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Research Article

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Active Faults on the Satellite Image of Azerbaijan Province, Northwestern Iran

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Abstract

Lake Urmia in northwestern Iran is one of the hypersaline lakes of world. In the Urmia region a Cenozoic island arc was formed by northeastward subduction of Neo-Tethyan oceanic plate beneath central Iran; the lake is therefore located in the fore-arc basin tectonic setting. Satellite imagery of the Urmia region illustrates that the trend of faults are in two main NE-SW and NW-SE directions. The morphology of Urmia Lake is controlled by these two fault systems, one is sub parallel to the strike of the Zagros Thrust System and the other in a perpendicular NE-SW direction with both fault systems belonging to two different generations. The strike-slip faults at the Urmia region were active in two phases surrounding Urmia from north, south and west. The first phase are old generation faults which aligned NE-SW trend. The second is new generated and active one as result of opening of Red Sea and movement of Arabian plate toward central Iranian microplate. The new generated structures are affected by the maximum stress field in NEE-SWW trend, causing seismic events after Cretaceous by present and are associated with collision between the Arabian plate and the Eurasian plate from early Tertiary to the present.

Keywords

Lake Urmia; Sahand; Ahar; Zagros; Active fault

Introduction

Iran, located in the Alpine-Himalayan seismic belt, is a vulnerable country of seismic hazards. The present-day tectonics of Iran is mainly the result of the motion between the Arabian and Eurasia plates, which at the location of Tabriz converge at a rate of 20–30mm/year accommodates both the northward motion of Arabia and the westward motion of Anatolia relative to Eurasia [1]. This convergence is distributed between the shortening across the Zagros, the internal deformation accommodated by the large strike-slip faults in central Iran, and the shortening of the Alborz Mountains [1]. Because of the oblique orientation of the motion relative to the mountain range, results in the partitioning of the motion between shortening in the Azerbaijan and right-lateral strike-slip motion along the North Tabriz fault [2].

In the Urmia Lake region (West-Azerbaijan Province) a Cenozoic island arc complex was formed by northeastward subduction of the Neo-Tethyan oceanic plate beneath central Iran (Figure 1). The lake is therefore located in the fore-arc basin of the Sahand Magmatic Arc [3]. Three types of tectonic settings are proposed for the central Iranian Volcanic Belt: rift, continental margin, and postcollision settings. However, geochemical, tectonic, stratigraphic, and metallogenic evidence favor an ensialic island-arc setting Shahabpour (2007) [4].

Structures at the Azerbaijan province are dominated by the tectonic activity during the Cenozoic causing numerously volcanic activities and faulting into the rock blocks, younger sedimentary units and even alluvial depositions that surface earthquakes demonstrate that [5]. As results of these tectonic movements in the Pliocene / late Quaternary, several faults were created or reactivated such as the main faults around the lake; North-Tabriz and Salmas faults caused huge damages due to severe earthquakes in the past [6,7]. To encounter with horrible earthquakes and reduce of casualties, any endeavor to assess earthquake hazard is of great value and could prevent excess damage to life and property.

This research focuses on faults trend identification using Landsat imagery of the Urmia and Tabriz regions, using 3D interpretation based on aerial photos and also ROSE diagrams. Additional field reconnaissance (measurements of dip, strike and fault displacements) were carried out, too.

Geology

East and central parts of the Urmia region consist of wide plains where northern, western and southern partitions consist of mountainous regions. Also, as described by Shahrabi [8], the

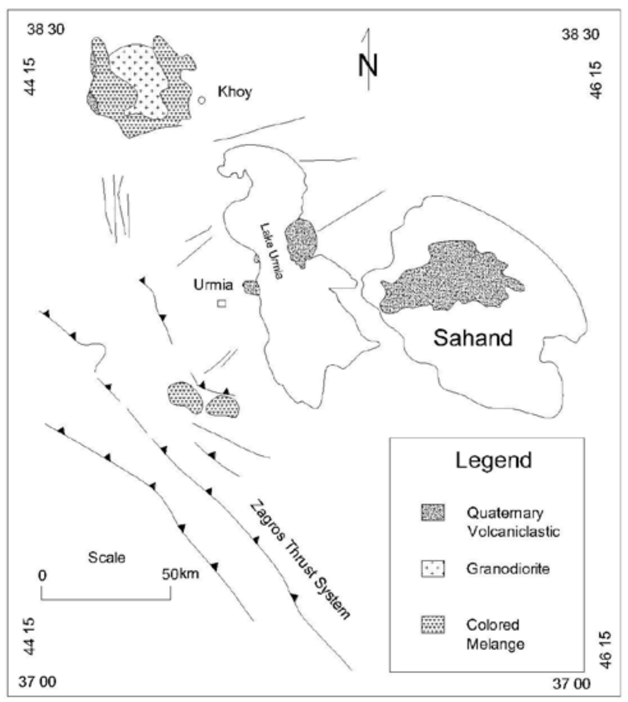

Figure 1: The Urmia Lake is regional map, Sahand Magmatic arc and Zagros Thrust System.

