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Structural style and hydrocarbon trap of Karbasi anticline, in the Interior Fars region, Zagros, Iran

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Structural style and hydrocarbon trap of Karbasi anticline, in the Interior Fars region, Zagros, Iran

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Abstract

Karbasi anticline between west-northwest parts of Jahrom town is located in north-west 40 km distance of Aghar gas anticline in interior Fars region. This anticline has asymmetric structure and some faults with large strike separation observed in its structure. The operation of Nezamabad sinistral strike slip fault in west part of this anticline caused fault plunge change in this region.

Because of complication increasing of structures geometry in Fars region and necessity to exploration activities for deeper horizons especially the Paleozoic ones, the analysis of fold style elements, which is known as one of the main parts in structural studies seems necessary. In this paper because of some reasons such as Karbasi anticline structural complication, importance of drilling and hydrocarbon explorations in Fars region, it is proceed to analysis and evaluation of fold style elements and geometry with emphasis on Nezamabad fault operation in Interior Fars region. According to fold style elements analysis results, it became clear that in east part of anticline the type of fold horizontal moderately inclined and in west part it is upright moderately plunging, so west evaluation of anticline is affected by more deformation. In this research the relationship present faults especially the Nezamabad sinistral strike slip one with folding and its affection on Dehram horizon and Bangestan group were modeled. Based on received results may be the Nezamabad fault is located between G–G′ and E–E′ structural sections and this fault in this area operated same as fault zone. In different parts of Karbasi anticline, Dashtak formation as a middle detachment unit plays an important role in connection to folding geometry, may be which is affected by Nezamabad main fault.

1 Introduction

The Zagros fold – thrust belt in Iran lies on the northeastern margin of the Arabian plate. This fold thrust belt with northwestern – southeastern strike located from Tarus mountain in the northeastern of Turkey and Kurdistan in north of Iraq up to Strait of Hormuz in southwestern of Iran (Fig. 1).

More than 65 % (~ 107.5 billion m^3) of the remaining prove oil resources (~ 159.6 billion m^3) and nearly 34 % (~ 49.5 trillion cubic meters) of the total gas resources (~ 146.4 trillion cubic meters) of the world have accumulated in numerous giant and super giant hydrocarbon fields of the Middle East. Clearly, the accumulation of hydrocarbons in the Middle East has been intricately related to the stratigraphy and structural evolution of the Zagros fold-thrust belt (Alavi, 2007). This belt as one of the valuable oil-rich provinces provides approximately 2/3 of oil-resources and 1/3 of gas-resources the world.

The anticlines of Fars region, which are placed in Zagros fold-thrust belt, are valuable because of possessing a lot of gas resources in the Permo-Triassic carbonate sediments. According to the geological classification, this understudy area is located in the Interior Fars region (Fig. 2).

A lot of studies to be done on this area based on stratigraphy and geophysical exploration for the reason that optimization method but no studies to be done based on folding geometry, folding style for obtain study and investigation of structural oil traps with emphasis basement involved. On the other hand, a few studies should be done on understudy area based on kinematics pattern of folding in this fold–thrust belt.

Fold geometric form and mechanical stratigraphy evolution are affected by thickness, detachment unit's ductility and stratigraphy sequence of formations. Moreover fold geometric form and mechanical stratigraphy evolution depends on above mentioned cases (Kashfi, 1972; Falkon, 1969; Alavi, 1994; Sherkati, 2006). Many studies to be done according to variation of structural style and effects of detachment folding on folding pattern (Sherkati and Letouzey, 2004; Sherkati et al., 2005). These investigations that mentioned above confirm the effects of mechanical stratigraphy on folding geometry in Zagros but did not study the relationship of folding patterns by middle detachment horizons in the Paleozoic horizons based on relationship kinematics with main folds.

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Other researchers such as Obain (1950) mentioned the effects of detachment layers on folding process for the first time. On the other hand, in the recent years, geologists present different types of geometric and mechanical models and the obtained results of these studies increase researcher's information. Other researchers such as Supp (1983), Jamison (1989), Mitra (2002, 2003), Dahlstrom (1990) present papers which cause to increase geologists information about cases mentioned above.

Geometry of anticlines in Zagros affected by type of deformation and mechanical behavior of stratigraphic units. Detachment units such as Dashtak formation in Zagros are important for controlled folding pattern especially in Fars region. Dashtak formation with Triassic age belongs to Kazeron group and this formation have evaporates units such as shale and dolomite. On the other hand, other detachment formations in this area are Kazdomi and Gachsaran formation.

In this paper because of some reasons such as structural complication of Karbasi anticline, importance of drilling and hydrocarbon explorations in Fars region, it is proceed to analysis and evaluation of fold style elements and geometry with emphasis on Nezamabad fault operation in interior Fars region.

Karbasi anticline is an asymmetric structure and its stratigraphic units are affected by many faults in this region. Some of these faults may affect on the Dehram horizon in this region. As the result of effects of this faults that exist in stratigraphic units, faults operation may affects on gas reservation in this horizon (Tavakoli, 2000). Because of complication increasing of structures geometry in Fars region and necessity to exploration activities for deeper horizons especially the Paleozoic ones, the analysis of fold style elements, which is known as one of the main parts in structural studies seems necessary.

Specific features are important for folds describes and understanding how they develop (Twiss and Moors, 1992). According to this cases that mentioned above, we tried analysis and investigated on the complications in Karbasi anticline with fold element style analysis, structural map, modified structural sections (based on Tavakoli, 2001) and folding–faulting relationship modelling.

