WILL A MAJOR EARTHQUAKE STRIKE THE EASTERN TURKEY?

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Abstract

The North Anatolian Fault Zone (NAFZ), where the Anatolian and Eurasian plates meet, is one of the world's most seismically active regions. The western part of NAFZ has a history of seismic activity and earthquakes are common in Marmara region of Turkey. A major earthquake with a magnitude of 7 or larger is expected to strike the region within the next three decades with a 60% probability. So the region draws attention by its long history of damaging earthquakes and Earth scientists are very interested in the western part of NAFZ. Although the eastern part of NAFZ also has high seismic hazard, there is a lack of geodetic information about the present tectonics of this region. Earthquakes occur quite frequently in

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the region and a strong earthquake is certain to hit eastern Turkey in the future. Even though many scientists would like to study this area, geographical and logistical problems make performing scientific research difficult. In 2003, we started a geodetic project in that region with the aim of measuring present crustal movements and strain. Geodetic observations were performed in three GPS campaigns in an area of 350 x 200 km square with 12-month intervals. 14 new GPS stations were constructed far from the deforming areas. Since this region includes the intersection of NAFZ and East Anatolian Fault Zone (EAFZ), deformation is complex and estimating seismic hazards is difficult. The Yedisu segment of the NAFZ has not broken since the 1784 earthquake. After the 1992 Erzincan and 2003 Pulumur Earthquakes, the Coulomb stress loading on the Yedisu segment of the NAFZ has increased significantly emphasizing the need to monitor this region.

Observed velocities relative to Eurasia based on three GPS campaigns reach ~29 mm/yr. Locally, the velocity difference for three sites (SOLH, USVT, ATAP) is 9 mm/yr consistent with the regional tectonics. These results show that strain is accumulating on the fault located between Bingol and Sancak. It is expected that one or more of the major faults in the region will rupture and trigger an earthquake with a magnitude of at least 7.

Introduction

Turkey is an earthquake country has a long history of natural hazards and disasters. 96 percent of the land containing 66 percent of the active faults is affected by earthquake hazards and 98 percent of the population lives in these regions. Marmara region includes 11 large cities with populations of more than one million and 75 percent of the country's largest industrial complexes. Scientific understanding of earthquakes is vital for assessing earthquake hazards. And earthquake hazard estimation is the most effective way for Earth scientists to reduce earthquake losses. The tectonic framework of the eastern Mediterranean and Middle East region is dominated by the collision of the Arabian and African plates with Eurasia (McKenzie, 1970; Jackson and McKenzie, 1988). Figure 1 shows the tectonic plates of Turkey and surrounding regions.

