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Use of morphometric indices in drainage network changes (indicators in the Kordkanlo basin), NE Ian

Mohammad Javanbakht*, Naser Kholghi, Mehdi Reza Poursoltani

Department of Geology, Mashhad Branch, Islamic Azad University, Mashhad, Iran

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Abstract
The Kordkanlo Basin, one of the Atrak sub-basins, located in the northeastern of the Ghoochan city, the Khorasan Razavi Province; is situated in Kopet Dagh geologic zone. The overall objective of this study is to evaluate the morphotectonic effects on the drainage network of the basin, using morphometric indicators. In this research, morphometric quantitative indicators of hypsometric integral (H), the ratio of the valley area to the an area of half-circle with a radius equal to the valley depth (V), the ratio of the width of valley floor to a height of the river (VF), asymmetry factor (AF), the river's length gradient index (SL), transverse topography symmetry factor (T) and index of mountain front sinuosity (SMF), the basin shape index (BS) and the index of (Lat) have been used. This purpose tries to identify the role of change in lithological and tectonic agents on the Kordkanlo river basin using topographic maps, digital elevation model (DEM) and the information obtained in the field survey. In this context, ArcGIS software has been used for determining geomorphic indicators to determine the tectonic characteristics of the basin. Finally, index values were evaluated by the lat index. The result reveals high tectonic activity in the study area.
Keywords: *Morphotectonic Indices, Geomorphic indicators, Drainage Network*

1. Introduction
Earth's surface has been affected by tectonic movements (Kelly and Pinter 2002). In this regard, morphometric indicators are intended as one of the most useful tools for the effectiveness of considered forces. The use of this type of indicator helps us in solving many issues related to basin morphology and sediment regime prevailing it. In most cases, due to the limited economic conditions, there is not the possibility for these studies as seismology and exploratory boreholes in basins, therefore in the Kordkanlo Basin, it has been tried to assess the effect of the mechanism of action of tectonic movements on the morphology of the basin and its drainage network by providing and evaluating morphometric indicators and its evidence. Morphometry is the quantitative measurement of the Earth's surface forms or natural landscapes (Kelley and Pinter 2002). Consequently, it can be concluded that morphometry is the most important method to determine the intensity of tectonic activity in a region. With this method, the tectonic forms are by identified as elevation. Based on the studies of Kelley and Pinter (2002), the quantitative measurement is conducted by geomorphologists (for example Burbank and Anderson 2001) for different geological forms and is less determined as direct parameters. Morphometric quantitative indicators are used, particularly in tectonic studies and for rapid tectonic assessment in the basin (with the help of topographic maps, aerial and satellite photographs) (Burbank and Anderson 2001).

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*Corresponding author.
E-mail address (es): mo_ja58@yahoo.com

The morphometric indicators are appropriate tools for determining the tectonic situation of the region in terms of activity or inactivity (Pourkermani and Solgui 2010).
Among all the factors and studies mentioned, the effect of tectonic factors on morphometric changes of basins has particular importance. Burbank According to the morphometric characteristics, we can of the tectonic effects on a basin. These characteristics have analytical capabilities for the way of degradation, erosion, sediment transport and storage in a basin (Bull and Fadden 1977).
For the first time, Hack (1973) offered gradient-length index (SL) to quantify the longitudinal profile of the main branch of the river. In his experimental review, he proved that the value of (SL) index depends on the size of the river bed particles and the difference in resistance of rocks and he came to the conclusion that the value of this index is correlated with the river energy. Quantitative indicators such as the ratio of the area of the valley to the area of half a circle with a radius equal to the valley depth (V), the ratio of valley floor width to valley height (VF), the river's length gradient index (SL), basin asymmetry (AF), Gradient index-river length (SL), transverse topography symmetry Factor (T) and index of mountain front sinuosity (Smf) show the basin morphotectonic activities in a basin. By examining the ratio of width to depth or height of the valley (VF), there is the possibility of determining and identifying the cause of erosion that has a major role in Valley morphology (Bull and Fadden 1972). Another important study shows that the higher the length of the river (for example Burbank and Anderson 2001), the There is a close relationship between morphometric indicators and

