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Folding Mechanism in the Asmari Anticline, Zagros, Iran

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Abstract

Asmari anticline is a NW-SE fold in the Dezful Embayment sub-basin of Zagros. Fars group (Late Moicene-Quaternary) is cropping out in the cores of anticlines in this area, but Pabdeh and Asmari formations (Oligocene-Early Miocene) have cropped out only in Asmari anticline in the Dezful Embayment. Therefore, it has formed a unique exposure for above formations. In order to this situation, folding mechanism of Asmari anticline has investigated in this research. According to our results, Asmari anticline has two mechanisms: flexural-slip in post-Cretaceous sequences (Khami-Quaternary) and fault-bend folding in pre-Cretaceous sequences. So, there is a hybrid folding mechanism that has introduced for the first time in this paper.

Keywords

Asmari Anticline, Mechanism, Hybrid Folding, Zagros, Iran

1. Introduction

In this article, we investigated the folding mechanism of a unique structure that has located in the Zagros-East Taurus Hinterland [1]. Dominant structural trends in Zagros Province (**Figure 1**) are NW-SE in northwestern part and E-W in southeastern part. From tectonics view, it contains the overthrust and simple fold belts of Zagros that formed on the northeastern part of Arabian plate's passive margin. Zagros Mountains have continued to East Taurus Mountains in Turkey and have named Zagros-East Taurus hinterland. The Zagros-East Taurus hinterland has formed an external platform (fold and thrust belt) in north margin of Arabian Craton. Vergence of folding in this hinterland is toward south and southwest [2] [3].

The several landslides, being linear structure in forward limb of the anticline, sulfur springs (**Figure 2**) and

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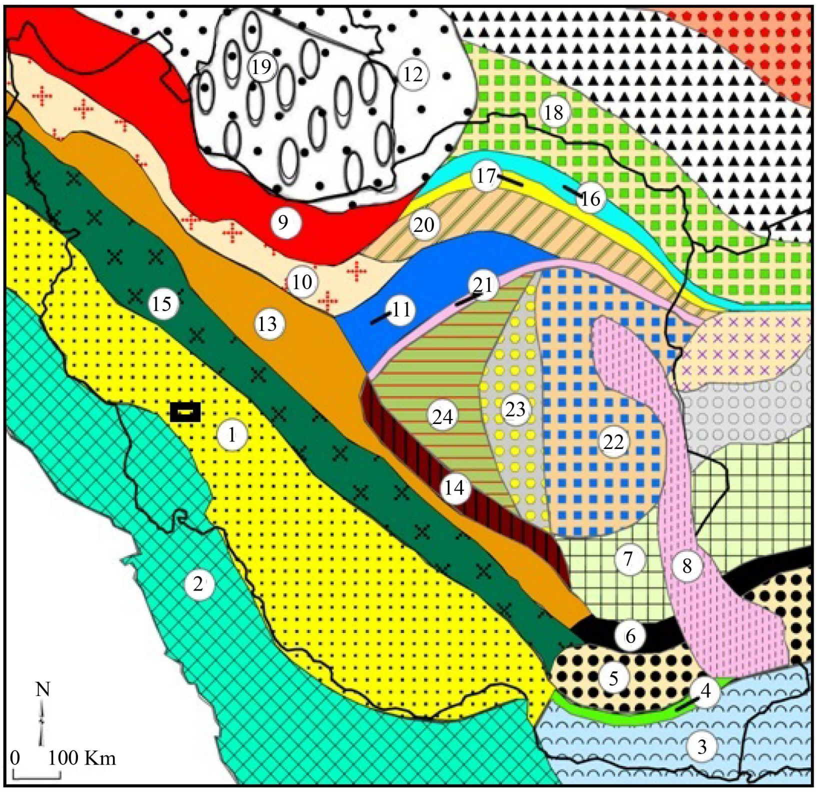

