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Evaluation of Active Tectonics of "Aras River" Using Geomorphological Indices

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ABSTRACT

Evaluation of active tectonics in Aras River Basin on the basis of geomorphological indices was the main goal of this study. It is carried out by dividing the Aras Basin Area into 14 sub- basins of different sizes, according to its topographic configuration, and examining the value of different geomorphic indices, include: stream length-gradient index (SL), drainage basin asymmetry (Af), ratio of valley-floor width to valley height (Vf), index of drainage basin shape (Bs), index of transverse topographic symmetry (T), hypsometric integral (Hi) and mountain front sinuosity(Smf), for each sub-basin. The interpretation of achieved results revealed that tectonic activity in the western parts of Aras Basin Area is moderate to high while it is moderate to low in the eastern part, and the reason for the almost higher activity in the western parts is the existence of several active faults in this area.

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INTRODUCTION

Study of active systems of the rivers is known geomorphology of streams. Shape of streams are described by several factors such as: width and height of channel, insoluble sediments, suspended sediments, sinuosity of channel, flow velocity, roughness of channel and many other factors. A delicate balance among these parameters within a stream system means that streams are vulnerable to any kind of alternation. Climax changes which frequently happened during Quaternary, have had tremendous effects on most geomorphic systems including streams [1]. With advances in tectonic geomorphology, the idea that active tectonics processes can also influence the shape and processes within streams has been enhanced [2,3,4,5]. Some morphological indices are used substantial identifying instruments for describing those areas which are subject to rapid tectonic deformation. These indices are very useful to obtain some information about active tectonics, because they can be used for examining large areas and required data can be easily obtained from topographic maps and aerial photos [6].Some indices include:

- Stream length-gradient index (SL)
- Drainage basin asymmetry (Af)
- Ratio of valley-floor width to valley height (V_f)
- Index of drainage basin shape (B_s)
- Index of transverse topographic symmetry (T)
- Hypsometric integral (H_i)
- Mountain front sinuosity (S_{mf})

By investigating several morphological indices and integrating resulting consequences with such other information as uplift rate, the degree of tectonic activity which is one of the significant indices of relative tectonic activity in one area, can be estimated [7].

Discussion:

Aras River Basin is located in northwest of Iran and is the second sub- basin of Caspian basin in aspect of its largeness. Geographically it is limited to Republic of Azerbaijan and Armenia in the north, Sefidroud sub-

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basin and Urmia lake in the south, Talesh- Anzali sub- basin in the east and Azerbaijan and Turkey in the west.This sub- basin is situated on 44° 05´ to 48° 30´ longitude and 37° 48´ to 39° 45´ latitude. This sub- basin is 38578.75 square kilometers. Important rivers in this sub- basin are Aras over than 1070 km, Gharesoo235 km, Ghotur Chai 204 km, Agh Chai 115 km, Zonouz Chai 114 km and Zulbin Chai 102 km can be mentioned. Important elevations from which the rivers of this basin spring include: Soltan Sabalan(4800m), Sabalan(4505m), Heram(4392m), Ararat (3909m)[8]For examining the geomorphological indices in Aras Basin, this area divided in to 14 sub- basins (Fig. 1).

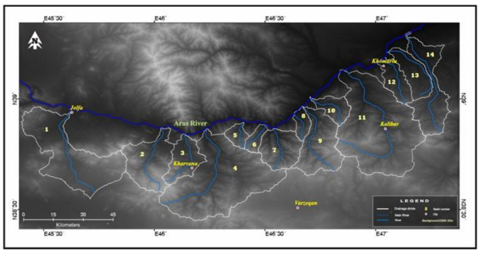

Fig. 1: The sub- basins in studied area, each sub- basin is labeled by a number.

Drainage Basin Shape (B_s):

Relatively young drainage basins in active tectonic areas tend to be elongated in shape normal to the topographic slope of mountain. With continued evolution or less active tectonic processes, the elongated shape tends to amore circular shape [9]. Horizontal projection of basin shape may be described by the elongation ratio B_s [10, 11], expressed by equation

$B_s=B_l / B_w$(1)

Where B_l is the length of the basin, measured from its outlet to the most distal point in the drainage divide and B_w is the width of the basin measured across the short axis (Fig. 2). The index reflects the difference between elongated basins with high values of B_s and more circular basins with low values. Basins with elongated shapes are characteristics of tectonically active areas, where streams primarily down cutting. Rapidly uplifted mountain front generally produce elongated, steep basins and when tectonic activity is diminished or ceases, widening of basins occur from mountain front up[11].In this study, the values of this index for 14 sub-basins of Aras River are calculated using the above mentioned equation (table 1).

