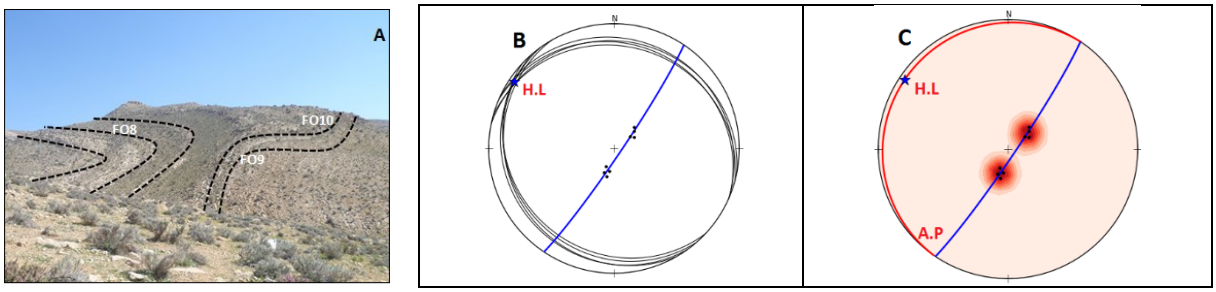

Fig.18 (a) Field view of the eastern outcrop of the mountain (b) βand π diagrams and determination of the joint line location in Anticline FO8 (5°/304), (c) counter plot of the sides of the fold in order to determine the intra-sides angle (149°) and obtain the axial plane position (89/033).

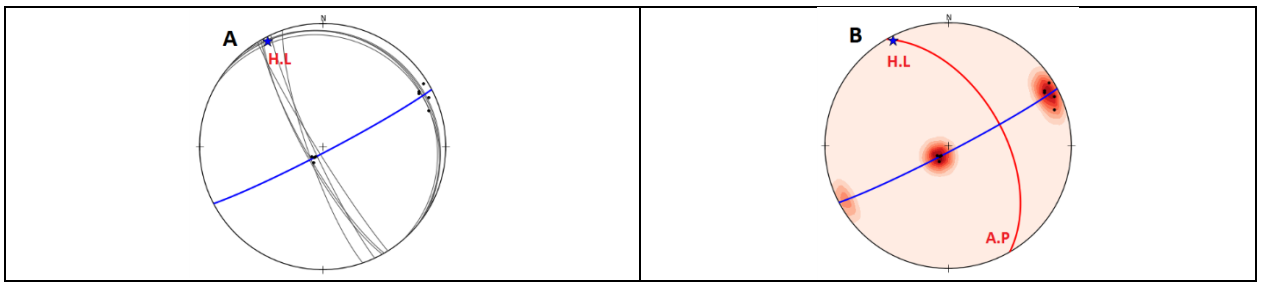

Fig.19 (a) βand π diagrams and determination of the joint line location for Anticline FO9 (4°/322), (b) counter plot of the sides of the fold in order to determine the intra-sides angle (89°) and obtain the axial plane position (060/53).

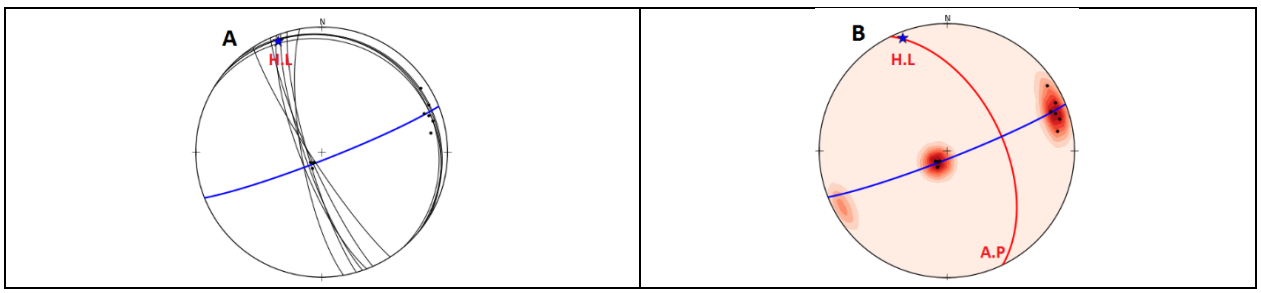

Fig.20 (a) βand π diagrams and determination of the joint line location for Syncline FO10 (5°/339), (b) counter plot of the sides of the syncline in order to determine the intra-sides angle (93°) and obtain the axial plane position (064/54).

