



Geodynamic study in the region south of Sofia by GPS

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Introduction

The region south of the Sofia complex graben represents a complicated tectonic node formed by the intersection of several recently active fault structures (Shanov et al., 1998). Its principal direction coincides with the primary neotectonic proto-fracture of general trend N115-120° limiting and separating the listric prisms originating from the northern and the southern borders of the graben. The main fault structures are the Vitosha, Back-Vitosha, Lozen and Zheleznitsa faults. Concentration of the recent seismic activity is observed mainly in the south-south-east and north parts of the graben as a result of geodynamic processes (Botev et al., 1991-2004). The geodetic investigations in the area were started in the 70-ies of the last century and were carried out mainly in the region of the so-called Pancharevo node (Петров, 1985; Totomanov et al., 1987; ДИМИТРОВ, 1993). The new satellite geodetic technologies and especially the Global Positioning System (GPS) provide the possibility of obtaining new quantitative assessments for the contemporary crustal movements.

The new results have been obtained on the basis of the analysis of geodetic measurements together with data from geological investigations. A local GPS network is being established in 1999, which is expanded to the west with time and is periodically measured. The results of the combined analysis of the geodetic measurements of 6 GPS campaigns performed from 1999 till 2005 confirm the activity of the Vitosha and Lozen fault as proven by geological data.

Results from previous geodetic investigations

Since 1982 the Central Laboratory of Geodesy and the Military Topographic Survey have started geodetic investigations in the Pancharevo-Bistritsa region (Петров, 1985; Totomanov et al., 1986, 1987). The first analysis of the triangulation measurements and the computed deformation parameters by the

method of mean strain tensors were presented in (Стефанов, 1993). The author reported that the horizontal movements of the points are about 10 cm and their directions show a tendency of predominantly strain compression for the whole network.

Dimitrov and Ivanov (ДИМИТРОВ, ИВАНОВ, 1997) determined horizontal movements and tectonic strains. The analysis of the results shows that there is clear tendency of strain compression with approximate orientation N25°. The authors determined three zones of compression: between the Vitosha and Plana Mountain confirmed to uplift movements of the Bistritsa Neogene basin over the Plana intrusive; between the Plana and Lozenska Mountains in confirmation of south dipping of the Iskar-Yavorets fault, and between the Vitosha and Lozenska Mts. along the Iskar fault zone in confirmation of northeast uplift with dip about 45° to the northwest, observed in the area of the Kokalyane Hydro-Power Plant near the Pancharevo village. The strain pattern along the length of the studied area marks zones of predominant compression from west to east. Along the Vitosha and Lozen faults a process of recent extension has been found out. During the period 1982-1991 Dimitrov and Ivanov (ДИМИТРОВ, ИВАНОВ, 1997) ascertained that the deformation processes were irregular, being most active in the period 1982-1988. The authors concluded that the Vitosha, Lozen and Zheleznitsa faults, and the Iskar dislocation were "symptomatically" active.

A vertical network around the Pancharevo fault junction was established in 1982 (Totomanov et al., 1986, 1987). The determination of the vertical deformations was done by repeated precise leveling covering the time span 1982-1991 (Totomanov et al., 1986, 1987; ДИМИТРОВ, 1993; ДИМИТРОВ, СТОЯНОВ, 1997; ЦЕНКОВ, ГРЕБЕНИЧАРСКИ, 1998). The 10-year monitoring shows activity of the Vitosha fault. It is expressed in relative uplift of the Vitosha structure and downward movement of the Sofia graben. No vertical movements are found out along the Zheleznitsa fault and the Iskar fault zone.

Preliminary results, from GPS measurements in 1999, 2002, and 2003, show recent activity of the Lozen and Vitosha faults, as well of the Iskar fault zone (Dimitrov et al., 2001; Pashova et al., 2002).

In Kotzev et al., (2005) analysis of 37 GPS sites located in central west Bulgaria is presented. The main conclusions made by the authors confirm the recent dominated north-south extensions at a rate of 1-2 mm/yr. Because of the comparatively sparse GPS network and short time span of observations the authors do not present results about the recent activity of the main tectonic structures. They found out non-uniformly distributed deformations and poorly defined local zones of compression and extension.

