Hittite Journal of Science and Engineering, 2015, 2 (1) 77-83
ISSN NUMBER: 2149-2123
DOI: 10.17350/HJSE19030000011

Recent Tectonic Features of the Central Part (Bolu-Corum) of the North Anatolian Fault

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ABSTRACT

After the 1999 Izmit and Düzce earthquakes, the earth science studies increase on the NAF to better understand mechanism and to monitor the motion of it. Monitoring such motion can be achieved by the instrumental tools or techniques like GPS, InSAR, LIDAR, creep meter, etc. The GPS observations showed that while the NW-SE trending section of the NAF between Karlıova and Vezirköprü has nearly strike slip mechanism, the NE-SW trending section of the NAF between Vezirköprü and Bolu has transpressive character. While the fault-parallel velocities have been estimated from just a few GPS vectors available in the region, little is known about the fault-perpendicular component of the regional velocity. The rate of conversion and how it varies along strike are not known due to the sparsely distributed GPS benchmarks in the region. At the same time, the aseismic fault creep determined using InSAR has needed to proof and improve by other techniques and tools. For this propose the new project has been started to determine quantitatively the rate of convergence and its variation along segment of the NAF between Bolu and Çorum. In this study, we focus on the Bolu-Çorum segment of the NAFZ using GPS technique. The main aim of this study is determination of creep rate with geodetic measurements and combination of the data obtained from seismology, geodesy and geophysics to understand fault mechanism. Therefore, in this paper we discuss tectonic phenomena on the central part of the NAFZ and present the first results of the project.

Key Words:
Creep; GPS; Deformation; Nort Anatolian Fault; Earthquake.

Article History:
Received: 2015/05/10
Accepted: 2015/06/17
Online: 2015/07/01

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INTRODUCTION

Seismic hazard and loss assessment are important phenomena to save human life. For this purpose, understanding the mechanism of the active fault under tectonic stress is still critical subject [1-2]. The active faults can move abruptly to release the strain accumulation and produce destructive earthquakes or slip continuously (aseismic fault creep) without produce earthquakes significantly. The sudden release of accumulated strain on locked active faults (earthquake) along active faults can be subdivided into four periods: interseismic, preseismic, coseismic, and postseismic. This sequence is called the earthquake cycle in the literature. On the contrary, faults which slip freely can be locked partially ([3] such as Hayward fault [4], the Superstition Hills fault [5], the Longitudinal Valley fault [6], and the Ismetpasa and Destek segments and of the North Anatolian Fault [7-9]. In this subject, the important ıssue is threshold of the aseismic slip rate. If it is equal or larger than long-term slip rate, the destructive earthquakes will not occur along the fault which has aseismic slip rate. On the contrary, if the creep motion is lower than long-term slip rate along the fault, the fault has potential to produce moderate-to-large size earthquakes [9]. Therefore, knowledge and motoring of the aseismic fault creep and also comparing the results with long-

Table 1. List of the earthquakes[26]

Date	Latitude (°)	Longitude (°)	Depth (km)	Magnitude
24.11.2013	40.8205	31.8691	5.99	5.1
06.06.2000	40.693	32.992	10	6
16.11.1999	40.717	31.608	10	5.1
05.10.1977	40.963	33.411	33	5.8
03.09.1968	41.86	32.463	20	6.3
07.09.1953	40.956	33.204	10	6.1

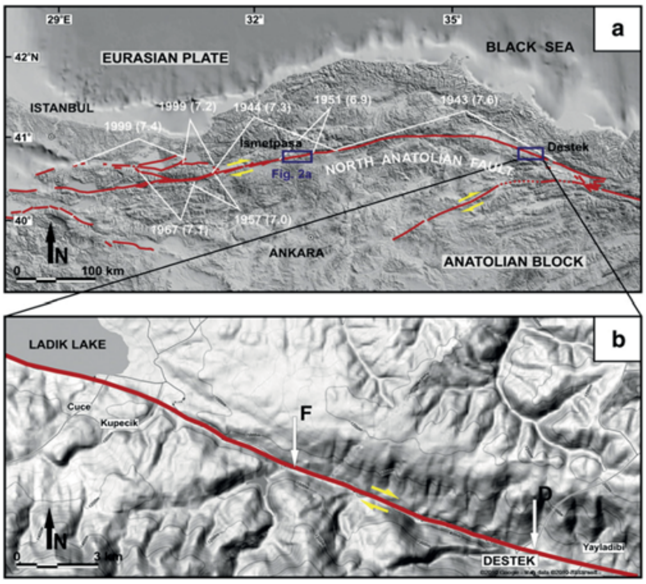

Figure 1. (a) Simplified map of the North Anatolian Fault showing creep locations and recent major earthquakes. (b) General trend of the North Anatolian Fault around Destek segment. "F" and "D" indicate the locations of the surveyed areas in and near Destek (Fig 2b) (after [9]).

