Journal of Geotechnical Geology
Zahedan Branch, Islamic Azad University
Vol.12 (2016), No.2 (137-155)
geotech.iauzah.ac.ir

Zahedan Branch,
Islamic Azad University

Tectonic of coastal- foothill region of Southwestern Caspian with a view on the marine hazards

Anahita, Keynezhad
Department of Earth Sciences, Chalus Branch, Islamic Azad University, Chalus, Iran
Anahita.keynezhad@gmail.com
Received: 21 Aug. 2016; accepted 24 Dec. 2016; available online: 25 May. 2017

Abstract

The development of knowledge of morphotectonic and seismotectionic during the past 10 years in the country reveals containing valuable information about the history of activity of a fault. These surveys in addition to reveal the activity of faults, they can be used in estimating the movement and rate of fault activity and detection of motion of shells blocks. This paper aims to identify fault in the sea and coastal-foothill areas and possibility of its activation and subsequent of marine hazards including tsunami and liquefaction, and to achieve this goal, it was investigated the structure status of region, coastal fractures and sea context, the shell motions and the status of stress field.

The study region is semi western of south of Caspian and mainly in the range of Astara fault and Caspian fault and outcome of studies conducted is based on geophysical data and remote measuring in coastal- foothill part and then on the sea context.

The result of data indicates that the draught faults are extended and their activity is likely and subsequently we will have producing massive waves (tsunami) caused by the fault activity.

Studies have shown the regions of coasts of Noshahr and Chalus, Ramsar and Tonekabon in Mazandaran and coasts of Rudsar- Langrud and Lahijan in Gilan province has the highest risk of drowning and its reason can be heterogeneous topography of various depths in the sea in the cities.

Keyword: Caspian Sea, Caspian fault, Astara fault, liquefaction, tsunami

1. Introduction

Alborz mountain range in the complex structural belt affected by various tectonic events is limited from Precambrian to Quaternary with structural zones of southern Caspian in north and central Iran in the south. (Berberian et al. 1981) (Alavi 1996) (Nazari 2006) (Shahidi 2008). Alborz tectonic structures due to two former Cimmerian orogeny phases and Alpine Orogeny phase and due to contact with Eurasia zone are formed and the Caspian Sea is formed due to this reason between the two zones due to tectonic structural changes. Alborz young deformation function indicates the emergence of Terra pressure deformation with left shear in direction and parallel of pushed and pulled buildings of Alborz or direction of East - West. (Nazari 2006) (Allen et al. B 2003) (Jackson et al. 2002). Many researchers in the past years have acted to young tectonic activities in the Alborz. (Ambrasis and Melville 1982; Chalenko 1974; Berberian et al. 1983; Allen et al. 2004 and 2003). This research provided the first institution of structural model from the historical development, young Geodynamics, geometry in the fundamental fault mechanism in this mountain. GPS network provides the estimate of the rate of shortening NS and left shear in this structural zone respectively equal to (Vernant et al. 2004). Determine and locate such lineaments and their function can have a significant influence in interpretation and analysis of risk performance of each fault systems on surrounding structures or any exploration activities in the region. In this paper in addition to another new findings of geologist, the methods of remote measuring and apply mathematical filters, the geophysical methods to determine the exact location of faults of South Caspian and their trend in sea context and coasts have been taken help.

2. South Caspian basin

South Caspian basin includes deep and thick central basin in the southern part of the Caspian Sea. The central basin can be divided into several sub-basins (Brent et al. 2003) (Fig. 1). The first sub-basin is located in the northern part of the South Caspian basin with a depth of 26 km to the north - North West near the bulge of Apsheron (Knap et al. 2000). The second important sub-basin is Pre Alborz trough with a thickness exceeding 20 km that is located in the southeast of South Caspian basin to the north of Alborz. The thickness of sediments in the South West of South Caspian basin in the basement depth maps diffused has difference. For example, Malovitsky (1967), Shykalybly and Grigoryants (1980) have estimated the thickness of sediments 20 km and

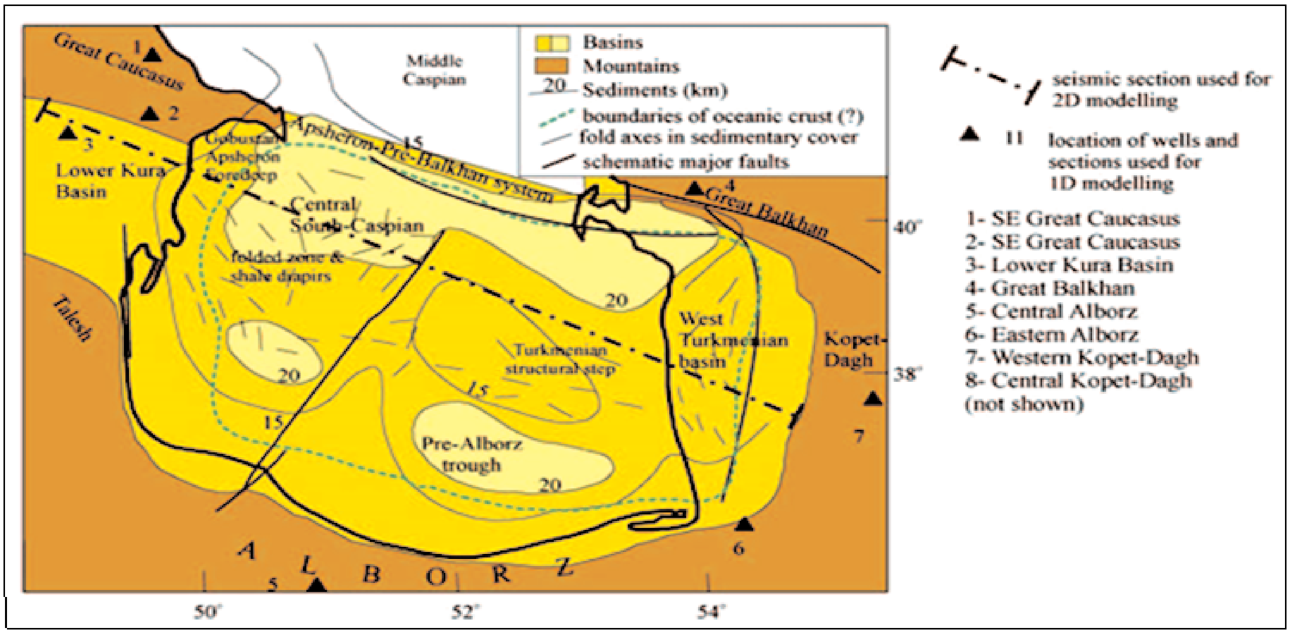


Figure 1. divide the sub-basins of South Caspian basin (Brent et al. 2003)

Ananymus and Wales estimated the thickness 10 km. The western part away from the south coast of sedimentation center of Apsheron- Balkhan) is occupied by a horst that basement depth is about 15 km (structural stage of Torkamanyan) and the shell is thicker than other parts of the Caspian.

3. Paleogeographic of South Caspian basin

In the absence of Continental crust in the south Caspian Basin and direct placement of sediments on a thick oceanic crust with a thickness of 12 to 18 km, different theories have been provided (Jackson et al. 2002), while some researchers consider this issue as a result of uplifting, erosion and next subsidence of granite crust, other researchers believe that the Continental crust of south Caspian basin is residual of an oceanic crust. About how and when the formation of oceanic crust, several theories have already been proposed. For example, the remaining of Tethys oceanic crust (Darvishzadeh 1991), being separated from a part of the marginal basins (back arc) Mesozoic or early Tertiary even South Caspian Basin is considered as a Pull-apart basin in an area of major strike-slip along the mountains of Kope Dagh and Caucasus (Sangur 1990). With recent advances in seismic techniques, our understanding is improved about the structure of the south Continental crust (Jackson et al. 2002). The results of new studies are consistent with previous theories that consider the south Continental crust as remaining of an oceanic crust. However, with the adoption of oceanic crust for the South Caspian basin, its immense thickness compared with oceanic crusts (7 km on average) is still controversial (Fig. 2).

Most researchers attribute such oceanic crust to a back-arc basin of Mesozoic to Paleogene (Zonen Shayn and Lipychon, 1986; Stamfly et al. 2002; Berberian 1983). Paleotethys on Brent and colleagues (2003) in such a model, Hercynian orogenic led to close ocean due to subduction towards the north, which finally has led to the addition of Gondwana blocks (blocks of Cimmerian to Eurasia in the Middle Triassic to late (Stamfly et al. 2002; Thomas et al. 1999; Brent et al. 2003).

Its compression outcomes have continued to late Jurassic -early Cretaceous (Thomas et al. 1999) Of outcomes of this closure can be considered basic rocks outcrop and ultra-basic of Melanges ophiolite of north of Iran to Sandu- Carboniferous (south of Mashhad- Talesh mountains) (Darvishzade 1991). Neotethys oceanic subduction (Zagros) in Bajocian led to the creation of a volcanic -magmatic arc (Central Caucasus) and the opening of a back-arc basin behind it (Shayn and Lipychon 1986; Brent et al. 2003) Basalts of Middle Jurassic of Cora and Neocomian basin of Alborz could be related to the

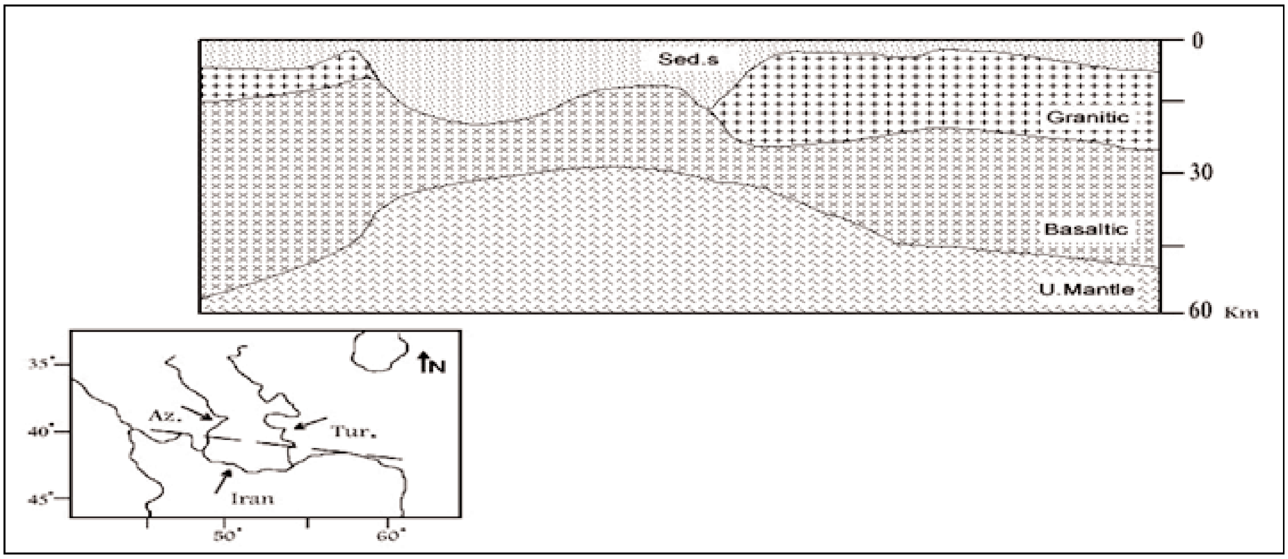


Figure 2. cross-section of the crust and the upper part of mantle in contour of Kura Basin in West of Caspian Basin

tension phenomenon of behind the arc. It is imagined, trough of Great Caucasus, the south Caspian Basin and Kopedagh have been existed from Calvin to Eocene as an integrated deep basin (Zunen Shayn and Lipychon). Eocene rift basins are located in the southern edge of the South Caspian basin. This means that the South Caspian Basin during the Eocene has been existed as a hard lithospheric block. This basin deforms due to stretch of the Eocene (Brent et al. 2003). During the Oligo-Miocene, Late Alpine orogenic phase led to the closure of the trough of Great Caucasus and Kopedagh. Finally, during the Pliocene and Quaternary, uplifting of the Great Caucasus led to the complete separation of crust of south Caspian from the Black Sea.