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2 Geological and geographical setting

Karbasi anticline is located in the West, North-West Jahrom city in Fars province (140 km to Persian Gulf). The general trending of this anticline is N60° W. This anticline is bounded from south by Chaghal, from southwest by Noura, from north-northeast by khaftar and from north-northeast by Jahrom anticlines (Fig. 2). Karbasi anticline is an elongated structure, which has 40 km length and 7.5 km width in the Asmari horizon. Mund River is flow with northern-southern path in this area and in the western part of anticline; this river has changes in flow of path. By whirling this river in the western part of anticline finally Mund River continue them path to south.

3 Structural setting

Karbasi anticline is an asymmetric structure. This anticline located in Interior Fars province. From point of topography is extension structure. Eastern part of anticline ended to Jahrom city and in the western part ended to mountains. The oldest formation that outcropped on the surface of this anticline is Gurpi formation that existed in the Gurbid strait (Fig. 3). In this anticline, some parts eroded on the surface and then cause outcrops the oldest formation such as Pabdeh-Gurpi on the surface. In the southern flank at the location which Asmari formation covered surface, some cliffs are exists with vertical walls. The highest part of Karbasi anticline has 2013 m elevation.

The most of surface of anticline generally covered with Asmari-Jahrom formation. This anticline is an asymmetrical anticline that the dip of southern flank is greater than the northern flank (Fig. 4). On the other hand, plunges dip value in western part of anticline more than eastern part.

Structure of Karbasi anticline is complicated also affected by some faults with high lateral displacement that operation faults could divided to different parts. By operation mentioned fault, western part of anticline plunged to north and in this part of flank has

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a regular dip. This anticline in the western part has complication structure but in the eastern part, structure has gentle change.

Some faults exist in the anticline that could be account to weakness for reservation gas in the Dehram horizon. In view of the fact that exist main faults in this anticline, may be anticline has complication in the deeper horizon. We tried to investigate these cases with modelling by structural cross section and drilling information well of anticline that investigate and analysis in the next part of paper.

Because of Karbasi anticline, has complication structure; the analysis of element fold style is necessity. Then for more studies in this structure, fold style elements changes will be analysis and investigation from east to west of anticline in the different structural cross section.

4 Faulting

Fault system in the Karbasi anticline has two type faults. One type is longitude fault and another type is transverse one. The Nezamabad sinistral strike slip fault is main fault in this area that affected on western plunge of Karbasi anticline. The longitude faults are located in the hinge line zone of anticline. On the other hand, some longitude faults located parallel with fold axis. Transverse faults located with high angle to fold axis.

5 Nezamabad fault

Nezamabad fault is one the strike slip fault with northeast-southwest trend in Gavbandi High that divided Gavbandi High from central Zagros (Setudehnia, 1978). This fault with 265 km length and northeast-southwest trend has sinistral component. In view of the fact that, at the first time Barzegar (1994) was introduced Nezamabad fault, he introduced this fault based on satellite image. This fault has 2.5 km strike slip displacement and beginning from southern flank of Shahini anticline to southeastern of Neyriz. The most displacement of Nezamabad fault easily observed in the satellite image of

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Khaftar anticline and caused until change and rotation of anticlines plunge by affected on them (Dehbashi, 2008).

According to fold style elements analysis results, it became clear that in east part of anticline the type of fold horizontal moderately inclined and in west part it is upright moderately plunging, so west evaluation of anticline is affects by more deformation. In this research the relationship present faults especially the Nezamabad sinistral strike slip one with folding and its affection on Dehram horizon and Bangestan group were modeled. Based on received results may be the Nezamabad fault is located between G-G′ and F-F′ structural sections, moreover a second order fault introduced in relationship with Nezamabad fault. In different parts of Karbasi anticline, Dashtak formation as a middle detachment unit plays an important role in connection to folding geometry, may be which is affected by Nezamabad main fault and second order one.

6 The description of folds

Descriptions of fold geometries are important because they allow comparisons within and between folds and allow us to recognize patterns in the occurrence and distribution of fold systems. For example, orogenic belts contain characteristic fold systems: along their flanks are large fold and thrust belts, with little metamorphism, but underlain by décollements; and in core zones where intense folding has been accomplished, accompanied by high-grade metamorphism under high temperature and pressure.

7 Elements of fold style

The style of a fold is the set of characteristic that describe its form. Over years of working with folds, geologists have identified certain features as particularly useful in describing fold and understanding how they develop (Twiss and Moors, 1992).

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7.1 Cylindericity

Folded surface forms a symmetric fold if in profile, the shape on one side of the hinges a mirror image of the shape on the other side, and if adjacent limbs are identifiable in length (Twiss and Moors, 1992).

Based on previous studies in the Karbasi anticline and layered location, this anticline has asymmetric anticline. In addition, anticline is an asymmetric anticline that the dip of southern flank is greater than the northern flank. Southern flank from 15° to 75° is changing and in northern flank dip value from 3° to 57° is changing.

7.2 Symmetry

The studied anticline is an asymmetric fold with changed plunge in the north of the western part of fold.

8 Materials and methods

The folded surfaces that analysis for top of Neyriz-Dashtak formations as Kazeron group and top of some formations of Bangestan group. According to gave result limbs in Karbasi anticline are unequal length.

