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Role of the Kazerun and Borazjan faults in emplacements Dashti salt dome, Boushehr

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ABSTRACT

The studied area is between two basement rock faults of Kazerun in north and Borazjan in south. They are a part of right- handed strike- slip fault system of Qatar- Kazerun. The north of this system is in Iran. Kazerun and Borazjan faults are En Echelon fault. Therefore, in separation zone, where tow fault have overlap, create a pull-apart basin. The result of this transtension is uplifting tow salt domes; one in the south of Kazerun fault (Dashti salt dome) and the other in the north of Borazjan fault (Khormuj salt dome).

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INTRODUCTION

The studied region is located in the south west of Iran between geographical longitudes 51^0 and $30'$ to 52^0 eastern and geographical latitudes 28^0 to 28^0 and $40'$ of northern part (figure 1). The general strike of the region is northwest – southeast. A considerable change in the thickness and sedimental facies defines the reaction to the complicated tectonic due to the collision of Arabic plate with Zagros region and the activity of basement faults (Alavi, 2004). On the basis of GPS measurements, the convergence is also active among the continental plates. The Arabic plate is moving with speed equivalent to 22±2mm a year proportionate to the Eurasia plate through N8±5E (vernant *et al*, 2004).

This convergence includes the shortening within the continent all over Iran except Makran, the speed of being shortened decreases from south of Zagros toward the north which defines right-handed movement through northeast boundary of Zagros Mountains (Talebian and Jackson, 2002).

Not any outcrop is seen from basement rock (stone foundation) in the Iranian part of Zagros (Alavi, 1991). The geographical construction of this studied region is simple, moderate and includes a set of big, close and condensed range of anticlines with a vertical axial level and northwest- southeast strike process (Alavi, 2004).

Geological setting:

This region includes fold part of Zagros toward Persian Gulf and coastlines and sediments besides Persian Gulf. Its geological construction is simple, moderate and includes a set of big, close and condensed range of anticlines with a vertical axial level and northwest–southeast strikes (Alavi, 2004).

From the Permian and beginning Triassic, the formations of Zagros Mountains are different from Permian of another part of Iran and a basin with continuous subsiding along with lengthy sedimentation has been formed. In this basin, the thickness of marine sediments is more than several thousand meters which cover the sediments of Paleozoic platform similar in slopes in Zagros Mountains.