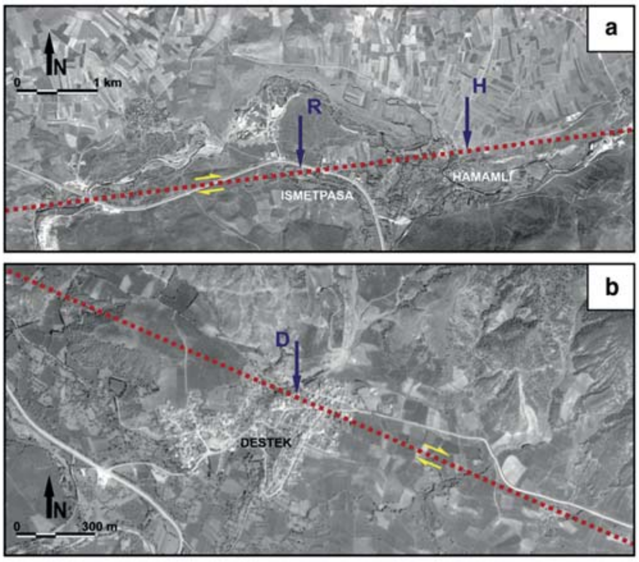

Figure 2. (a) Detailed map of the Ismetpasa. "R" is the railway station in Ismetpasa, "H" is the Hamamlı Village and the dashed line is the trace of the NAF. (b) Detailed map of (D) Destek. The dashed line is the trace of the NAF (after [9]).

term slip rate are critical to prevent loss of seismic hazard.

The Ismetpasa and Destek segments where lie from Bolu the west to Corum the east were ruptured by the earthquakes in 1943 (Tosya Ms=7.6), 1944 (Bolu-Gerede Ms=7.3) and 1951 (Kursunlu Ms=6.9) in the last century (Figure 1 and 2, the list of the other earthquakes are given in Table 1).

Geoscience Studies

In this study, we focus on the central part of the NAF with three sub-segments; Ismetpasa on the west, Destek on the east and central part between east and west boundaries.

Aseismic fault creep on the NAF was firstly reported by Ambraseys [7] at Ismetpasa segment and was calculated the rate of aseismic slip 20 mm/yr using tape meter measurements. After Ambraseys, the first geodetic study was started by establishing triangulation and trilateration network across the fault near Ismetpasa. The geodetic measurements indicate that the rate of creep is 9.3±0.7 mm/yr [10] and 7.8±0.5 mm/yr [11]. Using InSAR technique, Cakir et al., [8] estimated the rate 8±3 mm/yr for the creeping on the section. The LIDAR technology was also used

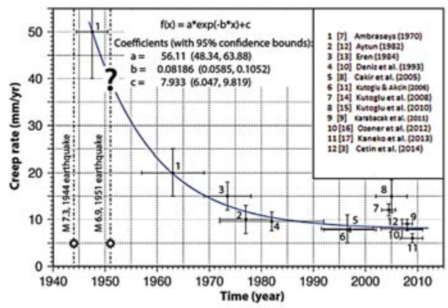

Figure 3. Time history of surface creep at Ismetpasa as reported by various studies following the 1944 earthquake (after [3]). Horizontal and vertical bars are the time window and error range of measurements, respectively. The question mark corresponds to the unknown effect of the 1951 earthquake on creep rate. Curve shows the fit of the exponential relaxation function to the change of the creep rate with time [18].