Results from previous geodetic studies concern a local region south of Sofia. The data from leveling measurements could not verify the geological concept for the Sofia depression with a general trend of continuing subsidence of the graben. Because the region is too small and the results obtained from the classical measurements (Стефанов, 1993; ДИМИТРОВ, ИВАНОВ, 1997) were with insufficient accuracy and consistency, the geological hypothesis for recent extension in N-S direction (Shanov et al, 1998) could not be confirmed, too. That was the reason for establishing the GPS network in 1999. The network covers the main tectonic structures in this region especially in the southern and western part of the graben.

GPS network, processing and analysis of data

The first configuration of the local GPS network, established in 1999, consisted of 4 points. The three points Bistritza (BIST), Gradishte (GRAD) and Lozen (LOZ2), along with the geodetic observatory "Plana" (PLA1) and the IGS permanent station SOFI are measured each year from 1999 to 2005 (fig. 1). A few points were added to extend the network in the successive years to obtain better coverage of the tectonic structures in the region. In the period 2004/2005, by GPS measurements of 6 points, a connection was established between the local network and the regional research network in Southwest Bulgaria (Georgiev et al., 2006).

All GPS campaigns were processed with the state of art GPS processing software Bernese, version 5.0. Details about the GPS processing strategy can be found in Geodesy 18 (Georgiev et al., 2006). All velocities are relative to Eurasia and their values are plotted in fig. 1. No velocities were calculated for points REDU, SOF2 and KOPI because of the short observation period between the GPS campaigns.

Conclusions

Summarizing the geodetic investigations carried out so far, as well as the newly obtained results, the following conclusion can be drawn:

— According to the obtained horizontal velocities of the points by the GPS data, two zones with different intensity of the horizontal movements may be distinguished in the studied region. In the first zone — northwest of the Zheleznitsa fault and southwest of the Vitosha fault, which comprises mainly the Vitosha pluton, the horizontal velocities of the points are within ~ 1 mm/yr higher than the point velocities in the rest of the area;

— The horizontal velocities of the two points — Plana and Lozen, situated on two different tectonic structures, on the Plana and Lozen horst respectively, exhibit homogeneous movement in southern direction. However, according to the map of the vertical movements, a subsidence of the eastern board of the Iskar fault zone and the northern board of the Lozen fault is observed. On the basis of the analysis of the map for the vertical velocities (Belijashki, personal communications), it may be concluded that the region northeast of the Vitosha fault and the Iskar-Yavorets fault zone subsides at a higher rate of ~ 1-2 mm/yr, while the Plana pluton subsides with lower rate of ~ 1 mm/yr. Subsidence of the northern board of the Lozen fault has been established too;

— Over-thrusting of the Vitosha pluton upon the Plana one is observed along the Zheleznitsa fault. This conclusion is confirmed also by the obtained results for the compressive stresses between the Vitosha and Plana horsts by Stefanov (Стефанов, 1993) and Dimitrov and Ivanov (ДИМИТРОВ, ИВАНОВ, 1997);

— Comparing the obtained results for the horizontal movements in Southwestern Bulgaria (Georgiev et al., 2006) with the obtained velocities of the points to the south of Sofia, gradual increase of the velocities are established from the north to the south. This is evident also from the direct comparison of the velocities of PLA1 and LOZ2 with these of SAPA and MALA (fig. 1).

— The mechanisms of the two seismic events (fig. 1) in 1995 and 2006, which might be referred to the Vitosha and Zheleznitsa faults respectively, confirm the established by the geodetic measurements character of the tectonic movements. The earthquake mechanism on 14. 12. 1995 shows dip-slip normal faulting along the Vitosha fault. The earthquake mechanism on 27. 04. 2006 has to be accepted with the condition that data from restricted number of seismic stations have been used (Botev, personal communications). Regardless of this, it is evident that the movement in the region of the Bistritsa village was realized along the Zheleznitsa fault. This movement is of the thrust type and the mechanism confirms the compression.

The basic conclusion that could be drawn is that the geodetic data are in agreement with the geological hypothesis for the recent activity of the Vitosha, Zheleznitsa and Lozen faults. The slow movements of the Earth's crust could be related with the con-