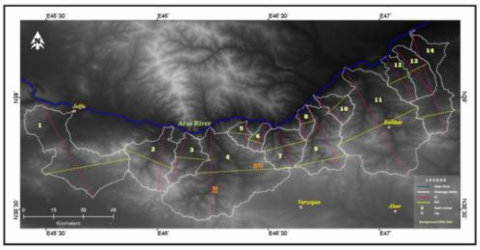

Fig. 2: B_l and B_w values for each sub- basins of Aras River.

Table 1: Result of B_s index calculation for Aras River sub- basins.

Drainage Basin Shape (Bs)				
Basin	*BI (m)*	*BW (m)*	*Bs*	*Tectonic Class*
1	49800	34220	1.46	3 (Low Activity)
2	32480	21070	1.54	3
3	26390	13500	1.95	3
4	43480	36860	1.18	3
5	12970	9790	1.32	3
6	14850	6340	2.34	3
7	21060	18200	1.16	3
8	14880	6040	2.46	3
9	34610	21900	1.58	3
10	17570	12190	1.44	3
11	58870	36010	1.63	3
12	24680	10050	2.46	3
13	27450	9260	2.96	3
14	51550	15150	3.40	2 (Moderate Activity)
BsClassification:1(High Activity): > 4 ,, 2(Moderate Activity):3-4 ,, 3(Low Activity): < 3				

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This table shows that sub-basin number 14 has a moderate activity and other basins have low activity (Fig. 3).

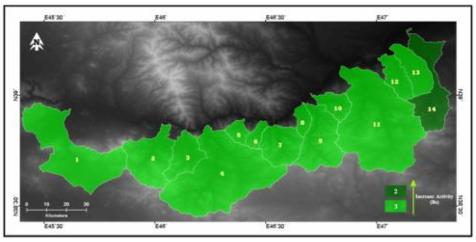

Fig. 3: Distribution of B_s index for Aras River sub- basins.

Stream Length - Gradient Index (SL):

This index first was defined by [12] using the mathematical equation:

SL= (ΔH / ΔL) × L (2)

Where *SL* is stream length-gradient index, *ΔH* / *ΔL* is the channel slope or gradient of the reach (ΔH is the change in elevation of the reach and ΔL is the length of the reach) and *L* is the total channel length from the point of interest where the index is being calculated upstream to the highest point on the channel. SL index is sensitive to channel gradient alternations and this sensitivity helps in examining the relation among morphological activity, rock resistance and topography, so that the index rate on soft and low resistance rocks like shale, siltstone, sandstone, and carbonate is relatively low, but when the stream passes over the hard rocks, SL increases considerably. In another word, land shape is completely related to rock resistance. Thus, the high amounts of SL index that is unusual in special kinds of rocks, can represent a new geomorphologic activity. This index for 14sub- basins of Aras River is calculated using the above-mentioned equation and the results are shown in table 2. As this table shows, sub-basins 1, 2, 3, 4, 5, 6, 7, 9, 10 and 11 have moderate activity and sub-basins 8, 12, 13 and 14 have a low geomorphological activity (Fig. 4).

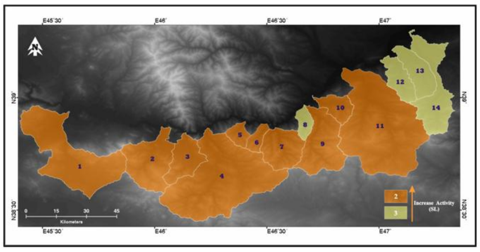

Fig. 4: Distribution of SL index for Aras River sub- basins.

Table 2: Result of SL index calculation for Aras River sub- basins.

