Available online at www.sciencedirect.com
ScienceDirect
Procedia - Social and Behavioral Sciences 120 (2014) 576 – 585
Procedia Social and Behavioral Sciences

The 3rd International Geography Symposium - GEOMED2013

Interpretation of the morphological characteristics of Şehir creek basin (İspir) regarding fluvial geomorphology and regional tectonics

Atilla Karataş[a]*, Deniz Ekinci[b]

[a]Mustafa Kemal University,Faculty of Art and Science, Geography Department, Antakya/Hatay, 31040-TURKEY
[b]İstanbul University, Faculty of Letters, Geography Department, Fatih/İstanbul, 34459-TURKEY

Abstract

Investigations on the morphometric characters of basins facilitate our understanding regarding many issues about the structure of the earth's crust, the life of earth and the related factors and processes. Those quantity-based studies that ensure provision of more concrete data about the fluvial process in the basins that are shaped by the rivers make it possible to generate more consistent and well pointed interpretations. In this context, some morphometric characteristics were identified in Şehir Creek Basin. The issues pointed by the data obtained in this manner were assessed to analyze and interpret basin morphology.
Accordingly; various factors that affect the shaping of the basin and their correlations were identified and it was determined that the basin is between youth and maturity stages in terms of erosion cycle however it also includes sections that reflect complete youth stages based on neo-tectonic activities seen in some parts. A serious asymmetry was observed between the source and estuary sections of the basin that shows a relation with the young faults that were active in the Quaternary which were not included in any geology maps of the area. Results obtained by interpreting the morphometric analyses were investigated and confirmed by field studies as well.

Selection and peer-review under responsibility of the Organizing Committee of GEOMED2013.

Keywords: Basin morphometry; fluvial geomorphology; Şehir Creek; İspir.

1. Introduction

Rivers are among the most important shareholders in shaping the earth based on their functions such as erosion, conduction and accumulation. The dominant external force in the fluvial morphogenetic region which substantially represents the zone Turkey is included in is the surface flowing waters, especially rivers. As is known, the concept of

*Corresponding author. Tel.: +90 326 245 5845-1110; fax: +90 326 245 5836.
E-mail address: akaratas@mku.edu.tr.

Selection and peer-review under responsibility of the Organizing Committee of GEOMED2013.
doi:10.1016/j.sbspro.2014.02.138

river corresponds to "all bodies of water that flow on earth that are subjected to beds" (Atalay, 1986; Hoşgören, 2004). From here, we can infer that flood waters that do not flow on a bed also trigger the fluvial process and under favorable conditions generate their own beds as a result of erosion and conduction activities. Therefore, operation of the fluvial process is shaped according to the relationship among all shareholders (Miller et al., 1990). Nevertheless, the character of the landscape resulting at the end of this process is determined based on the effective elements of the process and the geologic, lithologic, tectonic and geomorphic structure elements, which are the components of the landscape; direct the erosion activity and geomorphologic evolution in the fluvial morphogenetic region. Accordingly, it is not possible to assess the geomorphologic shaping process of the Şehir creek independently from the said components. However, there are discussions regarding the direction and extent of impact each parameter has.

On the other hand, it is now possible to clearly and quantitatively express these ambiguous and relative conditions through morphometric analysis methods developed researchers such as Horton (1932, 1945, Strahler (1952, 1957), Schumm (1956), Leopold & Miller (1956), Melton (1957), Hack (1957) and Morisawa (1959). These pioneer methods were later developed by Strahler (1964), Eagleson (1970), Doornkamp & Cuchlaine (1971) and Hack (1973) and they gained more functional structures. Krishnamurthy et al. (1996), Nag (1998) and Nag & Chakraborthy (2003) used Remote Sensing (RS) Data in their studies. Concrete data were obtained about the geomorphologic structure in Şehir creek whose morphometric analysis was undertaken in the light of these studies. The relationship of these data with the fluvial geomorphology, cyclical erosion processes and regional tectonism was interpreted and as a result, processes that have dominated the basin were displayed quantitatively.

2. Material and Method

The geology map of the basin was generated according to H 46 map sheet of geology map scaled 1/25.000 (Saraloğlu et al., 1992), H 46 map sheet of geology map scaled 1/100.000 (MTA, 2011) and Trabzon map sheet of geology map scaled 1/500.000 (MTA, 2002). Topography map and digital land model were composed based on ASTER GDEM 15 m resolution Digital Elevation Model (DEM) prepared by METI and NASA. Morphometric analyses were undertaken according to the methods cited literature and the basin area was divided into 1 km² grids in calculating the valley length per km² and erosion and fragmentation intensity. Therefore, it was possible to undertake analyses in narrower areas and locations with different quantities were identified in more detail.

3. Location and General Geographical Characteristics

Şehir creek Basin is located in northeastern Anatolia, in the west of the Black Sea Region and in the south part of Eastern Black Sea (Fig. 1). Çoruh River situated in a narrow gulley between Mescit Mountains in the south and Northern Anatolia Mountain in the north receives a great number of river branches from both mountainous areas. The topic of this paper is the draining of basin water of Şehir creek with springs in Mescit Mountains which is a branch in İspir district center of Erzurum that flows into Çoruh River.