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depressional zone embrassing the Urmia Lake and it is elevated in surrounding the lake with rough morphology. There are relatively complete stratigraphic successions in both east and west areas of the Urmia Lake. The oldest constitutes of crystalline rocks (igneous and metamorphic rocks) of the Azerbaijan region summarized as basement on the geological map (see Figure 2). The volcanic rocks and latter sediments deposition are described as other geologic units in the geological map of the area. These units could also be recognized on the satellite images in the areas where geologic maps were not available.

A large area in the Tabriz region is covered with the Miocene or younger volcanic rocks. This constitutes the complex of Sahand Volcano. The Sahand Magmatic Arc has been formed by northeastward subduction of Neo-Tethyan oceanic plate beneath central Iran. It contains andesitic rocks with dacite and felsic composition.

The Miocene transgression took place almost everywhere in the region. It crops out as carbonate and marl, overlying older formations with angular unconformity [8].

Except for the Quaternary and alluvial depositions, rocks in the Urmia region are deformed by fold and fault structures and influencing them. Figure 3 illustrates field photos of rock units and structures. At Figure 3a, the Oligo-Miocene limestone was folded by a thrusting fault at northwest of the Urmia Lake; the movement of main fault causes folding of the sedimentary rocks above the basement. Also folding of the Miocene limestone at Figure 3c results from the movement of a thrust fault at the west side of the lake. At Figure 3b, the Miocene limestone exhibit normal displacement about 2 m and at Figure 3d obduction of granite along a thrust has caused Permian limestone to steep about 46° to the east. The trend of maximum stress for both Miocene and Permian limestone differ at this region.

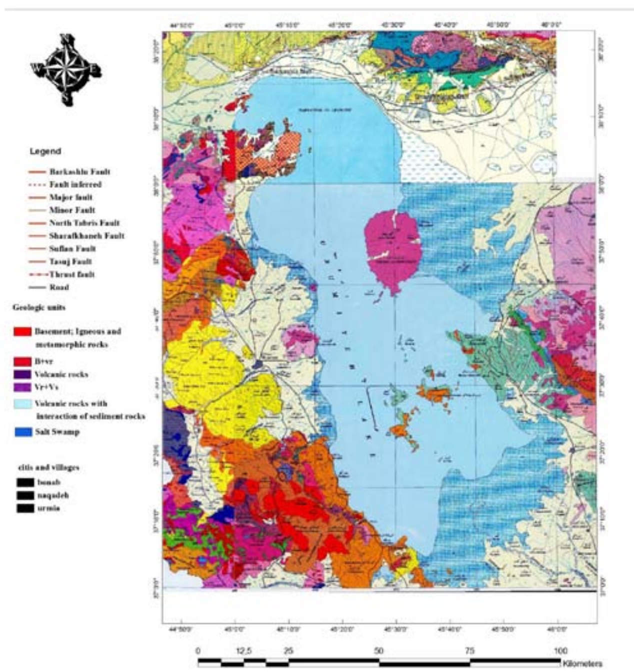

Figure 2: Geological map of the Urmia region, northwest of Iran. This map compiled of four 1:250000 geology maps of Geological Survey of Iran in ArcGIS-Arc Map software.

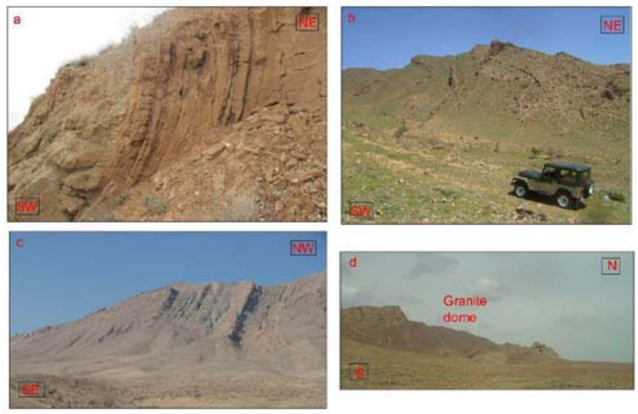

Figure 3: Outcrops of the Urmia region. a) Movement of fault has been caused folding of Oligo-Miocene limestone; b) the faulty rock units; c) the fold structure within Miocene limestone (the view of photo to NW) and, d) intrusion of granite during the post-Cretaceous events (view to N). The direction and dip of the layers were considered and entered on the map.

