

GEODETTIC TECHNIQUES ON EARTHQUAKE RESEARCHES (CASE STUDY: DEFORMATION STUDIES ON THE WESTERN PART OF THE NORTH ANATOLIAN FAULT ZONE)

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ABSTRACT

Geodetic methods make major contributions to geodynamic studies. With the rapid developments of geodetic techniques and the accuracy and reliability in geodetic measurements, the geodetic methods have gained importance for monitoring crustal deformation on earthquake researches. Microgeodetic networks which are designed for detecting crustal movements in seismically active areas are capable of monitoring 3-D position changes with a few mm. The North Anatolian Fault Zone (NAFZ) belongs to one of the largest recent active fault systems in the Earth. The study of monitoring horizontal crustal movements on the western part of NAFZ has started by Geodesy Department of KOERI, Bogazici University in 1990. Three geodetic control networks were established in Iznik, Sapanca, and Akyazi regions in order to monitor crustal displacements. The first period observations were performed by using terrestrial methods and these observations were repeated annually until 1993 by using total-station and electromagnetic distance-meter instruments. Since 1994 GPS measurements have been carried out at the temporary and permanent points in the area and the crustal movements are being monitored. In addition to GPS measurements, terrestrial methods were also repeated on Iznik network in the years of 2001 and 2002. Furthermore, there are several on-going and also completed projects which are being conducted by scientists from the universities and the other research institutes for the region of interest. One of these projects is a collaborative effort which is initiated by MIT, Turkish General Command of Mapping, Istanbul Technical University, TUBITAK Marmara Research Center and Geodesy Department of KOERI, since 1996. The goal of the study is to detect the crustal deformation using space techniques, especially GPS. This paper reports the data acquisition, processing, and analysis.

KEYWORDS: Crustal deformation; earthquake; geodesy; GPS; NAFZ

INTRODUCTION

Crustal deformation induced by the motion of tectonic plates produces a wide variety of landforms at the surface of the Earth and their size depends on the duration of the process involved in their formation. Deformation monitoring is conducted for the purpose of detecting and interpreting small changes in the geometric status of the earth. With the rapid developments in the field of modern geodesy, and with the unprecedented accuracy achievable in geodetic measurements using advanced techniques, the geodetic methods have gained world-wide

acceptance for monitoring crustal dynamics for earthquake studies. It is important to measure both the long-term rate of deformation and the short-term deformation associated with the seismic activity along individual faults. The first type of measurement requires accurate topographic maps to quantify the cumulative displacement of surfaces. The second type of measurements requires the capacity of estimating displacements of the ground at the millimeter level of precision over short time intervals. Contrary to the geological research, the studies of crustal deformation are based on the analysis of repeated geodetic measurements, and their combination with results of other geophysical investigations. Geodesy provides facilities to investigate the Earth's crust movements and shares these data with the other disciplines. Multidisciplinary studies on earthquake researches are:

- Investigations the Earth's crust structure
- Monitoring plate movements and deformations
- Determination of earthquake source parameters
- Examining geographical, historical, and depth distribution of earthquakes
- Earthquake prediction

As results of these studies:

- Theories are improved to understand earthquake mechanism
- It is possible to say where earthquakes will strike and at what magnitude
- It isn't possible to say when earthquakes will strike or even at what time intervals
- There isn't any study and advance to prevent earthquakes
- We need more data on large areas at long time scales from different instruments

Following is the list of geodetic tasks to provide contribution to earthquake researches:

- Monitoring global geodynamic phenomenon (polar motion, earth rotation and tides, plate movements)
- Determination of the Earth's gravity field and gravity changes
- Monitoring volcanic activities, plate movements and recent crustal movements
- Monitoring effects of earthquakes, and estimating the structural deformations in large engineering structures
- Compiling data from a variety of sources for GIS

(Gurkan, 1993)

Geodetic studies after an earthquake occurred can be summarized as follows:

- Assessment of damages
- Determination of roads, bridges, dams, buildings, and tunnels deformations
- Repair and strengthen of damaged buildings, and if necessary rebuilding
- Repair of damaged geodetic infrastructure
- Determination of deformation model

