# Active tectonic analysis of Buin Zahra-Avaj area, southern Qazvin

Masomeh Alaei[1], Maryam Dehbozorgi[*2], MohammadReza Ghassemi[3], Reza Nozaem[4],

1. M.Sc. Student, Faculty of Earth sciences, Kharazmi University, Tehran, Iran
2. Assistant Professor, Faculty of Earth sciences, Kharazmi University, Tehran, Iran
3. Associate Professor, Research Institute of Earth Sciences, Geological Survey of Iran, Tehran, Iran
4. Assistant Professor, School of Geology, College of Science, University of Tehran, Iran.

Received: 6 Nov 2016 Accepted: 17 July 2017

## Extended Abstract

Paper pages (123-152)

### Introduction

The Iranian plateau is situated in the Alpine-Himalayan orogeny between the Eurasian plate in the north and the Arabian plate in the south. It is being shortened by the northward movement of the Arabian plate, which causes the most parts of Iran to be active and dynamic in terms of tectonic movements. The recent tectonic activity in the southern edge of central Alborz causes both development and deformation of the tectonically active landforms. Seismic records indicate a high frequency of earthquakes of relatively small magnitude (<4) and infrequent large earthquakes (>5.1) in the Alborz. The studied area is located in the southern central Alborz and at the edge of northwestern central Iran between seismic faults of Ipak (with approximately E-W trend) and Avaj (with NW-SE trend) that includes significant earthquakes. Generally, the dominant tectonic structures of the study area involve thrust faults. The Ipak fault is one of the major fault systems in the area, located about 120 km west of Tehran, and caused the 1962 Buin Zahra earthquake of Ms 7.2 (Mw 7.0). The earthquake was associated with 95 km surface rupture along the Ipak reverse fault with average throw of 140 cm and left-lateral displacement of 60 cm. This investigation has evaluated the active tectonics and the acceleration zoning of the region in order to analyze and measure the recent tectonic activities.

## Material and methods

To assess the acceleration zoning of this region, seismic data, Kijko software, PSHA software and reduction equations were used; consequently, minimum and maximum acceleration for useful life of 75-year and 475-year building were estimated. In order to assess the relative tectonic activity through the study area, sub-basins and stream network were extracted by using Arc Hydro Tools software based on the DEM and in turn, 134 sub-basins have been resulted. The six geomorphologic indices were used as follow: Stream length–gradient index (SL), mountain front Sinuosity (Smf), Ratio of valley floor width to valley height (Vf), Asymmetric factor (Af), Hypsometric integral (Hi) and drainage Basin shape (Bs). Eventually, after calculating the relative tectonic activity index (Iat), the studied area was classified into four tectonic activity classes in ArcGIS10.1 as very high, high, medium and low.

**Stream Length–Gradient Index (SL):** The SL index indicates an equation between erosive processing as streams and rivers flow and active tectonics. The SL is defined by Eq. (1)

$$SL= (\Delta H/\Delta Lr)\ Lsc \qquad (1)$$

where ΔH is change in altitude, ΔLr is the length of a reach, and Lsc is the horizontal length from the watershed divide to midpoint of the reach. The SL index can be used to evaluate relative tectonic activity. The quantities of the SL index were computed along the streams for all sub-basins.

**Index of Mountain Front Sinuosity (Smf):** Index of mountain front sinuosity is defined by Equation (2).

$$Smf = Lmf / Ls \qquad (2)$$

where Lmf is the length of the mountain front along the foot of the mountain in which a change in slope from the mountain to the piedmont occurs; and Ls is the straight line length of the mountain front. Smf represents a balance between erosive processes tending to erode a mountain front, making it more sinuous through streams that cut laterally and into the front and active vertical tectonics that tends to produce straight mountain fronts, often coincidental with active faults or folds.

**Ratio of Valley** Floor **Width to Valley Height (Vf):** Vf is defined as the ratio of the width of the valley floor to its average height and is computed by Equation (3).

$$Vf = Vfw/ [(Ald-Asc) + (Ard-Asc) /2)] \quad (3)$$

where Vfw is the width of the valley floor, and $A_{ld}$, $A_{rd}$, and $A_{sc}$ are the altitudes of the left and right divides (looking downstream) and the stream channel, respectively. A significant relationship exists between the rate of mountain front activity and the Vf index. Consequently, the high Vf values conform to low uplift rates (Keller and Pinter 2002). The shape of a valley can also represent the Vf amount and uplift rate. Therefore, U-shaped valleys accommodate low Vf and high uplift.