Tectonic Setting

The tectonic events, which occurred around the Iranian Plate margins, are related to rifting processes of Gondwana and subsequent collision with the Arabian plate from the WSW that affected the Iranian Plate and the adjacent plates during Mesozoic to Tertiary times [9]. The geology and tectonic style of the Azerbaijan is influenced by Tethyan region. The Tethyan region, which includes the Iranian Plate and the adjacent areas, underwent three major evolutionary stages. The first stage was the closing of the Paleo-Tethys and rifting of the Neo-Tethys from early Permian to late Triassic times. With the second stage, the subduction process of the Neo-Tethys and the collision of the Indian Plate with the Eurasian Plate from the Jurassic to the early Lower Tertiary began. The third and last stage is associated with the collision between the Arabian plate and the Eurasian plate from early Tertiary to the present [10].

Tectonic analysis and available geological data in this research indicate that formation of the Urmia Lake is the result of multiple faulting events, specially two northwest-southeast and northeast-southwest trend of faults. The uplift and through system within the fault zones of Urmia area are accompanied with Eocene volcanic rocks which formed a large volcanic island in northeast of the Urmia lake (Eslami peninsula) [5]. The shape and morphology of the Urmia Lake is controlled and tectonically dominated by two main faults as there are more than two: One almost parallel to the strike of the Zagros Thrust System and the other, in a perpendicular NE-SW direction. It is situated between two fault systems namely the Soltaniye-Tabriz fault in the east and Zarrineh-Rood fault (called also the Urmia fault) in the west of the Urmia Lake [11].

The ROSE diagram representing a total of 40 faults around the Urmia Lake demonstrates that faults aligned in three main trends at: NE-SW and NN-SS, NW-SE directions (Figure 4). The NE-SW faults are older than the NN-SS and NW-SE faults. These faults belong to two generations with different ages of Paleozoic and Mesozoic relation with Paleo-Tethys and Neo-Tethys evolution respectively [12].

The tectonic mapping of lineaments on Landsat imagery was carried out two sets of faults (Figure 5):

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a) Primary lineaments include small and medium-sized lineaments, which are old and spread in the whole area. These lineaments are perpendicular to the main Zagros fault and almost contain inferred faults.

b) Secondary lineaments are relatively small with great dimension, which can clearly be recognized both on the aerial photographs and satellite images. They are parallel the main Zagros fault at the NW-SE and NN-SS trends and introduce as new generated faults.

In conclude lineaments and faults subdivided into two main groups:

- Northeast-southwest direction, which occurred mainly in older rock series according to the first order lineaments perpendicular to the main Zagros fault.
- Norwest-southeast direction, which corresponds with the general direction of the Zagros main thrust and sub parallel to the trend of second order lineaments.

In the eastern parts of the Lake Urmia, several lineaments seen on the satellite images are partly mapped as main faults or inferred faults. These are NW-SE oriented active faults in Tabriz region, northeast of the lake. One of these faults is the Varzeghan Fault System, which has caused an earthquake in the Azerbaijan (Figure 6).

The August 11, 2012 M 6.4 and M 6.3 earthquakes in northwestern Iran occurred as a result of oblique strike-slip faulting in the shallow crust of the Eurasia plate, approximately 300 km east of the plate boundary between the Eurasia and Arabia plates. The two earthquakes are separated by just 10 km in an east-west direction. Focal mechanisms, describing the style of faulting for the earthquakes, suggest slip on either fault planes striking roughly east-west, or those striking roughly north-south.

It is noteworthy that there is a step-over between the northern and southern segments of Varzeghan Fault System. These lineaments are not mapped on the existing geological map as a main fault. Hereby,

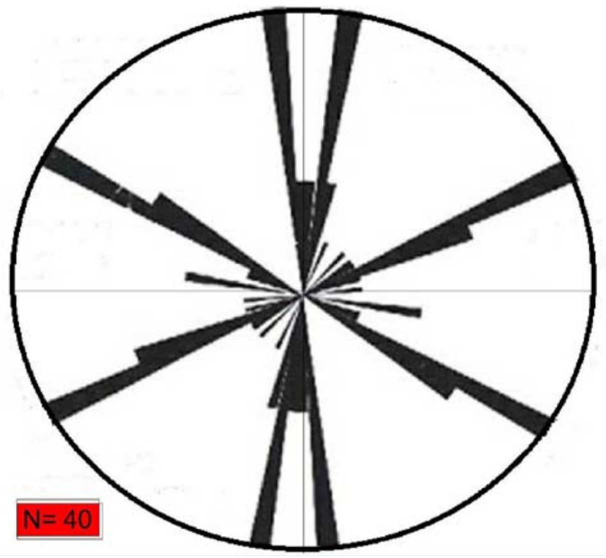

Figure 4: Rose diagram for the fault trends of the Urmia region. They provide important instructions to positioning of the faults.