EQUIPMENTS, TECHNIQUES AND MEASUREMENTS

Study Area

The North Anatolian Fault (NAF) is one of the most seismically active fault of the world. It runs along the northern part of Turkey about 1500 km, from the Karliova to the North Aegean. Because of the higher seismic activity on NAF Zone (Figure 1), many scientists have been focused on this region. Geodetic observations have been performed for monitoring both local and regional crustal movements by establishing microgeodetic networks along plate boundaries on the western part of NAFZ in Marmara region. The Marmara region is not only a region of critical tectonic significance, but also an area of cultural and industrial importance. This area had

experienced destructive earthquakes in the past. The last important earthquake at the NAFZ took place in August 1999 in Izmit. And more than 15,000 people died.

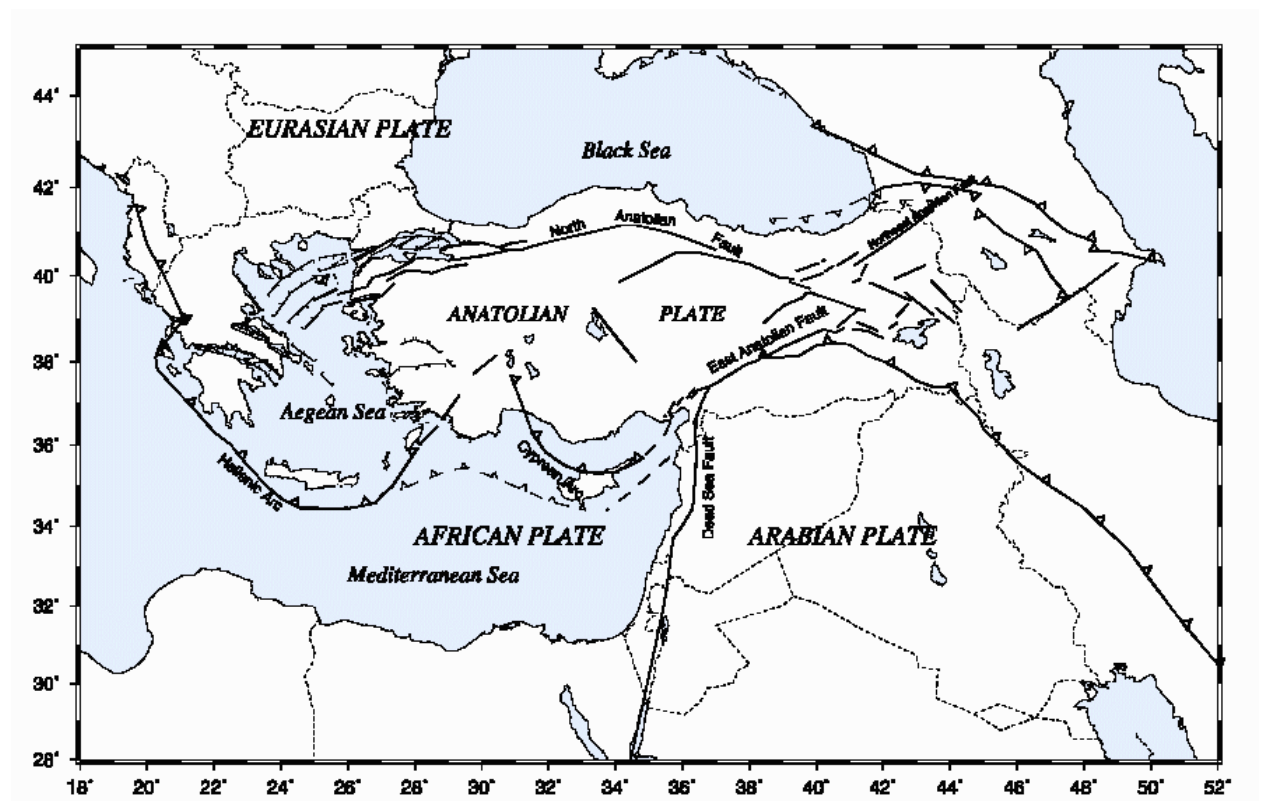


Figure 1: Distribution of active faults in Turkey.

