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Assessment of neotectonic of upper part of Kharroud drainage basin (Qazvin province) using morphitectonic evidences

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Abstract
The study area is located in the geological map of Avaj at 1: 100,000 scale. Also, the exploration area of Kharroud is over 550 km2 in Qazvin province. The Kharroud River is 217 km in length. This area is located between two structural-sedimentary zones of central Iran and the Sanandaj-Sirjan, which has the geological characteristics of both zones. Therefore, the area is very varied in lithology; types of metamorphic rocks of the upper Triassic and Jurassic, Tertiary magmatic series, and various types of sedimentary and chemical sedimentary rocks of different ages from Paleozoic to Neocene on the river flow path or at the surface of the drainage basin outcropped. The morphology many of the surface landforms is result of two groups of factors that group is trying to create heights and roughness of the earth, and other factors try to erode the same roughness. Using morphotectonic science and assess of morphotectonic indices, can be conclude that in the particular region, the forms of the earth's surface are influenced by which factors. This case study was carried out on the upper part of the Kharroud River in Qazvin province. Using the digital elevation model, the basin and sub-basins watersheds related to the Kharroud River was extracted. Then, using elevation data, the stream length-gradient (SL), Topographic Symmetry Index (AF), hypsometric curve and hypsometric integral were calculated for the study area. The results show that the upper part of the catchment Kharroud area is a region in which orogeny tectonic forces have reached balanced with erosion factors and the region has matured morphologically. In addition, the neotectonic activity of the region is low based on this index and the region is in the class of areas with low neotectonic activity.

Key word: Neotectonic, Kharroud, Qazvin, morphitectonic

1. Introduction

Morphotectonic or tectonic geomorphology is the knowledge which studies shapes and landforms on the surface, which are created by tectonic mechanisms and which are used as the application of geomorphic principles in the analysis of tectonic problems (Ahmadi and Rahimi Chakdel 2013; Farhoudi and Sharafi 2009: Burbank and Anderson 2008). In recent years, the usage of tectonic geomorphology has greatly increased. This science is one of the major tools for the detection of active tectonic forms and the provision of seismic hazard maps, as well as helping to understand and intelligence of the history of the landscape of the earth's surface (Burbank and Anderson 2001; Keller and Pinter 2002; Amirahmadi and Ebrahimi 2014).

Geomorphic indices are especially used for active tectonic environments. (Burbank and Anderson 2001; Ioannis et al. 2006). The main purpose of using geomorphic indices and measuring morphometric parameters is study the landforms and topographic features of the earth quantitatively and numerically. In morphometric studies, requirement data is obtained from topographic maps, aerial photos and satellite imagery (Stewart and Hancock 1994).

Geomorphic indices are particularly useful in morphotectonic studies because they can be used for rapid assessment of large areas and obtained essential information from topographic maps and aerial photographs (Keller and Pinter 2002). One of the most important morphotectonic indices is the hypsometric curve and hypsometric integral, which provides a general representation of the dominant processes in the region. Geomorphic indices such as the topographic asymmetry factor and stream length-gradient index provide a rapid assessment of the effect of tectonic activity on the drainage network.

In this research, it is attempted to derive the basin and sub-basins of the upper part of the Kharroud River sing the digital elevation model (DEM). Then, by performing morphotectonic studies and calculating morphometric indices, a more precise aspect of the role of tectonic factors in the formation of landforms in the catchment area is obtained.

2. Geology of the Area

Kharroud River with an area of about 550 square kilometers is located in the geological map of 1: 100000 Avaj. The area is located in the northwest of Iran along the geographical longitudes range from 30 - 49 to 49 east and latitudes from 30 - 36 to 35 north. In addition, the study area is located in the zone between central Iran and the Sanandaj-Sirjan zone (Bolourchi 1975). The study area has the features of both zones; the northern part of the region (Abgarm zone) is related to the Central Iran zone and the southern part of the Razan zone forms part of the Sanandaj-Sirjan zone (Mousavi 2009).

