Neotectonics of Kashaf Rud River, NE Iran by Modified Index of Active Tectonics (MIAT)

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Abstract

Kashaf rud river is located in border zone of East Alborz and Kopet Dagh physiographic provinces in the north east Iran. Geomorphic indices are useful tools to show the neotectonic regimes. These indices have got the advantage of being calculated from Arc GIS and remote sensing packages over large area as a useful tool to identify geomorphic anomalies possibly related to active tectonics. In this research, seven geomorphic indices (stream-gradient index, valley floor width-valley height ratio, mountain-front sinuosity, drainage basin asymmetry, hypsometric integral, drainage basin shape and transverse topographic symmetry factor) were calculated along the Kashaf rud river. Then, based on a new index or modified index of active tectonics (Miat) values that calculated by average of seven geomorphic indices, relative tectonic activities levels were revealed. The low class of Miat is mainly in the sub-basins of No. 6, 10, 13, 14, 21, 22, 23, 24 & 28 while the rest of the study area has moderate tectonic activities in the other sub-basins. Our results show that the moderate value has located along faulted area, which shows 2 class of relative tectonic activity. These faults have been formed above an old suture zone between Cimmerian and Eurasian plates.

Keywords
Neotectonics, Miat, Geomorphologic Index, Kashaf Rud, Iran

1. Introduction

The study area is around of Mashhad city in the border zone of East Alborz and Kopet Dagh physiographic provinces in the north east Iran (Figure 1). Dominant structural trend in East Alborz province is NW-SE in eastern part. From tectonics view, it contains Binalod magmatic arc and its fore arc basin with volcanic activities

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(especially in Silurian) on northeastern of Cimmerian miniplate. Obduction of Mashhad ophiolite during late Paleozoic has been the result of subduction into beneath this province.

Dominant structural trend in Kopet Dagh province is NW-SE. From tectonics view, it contains the Kopet Dagh hinterland or Kopet Dagh fold and thrust belt that are formed in passive margin of Eurasian plate until late Triassic and then marine sedimentation on Kopet Dagh proforeland basin has continued to Eocene. Kopet Dagh hinterland has uplifted related to Karakorum foreland basin in northeast along Eshghabad fault [1]-[3]. In this research, area is divided into 28 sub-basins and the following indices are calculated: stream-gradient index (Sl), valley floor width-valley height ratio (Vf), mountain-front sinuosity (Smf), drainage basin asymmetry (Af), hypsometric integral (Hi), drainage basin shape (Bs) and transverse topographic symmetry factor (T). We use geomorphic indices of active tectonics, which are known to be useful for assessment of relative tectonic activities. Methodology for active tectonic studies [4]-[7] has been previously tested as a valuable tool in different
tectonically active areas, namely SW USA [8], the Pacific coast of Costa Rica [9], Zagros, Iran [10], but in this research, we have used a new index as modified index of active tectonics (Miat) that calculated by average of seven geomorphic indices.

2. Materials and Methods

The calculated geomorphic indices are suitable for assessment of tectonic activity of the study area. The geomorphic indices such as: stream-gradient index (SI), valley floor width-valley height ratio (VF), mountain-front sinuosity (Smf), drainage basin asymmetry (Af), hypsometric integral (Hi), drainage basin shape (Bs) and transverse topographic symmetry factor (T) are calculated in Kashaf rud river by using of topographic data and DEM (Figure 2 and Figure 3).

Figure 2. Digital Elevation model of the Kashaf rud river region.

Figure 3. The relief of the Kashaf rud river region for identification of drainage pattern based on digital elevation model.
On the other hand, the area was divided into 28 sub-basins, and for each one, above indices were calculated, then all of the indices were combined to obtain index of active tectonics (Iat) by new method [11]. Therefore, sub-basins can be compared together. The study area is located between longitudes E58°, 30’-61° and latitudes N35°, 30’-37° in the Khurasan province, North East Iran. Based on previous work on the salt and mud diapirism [12]-[23] and neotectonic regime in Iran [24]-[29], Zagros in south Iran is the most active zone [30]-[47]. Then, Alborz [48]-[84] and Central Iran [85]-[100] have been situated in the next orders.