NAFZ is splitted of in two branches near Akyazi. Northern branch is called Izmit-Sapanca Fault, southern branch is called Iznik-Mekece Fault, and their intersection area is called Mudurnu Fault Zone. Three microgeodetic networks at Iznik (10 km² with 10 points), at Sapanca (30km² with 7 points), and at Akyazi (50km² with 10 points) on NAFZ have been established in order to monitor crustal displacements by Geodesy Department of Kandilli Observatory and Earthquake Research Institute (KOERI) of Bogazici University (Ozener, 2000) (Figure 2).

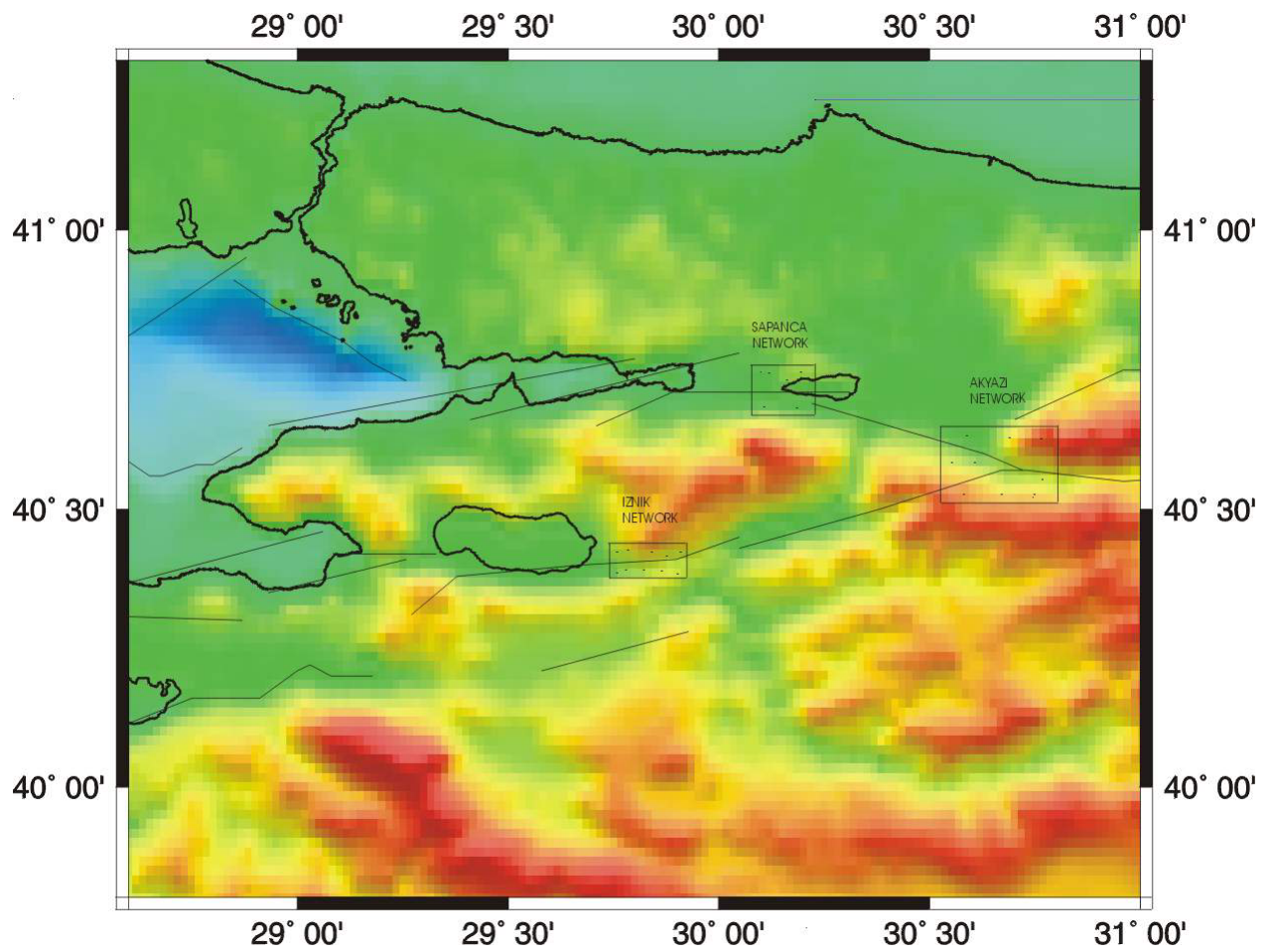


Figure 2: Locations and configurations of networks.

