Morphotectonic Analysis in the Ghezel Ozan River Basin, NW Iran

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Abstract

Morphotectonic analysis by the use of geomorphic indices serves as a tool of recognition in regions with active tectonic deformation. Landforms in active deformation area are created from interaction of tectonic and surficial processes. One of the most important landforms in ground are rivers that are very sensitive to tectonic movements especially uplift and tilting. Thus based on analysis of the rivers and related drainage networks by the use of geomorphic indices we will be able to attain valuable information about tectonic history of the area.

In this article, determine of tectonic movements bye the use of geomorphic indices is surveyed in the Ghezel Ozan River basin between 2007 and 2010. After segmentation of the Ghezel Ozan River and preparation of digital elevation model (DEM) amounts of geomorphic indices per segments is separately attained. The attained amounts show that different segments of the Ghezel Ozan River vary from each other regarding the amount of tectonic activity and tectonic movements increase from west to east and also, the amount of tectonic tilting is negligible in a lot of the Ghezel Ozan River segments. This situation is completely in agreement with the trend of the seismicity of the area.

Keywords: Landforms, the Ghezel Ozan River, Geomorphic indices, Morphotectonic

1. Introduction

Morphotectonic is the study of landforms produced by tectonic processes. The quantitative measurements of landforms are accomplished on the basis of calculation of geomorphic indices by the use of topography maps, digital elevation model，satellite images, aerial photographs and field works. In order to assess relative degree of tectonic activity in an area the results of several indices are usually combined. Analysis of landforms is known as a valuable tool in tectonic investigations related to several thousands to two million years ago.

In young orogens, fast sedimentation can cover young structures, in these cases geomorphic indices are very useful for the type of processes that make of landforms especially analysis of drainage pattern and rivers can help to the recognition of the position of active structures (Burbank and Anderson, 2001). One of the most important landforms on the ground are rivers that are extremely sensitive to tectonic movements. Morphometric data combined with seismic and geomorphic data seem to be a valuable tool in determining relative levels of tectonic activity and in providing data for seismic hazard assessment.

The study of active tectonic effects in the Ghezel Ozan River basin can elucidate a lot of tectonic ambiguities and detect surficial deformation pattern and active structures in the area. The aim of this study is to discriminate the geomorphic signals of different segments of the Ghezel Ozan River evolving under different ranges of uplift and tilting rates. The application of the most widely–known geomorphic indices in the Ghezel Ozan River basin enabled us to correlate active tectonics with erosional processes in the broad area. This article presents the results of investigations on the Ghezel Ozan River basin by the use of geomorphic indices.

2. Regional setting

The study area is located in Sanandaj – Sirjan, Centeral Iran and Western Alborz zones (Aghanabati, 2004) (Fig. 1). The Ghezel Ozan River originates from the Chehlcheshmeh mountain in the Kordestan province and after flowing for about 500 km joins the Shahroud river in the south of Gilan province, called Sefidroud. Around the

Ghezel Ozan River marl, sandstone, siltstone, limestone, tuff, agglomerate and volcanic rocks are extremely exposed. These rocks belong to Qom, Upper red, Lower red and Karaj formations.

Tectonic elements in the Ghezel Ozan River basin are folds and faults that often trend NW-SE and NE-SW (Fig. 2). This trends correlate with trends of fractures in basement of Iran.

3. Materials and methods

Geomorphic assessment of active tectonics by the use of geomorphic indices depends on the rock resistance, climatic variations and tectonic processes. The geomorphic indices associated with drainage networks are the stream gradient index (SL index; Hack, 1973), the valley floor width to valley height ratio (Vf index; Bull, 1977a, 1978), the mountain front sinuosity (Smf index; Bull and McFadden, 1977), the transverse topographic symmetry factor (T index; Cox, 1994) and the drainage basin shape (Bs).

The stream length gradient index was calculated via:

$$SL = (\Delta H/\Delta L)\ L \tag{1}$$

Which SL is the stream length gradient index, ΔH/ΔL is the stream gradient at a distinct point in the channel and L is the total channel length (Hack, 1973; Keller and Pinter, 2002).

The ratio of the width of valley floor to valley height (Vf) was calculated using the equation below:

$$Vf = 2Vfw/[(Eld - Esc) + (Erd - Esc)] \tag{2}$$

Which Vfw is the width of valley floor, Eld and Erd are the elevations of the left and right valley respectively and Esc is the elevation of the valley floor (Bull and McFadden, 1977).