Average elevation of the basin with a total 79,2 km² surface area of is 2.080 m. The section where elevation is the lowest is the mouth of the stream (1.163 m), and the section where the elevation is the highest is the Velibaba hill (3.186 m) in the north of Mescit Mountains (Fig. 1). Small rivers that are converged in the north of Sandıklı village in the basin are called Şehir creek and continue their flow roughly in the southeast-northwest direction. In Kavaklı village, the creek meets the Korgaçayı creek, an important branch, which flows from the south. The creek which continues southeast-northwest directional flow for a while more turns towards the west in the south of İspir with a bend and reaches Çoruh River.

In geologic terms, the basin is represented with a thrust belt in the south of Eastern Pontids and a zone which dominantly has deformed volcano-sedimentary units (MTA, 2011). The nappes which are collected through overthrust in the basin where many units from various periods and facies such as the Upper Jura to Quaternary are interconnected cause inconsistency between the geological ages of the units and their locations in stratigraphic storage (Fig. 1). This complex lithological structure and tectonic deformation facilitated the formation of a variable and rugged relief. It is possible to observe steep slopes and deep valleys in the basin along with wave cut terraces surrounded by flat ridges. These steep lands are not suitable for soil layers to cling to and mainly colluvial soil and clayish and salty soils are dominant in areas with relatively low slope. According to İspir meteorology station data, the average annual temperature in the basin is 10,3°C and average annual precipitation 473,5 mm.

The temperature and climate values that point to semi-arid conditions correspond to flora under anthropogenesis steppe dominance and rarely observed oak forests. According to 2011 data, the basin consists of a total population of 6.588; 6.257 of which live in the district center and 331 in villages (www.tuik.gov.tr). The economic activities of the population are mainly centered in service center and trade in the district but agriculture and animal husbandry are more common economic activities in the villages.

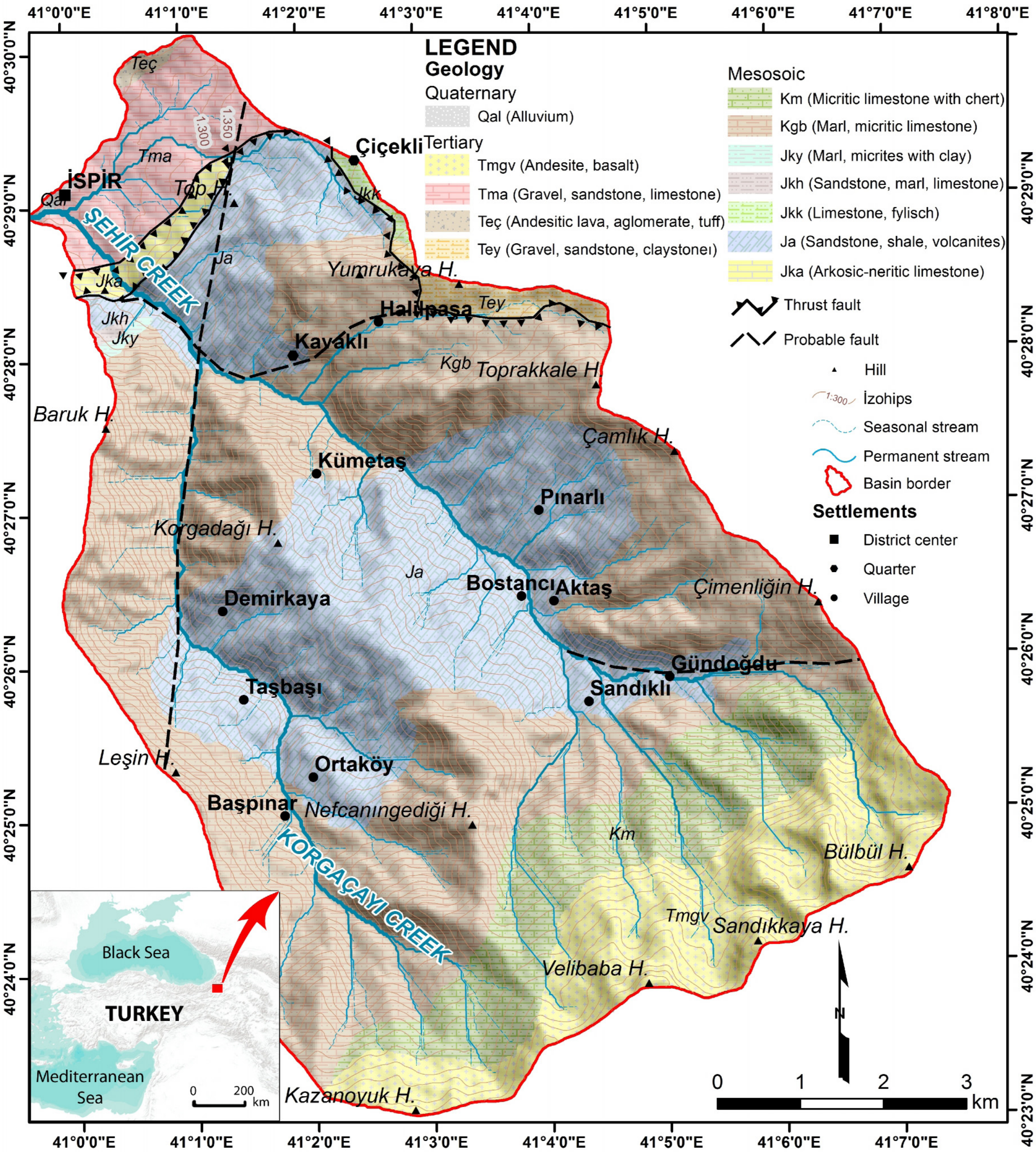

Fig. 1. Location, topographic and geological maps of Şehir Creek Basin

4. Findings and Discussion

Şehir creek Basin which can be regarded as a small scale basin considering the its surface area of 79,2 km² has a perimeter of 39,7 km. The width of the basin is 8 km and its length is 13 km. In geometric terms, a circle with the same surface area as the basin has a perimeter of 32 km with a radius of 5 km and a circle with the same perimeter as the basin has a surface area of 128 km² and its radius is 6,3 km. The length of the Şehir creek, the main river in the basin to the center point is 7 km from the estuary and 6 km from the spring. The morphometric characteristics of the Şehir creek were identified with the help of the data mentioned above:

