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TIMOK FAULT AND TERTIARY STRIKE-SLIP TECTONICS IN PART OF WESTERN BULGARIA

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ABSTRACT. The existence of NW-SE and NNW-SSE trending, regional-scale faults is well-known feature in the area of Tran and Breznik (West Bulgaria). Despite the numerous studies in the area, there is a lack of direct data about the kinematics of the main fault zones. Our investigations allow to define three groups of faults and also demonstrate the dominant dextral strike-slip kinematics of the faults from Pernik fault zone, as well as of several segments of Tran-Kosharevo fault. The field data, together with analysis of the existing maps, suggest the existence of another main strike-slip fault zone with almost N-S strike – the Timok fault. This fault is well-documented in Eastern Serbia, as its continuation in the area of Tran (Kraishte zone) was already suggested by Karaguleva et al. (1980) and Krautner and Krstic (2003). In the westernmost parts of Bulgaria, the Timok fault is traced along the fault segments, previously interpreted as parts of Tran-Kosharevo fault. To the Southward the zone is following the Serkirna fault. Unlike the northeast Serbia the translations along the Timok fault in western Bulgaria are much smaller – probably of not more than few kilometers. Additionally, our new data do not support the idea that these fault zones are part of Maritsa fault zone, well-defined southeast from Sofia.

Key words: Timok fault, strike-slip tectonics, western Bulgaria

ТИМОШКИЯ РАЗЛОМ И ТЕРЦИЕРНА ОТСЕДНА ТЕКТОНИКА В ЧАСТ ОТ ЗАПАДНА БЪЛГАРИЯ

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РЕЗЮМЕ. Съществуването на регионални разломявания с посока северозапад-югоизток до север-северозапад-юг-югоизток е отдавна познат феномен за района на Трънско и Брезнишко. Въпреки многобройните изследвания, конкретни данни за кинематиката на тези разломи не са излагани. Проведените теренни изследвания позволяват да се дефинират основно три групи разломи, като също указват за предимно дясно отседен характер на движенията по тези от Пернишката разломна зона, а така също и по редица сегменти на Трънско-Кошаревския разлом. Теренните данни, както и анализа на картните материали показват присъствието на още една регионална отседна структура – Тимошкия разлом, характеризиращ се с почти север-южна посока. Този разлом е ясно обособен в Сърбия като неговото продължение в района на Трънското Краище вече беше подсказано от Karaguleva et al. (1980) и Krautner and Krstic (2003). В най-западните части на българска територия, Тимошкият разлом съответства на разломявания, в миналото интерпретирани като оперяващи сегменти на Трънско-Кошаревския разлом. В южна посока негово продължение се явява Секирненския разлом. За разлика от североизточна Сърбия, в Трънско транслациите по Тимошкия разлом са много по-малки (до няколко километра). Не може да бъде потвърдена и идеята, че коментираните зони са част от Маришката разломна зона, добре дефинирана на югоизток от София

Ключови думи: Тимошки разлом, отседна тектоника, западна България

Introduction

One of the distinctive features of north vergent branch of the Alpine orogen in the Balkan Peninsula is its highly arcuate geometry (Fig. 1, e.g. Burchfiel, 1980; Csontos and Vörös, 2004; Schmid et al., 2008). Especially the linkage between the Carpathians and the Balkanides is characterized by a westward convex arc, probably formed by oroclinal bending during the northward movement of the Carpathians units when invading the so called Carpathian embayment (e.g. Channel and Horváth, 1976; Burchfiel, 1980; Csontos and Vörös, 2004; Fügenschuh and Schmid, 2005). This Early Oligocene to Early Miocene movement was accommodated by dextral strike-slip motion along curved fault systems such as Cerna-Jiu and Timok faults (Fig. 1, Berza and Drăgănescu, 1988; Ratschbacher et al., 1993; Kräutner and Krstić, 2002, 2006; Schmid et al., 2008; Tarapoanca et al., 2007) with total displacements of up to 100 km (Moser, 2001; Fügenschuh and Schmid, 2005). However, recently Shaw and Johnston (2012) presented an alternative model, based on paleomagnetic data, in which the Carpathian–Balkan bend formed as a result of vertical axis rotation of an originally linear orogen.

The existence of major wrench faults along the western boundary of the Moesian platform was already known since the 1950's (e.g. Sikošek, 1955) whereas their significance for the formation of the Carpathian-Balkan arc was recognized from the beginning of the 1980's (e.g. Karagjuleva et al., 1980). Unfortunately, the existence of these early contributions not only left unrecognized by the scientist dealing with large-scale Alpine reconstructions, but their implications were not taken into account in the most recent studies of the tectonics of western Bulgaria (Marinova et al., 2010 a,b).