tectonic activities. Their relationship with soil erosion and the sedimentation process show the importance of this type of indicator in the analysis of the morphology of a basin (Burbank and Anderson 2001). One of the studies that have been done in recent years is about the effects of tectonic features on quantitative features of the drainage network in four basins in the NE of Iran (Bahrami 2013). In this study indicators such as splits, anomaly and hierarchical density and the percentage of asymmetry of the basin have been investigated. Meanwhile, in another study, the relative location of tectonic activity of the Kheirabad river basin and the structure around the dam site was accomplished by Mohammadzadeh et al. (2013) that, in this study, the role of active tectonic zoning has been prepared quantitatively in several categories which contain the tectonic activity of low active to very active.

Another study is a quantitative analysis of lithology and tectonic influence on the longitudinal profile of the Ojanchai River (Maghsoudi et al. 2015) where impacts of both lithology and tectonic factors on the Ojanchai Basin has been assessed. Samandar and Roostaei (2016) have investigated the role of tectonics in morphometric abnormalities of drainage networks in the Hajilorchai Basin in the West of Aras River. In this study, a comparison has been done between the results of geophysical data and the results of the quantitative indicators in the basin. The Kordkanlo Basin is one of sub-basins named as Atrak located in the north of Quchan, Khorasan Razavi and between latitudes 37 º 02’ 41" to 37º 21´ 08" and longitude 58º 24´ 05" to 59º 03´55" at 145 km West of Mashhad (Fig 1). The Kordkanlo Basin with a range of 256.9 square kilometers leads to the West to the north to Allahu Akbar Heights and in the East to South the Zubaran anticline.

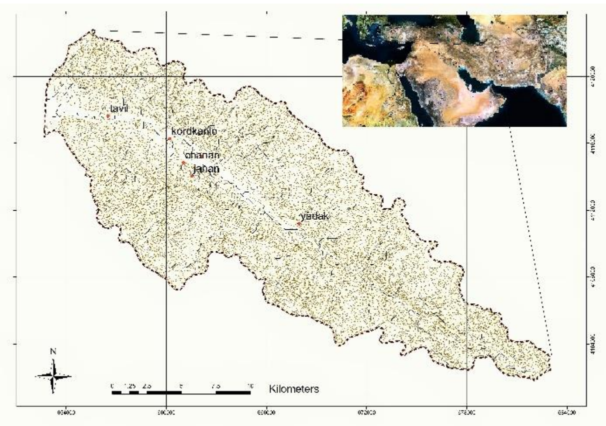

Fig 1. Geographic location and access roads to the Kordkanlo Basin

In terms of geology, the area is considered a part of the geologic zone of Kopet-Dagh (Afshar Harb, 1994). From the late Jurassic to early Cretaceous the Kordkanlo Basin, structures have been formed, and also young sedimentary deposits in this basin are related to the Quaternary (Afshar Harb 1994). Figure (2) shows the geology of the Kordkanlo Basin. Since the Dam has been built on this catchment and so far no such studies have been carried out even in preliminary studies, this study can be considered as a model for the construction of similar structures in the area. Since the obtained data can determine one of the effective factors in sediment production (tectonic factors) in catchments and on the other hand due to the lithology similarity on both sides of the Kordanklu catchment, its role can be independently evaluated. The basin was selected. It is hoped that the data obtained can be used in sediment control decisions in different parts of the basin.

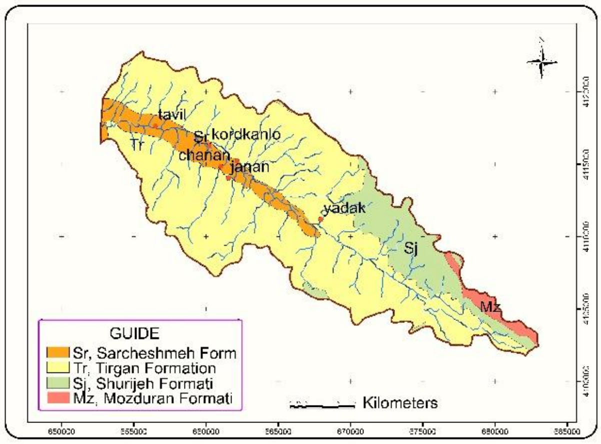

Fig 2. Geology of the Kordkanlo Basin (adapted from 1: 100,000 Kordkanlo, modified by Ghaemi 2004)