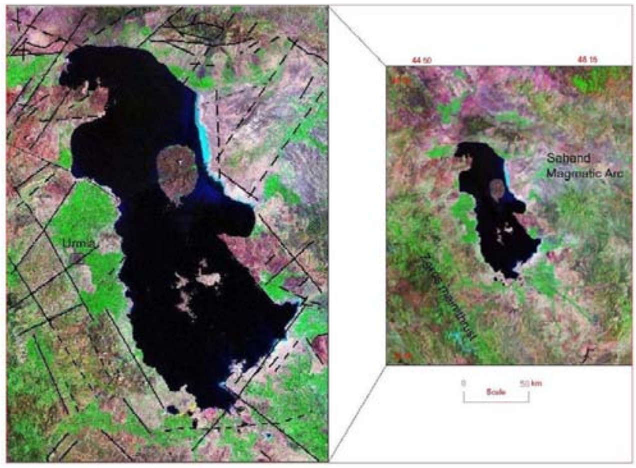

Figure 5: MrSID Satellite image: left: 495200, right: 4090000. Lineaments are mapped around the Urmia Lake on the left image and geographic position of the Zagros and Sahand Magmatic Arc are seen on the right image.

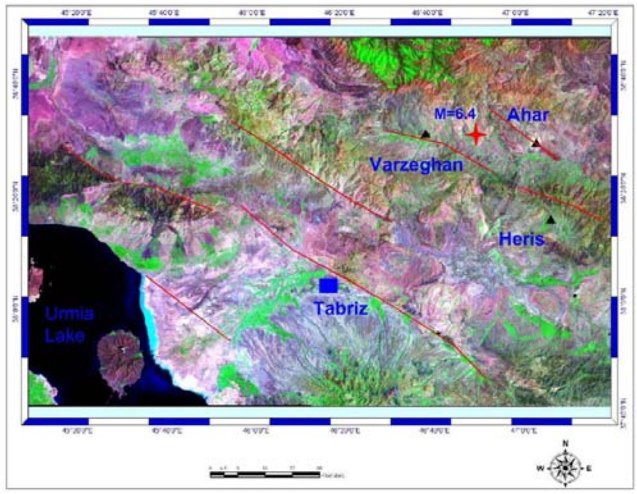

Figure 6: Active faults on the satellite image of northeast side of the Urmia Lake and the epicenter of 11.08.2012 earthquake.

this fault system is subdivided into two main faults which are oriented parallel to the main fault and can be described as follows:

- Ahar Fault, which is a large fault that separates the Permian crystalline rocks of the Quaternary alluvial.
- Heris-Varzeghan Fault, which the epicenters of earthquake overlie on this fault. This main fault lies across the damaged area of the recent earthquakes on 11.08.2012, 6.4 Mw.

On a broad scale, the seismotectonic of this region are controlled by the collision of the Arabia and Eurasia plates; at the latitude of the earthquakes, the Arabia plate moves almost due north with respect to the Eurasia plate.

Discussion and Conclusion

Iran is actively deforming due to the northward motion of the Arabia plate that collides with Eurasia and, Azerbaijan region will be deformed consequently. Therefore, intraplate deformation occurs as result of Arabia northward convergence in the Azerbaijan region.

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Two fault systems the Soltaniye-Tabriz fault in the east and Zarrineh-Rood fault in the west of the Urmia Lake have controlled the shape and morphology of this lake. These faults are in northeast-southwest and northwest-southeast directions respectively.

Field reconnaissance and results of this research indicate that the fold and fault structures belong to two different generations in this region. The old generation structures in Paleozoic relate to the closing of Paleo-Tethys and rifting of the Neo-Tethys from early Permian to late Triassic times so, the old generation is before Cretaceous affected by maximum stress trend in NW-SE direction. The new generated structures are affected by the maximum stress field in NEE-SWW trend, causing seismic events after Cretaceous by present and are associated with the collision between the Arabian plate and the Eurasian plate from early Tertiary to the present.

The primary lineaments are old generation faults which aligned NE-SW trend. Lineaments of second order are new generated and active as a result of opening of Red Sea and movement of the Arabian plate toward central Iranian microplate present. The greatest numbers of strike-slip faults consist of old and new generations are in northern, southern and westward of the Urmia, parallel with border line of Iran and Turkey.

In conclusion: 1. Two fault systems the Soltaniye-Tabriz fault in the east and Zarrineh-Rood fault in the west of the Urmia Lake, have controlled the shape and morphology of the Urmia lake; 2. Two generations of lineaments are mapped on satellite image of the Azerbaijan region; 3. The maximum pressure stress trend for the primary lineaments is NEE-SWW and NW-SE for the secondary lineaments; and 4. Second order lineaments are more active than the first one.

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