Twiss and Moors (1992) described the geometry of folded surface by specifying three style elements: aspect ratio, tightness and bluntness. Based on these cases we will analysis geometry of fold style for Karbasi anticline. Because of some parts of anticline affected by faults and faults effects observed on surface, we could not in this parts measured and calculated some parameters.

There are three chief descriptors of a folded surface: aspect ratio the ratio of the fold amplitude to the distance between two adjacent inflection points; tightness, or the interlimb angle; bluntness, a measure of the curvature of the surface in the zone of closure.

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In this part, we mentioned how calculated and measured this parameters for studied area. Finally gave results showed by comparable diagram (Table 2).

8.1 Aspect ratio

The aspect ratio P is the ratio of the amplitude A of a fold, measured along the axial surface, to the distance M, measured between the adjacent inflection points that bound the fold (Twiss, 1988). In the Karbasi anticline, measured the aspect ratio (P) or ratio of amplitude to half of wavelength fold in seven part of structural cross section of this anticline.

According to calculated values of aspect ratio, this parameter variable from −0.847 to −0.322 for top of Bangestan group formations (Table 1) and values of aspect ratio variable from −1.08 to −0.156. This variable result gave for tested top of folded surface from eastern part to western part. At finally folds based on aspect ratio defined in (Table 1).

Based on logarithm P and description term of folds in Karbasi anticline just between three parts of folds (E–E′ to G–G′) description term of fold is broad and in the other parts is wide for top of tested surface formations of Bangestan group. That seems this changes affected on the some faults in mentioned parts of anticline. Because of most changes in the western part observed same as one domain of deformation (from E–E′ to G–G′ sections). May be operation of Nezamabad Fault in this area operation same as fault zone that specific states especially observed in top of tested surface formations of Bangestan group.

8.2 Tightness

The tightness of Folding is defined by the Folding angle Φ or the interlimb angle (Twiss and Moors, 1992). As the degree of folding increases, the folding angle increase and the interlimb angle decreases. Based on interlimb angle calculated in seven parts of fold from A–A′ to G–G′ sections, the minimum of interlimb angle is 62° degree for western part of anticline that located in the G–G′ structural cross section (for top of tested surface formations of Bangestan group). In addition, the maximum of interlimb angle is 136° for Eastern part of anticline that located in the A–A′ structural cross section (for top of tested surface formations of Bangestan group), (Table 1). The minimum of interlimb angle for top of tested surface Nz–Dk is 84° degree for G–G′ structural cross section in western part and maximum of interlimb is 152° degree for A–A′ structural cross section in eastern part. In the Diagrams 1, showed comparable diagrams for gave results. Ramsey (1967) classified folds based on folding angle that used in this paper and gave results showed in Table 1.

According to gave results, only in one parts of Karbasi anticline, based on folding angle fold is close that observed in part of G-G′ structural cross section where as fold type of anticline is rabbit ear fold (in southwest flank of rabbit ear fold). This complication of structure May be affected by operation of Nezamabad Fault. In this area, seems that faults affects on folding style and complications of structures.

8.3 Bluntness

The bluntness *b* measures the relative curvature of the fold at its closure. It is defined by Twiss (1988). In seven parts of fold from A–A′ to G–G′ sections Based on bluntness *b* calculated for tasted surface of Bgp formations (Ilam-Sarvak formations) and Nz–Dk formation this parameter. Gave results showed folds in different parts are angular, sub-rounded, rounded and blunt and just in E–E′ section, fold is angular (Table 2).

9 Geometry of axial plane

In the Karbasi anticline, seems that geometry of axial plane is planner. In the Fig. 5, based on analysis and calculations of some parameters, showed gave locations of axial plane in the seven structural cross sections of anticline. Based on gave location of axial planes and changes of them may be operation of Nezamabad Fault operated same as fault zone. On the other hand, based on Fig. 6, Karbasi anticline is a horizontal fold. According to gave results and output of Tectonics FP software for seven parts of Karbasi anticline, gave seven stereoplots that showed location of axial plane (AP) and cylindericity (AC) for seven parts of Karbasi anticline (Fig. 7).

10 Folding mechanism

In the eastern and western part of Karbasi anticline observed rabbit ear folds (G–G′ and A–A′ cross sections). In the western part observed most of changes. In this part of fold exists specific style, that based on folding angle, fold has close style. May be operation of Nezamabad fault and some faults that exist in this anticline caused this changes. In the Proposed pattern of folding model for Karbasi anticline, we will represent changes in different parts of Karbasi anticline.

Based on classification of Rickard (1971) in the Karbasi anticline, type of fold is difference (Table 3). In the eastern part of anticline (A–A′ section) type of fold is moderately inclined horizontal and in the western part of anticline (G–G′ section) type of fold is moderately inclined moderately plunging. According to this results, seems that western part greater deformed than eastern part. May be Nezamabad fault affected on this case.

11 Results and discussion

In this research, the relationship present faults especially the Nezamabad sinistral strike slip one with folding and its affection on Dehram horizon and Bangestan group were modeled (Figs. 8 and 9). Based on received results may be the Nezamabad fault is located between G–G′ and E–E′ structural sections and this fault in this area operated same as fault zone. In different parts of Karbasi anticline, Dashtak formation as a middle detachment unit plays an important role in connection to folding geometry, may be which is affected by Nezamabad main fault. Relationship between Nezamabad

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Fault and Karbasi anticline modeled by 3-D modelling based on structural cross section from A–A′ to G–G′ (Tavakoli, 2001).

