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Quantitative Analysis of Tectonic and Lithology Effects on Longitudinal Profile of Ghale- Chay River

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Abstract

System of Rivers is greatly influenced by active tectonics and rate this effect can be measured by their deviation rate and recent characteristics of tectonic activities. Longitudinal profile of rivers is affected by lithology, renewal processes of erosion which is caused by tectonics and level of groundwater. Changes in flow, bed load and resistance of lithology, tributaries and tectonic movements are important in the development of profiles and interpretation of general form of longitudinal profile.

The longitudinal profile gives valuable information about evolution and environment changes of a river over time. Studying longitudinal profile of the rivers are important in many applied aspect such as flood control, quality and efficiency of reservoirs, watershed, etc. The present study is an analysis of lithology and tectonics in longitudinal profile river of Ghale chay in the western slopes of the Sahand Mountain (Ghale chay basin). Morphometric measurements were used for the aims of the current study. The following indexes are used in this paper; Stream length-gradient index (SL), (SL/K), Concavity index, hypsometric curve analysis and hypsometric integral. Generally, index measurement indicates assessments showed that tectonically the region is relatively active and in various parts the amount of activity is different, that is, all indexes are more active in downstream basin than other parts. Moreover, by using SL and Concavity index and geologic formations throughout profile of the river, it was found that the effect of lithology on longitudinal profile of the river was moderate.

Key words: Longitudinal profile of the river, Tectonics, The standardized index (SL/K), Concavity index, Basin of Ghale chay

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Introduction

Study and investigation of forms and processes which are formed on earth surface by interior activities of earth or tectonic are called tectonic geomorphology or morphotectonics (Bull, 2009). Phenomena that are studied in neotectonic include all the elements, processes and activities caused by new activities of the earth (in geological scale) and the shapes made by these activities. River systems are greatly influenced by tectonics and are sensitive to regional surface faulting and deformation. Thus by using their diversion level, the amount and characteristics of recent tectonic activities can be specified (Keller and Pinter, 1996: 174).

One of important characteristics of rivers is longitudinal profile of the river bed that is line of the biggest dip of the river which demonstrates the tilt toward the horizon in every area (Simafar, 1995:75). In fact, the shape of a waterway is the result of coordination between the conditions imposed by the environment and the processes of flow and sediment transfer (Javedani, 2019: 128). For this Longitudinal profile is very sensitive to river dip, tectonic activities in river bed can be assessed using this sensitivity (Bayati Katibi, 2009). Longitudinal profile of rivers usually includes three separate parts namely mirage steep and erosion, the middle section with a more developed and less steeped profile compared to mirage, costal that is the stage of development and sedimentation of river bed (Alizadeh, 2003: 481). Experimental studies show that river discharge changes, bed load dimensions and lithological resistance, tributaries entrance tectonic movements are important in profile development and interpretations of general shape of the longitudinal profile (M.Radoane, 2003 quoted in Roostai & Nayyeri, 2011: 139). Change in any variable such as changes in river forces like any increase or decrease in discharge and resistance forces in bed, slope of the longitudinal profile, and even height of attached tributaries to the main stream will lead to changes in all these elements (Bayati Khatibi, 2009: 31). Alan Clows and Peter Comfort (1987) attributed non-uniform longitudinal profile to changes in lithology and concluded that such non-uniformity exists when river flows in alluvial bed which are specified by shallow areas with fast flows and deep areas with slow flows. Findings of past studies shows that longitudinal profile of rivers are influenced by lithology, renewed erosion processes caused by tectonics and low water levels (Roostai & Nayyeri, 2011: 139). Investigation of longitudinal profile of rivers has a lot of use such as flood control, quality and efficiency of reservoirs, watershed, and etc., which makes it important (Ahmadi, 2001).

Investigation of tectonic activities using geomorphic indicators has rich literature. There are a lot of studies regarding this subject in Iran and all over the world such as Rezai Moghadam (1995), Bayati Khatibi (2008), Roostae et al, (2009), Maghsoodi et al (2011), Servati et al (2012), Rajabi and Soleimani (2013), Alaei Taleghani et al (2013), Bahrami (2014) and etc. who investigated tectonics of different areas and used geomorphic indicators to achieve their aims. Regarding tectonics and lithology, Roostai and Nayyeri (2011) analyzed lithology and tectonic effects on longitudinal profile of Mahabad river using geomorphic indicators; their findings shows that In some parts of the case area, longitudinal profile of the river is greatly affected by regional lithology and tectonically, tectonic uplift decreases effect of bed rock on the longitudinal profile. Moreover, on other parts of the world scholars have done studies about tectonics such as Keller et al (1999), Pinter and Keller (2000), Silva (2003, 2008), Sing and Jane (2008), , Figueroa et al (2010), Bhat et al (2013), Reyaz Ahmad et al (2014) and etc. The aims of this study are evaluation of tectonic activities and lithology effect regarding validity of geomorphic indicators in different studies, tectonic activities of Ghale- chay basin area, and lithology effect on longitudinal profile of Ghale-chay Rivers using a quantitative approach.

1. **Location of Case Study Area**

Ghale-chay is one of sub-basins of Urmia lake that is located in eastern part of the lake and ends in Ganbar-chay (Azar Shar-chay) from the north, Sufi-chay area (Maragheh) Chowan-chay from east and south, and Urmia lake from west; it is 346 square kilometer located in Ajabshir, Azarbayjan State in north of the city. Ghale-chay basin in terms of geographical location is located on $45^{\circ}\,55'$ to $46^{\circ}\,20'$ longitudinal east and $37^{\circ}\,27'$ to $37^{\circ}\,42'$ northern latitude. The highest part of the basin is located on Meydan- dagh that is 3412 meters high and the minimum height is located on Khanian and Gol-tapeh villages that is 1300 meters high. (Figure 1).