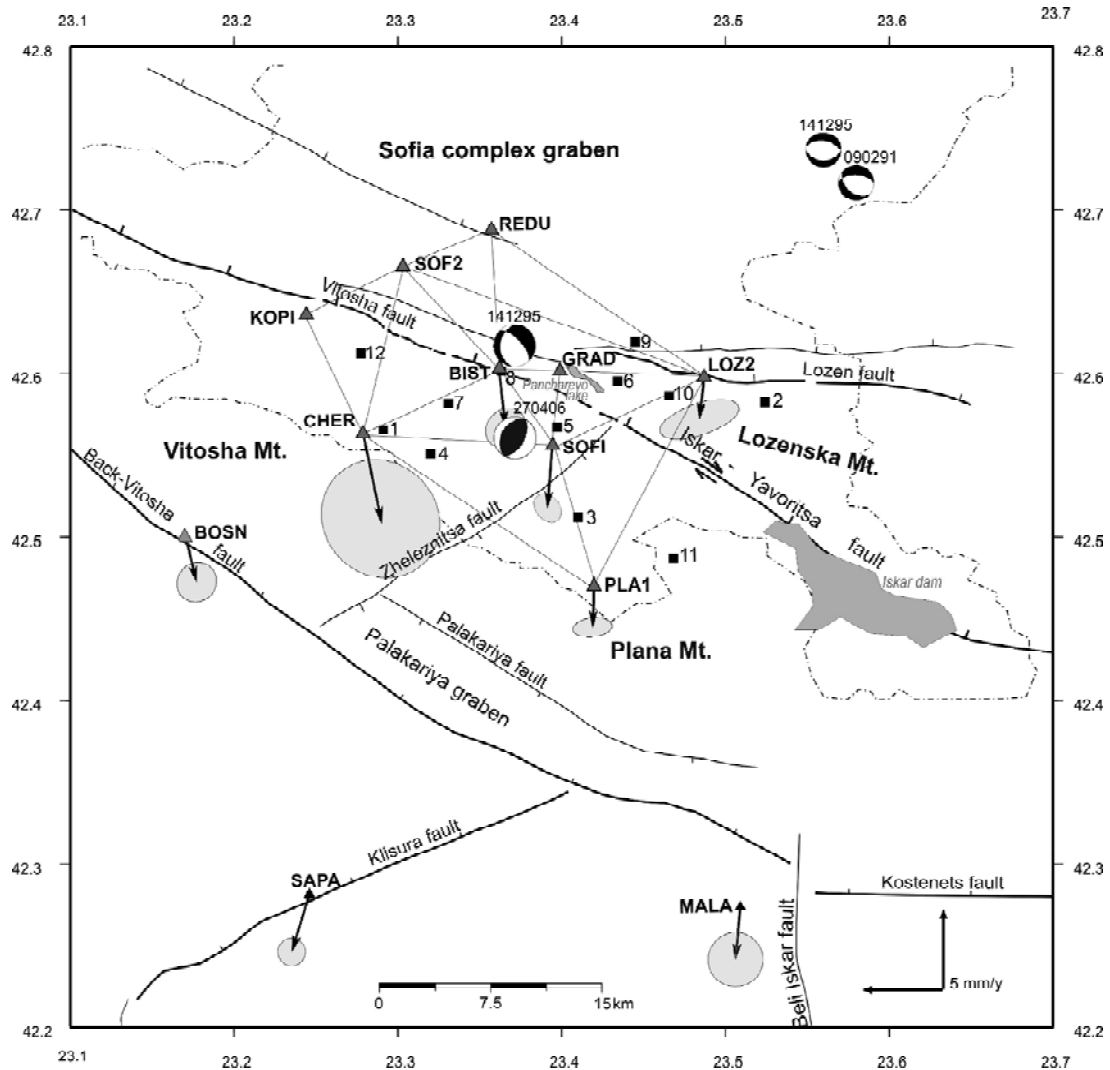


Fig. 1. Horizontal velocities of GPS sites relative to Eurasia

temporary tectonic processes. The determination of the velocities of the points Reduta, Sofia-2 and Kopototo will provide valuable estimates of the movements along the Vitoshka fault and the southern part

of Sofia. The extension of the local network to the southeast using points from the Pancharevo-Bistriza network will allow assessing the movements along the Iskar-Yavoritsa fault zone.

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Геодинамично изследване в района южно от гр. София с GPS

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Резюме. Представени са основните резултати от обработката и анализа на 6 кампании GPS измервания на геодинамична мрежа в района южно от гр. София за периода 1999—2005 година. Определени са скоростите на точките от GPS мрежата спрямо стабилната част на Евроазиатската тектонска плоча. Получените хоризонтални

скорости са анализирани съвместно с наличната геоложка информация. Резултатите потвърждават съвременната активност на Витошкия и Железничкия разломи, която се проявява в постоянната слаба сеизмичност и бавните тектонски движения, установени по геодезическите данни.