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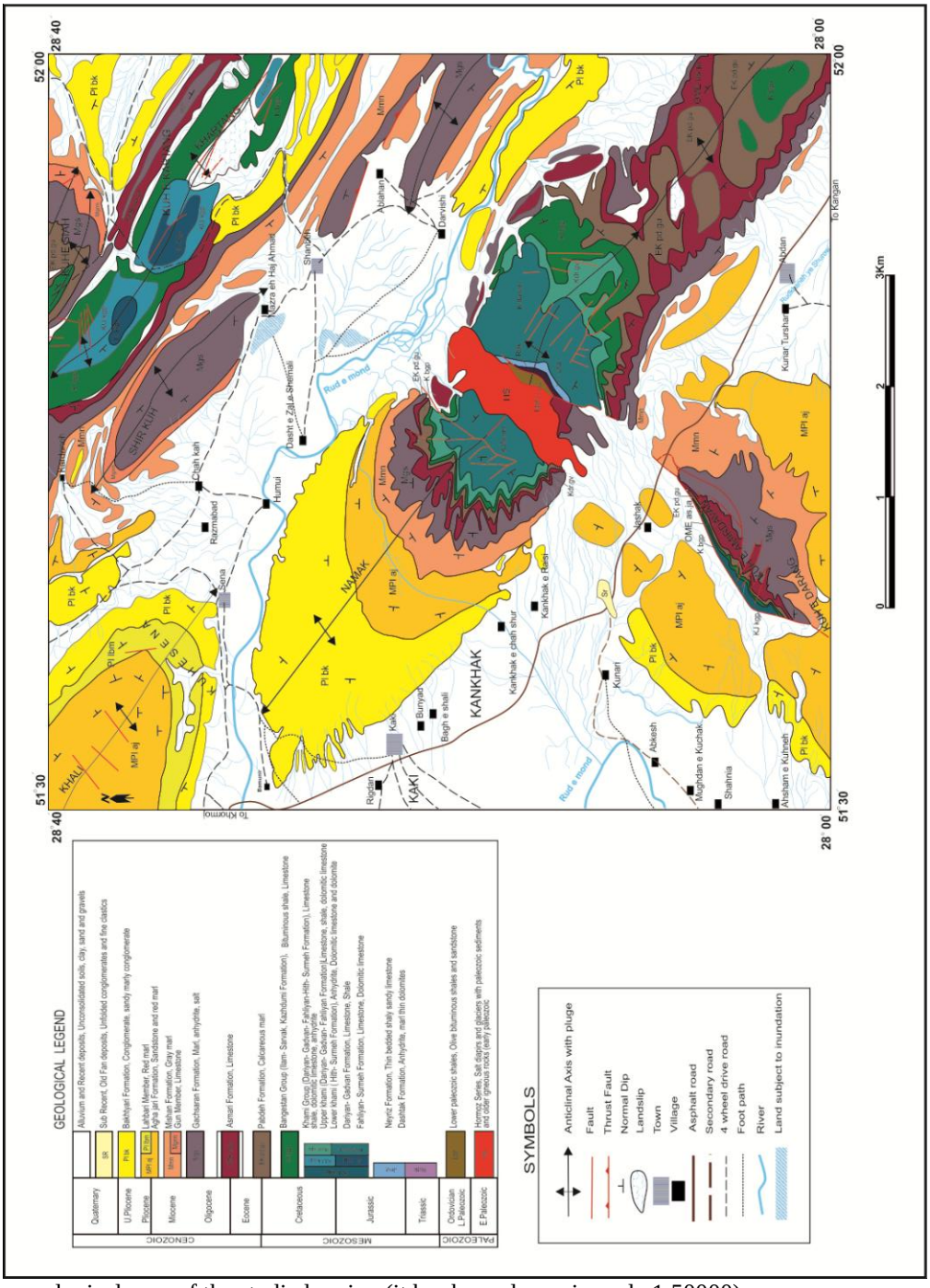

Fig. 1: the geological map of the studied region (it has been drawn in scale 1:50000).

The high thickness of former Cambrian salty sediments of Zagros Mountains is completely similar to the sediments of eastern part in Saudi Arabia and east of central Iran (Hosseini, 1988). As a whole, thick sediments of Zagros Mountains have been folded exclusively in the last process of alpiane orogeny which is pelio–peleistosen (Allen *et al*, 2004). The folded region of Zagros Mountains has been formed from a series of asymmetrical folds with an axis of northwest–southeast (Alavi, 2004).

As a whole, in the studied region, the following formations are seen from ancient times until now:

- Hormoz series with the age of Cambrian – infracamberian.
- Formations of khami group with the age of above Jurassic – below cretaceous.
- Pabde – Gurpi formations with the age of above cretaceous – Oligocene.
- Jahrom – Asmari formations with the age of Oligocene – Miocene.
- Gachsaran, Razak and mishan's formations from Fars group with the age of Miocene.
- Aghajari formations with the age of Pliocene and Miocene.
- Bakhtiari formations with the age of Pliocene – Pleistocene.

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In the studied region, two excreting salty dome (Dashty salt dome and khormoj salt dome) are seen. The salts of hormoz series have reached to the surface by making holes in the sediments. These two domes have come out due to the emergence of a tensile region between two strike-slip faults of kazerun and borazjan. In the continuation, this subject will be argued about.