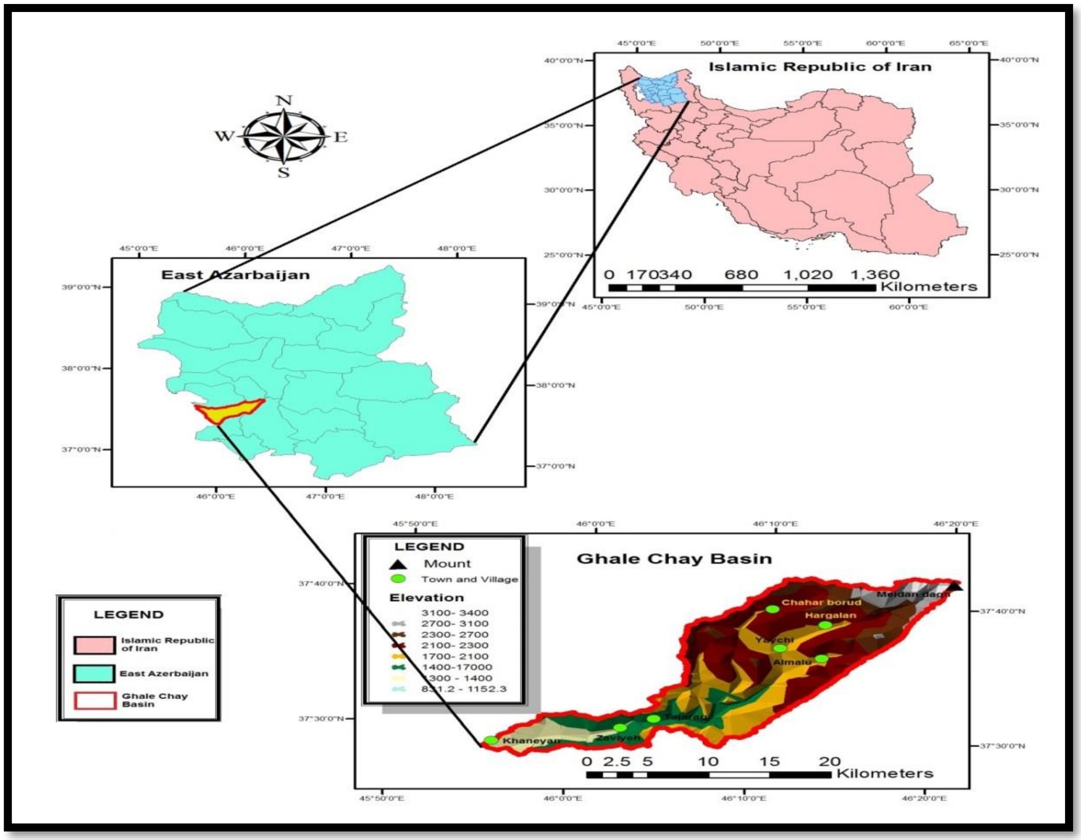


Fig. 1. Location of the study area in a map of Iran and East Azarbaijan

2. Lithology of the Region

Investigations of geological map with the scale of 1/100000 including Oskou, Azar Shar, Maragheh, and Ajabshir shows that in the region the rocks are distributed to three lithological groups: distribution nonresistant rocks is low in the area; it just includes young terrace deposits and alluvial terraces, most of which are next to Yangjeh and Barazlou villages. Half- resistant rocks regarding their gender and distribution in the region include limestone of Ghale-chay area which mostly are Dolomite containing orbitolinids located in central and western north parts. Orbitolinids of dolomitic lime and clay of Permian and Cambrian are mostly extended near Zaviyeh and Gonbad village to near Houri in north. Pumice and volcanic ash are in norther part of Hargalan village and extended in south-east of the area. Existence of these kinds of lithology units caused steeped valleys and plains. Finally volcanic rocks which are mostly extended between Tajaragh and Hargalan villages are the hard part builders of Ghale-chay area, resistant sedimentary rocks such as sandstone are also included resistant rocks of the area. There are Andesite, Dacite and grouts in Ghale-chay area. Andesite major expansion in the northern part of the field is between Harglan and sharbroud villages and Oulia Mountain. Dacite rocks are in central basin (Roostai, 1994). Plio rocks including pumicic lahar stones in north of Harglan village, stairs curves and andesitic lavas in northern east of the region, Cambrian rocks in south of the region that encompasses andesite, red rhyolite arkosi, and sandstone are also included in this group (Figure 2).