Each station point of networks was monumented on a badrock with a well designed pillar by a geologist and a civil engineer (Figure 3).



Figure 3: Pillar

Equipments, Techniques and Measurements

The first period observations were performed by using terrestrial methods in 1990 and these observations were repeated annually until 1993 by using very precise laser-based instruments (electromagnetic distance meters). Since 1994 GPS technique has been carried out at the temporary and permanent points in the area and the crustal movements are being monitored. Horizontal deformations which have not been detected by terrestrial methods were determined from the results of GPS measurements. Studies have been performed with modern instruments including four Trimble SSE and SSI GPS receivers and three Wild DI 2002, 3000 and Mekometer ME 3000 electronic distance meters.

By using space techniques, networks have been connected for establishing a link between terrestrial and GPS studies and also between the studies near and far fault zone along boundaries on the Western Part of NAFZ (Ozener, 2003). The network with 6 points has been formed by using 2 points from each microgeodetic network on NAFZ with appropriate coverage and geometry.

In 1992, a gravity network with 36 points was established on the region. First epoch observations were performed by two LCR-G type gravimeters. 16 points of this gravity network are pillars of Iznik and Sapanca microgeodetic networks. In 1993, a precise levelling between pillars of Iznik network was performed with a Wild N3 and an invar staff (Gurkan, 1993).

Table 1: Geodetic background of networks

YEARS	IZNIK NETWORK	SAPANCA NETWORK	AKYAZI NETWORK	INSTRUMENTS USED
1990	Construction of first 5 points of the network. Slope distance, horizontal direction and vertical angle observations.	Construction of the 6 pillars of this network has been completed.		Mekometer ME 3000, Wild DI 2002, Zeiss Elta 4
1991	Present network has been extended towards the west by constructing additional 5 pillars. Slope distance and angle measurements.	First epoch slope distance and angle measurements.		Wild DI 3000, Zeiss Elta 4
1992	Slope distance, angle and first epoch gravity measurements.	Construction of one additional pillar. Slope distance and angle measurements.	Construction of 10 pillars	Wild DI 3000, Wild DI 2002, Zeiss Elta 4, LCR G-type gravimeters
1993	Slope distance and angle observations, precise levelling.	Slope distance and angle measurements.	First epoch slope distance and angle measurements	Wild T202, Wild DI 3000, Wild DI 2002 and Wild N3
1994	First epoch GPS observations.	First period GPS observations.	First period GPS observations.	TRIMBLE 4000 SSE
1995	GPS observations.	GPS observations.	GPS observations.	TRIMBLE 4000 SSE, GEOTRACER 2000

1996	GPS observations.	GPS observations.	GPS observations.	TRIMBLE 4000 SSE
1997	GPS observations.	GPS observations.	GPS observations.	TRIMBLE 4000 SSE, GEOTRACER 2200
1998-2000	GPS observations.	GPS observations.	GPS observations.	TRIMBLE 4000 SSE, SSI, SST
2001	GPS observations, slope distance observations.	GPS observations.	GPS observations.	TRIMBLE 4000 SSE, SSI, SST, WILD DI2002, 3000
2002	GPS observations, slope distance observations.	GPS observations.	GPS observations.	TRIMBLE 4000 SSE, SSI, SST, WILD DI2002, 3000
2003	GPS observations.	GPS observations.	GPS observations.	TRIMBLE 4000 SSI, 5700

Beginning in 1996, MIT, Turkish General Command of Mapping, Istanbul Technical University, TUBITAK Marmara Research Center and Geodesy Department of KOERI initiated a collaborative effort to better determine earthquake hazards in Marmara region. Within this program, GPS campaigns have been performed at least twice a year at distributed 49 points that spread over the region. Results of the study is displayed in figure 4.