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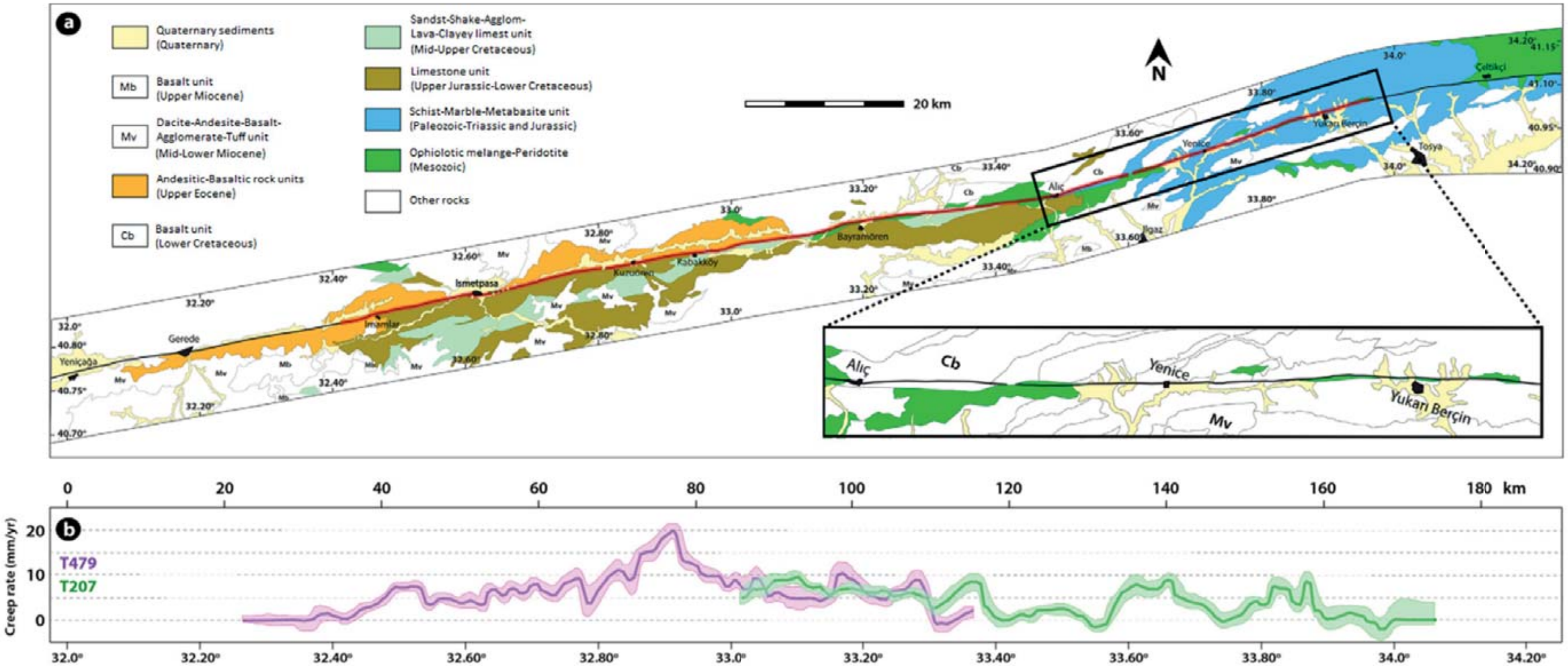

Figure 4. (a) Geology map of the study region. Geological units presumably involved in creeping are shown in colors and the others are labeled in white with abbreviations. Black and red lines represent the active fault and the creeping segment, respectively. The eastern end of the creeping section can be clearly seen in the inset rectangle. (b) Creep rates and error ranges for two individual tracks are indicated in purple (track T479) and green colors (track T207) (after [3]).

by Karabacak et al. (2011) [9] to calculate the rate of 6.8–10.0±4.0 mm/yr and 9.1–10.1±4.0 mm/yr. Cakir et al., (2012) [2] and Cetin et al., (2014) [3] reported that the rate is not stable along the fault and reaches a maximum of 20±2 mm/yr 20km to the east from Ismetpasa (Figure 3 and 4).

Another aseismic creep segment on the NAF was reported by Karabacak et al. (2011) [9] in Destek village on the northeast of the Corum. This segment of the NAF was ruptured in 26 November 1943 Tosya (Ms=7.6) earthquake. LIDAR results on this part of the fault showed an aseismic slip rate of 6.0–7.2±4.0 mm/yr, which releases considerable amount of strain in this part of the NAF but the results of the LIDAR measurements were not verified by the another techniques, observations or studies. This can be a handicap to explain the behavior of the fault in this segment.

The central part of the NAF in our study area, where no another aseismic surface slip section reported by previous studies. At the same time, Yavasoğlu et al. (2011) [19] and Peyret et al. (2013) [20] indicate that the central part of the NAF in between Destek and Ismetpasa are still active and going on strain accumulation with slip rate 20.5 ± 1.8 mm/yr.

DISCUSSIONS

The long term-slip rate is important issue in active tectonic studies to compare with aseismic slip rate and to understand the behavior of the active faults. The GPS is an accurate and economic tool to calculate the long-term slip rate for active faults. As explained in the previous section, the valuable studies have been published, except global and local GPS measurements for the central part of the NAF excluding studies that show general global slip rate, [19-22].

In this project, five profiles shaped GPS networks across the fault are established to determine local movement such as aseismic slip rate or creeping according to model (Figure 5).