Figure 1. Physiographic-tectonic zoning map of Iran's sedimentary basins Iran modified from [1]. Numbers in this figure are 1: Zagros-East Taurus hinterland; 2: Persian Gulf-Mesopotamian foreland basin; 3: Makran accretionary prism; 4: Bashagard Mountains; 5: Jazmorian-Mashkel fore arc basin; 6: Shahsavaran-Soltan magmatic arc; 7: South Lut-South Helmand back arc basin; 8: East Iran Mountain belt; 9: West-Central Alborz and lesser Caucasus hinterland; 10: Great Kavir-Northen Urmieh lake foreland basin; 11: South Great Kavirfold and thrust belt; 12: South Caspian-Black sea foreland basin; 13: Urmieh-Dokhtar Magmatic arc; 14: Naien-Kerman retro arc foreland basin; 15: Sanandaj-Sirjanoverthrust belts; 16: East Alborz or Binalod hinterland; 17: Torbat-e am-Neyshabour retro arc foreland basin; 18: KopetDagh hinterland; 19: South Caspian remnant basin; 20: Maiamay-Taibad Inverted back arc basin; 21: Khaf-Kavir Plain Magmatic arc; 22: Lut Plain-Gonabad back arc basin; 23: Tabas hinterland; 24:Yazd-Khour Piggy back basin. The study area is shown in the black rectangle.

Figure 2. A view from the sulfur springs of Garu in the north-westerly nose of Asmari anticline view toward SE.

pollution some of them to oil in depth and unusual outcrop of the Asmari and Pabdeh formations have been caused by an especial folding mechanism.

2. Materials and Methods

The Dezful Embayment, situated in the western part of the Iranian Zagros fold-thrust belt, hosts most of the hydrocarbon reservoirs of Iran. In the Dezful Embayment, several detachment units have been active during the evolution of Zagros orogenic belt. The lower detachment is within the Hormoz formation (Infra-Cambrian-Lower Paleozoic), and other important detachment units are in the Dashtak formation (Triassic), Kazhdoumi formation (Lower Cretaceous), Pabdeh formation (Paleogene) and Gachsaran formation (Upper Miocene).

The anticlines in the Dezful Embayment are in general asymmetric with a SW vergency. The anticlines are usually to be affected by longitudinal faults and they have been formed some types of fault-related folds.

The Asmari anticline represents a unique Asmari formation outcrop in the Dezful Embayment. **Figure 3** shows a generalized stratigraphic overview of the succession in the Dezful Embayment. From Cretaceous through quaternary period, this region is filled by shales of Kazhdoumi formation (Lower Cretaceous), limestones of Ilam and Sarvak formations (Upper Cretaceous), limestones of Ilam and Sarvak formations (Upper Cretaceous), shales and marls of Gurpi and Pabdeh formations (Upper Cretaceous-Oligocene), limesones of Asmari formation (Lower Miocene), evaporates of Gachsaran formation (Upper Miocene) and Plio-quaternary clastics.