4. South Caspian basin Subsidence

The subsidence that probably has been with the performance of thrust faults of southern border of South Caspian basin (Berberian 1983) caused a sharp drop in the water level of the Caspian Sea in the Miocene and especially Pliocene (Aleskero et al. 2004) and deposition of river - delta sequences of productivity classes and continental series equivalent them (Kronberg et al. 2004), these sequences with very high sedimentation rate (2 to 4 millimeters a year) between 3.3 to 5.4 million years ago, mainly by rivers of Paleo Volga, Paleo Kura and Paleo Amo Darya have deposited (Jones and Simmons, 1996; Reynolds et al. 1998), gradually rising level of sea water led to rise the conditions of marine deposition toward the top classes of the productivity (equivalent to deposits of Chelken) (Kronberg et al. 2004).

5. Tectonic of Caspian

South Caspian continental troughs is considered as tectonic block or page with little seismic activity that is crossed with a belt of flexure -arc fault including mountains of Talesh, Alborz and Kope Dagh which is considered as an arena with high seismic activity. Mountains mentioned are all influenced by crustal shortening due to contact of Arab-Eurasia plates and loss of shallow earthquakes in the Caspian region shows that the area has acted as a rigid block in Arabic Eurasia collision zone (Jackson et al. 2002). The basin mentioned is as pressure subsidence of time of Neogene -Quaternary that is inscribed with faults with thrust mechanism of several border of mountain and described with oceanic crust that is trapped in the old sutures. The height difference between subsidence and mountains that are as active fault - flexure belt is created due to difference in shell structure and thrust fault in pressure tectonic regime prevails in the area (Berberian 1983). Overall direction of the move is towards the northeast and depth of earthquakes surrounding the South Caspian basin in about 8 to 15 km. The move is created due to pressure deformation of Caspian area and South Caspian Basin now is blurred by drift on the north and west south edges (Jackson et al. 2002). Caspian shell thickness is estimated about 30 to 35 km which contains 13 to 20 km sedimentary sequence that are located on the lower crust of dense. South Caspian forms the deepest part of the basin that over 12 km sedimentation in Neogene and Quaternary shows a rapid subsidence in the course of time. The difference of depositional history between Alborz and Caspian is started since the initial setup of Alborz in Oligocene. But what separates Caspian deposit from the rest of Iran is emerged of Neogene and so far continued. Deposits that are known as the Caspian Neogene facies are formed in the Caspian area when Caspian with the Black and Aral Sea constituted Paratethys Sea. The sedimentation rate of South Caspian Basin from Pliocene has reached its peak. Active folding of Neogene and Quaternary sediments of the Caspian after Pliocene is started from Agchagil deposit and so far continues. The important feature of these flexures is that limited more to borders of Caspian. Short wavelength of folds in the context of the Caspian and its margin indicates that the thickness of folded classes in scale of shell is low and limited to the young sedimentary cover of Caspian (Ghasemi 2000).

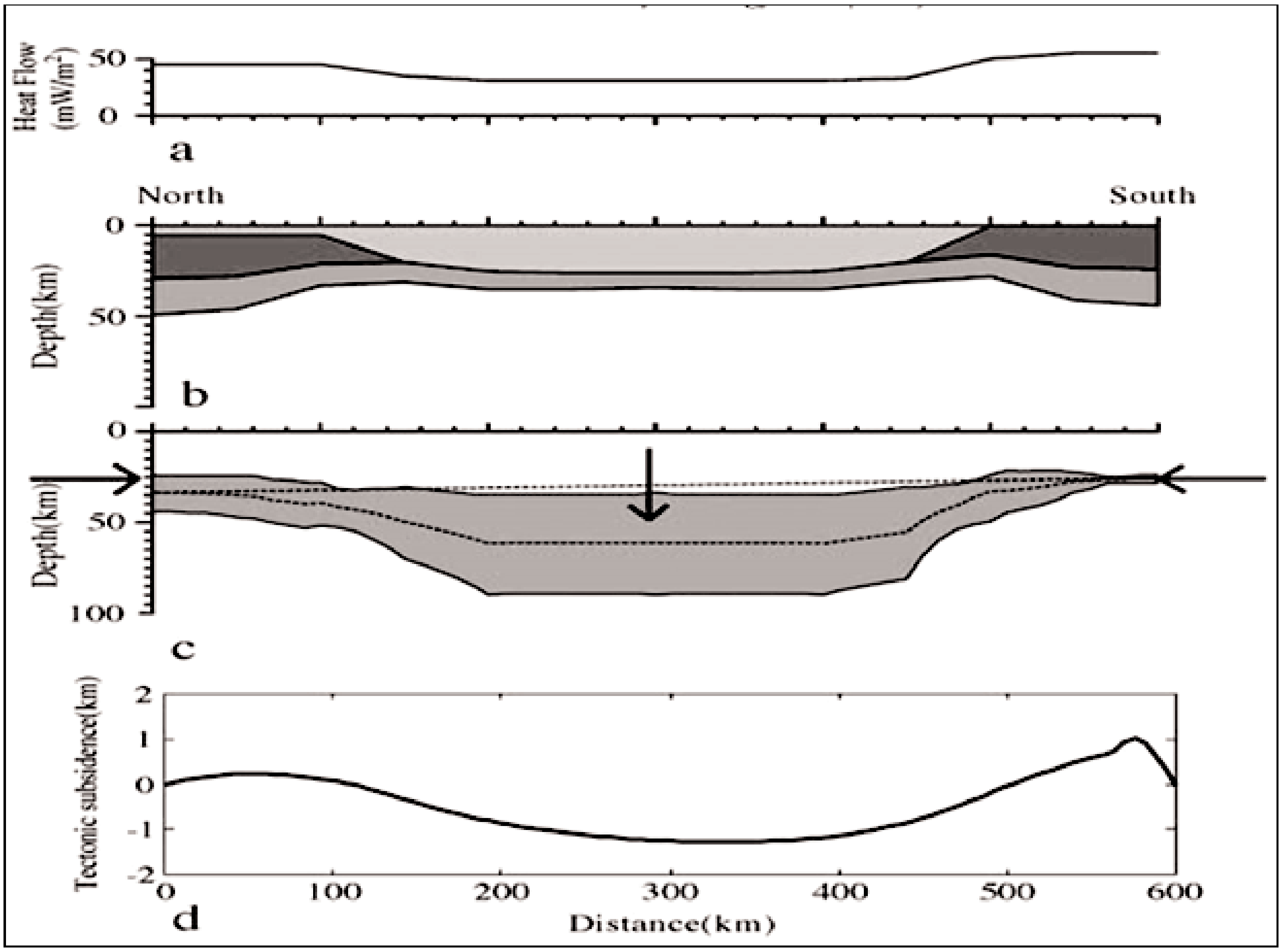


Figure 3. South Caspian basin subsidence model as bending downward due to performance of compressional forces, along with loading on the edges of the basin (Brent et al. 2003)

6. Coastal- foothills Fractures

Major fractures controlling coastal-foothill strip of western half of South Caspian include the Caspian faults, north of Alborz and Astara, which is mentioned briefly about them:

6.1. Caspian Fault (Khazar Fault)

Caspian Sea with length close to 450 km is located in northern border of Alborz and south plain of Caspian Basin (Berberian et al. 1993). The fault is mentioned as compressional faults with slope to the south. (Berberian et al. 1993; Allen et al. 2003) resulting from the operation of an active fault is obvious (Ghasemi 2005). Many earthquakes are located in performance range of many different branches of the fault. Earthquakes such as

874 AD (MS-6.0, Io = VII), 1498 AD, 1809 AD, Gorgan 1944 AD (Mb= 5.2, I, = VII), Gorgan 1952 AD (Mb = 4.7), Farsian 1970 AD (Mb = 5.0). Bobolkenar 1971 AD (M = 5.2) , Aliabad-e-katoul 1999 AD (Mb = 5.3), Gorgan 2004 AD (Mw = 5.6), Baladeh 2004 AD (Mw = 6.2) and Gorgan 2005 AD (Mw = 5.3)

can be considered as earthquakes resulting from re-movement of land on the plate of the Caspian fault. Caspian fault caused the formation of height of Alborz in the southern edge of Caspian Basin. (Fig. 4). Although in the past, the contact of metamorphic rocks known as Gorgan systems and Quaternary deposits of South Bank of Caspian is considered the result of function of the fault (Berberian et al. 1993). But based on recent research (Nazari 2006), the fault is considered in the number of compressional, active faults but hidden that unlike, reveal partitioning of fault on the northern edge of the Alborz never can be seen an outcrops from faulting on the earth. Processing of satellite images and aerial photographs in various scales with digital moles obtained from topographic maps 1:50000 partitions of the Caspian faults with network of current rivers is cut and drilled to the north.

In some areas, such as "embryo" function of young tectonic on the wall of the fault of Caspian in addition to the vertical deformation of geological structures causes detection of horizontal displacement due to the shear component of fault (Fig. 4) Based on seismic data obtained from subsurface geophysical research and analysis of seismic data obtained from earthquakes occurring in the area of the Caspian fault, there may be other progressive branches of the fault that under thick deposits of Caspian context and deposits of Gorgan plain have been buried although it does not exist the data on young movement of all this branch of progressive faults.

Unlike (Tatar et al. 2007) that considers the Caspian fault an independent single page seismic in depth of data obtained from combining aeromagnetic research and subsurface Nionc (Brookfield and Hashmat, 2001) and geomorphic studies and the Caspian fault (Nazari 2006) (Nazari and Ritz 2008) a branch obtained from fault plate of North Alborz in depth.