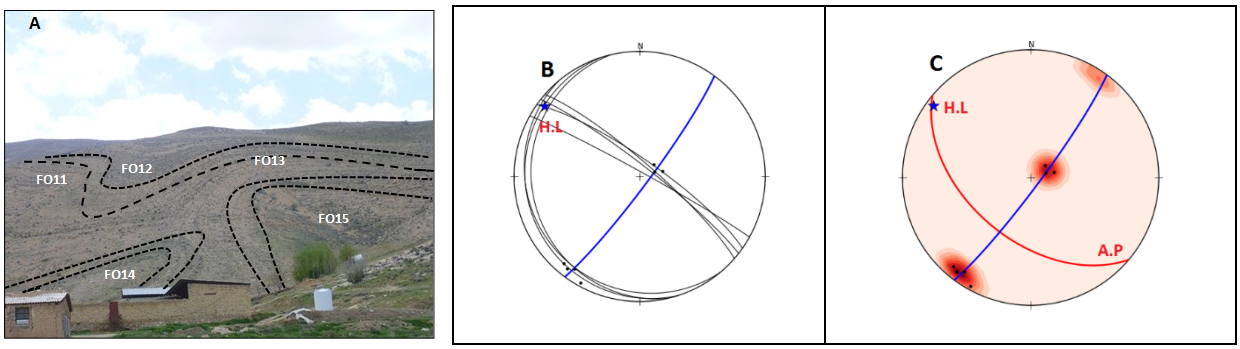

Fig.21 (a) Overall view of folding (viewed toward northwest), (b) βand π diagrams and determination of the joint line location for Anticline FO11 (6°/307), (c) counter plot of the sides in order to determine the intra-sides angle (86°) and obtain the axial plane position (50/220).

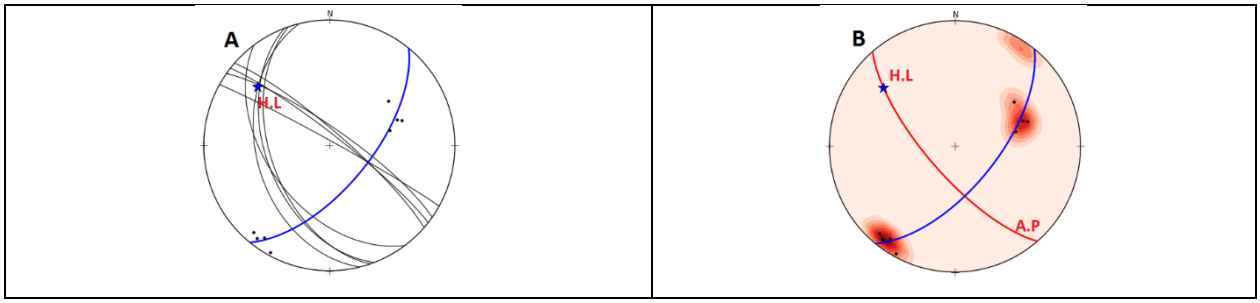

Fig.22 (a) βand π diagrams and determination of the joint line location for Syncline FO12 (27°/309), (b) counter plot of the sides of the syncline in order to determine the intra-sides angle (51°) and obtain the axial plane position (72/226).

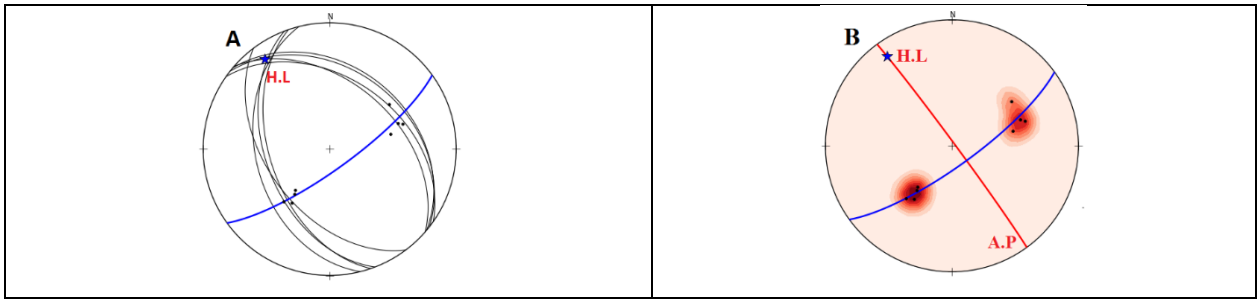

Fig.23 (a) βand π diagrams and determination of the joint line location for Anticline FO13 (13°/324), (b) counter plot of the sides of the fold in order to determine the intra-sides angle (92°) and obtain the axial plane position (86/053).