The basement faults of study area:

The right-handed strike-slip fault system of Qatar-kazerun causes the folded Zagros Mountain to have complicated deformation geologically in the south west of Iran with an approximate north-south strike and it is considered as one of the active and seismic faults (Talbot *et al*. 1984). This fault system has been formed from two northern and southern parts, which the northern part itself is in the arid part of Iran and includes two parts of kazerun fault in the north and borazjan fault in the south of Iran.

This system of faults from kazerun's fault is located in the 15 kms of kazerun west and 143 kms of Shiraz west. In other words, it starts from dena fault in north of yasooj and continues to Qatar in the south with a whole length of 500 kms along with several curvatures (Sajedi, 1386).

The northern part of the fault system of Qatar-kazerun (the part which has been located in the arid part of Iran), as it was said, has been formed from two parts of kazerun's fault in the north and borazjan's fault in the south. These two parts have been located with separation over lapping toward each other through steps. Kazerun's fault is a basement and ancient fault with an approximate north-south strike which passes from 15 Kms of Kazerun's west with a length about 125 kms on the earth. This fault forms the western limit of salty domes development of Persian Gulf and it has outcrop along those two salty domes. It seems that kazerun's fault continues to Qatar. For this reason that fault is called Kazerun-Qatar fault (Aghanabati, 1386).

Kazerun's fault has N20E strike approximately and it has affected the range lines of 8 Kms depth (Berberian, 1995). According to Aghanabati (1383), this fault has affected the sediments of Zagros Mountains despite controlling the western boundary of the salty basin of Hormoz: in the way that it has bent and moved structures of Zagros Mountains through a right handed direction. In Fars province, this bent is so notable. The evidence show that the fault of Kazerun has an approximate strike of northern-southern and or north north west-south south east through a right handed movement at least slightly. For instance, the tectonic processes, in the north of Persian Gulf, show that the border line of Saudi Arabia platform and Zagros Mountains unit has been moved by this fault through a right handed direction. Apparently, this fault forms the western boundry of evaporating basin's development of comberin-latter Precambrian of Iran and it has the outcrop of two salty domes along itself (Esfandiari and barzgar, 1358).

Lock of macro-scismic data and shortage of earthquake's epicenter shows Lock of this fault's new activity. But, earthquakes of January 1967 (with magnitude 4.7) and October 1971 (with magnitude 4.5) in the southern part of Kazerun's fault (in most references, it has been called borazjan's fault) which shows the activity of a part of kazerun's fault in the Quaternary period (berberian, 1981).

The Kazerun-borazjan fault is an active fault with a northern-southern strike through the Zone of Zagros Mountains (Manafi and arian, 1387). Because of the kazerun-borazjan fault's activity, the right handed movements can be measured about 140 and 150 kms respectively along the mountain front fault of Zagros (MFF) and Zagros foreland fault (ZFF) from this fault system (Manafi and Arian 1387). If the movement of this fault has started after sedimenting of the fault's slippage is about 5.14 mm in a year (Sajedi, 1386). This fault has been formed from two faults by steps; Kazerun in the north and borazjan in the south with an overlapping between them (Berberian, 1995), (figure 2). Borazjan fault is located in the south of Kazerun's fault with a length about 180 km. Consequently, the right-handed movement along this fault has been stretched and folded through the axis of northwest-southeast of Khormouj and Gisakan' antidines toward a northern-southern strike; so that Ghale Dokhtar anticline has a northern-southern axis among them. The fault precipice of Borazjan is obviously observed from a region in the north of Bandar Abbas to Khormouj several sulfur springs and hot waters have been located besides each other in the foothill of the fault precipice (Sajedi, 1386).

The processes of developing pull-apart basins:

In the region where in the strike-slip fault has curvature or steps and a general tensile region is created in the bending place, the development process of pull-apart basin is observed (figure 3). In general tensile region, normal faults and tensile fractures (breakages) have been occurred and; Consequently, the region is subsided and suitable condition are provided for subsiding sedimental substances in this basin.