It can be considered more than 200 meters difference and change in height of the partition of mentioned fault measured by (Nazari and Ritz 2008) a trace on Gest viewpoint et al (2006) that mentions the partition of Caspian fault as boundary partition and not fault partition.

6.2. North Alborz Fault

North Alborz fault is long nearly 100 km and in most of its length is placed in parallel of Caspian fault in 80 kilometers south of it (Figures 4 and 5). Two North Alborz faults of the Caspian in Chalus region have joined together and continue till Lahijan fault in west Alborz. In the west part, North Alborz fault become apparent in the wrinkles from its faults. The fault with the slope to the south has pressure mechanism and causing thrust of series of Mesozoic sediments on Cenozoic series (Saeedi and Ghasemi 2003). Neogene deposits in the Caspian basin are limited to the southest spread to North Alborz fault (Ashtoklyn, a 1974). On this basis, the movement of rock of Neogene sediments above mentioned fault is over 2 km. Some researchers such as (Ghasemi and Mosavari 2001) have considered the fault as suture obtained of the convergence of the South Caspian below Alborz in Neogene. Although Nazari (2006) in Neotectonics research in Central Alborz by drawing two structural cutting to the ratio of balancing considered North Alborz fault as an old structure related to hindmost Precambrian that caused the first deformations occurred in the Alborz.

Due to the geographical location on the center of earthquakes occurred in the twentieth century, it can be considered earthquakes to the reactivation of this fundamental fault that considering the building pattern of plates of North Alborz fault and Caspian at depth, and depth of seismic in central Alborz , separation of earthquakes associated with the movement of North Alborz fault and fault movement of Caspian as a progressive fault from the page of North Alborz fault is very difficult (Fig. 6).

Earthquake such as

Farim-Chahar dangeh 1127 AD (Ms = 6.8. Io = VII)

Farim 1301 AD , Mazandaran 1686 AD, Haraz 1805 AD

Amol 1809 AD , Haraz 1825 AD , Kosout - Mazandaran 1935 AD, Sangehal 1957 (Ms = 6.8) , Nomel - Tashi 1985 AD (Mb = 6.0)

Hezar, Jarib 1999 AD (Mw = 4.8) and Baladeh 2004 (Mw = 6.2)

Including earthquakes occurred in the geographical area is this fault. So far no surface cutting of the earthquake on North Alborz fault has been observed. In the eastern part that Central Alborz of tilted and deformed Quaternary deposits in over the wall of North Alborz fault, including the data that is a reason on the young activity of (Quaternary) the fault (Ghasemi and Qureshi 2004).

In general, about the young movement of the North

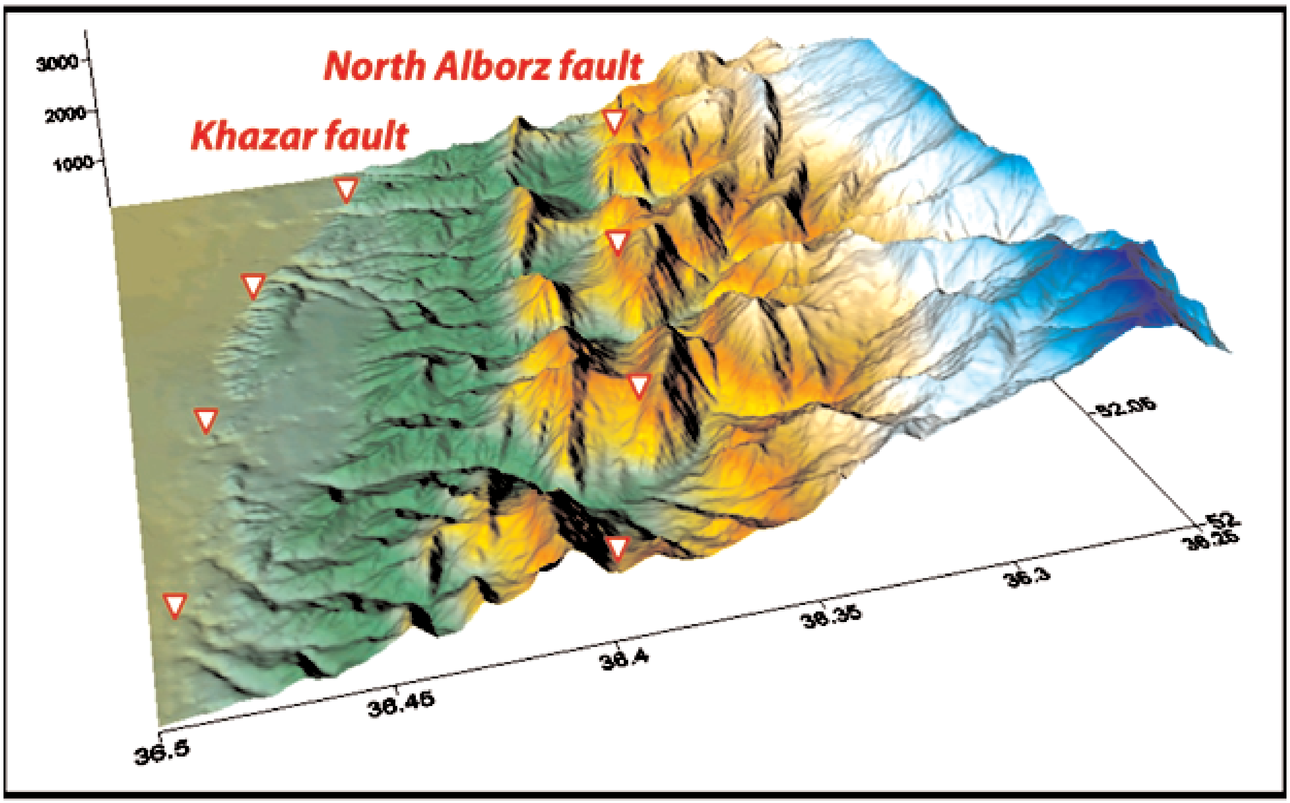


Figure 4. The three-dimensional model of the Caspian and west heights of Central Alborz indicating northern Alborz faults in West of Amol (Nazari, 2006)

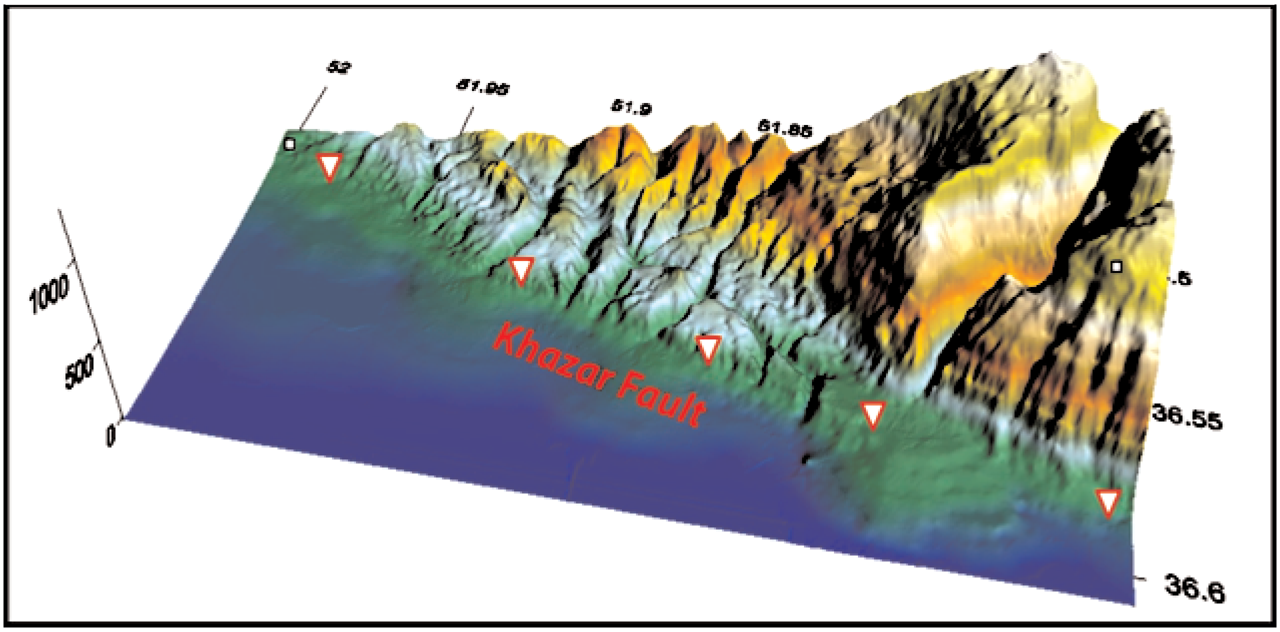


Figure 5. The three-dimensional model of the west heights of Central Alborz indicating Caspian faults in west of Chalus Valley (Nazari, 2006)

Alborz fault, there is no significant and reliable geomorphological data and seismic. So perhaps today it can be considered the fundamental fault of the central Alborz as semi-active fault that seismic activity and the movement happens on the younger branches as Caspian fault. Alborz folding system is justified in a combination of detachment folds systems for folding Jura Mountains (Mitra 2003) as well as stress distribution in systems in Rozgon systems that in parts with Lift-up of Precambrian and Paleozoic facies has been associated in different periods.

Structure of extension and deposition of sediments shows the subsidence and sedimentation in systems of ensile or transtentional and folding and uplift due to trying again with change of mechanism of fundamental faults as North Tehran faults- Musha-Kandovan and North Alborz. So many faults that in terms of the geometry are divided in line of stretching faults appear due to overcome pressure forces from the consecutive collisions of adjacent blocks of Alborz in the form of faults with pressure mechanism (Figures 7 and 8).

As a result, a significant amount of cumulative compressive stress become the cost of removal of displacements due to the pull system at the time of formation of the basin and hence theoretically thickness of the crust and the depth of the Moho theoretically pre-rift and after contact will not have significantly difference.

Deposits of outcrop and uplifting of Kahar formation Precambrian and other Paleozoic deposits in anticline of "mansion" in cutting "Damavand - Amol and mountain " Zynush "in cutting" Karaj-Chalus" in wall of North Alborz fault is the ancient events from Khzad late Precambrian (Nazari 2006). Such structure is justified with tensional systems of stages of ending contact and infuenced by lithospheric powers on the lower crust against classical models (Dogliyoni 1995) (Figure 8).