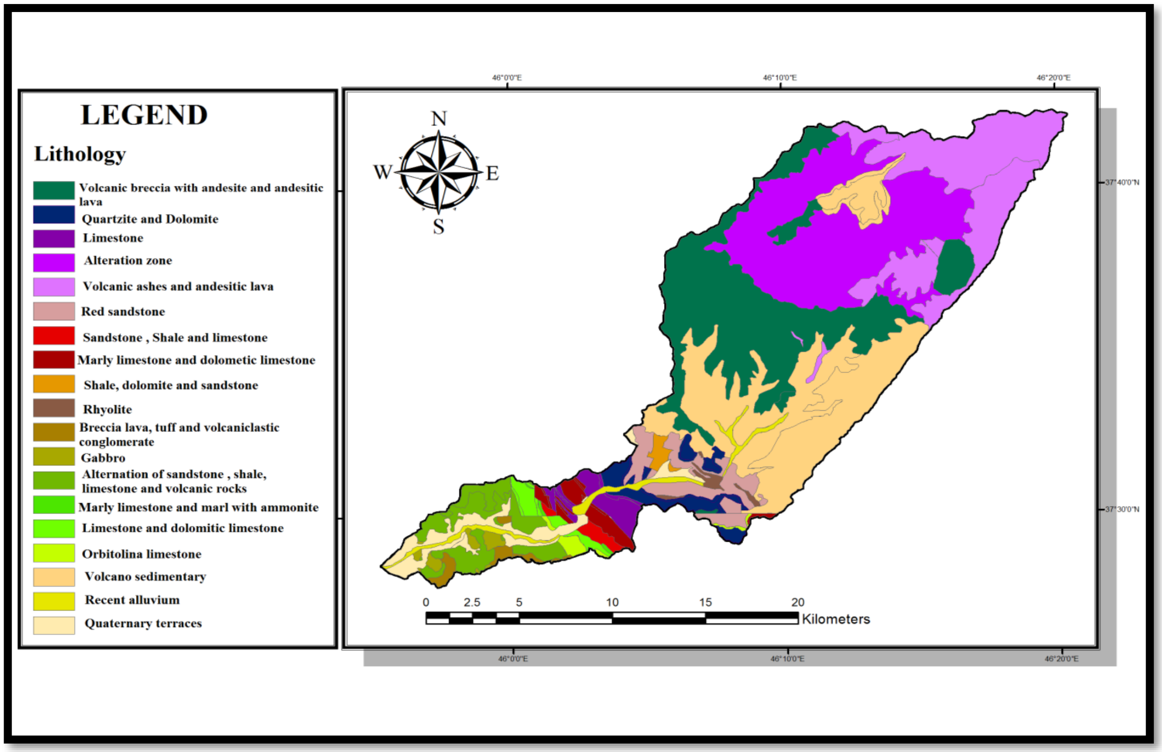


Fig. 2. Lithological map of case study area

3. **Methodology and Materials**

In this study aerial photos with scale of 1/55000, satellite images, geological maps 1/100000 of Azar Shar, Oskou, Ajabshir, and Maragheh sheets and 1/50000 topographic maps of Hargalan index number III 5265, Shir Amin index number II 5165, Maragheh index number IV 5264, and Ajabshir index number I 5164 is used for drawing figures and tables. Moreover, in this research Digital Elevation Model (DEM) is used to analysis and extraction of tectonic activity indicators and drainage networks. Arc GIs 10.2, Excel soft wares were used to prepare different maps, finding required data and data analysis.

In this study SL index, standard SL index, concavity index, analysis of hypsometry curve and hypsometry integral is used to investigate the effect of tectonic activities on valleys and rivers and as well as calculating the required indexes in Ghale-chay basin, main stream, and subsidiary stream (By Astraler method).

1.3. Stream length-gradient index (SL)

It is one of indexes for tectonic force assessment which shows any irregularities in the river longitudinal profile and is stated by the following correlation:

Equation 1: $$SL = (\Delta H / \Delta L). L$$

SL= Stream length gradient

$\Delta H/\Delta L$= Stream slope or gradient of a sheet

ΔH= height difference of the case sheet

ΔL= branch length of the case sheet

L= length of the river from central point of the measured sheet to the headstream (Hack, 1973).

Theses parameters are measured by topographic maps and digital elevation model (DEM). The values of SL index were classified into three categories: 1 ($SL \geq 500$), 2 ($300 \leq SL < 500$) and 3 ($SL < 300$) (El Hamdouni et al., 2007).

2.3. Standard Index (SL/K)

Seeber and Gornitz (1983) presented force index in SL area for Assor River. Its high rate indicates river activity by a model called K known as (SL/K) index which tectonically is standard (Roostai and Nayyeri, 2011:144).

K= line slope which is computed by the following formula:

Equation 2: $K = (Hi - Hj) / (\ln Lj - \ln Li)$

Are beginning and end of the line in which K is calculated, i and j are length of the river.
This index which is related to tectonic activities; its high rate indicates more tectonic activity.
The river gradient index (K) is regarded as river slope balance (Hack, 1973). Tectonic events, weather and geomorphic history should be considered when relationship between the slope of the stream and the river gradient index (SL / K) is used (F. Colomboa, , P. Busquetsa, E. Ramosa, J. Verge´sb, D. Ragonac, 2000: 622). That the gradient indices for these subdivisions has been computed from 1.

3.3 **Hypsometry Curve Analysis**

Hypsometry curves illustrate distribution of land surface elevation in an area such as drainage basin and specify development of drainage areas (Guarnieri and Pirrota, 2008: 267).

On this basis the main variables needed for drawing hypsometry curves are:

h: height of a certain contour surface

H: total height of drainage basin
A: total area of drainage basin

a: The area of a specific curve from basin to the highest point of the curve(Guarnieri and Pirrota, 2008: 267).
In order to have dimensionless basic parameters that are x and y, their variables are assessed with relation to the whole, so that dimensionless numbers of x is the ratio of the total area of the partial area (Guarnieri and Pirrota, 2008: 267).

Equation 3: $X = a / A$

Dimensionless numbers of y is the ratio of the total elevation difference of the partial elevation difference.