The geometry of pull-apart basin and it's maximum subsiding depends on three factors: These factors are as the followings:

1- The separation among overlapped faults
2- Overlapping rate
3- depth of basement rocks

Regarding the above cases, three conditions can be created in the development process of pull-apart basin which is:

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1) If the ratio of separation rate to the overlapping is more than one and the depth of stone-foundation is so much more than two, in this case; a pull-apart basin is formed which the sediments are accumulated in it's center (poorkermani and Solgi, 1388).

In other words, we have an ordinary pull-apart basin (figure 3a).In this condition; the rhombic subsidings (graben basins) of earth are done along with a subsiding center which is the accumulation place of sediments.

The depth of basement rocks > the separation rate and overlapping rate.

The ration of separation rate on the overlapping rate > 1

2) The condition in which the ratio of separation rate on the overlapping is lower than one and the depth of basement rock is so much more than separation and overlapping, instead of one accumulation center of sediments, two accumulation centers are made around two branches of the fault (figure 3b). In this condition, two subsiding centers which are those accumulation centers of sediments are made along with rectangular grabens and we will have a narrow pull-apart basin.

The depth of basement rocks > the separation rate and overlapping rate.

The ration of separation rate on the overlapping rate < 1

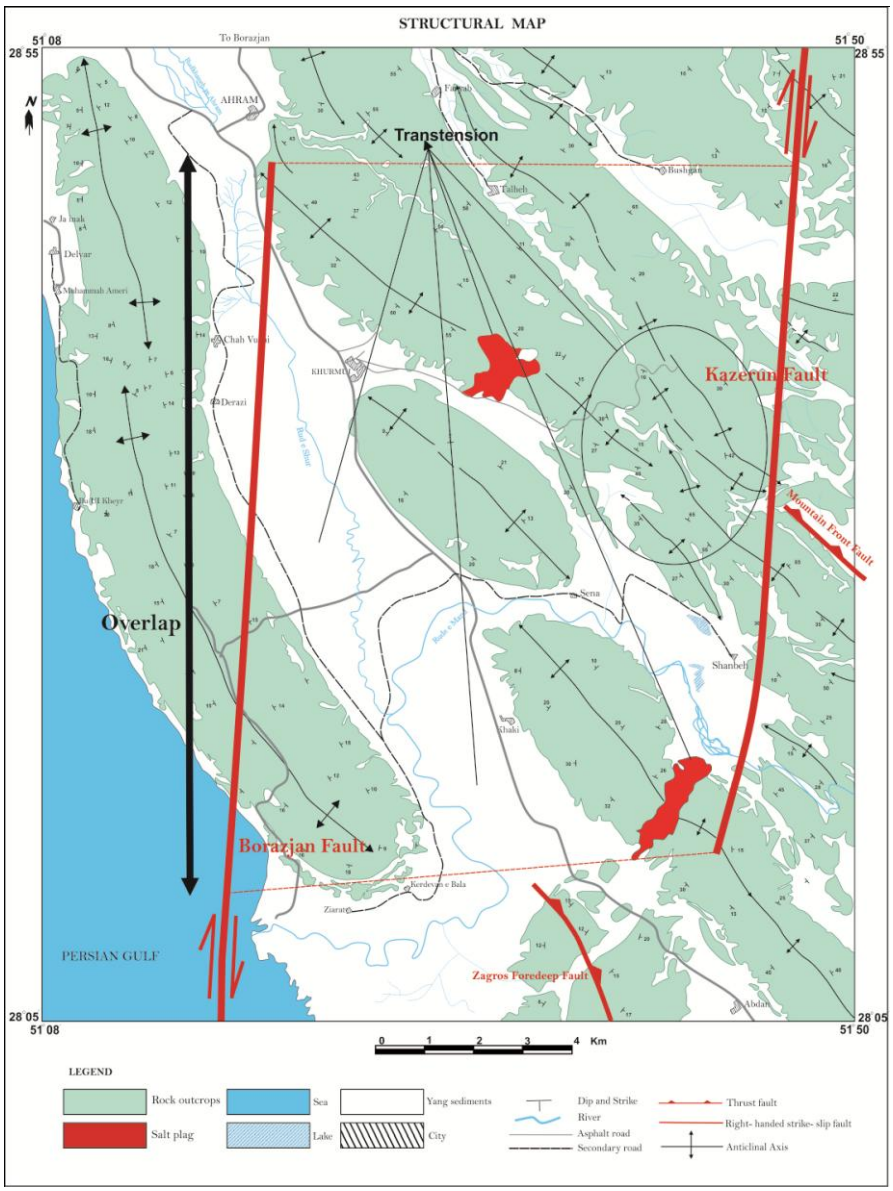

Fig. 2: The structural map of the studied region, as it is seen in the map, two faults of Kazerun and Borazjan have overlapping in the separation region which has been shown in the figure with a black line due to the right-handed movement of two faults in the overlapping region, a trans tension basin has been made between two faults. This tensility has been represented in the region through tensile structures (they have been recognized in the figure by black marks) such as two salt domes, a big sedimental region and right-handed movement of fold's axis.

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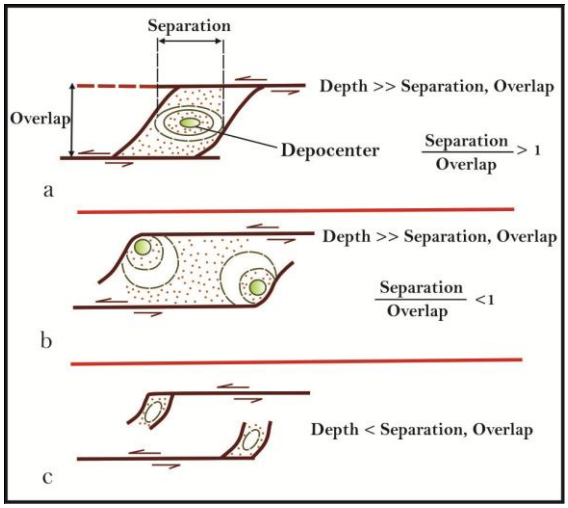