Elongation ratio is the ratio of main river bed to the radius of a circle that has the same surface area as the basin. Basin elongation ratio for the Şehir creek Basin is 1,5 (Table 1). This value shows that the basin has an elongated shape in the level of 1 1,5. Therefore, it can be argued that fluvial erosion mostly operates in the vertical direction.

Table 1. Some morphometric values of Şehir Creek Basin

Area (km²)	Perimeter (km)	Elongation Ratio	Form Factor	Asymmetry Factor (%)	Gravelius Indices	Relief Ratio	Mean Slope (%)	Mean Altitude (m)	Stream Slope (Benson)	Hypsometric Integral	Drainage Density	Stream Density
79,2	39,7	1,5	0,47	40,5	1,25	0,87	38	2.080	1,97	0,45	2,51	1,19

Form factor is the ratio of basin area to basin length squared (Eagleson, 1970). This ratio helps to understand whether the basin has a circular of elongated geometry. This characteristic has a determining impact on the catastrophic parameters such as flood magnitude and flood lag time as well as providing ideas about the erosion cycle in the basin. Basin form factor was calculated to be 0.47 for Şehir creek Basin. Therefore, it can be argued that the basin has an elongated look, close to oval. This shows that the basin has not completely recovered from the primary relief impacts of the fluvial erosion.

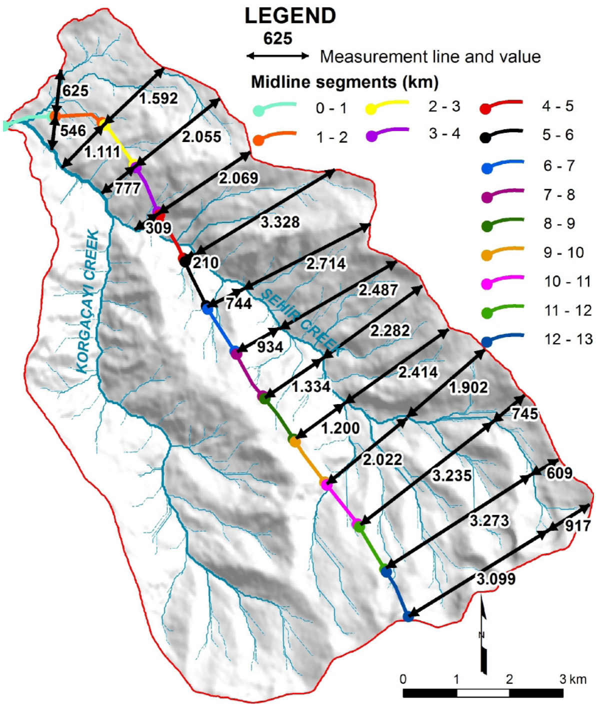

Fig. 2. Transverse topographic symmetry factor components

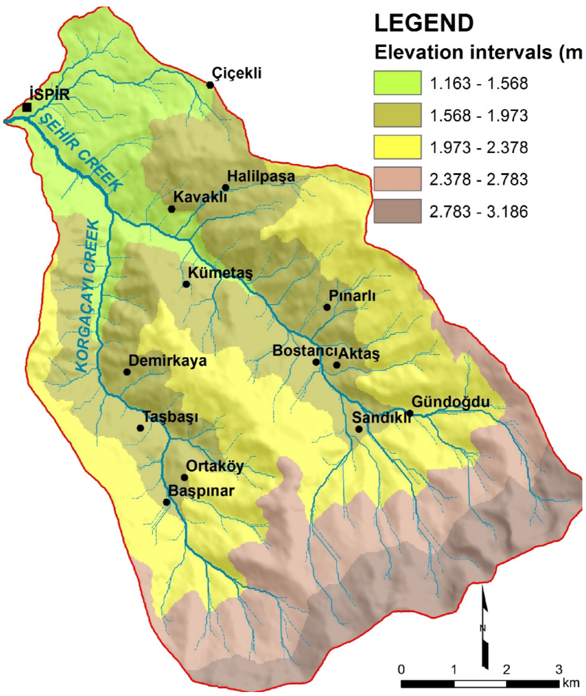

Fig. 3. Elevation Grades Map of Şehir Creek Basin

Gravelius indices expressed as the ratio of basin perimeter to a circle perimeter of the same surface area as the basin (Gravelius, 1914) points out to larger impact of relief on erosion activities in the basin. Gravelius coefficient was calculated to be 1.25 for Şehir creek Basin. This can be interpreted as relief's gradually becoming indistinct or the manifestation of a lithological character that will act as a foundation to flattened ridges that have not been much exposed to fracturing by the rivers.