Mountain front sinuosity (Smf) was calculated via:

$$Smf = Lmf/Ls \tag{3}$$

Which Smf is the mountain front sinuosity, Lmf is the length of the mountain front along the bottom of the mountain and Ls is the straight line length of the mountain front (Bull and McFadden, 1977; Keller and Pinter, 2002).

The transverse topographic symmetry factor (T) was calculated via:

$$T = Da/Dd \tag{4}$$

Which Da is the space from the midline of the drainage basin to the midline of the active belt and Dd is the space from the midline to the basin limit (Cox, 1994). In a completely symmetric basin T = 0 and as asymmetry increases T approaches to value of 1.0.

Another quantitative index is drainage basin shape (Bs), which was calculated from the equation:

$$Bs = Bl\ /\ Bw \tag{5}$$

Where Bl is the length of the basin, measured from its outline to the most distal point in the drainage divide, and Bw is the width of the basin.

For the calculation of the above–mentioned geomorphic indices we used topographic maps at scale 1: 25,000, geology maps at scale 1:100,000 and satellite images.

In this study we have used 10-m grid cell DEM. Its projection was the UTM zones 38 and 39 N. The DEM was derived from the contour lines of the 1: 25,000 topographic maps provided by Iranian Survey Organization (ISO) with 10-m contour intervals. The DEM is employed for the calculation of the stream length gradient index (SL), the ratio of the width of valley floor to valley height (Vf), the mountain front sinuosity (Smf), the transverse topographic symmetry factor (T) and drainage basin shape (Bs).

The geology maps are used for the determination of the type of rocks in the area. Moreover the rock resistance against erosion and weathering is determined via fieldwork regarding the type and quantity of joints and fractures of rocks.

In order to collect data, first the Ghezel Ozan River is segmented to several distinct segments. The segmentation is accomplished on the basis of orientation and abundance of structures in the course of the river. In this way, the Ghezel Ozan River from upstream to downstream is segmented to 6 segments respectively A, B, C, D, E and F (Fig. 3).

Then digital elevation models in each segment are prepared and drainage patterns are drawn. In order to recognize of longitudinal and lateral tiltings in the area the following works are accomplished:

- The measurement of the stream length gradient index (SL)
- The measurement of the ratio of the width of valley floor to valley height (Vf)
- The measurement of the mountain front sinuosity (Smf)
- The measurement of the transverse topographic symmetry factor (T)
- The measurement of the basin drainage shape (Bs)

4. Results

In order to collect necessary data, geomorphic indices are calculated in each of river segments separately.

4.1 The stream length gradient index (SL)

In order to measure the stream length gradient index, first the small-scale streams are isolated on the DEM and then for each stream, SL index is calculated by the use of equation (1).

The least values of SL index is related to A, B and C segments respectively and is caused through lithology because a lot of rocks in this region are marl , shale and other weak sedimentary rocks (Khodabandeh *et al*., 1999; Fonoudi and Sayareh, 2000; Shahidi and Baharfirozi, 2001; Lotfi, 2001). The increasing trend of SL index in D and E segments is affected by the existence of rocks such as basalt, andesite, rhyolite and tuff (Davies *et al*., 1972; Faridi and Anvari, 2001) because in this region igneous rocks are extremely exposed. Nevertheless, the values of SL index in E segment as compared with D segment show higher values that imply an increase in tectonic activity in E segment.

The highest values of SL index is related to F segment whereas the vast parts of this segment is covered by weak sedimentary rocks such as weak cemented conglomerates and alternation of marl, gypsum and sandstone (Nazari and Salamati, 1998; Amini, 2004). This status shows more tectonic movements in F segment.

However, values of SL index in each segment of the Ghezel Ozan River show the highest and the lowest value of SL index in A segment are 948 and 98, in B segment are 1033 and 75, in C segment are 770 and 179, in D segment are 1415 and 146, in E segment are 2850 and 263, in F segment are 4599 and 380 respectively. The least fluctuations of SL index is related to C segment and the most fluctuations of SL index take place in E and F segments. The low fluctuations of SL index in C segment and somewhat in A and B segments highlight the domination of the alluvial processes over the tectonic activity , while anomalous variations of SL index in E and F segments is caused by high tectonic activity.