According to the existing geological maps of the area (Bolourchi and Hajian 1979; Yousefi 2000), in this region Precambrian to the upper Triassic rocks have not been exposed, and the Upper Triassic -Jurassic slates, Limestone and shale slightly metamorphic Cretaceous and sequences. The non-metamorphic of

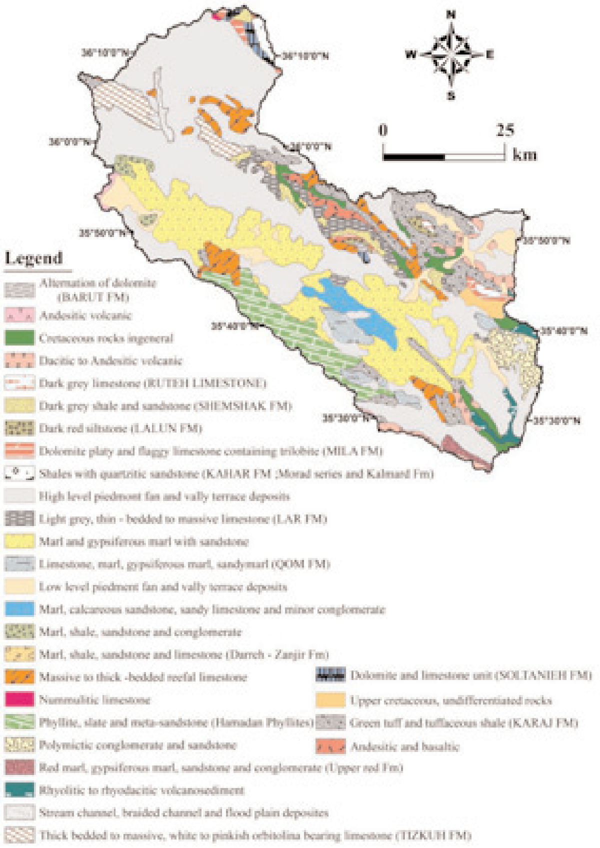

Figure 1. Geological map of the study area

the Tertiary to the present day is a characteristic of this area (Fig. 1).

Also, the eastern part of the river flows in the quaternary sediments and the western part in sedimentary rock units (mainly Neogene and the other Paleozoic and Mesozoic units). The two zones of Abgarm and Razan in the Avaj region are separated by the Avaj fault. The fault is along the northwest to south-east (NW- SE), and controls the geology setting of the area, in particular the Mesozoic and lower Tertiary fancies and magmatism. The upper red formation consists of conglomerate, (anhydrous conglomerate), Avaj red layers, marl, sandstone, salt, and gypsum, and plays a major role in the quality of surface waters such as the Avaj River near the bridge of the Irwan.

3. Discussion

3.1. Extraction of Basin Boundary and Channels

The digital elevation model (DEM) saves itself as an altitude-spatial data raster structure file. With these features, DEM provides easy, fast and inexpensive data processing in a GIS environment. Hence, DEM has been widely used in various studies of structural geology, morphotectonic, hydrology, and so on. Using the digital elevation model and using the Arc Hydro software, the layer of streams and boundaries of the basin and sub-basins of the study area were extracted (Fig. 2). Fifteen sub-basins were detected for the study area

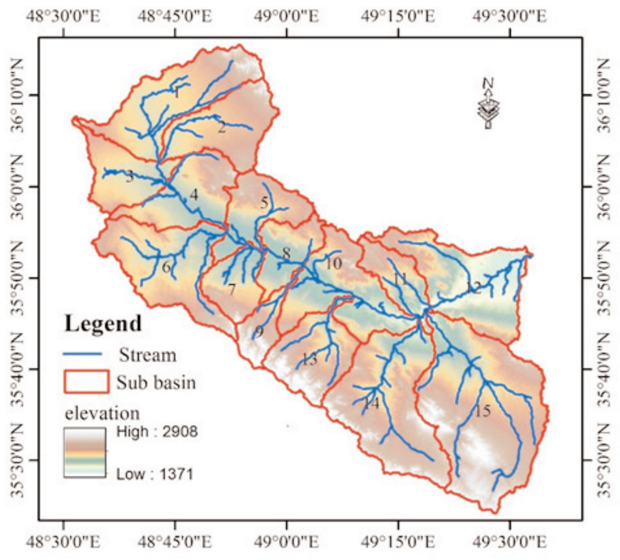

Figure 2. Displaying the basin and sub-basin of the upper part of Kharroud River and its drainage network and the elevation model of the region (Draw by using ArcGIS 10.3 software)