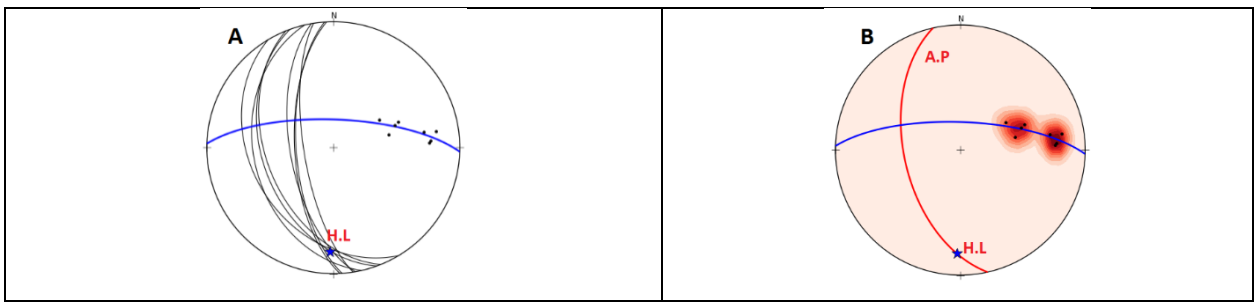

Fig.24 (a) βand π diagrams and determination of the joint line location for Anticline FO14 (18°/82), (b) counter plot of the sides of the anticline in order to determine the intra-sides angle (77°) and obtain the axial plane position (76/037).

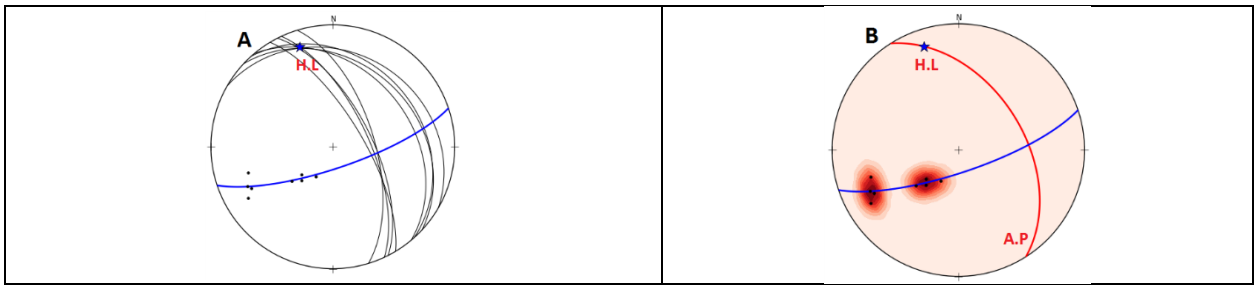

Fig.25 (a) βand π diagrams and determination of the joint line location for Anticline FO15 (14°/342), (b) counter plot of the sides of the fold in order to determine the intra-sides angle (86°) and obtain the axial plane position (72/067).

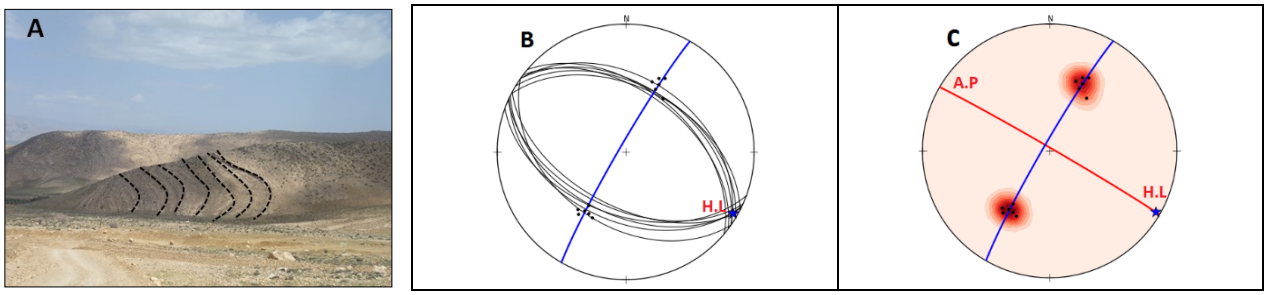

Fig.26 (a) View of Fold FO16 (viewed toward east), (b) βand π diagrams and determination of the joint line location (4°/120), (c) counter plot of the sides of the fold in order to determine the intra-sides angle (84°) and obtain the axial plane position (89/210).

