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Active Tectonics of the East Anatolian Fault Zone based on morphometric analysis on the Şiro Valley (East Anatolia)

Eastern Mediterranean is being deformed by major intraplate strike-slip fault systems such as North Anatolian Fault Zone (NAFZ) and East Anatolian Fault Zone (EAFZ) due to the convergence between the Arabian Plate and the Eastern Anatolian Plateau. Even though the studies regarding the paleoseismology and tectonic evolution of the EAFZ have been studied since 20th century, the recent earthquakes that occurred on EAFZ (January 24, 2020-Mw:6.8) have drawn attention to the deformation dispersed into Pütürge, Sivrice and nearby segments of it. The normalized steepness index (ksn), Chi (χ), and knickpoints (KP) are powerful geomorphological tools for determining the uplift rate and stress distribution at the convergence zones. To unravel the deformation pattern, ksn, χ, and KP analyses were performed along the longitudinal course of rivers on northern margin of the Şiro valley that is bounded by strike-slip faults with significant vertical components from its northern and southern sides. The preliminary morphometric analysis revealed that: (i) the occurrence of knickpoints coincides with known and/mostly undefined faults affecting the elevated fluvial terraces on the main valley, (ii) the calculated ksn values increase towards the inner part of the valley. Ultimately, these calculated morphometric indices not only will provide many benefits for determining the target sites for the geochronological studies on the uplifted river terraces in the valley, but they will also contribute to defining new secondary active faults linked with principal displacement zone and evaluation of uplift rate, erosion rate, and slip rate. This study is supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK; Project No:122Y266).

HIGHLIGHTS

- Morphometric analysis (k_{sn}, χ, and KP) is revealed on the Pütürge segment,which displays a specific geometry along the Şiro Valley.
- k_{sn} and KP variations depend on slope and tectonism along the drainage basin of the Şiro Valley correlated with lithological contact.
- High k_{sn}, χ, and KP values indicate active tectonic lines and vertical components along the strike slip-fault zone.

INTRODUCTION

Morphometric indices and landforms are very useful in identifying areas where tectonic activity and rates of active tectonic processes can be evaluated (Keller, 1986). Quantitative measurement of land; It is based on topographic maps, aerial photographs and field studies and calculation of morphometric indices. Quantitative measurement of land has based on topographic maps, aerial photographs, field studies, and the calculation of morphometric indices. These calculations are used to understand the complex interplay of tectonics, sedimentation, and erosion processes. Morphometric analysis of drainage basins is the most important data source to understand this complex interaction (Keller and Pinter, 1996).

The East Anatolian Fault Zone (EAFZ), which has produced devastating earthquakes for the last few years, is a strike-slip fault zone that displays a very complex fault geometry that provides intra-continental deformation (Şengör et al., 1985). Previously, the classic morphometric indices were applied by Khalifa et al. (2018) along the EAFZ based on a DEM with a 30 m resolution. According to this study, the Pütürge segment is determined as the second active segment along the EAFZ tectonically. However, the detailed examinations of local areas to be controlled based on the dating and the morphometric analyses are prominent in understanding the deformation mechanism of the segments. The tectonic activity of the valley is revealed according to the channel steepness (ksn), chi (χ), and knickpoint (KP) indices along the Şiro valley, which presents a specific geometry on the local scale on the Pütürge segment, attracted attention with the Sivrice-Doğanyol earthquake that occurred on January 24, 2020.In this scope, we aimed to quantitatively determine the effects of tectonism and erosion on the topography using these morphometric indices.