12 Conclusions

Orientation of axial plane in difference parts of Karbasi anticline is different and may be Nezamabad Fault affected on this case. Varity of axial plane characteristic and axis of fold in different parts of anticline showed may be plunge rotation of anticline affected by Nezamabad Fault operation.

In the eastern part of anticline, type of fold is moderately inclined horizontal and in the western part of anticline, type of fold is moderately inclined moderately plunging. According to this results, seems that western part greater deformed than eastern part. Relationship between geometry of folding and faulting with operation faults in this area is possibility. Some faults that exist in the upper stratigraphic units of anticline is possibility jointed with Nezamabad Fault in the western part and because of operation this joint; fold in the western part tightness than other parts.

At finally, in different parts of Karbasi anticline, Dashtak formation as a middle detachment unit plays an important role in connection to folding geometry, may be which is affected by Nezamabad main fault.

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Table 1. Indicate style for tasted surface of Bgp formations (Ilam-Sarvak formations) and Nz–Dk formation.

Calculated Geometry Parameters of Karbasi Anticline

Row	Structural Section	A (km)	M (km)	Log P	Descriptive Term based on LogP	Interlimb	Folding Angle φ	Descriptive Term based on φ	rc (km)	ro (km)	Bluntness	Descriptive Term based on b	Top of Folded Formation
1	A-A'	0.5	3.25	-0.815	Wide	136	44	Gentle	5.2	5.3	0.981	Rounded	Top of Bgp
2	B-B'	0.7	2.8	-0.602	Wide	118	62	Open	4.4	4.7	0.936	Rounded	Top of Bgp
3	C-C'	12	3.6	-0.785	Wide	123	57	Gentle	5.2	7.2	0.722	Sub rounded	Top of Bgp
4	D-D'	1	4.45	-0.649	Wide	131	49	Gentle	6	6.4	0.937	Rounded	Top of Bgp
5	E-E'	5	3.5	-0.847	Wide	96	84	Open	1.7	6.2	0.274	Angular	Top of Bgp
6	F-F'	15	3.1	-0.316	Broad	79	101	Open	2.4	6.3	0.38	Sub angular	Top of Bgp
7	G-G'	1.2	3	-0.397	Broad	62	118	Close	3.9	5.5	0.709	Sub rounded	Top of Bgp
8	G-G'	1	2.1	-0.322	Broad	75	105	Open	5.1	2.5	1.5	Blunt	Top of Bgp

Row	Structural Section	A (km)	M (km)	Log P	Descriptive Term based on LogP	Interlimb	Folding Angle φ	Descriptive Term based on φ	rc (km)	ro (km)	Bluntness	Descriptive Term based on b	Top of Folded Formation
1	A-A'	0.7	7	-1	Wide	130	50	Gentle	6.4	7	0.914	Rounded	NZ-DK
2	A-A'	0.6	7.2	-1.08	Wide	152	28	Gentle	6.8	6.6	1.02	Blunt	NZ-DK
3	B-B'	0.7	2.5	-0.552	Broad	118	62	Open	3.4	5.2	0.653	Sub rounded	NZ-DK
4	C-C'	0.6	2.5	-0.619	Wide	129	51	Gentle	3.4	3.5	0.971	Rounded	NZ-DK
5	D-D'	0.8	3.05	-0.581	Broad	125	55	Gentle	4.8	6.5	0.738	Sub rounded	NZ-DK
6	E-E'	2	4	-0.301	Broad	111	69	Open	1.3	6.2	0.171	Angular	NZ-DK
7	F-F'	0.6	1.5	-0.397	Broad	90	90	Open	1.5	2.9	0.502	Sub rounded	NZ-DK
8	G-G'	1.5	2.15	-0.156	Equant	84	96	Open	3.4	3.8	0.894	Rounded	NZ-DK

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Table 2. Comparable diagrams 3-D line chart and 3-D Bar chart showed interlimb angle, folding angle, amplitude and wavelength for tasted surface of Bgp formations (Ilam-Sarvak formations) and Nz–Dk formation.

