Slip Partition on the North Anatolian Fault and Its Splays in Central Anatolia Using GPS Data

Hakan Yavasoglu, Ergin Tari (Turkey) and Frederic Masson (France)

SUMMARY

The one of the major fault system all over the world is the North Anatolian Fault (NAF). There have been lots of destructive earthquakes on the NAF. The important part of the NAF is central part (mid-NAF) such as from Ladik to Ilgaz. In its central and eastern part, the NAF has an asymmetric fish bone structure consisting of an east-trending main branch and splines veering southwestward, towards the interior parts of Asia Minor. Main branch and the splines of the NAF dissected the Anatolian Plate into fault-bounded continental blocks. The GPS campaigns were carried out in order to describe earthquake potential and block kinematics in study area by financial support of TUBITAK and ITU. GPS observations were carried out between 2000 and 2004. The data from campaigns were processed by using GAMIT/GLOBK software. The GPS observations were obtained annually and each period was selected approximately at the same time in year. In each campaign, 8 hours of data in consecutive 3 days with 15 second interval were observed for each station. In this study, the valuable geoscientific results will be presented. In addition, the information about the block modeling and the earthquake potential of mid-NAF will be given.

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INTRODUCTION

The tectonic framework of the Eastern Mediterranean is complexity and dominated by the collision of the Arabian and African plates with the Eurasia plate (Hubert-Ferrari et al., 2002). This collision has created wide variety of tectonic processes on Anatolia such as folds and thrust belts, major continental strike-slip faults, opening of pull-apart basins etc. All these tectonic activities have caused long-term destructive earthquakes in Anatolia (Stein et al., 1997, Hubert-Ferrari et al., 2002).

The Last main earthquakes occurring at the end of the 20th Century, on August 17 and November 12, 1999 in Golcuk and Duzce, also drew the attention of international scientific community over the tectonics and kinematics of the NAF. Due to its geographical position, Turkey forms a natural laboratory to study and understand tectonic events. By analyzing GPS data, it is clear now that the Anatolian plate is escaping towards the west along the North and Eastern Anatolian Faults and is rotating anticlockwise.

The aim of this study is to provide new data to the knowledge on the central part of NAF by using GPS techniques and to interpret these data in a tectonic and kinematics framework.

GEOLOGICAL FEATURES OF NAF

The North Anatolian Fault (NAF) is one of the largest currently active strike-slip faults in the world (Dewey and Şengör, 1979; Jackson and McKenzie, 1984, Şengör et al., 2005). The collision of the African and Arabian plates with Eurasia affected the Anatolian plate. The Arabian plate moves in the north-northwest direction relative to the Eurasia at a rate of about 18-25 mm/yr (McClusky et al., 2000, Reilinger et al., 2006). The African plate also moves at a rate of about 10 mm/yr in north direction relative to the Eurasia. The Anatolian plate escapes from eastward to westward and rotating anticlockwise. Slip rate of the NAF was estimated from the GPS data as approximately 24mm/yr (McClusky et al., 2000, Meade et al., 2002, Reilinger et al., 2006).

The right-lateral NAF extends for 1000 km from Eastern Turkey to the Aegean Sea in an arc parallel to, and 80–90 km from, the Black Sea coast (Ambraseys, 1970, McKenzie, 1972, Barka, 1992). Our study area (LVKI) is between Ladik and Ilgaz with a total length of about 200 km. The project area is 16500 km^2.

One of the important features of the NAF is seen in the central part (Koçyiğit et al., 1998). Here NAF consists of southward splitting concave branches. These splines have generally right-lateral slip and can be compared with the Riedel fractures. One of the biggest splays is known as Sungurlu fault. The other important splays are Merzifon and Lacin faults. In the twentieth century, the faults forming the central part of the NAF and its splays produced different earthquakes greater than magnitude 5 (Canıtez and Üçer, 1967, Eyidoğan, et al. 1991, Blumenthal, 1945, 1948, Taymaz, 2000) (Table 1).