2. Material and Methods

In the Kordkanlo Basin, we have been faced with limitations that include geophysical studies, (Seismicity and Seismology) and geochemistry, therefore, morphometric information in this basin was used to achieve the purpose of the study. In this study the geological map at a scale of 1: 100,000 Kordkanlo, GSI (2001) and maps with a topographic scale of 1: 50,000 geo-military organization (1957) have been used. Important morphotectonic parameters have been examined in this study including (Sm, T, AF, SL, VF, V). The indicators of (Bs) and classification of (Lat) have been used in the study. It is noteworthy that all the digital layers were prepared from base maps (topographic and geological) and parameters mentioned have been determined in ArcGIS. Initially, the data were analyzed and interpreted using measurable data from morphometric indices. This information was then compared with the impact of tectonic activity below the basin. Then morphology and sub-types of drainage networks were studied. Finally by combining all of the above, erodibility which is dominated by quantitative indicators mentioned above has been discussed.

3. Result and Discussion

According to this study conducted morphotectonic indicators of the Kordkanlo Basin are as follows:

A) Curve hypsometric integral

Hypsometric curves show the ratio from the dispersion of heights curves in a basin to the total area of that basin (Alizadeh, 2011). Hypsometric curves are obtained of the ratio of the height h to H or h / H ratio of the total area of the basin a to A or a / A To calculate. The hypsometric integral or H (height of the bumps) we use the relationship as follows

.Equation (1):

$$H = \frac{H_{mean} - H_{min}}{H_{max} - H_{min}}$$

a: Total area of the basin, the total area inside the curved lines (both sides of the basin), A) surface area ranging between two curved lines with the height difference h

In this relationship, H show hypsometric integral. (H_{mean}) indicate the Average height, (H_{min}) represents the minimum height of the basin and, (H_{max}) represents the maximum height of the basin. The value of the above hypsometric integral reflects the young topography (Kelley and Pinter 2002). The closer the hypsometric integral number to the number 1, it represents the youth of the basin and the more distance of 1 indicates that the basin is older. According to equation (1) for the Kordkanlo Basin we will have:

$$H = \frac{(2650/30) - (1501)}{(2713/38) - (1501)}$$

As a result, the hypsometric integral value of the Kordkanlo Basin (H) is equal to 0.95, which reflects the active state of the basin and its hypsometric curve has (S) form. There is a logical proportion between the hypsometric integral and Davis erosion cycle (Hancock 2015) in such a way that high levels of hypsometric integral represent the youth stage in Davis model.

Figure 3 shows hypsometry of the Kordkanlo Basin.

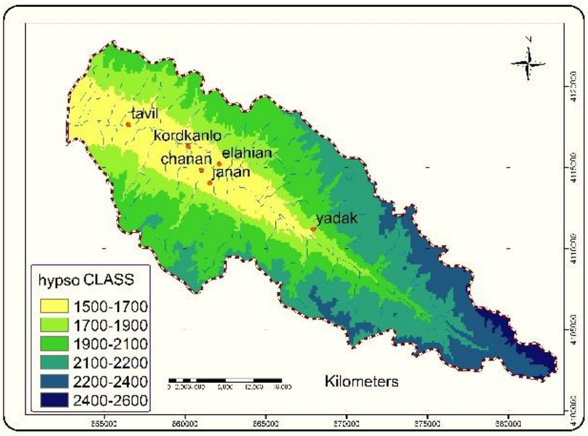

Fig 3. Hypsometry of the Kordkanlo Basin.

B) Basin asymmetry factor

Using the asymmetry factor, a tectonic tilt of the basin can be demonstrated (Burbank and Anderson 2001).