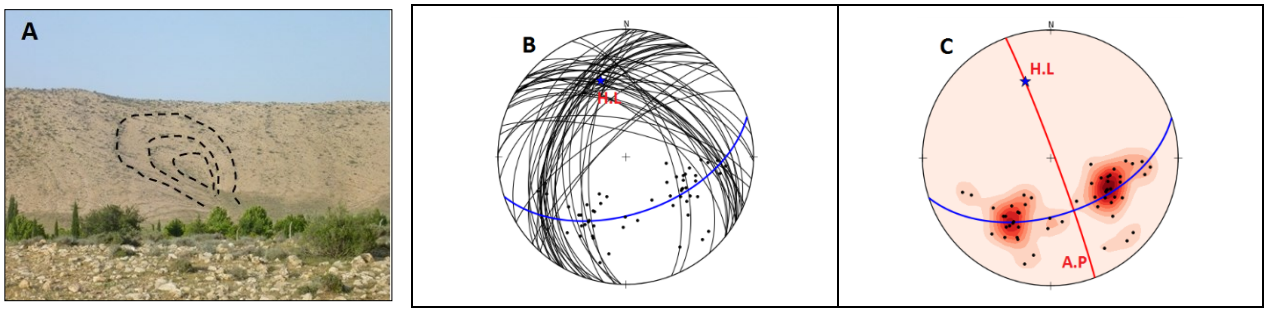

Fig.27 (a) View of fold FO17 (viewed toward northwest), (b) βand π diagrams and determination of the joint line location (36°/341), (c) counter plot of the sides of the fold in order to determine the intra-sides angle (91°) and obtain the axial plane position (87/068).

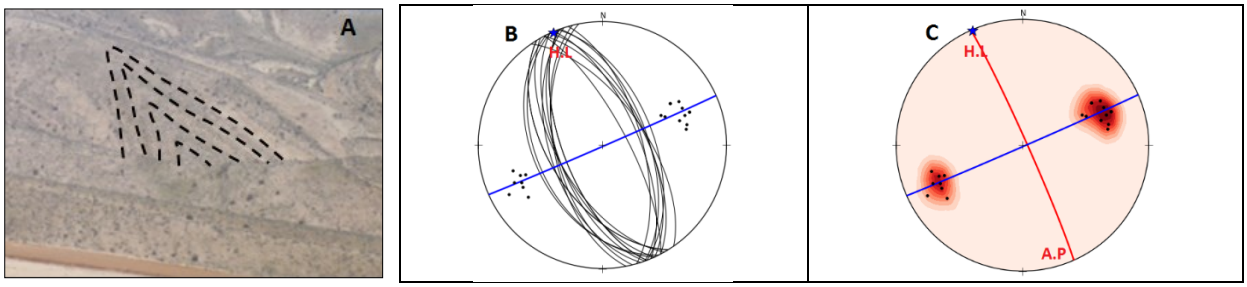

Fig.28 (a) View of Fold FO18 (viewed toward northwest), (b) βand π diagrams and determination of the joint line location (7°/337), (c) counter plot of the sides of the fold in order to determine the intra-sides angle (57°) and obtain the axial plane position (87/066).