On the other hand, the difference in the rate of motion of Alborz crust and south Caspian after the Pliocene caused the formation of extensional structures in the northern slope of the Alborz and causes deposition of very thick deposits in the southern basin of Caspian

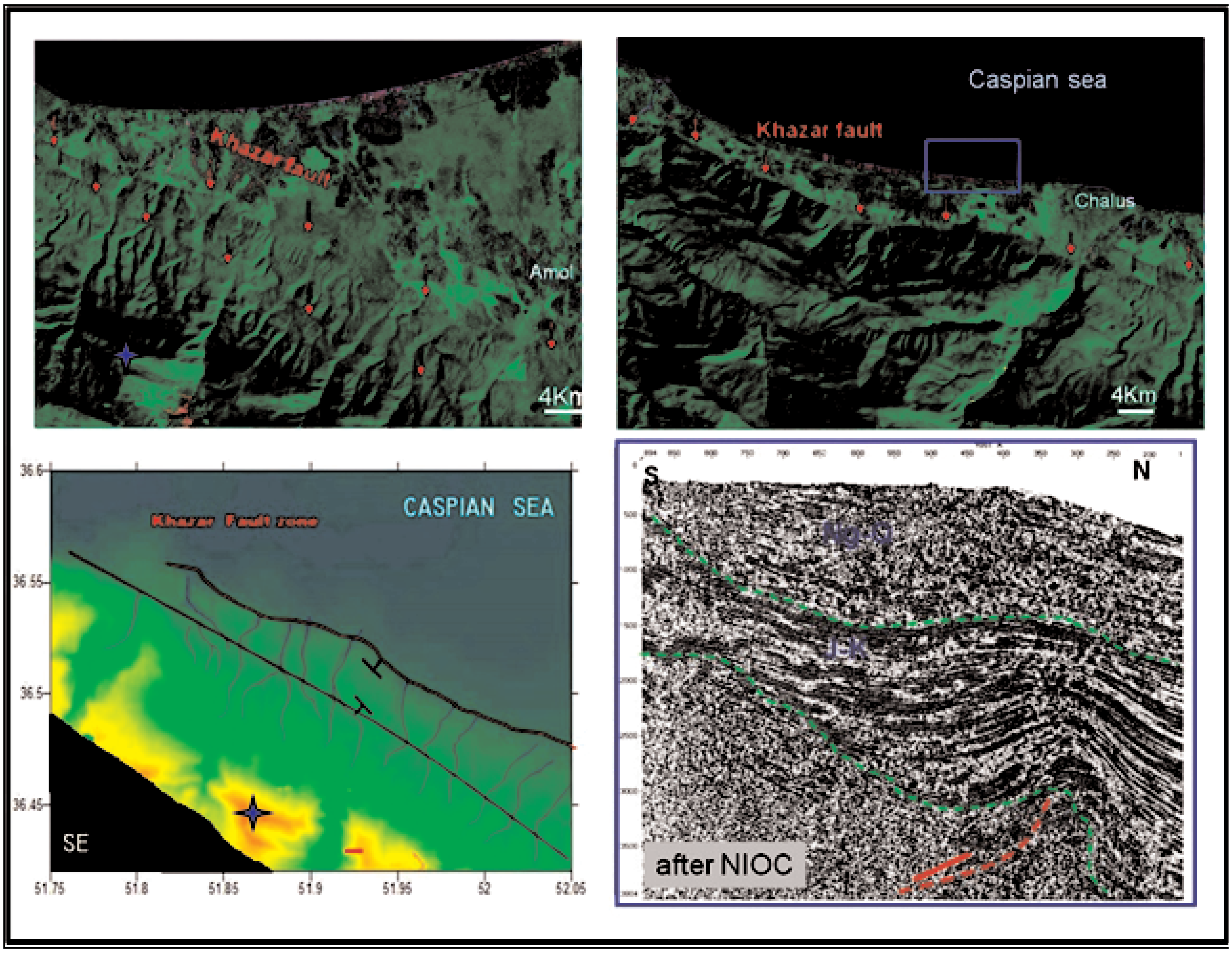


Figure 6. Two top views, the effect of the Caspian fault on Landsat 7 satellite image in the range of Amol and Ramsar, blue square in the upper right image in the West of Chalus is equal to the relative position of cutting of deep seismic geophysical (shown in bottom right image) from the deposition of sea context that indicates deformation of the development of China-fault system in north among Mesozoic rock units. Virtual bottom left view from the building of progressive conic fold caused by the performance of Caspian fault in south of embryo.

with slope to the north. Although in more internal parts due to the performance of progressive faults to the north, especially in the upper cover of detachment, Jurassic in the central Northern Alborz range caused the formation and growth of asymmetric folds to the north (Nazari et al. 2003).

Such structural feature as a tectonic process of subduction of an old oceanic crust as the crust of Prototethyan below Alborz and activity again and cutting the fault zone with tension systems of Antitethic compared to models offered by Doglyuny (1995) is justified. Taloqan dynamic fault and Musha fault behavior in west cutting of the Karaj-Chalus is from this rank. Processed and digested delayed residue of the oceanic crust beneath driven in the Precambrian through initial Mesozoic can cause the formation and emplacement of Damavand in this structural block with rising again in the initial Quaternary from tectonic transtentional of Central Alborz (Ritz et al. 2006 and Nazari 2006).

Based on displacement and geological evidence about Tehran and in the range of fundamental faults of Musha and northern Alborz in 5 million year period, the amount of shortening in the central Alborzis is calculated equal to (Allen et al. B 2003), but following a research of this kind, based on cutting balanced of central Alborz, the amount of final shortening in line with NS is calculated close to that is slightly more than previously calculated, and this is despite the fact that more than 75% of this shortening occurred after the Eocene (Nazari 2006)

The emergence of a sign of more tectonic movements such as displacement and folding and uplift from North Alborz fault activity in the West cutting to east cutting with uplift and repeat crystalline crust in the mountain of "Zin Vash" (cutting of Karaj-Chalus) is the other features of construction in the area affected by the performance of the underlying fault.

6.3. Astara fault

Astara fault with north-south trending in the northern half and NW-SE direction in the southern half in the form of a right-handed pressure system with a length of 110 kilometers forms the east border of Talesh heights to the Caspian coastal plain. Geophysical and morphotectonic data indicates the east spread of increasing plates of fault towards coastal plain, as well as water zone of the Caspian.

Although the structural evolution history of Astara

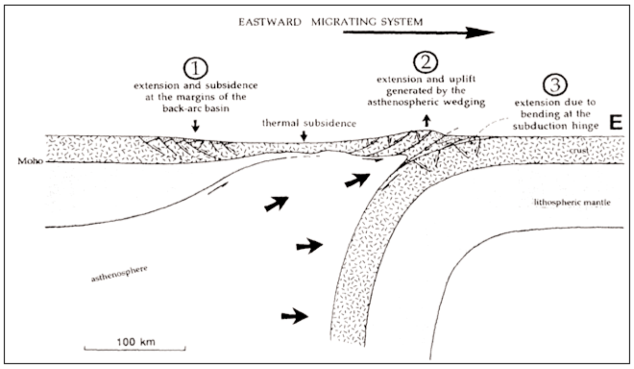


Figure 8. structural model of how the tensile range in a pressure system (Doglyony 1995)

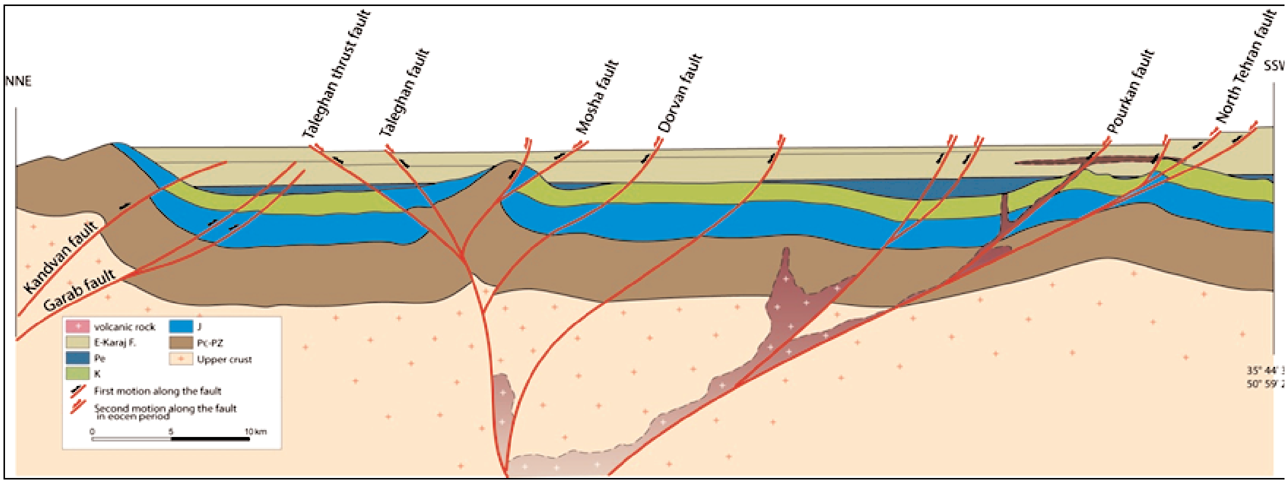


Figure 7. structural cutting reconstructed from the formation of Eocene basin in Central Alborz (southern slope of cutting of Karaj - Chalus) (Nazari 2006)

fault that mostly caused thrust of Cretaceous rock units on young deposits coastal plain in western Caspian returns to the late Cretaceous. However, considering the geodynamic characteristics and evolution of young tectonic of South Caspian Basin in association with heights of Alborz in south and Talesh in west and new signs of tectonic and geomorphic, Astara fault is placed in the active faults around the South Caspian Basin. From the perspective of geometry, Astara fault has been planned into two branches of ATF thrust Astara fault and strike-slip Astara fault ASF and some faults 3's in thrust branch and 2's in the right lateral branch (Fig. 9 and 10).

The maximum and minimum of horizontal displacement H on compressional branch of Astara ATF is estimated equal to 1,500 and 190 meters in piece one with a spatial resolution of 30 meters on the basis of data of satellite images ASTER. On the basis, maximum and minimum vertical displacement V of this branch from Astara fault system is 130 and 10 meters that indicates the maximum H / V will be equal to 13 for fault ATF from Astara fault system. However, measurements of displacement H and V on strike slip branch ASF due to changes and disturbance resulting from human activities on coastal plains is empty and not far from error but according to the default maximum and minimum, values of handling H and V for ASF fault from Astara fault system, respectively are equal 840 and 70 meters with an approximate ratio of 20 and 7.

Right-lateral strike slip mechanism of Astara fault, especially in northern and central parts that fault system is more north-south, we see many signs of the formation and development of structures such as Shutter Ridge as long as heights of Talesh that is in the form of progressive conic folds and beams taken among a part of the strike-slip faults with a different movement rate towards the south is moving. The continuous movement over time causes to form horizontal displacement accumulated in various scales 1500-10 meters, especially in line with ATF fault (Fig. 11).