**Asymmetric Factor (Af):** The asymmetric factor (Af) is a way to evaluate the existence of tectonic tilting at the scale of a drainage basin. The method may be applied over a relatively large area. Af is defined by Equation (4).

$$Af= 100(Ar/At) \quad (4)$$

where Ar is the area of the basin to the right (facing downstream) of the trunk stream and At is the total area of the drainage basin. If the value of this factor is close to 50, the basin has a stable condition with little or tilting; while values above or below 50 may result from basin tilting, resulting from tectonic activity or other geological conditions such as lithological structure.

**Hypsometric integral (Hi):** The hypsometric integral is an index that describes the distribution of the elevation of a given area or a landscape. The Hi is independent of basin area. This index is defined as the area below the hypsometric curve and thus expresses the volume of a basin that has not been eroded. A simple equation that may be used to calculate the index is defined by Equation (5).

$$Hi = (\text{average elevation - min. elev.}) / (\text{max. elev. - min. elev.}) \quad (5)$$

Then Hi values were grouped into three classes with respect to the convexity or concavity of the hypsometric curve: Class 1 with convex hypsometric curves ($Hi \geq 0.5$); Class 3 with concave hypsometric curves ($Hi<0.4$); and Class 2 with concave–convex hypsometric curves ($0.4 \leq Hi<0.5$).

**Index of Drainage Basin Shape (Bs):** Horizontal projection of basin shape may be described by the elongation ratio, Bs, expressed by Eqation (6):

$$Bs = Bl/Bw \quad (6)$$

where Bl is the length of the basin measured from the headwaters to the mouth, and Bw is the width of the basin measured at its widest point. High values of Bs are associated with elongated basins, generally related to relatively higher tectonic activity. Low values of Bs indicate a more circular-shaped basin, generally associated with low tectonic activity.

**Evaluation of Relative Tectonic Activity** (Iat): The average of the six measured geomorphic indices (Iat) was used to evaluate the distribution of relative tectonic activity in the study area. The values of the index were divided into four classes to define the degree of active tectonics.

**Results and discussions**

Results of probabilistic seismic hazard analysis have shown that the minimum and the maximum acceleration for useful life of 75-year building is estimated as 0.33g and 0.45g and for 475-year one are 0.46g and 0.60g, respectively. These values are indicative of high risk in the studied area. Acquired values from geomorphologic indices and also acceleration zoning of the realm are indicative of high recent tectonic activities near Ipak, Hasanabad, Soltaniyeh and Avaj faults; they are extremely concordant with the obtained evidences and geomorphologic characteristics of the field samples. In this study, considering the diversity of the morphotectonic features, six morphometric indices relevant to the river channels, drainage basins, and mountain fronts were computed for every catchment, and consequently, a single index (Iat) was calculated from these indices for each of 134 subbasins to define the degree of active tectonics. Finally, the Index of the Active Tectonic (Iat) was calculated through which the study area is classified into four tectonic activity classes, from very high to low; 1—very high ($1.0 \leq Iat<1.5$); 2—high ($1.5 \leq Iat<2.0$); 3—moderate ($2.0 \leq Iat<2.5$); and

4—low (2.5≤Iat). The distribution of the four classes of Iat has been presented in a well classified map. The indices have represented a quantitative approach to differential geomorphic analysis related to erosion and depositional processes which include the river channel and valley morphology as well as tectonically derived features, such as fault scarps. We also evaluated the outputs of the morphometric analyses based on field-based geomorphological observations. Thus, these results are proved to be extremely beneficial to evaluate relative rates of active tectonics of this region.

The values of Af show widespread drainage basin asymmetry related to tectonic tilting, particularly associated with Ipak fault. The values of Smf suggest that mountain fronts are tectonically active, and the values of Vf show that some valleys are narrow and deep, suggesting a high rate of incision. The parts with class 1 and 2 of the relative tectonic activity are located along the main faults of the region, such as Soltaniyeh, Avaj, Hasanabad and Ipak faults and show high correlation with observed landforms during the field investigations such as the direct mountain fronts, fault gorges, fault scarps, and deep v-shaped valleys. Besides, the high amount of the relative active tectonic index shows a good consistency with the recent tectonic activity, namely tilting and deformation of the Quaternary units, which is the indicative of the effect of compressive stresses, affecting the region.

**Conclusion**

In this study, according to the current tectonic activity using the Iat index, it was found that the study region represents a high current tectonic activity along the fault zones. The values of SL, Hi, and Bs were found to be high along Soltaniyeh, Avaj, Hasanabad and Ipak faults segments.

According to the earthquakes and probabilistic seismic hazard analysis in the study area, it is worthy to note that some basins which are located among active faults, are seismically dangerous. However, they show low relative active tectonic index (Iat).

**Keywords:** Active tectonic, geomorphic indicators, earthquake, Probabilistic seismic hazard analysis (PSHA), Central Alborz.

*Corresponding Author: M_dehbozorgi@khu.ac.ir