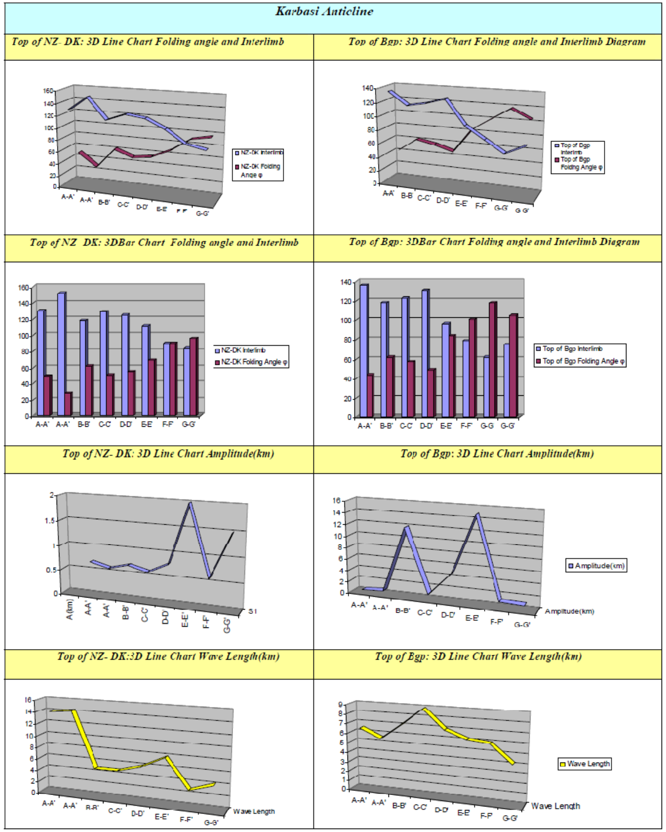

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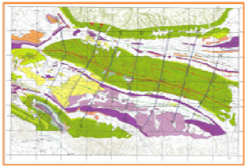
Table 3. In this table showed type of fold in seven sections of Karbasi anticline. This classification based on classification of Rickard (1971) and Ragan (1985).

	A-A' P:9/ 110 AP:117/ 73 *Fold type: Moderately inclined horizontal*	B-B' P:3/ 286 AP:105/ 88 *Fold type: upright horizontal*	C-C' P:3/ 291 AP:111/ 83 *Fold type: upright horizontal*
D-D' P:1/ 105 AP:106/ 66 *Fold type: Moderately inclined horizontal*	E-E' P:2/ 303 AP:122/ 66 *Fold type: Moderately inclined horizontal*	F-F' P:8/ 107 AP:129/78 *Fold type: upright horizontal*	G-G' P:42/ 086 AP:088/ 89 *Fold type: Moderately inclined moderately plunging*

P: Plunge AP: Axial Plane

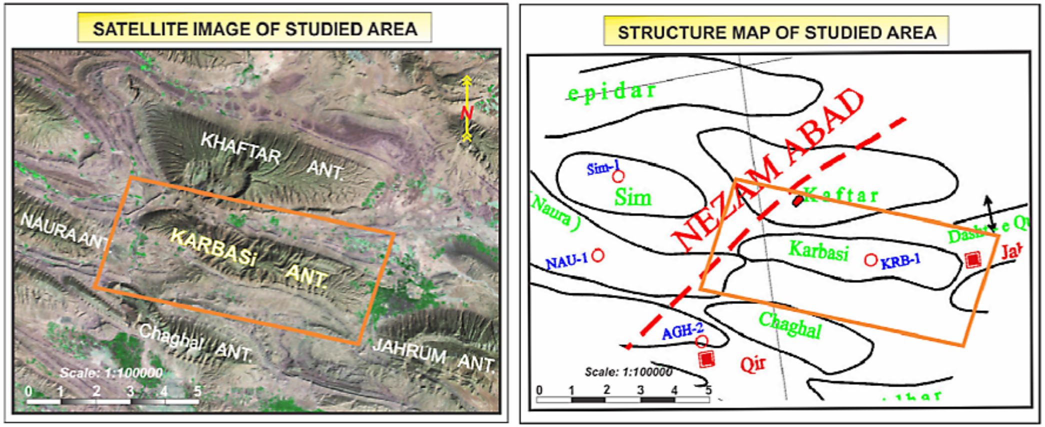


Figure 1. Location of the study area in the satellite image and structural map.

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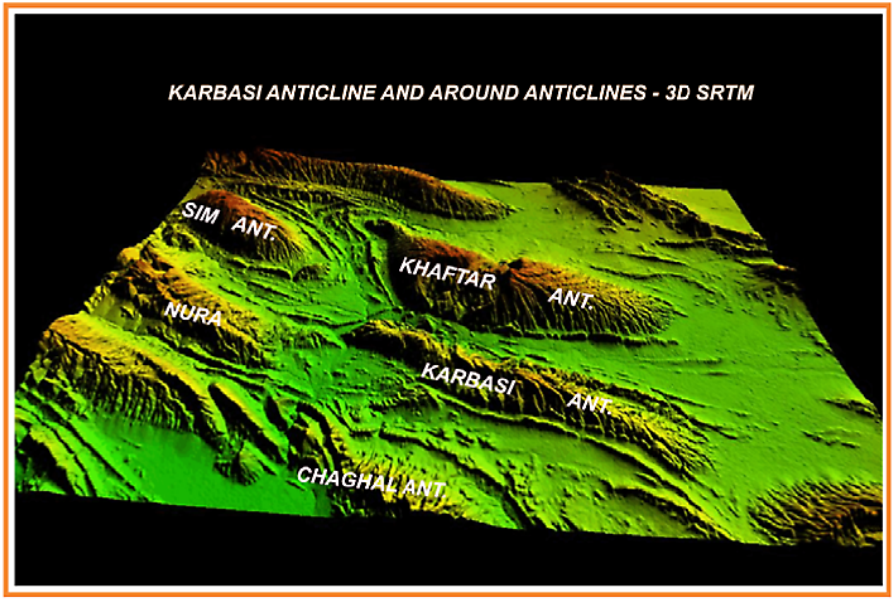

Figure 2. 3-D SRTM image of Karbasi anticline and adjacent anticlines.