Basin asymmetry factor is the ratio of the section on the right part of the basin elongated axis from the spring to the estuary to the total basin area and it is expressed in percentages (Hare & Gardner, 1985). This characteristic, an evidence of tectonic distortions that affected the basin provides ideas about the hidden dislocation lines. Area distribution in Şehir Creek Basin is 32 km² on the right of the elongated part and 47,2 km² on the left. This distribution has caused the basin asymmetry factor to reach the level of 40.5% (Table 1). Therefore, it is clear that a distortion evidencing tectonic impact took place in the basin.

Transverse topographic symmetry factor is another element used in the morphometric assessment of the basin. It is the ratio of the length of thalweg line-middle line to the length of watershed-basin middle line (Cox, 1994). This index, beneficial to detect the divergence and distortions in the course of the main river, was found 0,47 for Şehir creek Basin. This level of transverse topographic symmetry value is indicative of asymmetric structure in the basin and the deformation which caused the structure and whose traces have not been disappeared yet (Ekinci,2011) (Fig. 2).*Elevation* values of the basin change between 1.163-3.186 m land the average elevation is 2.080 m. Sections with higher elevation are mostly situated in the south and southeast mountainous areas and the lowest elevation in the basin is observed in the north where the estuary of Şehir creek is located (Fig. 1).

Slope in the basin is average 38% and the maximum slope is observed to be 145%. Slope levels with irregular and unbalanced distribution throughout the basin are low in the lower courses of Şehir creek but increase in the upper courses of Şehir Creek and in the lower course of Korgaçayı creek. Areal investigation of slope ranges in the basin shows that the widest area is covered with 20-30% range and the narrowest area is covered with 10-20% range. In 12% of the basin slope is higher than 49%.

Aspect conditions generally show parallelism with valley extensions. The basins where the main rivers roughly extend in the southeast-northeast direction, the predominant aspect conditions are centered in southwest and northeast. Therefore the declivities with north and west components generate the predominant aspect conditions. Average aspect value in the basin is southwest sectored with 205,8°. This situation is an indicator that declivity slope directions are shaped according to fluvial processes.Basin relief is composed of the difference between the maximum and minimum elevation values in the relief (Schumm, 1956; NIH, 1998). This value is 2.023 m in Şehir creek Basin and it is regarded as high level for a basin whose length is not more than 13 km. however when the average slope of 38% is entered in the equation, the slope value which corresponds to 15.6% in the basin relief ratio will be seen as low in reality. This situation is evidence that the actual relief of the basin is processed in such a manner by erosion activities to create unevenness in the territory.

Relative elevation is calculated by dividing the elevation values for specific elevation grades in the basin to relief ratio and relative area is obtained by comparing the total area under each of these elevation grades to the basin area (Strahler, 1952). 5 grades in 405 m amplitude were identified in Şehir creek Basin to calculate the relative elevation and relative area (Fig. 3). Their relative elevations change between 0-0,79 and their relative areas change between 0,-0,86 (Table 2). Accordingly, the highest relative area ratio is in the range of 1.973-2.378 m (0.31) whereas the lowest relative area ratios are in 1.163-1.568 and 1.568-1.973 ranges (0,14). This situation shows that the lower sections in the basin cover narrow areas whereas sections with medium elevations cover wider areas.

Transition from youth to maturity in terms of fluvial erosion process may be claimed in the basin where hypsometric integral (Pike & Wilson, 1971; Mayer, 1990; Keller & Pinter, 2002) corresponds to the value of 0,45. Hypsometric curves of the basin were drawn according to both relative elevation and relative area ratios (Strahler, 1952; Pike & Wilson, 1971) and to areas that correspond with each elevation grade (Bilgin, 2006). The fact that the hypsometric curve includes both concave and convex curves shows that the basin is active in terms of tectonics and/or surfaces with different erosion characteristics in terms of lithology are found together in the basin (Ekinci, 2011). On the other hand, the abundance of areas whose digital values are close to 1 proves that newly formed surfaces are common.

Curvature degrees of basin relief are distributed as follows: 50,25 % concave, 49,25 % convex and 0,50 %

flatland (Fig. 4). The basin has the characteristics of advanced youth and sometimes maturity in terms of the distribution of curvature degrees (Scheidegger, 1991). This type of result is peculiar for a tectonically active zone.

Erosion and Fragmentation Intensity Degrees for Şehir creek Basin were identified by gridding the total basin area to grids of 1 km² and by calculating the elevation differences in each grid to interpolate the results. Accordingly, the elevation difference for each 1 km² grid is minimum 76,45 m and maximum 633,17 m. the areas that were subjected to severe erosion with high elevation differences are mostly found in the lower course of Korgaçayı creek and in areas below the perennial snow limit where fluvial activity increase in the spring of Şehir creek (Fig.5).

Stream slope features in the basin was identified by calculating the average slopes of the streams in each order. Accordingly, the lowest river slope in Şehir creek Basin belongs to the 5th order with 0,05 and the highest river slope belongs to the 1st order with 0,33 with an average river slope of 0,18 for the basin (Table 2). Benson Method was also utilized which is based on calculating the average slope between the two points that correspond respectively to the 10% and 85% of the main river from its spring and the average river slope in the basin was calculated to be 1,97.