Four profiles were established in Ismetpasa segment and one for Destek region. Each profile has eight force-centered stations located approximately from the north to the south and almost perpendicular to the fault on the profiles (Figure 6a, 6b and 6c).

We also combine the creeping and non-creeping sections of the NAF using continuous GPS sites (CORS-TR) (Figure 7).

CONCLUSIONS

The new geodetic network with 43 stations was established to monitor the creep and non-creep sections of the NAF. The first GPS campaign was carried out in August 2014 (on GPS days; 235, 236, 237, 238 and 241) with 5 second sample interval and 15 degree elevation mask. The first campaign data both obtained from new 43 sites and 48 continuous GPS stations (IGS and CORS-TR) was evaluated by GAMIT/GLOBK software [23].

Pseudo-range and phase GPS data are analyzed using GAMIT software as single-day solutions. Station coordinates, satellite orbits, 13 tropospheric zenith delay parameters per site and phase ambiguities using doubly-differenced phase measurements are solved while applying loose a priori constraints to all parameters.

The IGS final orbits, IERS earth orientation parameters are used, and azimuth and elevation dependent antenna phase center models are applied.

After the second and third campaigns, the project will be valuable. The similarities and differences in seismological behavior of the NAF along its creeping and non-creeping sections will be investigated for the first time in this project. It is an important shortcoming that such an investigation has not been conducted yet even though the phenomenon of surface creep in Ismetpasa has been known for over 40 years and in Destek discovered recently. Creeping section of the San Andreas Fault at Hayward has been monitored using micro geodetic and seismic networks for many years, which have revealed important information about the rheology and temporal behavior of the fault and its potential for producing earthquakes [24]. This will be the first study on the seismic characteristics of the creeping section of the NAF.

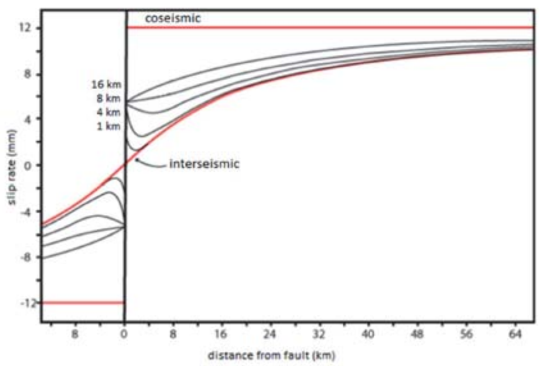

Figure 5. Black lines show creep model in different locking depth from 1km to 16km. Red lines show the interseismic and coseismic behavior without creeping.

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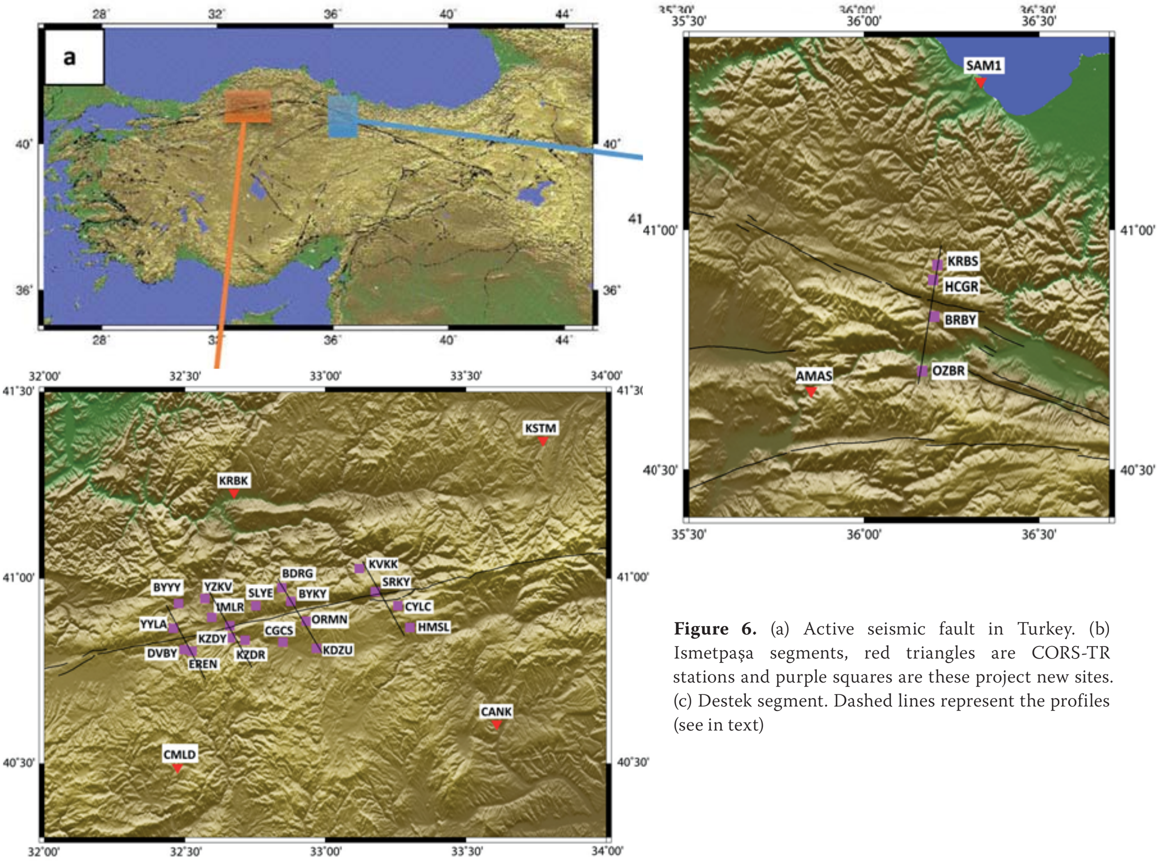