3. Results and Discussion

To study the indices, there is a formula which we turn to describe each one of indices. It is necessary to have some primary maps to calculate the indices, and the most important are: Digital Elevation Model (DEM), the drainage network and the sub-basins map of the Kashaf rud river that have been extracted from DEM (Figure 3). DEM extracted from a digitized topographic map (with 30 m intervals).

3.1. The Stream-Gradient Index (SL)

The rivers flowing over rocks and soils of various strengths tend to reach equilibrium with specific longitudinal profiles and hydraulic geometrics [101]-[103] defined the stream-gradient index (SL) to discuss influences of environmental variables on longitudinal stream profiles, and to test whether streams has reached equilibrium. The calculation formula is in this manner:

$$SL = \left( \frac{\Delta H}{\Delta L} \right) L$$

where \(\frac{\Delta H}{\Delta L}\) is local slope of the channel segment that is located between two contours and \(L\) is the channel length from the division to the midpoint of the channel reaches for which the index is calculated. This index is calculated along the master streams of 28 sub-basins (Table 1). The SL index can be used to evaluate relative tectonic activity. An area on soft rocks with high SL values can be indicated for active tectonics. Based on our results, there are 2 and 3 classes (Figure 4).

3.2. Valley Floor Width-Valley Height Ratio (Vf)

Another index sensitive to tectonic uplift is the valley floor width to valley height ratio (Vf). This index can separate v-shaped valleys with small amounts from u-shaped valleys with greater amounts. The calculation formula is in this manner:
### Table 1. Values of stream length-gradient index for sub-basins No.1 and 28.

| Points of Basin 1 | H (m) | L (m) | L (m) | SL (m) | Tectonic Class | Tectonic Class/Basin |
|-------------------|-------|-------|-------|--------|----------------|----------------------|
| 1, 2              | 50    | 2419  | 13,856| 286.40 | 3              |                      |
| 1, 3              | 50    | 2545  | 11,447| 224.89 | 3              |                      |
| 3, 4              | 50    | 1986  | 10,132| 255.09 | 3              |                      |
| 4, 5              | 50    | 796   | 8958  | 562.69 | 2              |                      |
| 5, 6              | 50    | 1750  | 7799  | 222.83 | 3              |                      |
| 6, 7              | 50    | 377   | 7199  | 954.77 | 2              |                      |
| 7, 8              | 50    | 850   | 5651  | 332.41 | 3 (Low Activity)|                      |
| 8, 9              | 50    | 1914  | 4780  | 124.87 | 3              |                      |
| 9, 10             | 50    | 206   | 4387  | 1064.81| 1              |                      |
| 10, 11            | 50    | 469   | 3962  | 422.39 | 3              |                      |
| 11, 12            | 50    | 361   | 1505  | 208.45 | 3              |                      |
| 12, 13            | 50    | 157   | 1230  | 391.72 | 3              |                      |
| 13, 14            | 50    | 1160  | 687   | 29.61  | 3              |                      |