Fig. 3: The suggestive pattern for the geometry of pull-apart basins which depends on the separation distance ratio in the ending segments of strike-slip faults with the overlapping rate of two faults and depth of basement rock (Poorkermani and Solgi, 1388).

3) If the depth of basement rock is lower than the rate of overlapping and separation, the amount of tensility hasn't been adequate and some small basins are emerged for accumulating sediments in the ending parts of faults. In this condition, the tensile fractures develop well in the region, but the formed basin is not considered as a pull-apart basin (figure 3c).

The depth of basement rocks < the separation rate and overlapping rate

Discussion:

For studying the region and proving the existence of tensility between two faults of Kazerun and Borazjan, firstly the basement rock condition of these two faults and other faults around should be investigated. For this reason, ancient plots of Zagros Mountain's basement rock, like kugler map (1971) and A.K map (1973) were investigated, then, basement rock map of Tabatabaiee (1370) was compared with the previous plots.

After comparing on the basis of the best overlapping of faults with different interpretations, the map of basement faults of the region was recognized through figure 2 which is also the structural map of the region. In this map, the faults are recognized with names "Kazerun Fault" and "Borazjan fault" (approximately is northern-southern strike) and also the Zagros foreland fault (ZFF) and mountain front fault of Zagros (MFF).

Kazerun fault is included of two segments: One of them is in the north called Kazerun segment and the other is in the south under the title "Borazjan" which there is a gap between these two segments (Berberian, 1981). This fault and its segments are obviously observed along with the separation existed in figures 2 and 4.

Kazerun segment with northern-southern strike is explicit about 15 kms of Kazerun west with the length 125 kms. Borazjan segment is observed with length 180 kms in the southern part of this fault. The mechanism solution of epicenter of 1990 in the Kalameh region (near Siah anticline) shows rotation of active thrust faults of basement rock drift under the effect of right-handed strike-slip fault of Borazjan (berberian, 1995).