Equation 4: $Y = h / H$

3.4 Integral hypsometry

A simple way to understand the hypsometric curve of a watershed is computation of integral hypsometry (Keller and Pinter, 2002). Integral is an index that depends on area of the region and is explained by the area under the curve.

Integral hypsometry of every area can be calculated by the following relation:

Hi = (average elevation – min. elev.) / (max. elev. –min. elev.).

Required data for calculate integrals is easily dragged from topographic maps. Minimum and maximum heights can be directly read in the map. Besides The average height can be extracted by reading at least 50 points altitude on a topographic map or can be calculated by using digital elevation model (DEM) (Keller and Pinter, 2002).

Moreover, integral values explain view transformation process in the cycle of erosion. So that integral value greater than 0.5 with a convex curve point out a young topographic landscape (as upland with deep valleys) and young topography means tectonic uplift of the region and new activities. The average value of the integral 0.4-0.5 and Sigmoid shape curve shows maturity of topographies and at last low value of this index (Less than 0.4) with a concave curve demonstrates aging stage of drainage basins which explains low activity of region tectonically (Garneer and Pirota, 2008).

3-5- concavity index

Longitudinal profile of a river represents slope of through length of the river. Generally river is more steeped in higher parts and up streams and gradually gets lower in the downstream. Such a feature may result in deformation of longitudinal profile which value may be different as an index reflects geomorphic features.

In order to draw it the ratio of h / H and a / A is used as well as finding x and y points that are as y=h / H and x = a / A.

Final data id made dimensionless by software, then area under the curve (A) is computed by math functions including integral, and finally Concavity index is calculated as measured areas of profile ratio using nexus 5 and subtracting it from number one (Ohmori, 1991, 1994; quoted in Nayyeri, 2010) (figure 3).

Equation 5 : $Ca=A_1/(A_1+A_2)$

In the current study determining type of fracture in longitudinal profile, overlay and intersection of various formations is done by using geological map 1/100000 of the longitudinal profile of the river and analysis of longitudinal profile accompanied with stone type show two kinds of fractures:

- **Fractures that are in accordance with the lithology changes.**
- **Fractures that are completely inside the lithology.**

The first type of fractures which are consistent with lithology attribute to lithology change. But those which are not consistent with lithology are interpreted as non-lithology effect (Roostai and Nayyeri, 2011).

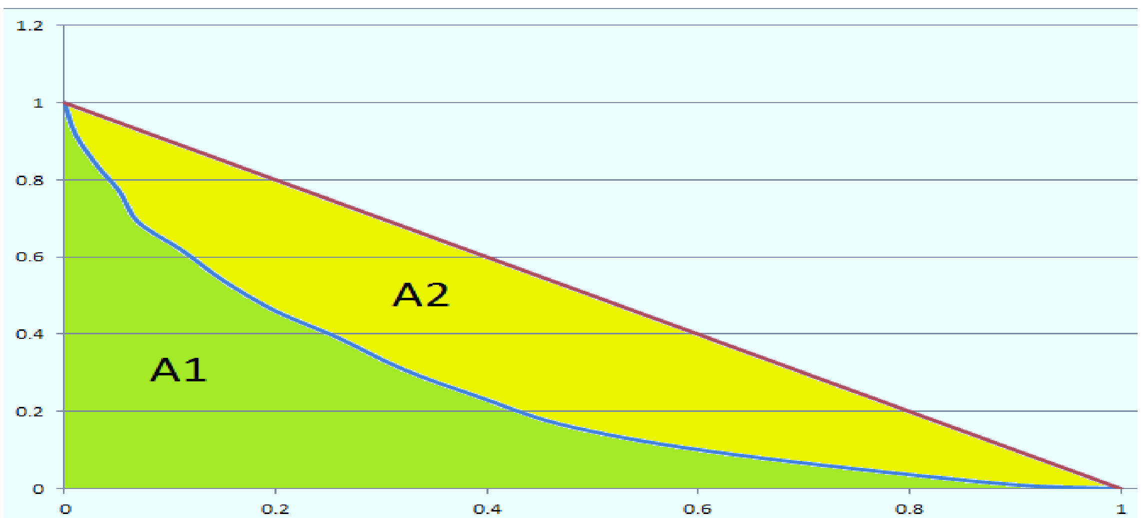


Figure 3. Concavity measurement method, here A1 is distance between the longitudinal profile and horizontal axis; A2 is distance between the longitudinal profile and the straight line connects highest point of profile to the bottom of it.

4. **Discussion**

In order to compute longitudinal slope of the river and standard Index in Ghale-chay basin area in 9 altitude on the main stream, 5 altitude on the channel sub 1, and finally 4 height areas on sub-channels 2 and 3 were investigated, longitudinal profile was drawn, SL values and standard index for each of them were computed, and The results are given in related tables (Tables 1 to 4).