| Points of Basin 28 | H (m) | L (m) | L (m) | SL (m) | Tectonic Class | Tectonic Class/Basin |
|--------------------|-------|-------|-------|--------|----------------|----------------------|
| 1, 2               | 50    | 5480  | 36,880| 336.50 | 3              |                      |
| 2, 3               | 50    | 3060  | 33,539| 548.02 | 2              |                      |
| 3, 4               | 50    | 3200  | 29,259| 457.17 | 3              |                      |
| 4, 5               | 50    | 4615  | 25,915| 280.77 | 3              |                      |
| 5, 6               | 50    | 2297  | 22,498| 489.73 | 3              |                      |
| 6, 7               | 50    | 2602  | 19,908| 382.55 | 3              |                      |
| 7, 8               | 50    | 3715  | 16,654| 224.15 | 3              |                      |
| 8, 9               | 50    | 2134  | 13,634| 319.45 | 3              |                      |
| 9, 10              | 50    | 2809  | 10,997| 195.75 | 3              |                      |
| 10, 11             | 50    | 1949  | 8836  | 226.68 | 3              |                      |
| 11, 12             | 50    | 2145  | 6718  | 156.60 | 3              |                      |
| 12, 13             | 50    | 1823  | 4657  | 127.73 | 3              |                      |
| 13, 14             | 50    | 1127  | 3171  | 140.68 | 3              |                      |
| 14, 15             | 50    | 1196  | 2165  | 90.51  | 3              |                      |
| 15, 16             | 50    | 384   | 1396  | 181.77 | 3              |                      |
| 16, 17             | 50    | 800   | 839   | 52.44  | 3              |                      |
| 17, 18             | 50    | 304   | 279   | 45.89  | 3              |                      |

**SL classification→1** (High Activity): > 1000, **2** (Moderate Activity): 500 - 1000, **3** (Low Activity): <500

\[
V_f = \frac{2 \cdot V_{fw}}{E_{ld} + E_{rd} - E_{sc}}
\]

where Vfw is the width of the valley floor, and Eld, Erd and Esc are the altitudes of the left and right divisions (looking downstream) and the stream channel, respectively [102]. [4] found significant differences in Vf be-
tween tectonically active and inactive mountain fronts. Also, they found significant differences in Vf between tectonically active and inactive mountain fronts, because a valley floor is narrowed due to rapid stream down cutting.

Vfw value is obtained by measuring the length of a line which cuts the river and limits to two sides of a contour through which the river crosses (Table 2). In this research, Vf values are divided into 3 classes: 1 (Vf < 0.5), 2 (0.5 < Vf < 1), and 3 (Vf > 1). Therefore, all of the valleys are in 1 class and show V-shape valleys (Figure 5).

3.3. Mountain-Front Sinuosity Index (Smf)

This index represents a balance between stream erosion processes tending to cut some parts of a mountain front and active vertical tectonics that tend to produce straight mountain fronts. Index of mountain front sinuosity [3] is defined by:

\[ \text{Smf} = \frac{L_j}{L_s} \]

| Basin Number | Vfw (m) | Eed (m) | Eef (m) | Vf (m) | Tectonic CLASS | Tectonic Class/Basin |
|--------------|---------|---------|---------|--------|----------------|---------------------|
| 1 P1         | 70      | 1433    | 1410    | 1.77   | 3              | 3 (Low Activity)    |
| 2 P1         | 200     | 1286    | 1281    | 6.78   | 3              |                    |
| 3 P2         | 8       | 1236    | 1235    | 3.20   | 3              |                    |
| 3 P1         | 80      | 1277    | 1258    | 3.20   | 3              |                    |
| 4 P1         | 20      | 2937    | 2900    | 0.73   | 2              | 2 (Moderate Activity) |
| 3 P2         | 100     | 2781    | 2571    | 0.28   | 1              |                    |
| 3 P3         | 70      | 2336    | 2145    | 0.82   | 2              |                    |
| 4 P4         | 60      | 2513    | 2437    | 0.34   | 1              |                    |
| 4 P5         | 70      | 2158    | 2195    | 0.41   | 1              |                    |
| 4 P6         | 100     | 1601    | 1555    | 0.79   | 2              |                    |

Figure 5. Classification map for the valley floor width to valley height ratio.
where $L_j$ is the planimetric length of the mountain along the mountain-piedmont junction, and $L_s$ is the straight-line length of the front. The Mountain fronts map of the study area has drawn in Figure 6. Smf is commonly less than 3, and approaches 1 where steep mountains rise rapidly along a fault or fold [102]. Therefore, this index can play an important role in tectonic activity. Considering that mountain fronts sites are independent from basins places, chances are some of them have various fronts (Table 3). Values of Smf are readily calculated from topographic maps for sub-basins. In this research, Smf values are divided into 3 classes: 1 ($Smf < 1.53$), 2 ($1.53 \leq Smf < 2.3$), and 3 ($Smf \geq 2.3$) and in the study area most of the obtained values are in 3 class (Figure 7).