4.2 The ratio of the width of valley floor to valley height (Vf)

In order to measure the ratio of the width of valley floor to valley height, first on the DEM the transverse profiles of the Ghezel Ozan River are drawn and then for each profile, Vf index is calculated by the use of equation (2). The values of Vf index in A, B and C segments is considerably more than D, E and F segments. The high values of Vf index in A, B and C segments is somewhat due to lithology because a lot of rocks in this region are marl , shale and other weak sedimentary rocks. The highest values of Vf index in D and E segments is between 0-0.33 that imply V-shaped valleys and active incision of river and show an active tectonic region. The low values of Vf index in D and E segments is somewhat due to lithology because often rocks in this region are strength rocks such as basalt, andesite, rhyolite and tuff (Behrozi and Aminiazar, 1992; Hajialilo and Rezaei, 2001). Therefore the range of the values of Vf index in E segment toward D segment is minor and imply an increase in tectonic activity in E segment.

In F segment the values of Vf index is somewhat increased. The existence of the weak sedimentary rocks such as weak cemented conglomerates and alternation of marl, gypsum and sandstone in this segment is the reason of increasing the values of Vf index. Whereas the range of the values of Vf index in F segment shows high tectonic activity.

The mean values of Vf index in the study area also imply high tectonic activity in D, E and F segments, and the intensity of the activity is related to E and F segments. Moreover, the high mean values of Vf index in A, B and C segments is not only due to lithology but also imply the decreasing of uplift in these segments.

The highest values of Vf index is related to C segment. In this segment the orientation of the Ghezel Ozan River is different from other segments; namely, NE – SW and the main structures are cut by the river.

In general, the values of Vf index for the Ghezel Ozan River is ranges from 0.05 to 45.20 which include an extended range.

4.3 The mountain front sinuosity (Smf)

In order to measure the mountain front sinuosity, first the main mountain fronts are isolated on the DEM and then for each front , Smf index is calculated by the use of equation (3). The mean values of Smf index in A, B, C, D, E and F segments are 1.24, 1.41, 1.38, 1.31, 1.21, and 1.13 respectively. Therefore, all mountain fronts in the Ghezel Ozan River basin fall in the 'active front' category.

The obtained data show that E and F segments are the most active segments of the Ghezel Ozan River. Also, the tectonic activity has gradually increased from A to F segment and the relative decrease of Smf index in A segment could be due to the existence of the fold and thrust systems that have also caused an intense change in the orientation of the Ghezel Ozan River.

4.4 The transverse topographic symmetry factor (T)

In order to measure the transverse topographic symmetry factor, first on the DEM the drainage basins around the Ghezel Ozan River are isolated and then for each basin, factor T in different sections of valley is calculated by the use of equation (4). Also, the bearing of the migration of streams in perpendicular direction on drainage axis is measured.

The assessment symmetry of the drainage basins around the Ghezel Ozan River by the use of the transverse topographic symmetry factor show that in majority of segments the drainage basins have relative high symmetry and show negligible tilting, because 79.41 percent of valleys in A segment, 50 percent in B segment, 62.5 percent in C segment and 100 percent in E and F segments fall into the range of 0.00 to 0.50.

D segment is the most asymmetric segment, because 87.5 percent of valleys in this segment fall in 0.50 - 1.00 range, whereas E and F segments are the most symmetric segments. In general, the calculated T values in the study area vary from 0.05 (almost symmetric) to 0.74 (roughly asymmetric).

4.5 The drainage basin shape (Bs)

In order to measure the drainage basin shape, first the drainage basins are isolated on DEM and then for each basin, Bs index is calculated separately by the use of equation (5). The drainage basins in active tectonic area have high Bs index, but when tectonic activity diminish, this index also decreases. The mean values of Bs index in A, B, C, D, E and F segments are 3.22, 2.81, 3.77, 4.57, 3.91, and 5.94 respectively.

The trend of the change of Bs values in the Ghezel Ozan River basin is almost in agreement with other indices so that the relative increase this index in D, E and F segments imply high tectonic activity in these segments. The evolution of drainage basins or diminishing tectonic activity in A, B and C segments is the main cause of decreasing Bs values. The highest values of Bs index is related to F segment which is also previously known as the most active segment.

The mean values and range of the geomorphic indices in each of the Ghezel Ozan River segments are shown in Table 1.

5. Discussion

In this study, spatial variations of tectonic activity along the Ghezel Ozan River segments were investigated by morphotectonic analysis. The changes of geomorphic indices point to a general trend of increasing tectonic activity towards the east, which is gradually decreasing towards the west. From A segment toward F segment, the Vf values is decreased and instead the fluctuations of SL index is increased which both imply the increasing of tectonic uplift toward F segment. The trend of the change Smf and Bs indices is completely in agreement with other indices so that Smf index is decreased toward F segment and imply the existence of more active mountain fronts inside E and F segments and increasing of Bs index in D, E and F segments also imply higher tectonic activity in these segments.