In the southern parts of Astara fault, geometry of the fault by changing direction from north-south to the SE- NW to the tension increases sign of the compressional mechanism to strike slip mechanism that by increasing rate of western heights and eastern fall in a range between Rezvanshahr to Asalem can be observed

Focus of earthquakes of the past century and deformation observed in young sediments and thick deposits of context of the South Caspian in the west is considered as a sign of the development of progressive structures of fold and fault with the east move attributed to the fault system of Astara (Berberian 1983 ; Jackson et al. 2002; Allen et al. a,

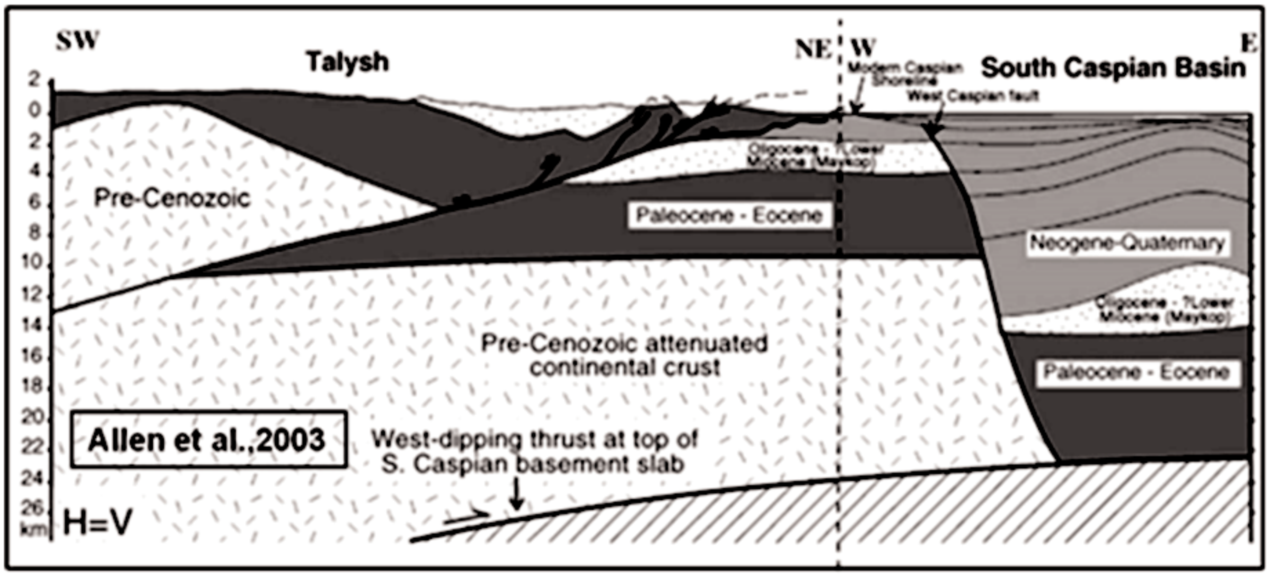
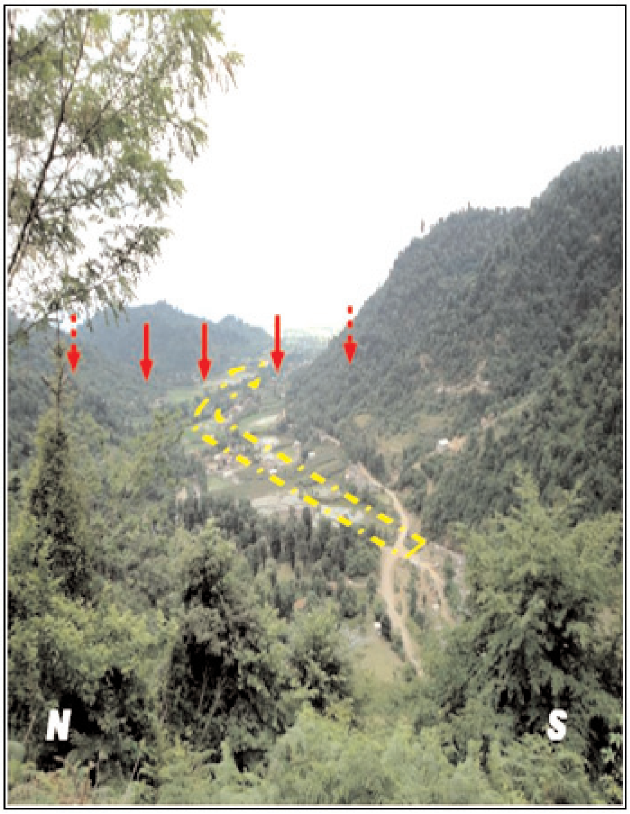


Figure 9. Structural model of South Caspian in the west and heights of Talesh (Allen et al. 2003)

b2003; Brent et al. 2003) So far, due to the characteristics of climate and vegetation on the heights of Talesh and narrow coastal plain, the structural relationship of the system increasing in nshore as fault of Astara on the mountain, plain and structures of fold and fault in the water part has been unknown or less known. On this basis, by the aim of identifying and map out some possible young faults isolated from Astara fault that caused the deformation and cutting of young alluvial and coastal deposits in the west and southwest of South Caspian Basin, according to the capabilities and environmental and instrumental limitations of the use of different geophysical methods, three methods of geophysical and geomagnetic observations, Georadar GPR and resistivity surveys

Figure 10. The fault system of Astara on the basis of the map of Seismotectonics of Talesh heights and map simplified of geology, earthquakes displayed in the water area of west of the Caspian shows the structures of fold and the fault of growth of fault system of Astara among deposits of sea context in the East, the colored columns of map side shows the segmentation of fault system of ATF and ASF based on the geometric changes (Kave Firuz et al. 2013).

and RS at the same time and place or separately in different parts with the aim of controlling possible Morphotectonical signs seen in forest or agricultural lands along the Astara fault system is used (Fig. 12). According to user restrictions of geophysical instruments and environmental conditions such as groundwater level, power transmission lines and agricultural lands only in the coastal area of Gisoum in the south of Hashtpar, we were able to use the location of the three different methods mentioned geophysical in the eastern part of the International Astara road, but since the partition of the data of morphotectonic in different depth is approved clearly in methods of geophysical geomagnetic, Georadar and resistance testing (Fig. 13), it can be seen that the independent performance of each of the methods of geophysical observation is in other parts of the fault of Astara



Total 11. cumulative right moving 800 m from right cutting of Astara fault (red arrow) and the tilt of axis of the main channel (shown by yellow arrow) over the fault caused by the growth of the structure of compression stacks from the performance of right cutting mechanism Astara fault in the west of the village of Chubar at the foot of the east of Talesh heights between pyroclastic rock units and Cretaceous turbidite and young coastal plain deposits.

such as cutting implemented in the areas of Peisarais in the north and Paresar.

7. Fractures of sea bed

Tectonic structures such as faults often have decisive role in the control and creating the risks and somehow the risks are associated with tectonic structures (fault, the collision points of fault), in other words it can be said that the phenomenon of tectonic have important role in control and creating high-risk areas

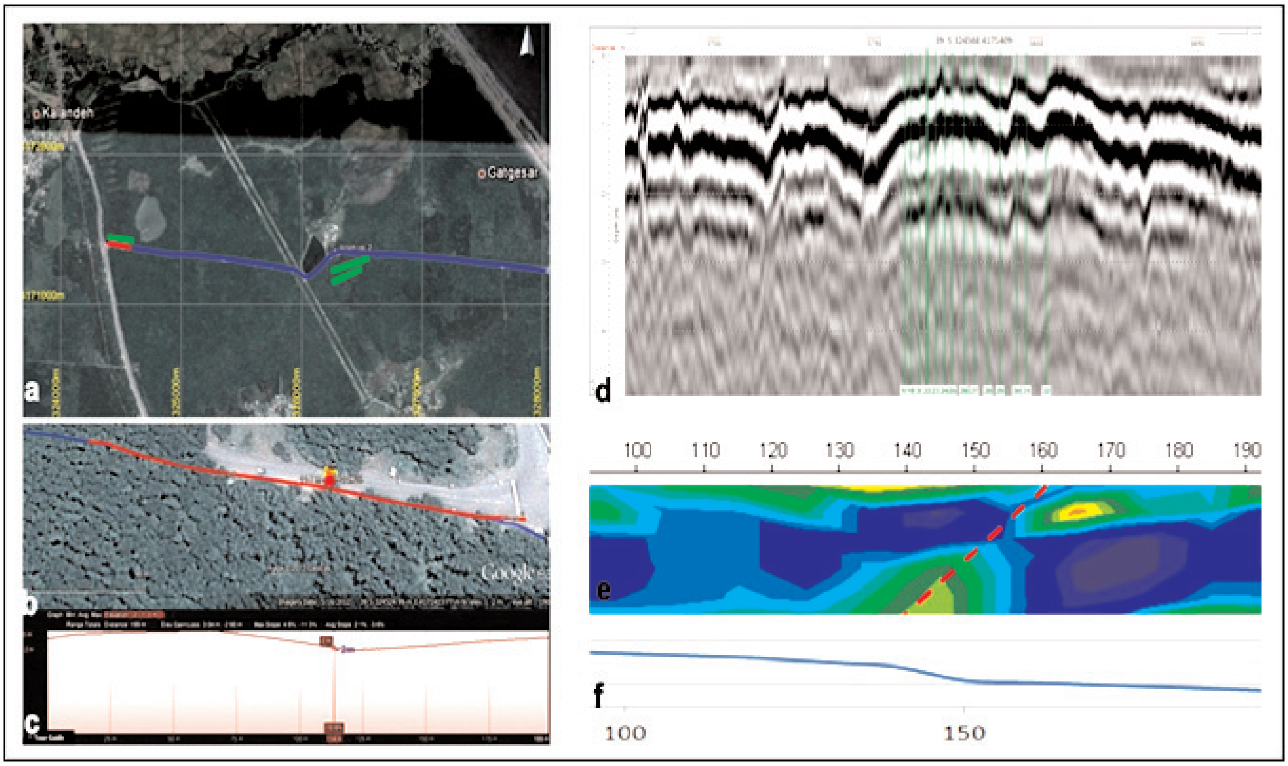


Fig. 12. (a) - GPR Geophysical cutting position implemented in the region of Gisoum (Klandeh and Gagsar), the blue line is along the cutting and the red line has anomaly. (B) - red arrows on cutting anomalous area indicate position of visible partition (~ 2m) in level (c) - and anomaly seen in the cut. (D) - GPR cutting from abnormal section is derived of the fault with vertical accumulative displacement increasing in depth. (E) - a view of the data provided from geophysical interpretations RS in Gisoum, red segment indicates anomalies consistent with the progressive branch of Astara fault towards East. (F) - cutting topographical image of partition with the SE. (Jahandar, 2014)