Stream Length - Gradient Index (SL)			
Basin	*Tectonic class*	*Basin*	*Tectonic class*
1	2	8	3
2	2	9	2
3	2	10	2
4	2	11	2
5	2	12	3
6	2	13	3
7	2	14	3
SL classification 1(High Activity): > 1000 ,, 2(Moderate Activity): 500-1000 ,, 3(Low Activity): < 500			

Ratio of Valley Floor Width to Valley Height Index (V_f):

The V_f is defined as ratio of valley floor width to valley height was first introduced by [13] and is computed by:

$$V_f = 2V_{fw} / ((E_{ld} - E_{sc}) + (E_{rd} - E_{sc})) \quad (3)$$

Where V_f is the valley- floor width to height ratio, V_{fw} is the width of the valley floor, E_{ld} and E_{rd} are elevations of the left and right valley divides and E_{sc} is the average elevation of the valley floor. This index differentiates between broad- floored (U- shaped) canyons with relatively high values of V_f and V- shaped valleys with relatively low values. High values of V_f are associated with low uplift rates, so that streams cut broad valley floor. Low values of V_f reflect deep valleys with streams that are actively incising, commonly associated with uplift. The results of calculating of this index for Aras River sub- basins (table 3) show that the sub- basins 3, 5, 6, 7 and 9 have high activity, sub- basins 1, 2, 4, 8, 10, 11, 12 and 14have moderate activity and sub- basin 13 has low activity (Fig. 5).

Table 3: Result of V_f index calculation for Aras River sub- basins.

Ratio of Valley floor width to valley height Index (Vf)			
Basin	*Tectonic class*	*Basin*	*Tectonic class*
1	2	8	2
2	2	9	1
3	1	10	2
4	2	11	3
5	1	12	2
6	1	13	3
7	1	14	2
Vf classification 1(High Activity): < 0.5 ,, 2(Moderate Activity):0.5-1 ,, 3(Low Activity): > 1			

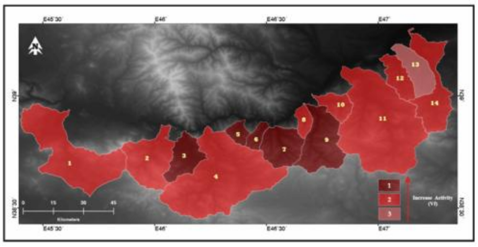

Fig. 5: Distribution of V_f index for Aras River sub- basins.

Transverse Topographic Symmetry Factor (T):

Transverse Topographic Symmetry Factor (T) was first introduced by [14] is a method that evaluates the amount of asymmetry of river within a basin and the variation of asymmetry in different segments of valley. The basin midline would be location of a river that is symmetrically placed with regard to the basin divide. It is calculated regarding the large axis of basin, which extends from the outlet of basin to the most distal point in the headwater. For each segment, *T* is the ratio of distance from the basin midline to the active meander belt midline *(D_a)* to the basin divide *(D_d)*:

$$T = D_a/D_d \quad (4)$$

This value varies between 0 and 1, which represent the minimum and maximum asymmetry of segment respectively. T values are calculated for different segments of valleys (T_{ave}) and indicate preferred migration of streams perpendicular to the drainage- basin axis. The results of calculation of this factor for Aras River Basin are shown in table 4 and figure 6.

Table 4: Result of T factor calculation for Aras River sub- basins.

Transverse Topographic Symmetry Factor (T)					
Basin	*T_{ave} (m)*	*Tectonic class*	*Basin*	*T_{ave} (m)*	*Tectonic class*
1	0.71	1	8	0.18	3
2	0.33	2	9	0.37	2
3	0.21	2	10	0.23	2
4	0.24	2	11	0.26	2
5	0.39	2	12	0.24	2
6	0.36	1	13	0.51	1
7	0.21	2	14	0.34	2
T classification: 1(High Activity): > 0.4 ,, 2(Moderate Activity):0.2-0.4 ,, 3(Low Activity): < 0.2					

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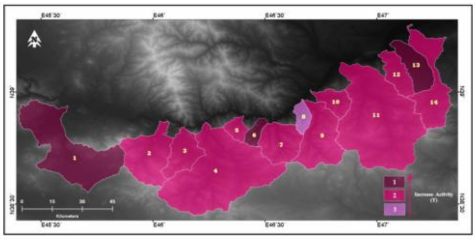

Fig. 6: Distribution of T factor for Aras River sub- basins.