Figure 6. Position map for Mountain-fronts of study area.

Figure 7. Classification map for Mountain-front sinuosity index.
Table 3: Values of Smf index for sub-basins No. 1 to 4.

| Basin | Fault | Segment | \(L_{mf}\) (m) | \(L_s\) (m) | \(Smf/segment\) | Average of \(Smf/Basin\) | Tectonic class |
|-------|-------|---------|----------------|------------|----------------|------------------------|---------------|
| 1     | F1    | 1       | 1490           | 6400       | 3.94          | 3.94                   | 3 (Low Activity) |
| 2     | F2    | 1       | 1250           | 8600       | 1.31          | 1.31                   | 1 (High Activity) |
| 3     | F3    | 1       | 1220           | 20,930     | 1.66          | 1.66                   | 2 (Moderate Activity) |
| 4     | F4    | 1       | 1330           | 20,660     | 1.35          | 1.60                   | 2              |
|       | F5    | 1       | 1130           | 48,530     |               |                        |                |

3.4. Asymmetry Factor (Af)

This index is related to two tectonics and none tectonic factors. None tectonic factors may relate to lithology and rock fabrics. It is a way to evaluate the existence of tectonic tilting at the scale of a drainage basin. The index is defined as follows:

\[
Af = \left(\frac{Ar}{At}\right)100
\]

where \(Ar\) is the right side area of the master stream basin (looking downstream) and \(At\) is the total area of the basin that can be measured by GIS software. To calculate this index in the area \(At\) and \(Ar\) are obtained using the sub-basins and the master river maps. \(Af\) is close to 50 if there is no or little tilting perpendicular to the direction of the master stream. \(Af\) is significantly greater or smaller than 50 under the effects of active tectonics or strong lithologic control. The values of this index are divided into three categories: 1: \((Af > 15)\) 2: \((7 < Af < 15)\) and 3: \((Af < 7)\).

Among the obtained values (Table 4), a map has prepared that it shows Asymmetry factor of study area (Figure 8).

3.5. Basin Shape Index (Bs)

Relatively young drainage basins in active tectonic areas tend to be more elongated than their normal shape to the topographic slope of a mountain. The elongated shape tends to evolve into a more circular shape [4]. The horizontal projection of the basin shape may be described by the basin shape index or the elongation ratio, Bs [7]. The calculation formula is:

\[
Bs = \frac{Bl}{Bw}
\]

where \(Bl\) is the length of the basin measured from the headwater to the mount, and \(Bw\) is basin width in the widest point of the basin.

To calculate this index in the area, \(Bl\) and \(Bw\) are obtained using the sub-basins (Table 5) and the master river maps then the values are divided into 3 classes. 1: \((Bs > 4)\) 2: \((3 < Bs < 4)\) 3: \((Bs < 3)\), based on [11]. According to Figure 9, this index has calculated and the maximum value belongs to sub-basin No. 19 (Class 1 in Figure 10).

3.6. Hypsometric Integral Index (Hi)

The hypsometric integral (Hi) describes the relative distribution of elevation in a given area of a landscape particularly a drainage basin. The index is defined as the relative area below the hypsometric curve and it is an important indicator for topographic maturity. *H\text{max}, H\text{min}, and H\text{ave} are calculated on DEM. This index is calculated to all sub-basins in the area. The hypsometric integral reveals the maturity stages of topography that can, indirectly, be an indicator of active tectonics.