3.2. Topographic Symmetry Factor (AF)

When the tectonic processes are active, the rising and tilting of the ground will cause the main flow to shift from the midline of the basin and move to the side where the rise is less. Asymmetry in the drainage network shows the active neotectonic (Cox 1994). Accordingly, the Asymmetry Factor (AF) is defined as follows:

$$AF = Ar/At \times 100 \qquad (1)$$

In the above equation Ar is the area of the right drainage basin and At is the total area of the basin. For tectonically inactive areas, the value of the asymmetry of the channel will be 50%, indicating asymmetry in the drainage of the area. In active areas, the index will be less or more than 50%. For the studied area, considering the main channel, the basin was

Table 2. Area of sub-basins and calculation of AF for upper part of Kharroud basin

1041.47	Sub-basin area right(km2)
527.012	Left Sub-basin area (km2)
1568.482	Total area of the basin (km2)
66.4	index (%)AF

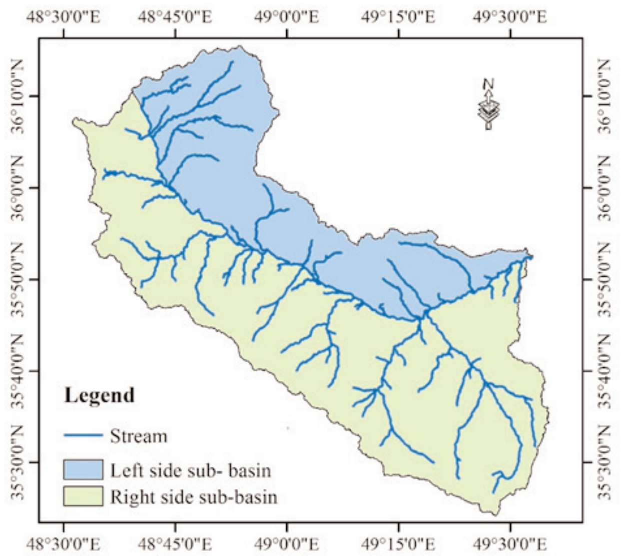

Figure 3. Right and left sub-basins in the upper reaches of the basin of the Kharroud River (Draw by using ArcGIS 10.3 software)

divided into two sub-basins of left and right (Fig. 3). The area of both sub-basins was measured and the AF value for the catchment area was 66.4% (Table 1). This index shows the effect of tectonic factors on the drainage network of the region, so that the main channel of the basin is transferred to the left side (north region) basin, and the tributaries of right sub-basin are much longer than of the left sub-basin (Fig. 3).

3.3. Stream length-gradient index (SL)

River channels are very sensitive to changes in sediment load and flow Debate, and river change morphology is related to change in these characteristics (Soleimani 1999). Tectonic movements can have affected the flow velocity and debate of the stream by change the slope of the area, and change the morphology of the river. To quantify the variation of slope of the river channel, a concept called the Stream length-gradient index (SL) is used (Keller and Pinter 2002):

$$SL=\Delta H/\Delta L \quad (2)$$

In the above equation, ΔH is the difference between the height of the beginning and the terminal of the measurement section, ΔL is the length of the measuring section, L is the length of the flow from the first point of stream to the midpoint of the measurement section, and SL is Stream length-gradient index (Keller and Pinter 2002).