Bifurcation ratio in Şehir creek Basin was determined according to Strahler (1957, 1964) method. Results show that bifurcation degrees between indices change between 1 - 5,07 with an average of 3,57 (Table 2). The fact that northern sectored rivers in Şehir creek Basin are longer and heavily bifurcated shows that the basin has been affected from tectonism and lithological differences have affected the erosion activities.

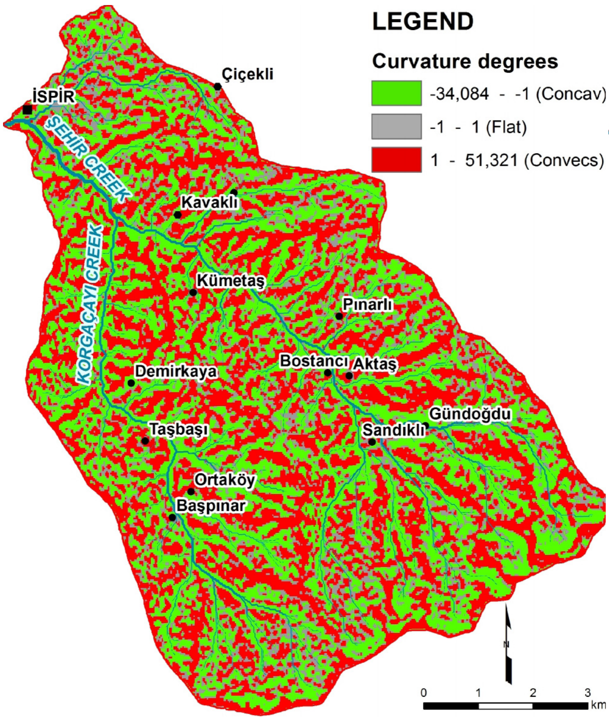

Fig. 4. Curvature degree map of Şehir Creek Basin

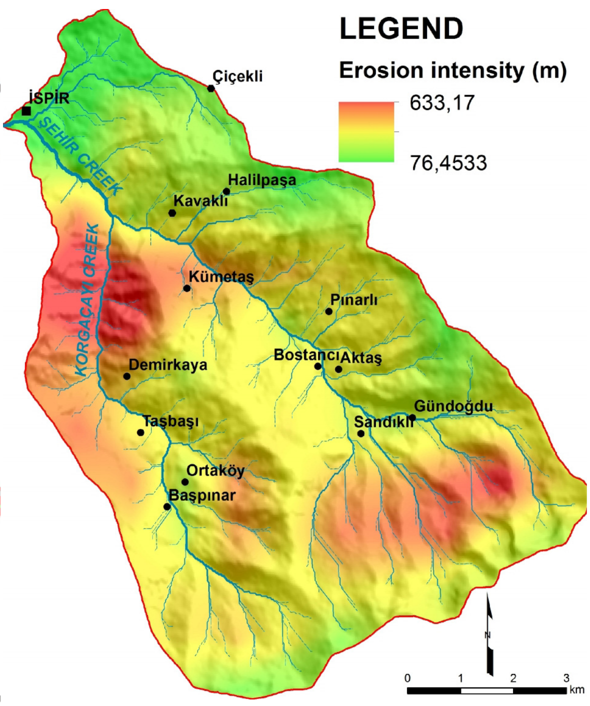

Fig. 5. Erosion and fragmentation intensity map of Şehir Creek Basin

Drainage density is the ratio of total drainage length in the basin to basin area (Horton, 1932). Accordingly, valley density in Şehir creek Basin is 2.51 and valley length calculated for each 1 km2 grid is maximum 5.615 m and minimum 0 with an average of 2.300 m. The fact that valley density is higher in areas closer to main rivers and lower in areas with lower level indices throughout the basin show that surface flow based on precipitation is low and permeable units are common in general.

Stream density based on the total stream numbers in all indices and the ratio of basin area (Horton, 1932) was found to be 4,82 for Şehir creek Basin . This value shows that number of streams for each km2 of the basin is close to 5 and the relatively high level also implies the existence of semi-arid conditions. Total river lengths in the basin are included in the range between 3 km (5. Order) and 104 km (1.Order) with an average of 0,92 km. considering the average value, it is possible to mention the existence of rather short rivers in the basin. Therefore, although there are many indicators that point to a relief close to maturity stage in general, the existence of a young drainage network which has not completed its development proves an inconsistency between the observed relief and the actual geomorphologic process that is still generated.

Table 2. Numerical values of elevation, slope and drainage characteristics in Şehir Creek basin

Area (km²)	Bifurcation Ratio	Stream Length (km)	Stream Number	Stream Slope	Elevation Limit (m)	Area (km²)	Relative Elevation	Relative Area
1. Order	3,78	104	287	0,33	*1.163*	79,2	0	1
2. Order	5,07	52	76	0,24	*1.568*	68	0,19	0,86
3. Order	5	21	15	0,19	*1.973*	56,7	0,39	0,72
4. Order	3	18	3	0,09	*2.378*	32,2	0,60	0,41
5. Order	1	3	1	0,05	*2.783*	19,9	0,79	0,25
Average	3,57	39,6	76,4	0,18	*3.186*	0	1	0

Lengthwise profile of the Şehir creek is concave and provides and image relatively close to balance profile. The fact that predominant "V" shaped valleys are observed in cross sections taken from various parts of the basin proves to be contradictory with the lengthwise profile of the Şehir creek. In the upper course where elevation is over 2.000 m the existence of 'U' profiled valleys are noteworthy. These areas point to the existence of glacier activities in the recent geological past. The existence of "V" shaped young koyaks in the floors of some "U" profiled valleys is another point which needs to be studied in the topographic profiles of Şehir creek Basin.