Table 1: Values of the SL classes (stream-gradient index) and SL/K in 9 elevation ranges in the main stream

SL/K	K	Class of SL	Values (m) SL	elevation ranges
1.006	740.74	1	745.07	1300-1500
1.003	571.42	1	573.34	1500-1700
1.02	465.1	2	475.12	1700-1900
1.02	434.78	2	446.77	1900-2100
1.007	500	1	503.85	2100-2300
0.98	1250	1	1226.23	2300-2500
1.02	476.19	2	486.69	2500-2700
1.03	298.5	2	307.27	2700-2900
1.03	294.11	2	305.16	2900-3100

563.27∑ :

Table 2: Values of the SL classes (stream-gradient index) and SL/K in 5 elevation ranges in Sub-stream 1

SL/K	K	Class of SL	Values (m) SL	elevation ranges
1.02	454.5	2	466.13	1900-2000
1.003	256.4	3	257.18	2000-2100
1.03	163.93	3	170.42	2100-2200
1.04	140.84	3	146.6	2200-2300
1.05	123.45	3	130	2300-2400

234.06∑ :

Table 3: Values of the SL classes (stream-gradient index) and SL/K in 4 elevation ranges in Sub-stream 2

SL/K	K	Class of SL	Values (m) SL	elevation ranges
1.006	416.66	2	419.18	1700-1800
0.99	344.8	2	343.63	1800-1900
1.02	250	3	256.14	1900-2000
1.03	153.84	3	159.18	2000-2100

294.53∑ :

Table 4: Values of the SL classes (stream-gradient index) and SL/K in 4 elevation ranges in Sub-stream 3

SL/K	K	Class of SL	Values (m) SL	elevation ranges
1.008	526.31	1	530.72	1900-2000
1.005	400	2	402.2	2000-2100
0.99	454.54	2	453.88	2100-2200
0.98	416.66	2	412.15	2200-2300

449.73∑ :

Regarding value of SL index main waterway can be attributed to class 1 according to Hamadoun (2008) classification which means with many changes, Sub channel 1 in the class 3 which means with calm tectonic and regular profile and without changes. Sub channel 2 from an altitude of 1700 to 1900 has moderate tectonic activities, and from 1900 to 2100 height there are no tectonic activities. However, the average value of SL index is classified in Class 3 that is with calm tectonic and regular profile and without changes, and sub stream No. 3 is in Class 2 with low and semi-active changes (Figure 4).

Based on standard index, there are no balance state in any parts of the river and most of major streams and tributaries has a steeper slope than the equilibrium which can be the result of active tectonics and lithology of the area.

To determine the shape of hypsometric curve in the case area, hypsometry integral of the area should be computed. Large amounts of integral that is greater than 0.5 means highland areas are less subject to erosion or it may be indicator of young views which are made by tectonic activities. Moreover there are peaks and valleys, and high topography compared to the average drainage basin such as raised levels and plateaus that have been cut by rivers. The average value of hypsometry integral and average value of the hypsometry integral indicate changing stage of the area; aging process or further developments in the region, *Hi* value is less than or equal to 0.4. Except that erosion maintain new topography (Keller and Pinter, 2000).

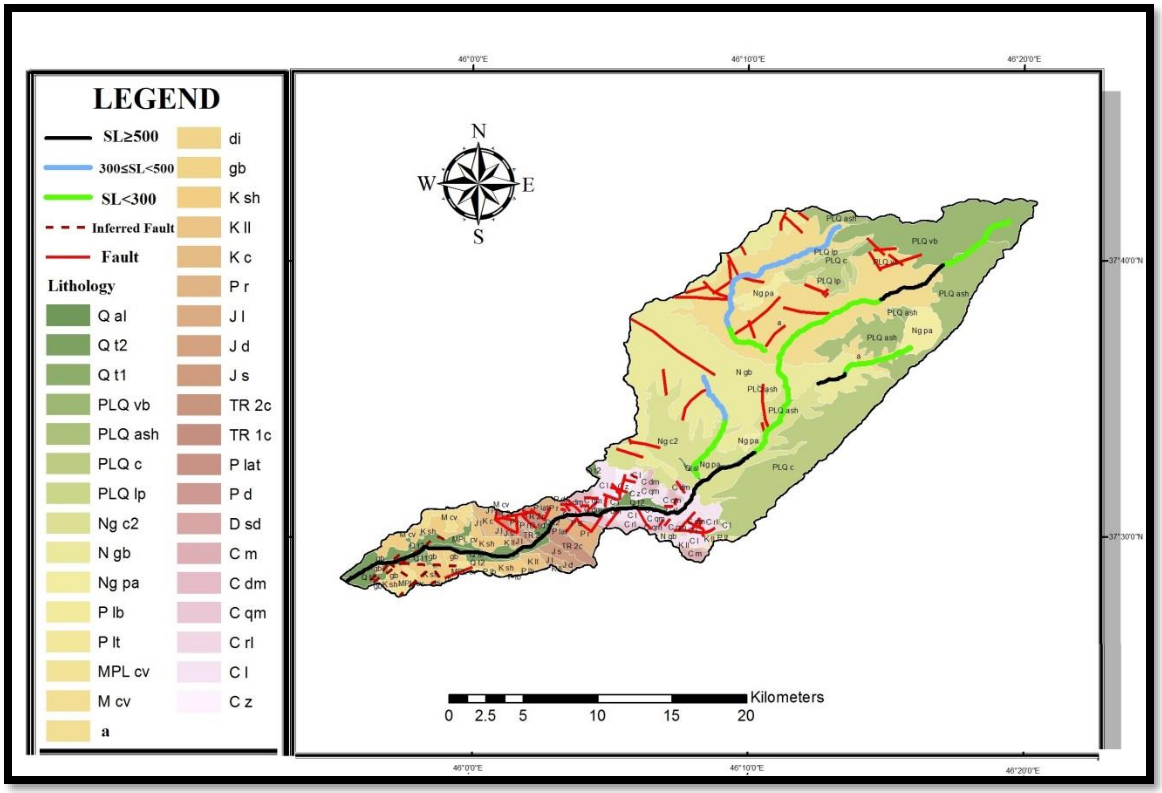
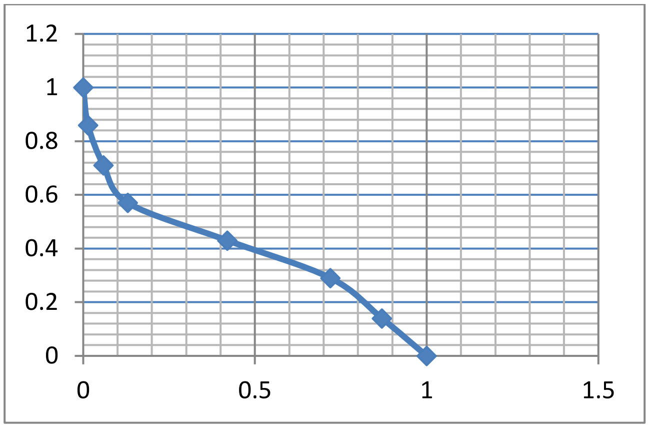