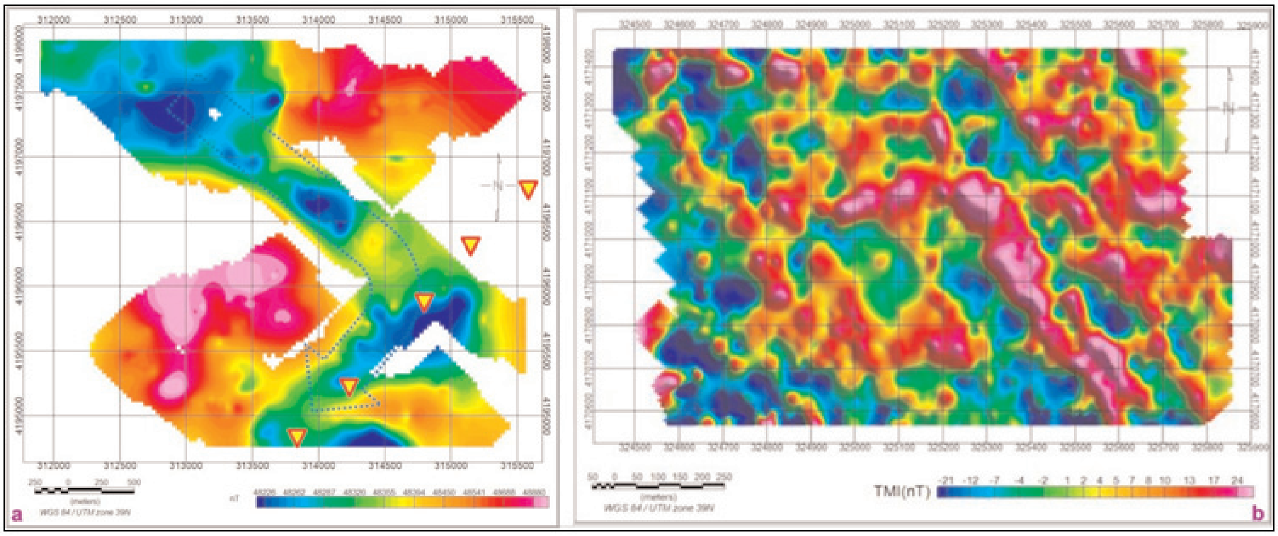


Figure 13. (a) data derived from geomagnetic perceptions in the region of Lavandevil, three corners show the location of the fault on the East of Talesh heights and west of faulted stack with moving right. (B) - three-dimensional map derived from geophysical geomagnetic. (Jahandar 2014).

of earthquake. Therefore, identification of structural elements and identify structures of each region must be done with high accuracy by the technique of remote measuring and drawing structures of each region in the study area is a big move towards the ranges and high-risk areas and due to the lack of access to the depths of the deep sea and recognition structural effects, the use of remote measuring science is a proper and low-cost way to understand the structural effects.

Several methods can be used to draw faults; one way is that all categories of faults and lineaments using geological maps based on satellite imagery can be drawn. As well as other methods, the use of computer processing, including the use of low-pass filter that in this filter, the most abundant image band can be removed and by using high-pass filter causes clear edges and detecting linear phenomena and lineaments. Also, using Edge Detector Laplacian the first type on the bands causes revealing ring structures. As well as it can be used other factors of geology and morphology in the interpretation of the of fractures.

To determine the structural effects of balance of the Caspian Sea, for example, in plate 1: 100,000 of linear Ramsar, filter (directional) is used, the determination of normal faults and inverse, Low Pass) and High Pass filters are used and for the structural nonlinear effects such as horseshoe structures that in marine areas caused by performance of normal faults is occurred, Edge Detector Laplacian) is used

According to the map (Fig. 14), major faults developed in the Caspian area within the Ramsar have

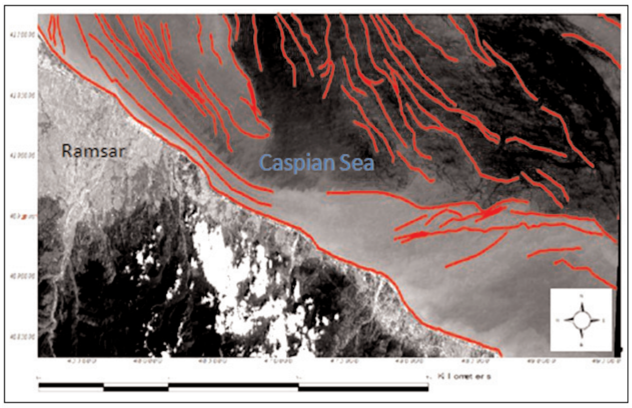


Figure 14. faults of sea context near the coast of Ramsar

trend NW-SE that in the coastal range of older faults with east-west trending are cut and placed obvious traces in modern coastal morphology as well as seen along the performance of older faults with the east-west trend of ironing structures iron flat or horseshoe structures that this can approve the phenomenon of secondary function of major faults developed by the North West South East trend.

8. Marine Hazards

Due to the locating of Iran in an area with high seismic risk, forces resulting from earthquake is one of the factors controlling the design in Civil Engineering. Nature and method of applying these forces on structure is a known issue that in different laws about them is explained in detail. In the field of geotechnical, despite years of observing the different seismic risks, the phenomenon is more unknown to the earthquake effects on structure. It seems that the complexity of the mechanism and the need for extensive and costly research is the main reason for this lack of relative cognition.

8.1. Liquefaction in the south Caspian

One of these seismic hazards that according to statistics in recent earthquakes have been the most destructive earthquake effect in prone areas is liquefaction. This phenomenon in the world was known with two Niigata and Alaska earthquakes in 1964 and in our country as Manjil earthquake in 1990 as a major seismic hazard. Liquefaction is now studied one of the main sub branches of seismic geotechnical in most of the research centers in the world. Locating Iran in the area with the risk of high seismicity on the one hand and the susceptibility of the soil conditions in many coastal areas and areas with groundwater level above on the other hand provides the guidance to evaluate the probability of occurrence of this phenomenon and control its effects.

Liquefaction can affect buildings, bridges, offshore structures, lifelines, slopes and most of the other equipment made in different ways. Liquefaction is associated with different phenomena such as pore pressure, boiling sand and different modes of deformation. But these deformations are significant for engineers only when it is large enough and damage structures. This type of deformation of the earth is called failure of earth and may appear in different forms and types. After the earthquake, observations of earth failure are used as an evidence of the liquefaction in depth of soil layers.

Before occurring vigorous shaking of the ground, the groundwater of a layer of loose saturated soil is placed in static conditions. Effective stress exerted on the soil component in any level is equal to the sum of the tension affecting total weight of the soil above the groundwater and the weight of soil immersion below it. Intense movements on the ground increase the pore pressure in the underground water level. Pore pressure due to seismic movements is scattered by flowing of pore water to the top and sides during shaking and after its completion. Although this phenomenon since that alone does not ground deformation, exactly not considered a kind of ground failure, but it is known as evidence to determine the pore pressure in the depth and a sign of liquefaction. Although boiling sand usually does not cause damage, but water and sand and sediment can cause economic losses and other injuries.

The first necessary condition for the formation of boiling sand is the existence of sufficient pore water pressure that is created by a vigorous shaking of the earth, many of the largest and damages of flow discontinuities occurred in coastal areas, soil liquefaction can be led to disruption of building foundation and the structures with different mechanisms. Both shallow and deep foundations may be damaged by liquefaction. Perhaps the most obvious failure mechanism of surface foundations is the loss of capacity of loading in the loose soils saturated with low hysteresis resistance. When the soil of base of a building or other structures become liquefaction and loses its strength, large deformations occur in soil that leads to subsidence and tilting of structure (Fig. 15). Earth's gravity causes always to apply a downward force to the material. Due to apply the force that is the result of the analysis of the weight force on domain, unstable material available on the domains, to achieve sustainability, begin to move on the domain and create types of domain movements. Basically slope instability depends to two factors of external driving force and resistance of material against movement.

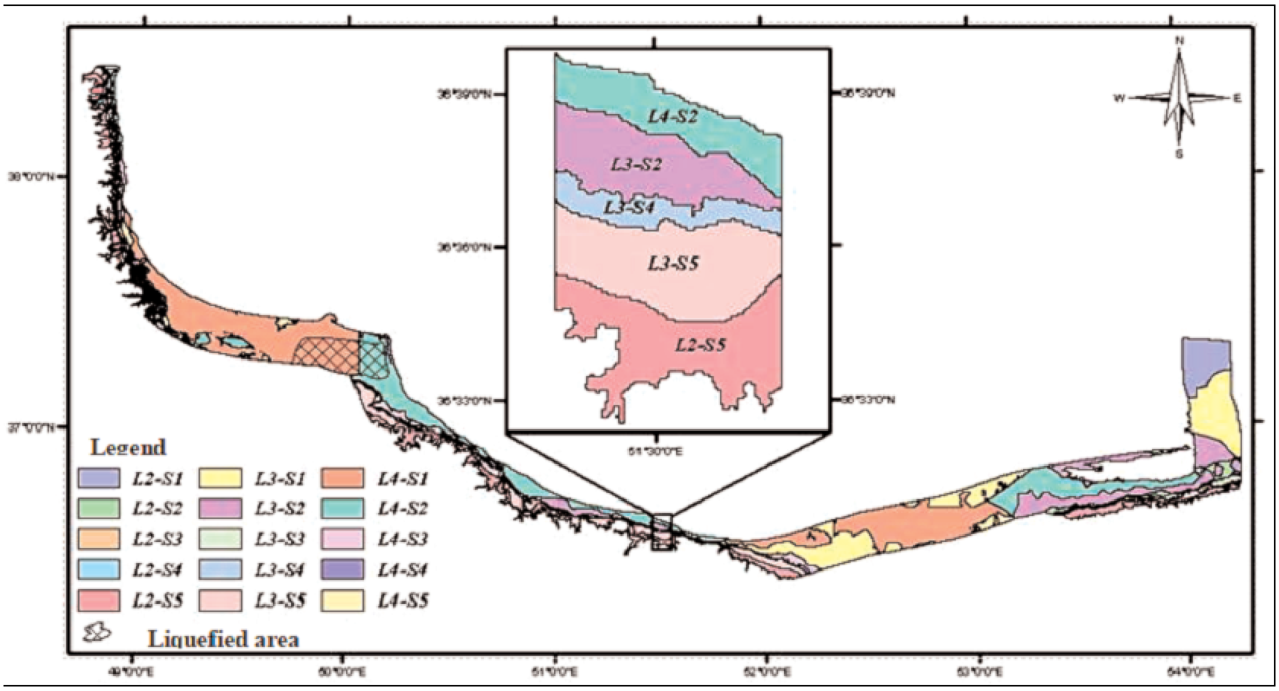


Figure 15. Zoning map of geotechnical seismic hazards in the coastal area of the Caspian Sea (Memarian et al. 2009).
L = risk of liquefaction, S = the landslide hazard, 1 = very low, 2 = low, 3 = average, 4 = high, 5 = Very High

Including external driving forces is the forces of gravity and shivering, while the strength of the material is often controlled by geological conditions and geotechnical. Memarian et al (2009) prepared hazard zonation map of liquefaction in the three categories of risk and landslides in five risk classes (Fig. 15) which shows that about 50% of the area have liquefaction risk and only 17% of the area have very high relative risk against landslide. At the same time, the final map of geotechnical seismic hazards shows that the zone related to risk of high liquefaction and very law landslide hazard covers maximum area level and approximately 30 percent.