As table 4 and figure 6 show, sub- basins 1, 6 and 13 have the highest activity, sub- basins 2, 3, 4, 5, 7, 9, 10, 11, 12 and 14 have moderate activity and sub- basin 8 has a low activity.

Asymmetry Factor (AF):

This factor was first introduced by [12]. The asymmetry factor (AF) is a way to evaluate the existence of tectonic tilting at the scale of drainage basin. It is defined as:

$AF = 100(A_r/A_t)$ (5)

Where A_r is the area of the basin to the right (facing downstream) of trunk stream and A_t is the total area of the drainage basin. When AF=50, the drainage is perfectly symmetric, while values greater or less than

50 belong to asymmetric basins [7]. The results of the calculation of this factor (table 5), for Aras River sub- basins show that the sub- basins 1, 2, 3, 7, 12 and 14 have a high tectonic activity, the sub- basins 4, 5, 8 and 13 have low activity (Fig. 7).

Table 5: Result of AF factor calculation for Aras River sub- basins.

Asymmetry Factor (AF)						
Basin	A_r(sq km)	A_t(sq km)	AF	Tilting Part	Flow Direction of River	Tectonic class
1	347.7	806.1	43.1	East	South→North	3 (Low Activity)
2	189.6	407.1	46.6	East	South→North	3
3	98.4	222	44.3	East	South→North	3
4	851.5	1159.5	73.4	West	South→North	1 (High Activity)
5	22	73.2	30.1	East	South→North	1
6	41.2	68.2	60.4	West	South→North	2 (Moderate Activity)
7	153.1	272.6	56.2	West	South→North	3
8	50.1	75.8	66.1	West	South→North	1
9	254	406.8	62.4	West	South→North	2
10	78.2	128.4	60.9	West	South→North	2
11	728.3	1222.9	59.6	West	South→North	2
12	77.7	169.8	45.8	East	South→North	3
13	45.1	213.5	21.1	East	South→North	1
14	222.1	396.1	56.1	West	South→North	3
AF classification: AF-50 → 1(High Activity): >15 ,, 2(Moderate Activity): 7-15 ,, 3(Low Activity): <7						

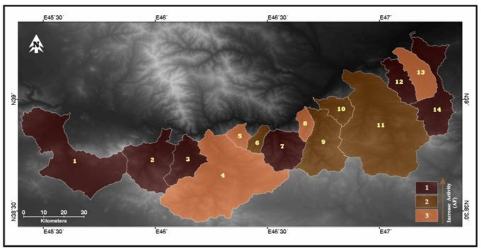

Fig. 7: Distribution of AF factor for Aras River sub- basins.

Mountain Front- Sinuosity (S_{mf}):

Mountain front sinuosity was first introduced by [15] is defined as:

$S_{mf} = L_{mf}/L_s$ (6)

Where S_{mf} is mountain- front sinuosity, L_{mf} is the length of mountain front along the floor of mountain and L_s is the straight- line length of mountain front. Mountain- front sinuosity is an index that reflects the balance between erosional forces that tend to cut embayment into a mountain front and tectonic forces that tend to produce a straight mountain front coincident with active range-boundary fault. Those mountain front associated with active tectonics and uplift are relatively straight, with low values of S_{mf}. If the rate of uplift is reduced or ceases, then erosional processes will crave a more irregular mountain front and S_{mf} will increase. The results of the calculation of this factor (table 6), for Aras River sub- basins show that the sub- basins 1and 10 have a high

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tectonic activity, the sub- basins 2, 4 and 13 have moderate activity and the sub- basins 3 and 14 have low (Fig. 7).

Table 6: Result of S_{mf} calculation for Aras River sub- basins.

Mountain Front Sinuosity (S_{mf})		
Basin	Average of S_{mf} / Basin	Tectonic Class
1	1.45	1
2	1.94	2
3	2.44	3
4	1.94	2
10	1.44	1
13	1.93	2
14	2.52	3
S_{mf} Classification→ 1(High Activity): < 1.53 ,, 2(Moderate Activity):1.53-2.3 ,, 3(Low Activity): > 2.3		

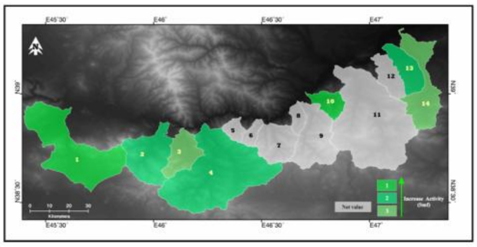

Fig. 8: Distribution of S_{mf} for Aras River sub- basins.