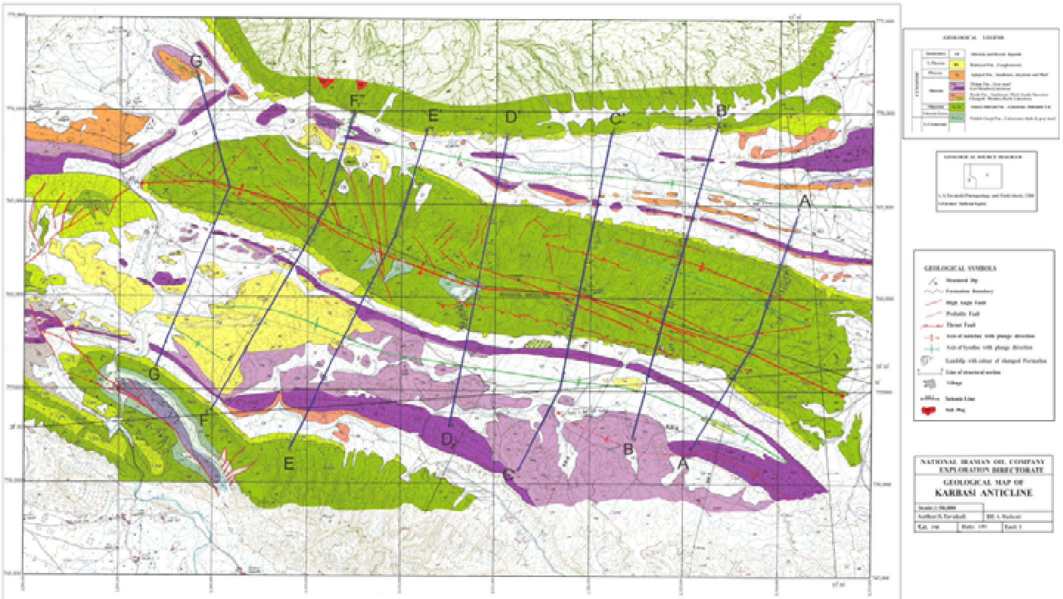

Figure 3. Geological map of Karbasi anticline and structural cross section.

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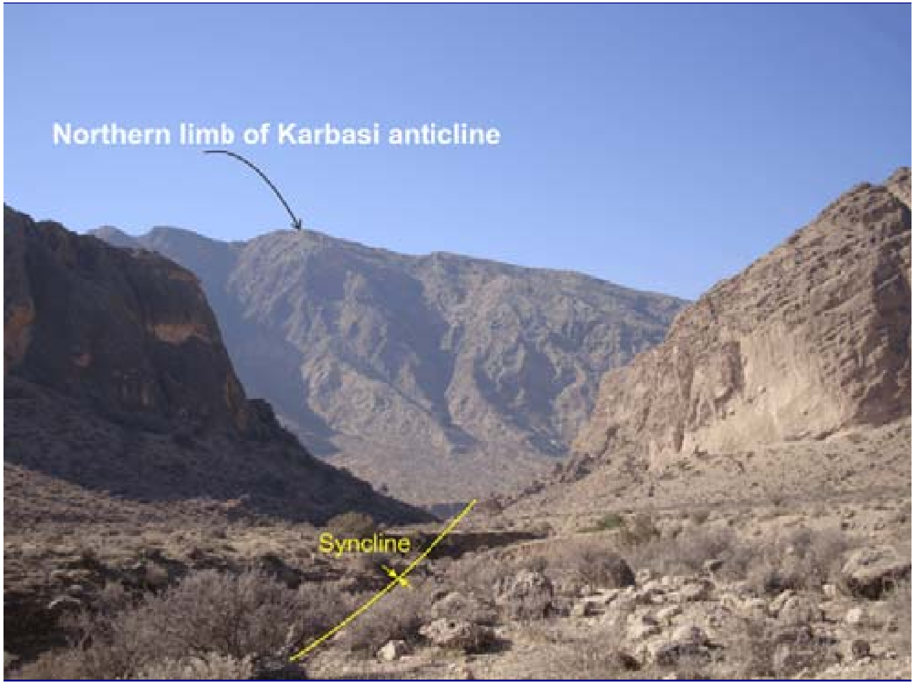

Figure 4. View to the south-west that shows northern limb of Karbasi anticline and syncline between Karbasi anticline in northern limb and Khaftar anticline in southern limb.

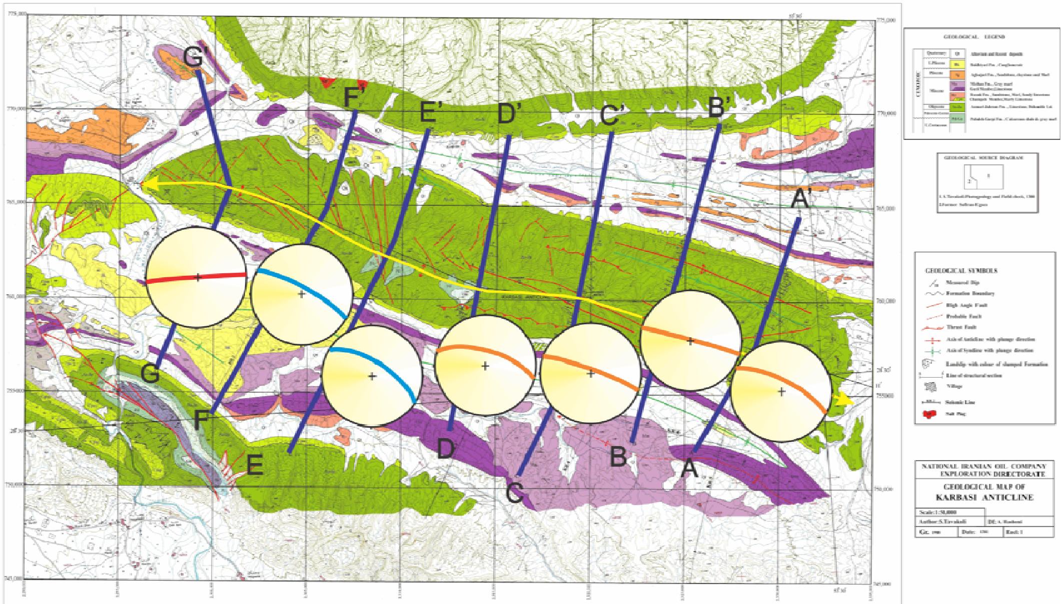

Figure 5. How located axial plane based on gave results in seven sections of Karbasi anticline.