Inclined convergence between Arabic plates and Zagros Mountains is analyzed in to two elements which one of them is thrusting along the basement faults and the other one is the right-handed element along the main and young fault of Zagros Mountain (main recent fault).

The main Zagros reverse faults (MZRF) and high Zagros faults (HZF) and mountain front faults of Zagros (MFF) and Zagros foreland front fault (ZFF) act in a thrust condition due to this movement of Arabic plates along Zagros Mountains. These faults are seen clearly in figures 2 and 4.

The fault which has simple folds and excreting determines the Asmari formation with the age of Eocene and Oligocene which has important topographical and seismic structural features. This fault is seen in the distance 500 meters of the transversal fault east of Kazerun-Borazjan in the Persian states and west of Kabir Mountain in Lorestan. This fault has 140 kms longitudinal movement in the joint place with Kazerun fault wich has been done by kazerun-Borazjan transversal fault.

The Zagros foreland front fault (ZFF) separates the coast of Persian Gulf in the southwest from the front fault in the north and northeast through a reverse system. This fault is parallel to the Mountain front fault of Zagros and is located in the several hundred-meter heights from the sea. This fault has been moved by Kazerun-Borazjan fault with the length 150 kms in a right-handed way. Like the mountain front fault of Zagros, the movement is along with the increase in the height of surface and in the west of Kazerun fault (Berberian, 1995).

The southern Dezfool region should be really called Borazjan collapse (Manafi and Arian, 1388). Accordiing to the topographical map of basement rock (figure 4), the collapse of the region is completely conformed on Borazjan. This region with an approximate length 40 kms and width 25 kms is located in the separation place of two faults. The khoormoj salt dome has been raised in the furthermost of south east of this block; that is approximately the starting place of the fault segment of Borazjan. The depth of basement rock decreases toward the sides; while this depth decrease has a lower slope in the west than the east. For explaining this problem, it should be mentioned that the entire region has been located in a lower level than the adjacent regions and the basis of this region's topography is relative.

About Kazerun faults this point should be pointed out that this fault has been remembered as a right-handed strike-slip fault and no slippage slope movement has been imagined for it. While this fault has a very moderate slope toward the west (Manafi and Arian, 1388).

Basement faults in Persian Gulf:

On the basis of information obtained from satellite gravimetry of Persian Gulf (Tabatabaiee, 1384), it is recognized that the transversal faults of the region also continue under Persian Gulf. This matter is another reason for proving that these faults are basement fault.

In figure 5, this mather has been expressed. In this figure, the plot of the region's faults has been conformed to the gravimetery plot of Persian Gulf which the faults existed in it have been explained about. As it was said before, the clarity of these faults continuation can be considred in the topograph plot (Manafi and Arian, 1387).

Regarding this point that in the gravimetrical studies, the higher the amount of gravimetery intensity, the thickness of earth's crust becomes lower. In figure 5, the blue color shows the intensity of low gravity and the red color shows the intensity. Of high gravity; so it can be said that the thickness of the crust increases from south of Persian Gulf toward the north which is caused by the Thick-skinned Tectonics through being close to the earth in Zagros Mountains.

Geological formations, basement faults, and earthquakes:

Manafi and Arian (1387) have told in their essay that Mishan formation has been separated from Bakhtiari and Aghajari formations and quaternary sediments which are younger through a liner condition along Kazerun fault. The regions of eastern part of Kazerun fault include excreting of bakhtiary and Aghajari formations, and quaternary sediments which has similarity with the graben of Borazjan.