When the superimposed, extrapolated and combined profiles of the basin are examined, glacial erosion and fluvial erosion are observed to be predominant in higher and lower areas respectively. Although it is not highly possible to observe linearity related to erosion surfaces in the region, a uniform and colorless topography that points to the activities of cover glaciers in areas higher than 2.700 m is noteworthy.

The geological cross section of the basin was generated based on the line between İspir and Kazanoyuk Hill. In this way, contact relationships of all geological units and their distribution in the basin were better understood along a line that represents the basin in general.

Investigation of the North-South direction geological cross section of the basin shows that autochthonous that belong to the Pontid Zone in the north and the their cover units that develop along the south side were pushed to Upper Jura-Cretaceous old sediments that belong to Çermeli Nappe (Akdeniz et al., 1994) overlaid by volcanites discordantly settled on the unit and on Ovacık assembly on farther south. It was also observed that Ovacık Assembly consisted of overthrust nappe and nappes in itself due to compression impact. Although the geological cross section shows these results, it is known that the units in the south are collectively pushed to Pontid autochthonous in the North (Akdeniz et al., 1994).

5. Discussion

Şehir Creek Basin where regional effects of the compression regime are still observed the traces of the exact location of the paleotethys suture zones were generally lost due to the activities of the neo-tectonic enclave (Şengör et al., 1980; Akdeniz et al., 1994). They have been transformed into narrow and lengthwise basins acted as nappe pockets in especially Lower Miocene and inlets and lakes with limited relationships with the seas. These sedimentation basins were filled in Upper Miocene period and caused the disappearance of lakes between the Miocene and Pliocene periods and later marine sediments were replaced by fluvial sediments with evaporate characters (Akdeniz et al., 1994). This situation has made it harder to comprehend the shaping of the suture zone basins which includes the Şehir creek Basin during the fluvial process.

Supporting data about some hidden tectonic structures and the obscured parts of fluvial process were obtained through morphometric investigation of morphologic evidence. In this context, vertical erosion velocity is low in the lower course of the basin located in the over thrust zone where old ocean sediments were pushed onto Pontid autochthonous. This situation is clearly manifested by parameters such as vertical and lengthwise topographic profiles, distribution of erosion and fragmentation degrees and slope parameters.

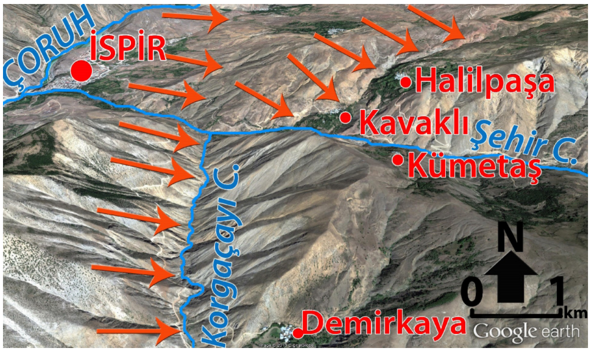

Fig. 6. Linearity that belongs to fault morphology in Şehir Creek Basin (from the south)

Fig. 7. Relationship of the line where river bed is located to the geological structure (from southeast)

The fact that hypsometric curve follows a fluctuating course instead of a perpetual/chronic one can be interpreted in the context of the existence of different situations in terms of fluvial processes and tectonic activities in various segments of the basin. On the other hand, curvature degrees and erosion and fragmentation intensity degrees calculated for the whole basin point to a fluvial process in advanced youth period. However, according to indices such as transverse topographic symmetry and basin asymmetry factors present the traces of severe deformation whose marks have not been erased yet. As stated by many researchers before (Şengör at al., 1980; Görür et al., 1983; Akdeniz et al., 1994), some structural tectonic elements are not observed although they are included in literature related to regional geology or in geology maps of various scales due to the fact that the structures that belong to deformation are well hidden by cover units. Only by taking into consideration the linearity that directs the river beds, the facets generated by fault morphology in valley slopes and the routes where rivers are embedded in can one easily comprehend and prove that active tectonics is still effective in the region (Fig. 6, 7).

Fig. 8. Native rock terraces and rejuvenated valleys in the west of Kavaklı

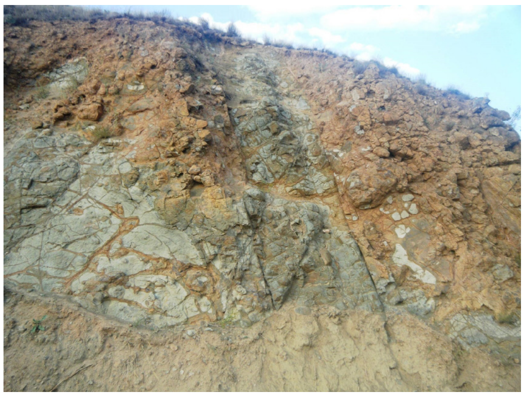

Fig. 9. In the northwest of Kavaklı Village, a sample of faulting created in the post-ophiolitic process

Basically it is possible to observe evidence similar to active tectonics in the field as well. Native rock terraces created as a result of rejuvenation caused by both regional rejuvenation, hanging valleys and incised meanders and faults that have been recently active are indicators of a tectonically active area (Fig. 8, 9).