8.2. Possible tsunami in the South Caspian

South Caspian basin by heights of the central Alborz in south and Mountains of Talesh in the southwest is covered. Heights of the central Alborz with EW direction and Talesh with North South direction are considered a part of Alpine-Himalayan seismic belt. Fault of Caspian with a length of more than 450 km and fault of Astara with a length of 110 km as the northern boundary of Central Alborz and eastern boundary of Talesh Mountains are observed where Mesozoic and Paleogene rocks on the young deposits of coastal plain of south Caspian driven. Based on research of paleoseismology and morphotectonic, it is believed that a large part of the current disruption in the Alborz is concentrated on mountains north domain and along the fault zone of Caspian. Such a border can be interpreted as a frontal Hembree contact between Alborz and the South Caspian Basin. Recent studies of stratigraphy of the Pleistocene Holocene deposits in the East of Valley of Haraz indicate rate equal in 12 thousand past years. Assuming the connection with the performance of the vertical component on the fault of Caspian, the north-south shortening on the fault with slope degree 35 towards the south estimate equal that only is a tenth of the total amount of shortening ( ) Alborz. Based on observations of geophysical and seismic of Caspian fault, the fault of Astara as an active and main system in the edge of Southwest of Caspian Basin as progressive fault system is extended under the sea. The occurrence of many earthquakes could be the result of the movement of various branches of the fault system in land and water zones of South Caspian Basin. Based on the geometry of the basin, progressive faults to the north or east and the coastal slope, in addition to more than 20 km thickness of sediments of Neogene and Quaternary of South Caspian Basin in the idea of the probability of a seismic activity ( ) on the fault of Caspian or fault of Astara, or one of the northern branches forwarded and east as the nearest active faults to the great lake of occurrence of earthquake faults or submarine landslides have the ability to produce wave in the slope coasts of the southern.

Iran by locating between the pages of Arabic in the south and the Eurasian in north sustained tension equal to (Vernant et al. 2004) that the result of such tension in addition to the deformations of plastic, especially in the area of Zagros causes the occurrence of many earthquakes in the heights of Zagros in south-southwest, Alborz in the north and also Kope Dagh and Caucasus Mountains in the east and west of Caspian.

South Caspian by earthquakes around as the deepest part of Caspian Sea with a thick and sustainable crust from the perspective of seismic is placed among the seismic zones.

Although great instrumental earthquake cannot be considered directly resulting from one of the faults known around the South Caspian however, due to the expansion and distance of active faults particularly range of central Alborz in the southern coast of the Caspian Sea cannot deny the dynamic relationship of largest lake of land and a great potential movement of earth resulting from earthquake occurrence (Fig. 16). A survey by instrumental earthquakes registered in the last century so far and historical earthquakes reported in the range of tectonic on the one hand and population concentration of coastal side of south Caspian shows the importance of further understanding of the processes of geodynamic in the past and future of the structural dynamic zone from Iran (Fig. 16).

9. Conclusion

South Caspian water area with a maximum depth of 960 meters in the south and west sides is limited to the Caspian and Astara active fault systems. Caspian fault as the largest active fault system in northern domain of the Alborz that in the number of progressive compression fault structures to the north which is rooted in the North Alborz fault is considered the most important linear sources of earthquake in coast zone of southern part of Caspian.

This fault system due to geographical position, geometry and mechanism is considered as linear source of earthquakes such as: 874 AD Gorgan-Gonbad Kavus (Ms = 6.0, Io = VII), 1498 AD, 1809 AD, Gorgan 1944 AD (Mb = 5.2, Io = VII) and Gorgan 1952AD (Mb = 4.7), Sangchal 1957 AD (Ms = 6.8) Farsynaj 1970 AD (Mb = 5.0), Babol Kenar 1971AD (M = 5.2), Ali Abad Katul 1999AD (Mb = 5.3) Gorgan 2004AD (Mw = 5.6), Firozabad Kojour 2004AD (Mw = 6.2) and Gorgan 2005AD (Mw = 5.3), Mckenzie 1972; Berberian & Yeats 1999 & 2001; Tatar et al., 2007), Ambrasys & Melville, 1982) (Fig. 17)

Micro-seismic scattered like earthquakes recorded in the water zone in north of Anzali (05 Feb. 2012) also are evidence of activeness of progressive branches of the youngest fault system in the sea context.

In the West Bank of South Caspian, although there is no direct evidence of the occurrence of destructive earthquake during the last century attributed to the activity of one of the branches of fault system, Astara in the land or marine zone, but many instrumental

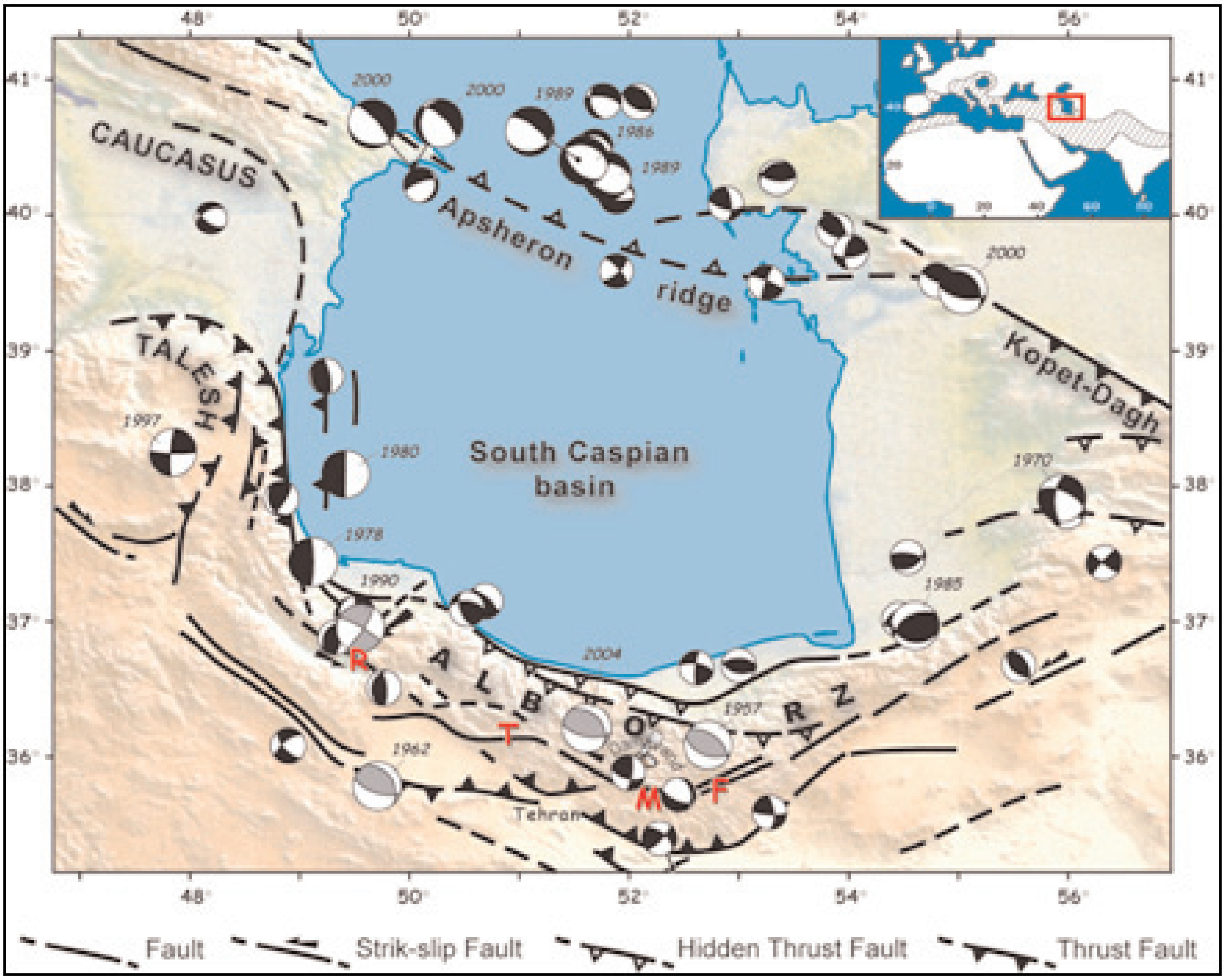


Figure 16. Map of Seismotectonic of Central Alborz (Nazari 2006)

earthquakes is registered in the range of effect of this fault system. Historical earthquakes in 1709 and 1713 that caused wide destruction of Rasht in the 18th century can be considered the result of activity of south branches of this fault system. Geographical proximity and direction of both active faults of Caspian in south and Astara in the west of south Caspian with active progressive branches apart from each that caused deformation, folding and sometimes cutting of very young sediments of the sea context with record of seismic and rate of movement *>2/5mm /y* for the fault of Caspian and *<1/5mm/y* for Astara fault considers impossible the probability of an earthquake with a moment magnitude of middle to the great (M> 6) the result of the re-movement of one of the active fault systems in the coasts of south Caspian or water zone. Undoubtedly, in the case of such possible seismic event in fault direction parallel to each of the coasts of water basin of the South Caspian in the south or west of it as a linear seismic source on land and near water area or one of the progressive fault branches in sea context will cause production and propagation of seismic waves in the crust and then in water thickness of the deep lake.