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Fig 1

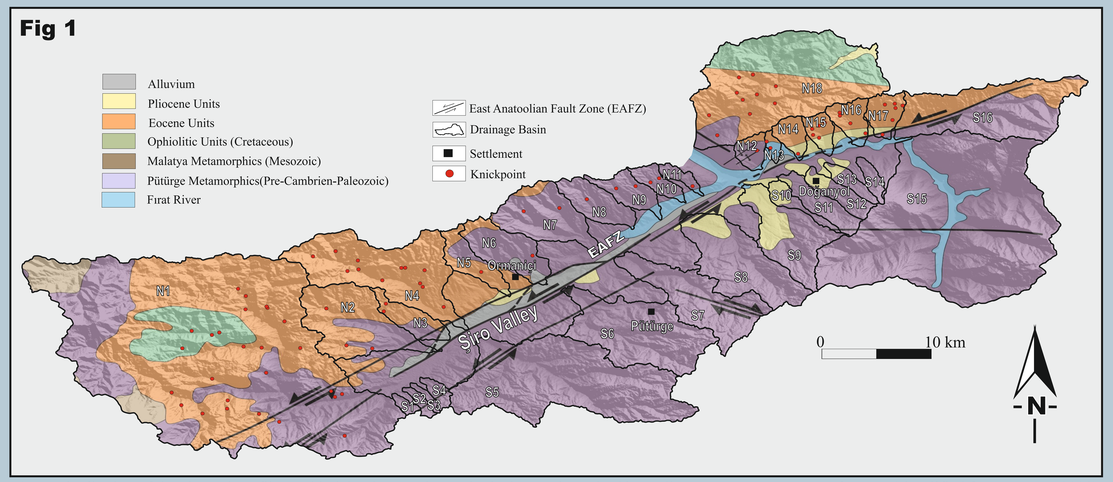

Fig 1. Distribution of the channel profiles and knickpoints on the geological map along the Şiro Valley on Pütürge segment of EAFZ (simplified from Herece, 2008)

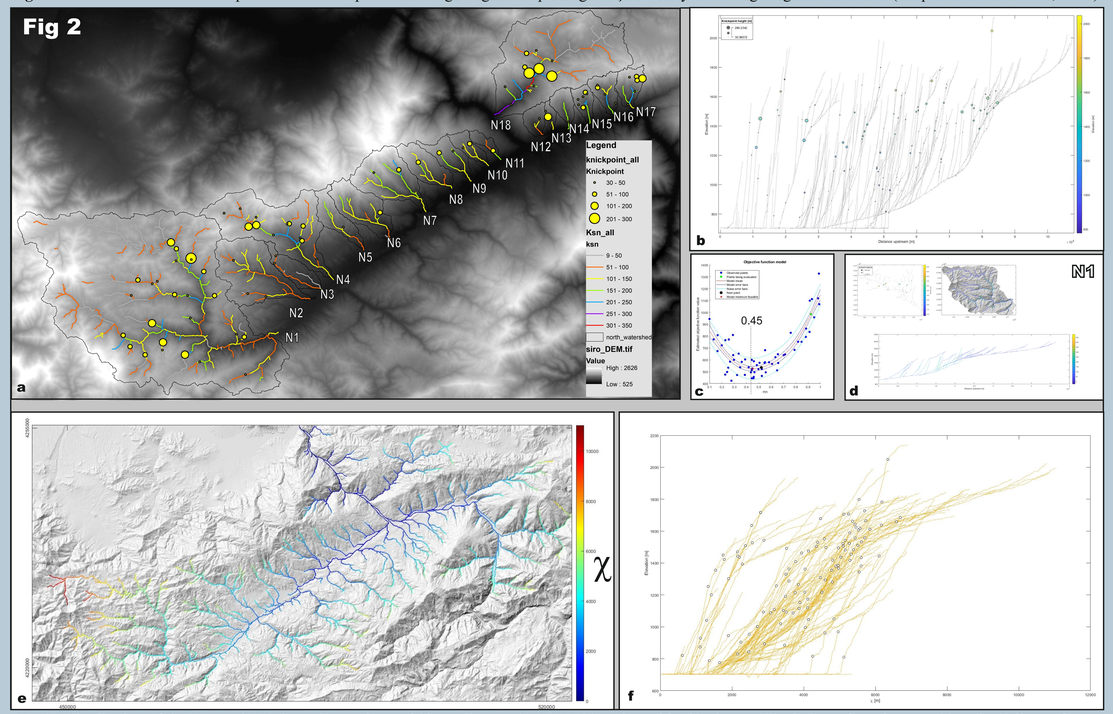

Fig 2. Distribution of the Ksn and KP along the northern of Şiro valley on the DEM (a) and graphic (b), the graphical view of erosion rate (c), calculatiions of Ksn and KP values of N1 channel profil (d), distribution of Chi vaules on the DEM (e) and graphic (f).