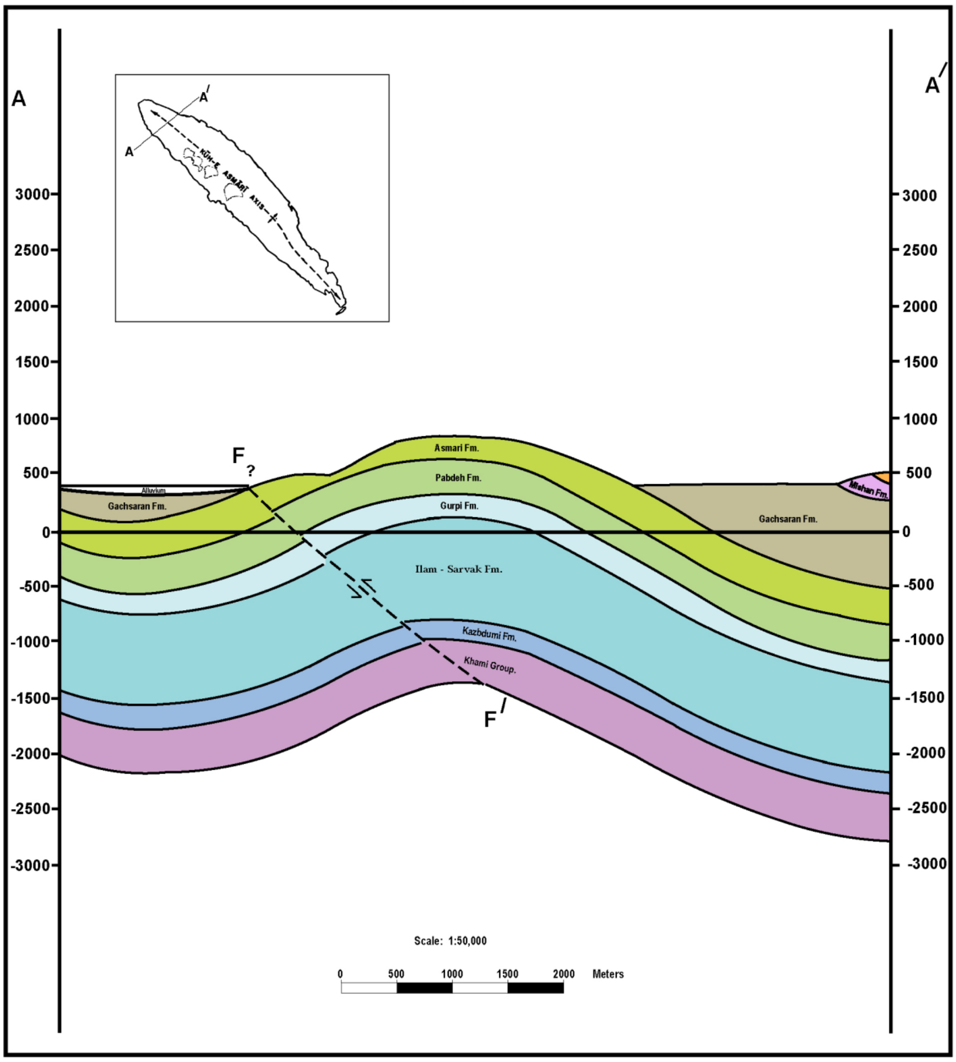

Figure 3. Cross section AA' of the Asmari anticline.

Asmari anticline is situated in Gulgir village of 22 km distance SE Masjed-e-Suleyman city. This structure is located between longitudes 49˚30'E and 49˚42'E and latitude 31˚36'N and 31˚42'N (**Figure 1**). This anticline with 30 km length and 10 km width in axis is a fold decreases toward lateral. Maximal height of fold is in the Asmari formation and fold hinge with 1391 m. The oldest outcrop formation in this area is Pabdeh formation.

From descriptive point of view, Asmari anticline is a whale back, pericline and asymmetric fold. Our geometric analysis have shown post-Cretaceous sequences (Khami-Quaternary) in the Asmari anticline which has formed a sub-cylindrical fold (in middle part), a coniferous with ellipse section fold (in south-easterly and north-westerly) and fore limb slope is more than back limb. Aspect ratio in this anticline is 0.26 (P_E = 0.26), so it is a broad fold. Bluntness of fold is 0.56 (b = 0.56) and it is a surrounded fold. Folding angle changes from 60 to 75 degree, so it is an open fold. Fourier analysis is calculated in top and base parts of the Asmari formation by using structural cross section and seismic profile. Based on fourier analysis, fold type defines parabolic to sub-elliptical with amplitudes 2 - 3.

True thickness of the Asmari formation (350 meters) and axial surface parallel thickness (450 meters) were measured. Dip isogons mode of the Asmari formation is convergent type (1 class), and dip isogon mode changes from 1A to 1C from anticline core toward limbs [4].