The asymmetry index named (AF) is calculated by the following equation:

Equation (2): $$AF = 100 \left(\frac{Ar}{At}\right)$$

In this equation, we have:

(Ar): Basin area in the right side of the basin (square kilometers) (the view is in the direction of flow)

(At): Shows the total area of the basin (square kilometer).

Based on this relationship for the Kordkanlo Basin, we have:

$$AF = 100 \left(\frac{138/726}{256/9}\right)$$

Consequently, the asymmetry factor (AF) of the Kordkanlo Basin is equal to 0.54, which shows the high symmetry of the basin. Figure 4 illustrates the asymmetry factor in the Kordkanlo Basin upon which it becomes clear that the southern part of the basin has been drawn down compared to the northern part and branches of the Kordkanlo River in the north have been longer than the south. Although in total according to the calculations (AF = 0.54) it can be concluded that this basin is symmetrical.

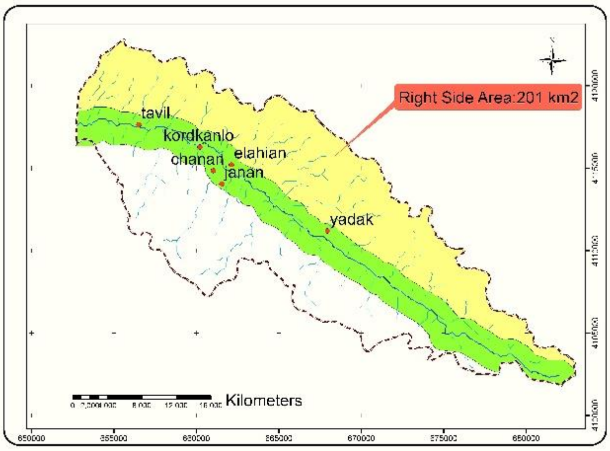

Fig 4. Asymmetry factor in the Kordkanlo Basin

For most of the networks that have arisen in the present age, in which water flows are continuing and are symmetry, the asymmetry factor is about 50% (Burbank and Anderson, 2001). Basically, asymmetry factor (AF) versus tilting of the river structure is sensitive and the amount less or more than 50% shows tilt (Pourkermani and Solgi 2009).

C) Transverse topographic symmetry

This index is calculated using the following equation:

Equation (3): $$T = \frac{Da}{Dd}$$

Where (Da) is the distance from the middle drainage area to middle the active meander belt and (Dd) is the

distance from the middle basin to the basin divide (Kelley and Pinter 2002). For a basin with perfect symmetry T = 0 and asymmetry increases with taking distance from the middle basin and T is gradually increased and gets close to one.
According to the equation (3), we get:

$$\mathrm{T} = \frac{9/79}{11/2} = 0/874$$

The (T) obtained for the Kordkanlo Basin represents relatively high transverse topography. Figure (5) shows the transverse symmetry of the Kordkanlo Basin.

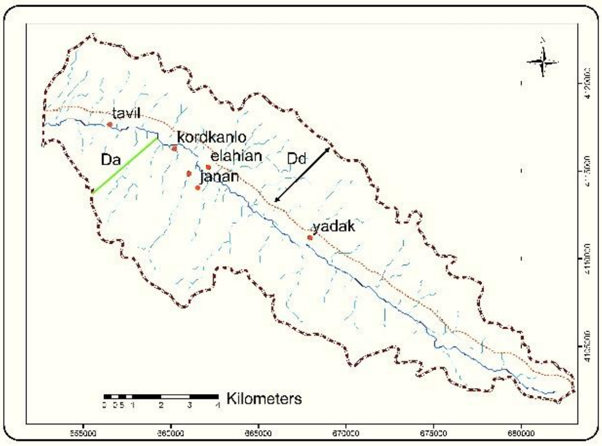

Fig 5. Transverse symmetry of the Kordkanlo Basin

D) Slope to flow length ratio (SL)
In this equation (SL) is stream length to river's slope and ΔH / ΔL is gradient and (L) is the total length of the channel from the branching point to the middle point in which the index is calculated. According to the survey conducted by Anderson and Burbank (2001), the SL factor is an appropriate fitness for the power of the stream. Total stream power in the available part is one of the most basic hydrological variables because the power of the stream destroys the river bed and transports sediment to downstream areas. The index of the slope to length ratio of the stream (SL) for a specific profile of the tiver is obtained from the following equation:

Equation (4): $\mathrm{SL} = \frac{\Delta \mathrm{H}}{\Delta \mathrm{L}}$.