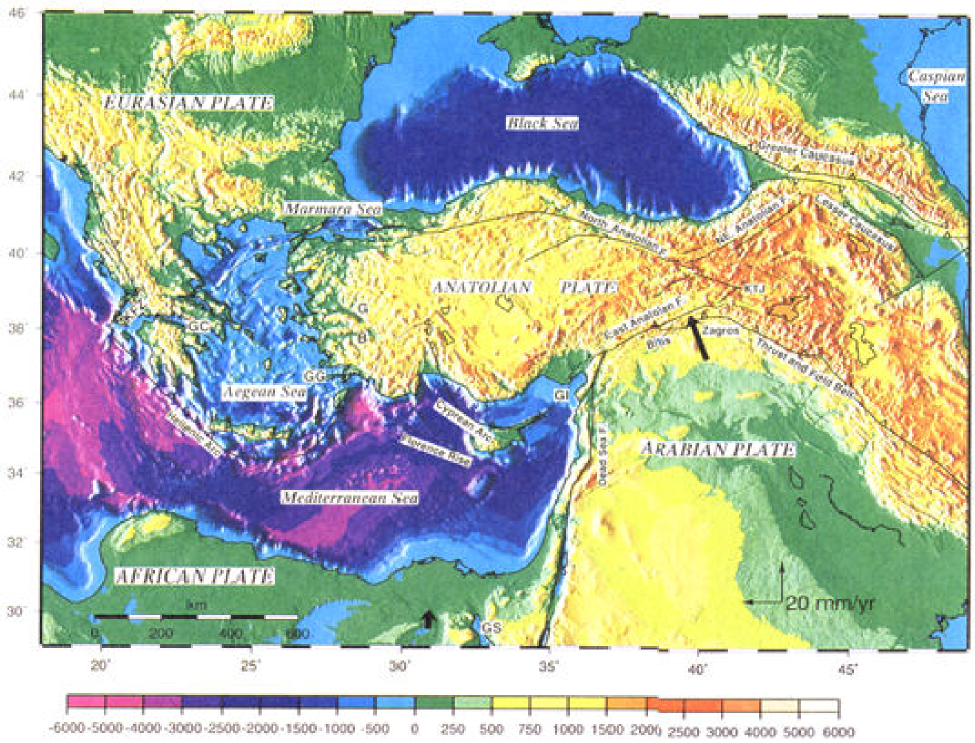

Figure 1. Tectonic setting of Turkey and surroundings (McClusky et al., 2000).

Since the geodetic information about the present tectonics of this region is not known very well, the region is an ideal one to carry out the geodetic crustal deformation investigations. Historic records (Ambraseys, 1970, 1971) reveal that the East Anatolian Fault Zone exhibits occasionally large seismic activity (Arpat and Saroglu, 1975). Since the beginning of 19th century, large earthquakes have been recorded with the information of location and magnitude in the region very well, and these events verify the fault lines determined in that area (Ambraseys, 1989; Ambraseys and Melville, 1995; Ambraseys and Jackson, 1998; Nalbant 2002; Nalbant, 2005) (Figure 2).

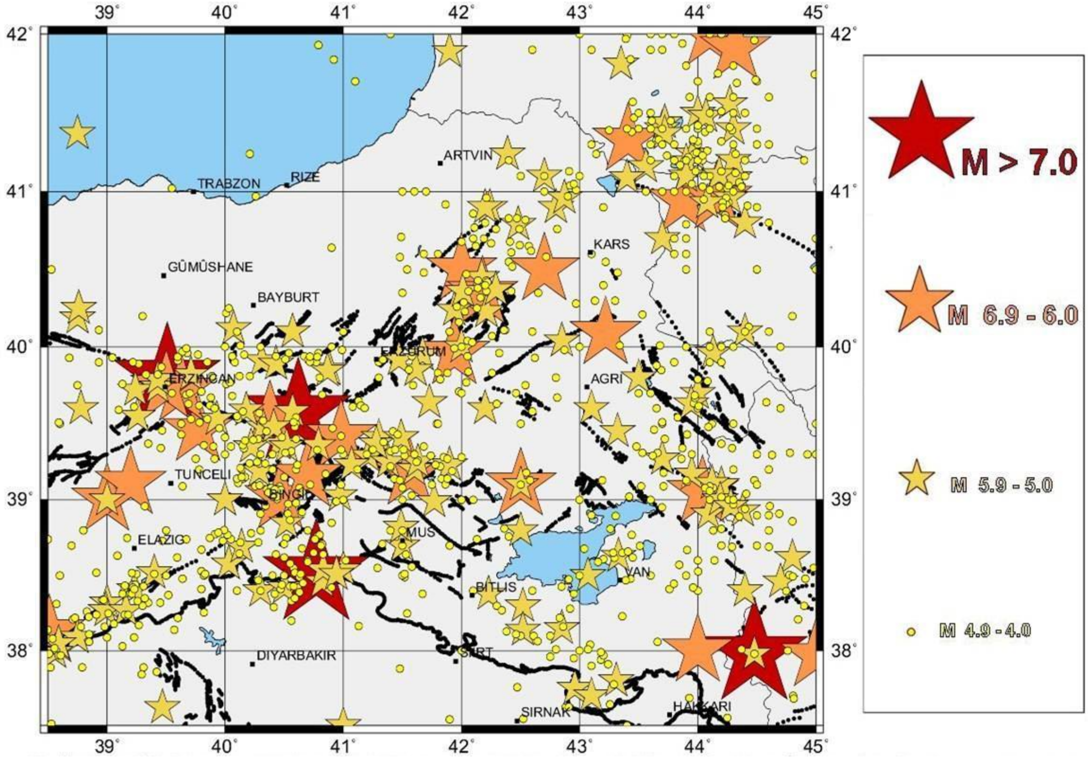

Figure 2. Seismicity of the study area including active fault lines (KOERI-NEMC).