3. Results and Discussion

We have prepared four geologic cross sections and a longitudinal section by surveying through the Asmari anticline. The results have been shown by **Figures 3-7**. The cross sections AA', BB', CC' and DD' have been drawn on the base of the Khami Group and possibly fault (?) has cut its forelimb. This fault can be related to flexural slip mechanism and it may be a main factor of formation of several landslides in forelimb and its linear shape.

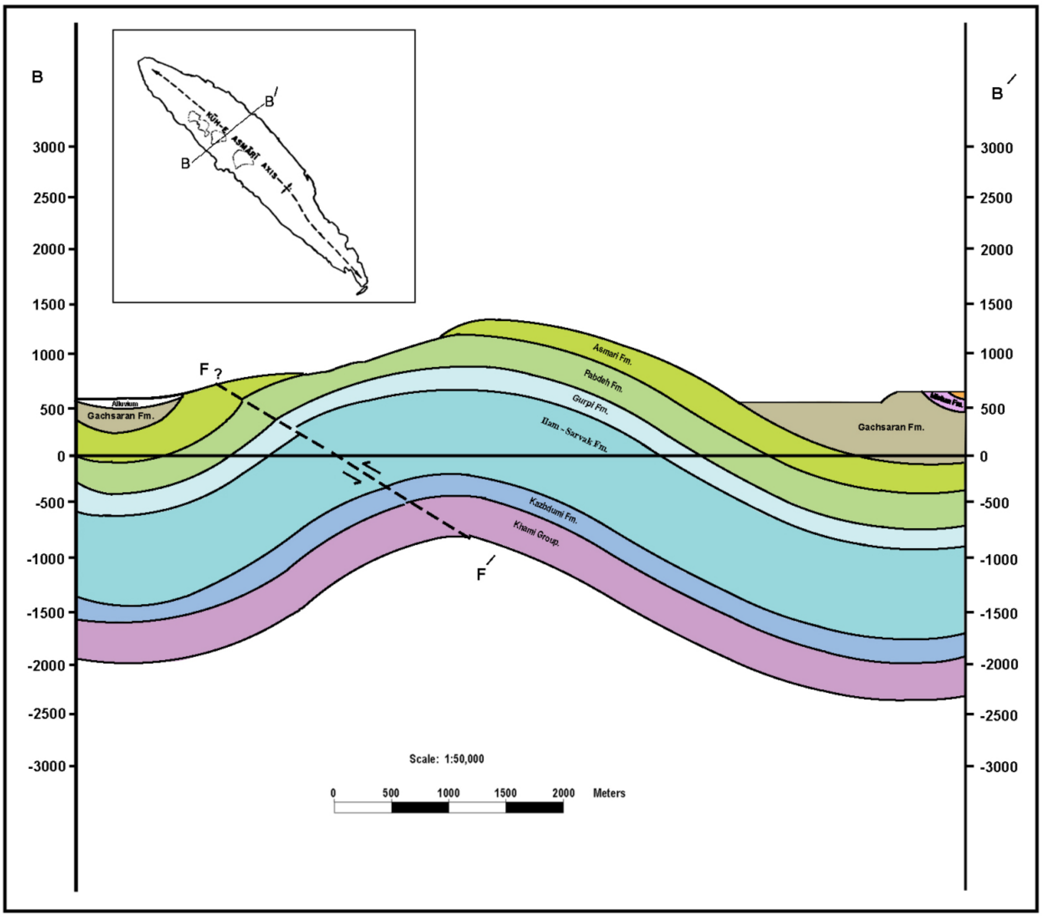

Figure 4. Cross section BB' of the Asmari anticline, modified from [5].