In spite of the relatively high uplift in the study area, values of tilting are much lesser, because the transverse topographic symmetry factor is often <0.50, thus it will be concluded that the majority of drainage basins are almost symmetric. The obtained result from this study is concordant with results of previous studies on the Ghezel Ozan River (Arian and pourkermani, 2001).

The high tectonic activity in the eastern section of the study area is in agreement with the seismicity of region, for example the Rudbar earthquake of June 20, 1990 (MS = 7.7, MW= 7.3, mb = 6.4) (Sarkar *et al*., 2003) occurred in this portion. The structural map of the Ghezel Ozan River basin (Fig. 2) shows that numerous numbers of folds and thrusts exist in the east of area that are cut by some transverse and young faults, and these structures can be the principal cause of increasing tectonic activity in the east of the area (E and F segments).

6. Conclusions

The following conclusions have emerged from morphotectonic analysis in the Ghezel Ozan River basin:

1. The variety in different segments of the Ghezel Ozan River in view of tectonic activity.

All the geomorphic indices applied in this study imply the gradual increase of tectonic activity toward the east of the area.

2. The increasing tectonic movements from A segment toward F segment.

3. Considering E and F segments as the most active segments and B and C segments as the most quiescence segments of the Ghezel Ozan River.

The trend of the change of geomorphic indices in the study area show that in B and C segments, the uplift is low and drainage basins are more evoluted, but in E and F segments, the uplift is high and the indices emphasize on the domination of the tectonic processes over the alluvial processes.

4. The existence of tilting in the majority of segments of the Ghezel Ozan River especially A and D segments.

The values of transverse topographic symmetry factor are the indication of tilting in the most of segments of the Ghezel Ozan River. The largest of tilting is in the A and D segments which include the largest deflection of the river course.

5. Being concordant with the trend of the increase of tectonic activity with situation of structures and seismicity history of the area.

The emphasis of the geomorphic indices on the active tectonic region in the east of area, is completely in agreement with structures in this portion, moreover its seismicity in the past and present is perceptible.

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Table 1. The mean values and range of each geomorphic indices in the study area.

Segments of the Ghezel Ozan River	Type of River	Orientation of River	River channel Length (KM)	Smf index Mean Range	Vf index Mean Rang	SL index Mean Rang	T factor Mean Rang	Bs index Mean Rang
Segment A	Alluvial	E - W NW - SE	187	1.24 1.18 1.33	8.05 0.25 45.21	351 98 948	0.34 0.018 0.73	3.22 1.33 7.47
Segment B	Alluvial	NW - SE	54	1.41 1.35 1.49	2.84 0.42 15.23	442 75 1033	0.51 0.35 0.67	2.81 1.80 4.49
Segment C	Alluvial	NE - SW	79	1.38 1.29 1.46	10.76 0.05 35.38	429 179 770	0.44 0.31 0.63	3.77 1.83 8.43
Segment D	Alluvial Bed rock	E - W	76	1.31 1.27 1.34	2.28 0.05 18.78	570 146 1415	0.49 0.08 0.74	4.57 2.10 8.25
Segment E	Bed rock	NW - SE	92	1.21 1.14 1.25	0.63 0.13 3.27	764 263 2850	0.44 0.33 0.50	3.91 1.19 6.30
Segment F	Alluvial	NW - SE	85	1.13 1.10 1.17	1.31 0.12 6.00	965 380 1920	0.16 0.006 0.35	5.94 2.35 10.41