In general, high values of the hypsometric integral are convex, and these values are generally > 0.5. Intermediate values tend to be more concave-convex or straight, and generally have values between 0.4 and 0.5. Finally, lower values (<0.4) tend to have concave shapes [11]. We can consider class 1 for Hi > 0.5, class 2 for Hi between 0.4 and 0.5 and class 3 for Hi < 0.4 and so, sub-basin No.11 shows younger topography (Table 6, Figure 11).
Table 4. Values of Af index for sub-basins No. 1 to 6.

| Basin | $A_r$ (sq km) | $A_t$ (sq km) | AF | Tilting Part | Flow Direction of River | Tectonic Class |
|-------|---------------|---------------|----|-------------|-------------------------|---------------|
| 1     | 22.19         | 97.55         | 22.75 west | N→S         | 1 (High Activity)       |
| 2     | 80.27         | 155.93        | 51.48 east | N→S         | 3 (Low Activity)        |
| 3     | 99.7          | 431.5         | 23.11 west | N→S         | 1                        |
| 4     | 786.6         | 1032.7        | 76.84 east | N→S         | 1                        |
| 5     | 696.5         | 1098.7        | 63.39 east | N→S         | 2 (Moderate Activity)    |
| 6     | 311.2         | 498.6         | 62.41 east | NE→SE       | 2                        |

Table 5. Values of Bs index.

| Basin | BI (m)   | BW (m)   | Bs | Tectonic Class |
|-------|----------|----------|----|----------------|
| 1     | 16,580   | 8430     | 1.97 | 3 (Low Activity) |
| 2     | 21,400   | 9850     | 2.17 | 3              |
| 3     | 32,350   | 16,670   | 1.94 | 3              |
| 4     | 47,180   | 34,380   | 1.37 | 3              |
| 5     | 59,070   | 25,880   | 2.28 | 3              |
| 6     | 47,710   | 26,670   | 1.79 | 3              |
| 7     | 34,380   | 30,860   | 1.11 | 3              |
| 8     | 19,670   | 12,660   | 1.55 | 3              |
| 9     | 13,790   | 6520     | 2.12 | 3              |
| 10    | 35,040   | 20,540   | 1.71 | 3              |
| 11    | 22,480   | 6930     | 3.24 | 2 (Moderate Activity) |
| 12    | 31,370   | 8410     | 3.73 | 2              |
| 13    | 26,100   | 11,600   | 2.25 | 3              |
| 14    | 34,130   | 30,700   | 1.11 | 3              |
| 15    | 31,620   | 16,970   | 1.86 | 3              |
| 16    | 30,060   | 15,920   | 1.89 | 3              |
| 17    | 28,510   | 14,390   | 1.98 | 3              |
| 18    | 40,390   | 27,540   | 1.47 | 3              |
| 19    | 39,570   | 6390     | 6.19 | 1 (High Activity) |
| 20    | 39,910   | 8330     | 4.79 | 1              |
| 21    | 43,500   | 14,090   | 3.09 | 2              |
| 22    | 41,240   | 17,940   | 2.30 | 3              |
| 23    | 47,830   | 20,770   | 2.30 | 3              |
| 24    | 63,390   | 61,390   | 1.03 | 3              |
| 25    | 38,620   | 37,440   | 1.03 | 3              |
| 26    | 50,780   | 18,930   | 2.68 | 3              |
| 27    | 49,160   | 24,170   | 2.03 | 3              |
| 28    | 38,040   | 20,500   | 1.86 | 3              |
Table 6. Values of Hi index for sub-basin No. 11.

| h (m) | h₀ (m) | h₀/H (m) | a (km²) | A (km²) | a/A (km²) |
|-------|--------|----------|----------|---------|----------|
| 900   | 0      | 0.00     | 29.21    | 1.00    |          |
| 1200  | 300    | 0.50     | 78       | 108.64  | 0.73     |
| 1500  | 600    | 1.00     | 1.11     | 0.01    |          |

3.7. Transverse Topographic Symmetry Factor (T)

The transverse topographic symmetry factor (T) was calculated as follows:

\[ T = \frac{D_a}{D_d} \]

where \( D_a \) is the space from the midline of the drainage basin to the midline of the active belt and \( D_d \) is the space from the midline to the basin limit [104]. In a completely symmetric basin \( T = 0 \) and as asymmetry increases \( T \) approaches to value of 1.0. We can consider class 1 for \( T > 0.4 \), class 2 for \( T \) between 0.2 and 0.4 and class 3 for \( T < 0.2 \) and so, sub-basin No. 3 shows higher activity (Table 7, Figure 12 and Figure 13).
Figure 9. Basic map for Basin shapeindex calculation.