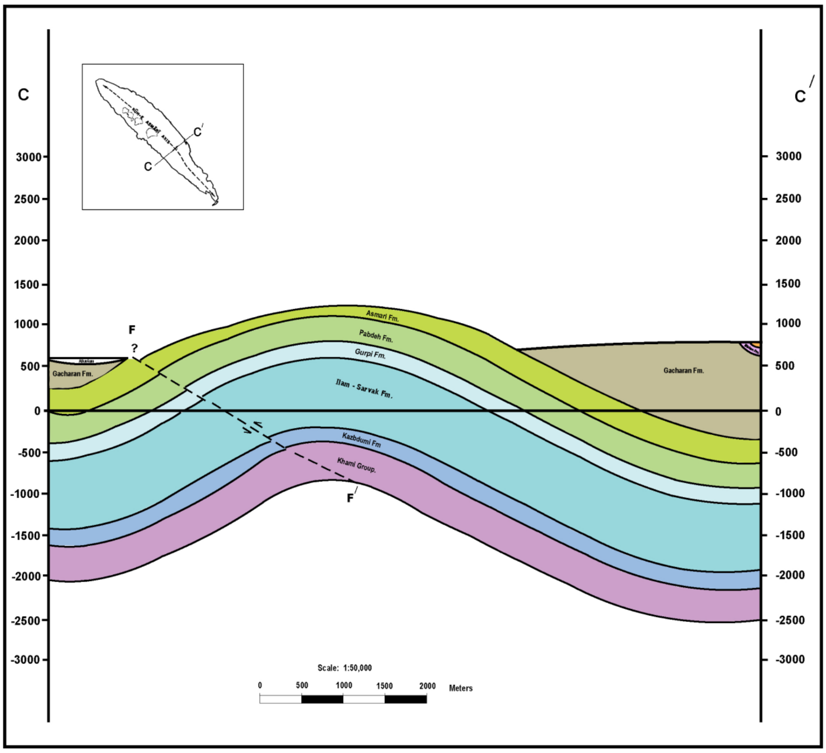

Figure 5. Cross section CC' of the Asmari anticline.

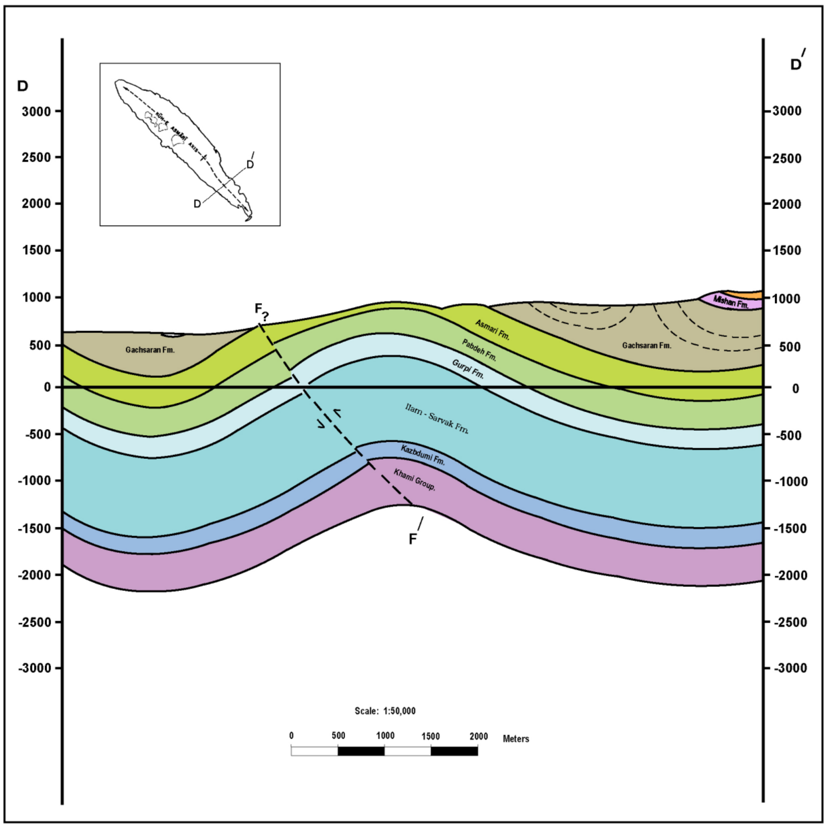

Figure 6. Cross section DD' of the Asmari anticline.