MATERIALS & METHODOLOGY

To show the change of the neotectonic uplift along the direction due to the variable structure of the segmentation developed along the Şiro valley, normalized steepness (ksn) , Chi (χ), and knickpoints (KP) morphometric indices were applied. Analyzes were performed using ALOS-PALSAR DEM with 10-m ground pixel resolution.Drainage networks and basins were determined using ArcGIS Pro software, and morphometric index calculations were calculated with MATLAB-based TopoToolbox software.

Drainage basin boundary and river branches have been determined for each channel along the Şiro Valley to obtain ksn values. River longitudinal profiles will take according to the distances of the riverbed heights to the river mouth. Stream systems where tectonic forces and erosion are in balance give longitudinal profiles, which are concave in the upper east, while streams that are out of balance (elevated, over-steeped, carved) due to the effect of tectonism show convex longitudinal profiles (Kirby and Whipple, 2001). The evolution of channel profiles can be described using the effect of bedrock lithology, stages of erosion, and slope-area relations of streams (Whipple and Tucker, 1999; Perron and Royden, 2013). The inconsistencies between the channel slope and the source area can be explained by active tectonism (Zabcı, 2020).

Errors in the resolution of contour curves on the topographic map, produced based on DEMs, can cause scattering of slope-area graphs, thus causing errors in the calculations of the normalized steepness index.To overcome the problem arising from these errors, Perron and Royden (2013) proposed a new method based on the integral transformation of a variable called χ(chi) of horizontal coordinates in channel profiles.The factor χ shows longitudinal changes in a drainage area, and these variations display chi-graphics (Perron and Royden, 2013; Mudd et al., 2018).

Knickpoint is a location of the anomalous change in river gradient within longitudinal river profiles that could form base-level changes caused by lithologic variation, climate, shear stress increase, tectonic uplift (A Shresta and Gani, 2023). These irregularities of slope in channel profiles are recorded as a long-term signal of tectonic activity and stream disequilibrium (e.g., Gani et al., 2007; Kirby & Whipple, 2012).

ANALYSIS & RESULTS

Drainage networks were extracted along the Şiro valley, controlled by the Pütürge segment, and total of 34 drainage basins were identified on the northern (18) and southern (16) sides of the valley (Fig 1). We investigated whether the calculated knickpoints correspond to the unit boundaries on the geological map of the drainage basin (Fig 1).Morphometric index applications were carried out along the channels identified on the northern edge of the Şiro valley.

Normalized channel steepness index values range from 9-350, and high values indicating tectonism are concentrated in the northeast and southwest ends of the valley (Fig 2a). The 110 knickpoints were calculated, and they are clustered at high Ksn values and reached the maximum value (Fig 2a&b). A reference value (θref) of 0.45 was used for the concavity index in Ksn calculations to find the optimum concavity index for each of the basins using the mnoptimvar function in Topo Toolbox-2 (Fig 2c). The Ksn, Chi, and KP values were calculated separately for each channel on the northern side of the valley (Fig 2d).The 110 knickpoints were calculated, and they are clustered at high Ksn values and reached the maximum value.Chi values calculated according to the elevation of the drainage basins reach their maximum value at the southwest end of the valley and are consistent with the Ksn and KP values (Fig 2 e&f).

The results of the morphometric analysis studies pointed out that the faults are not only active in the valley but also in high tectonic activity, especially in the northern parts of the valley. In addition, while low values are calculated in the valley due to the dominant pure strike-slip character of the EAFZ, high values are remarked in the north of the valley based on the segment acquires an oblique character with the vertical component.

CONCLUDING REMARKS

- Morphometric index studies were performed along the northern edge of the Şiro valley controlled by the Pütürge segment of the EAFZ.
- Ksn, Chi, and KP values were calculated for each of the determined 18 longitudinal channel profiles on the northern edge along the Şiro valley.
- A total of 110 knickpoints were detected throughout the Ksn values offering a range of 9-350, especially clustering at high Ksn values.
- Chi values are compatible with Ksn and KP values.
- Morphometric indices will be applied on the channel profiles determined at the southern edge of the Şiro Valley, and will be compared for the both sides of the valley.
- These results are the primary findings of morphometric index studies and will be supported by field and dating studies.
- These high values will be correlated with the focal mechanism of the moderate-size earthquakes developed on these points.