Figure 6. (a) Active seismic fault in Turkey. (b) Ismetpaşa segments, red triangles are CORS-TR stations and purple squares are these project new sites. (c) Destek segment. Dashed lines represent the profiles (see in text)

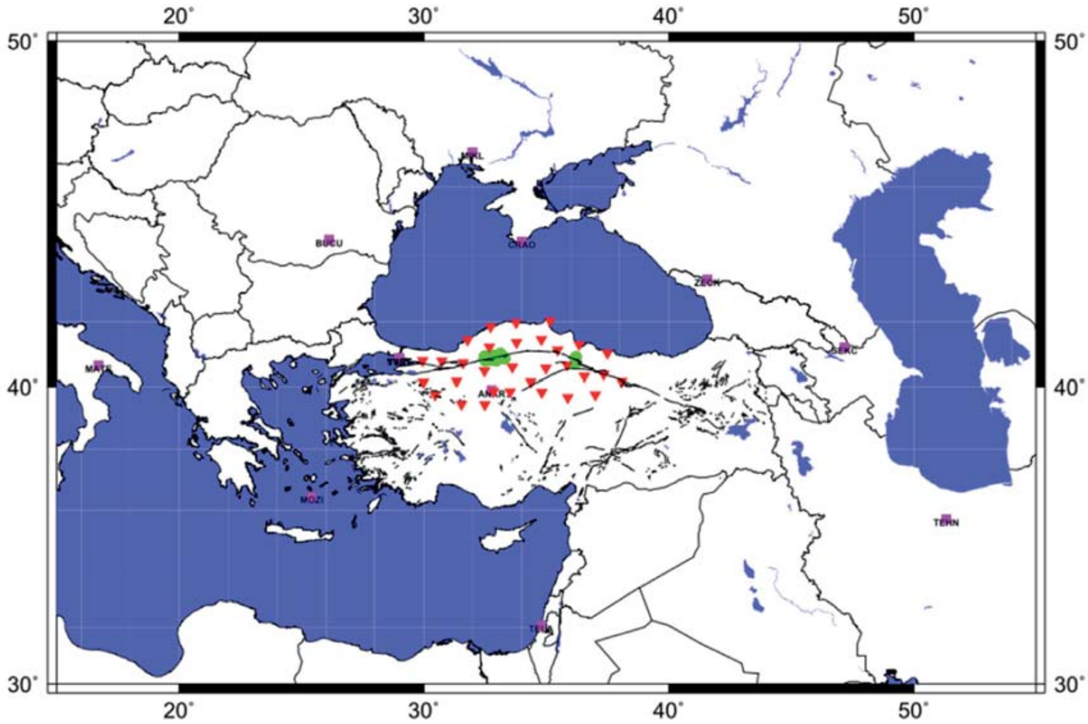

Figure 7. Green circles are new GPS sites, red reverse triangles for CORS-TR sites, and purple squares are IGS GPS stations..

ACKNOWLEDGEMENT

We would like to thank to Prof. Dr. Reha Metin Alkan the Rector of Hitit University. Financial supports of the projects are from Hitit University Fund and Istanbul Technical University Fund with numbers, MYO19001.14.001 and 38146, respectively. The figures in this paper were generated using the public domain Generic Mapping Tools (GMT) software [25]. We thank to Afyon Kocatepe University (Dr. Saffet Erdogan, MSc. Mehmet Ali Ugur).

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