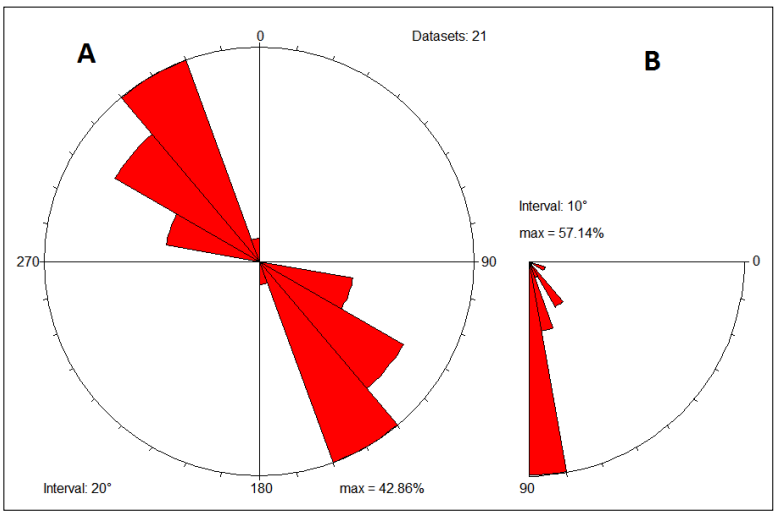

Fig.29 Rosaceous plot for axial planes of the folds, (a) linear rosaceous plot depicting the governed northwest-southeast trend, (b) grade rosaceous plot, all axial planes of folds have a gradient between 78° and 90° and this value is almost greater than 79°

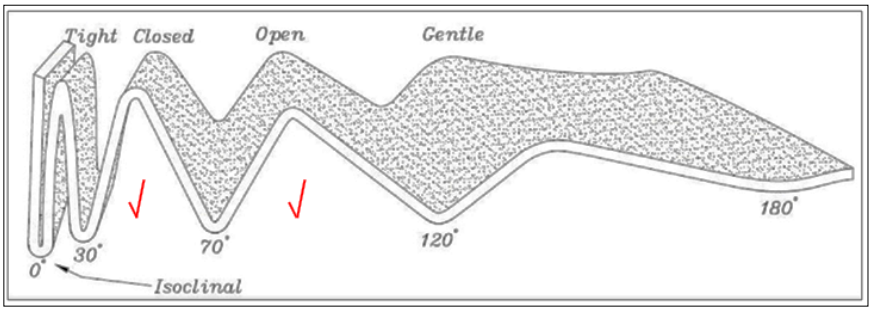

Fig.30 Classification of the folds based on intra-axial angle (Fleuty 1964).

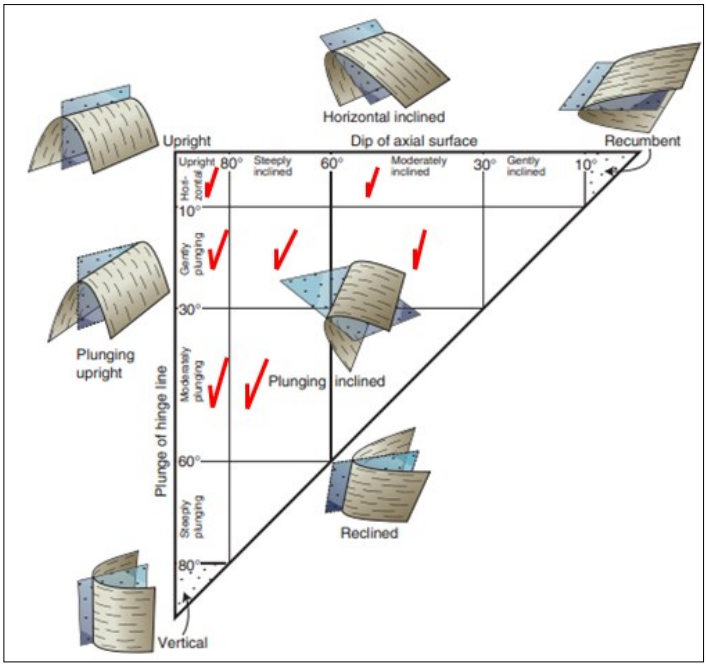

Fig.31 Categorization of the folds based on axial plane gradient and joint trend [11] (Based on [12]) The positions of the studied zone's folds in this category are shown in this image.

5. Conclusions

The axial surface trend of the folds in the formations related to the Cenozoic era is northwest-southeast (Fig.29). According to classification based on the axial surface slippage and joint line trends, the geometric statutes of the folds of the zone's Tertiary era formations are classified [11], based on the slope and shaft pivot hinge, into the classes: upright- gently plunging, steeply inclined-gently plunging, steeply inclined-moderately plunging, upright moderately plunging, upright- sub horizontal, moderately inclined-sub horizontal, moderately inclined- gently plunging (Fig.30). According to their intra-sides angle, they are ranked as being in the open or close class (Fig.31). The history of the studied area as a part of the Folded Zagros Belt shows direct contact with the convergence of the Arabian plane relative to central Iran. Changes in the Tertiary era formations in the region are in the process of convergence and have caused folds of various categories to form.be considered for more detailed exploration.

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