Hypsometric Curve and Hypsometric Integral

The hypsometric curve describes the distribution of elevation across an area of land, form one drainage basin to the entire planet. The curve is created by plotting the proportion of total basin height against the proportion of total basin area [16]. The total surface area of basin *(A)* is the sum of the area between each pair of adjacent contour lines. The area *(a)* is the surface area within the basin above a given line of elevation *(h).* The value of relative area *(a/A)* always varies from 1.0 at the lowest point in the basin *(h/H=0.0)* to 0.0 at the highest point in the basin *(h/H= 1.0)*. A useful attribute of the hypsometric curve is that drainage basins of different sizes can be compared with each other because area and elevation are plotted as functions of total area and total elevation [16]. A simple way to characterize the shape of the hypsometric curve for a given drainage basin is to calculate its hypsometric integral. The integral is defined as the area under the hypsometric curve. One way to calculate the integral for given curve is follow:

Mean elevation – minimum elevation/ Maximum elevation – minimum elevation (7)

The results of calculation of this index for Aras River Basin are shown in table 7and figure 9.

Table 7: Result of Hypsometric Integration calculation for Aras River sub- basins.

Result of Hypsometric Integration					
Basin	H_i	Tectonic Class	Basin	H_i	Tectonic Class
1	0.39	3	8	0.46	2
2	0.55	1	9	0.62	1
3	0.35	3	10	0.33	3
4	0.53	1	11	0.57	1
5	0.62	1	12	0.39	3
6	0.52	1	13	0.45	2
7	0.59	1	14	0.11	3
H_i Classification→ 1(Immature=High Activity): > 0.5 ,, 2(Mature=Moderate Activity):0.4-0.5 ,, 3(Super mature=Low Activity): < 0.4					

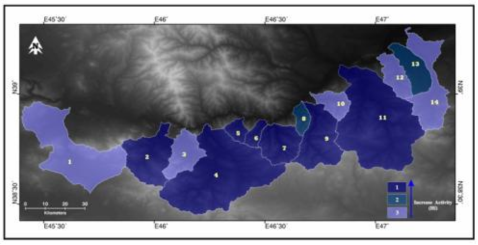

Fig. 9: Distribution of Hypsometric Integration for Aras River sub- basins.

Conclusions:

In this study which was conducted to examine active tectonics in Aras Basin based on geomorphologic indices, the whole area of Aras River Basin was separated and divided in to 14 sub- basins with various sizes and values of different geomorphologic indices including: stream length-gradient index (SL), drainage basin asymmetry (AF), ratio of valley-floor width to valley height (V_f), index of drainage basin shape (B_s), index of transverse topographic symmetry(T)), hypsometric integral (H_i) and mountain front sinuosity(S_{mf}) were measured and calculated for each 14 sub-basin. Based on the results of these calculations, all sub- basins are circular and their lithology consists of low resistant rocks. Thus, in most sub- basins valleys are narrow with steep and V- shaped due to strong concavity (table 8). Finally, two geomorphologic ranges can be identified in this region. Western part which is geomorphologically more

active than the eastern part(fig. 10), so the most indices have moderate to high activity rates which results from the existence of some faults in this area.

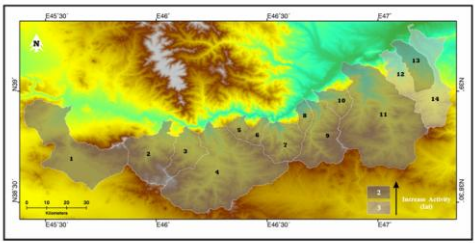

Fig. 10: Distribution of I_{at} for Aras River sub- basins

Table 8: Result of I_{at} calculation for Aras River sub- basins.