Table 1. Major Earthquakes on The Mid-Anatolia Segment of The NAF in The Last Century

DATE	SETTLEMENT	MAGNITUDE
9 March 1902	Çankırı	5.5
25 June 1910	Osmancık	6.1
21 November 1942	Osmancık	5.6
2 December 1942	Osmancık	5.9
20 December 1942	Erbaa	7.1
27 November 1943	Ladik	7.2
13 August 1951	Kurşunlu	6.9
7 Semtenber 1953	Kurşunlu	6.0
14 August 1996	Mecitözü	5.6
6 June 2000	Orta	6.1

In contrast to the other parts of the NAF, the central part has not been studied using GPS and other geodetic methods in detail yet (McClusky et al., 2000, Reilinger et al., 2006). The data, which will be produced in this project, is expected to add an important contribution to the present knowledge on the NAF.

THE GPS MEASUREMENTS

The Design of Mid-NAF GPS Network

The estimated lateral movement on the LVKI segment of NAF is approximately 24mm per year (McClusky et al**.,** 2000**,** Meade et al**.** 2002). In order to determine movements at the level millimeters, point marks in the network are planned to be built with forced centering instruments (pillars or steel rods etc.) (Oral et al., 1988).

The network was formed by 16 stations (Table 2) because of financial limitations. The stations were named with the four letter abbreviations of the nearest settlement. The stations were chosen so that they could represent the motions of the blocks in the region determined by Isseven and Tuysuz, 2006.

The GPS sites were mainly chosen as representative of the fault-bounded continental blocks. Although there are lots of faults in the area, active and recently earthquake producing faults and continental blocks that are bounded by these faults were taken into consideration.

Table 2. Mid-NAF GPS Network Sites

Site ID	Site Name
ALAC	Alaca
CNKR	Çankırı
DDRG	Dodurga
GBAG	Göllübağlar
GHAC	Gümüşhacıköy
GKCB	Gökçebel
GOL1	Göl
GYNC	Göynücek
HMMZ	Hamamözü
HVZA	Havza
IHGZ	İhsangazi
KRGI	Kargı
KVAK	Kavak
ORTC	Ortalıca
OSMC	Osmancık
SNGR	Sungurlu

GPS Measurements

The campaigns were carried out in or around the month of August between 2001 and 2004. Each station was observed for at least three days in each campaign. SNGR (Sungurlu) and IHGZ (Ihsangazi) stations for the first, third and fourth campaigns, and IHGZ (Ihsangazi) and ALAC (Alaca) stations for the second campaign were selected as continuous stations to control the network against any error and to link the measurements that observed at different times. The duration of the measurement in each day was about 8 hours with the interval of 30 seconds.

GPS Analysis

GPS measurements were analyzed using GAMIT/GLOBK software package (Herring, 1998, King and Bock, 1998) in three-step approach described before (Feigl et al., 1993), and (Dong et al. 1998). Firstly, doubly differenced GPS phase measurements from each day were used to estimate station coordinates EOP (Earth Orientation Parameters) and zenith delay. Loose a priori constraints were applied to all parameters.

Furthermore, in the GPS campaign analysis sites from IGS as global sites were included in the analysis to link IGS network and our regional network (Table 3).

Table 3. Global GPS Sites Used in Analysis

First Campaign		Other Campaigns	
Station	**Location**	**Station**	**Location**
ANKR	Ankara (Turkey)	ANKR	Ankara (Turkey)
BUCU	Bucuresti	GRAZ	Graz (Austria)
ISTA	Istanbul (Turkey)	ISTA	Istanbul (Turkey)
MATE	Matera (Italy)	MATE	Matera (Italy)
NICO	Nicosia (South Cyprus)	NICO	Nicosia (Souht Cyprus)
TELA	Tel Aviv (Israel)	MERS	Mersin (Turkey)
TUBI	Tubitak (Turkey)	TUBI	Tubitak (Turkey)
		ONSA	Onsala (Sweden)
		SOFI	Sofia (Bulgaria)
		WTZR	Wettzell (Germany)
		ZECK	Zelenchukskaya

Secondly, loosely constrained estimation of station coordinates, orbits and EOP and their covariance from each day as quasi-observations were utilized to estimate consistent set of coordinates and velocities with using Kalman filter. Quasi-observations are estimated parameters and associated covariance matrices for station coordinates, earth-rotation parameters and sources positions generated from analyses of the daily GAMIT solution (Herring, 1998). In addition to this, quasi-observations from each day were combined with IGS quasi-observation for same day performed by SOPAC. After this, all quasi-observations from our process and IGS were combined into single quasi-observation. We determined weight from IGS and our process solutions which were combined separately. In addition, repeatabilities of measured days and their nrms (normalized root mean square) and wrms (weighted root mean square) were used to check measurements accuracy.