In the light of all these data, it is observed that Şehir creek Basin follows a fluvial erosion course that contradicts the regional tectonism. One of the basic reasons for this situation to occur is related to the relationship of lithological structure with the river erosion. It is clearly seen that while moving towards the estuary in the middle course, with a movement similar to a monoclinal dislocation; the main river is directed into the flysch in the right (eastern) slope over the lime stone-marl dominant units that form the left (western) slop (Fig. 10). However, the limestone-marl dominant slopes still have a higher slope which can only be explained by the existence of a dislocation line.

Fig. 10. The progression of Şehir creek valley in limestone- flysch contact to the detriment of flysch (West of Kavaklı)

Fig. 11. Terraces (T) and superimposed Çoruh valley (SV) on the evaporates in Şehir creek estuary

This and similar lines were marked on the geology maps generated in the context of the study as possible faults (Fig. 1). Another reason is the fact that Çoruh River which forms the local floor level for Şehir creek is lodged in a resistant threshold created by superimposition starting from the estuary of Şehir creek (Erinç, 2000). That case results in the decrease of the velocity of vertical excavation in Çoruh River and causes loss of slope for Şehir creek especially in areas closer to estuary. Therefore, materials carried from the spring of the basin in a speedy manner are collected in the estuary which cannot keep up with the velocity. The most important evidence that points to the slowing of erosion and starting the collection phase in these regions is the fact that terraces keep their existence since the old lake deposits and the existence of the alluvial embankment area behind the superimposed gorge (Fig. 11).

The last argument that will support this case and that will defend the fact velocity of erosion decreases in the lower course of the Şehir creek is the ascendant characteristic of the cover sediments in the basin based on the compression. These sediments are exposed to regional ascent by forming a local over thrust zone on the units from the south after being wedged between two comparatively old masses that move towards each other in addition to being pushed on the backs of deposits pushed on Pontid autochthonous towards the North. Although such an ascent increases the relative vertical erosion in the estuary of the basin, it also decreases the effects of vertical erosion in the real sense.

As a result, fluvio-geomorphologic investigation of Şehir creek Basin helped to reveal and interpret some of the geo-tectonic characteristics that required explanation. Accordingly, it was understood that regional tectonics and lithological structure affected the fluvial process to a great extent. It was also seen that data obtained through morphometric analyses about the tectonic and geologic structure of the basin and the correlation of some deficiencies and inconsistencies in the fluvial process have correspond to the field.

References

Akdeniz, N.; Akçören, F.; Timur, F. (1994). *Aşkale-İspir Arasının Jeolojisi*. Rapor No: 9731. MTA Genel Müdürlüğü, Jeoloji Etütleri Dairesi Başkanlığı, Ankara.

Atalay, İ. (1986). *Uygulamalı Hidrografya I*. Ege Üniversitesi Edebiyat Fakültesi Yay. No: 38, Ege Üniversitesi Basımevi, İzmir.

Bilgin, T. (2006). *Genel Kartografya II*, Filiz Kitabevi, İstanbul.

Cox, R.T. (1994). Analysis of Drainage Basin Symmetry as a Rapid Techniqueto Identify Areas of Possible Quaternary Tilt-Block Tectonics: an