Study area covers 350x200 km square in size and 7 administrative provinces (Erzincan, Erzurum, Tunceli, Bingol, Elazig, Malatya, Sivas). This region is capable of generating major earthquakes in every 3-4 years and needs to be monitored. Since there is a lack of geodetic information about the present tectonics of this region, this study is an important GPS geodynamic research covering the region in terms of detailing and having high density of GPS stations.

Data and Method

The first step was the mapping of the active faults using aerial photographs to select the appropriate locations of geodetic control points for detecting crustal movements. 394 air photographs at 1:60.000 scale and 28 air photographs at 1:35.000 scale were evaluated in the office. After this study, a 10-day field reconnaissance was realized in the working area and 14 new stations were established and 2 existing Turkish National Fundamental GPS Network (TUTGA) points were selected to be used. The tectonic significance and the GPS requirements were taken into account at the site selection. GPS points possibly were established in optimum number at least 3 km away from active faults. GPS points were required not to be affected by surface movement (such as landslide) and transportation possibilities and the owners of the lands were also considered. GPS sites, except for two

TUTGA permanent stations, were monumented into bedrock using high quality geodetic monuments. Selection of session lengths, receiver and antenna distribution, and performing the measurements in the same period of the year are necessary in order to avoid the systematic biases (daily and seasonal variations, antenna specific effects). Figure 3 shows the network configuration.

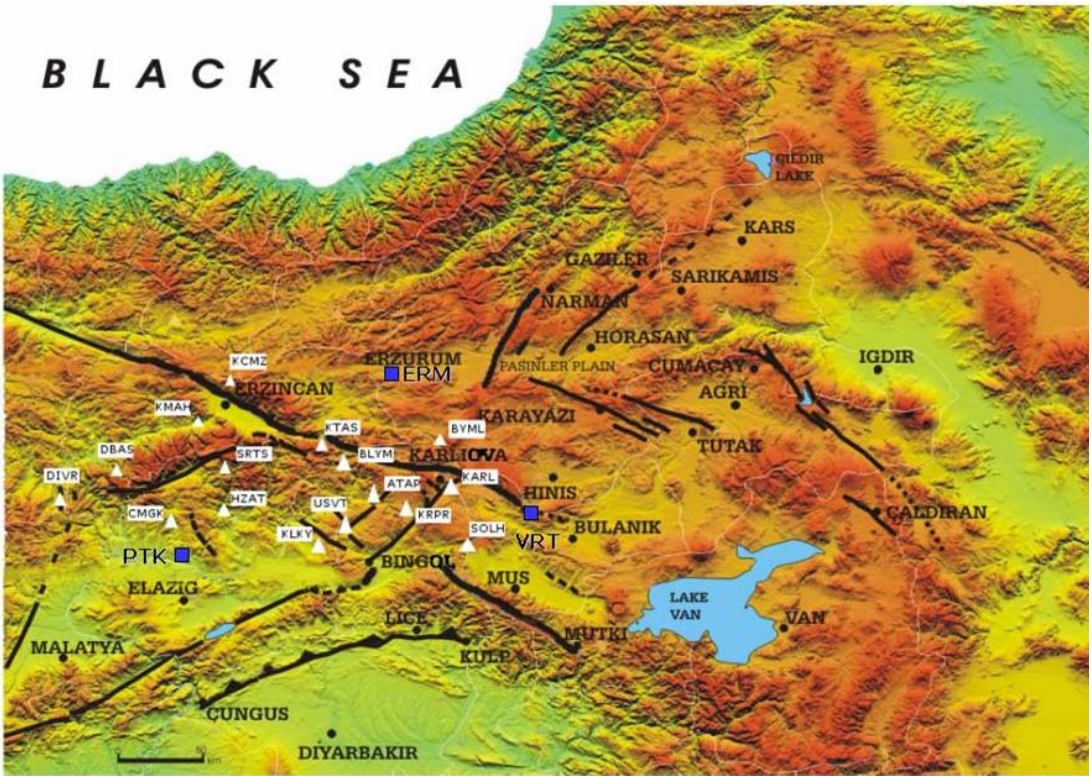

Figure 3. Locations of GPS stations (white triangles) and seismic stations (blue quadrangles) built during the project, with fault lines.