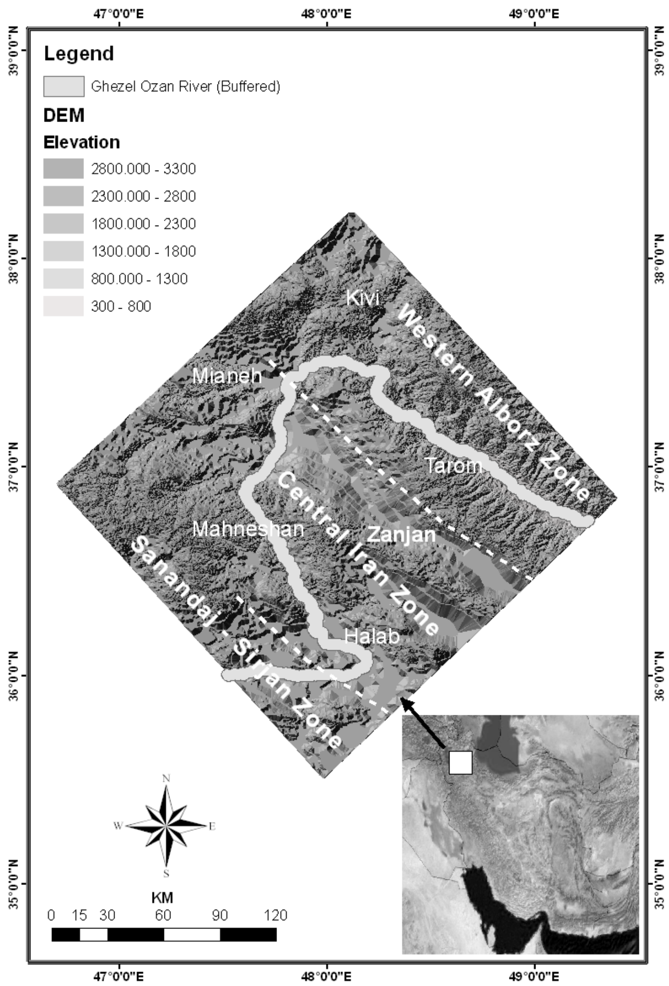

Figure 1. DEM of the study area (USGS/SRTM data) illustrating structural and sedimentary zones marked by dashed lines and some urban points in NW Iran. Inset shows DEM of Iran with location of the study area.

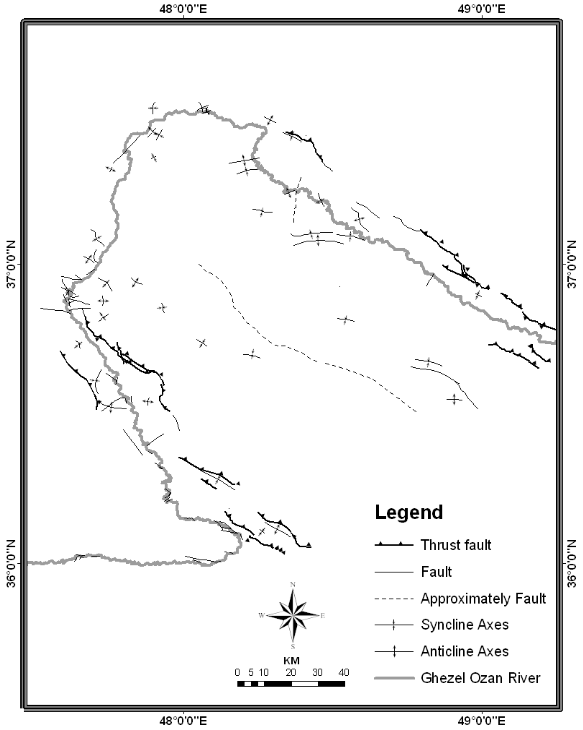

Figure 2. This map shows the main structures in the Ghezel Ozan River basin.

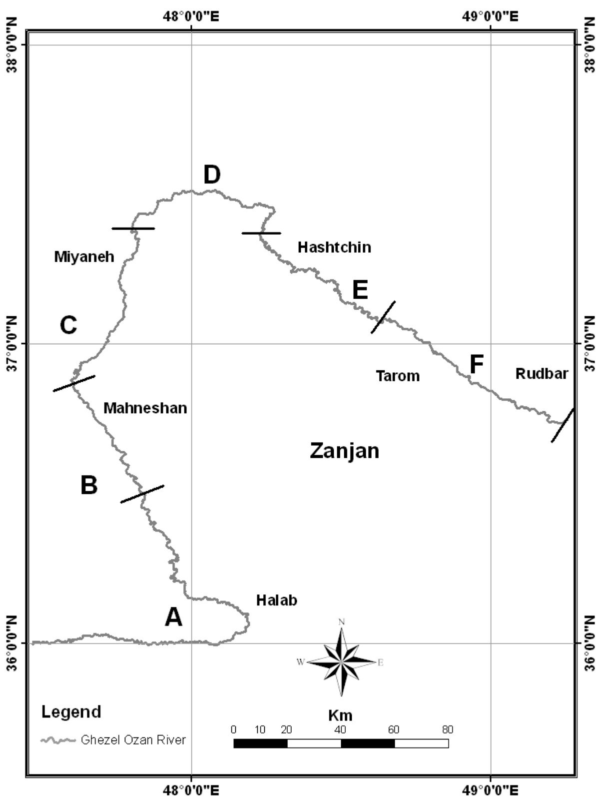

Figure 3. This map shows the situation of segments A , B , C , D , E and F in the Ghezel Ozan River with several urban points in the area.