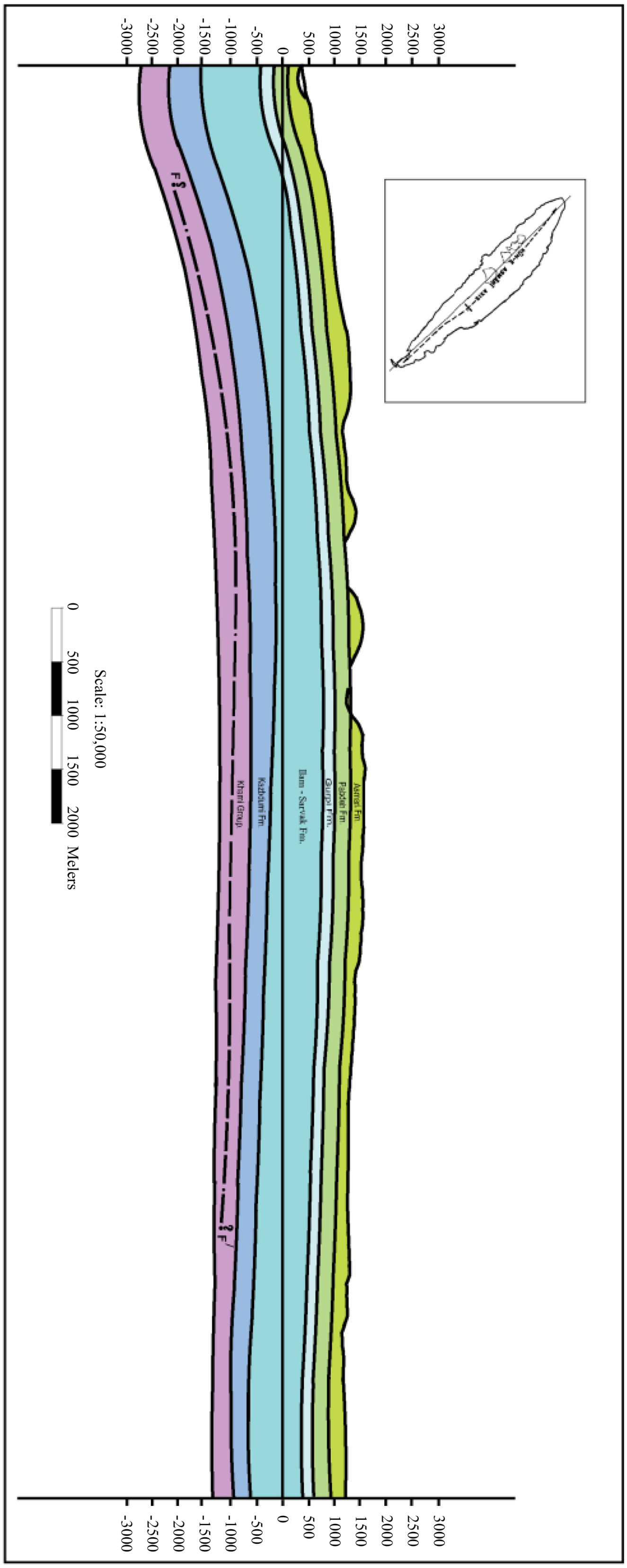

Figure 7. Longitudinal section of the Asmari anticline.