10-hour/day observation was performed at each station in the fall season for three years. The first measurement campaign was performed in October 2003 at sixteen GPS stations in the region. The sites in each campaign were occupied with Trimble 4000 SSI and 4000 SSE receivers. In order to avoid antenna-specific systematic effects, the sites were occupied with the same antenna. The campaigns were organised yearly about the same time of the year to avoid seasonal effects. Three campaigns have been performed during the project.

The processing and evaluation of the GPS campaigns was performed with the GAMIT (King and Bock, 2004) / GLOBK (Herring, 2004) software package. Each campaign were processed using the International Terrestrial Reference Frame; the ITRF2000. Precise orbit by International GPS Service (IGS) was obtained in SP3 (Standard Product 3) format from SOPAC (Scripps Orbit and Permanent Array Center). Earth Rotation Parameters (ERP) came from USNO_bull_b (United States Naval Observatory_bulletin_b). 9-parameter Berne model was used for the effects of the radiation and the pressure. Scherneck model (IERS standards, 1992) was used for the ocean tide loading effect. Zenith Delay unknowns were computed based on Saastamoinen apriori standard troposphere model with 2-hour interval. Iono-free LC (L3) linear combination of L1&L2 carrier phases was used. The model which depended on the height was preferred for the phase centers of the antennas. Losely-constrained daily solutions obtained from GAMIT were included in the ITRF2000 reference frame by 7 parameters (3 offset-3 rotation-1 scale) transformation with 14 global IGS stations.

Results and Discussion

The weights of vertical coordinates were taken as 1/100 of horizontal coordinates' weight. Station velocities were obtained from trend analysis by time series which formed by daily precise coordinates combined with Kalman analysis (Ozener, H., et al., 2005). Velocities in the region by processing data after the completion of three GPS campaigns are shown in Figure 4. Velocity vectors produced by three GPS campaign made the results more reliable. The outlier detection was performed and the outliers were discarded

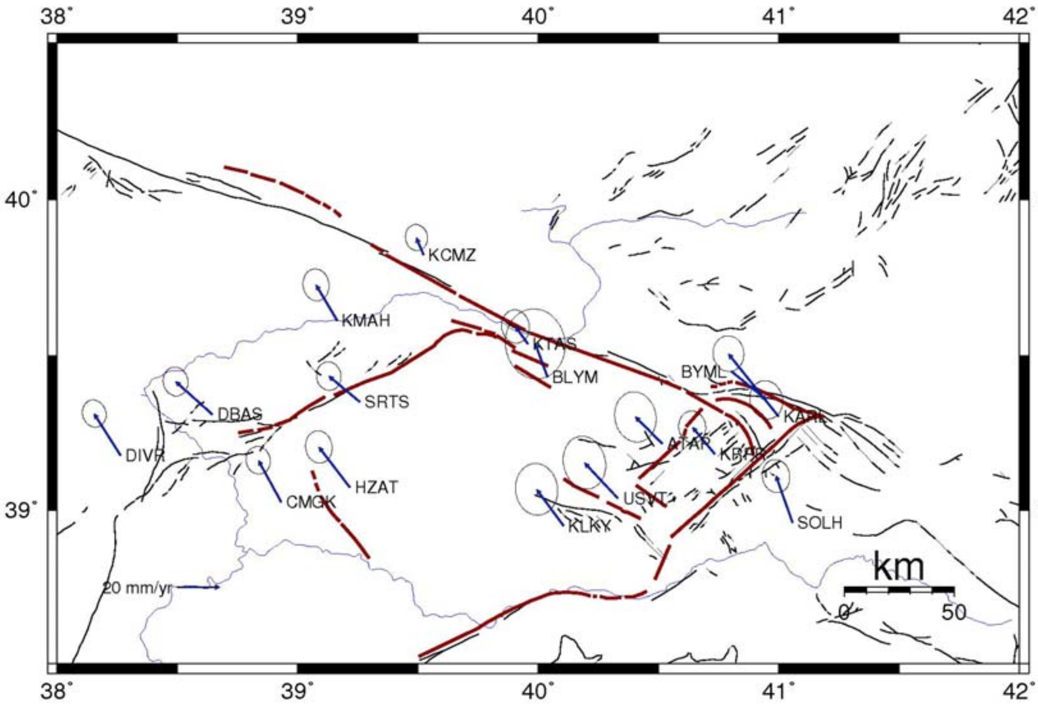

Figure 4. Displacement vectors with respect to Eurasia-fixed reference frame (ellipses are at 95% confidence level and the data covers 2003–2005 time intervals, bold-red lines indicate the faults mapped by this project).