Example from the Mississippi Embayment. Geological Society of America Bulletin, 106, 571-581.
Doornkamp, J.C.; Cuchlaine, A.M.K. (1971). *Numerical Analysis in Geomorphology. An Introduction*. Edward Arnold, London.
Eagleson, P.S. (1970). *Dynamic Hydrology*, McGraw-Hill, New York, USA.
Ekinci, D. (2011). *Safranbolu ve Çevresinin –Araç Çayı'nın, Soğanlı ve Eflanlı Çayları Ağız Noktaları Arasında Kalan Kısmına Ait Akarsu Havzasının- Jeomorfoloji Özellikleri*. Titiz Yayınları, İstanbul.
Erinç, S. (2000). *Jeomorfoloji I*. Güncelleştirilmiş 5. Basım, Güncelleştirenler: Ahmet Ertek, Cem Güneysu. Der Yayınları, İstanbul.
Görür, N.; Şengör, A.M.C.; Akkök, R.; Yılmaz, Y. (1983). Pontidlerde Neo-Tetis'in Kuzey Kolunun Açılmasına İlişkin Sedimentolojik Veriler, Bulletin of the Geological Society of Turkey, V. 26, 11 – 20.
Gravelius, H. (1914). *Grundrifi der gesamten Gewcisserkunde. Band I: Flufikunde (Compendium of Hydrology, vol. I. Rivers, in German)*. Goschen, Berlin, Germany.
Hack, J.T. (1957). Studies in Longitudinal Stream Profiles in Virginia and Maryland. U.S. Geological Survey Professional Paper 249-B, 45–97.
Hack, J.T. (1973). Stream Profile Analysis and Stream-Gradient Index. U.S. Geological Survey Journal of Research, 1, 421-429.
Hare, P.W.; Gardner, T.W. (1985). Geomorphic indicators of vertical neotectonism along converging plate margins, Nicoya Peninsula, Costa Rica, In: Tectonic Geomorphology: Proceedings of the 15th Annual Binghamton Geomorphology Symposium, (Eds) Morisawa, M. & Hack, J. T., September 1984, Allen and Unwin, Boston, 90–104.
Horton, R.E. (1932). Drainage Basin Characteristics. Transaction of American Geological Union, 13, 350-361.
Horton, R.E. (1945). Erosional Development of Streams and Their Drainage Basins: Hydrophysical Approach to Quantitative Morphology. Bulletin of the Geological Society of America 56, 275-370.
Hoşgören, Y. (2004). *Hidrografya'nın Ana Çizgileri I Yeraltısuları-Kaynaklar-Akarsular* (5. Baskı). Çantay Kitabevi, İstanbul.
Keller, A.E.; Pinter, N. (2002). *Active Tectonics, Earthquakes, Uplift and Landscape*. Prentice Hall, New Jersey.
Krishnamurthy, J.; Srnivas, G.; Jayaram, V.; Chandrasekhar, M.G. (1996). Influence of Rock Types and Structures in the Development of Drainage Networks in Typical Hardrock Terrain. ITC Journal 3–4, 252–259.
Leopold, L.B.; Miller, J.P. (1956). Ephemeral Streams: Hydraulic Factors and their Relation to the Drainage Network. U.S. Geological Survey, Geological Survey Professional Paper 282 A, Washington, D.C., pp. 1–37.
Mahadevaswamy, G.; Nagaraju, D.; Siddalingamurthy, S.; Lakshmamma, Mohammad, S. I.; Nagesh, P.C.; Krishna, R. (2011). Morpometric Analysis of Nanjangud Taluk, Mysore District, Karnataka, India, Using GIS Techniques, International Journal of Geomatics and Geosciences, 1 (4), 721-734.
Mayer, L. (1990). *Introduction to Quantitative Geomorphology*: Prentice Hall, Englewood Cliffs, New Jersey.
Melton, M.A. (1957). *An Analysis of the Relations Among Elements of Climate, Surface Properties and Geomorphology*. Proj. NR 389-042, Tech. Rep 11, Columbia University, Department of Geology, ONR, New York.
Miller, J.R.; Ritter, D.F.; Kochel, R.C. (1990). Morphometric Assesment of Lithologic Controls on Drainage Basin Evolution in the Crawford Upland, South-Central Indiana. American Journal of Science, 290, 569-599.
Morisawa, M.E. (1959). *Relation of Morphometric Properties to Runoff in the Little Mill Creek, Ohio, Drainage Basin*. Tech. Rep., 17. Department of Geology, ONR, Colombia University, New York.
MTA (2002). 1/500.000 Ölçekli Türkiye Jeoloji Haritası. Trabzon Paftası.
MTA (2011). 1/100.000 Ölçekli Türkiye Jeoloji Haritası. Tortum-H 46 Paftası, No: 154.
Nag, S.K. (1998). Morphometric Analysis Using Remote Sensing Techniques in the Chaka Sub-basin, Purulia District, West Bengal. Journal of the Indian Society of Remote Sensing, Vol. 26, No. l&2.
Nag, S.K.; Chakraborty, S. (2003). Influence of Rock Types and Structures in The Development of Drainage Network in Hard Rock Area. Journal of Indian Society of Remote Sensing 31, 25–35.
NIH (1998). *Representative Basin Studies: Morphometric Analysis of Suddagedda Basin, Andhra Paradesh*, National Institute of Hyrology, Jal Vigyan Bhavan, Roorke-India.
Özdemir, H. (2011). Havza Morfometrisi ve Taşkınlar, *Fiziki Coğrafya Araştırmaları: Sistematik ve Bölgesel*, Türk Coğrafya Kurumu Yayınları, Sayı: 6, 507-526, İstanbul.
Pike, R.J.; Wilson, S.E. (1971). Elevatio-Relief Ratio Hypsometric Integral and Geomorphic Area-Altitude Analysis. Geological Society American Bulletin 82, 1079-1084.
Saraloğlu, A.; Erçin, A.İ., Özdoğan, K.; Yılmaz, H. (1992). *Bayburt-Pazaryolu-İspir-Yusufeli-Artvin Arasında Kalan Çoruh Vadisinin Jeolojisi ve Linyit Prospeksiyon Raporu*. Enerji Hammadde Etüt ve Arama Dairesi Başkanlığı, Rapor No: 9452, Trabzon.
Scheidegger, A.E. (1991). *Theoretical Geomorphology*, Springer-Werlack, Berlin Heidelberg.
Schumm, S.A. (1956). The Evolution of Drainage Systems and Slopes in Bad Lands at Perth, Amboi, New Jersey. Geol. Soc. Ame. Bull. 67 (5), pp. 597-646.
Strahler, A.N. (1952). Hypsometric (Area-Altitude) Analysis of Erosional Topology. Geological Society of America Bulletin 63 (11): 1117–1142.
Strahler, A.N. (1957). Quantitative Analysis of Watershed Geomorphology. Transactions of the American Geophysical Union 8 (6): 913–920.
Strahler, A.N. (1964). Quantitative Geomorphology of Drainage Basin and Channel Networks. In : *Handbook of Applied Hydrology* (edt. by V.T.Chow), pp. 4.39-4.76.
Şengör, A.M.C.; Yılmaz, Y.; Ketin, İ. (1980). Remnants of Pre-late Jurassic Ocean in Northern Turkey : :Fragments of Permian - Triassic Paleo-Tethys : Geol. Soc. America Bull., 91, 599 - 609.
www.tuik.gov.tr