Fig. 4. SL index along the geological map

In this study maximum and minimum height and average height of the region is calculated using topographic map of the area 1/ 50000 and DEM in GIS environment. Hypsometric index 0.5 of main channel of the area shows its young state toward maturity which indicates balanced proceeding of geomorphic processes but it needs time to reach the stage of aging and smoother topography. Figure 5 and table 5 illustrates its characteristics.

To obtain the concave (curved) rate, firstly the data have been made dimensionless using equation 3 and 4 and related numbers are computed on the transfer axis, related curve is drawn, and area under the curve is calculated using integral in Excel software by (B1 + B2) / 2 * (A2-A1); by subtracting the resulting data from number one, amount of curvedness is computed.

Table5. Hypsometric table Of main stream



h(m)	X=a/A	Y=h/H
1300	1	0
1600	0.87	0.14
1900	0.72	0.29
2200	0.42	0.43
2500	0.13	0.57
2800	0.059	0.71
3100	0.014	0.86
3400	0	1

Fig. 5. Hypsometry curves of main stream

$Ca=A_1/(A_1+A_2) \longrightarrow \quad Ca= 0.407/(0.407 + 0.12345) = 0.76$

According to this, Concavity index of basin is 0.24 which indicates moderate tectonic activities in the area (figure 6). The most important reason of the fact that longitudinal profiles concave increases in upper side and up streams is resistant lithology in this area and convexity status in downstream is caused by multiple faults in this area.

Determining type of fracture in longitudinal profile, overlay and intersection of various formations is done by using geological map 1/100000 of the longitudinal profile of the river and analysis of longitudinal profile accompanied with stone type show two kinds of fractures:

- **Fractures that are in accordance with the lithology changes.**
- **Fractures that are completely inside the lithology.**

The first type of fractures which are consistent with lithology attribute to lithology change. But those which are not consistent with lithology are interpreted as non-lithology effect (Roostai and Nayeri, 2011).

There are a lot of differences across the main stream regarding distribution of these two types of fractures. The place in which lithology changes, there are numerous fractures so that in the downstream areas in height between 1450 to 1600, fracture are more consistent with lithology because in this area there is a difference between the types of rocks and moving from a resistant structure to a nonresistant structure have to be accompanied with fracture (Zavoianu 1985:195). In this region on the border of quartzite, red sandstone and rhyolite with the recent alluvial fracture is created. Moreover, in 1700 to 1900 heights, there are fractures between andesitic volcanic breccia associated with altered zone and conglomerates, agglomerate, but in downstream on the border of limestone, gabbro, shale and sandstone terraces of young and recent alluvial, no fracture can be observed. Existing fractures inside the lithology can be the result of regional faults. Finally in upstream of the region after the altered zone due to the similarity of gender and strength of rock compared to each other, there are less fracture than central and down streams (figure 7).