The velocity value by the evaluation of three GPS campaigns is reaching approximately 30 mm/yr. As expected the largest velocities were found in the KARL station point. And the minimum velocity is 3.46 mm/yr. Stations have movements towards north-west directions. The different direction of the CMGK-HZAT group with DBAS suggests that strain has been accumulating in that area which may cause left-lateral release. The western segment of the Ovacik Fault has a distinct morphological aspect showing that it is active. This segment alone is 63 km long. Taking into consideration its intraplate nature with low straining rate, it can be deduced that it can generate earthquakes with magnitudes 7.1 to 7.2. The low rate of strain accumulation on this fault indicates that the fault can produce large earthquakes with a roughly 500-year recurrence interval.

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References

Ambraseys, N. N., 1970. Some characteristic features of the North Anatolian Fault Zone, Tectonophysics, 9, 143-165.

Ambraseys, N.N., 1971. Value of historical records of earthquakes, Nature, 232, 375-379.

Ambraseys, N. N., 1989. Temporary seismic quiescence: SE Turkey, Geophysical Journal, 96, 311-331.

Ambraseys, N. N. and Jackson, J., 1998. Faulting associated with historical and recent earthquakes in the Eastern Mediterranean region, Geophys. J. Int., 133, 390-406.

Ambraseys, N.N. and Melville, C.P., 1995. Historical evidence of faulting in Eastern Anatolia and Northern Syria, Annali Di Geofisica, 38, 337.

Arpat, E. and Saroglu, F., 1975. Some significant tectonic events in Turkey (in Turkish), Bulletin of Geology Institution of Turkey, 18, 91-101.

Herring, T. A., 2004. GLOBK Global Kalman filter VLBI and GPS analysis program, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.

Jackson, J., and McKenzie, D.P., 1988. The relationship between plate motions and seismic tremors, and the rates of active deformation in the Mediterranean and Middle East, Royal Astronomical Society Geophysical Journal, 93, 45–73.

King, R. W., and Bock, Y., 2004. Documentation of the MIT GPS analysis software: GAMIT, Mass. Inst. of Technol., Cambridge, MA.

KOERI NEMC. Bogazici University, Kandilli Observatory and Earthquake Research Institute, National Earthquake Monitoring Center Home Page, February 2007, <http://www.koeri.boun.edu.tr/sismo>.

McClusky, S., Balassanian, S., Barka, A., Demir, C., Ergintav, S., Georgiev, I., Gurkan, O., Hamburger, M., Hurst, K., Kahle, H., Kastens, K., Kekelidze, G., King, R., Kotzev, V., Lenk, O., Mahmoud, S., Mishin, A., Nadariya, M., Ouzounis, A., Paradissis, D., Peter, Y., Prilepin, M., Reilinger, R., Sanli, I., Seeger, H., Tealeb, A., Toksoz, M. N., Veis, G., 2000. Global Positioning System constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus, Journal of Geophysical Research 105, 5695–5719.

McKenzie, D.P., 1970. The plate tectonics of the Mediterranean region, Nature, 226, 239-243.

Nalbant S. S., McCloskey J., Steacy S., 2005. Lessons on the calculation of static stress loading from the 2003 Bingol, Turkey earthquake, Earth and Planetary Science Letters, 235, 632-640.

Nalbant, S. S., McCloskey, J., Steacy, S., Barka, A. A., 2002. Stress accumulation and increased seismic risk in eastern Turkey, Earth and Planetary Science Letters, 195, 291-298.

Ozener, H., Dogru, Garagon A., Turgut, B., Yilmaz, O., Ergintav, S., Cakmak, R., Sanli, U., Arpat, E., Gulen, L., Gurkan, O., 2005. Investigation of crustal deformation and block kinematics along the eastern sector of the North Anatolian Fault by GPS technique (in Turkish), 10th Technical and Scientific Map Assembly of Turkey, March 28-April 1, Ankara, Turkey.

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