The Stream length-gradient index (SL) is sensitive to both resistances of rock and tectonic movements, and therefore can show anomalies due tectonic movements or lithology changes (Ramirez-Herrera 1998). In general, when rock resistances would high or young tectonic movements occur in the region, higher SL values are obtained. The severance of the active tectonic effect from rock resistance on the value of the SL index may be difficult. However, when the lithology of region is the same, changing in the rate of this index can be attributed to tectonic activity, or when the resistance of the rocks is low, high values of the SL index can be due to tectonic activity. High values of the Stream length-gradient index (3000 < SL) represent high tectonic activity areas. The areas with low SL activity are less than 1000 (Pourkermani 1997).

In this study, for calculating the SL index for the main channel of the catchment area, using a digital elevation model of the area, sections with a height difference of 50 meters along the main channel from the beginning of the channel to the exit point of river from the basin was considered. The following table shows the parameters obtained from these sections for calculating the SL index and its calculated value for each section. This table shows the SL value at the beginning of the channel is 8.5 and its value is gradually increased and reaches 457.1 at the outlet of the basin. According to this table, SL in most of the basin's main channels is less than 1000, and therefore the region is in the class of areas with low neotectonic activity.

3.4. Hypsometric curve

In 1989, William Davis presented a cyclical evolu-

Table 2. Calculate the Stream length-gradient index for the upper part of the Kharroud river

Section	h (m)	L1 (m)	L2 (m)	L (m)	L (m)	SL
1817 - 1800	17	0	3022	3022	1511	8/5
1800 - 1750	50	3022	16293	13270	9657	36/4
1750 - 1700	50	16293	27592	11299	21942	97/1
1700 - 1650	50	27592	63917	36325	45754	63/0
1650 - 1600	50	63917	78911	14994	71414	238/1
1600 - 1550	50	78911	90305	11394	84608	371/3
1550 - 1500	50	90305	100755	10450	95530	457/1
1500 - 1450	50	100755	111144	10389	105949	509/9
1450 - 1400	50	111144	121399	10256	116272	566/9
1400 - 1372	28	121399	127382	5983	124391	582/2

tionary surface topography for each drainage basin. Based on this cycle, the variations in the topography of a region from the growth age of mountain to its erosion season are defined in three stages: youth, maturity and old age, each stage characterized by the shape of topographic features and the degree of altitude. Strahler was introduced to describe and quantify the heights of a hypsometric concept.

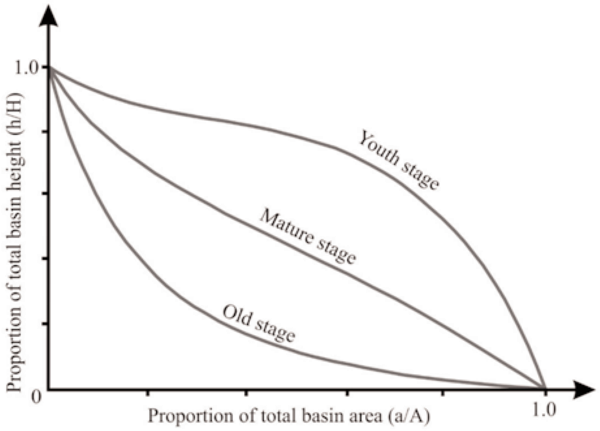

Figure 4. Comparison of the Hypsometric curve in three stages: youth, maturity and old age Davis erosional Cycle (adapted from Keller and Pinter, 2002)

The hypsometric curve shows distribution of heights at a catchment area (Strahler 1952). This curve is plotted based on relative height for relative area (Keller and Pinter 2002). On the vertical axis, the relative height is displayed on the horizontal axis of the relative frequency of the area.

In fact, this curve shows the contribution of each elevation class from the area of the region. Since the values on both axes are devoid of dimension, they can be compared to the different areas and basins, independent from shape and area.