Figure 10. Classification map for Basin shapeindex.

Figure 11. The hypsometric integral classification map for study area.
4. Results and Discussion

The average of the seven measured geomorphic indices (Vf, Smf, SL, Af, Bs, Hi and T) was used to evaluate the distribution of relative tectonic activity. Through averaging these seven indices (Table 8), we obtain one index that is known as modified index of active tectonics (Miat). The values of the index were divided into four classes to define the degree of active tectonics: 1-high (1 < Iat < 1.5), 2-moderate (1.5 < Iat < 2.5) and 3-low (2.5 < Iat).

Thus, there are low relative tectonic activities in sub-basin No. 6, 10, 13, 14, 21, 22, 23, 24 & 28 and moderate relative tectonic activities in the other sub-basins (Figure 14). These sub-basins have got the more active uplifting by Cimmerian-Eurasian convergent movements. These uplifting are related to active faults and folds [105] [106].
Table 7. Values of T index for 5 sub-basins.

| Basin | Number | Da (m) | Dd (m) | T (m) | Tave (m) | Tectonic Class |
|-------|--------|--------|--------|-------|----------|----------------|
| 1     | 1      | 2270   | 3589   | 0.63  | 0.52     | 1 (High Activity) |
|       | 2      | 1289   | 3179   | 0.41  |          |                |
|       | 1      | 299    | 5520   | 0.05  |          |                |
|       | 2      | 1172   | 3405   | 0.34  | 0.31     | 2 (Moderate Activity) |
|       | 3      | 1543   | 4602   | 0.34  |          |                |
|       | 4      | 1956   | 3860   | 0.51  |          |                |
|       | 1      | 4386   | 7830   | 0.56  |          |                |
| 2     | 2      | 6280   | 7480   | 0.84  | 0.57     | 1              |
|       | 3      | 2178   | 7200   | 0.30  |          |                |
|       | 1      | 8530   | 11,010 | 0.77  |          |                |
| 3     | 4      | 10,920 | 14,770 | 0.74  | 0.53     | 1              |
|       | 3      | 427    | 5280   | 0.08  |          |                |
|       | 1      | 3091   | 11,440 | 0.27  |          |                |
|       | 2      | 1602   | 10,110 | 0.16  |          |                |
| 4     | 3      | 3082   | 12,290 | 0.25  | 0.34     | 2              |
|       | 4      | 5010   | 11,210 | 0.45  |          |                |
|       | 5      | 6810   | 12,200 | 0.56  |          |                |

Also, based on [96], this area is a moderate seismic risk zone with following seismicity parameter: b = 0.83, Mmax = 7.5. Focal mechanisms of several earthquakes are dextral strike slip faulting such as Garmkhan-e Bojnourd (Ms = 6.4, 1996) and thrusting. This region experiences low to moderate earthquakes with high frequency,
short repeat time and down to 20 Km focal depth. Sometimes in northern margin of south Caspian basin, focal depths exceed to 70 Km which is a depiction of its subduction. Intensity of earthquakes is in low levels. The most serious seismic hazards in this province, which contains large city such as Mashhad are landslide in high regions, settlement in some plains, and surface faulting.

5. Conclusions

The calculated geomorphic indices are suitable for assessment of tectonic activity of the study area. The seven geomorphic indices: stream-gradient index (Sl), valley floor width-valley height ratio (Vf) and mountain-front sinuosity (Smf), drainage basin asymmetry (Af), hypsometric integral (Hi), drainage basin shape (Bs) and transverse topographic symmetry factor (T) have calculated in Kashaf rud river.