In general, the larger the slope of the river body, the steep the river surface increases and thus the amount of damage and sediment transfer and water discharge rate increases (Anderson and Burbank, 2001). The SL factor is very sensitive to changes in channel slope and by changing the channel slope, SL has changed and this amount can be used to evaluate the active tectonic activity of the basin and rock strength and topography. Index (SL) is sensitive to the strength of rocks in such a way that in areas where rocks are stable, the SL value will increase and in areas where rocks are unstable SL decreases. As in the studied basin, this index increases in the areas where the dominant lithology is limestone or dolomite and in the areas where the dominant is shale lithology this index decreases. It should be noted that, if rock strength is not considered in these areas, it is possible to increase and decrease the index (SL) to tectonic processes. According to the instructions in the Kordkanlo sub-basin, the rock strength to the center of a syncline is gradually decreased, and therefore SL value decreases. The SL for this sub-basin is averagely 305.99 gradient meters.

E) Mountain front sinuosity (S_{mf})
The index indicates the curve and maze of the mountain are obtained by the following equation.

Equation (5): $$S_{mf} = \frac{L_{mf}}{Ls}$$

Where (S_{mf}) is mountain front sinuosity, (L_{mf}) is mountain front length in the intersection of mountains and plains and, L_s is mountain front straight length. Mountain front sinuosity is an indicator to reflect the balance between the attrition forces that, on the one hand, desires to create sinuosity structure and, on the other hand, is tectonics forces that tend to have a straight line on the mountain front (Pourkermani and Solgi, 2009). In mountain fronts that are associated with active tectonic and uplift, S_{mf} is low and is close to one, while the uplift is reduced or stopped, erosional processes because digging and building sinuosity structures. Satellite images and large-scale topographic maps have been used for investigating index (S_{mf}) for the Kordkanlo Basin. According to equation (5) we have:

$$S_{mf} = \frac{1/534}{2/6}$$

As a result, the amount of (Smf) is calculated for the Kordkanlo sub-basin equivalent to 0.59. Kordkanlo mountain-front sinuosity can be seen in Figure (6).

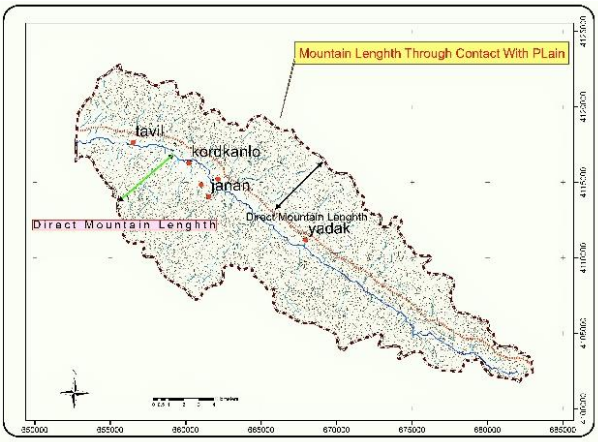

Fig 6. Mountain-front sinuosity in the Kordkanlo Basin

F) The ratio of the width of floor to height of the valley (VF)

This indicator can be obtained by the following equation:

Equation (6):

$$V_F = \frac{2V_{FW}}{(ELD - ESC) + (ErD - EsC)}$$

According to the above equation:
(Vfw) is the width of the valley floor, (LED) is left-valley height, (ErD) is right-valley height and (ESC) is the height of the valley floor. The amount of (F) for wide valleys with a large extent is high and V-shaped valleys are low (Anderson and Burbank 2001). Large amounts of Vf with relatively low uplift areis associated with lack of cutting the river floor and small amounts of Vf represent the depth valley with equivalent streams and large uplift (Burbank and Anderson 2001). If the index (Vf) is small, it indicates active tectonic in the area, and vice versa and, whenever the index (Vf) is high, it indicates low-active tectonic in the area (Pourkermani and Solgi, 2009). According to equation (6) for the Kordkanlo Basin we have:

$$V_F = \frac{2(45)}{(1950 - 1670) + (1780 - 1670)}$$

Based on the above calculation, the amount of (Vf) for the basin is 0.23, which indicates the high tectonic activity. Figure (7) shows the status of Vf compared to the valley floor width to valley height (Vfw) in the Kordkanlo basin.

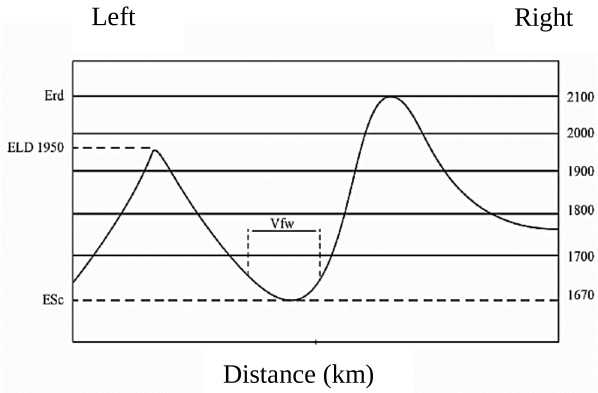

Fig 7. Status of (Vf) compared to the valley floor width to valley height (Vfw) in the Kordkanlo Basin.

G) Ratio (V)

This index is expressed by the following equation:

Equation (7): $V = \frac{Au}{Ac}$

Where Au is cross-sectionally Valley area and Ac is semi-circular area with a radius h. If the value of V is less than 1 it indicates the valley is V-shaped and is much lower than 1, it shows thinner V-shaped valleys which reflects the relative and limited tectonic activity (Burbank and Anderson 2001). The lower the value V, to the same degree the tectonic activity is higher and consequently, uplift rates will be higher (Keller 2001). Basically ratio V provided us with the correct information of the uplift (Burbank and Anderson 2001). In Figures (4-6) an overview of the status of V index in a valley has been shown. According to equation (7) for the Kordkanlo Basin we have:

$$V = \frac{2/25}{3}$$

Therefore, the ratio (V) has been calculated for the basin equal to 0.75, which represents almost V-shaped valley with high tectonic activity.

H) Basin Form Factor (Bsc)

In general, stretching ratio factor for a basin is defined as follows:

Equation (8):

$$Bs = \frac{Bi}{Bw}$$

Where:
Bs is the basin form (M), Bi is the basin length; distance of the lowest height of the basin to the farthest point from there and Bw is basin width at the widest part (Soleimani 2002), Figure (8) shows the calculation method for Bs.

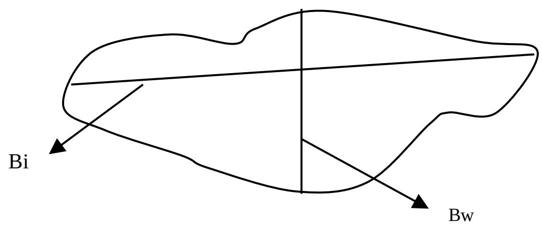

Fig 8. Calculation of Bs (adapted from Soleimani 2002)

Based on studies conducted by Hamduni (2008) large amounts of Bs index are associated with basins in tectonically active areas. While small quantities of this index show circular basins indicating tectonically inactivity. Mountain fronts that have risen quickly, create steep and stretched basins and when tectonic activity is low or stopped, the extent of the basin shows itself as broadening.

According to equation (8):

$$Bs = \frac{28/5}{3/1}$$

According to the classification adopted by Hamduni (2008), this basin is placed in the first class and is quite stretched.

H) Classification of quantitative indicators based on Lat

The classification given for indicators SL, BS and AF by Hamduni et al (2008), considered indicators have been classified into o the three classes 1, 2 and 3. In this classification, Class 1 and Class 3 have the highest and lowest neotectonic activity, respectively (Table 1).