Based on our previous works [5], pre-Cretaceous sequences in the Asmari anticline shows a fault-bend folding (mode I) in depth (**Figure 8**) and its forelimb thinning is less than 25 percentages.

Also, from active tectonics point of view, Asmari anticline is an active fold, because Mountain front sinuosity (Smf index) was calculated 1.21 (**Figure 9**), so it explained that entablature of the Asmari anticline accompanied with active uplifting. Ratio base width of valley altitude (Vf index) was calculated between 4.1 to 31.16. Low amountsof Vf (**Figure 10**) may be result of performance of active tectonics (**Table 1**). Based on previous work on the salt diapirism [8]-[17] and neotectonics regime in Iran [18] [19], Zagros in south Iran is the most active zone [20]-[29]. Then, Alborz in north Iran [30]-[59] and Central Iran [60]-[68] have been situated in the next orders.

On the other hand, fracture analysis of the Asmari anticline shows that, in this fold, longitudinal, dextral and sinistral shear fractures (**Figure 11**) have the most development toward north-westerly nose. Although transverse fractures have developed well toward mid fold.

Fractures survey on the anticline shows these fractures formed before and synchronic with event folding. So we should say fractures on the Asmari formation and older units are forming in sync with anticline formation.

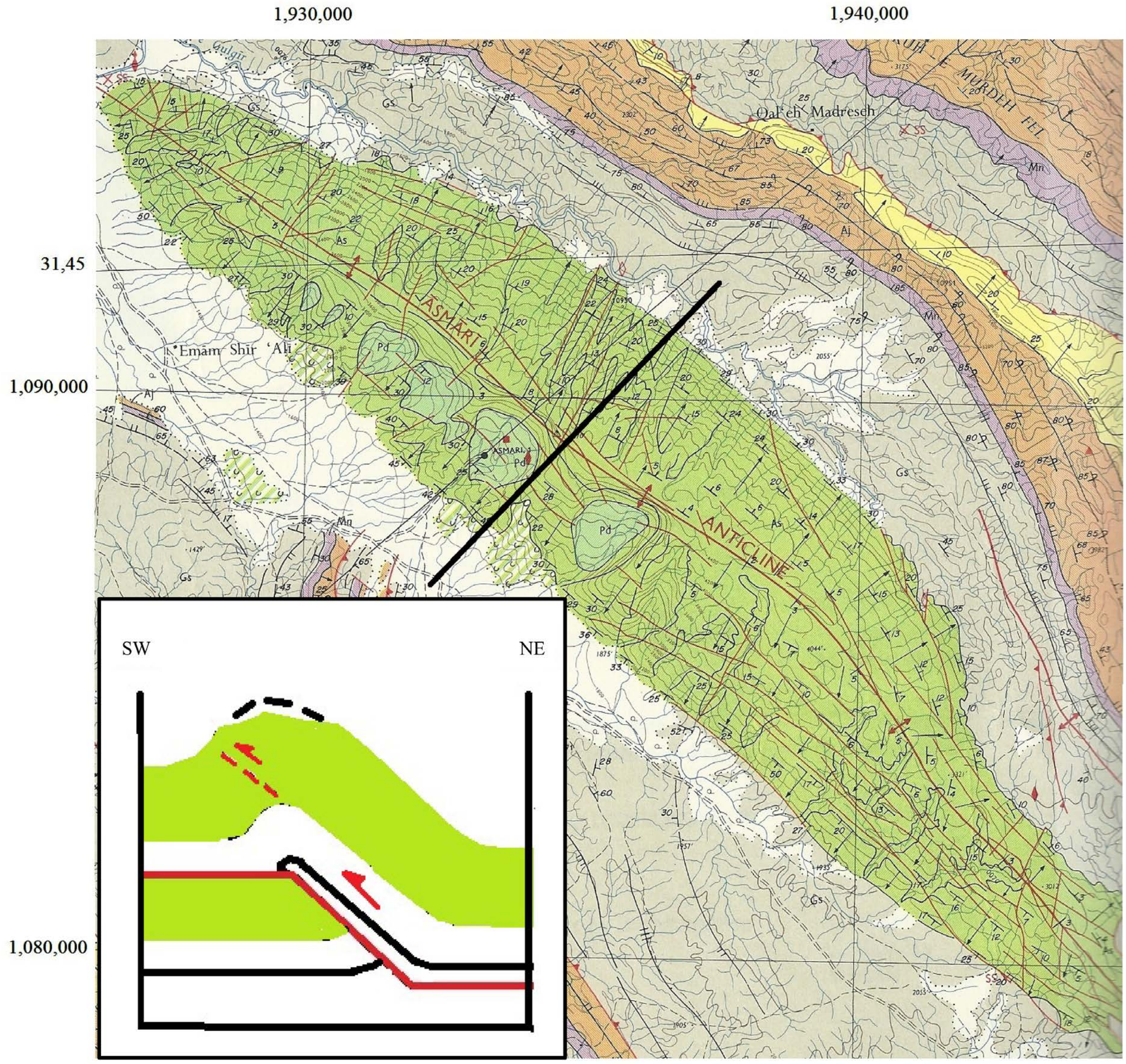

Figure 8. Geologic map of Asmari anticline with a cross section line (black line), modified from [6] and a schematic cross section of Asmari anticline, based on [7]. Post-Cretaceous sequences (Khami-Quaternary) are in green color.

Figure 9. Mountain front of the Asmari anticline, view to the NW.

Figure 10. An V shape of valleys on the northeastern limb of the Asmari anticline, view to the SW.

Figure 11. Asmari limestones and their fractures on the northeastern limb of the Asmari anticline, view to the SE.