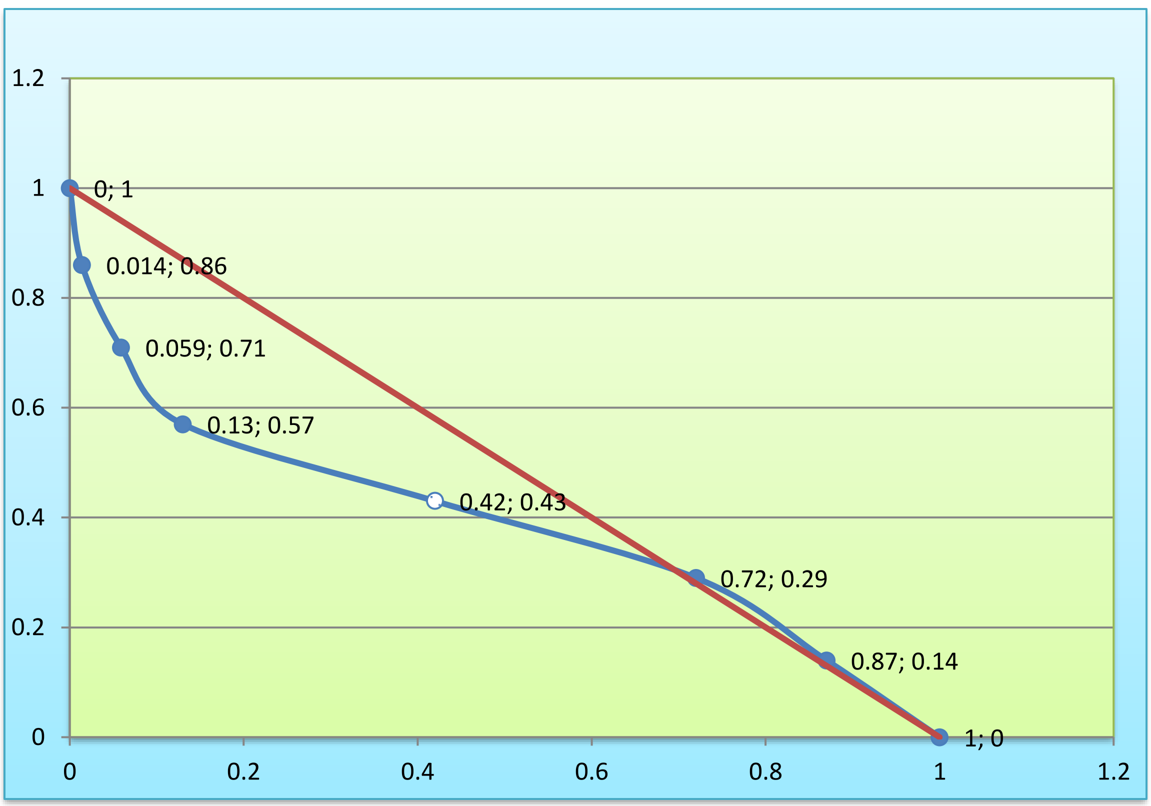
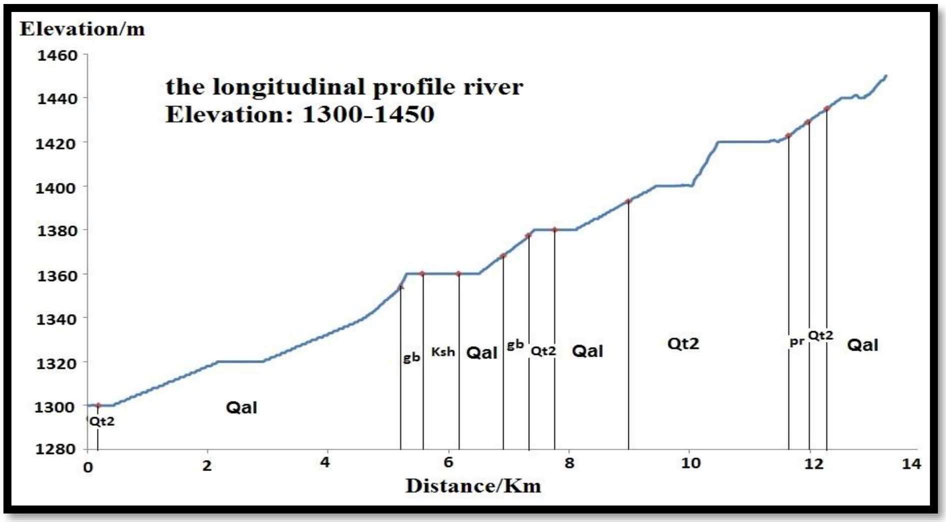