Index of active tectonic (I_{at})									
Basin	B_s Tectonic Class	AF Tectonic Class	T Tectonic Class	V_f Tectonic Class	H_i Tectonic Class	SL Tectonic Class	S_{mf} Tectonic Class	I_{at} Detail of Average	I_{at} Tectonic Class
1	3	3	1	2	3	2	1	2.14	2
2	3	3	2	2	1	2	2	2.14	2
3	3	3	2	1	3	2	3	2.43	2
4	3	1	2	2	1	2	2	1.86	2
5	3	1	2	1	1	2	_	1.67	2
6	3	2	1	1	1	2	_	1.67	2
7	3	3	2	1	1	2	_	2.00	2
8	3	1	3	2	2	3	_	2.33	2
9	3	2	2	1	1	2	_	1.83	2
10	3	2	2	2	3	2	1	2.14	2
11	3	2	2	2	1	2	_	2.00	2
12	3	3	2	2	3	3	_	2.67	3
13	3	1	1	3	2	3	2	2.14	2
14	2	3	2	2	3	3	3	2.57	3
I_{at} Classification: 1(High Activity) ,, 2(Moderate Activity) ,, 3(Low Activity)									

REFERENCES

[1] Bull, W.B., 1991. Geomorphic Response to Climatic Change. New York: Oxford University Press.
[2] Adams, J., 1980. Active tilting of the United States mid-continent: geodetic and geomorphic evidence. Geology, 8: 442-446.
[3] Deffontaines, B., J. Chorowicz, 1991. Principles of drainage basin analysis from multisource data: application to the structural analysis of the Zaire basin. Tectonophysics, 194: 237-263.
[4] Holbrook, J., S.A. Schumm, 1999. Geomorphic and sedimentary response of rivers to tectonic deformation: a brief review and critique of a tool for recognizing subtle epeirogenic deformation in modern and ancient settings. Tectonophysics, 305: 287-306.
[5] Schumm, S.A., J.F. Dumont, J.M. Holbrook, 2000. Active Tectonics and Alluvial Rivers, Cambridge University Press: Cambridge.
[6] Keller, E.A., 1986. Investigation of active tectonics: use of surficial Earth processes. In: Wallace, R.E. (Ed.), Active Tectonics, Studies in Geophysics. National Academy Press, Washington, DC, 136-147.
[7] Keller, A.E., N. Pinter, 2002. Active Tectonics: Earthquakes, Uplift and Landscape, Prentice Hall, New Jersey.
[8] The Gazetteer of Rivers in the I.R of Iran, Caspian Sea, 2003. Geographic Organization of Ministry of Defense and Armed Forces Logistics.

[9] Bull, W.B., L.D. McFadden, 1997. Tectonic geomorphology north and south of the Garlock fault, California. In: Doehring, D. O (eds), Geomorphology in Arid Regions. Proceedings of the Eighth Annual, Geomorphology Symposium. State University of New York, Binghamton, 115-138.
[10] Cannon, P.J., 1976. Generation of explicit parameters for a quantitative geomorphic study of Mill Creek drainage basin. Oklahoma Geology Notes, 36 (1): 3-16.
[11] Ramírez-Herrera, M.A., 1998. Geomorphic assessment of active tectonics in the AcambayGraben, Mexican volcanic belt. Earth Surface Processes and Landforms 23: 317-332.
[12] Hare, P.W., T.W. Gardner, 1985. Geomorphic indicators of vertical neotectonism along converging plate margins, Nicoya Peninsula, Costa Rica. In: Morisawa, M., Hack, J.T. (Eds.), Tectonic Geomorphology. Proceedings of the 15th Annual Binghamton Geomorphology Symposium.
[13] Bull, W.B., 1977. Tectonic geomorphology of Mojave Desert. U. S. Geological Survey Contract Report14-08-001-G-394. Office of Earthquakes, Volcano and Engineering: Menlo Park, CA.
[14] Cox, R.T., 1994. Analysis of drainage basin symmetry as a rapid technique to identify areas of possible Quaternary tilt- block tectonics: an example from the Mississippi Embayment. Geological Society of America Bulletin, 106: 571-581.
[15] Bull, W.B., 1978. Geomorphic Tectonic Classes of the South Front of theSan Gabriel Mountains, California. U.S. Geological Survey ContractReport, 14-08-001-G-394, Office of Earthquakes, Volcanoes andEngineering: Menlo Park, CA.
[16] Strahler, A.N., 1952. Hypsometric (area-altitude) analysis of erosional topography. Geological Society of America Bulletin 63, 1117–1142.