Therefore, firstly the area was divided to 28 sub-basins and for each one, indices were calculated, then all of the indices were divided into relative tectonic activity classes. Afterwards, the seven measured indices for each

| Sub-Basins | Class of Vf | Class of Smf | Class of Hi | Class of Bs | Class of AF | Class of SL | Class of T | S/n | Iat Index |
|------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-----|-----------|
| 1          | 3           | 3           | 1           | 3           | 1           | 3           | 1           | 2.14| 2         |
| 2          | 3           | 1           | 2           | 3           | 3           | 3           | 2           | 2.43| 2         |
| 3          | 3           | 2           | 3           | 3           | 1           | 3           | 1           | 2.29| 2         |
| 4          | 2           | 2           | 2           | 3           | 1           | 2           | 1           | 1.86| 2         |
| 5          | 2           | 2           | 3           | 3           | 2           | 3           | 2           | 2.29| 2         |
| 6          | 3           | 3           | 2           | 3           | 2           | 3           | 2           | 2.57| 3         |
| 7          | 3           | 2           | 1           | 3           | 1           | 3           | 2           | 2.14| 2         |
| 8          | 2           | 3           | 2           | 3           | 1           | 3           | 1           | 2.14| 2         |
| 9          | 3           | 2           | 1           | 3           | 2           | 3           | 3           | 2.29| 2         |
| 10         | 3           | 3           | 2           | 3           | 3           | 2           | 2           | 2.57| 3         |
| 11         | 3           | 2           | 1           | 2           | 2           | 3           | 1           | 2.00| 2         |
| 12         | 2           | 2           | 1           | 2           | 2           | 3           | 3           | 2.14| 2         |
| 13         | 3           | 1           | 3           | 3           | 3           | 3           | 3           | 2.57| 3         |
| 14         | 3           | 2           | 2           | 3           | 3           | 3           | 3           | 2.86| 3         |
| 15         | 1           | 1           | 2           | 3           | 2           | 3           | 1           | 2.17| 2         |
| 16         | 1           | 1           | 1           | 3           | 2           | 1           | 2           | 1.83| 2         |
| 17         | 1           | 1           | 1           | 3           | 2           | 2           | 1           | 1.67| 2         |
| 18         | 3           | 3           | 3           | 3           | 1           | 3           | 2           | 2.40| 2         |
| 19         | 3           | 3           | 3           | 3           | 1           | 3           | 2           | 2.20| 2         |
| 20         | 1           | 1           | 3           | 1           | 1           | 2           | 1           | 1.60| 2         |
| 21         | 3           | 3           | 3           | 3           | 2           | 3           | 2           | 2.57| 3         |
| 22         | 3           | 3           | 3           | 3           | 3           | 3           | 2           | 2.86| 3         |
| 23         | 3           | 3           | 3           | 3           | 3           | 3           | 2           | 2.71| 3         |
| 24         | 3           | 3           | 3           | 3           | 3           | 3           | 3           | 2.86| 3         |
| 25         | 3           | 2           | 3           | 3           | 1           | 3           | 2           | 2.43| 2         |
| 26         | 3           | 3           | 3           | 3           | 3           | 3           | 1           | 2.00| 2         |
| 27         | 3           | 2           | 3           | 3           | 2           | 3           | 2           | 2.43| 2         |
| 28         | 2           | 3           | 2           | 3           | 2           | 3           | 3           | 2.57| 3         |
sub-basin were compounded and a unit index obtained as the modified index of active tectonics (Miat) for the first time. According to this index, there are low and moderate relative tectonic activities levels.

Low relative tectonic activities level has been fund in sub-basin No. 6, 10, 13, 14, 21, 22, 23, 24 & 28 and moderate relative tectonic activities level has been fund in the other sub-basins. It means that these sub-basins have got the more active uplifting by Cimmerian-Eurasian convergent movements, because they are on the longitudinal faults that have been formed above an old suture zone.

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