Fig.6. Concavity index chart


Elevation/m
the longitudinal profile river
Elevation: 1300-1450
1460
1440
1420
1400
1380
1360
1340
1320
1300
1280
0
2
4
6
8
10
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Distance/Km
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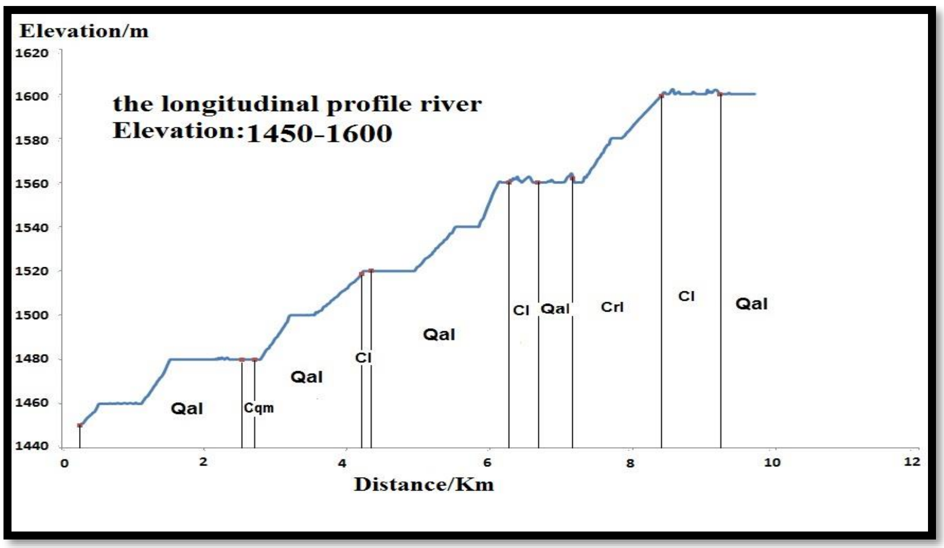
Elevation/m
the longitudinal profile river
Elevation:1450-1600
1620
1600
1580
1560
1540
1520
1500
1480
1460
1440
0
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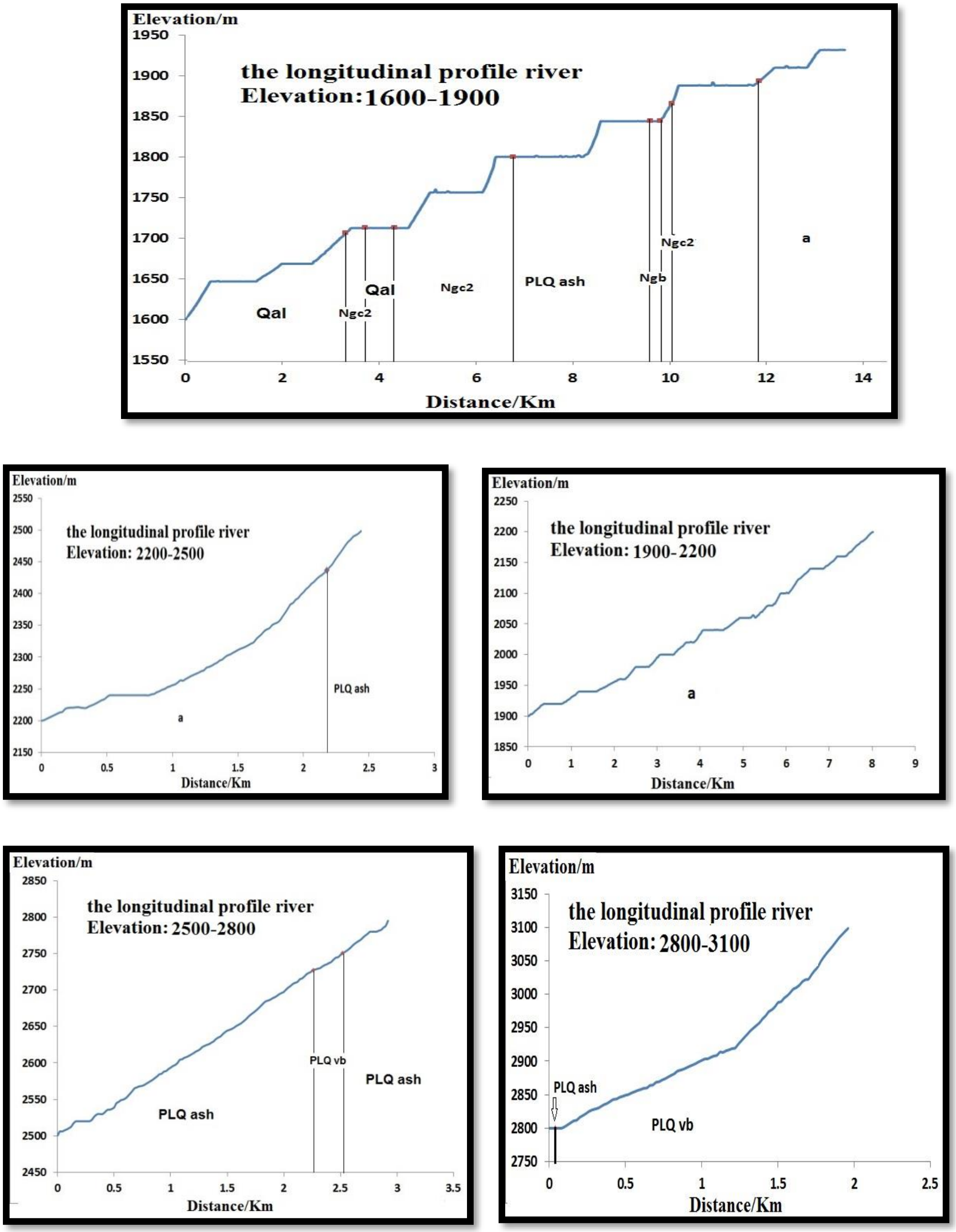

Figure7. Intersection of the longitudinal profile of the main stream and lithology: Qal: Recent alluvial, gb: gabbro, Ksh: shale, sandstone, limestone and volcanic rocks, Qt2: Young terraces, Pr:

Limestone (Ruteh), Cqm: Quartzite (Mila Formation), Cl: red sandstone, Crl: Rhyolite, Ngc2: conglomerate, agglomerate and volcanic breccia, PLQ ash: Volcanic ash, Ngb volcanic breccia with andesite, a: altered zone, PLQvb breccia and andesitic lava.

5. Conclusion

River systems are greatly influenced by active tectonics and are sensitive to faulting and deformation of the surface area. In this study based on geomorphic indexes, tectonics and lithology of the longitudinal profile of Ghale-chay River was investigated. According to Figure 4 SL index is semi-active in the upstream basin by Changes in lithology and alteration zone at the beginning of the river, SL index is activated and the area gets steeper. After passing a specific distance the river returns ti semi-active state and in the middle of the basin on at the beginning recent alluvium to downstream areas remain active. In addition, in downstream areas, effect of many active faults on SL index is evident. Also based on standardized index, there are no equilibrium in length of the river and most of the major streams and tributaries has a steeper slope than the equilibrium which can be the result of active tectonics and lithology of the area.

To determine the hypsometric integral of the case area, hypsometric integral was calculated; hypsometric indexes indicate a young state moving towards maturation stage for the basin which explains balancing state of the geomorphic processes but it needs time to reach aging stage and smoother topography. Concavity index is correlated with tectonic activities and its high levels shows high tectonic activity. According to this, Concavity index of basin is 0.24 which indicates moderate tectonic activities in the area. The most important reason of the fact that longitudinal profiles concave increases in upper side and up streams is resistant lithology in this area and convexity status in downstream is caused by multiple faults in this area. So based on indexes under investigation, Ghale-chay area has relatively active tectonic activities.

To investigate the effect of lithology on longitudinal profile of the river, overlay and intersection of various formations, geological map 1/100000 with longitudinal profile of the river was used. It was found that in downstream areas fracture are more consistent with consistency between lithology because there are differences between stone types. In upstream areas after altered zone, due to the similarity of genders and resistance rocks compared to each other, there are less fractures in central and downstream areas of the region.

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