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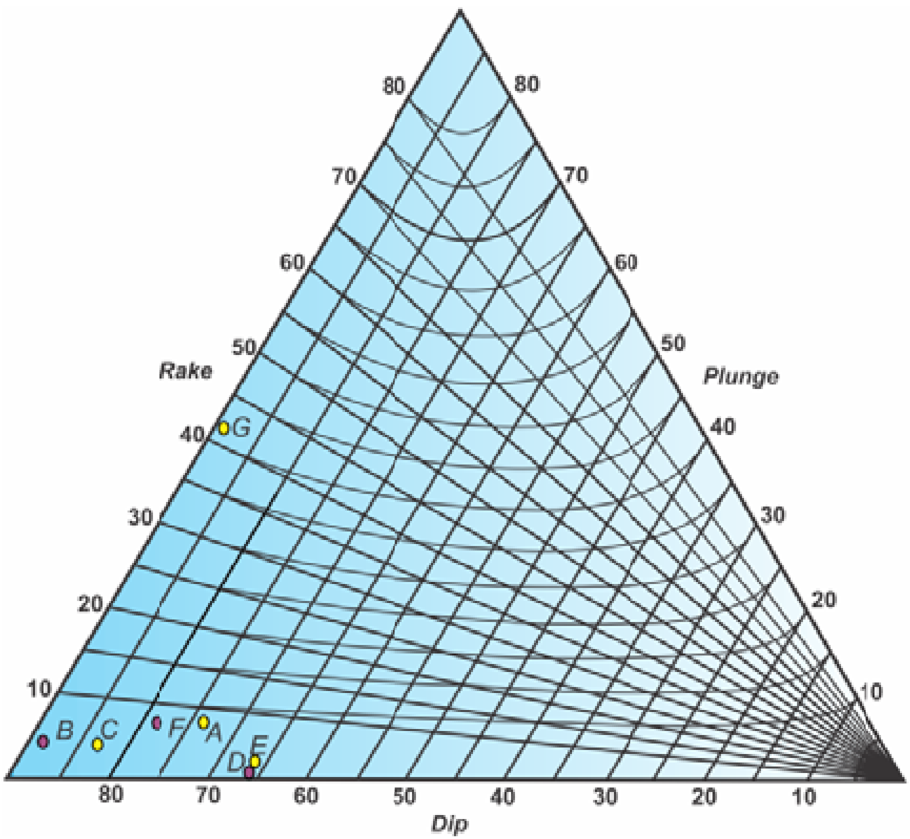

Figure 6. Triangle form diagram showed type of fold in seven sections of Karbasi anticline, based on Rickard (1971). This Diagram gave based on Rickard classification. Type of fold in Part G (G–G′ section) is different to other section completely.

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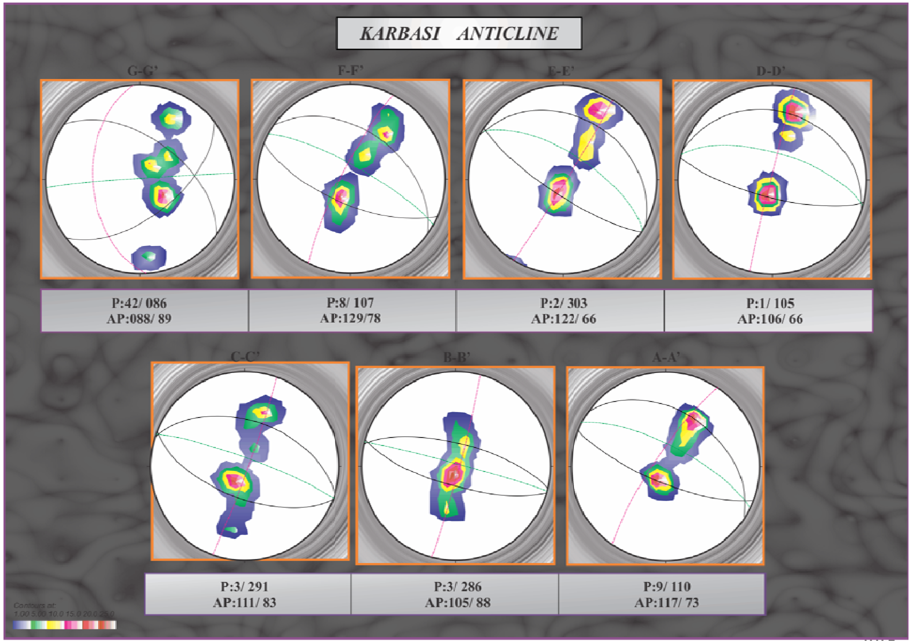

Figure 7. Stereoplots showed axial plane (AP), cylindericity (AC) for seven sections of Karbasi anticline.