The shape of the hypsometric curve shows the dominant geomorphic process in the region. According to the Davis cycle, the geomorphic evolution of each region occurs in three stages: youth, maturity, and old age, each stage being known to be one of the processes of erosion or uplifting. The graph of the maturity regions is S-shaped the young zone graph is convex,

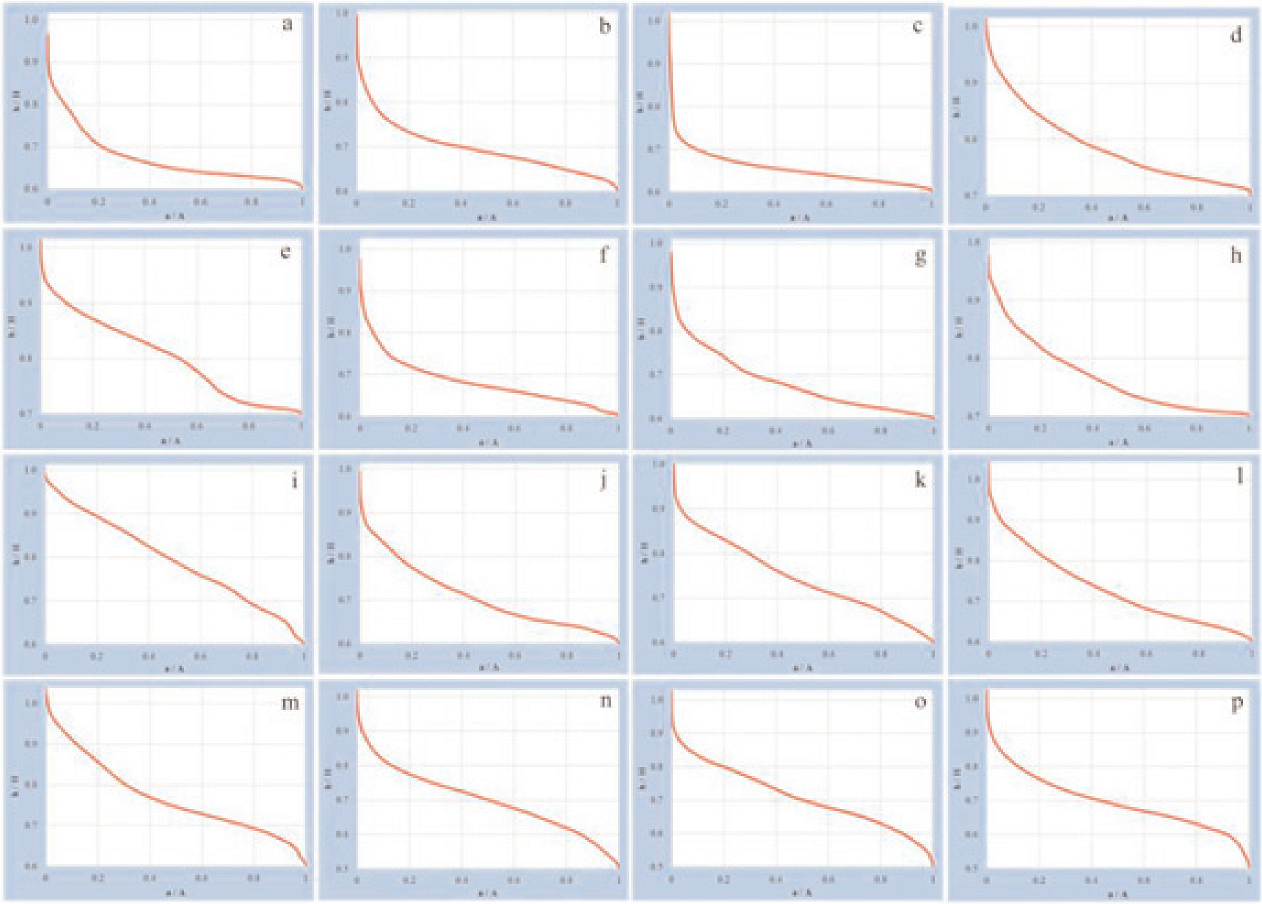

Figure 5. a - o) Hypsometric curves for sub basins 1 to 15 of the Kharroud River and p) whole the study area Vertical axis ∆h/H and horizontal axis a/A.