Therefore, first migration of the oil fluid was possible where the anticline was uplifted. So, Khami group can be introduced as proper reservoir. There are several springs. Some of these springs originate from the piedmont alluvial reservoirs, and they have water with normal quality, for example, Bidzard spring, Sulfur springs which place in north-westerly nose of the Asmari anticline (**Figure 12**). Eight other springs have situated along longitudinal fractures in this anticline.

4. Conclusions

Hybrid folding mechanism has introduced for the first time for the Asmari anticline. This mechanism has been resulted for combination of flexural-slip folding in post-Cretaceous sequences (Khami-Quaternary) and fault-bend folding in pre-Cretaceous sequences. So, there is a hybrid folding mechanism that has introduced for the first time in this paper.

We have investigated mechanism of the Asmari fold by preparation of four cross sections AA', BB', CC' and DD'. Also, geomorphic evidence shows that the Asmari fold is an active fold. Asmari anticline is important because of its oil reservoirs, but clear characteristic phenomenon of Asmari formation is the development of three fracture set (longitudinal, transverse and shear) that caused oil spills from its reservoir. With considera-

Table 1. Values of Vf index.

Station	E_{ld} (m)	E_{sc} (m)	E_{rd} (m)	V_{fw} (m)	V_f
1	548/64	426/72	548/64	1000	8/2020
2	548/64	426/72	670/56	900	5/9055
3	609/6	486/68	670/56	1000	6/5189
4	670/56	548/64	670/56	500	4/1010
5	670/56	548/64	670/56	600	4/9212
6	609/6	548/64	670/56	1100	12/0693
7	731/52	609/6	670/56	800	8/7489
8	670/56	609/6	670/56	1900	31/1679
9	853/44	670/56	792/48	2000	13/1232
10	486/68	426/72	548/64	700	7/6973

Figure 12. North-westerly nose of the Asmari anticline, view to the SW.

tion of Asmari fault depth and fractures development before and in sync with anticline formation, we can say when the anticline is uplifted, first migration of the oil fluid is possible on the Asmari formation, so there is impossible oil escape from the Khami group, and it can be surveyed for posterior oil exploration and extraction in this area.

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