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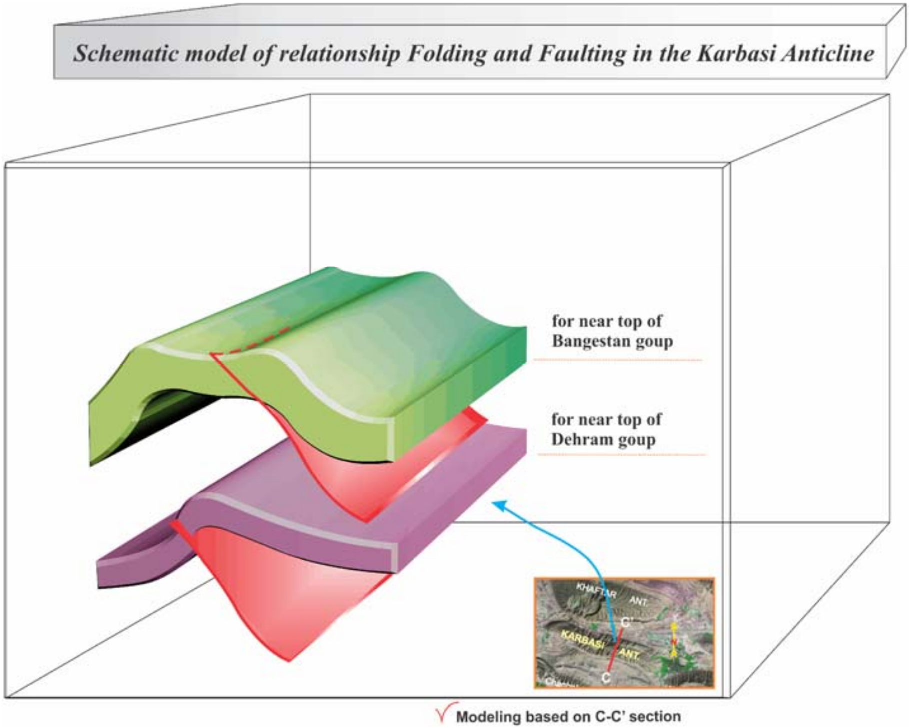

Figure 8. Schematic model for relationship between folding and faulting for near top of Bgp and near top of Dehram horizon in C–C′ part of Karbasi anticline that observed fault rapture in surface. This modelling is based on information of C–C′ structural cross section with 3-D modelling software.

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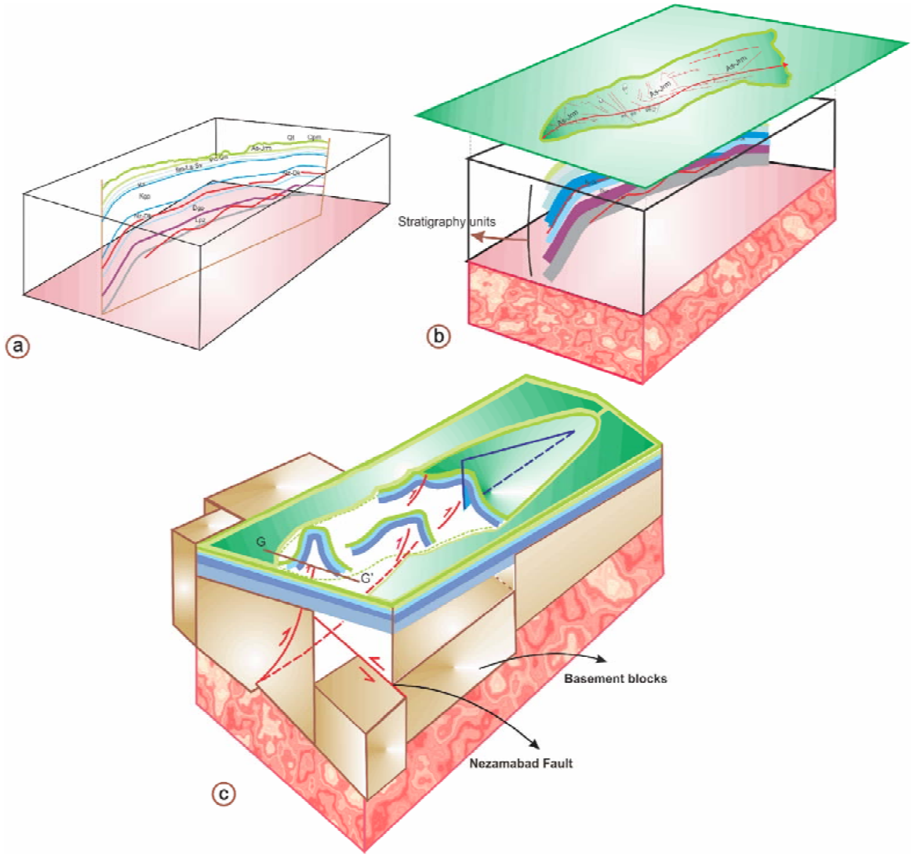

Figure 9. (a) 2-D model of longitude structural cross section of Karbasi anticline. **(b)** Forms of fold with location of longitude structural cross section. **(c)** Relationship between Nezamabad Fault and Karbasi anticline, 3-D model (based on structural cross section from A–A′ to G–G′).

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