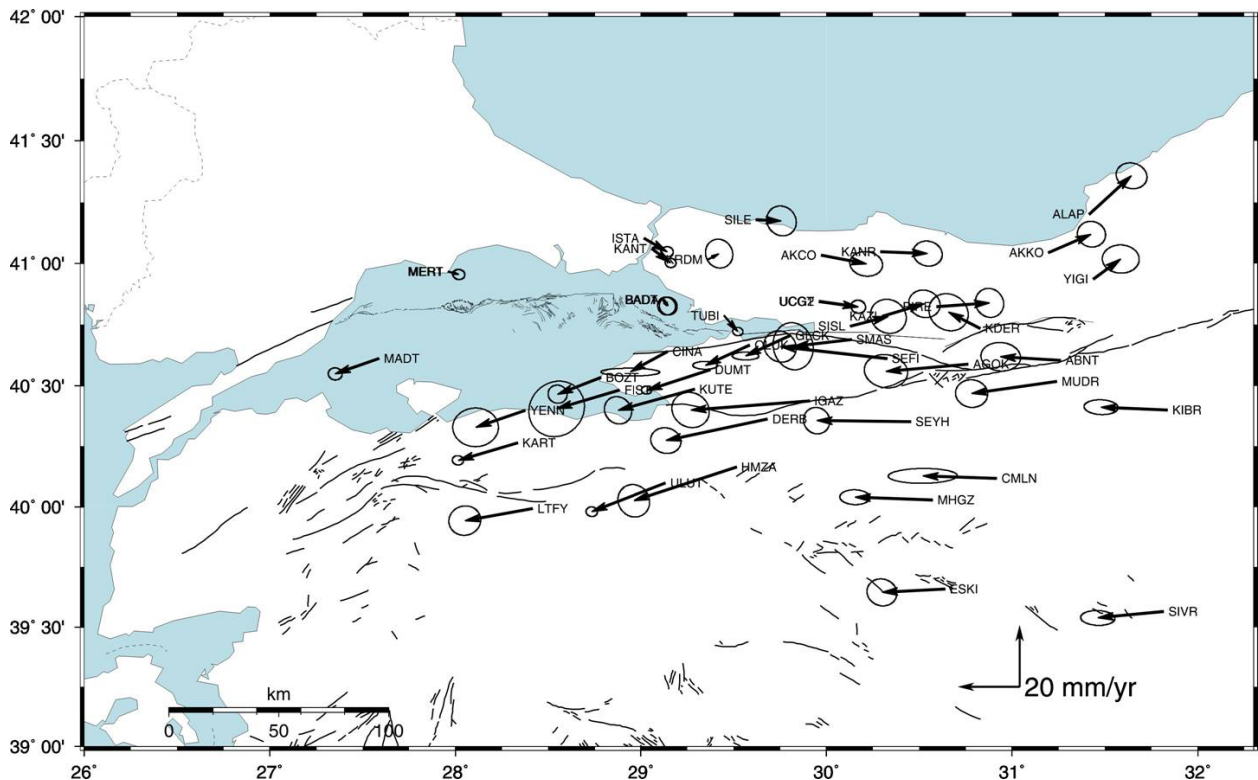


Figure 4: Based on GPS observations between 2001-2003.

CONCLUSIONS

Geodetic studies having geodynamic purposes are increasing world-wide with the advance of technology. Geodetic networks should be established in such a way that they are capable to detect variations in time and crustal movements. In order to understand earthquake mechanism,

data from interdisciplinary studies should be evaluated together and a geographic information system aimed at earthquakes should be formed.

This observed displacement field of interest can be explained by different approaches but in all cases more measurement data are needed. The results of the terrestrial and GPS campaigns suggest that very small relative site deformations in local GPS Networks and terrestrial networks. Furthermore, no significant movement between the northern and the southern part of the Iznik-Mekece fault has been detected. But presence of seismic gaps in the area implies potential sites for future large earthquakes. Internal deformation of southern branch is much smaller (before and after Izmit Eq.) Our local network in the northern branch indicates the normal NAF right lateral motion (Ozener, 2003).

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