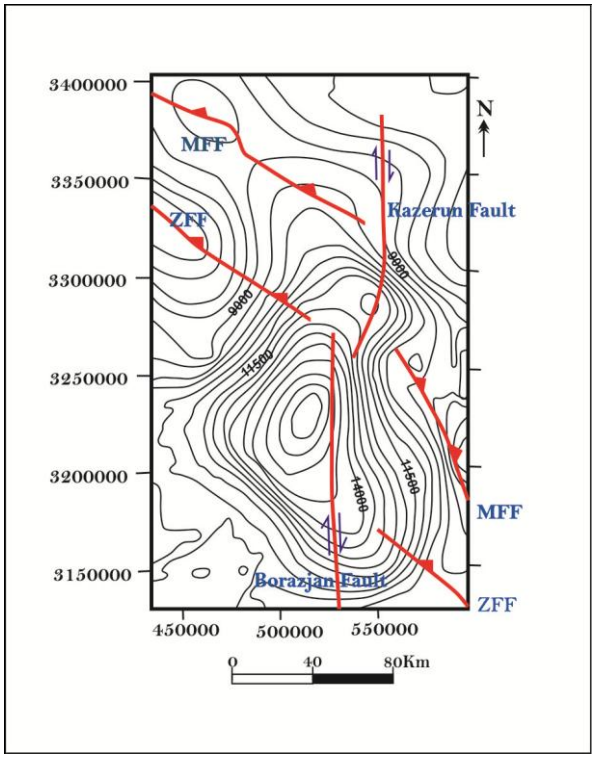

Fig. 4: Topography map of stone-foundation and faults exited in the region.

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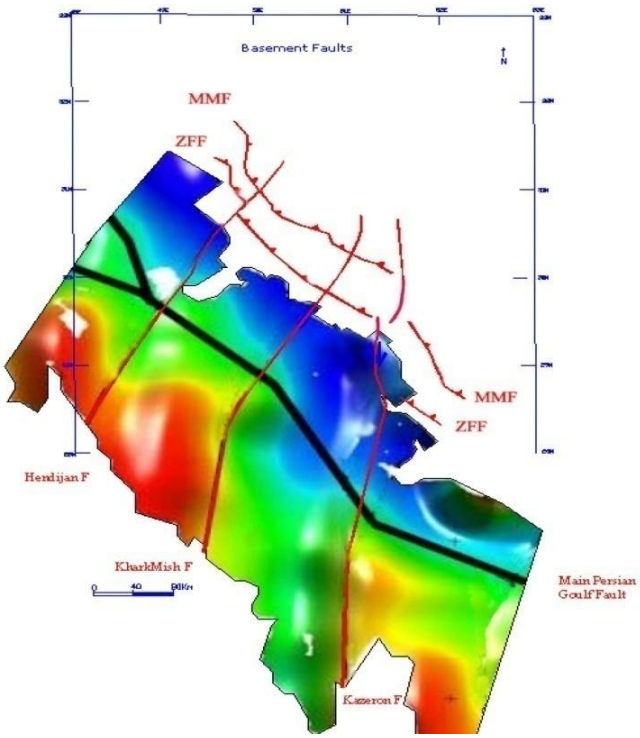

Fig. 5: The gravimetery plot of Persian Gulf which shows the continuation of basement fault of Kazerun-Borazjan to the south of Persian Gulf (Manafi and Arian, 1387).

These distinctions don't have enough clarity in northern part of Kazerun faults as much as southern part of it. An important problem about Kazerun fault is that there is an Asmari fault's outcrop in the western side of this fault (Manafi and Arian, 1387).

In figure 6, regarding the location of faults and earthquakes, it is concluded that Kazerun and Borazjan faults are basement faults and have seismic activity. The more important thing here is the earthquakes being in a line in kazerun and Borazjan faults and lock of earthquakes in the separation region between these two which makes us more hopeful than the past about the result of our work. The region between these two segments (Kazerun fault in the north and Borazjan fault in the South) is a non-seismic or low-seismic region.

The relation among surface faults, earthquakes and salt domes (salt diaper):

In figure 6, regarding the study of earthquakes and surface faults in geological maps, there is no logic relation between surface faults and earthquakes and most of the earthquakes are related to the basement faults. However, it was expressed in previous chapters, the focal depth of most earthquakes in the region imply more on the rupture in basement rocks than sedimental covering.