Table 1. Classification of indicators SL, BS and AF (Hamduni et al. 2008)

Indicators	Class 1	Class 2	Class 2
SL	High variation	Low variation	Without variation
Bs	4>Bs	4-3:Bs	3>Bs
Af	15>Af50	15-7>Af50	15<Af50

The lat index is obtained by an average of different classes of geomorphonic indicators (S / n) and is divided into four classes based on the obtained values (S / n) (Table 2). In Lat classification, classes 1, 2, 3 and 4 are identified with very high neotectonic activity, high neotectonic activity, moderate neotectonic activity and low neotectonic activity, respectively.

Table 2. Classification of Index Lat

S/n	Neotectonic activity	Class
1-1.5	very high	1
1.5-2	high	2
2-2.5	moderate	3
2.5>	low	4

I) Classification of indicators based on Lat

On the basis of Lat, tectonic activity of the Kordkanlo Basin has been examined that, the results have been provided in Table (3). According to surveys and calculations and the results of the indicators calculated for the Kordkanlo Basin and by analyzing tables (1) and (2), the studied basin has very high tectonic activity and is placed in Category 1 (Table 4).

Table 3. Classification of geomorphic indicators of the Kordkanlo Basin based on Lat

Basin	Indicator class			Lat
Kordkanlo	SL	Af	Bs	
	Class 1	Class 1	Class 1	Class 1

Table 4. Summary results calculated for the Kordkanlo Basin

No.	Indicator	Calculated values	Description
1	Hypsometric integral (H)	0.95	High activity of the basin and the S-form curve
2	Asymmetry Factor (AF)	0.54	symmetric basin
3	Transverse Topography symmetry (T)	0.874	Relatively high symmetry
4	Stream length to Stream slope (SL)	305.99	Reduced resistance and increased erosion in the Kordkanlo Syncline center
5	Mountain front sinuosity (Smf)	0.59	The average erosion rate in the center of valley
6	The ratio of floor width to height of valley (VF)	0.23	High tectonic activity
7	Ratio of (V)	0.75	Almost V-shaped valley with relatively high tectonic activity
8	Form factor of the basin (Bs)	0.92	stretched basin with relatively high tectonic activity
9	SL	Class 1	High variation
10	Lat	Class 1	Very high variation

4. Conclosion

In the study conducted to assess the morphometric condition of the basin, indicators of AF, SL, T, VF, BS and S_{mf} have been used. Considering these cases, changes and frequency of (SL) in almost all parts of the basin are the same that revealed no changes in the tectonic and lithological conditions of the region. Tectonic and lithological conditions have not changed in a long time. The value of BS is assessed using the Lat index in Class 1 in other words, with the very high variations and the basin form is fully stretched. AF indicator has been calculated for the Kordkanlo River and according to the corresponding table and the figures represent asymmetry of the Kordkanlo River. AF index value of considered area with the value obtained in the study represents a tectonic tilting in the basin. The results obtained by the mentioned indicators were evaluated using the classification of Lat and according to figures obtained and also an explanation of each of the indicators, it can be concluded that the Kordkanlo Basin has very high activity in terms of regional tectonics. Height codes include H_{min}, H_{mean} and H_{max} and finally Hi in the Kordkanlo Basin show that this basin is still a young stage in terms of erosion. The asymmetry factor (AF) shows that tectonic activity moves it downward to the southern part and has made the channels of northern part longer than the southern part. Relatively high values of transverse topographic symmetry (T) represent a relatively high transverse topographic symmetry in this basin. The length to slope index (SL) shows reduced resistance of rock units from heights toward the center of the basin (Kordkanlo Syncline that has arisen from the sources). Mountain front sinuosity (S_{mf}) in this basin represents a tectonic uplift in it. Valley floor width to height (VF) in the Kordkanlo Basin is a quantitative value that shows a small amount of width of valleys in this basin. V factor is about 0.75 that, in this V-shaped basin the valley has high tectonic activity.

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