Table 3. Calculation of the Hypsometric Integral for the Basin and Sub-basins of study area

Sub Basin	Average Elevation	Minimum Elevation	Maximum Elevation	Hypsometry
1	1954/854	1753	2770	0/20
2	1993/958	1757	2728	0/24
3	1869/792	1730	2782	0/13
4	1878/482	1665	2433	0/28
5	1914/389	1371	2434	0/51
6	1900/869	1679	2690	0/22
7	1884/084	1664	2683	0/22
8	1805/805	1654	2287	0/24
9	2180/762	1654	2722	0/49
10	1813/14	1537	2539	0/28
11	1884/16	1515	2537	0/36
12	1691/261	1371	2467	0/29
13	2100/601	1614	2881	0/38
14	2062/195	1539	2904	0/38
15	2073/834	1522	2908	0/40
Total Basin	1945/251	1371	2908	0/37

and the graph of the old areas is concave (Fig. 4) (Keller and Pinter 2002)

The elevation data of DEM was used to plot the hypsometric curve of the area. The frequency of elevation classes was extracted from the model and based on this; a hypsometric curve for the entire basin was prepared separately for the 15 sub-basins (Fig. 5).

Hypsometric curves show sub-basins 2, 5, 9, 11, 12, 13, 14 and 15 of the erosion cycle maturity stage in which elevation factors and erosion factors are balanced. Curves 1, 3, 4, 6, 7, 8, and 10 show that the sub-basins have reached their old stage. Also, the hypsometric curve of the whole basin shows that the basin is in the erosional cycle at the maturity stage. Therefore, the region undergoes the peak tectonic activity, and orogeny processes are refluence. In this area, the erosion and tectonic orogeny factors are balanced and the area is in the second stage of the Davis cycle.

3.5. Hypsometry integral

A hypsometric integral is a simple way to describe the roughness of a drainage basin defined by the following relationship (Keller and Pinter 2002):

$$\text{Hypsometric Integral} = \frac{(H_{men}-H_{min})}{H_{max}-H_{min}} \quad (3)$$

In the above equation H_{mean} is the average height of the basin and H_{max} and H_{min} are the maximum and minimum altitudes in the basin respectively. In fact, the resulting value of this equation is proportional to the area under the hypsometric curve. For regions with low neotectonic activity, the hypsometry integral is greater than 0.5 and for areas with a medium activity it is between 0.4 and 0.5 and in areas with low or no activity; the amount is less than 0.4.

In order to calculate the hypsometric integral of the study area, the maximum and minimum height of the area was obtained from the elevation data extracted from the DEM. Then, the average height of the whole area was calculated according to the frequency of each height. Finally, using the equation (2), the hypsometric integral value of the hypsometry was calculated (Table 3).

Table 3 shows that in most of the sub-basins in the region, the hypsometric integral value of the is less than 0.4 and is classified in the low neotectonic activity regimen. The only sub-basin 9 with a hypsometric integral value is 49. 0 shows a moderate neotectonic activity. The value of this index for the whole study area is 0.37 and indicates the low neotectonic activity of the region.

4. Conclusion

Calculation of the morphotectonic indices of the upper part of the Kharroud River indicates that this region has left behind the peak of the orogeny tectonic processes and the tectonic and erosion factors have been balanced. The topographic asymmetry index shows that the main channel of the catchment area has been moved to the left of the basin (north of the region) and the drainage network in the right part of the basin has more developed, this can be attributed to the higher rate of uplifting in the southern heights of the area. Based on the Stream length-gradient index of the main channel, the area is classified as a low tectonic activity area. However, it is difficult to recognize the contribution of tectonic factors or lithological factors in the amount of SL, regarding the region's various lithology. Based on the hypsometric curves of the sub-basins and the curve of the entire basin, it can be concluded that the region is at the maturity stage of the Davis erosion cycle and the rate of tectonic and erosion factors has been balanced in shaping morphological complications. Calculation of the hypsometric integral also places the area in the class of areas with low neotectonic activity, which is consistent with the results of calculating the SL. totality it can be concluded that tectonic processes and orogeny factors in the upper part of the Kharroud River have somewhat subsided and there is little neotectonic activity in the region. The tectonic and erosion factors have reached a balance and the role of the two groups in the morphology of the region is equal.

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