Most of the Zagros earthquakes are without surface faulting. This event can be due to the existence of salty layers of Hormoz series in the border of basement rock and sedimental covering. meanwhile, the existence of gypsum sediments (plastery), anhydrite sediments dependent on Dalan, Dashtak, Kangan, Heys, Gotenia formations and especially Gachsaran's formations are among important and effective factors in decreasing energy and preventing the surface faulting (Aghanabati, 1383).

Falkon (1969) considers the salt domes and their movement in Zagros earthquakes regarding the extension of salt domes and lock of earthquakes conformity with distinguished faults.

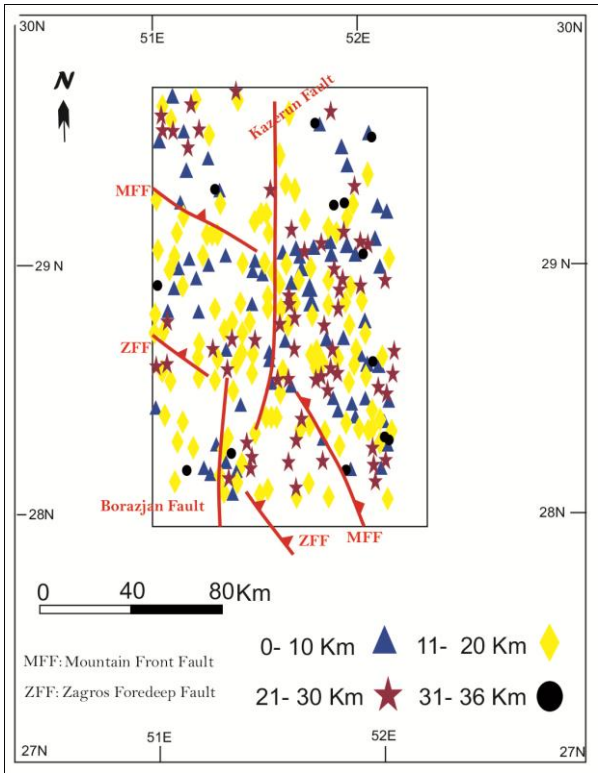

Fig. 6: The map of region's faults and earthquakes occurred in it regarding the focal depth.

The rate of separation and overlapping of Kazerun and Borazjan faults:

regarding this matter that these two faults (Kazerun fault in the north and Borazjan fault in the south) have been located through steps (figure 2, structural map of the region) in a parallel way, they have separation and overlapping; for this reason, the place of these two faults and the rate of separation and overlapping were recognized based on maps which were provided by different organizations. In this research, the rate of separation was estimated about 16 Kms and the rate of overlapping was estimated about 8 Kms. Regarding the pattern of separable tensile basins, if we divide the separation the pattern of pull-apart basins, if we divide the separation rate on overlapping rate (16/8=2), the figure which is obtained is larger than 1. On the other hand, in different resources, the depth of basement rock has been expressed about 16 Kms (Arian and Hashemi, 1387. Berberian, 1981, 1995 and manafi, 1387 and etc…).

Conclusion:

Regarding the whole of studies, Kazerun and Borazjan faults which are actually two pieces of one faulting system are basement faults and their movement is right-handed strike-slip. These two faults have been located through steps and have some separation and overlapping. Regarding that two faults have right-handed movement, A tension region is existed in the separation limit between them which causes two salt domes to be come up; one of them in the south of Kazerun fault (the place where in the fault is finished) Called Dashti salt dome (jushak diapir) and the other one in the north of Borazjan fault (the place where in the fault is started) called Khoormoj salt dome. Borazjan fault which is actually the continuation of faulting system of Kazerun is located under Persian Gulf. There is a region with a number of low earthquakes between two peices of Kazerun and Borazjan faults which is that tension region which causes some conditions to be made for salt diapir rising.

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