Seismic wave propagation due to the rock strata failure in depth of crust and broke and surface fault in the dry zone and close to such deep water basin has the ability to produce high waves from the type of Seiche Wave or the movement and broke with the movement on one of the fault branches of sea context in water zone of tsunami formation. Creating and expansion of each of the sea waves caused by seismic event in the area of land or water area arising from re-movement of the Caspian fault system or Astara fault system due to the geometry of the basin, relatively low bandwidth and high population concentration of south and west coasts of Caspian will lead to contact of high waves and devastating the coasts. Considering the extent and coastal slope to the geometry of the context and depth of water of possible, the power of making waves with heights up to 6 meters in most parts easily will have the capacity of smashing of more than 30% of the Iranian coast of the Caspian (Fig. 18)

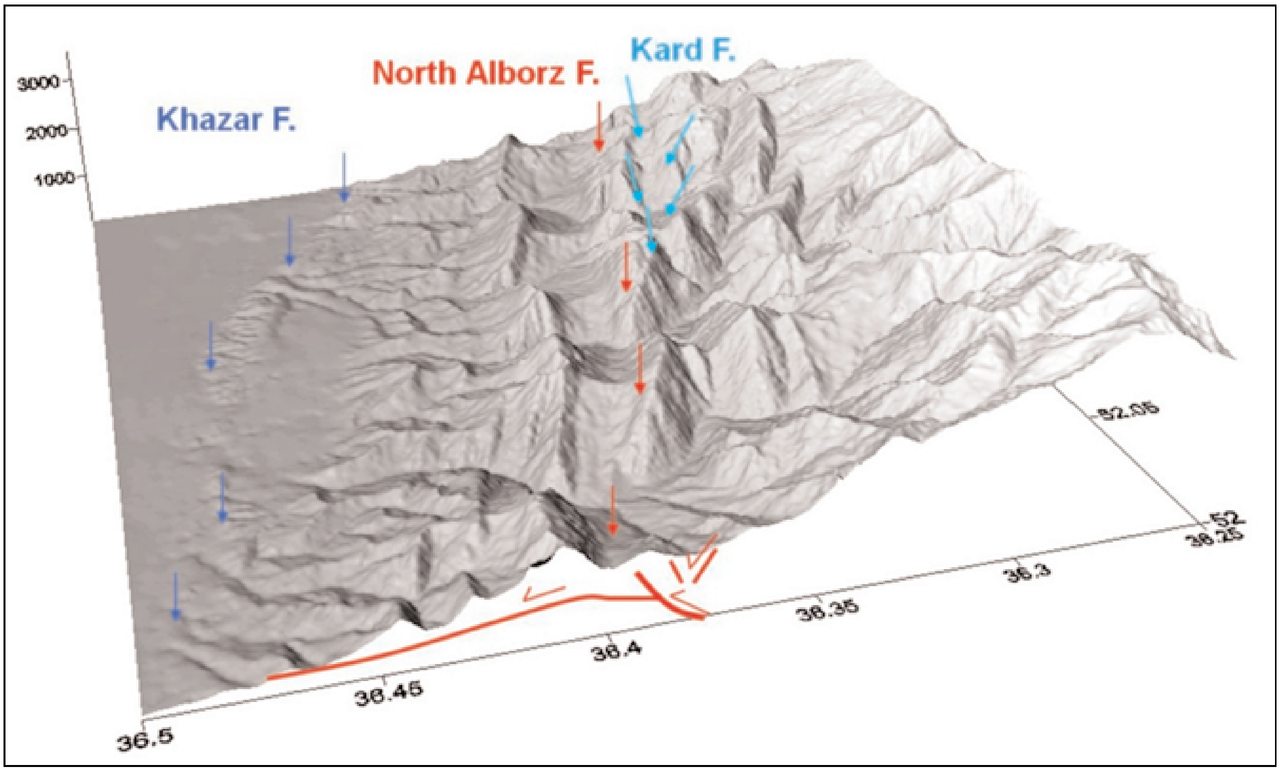


Figure 17. schematic model and structural relationship of North Alborz fault (red arrows), fault of Caspian (blue arrows) and stretching fault of Kard (turquoise arrows) on the wall of fault of north Alborz on a field of digital height model provided from topographic maps in scale 1.50000 in Chamestan area (west of Amol), which represents the progressive structures of fold and fault to the north. (Jahandar, 2014)

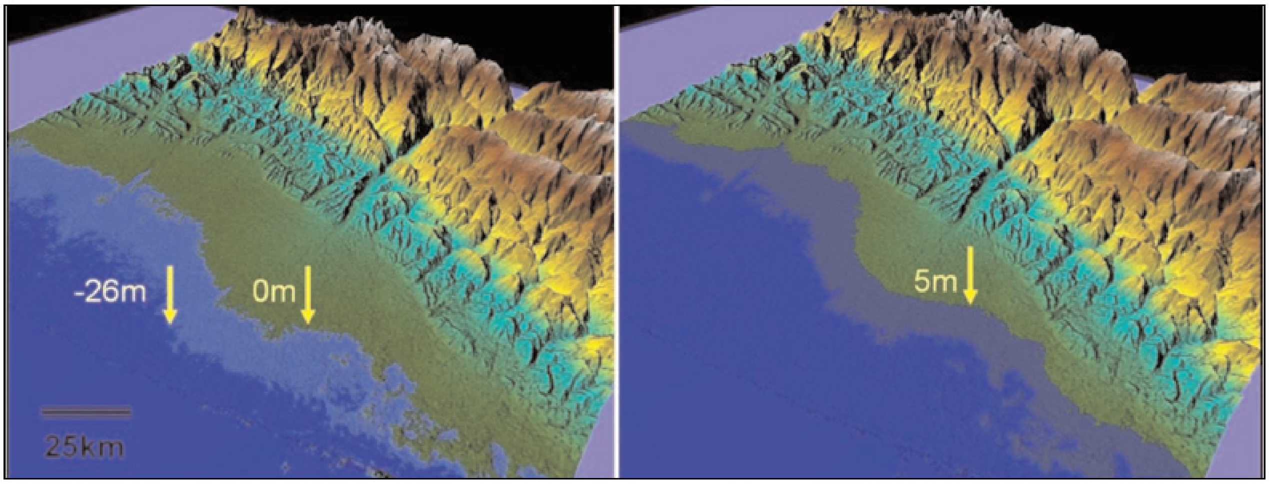


Figure 18. The range of waves effect with heights up to 5 meters in coastal zone of south coasts of Caspian, yellow arrows indicate the line of effect of the waves in current situation (level 26 m) and in the case of occurring waves with height of 3 meters (level of topography of Zero m) on the left image and the waves with a height of 5 meters (level 5+ m) in the right image and cover of damage range nearly 30% of the part of south coast of Caspian. (Jahandar, 2014).

Faults in land, their length is continued in sea and will cause earthquakes and by the quake, we will have tsunami and also liquefaction. Caspian fault with the clear height caused the formation of height of Alborz in the southern edge of Caspian basin and proximity of metamorphic rocks known as change of Gorgan and Quaternary deposits of the southern part of the Caspian is considered the result of the fault.

Based on the information obtained from seismic data obtained from the study of geophysical subsurface and analysis of data obtained from the earthquakes occurred in the area of the Caspian Sea can be concluded that the existence of other progressive branches of the fault are buried below the deposits of Caspian context, but data from geological research (Nazari 2006) considers fault of Caspian as a branch of page of fault of north Alborz in the depth and also sandy beaches have more pore depth and sedimentation process and sedimentary facies is detected and a sign of the regime of the coastal sedimentation of Caspian Sea is evident and in the Caspian coastal plain, young sediments are cut off and the faults have been taken to the sea that the faults activate them. Anzali wetland in the past has been a part of the Caspian Sea and sea coasts in the past are extended to southern areas of wetland.

References

Berberian M., Qureshi M. Arjang Rush B. 1985. Study tectonics and seismic hazard.

Bahar Firuzi Kh., Qureshi M., Nazari H. 2011.The Caspian Sea tsunami.

Jahandar N. 2014.Review seismic stratigraphy and identification of fault and subsurface tectonic seismic of shallow seismic geophysical method of sea context of Caspian.*Geophysical master's thesis*, Islamic Azad University of Chalus.

Mohammadian Vije M. 2013. Geophysical studies using GPR in order to identify active fault.

Memarian H., Babakan S., Zare M. 2009. Review seismic stratigraphy and identification of fault and subsurface tectonic seismic of shallow seismic geophysical method of sea context of Caspian. *Journal of Technical College*, 43(3): 229 - 238.

Mousavi Ruhbakhsh M. 2001. *The Caspian Sea Geology.* Geological Organization and Mineral Explorations.

Nazari H., Shahidi A.2011. *Iran Tectonics (Alborz).* Geological organization and Mineral Explorations.

Hashemi M., Nikudel M., Hafezi Moghaddas N., Khamechian M. 2012. Engineering geological model of the western coasts of the Caspian Sea. *Journal of Earth Sciences*, 86: 171-182.

Abdullayev N. A., Kadirov F., Guliyev I. S. 2017. Subsidence history and basin-fill evolution in the

South Caspian Basin from geophysical mapping, flexural backstripping, forward lithospheric modelling and gravity modelling. *Geological Society of London.*

Alavi M. 1996. Tectonostratigraphic synthesis and structural style of the Alborz Mountains in northern Iran. *J. Geodynamics* 21(1): 1-33.

Allen M. B., Ghassemi M.R., Shahrabi M., Qorashi M. 2003b. Accommodation of late Cainozoic oblique shortening in the Alborz range, northern Iran. *Journal of Structural Geology* 25: 659-672.

Allen M. B., Jones S., Ismail Zadeh A., Simmons M., Anderson L. 2002. Onest of subduction as the cause of rapid Plio-Quaternary subsidence in the South Caspian basin.

Allen M. B., Vincent S.J., Ian Alsop G., Ismail Zadeh A., Flecker R. 2003a. Late Cainozoic deformation in south Caspian region: effects of a rigid basement block within a collision zone. *Tectonophysics* 366: 223-239.

Axen G. J., Lam P.S., Grove M., Stokli D.F., Hassanzadeh J. 2001. Exhumation of the west-central Alborz Mountain, Iran, Caspian subsidence and collision-related tectonics. *Geology*, 29(6): 559-562.

Berberian M. 1983. The southern Caspian: A compression depression floored by a trapped, modified oceanic crust. *Canadian Journal of Earth Sciences,* 20: 163-183.

Doglioni C. 1995. Geological remarks on the relationships between extension and convergent geodynamic settings. *Tectonophysics*, 252: 253-267.

Mitra S. 2003. A unified kinematic model for the evolution of detachment folds. *Journal of Structural Geology,* 25: 1659-1673.

Nazari H. 2000. Tectonomagmatic and Tectonostratigraphic of Alborz Magmatic Arc. *In: Proc of the 18th. Symposium on Geoscience, GSI.*

Nazari H. 2006. Analyse de la tectonique récente et active dans l'Alborz Central et la région de Teheran: Approche morpho tectonique et pale séismologique. *Science de la terre et de l'eau. Montpellier,* Montpellier II: 247.

Nazari H., Omrani J., Shahidi A.R. 2004. Geological map of Anzali. *GSI.*

Nazari H., Ritz J.F., Ghorashi M., Abbasi M., Saidi A., Shahidi A.R., Omrani J. 2003. Analyzing Neotectonic in Central Alborz: Preliminary results. *In: Proc of the 4th. Symposium on Seismology,(See 4), IIEES.*

Nazari H., Salamati R. 1998. Geological map of Rudbar. GSI.

Priestly K., Baker C., Jackson J. 1994. Implications of earthquake focal mechanism data for the active tectonics of South Caspian Basin and surrounding regions. *Geophys J Int*, 118: 111-141.

Soltanpour M., Rastgoftar E. 2011. Study of tsunami attacks on neighbouring countries of Caspian Sea caused by a probable submarine landslide. *Journal of Coastal Research, SI 64 (Proceedings of the 11th International Coastal Symposium),* 1195 - 1199. Szczecin, Poland.

Vernant P., Nilforoushan F., Chery J., Bayer R., Djamour Y., Masson F., Nankali H., Ritz J.F., Sedighi M., Tavakoli F. 2004. Deciphering oblique shortening of central Alborz in Iran using geodetic data. *Geology.*