In the third step, reference frame for our velocity estimates were defined by using generalized constraints for transformation parameters. (McClusky et al., 2000). Eurasian plate was defined by minimizing horizontal velocities of sites (Table 4). After the transformation the root mean square (rms) of station was 0.7 mm/yr. A lot of alternatives were tested to attain the current solution.

Table 4. GPS Sites Used for Definition of Eurasia Plate

Site ID	Location	Site ID	Location
ONSA	Onsala, Sweden	BOR1	Boroweic, Poland
NYAL	Ny-Alesund, Norway	BRUS	Brussels, Belgium
POL2	Bishkek, Kyrghyzstan	HERS	Hailsham, England
POTS	Potsdam, Germany	GRAZ	Graz, Austria
TROM	Tromsoe, Norway	JOZE	Jozefoslaw, Poland
WTZR	Koetzting, Germany	KIT3	Kitab, Uzbekistan
ZIMM	Zimmerwald, Switzerland	KOSG	Kootwijk, The Netherlands
ZWEN	Zwenigorod, Russia	METS	Kirkkonummi, Finland

The velocities in the region following the analysis of the fourth campaign were computed (Figure1).

CONCLUSION

Velocity vector directions and magnitudes are in harmony with the escape of Anatolian Plate towards the west along the North and Eastern Anatolian Faults.

According to GPS velocity vectors, there is no significant movement differences both sites on Sungurlu fault. As there is no record of a big earthquake on this fault in the historical and instrumental period on this fault, the second possibility is most favorable.

When GYNC (Göynücek) and GBAG (Göllübağlar) vectors are examined, there are differences due to their directions. These differences show that Merzifon Plain has continued to improve as a pull-apart basin.

The stations in the middle of the project region (GHAC, HMMZ, OSMC, DDRG) show that Merzifon-Hamamözü-Osmancık fault zone is active, but has been moving slowly.

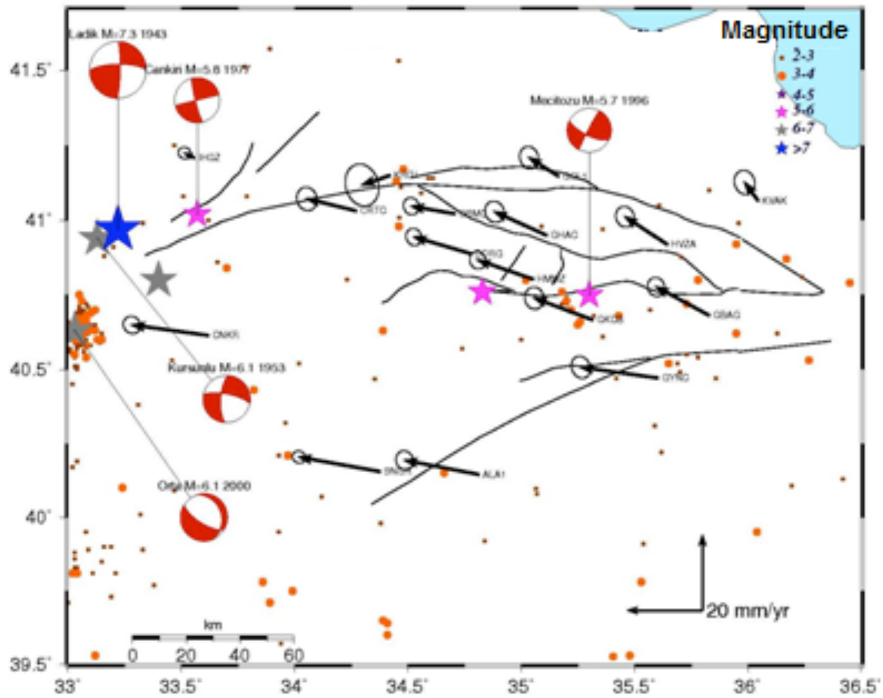

Fig. 1. According to Eurasia Plate, MID-NAF GPS Network Velocity Vectors in ITRF00

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