Sikošek (1955) describes the north-south trending large strike-slip fault zone in the easternmost Serbia as Poreč-Timok dislocation. Based on the offset of rock units, minimum displacement of about 50 km along this structure was estimated. Furthermore, Karagjuleva et al. (1980) described the Poreč-Timok dislocation as part of much longer fault (Timok-Pirot-Bunovo fault) that stretches for more than 150 km from Southern Carpathians to the western Bulgarian Kraishte area. To our knowledge, the study of Karagjuleva et al. (1980) is the only one dealing with the problem of the continuation of Timok strike-slip zone in Bulgaria. According to these authors the trace of the fault runs along a complexly faulted area east to southeast of Tran and further south in Kraishte area. Much later, Kounov et al. (2011) connected Timok fault zone with strike-slip structures, responsible for the development of Late Oligocene - Early Miocene basins in Kraishte area. The most prominent fault zones in the Kraishte are the Tran-Kosharevo and Pernik faults (Figs. 2 and 3,e.g. Kostadinov, 1977, 1971). They are both described as up to several kilometers wide faulted domains incorporating single faults or fault zones with various kinematics all having similar NNW-NW–SSE-SE strikes. They are considered as marking the boundary between Sredna Gora and Kraishte zones of the Balkanides (e.g. Ivanov, 1998) recording a complex evolution including multiple reactivations (e.g. Zagorchev et al., 1995). According to Bojadjiev et al. (1971) the Pernik fault represents the westernmost continuation of the Maritsa fault zone (Fig. 1). Similar suggestion about the western prolongation of the Maritsa fault system was made later by Ivanov (1998). He also interpreted the Tran-Kosharevo and Pernik zones as Late Alpine strike-slip faults.

Unfortunately the suggested relationships between the Timok fault in Serbia and the Tran-Kosharevo and Maritsa faults rests purely empiric and the last detailed structural studies in the area dates from the early 1970's. Here we present some new structural data and observations from the area of Tran shedding some new lights on the problems related to the correlations and direct interconnections between these major Cenozoic tectonic features in the Balkanides.

Gelogical setting

The major tectonic features characterizing the area of Tran are the Tran anticlinorium and the Lyubash monocline (for overview and detailed references see Ivanov, 1998; Zagorchev, 2001). The Precambrian metamorphic rocks (Vukan complex of Marinova et al., 2010) in the core of the Tran anticlinorium are intruded by Ediacaran-Cambrian and Variscan magmatic rocks. The post-Variscan sedimentary cover from the limbs consists of Permian to Valanginian deposits (Fig. 2). The structure is strongly fragmented by several fault systems (Fig. 2).

To the northeast the Tran anticlinorium is separated from Lyubash monocline by the various faults and fault segments collectively known as Tran-Kosharevo fault (Kostadinov, 1977). The monocline is extending more than 40 km from the Bulgarian border to the Pernik basin and is built of Paleozoic to Mesozoic northeast dipping sediments (Fig. 2, Kostadinov, 1977). Its continuation northwest in Serbia is known as Kusovrana anticline (Fig. 2, Anđelković et al., 1977). To the northeast Pernik fault zone separates the Lyubash monocline form the Late Cretaceous sedimentary basin of Sredna Gora zone (Fig. 2).

The Tran anticlinorium and the Lyubash monocline were formed most probably during the Early Alpine (late Early Cretaceous) orogeny (e.g. Zagorchev, 2001) whereas they, or at least part of them, have experienced some exhumation during the later tectonic phases (e.g. Antić et al., 2016).

Tran anticlinorium and Lyubash monocline are situated in the footwall of a prominent Early Alpine thrust (e.g. Zagorchev, 2001) that emplaces the Lower Paleozoic sediments of the Morava Unit onto the Mesozoic sediments from the southwest periphery of the Tran anticlinorium (Fig. 2). The easternmost preserved frontal part of the allochthon (Penkiovtsi klippe) is cropping out in the western part of the study area (Figs. 2 and 3).

Main results and previous considerations

Field studies aiming to unravel the evolution of the complicated fault network in part of Kraishte zone were carried out in the area of Tran (Fig. 2). When outcrop conditions allowed a structural analysis of the faults was also conducted.

Our study also includes a careful analysis of all previous maps and cross-sections, combined with the use of detailed satellite imagery. We have been able to produce compiled geological map of the investigated area (Fig. 2) which is primary based on recently published maps for the Bulgarian part of the area (Marinova et al., 2010a, 2010b) and the geological map of SFR Yugoslavia 1:100 0000, sheet Breznik (Anđelković et al., 1977) for the Serbian territory.

Our structural data were combined with the analysis of the published maps, which performed along the three previously recognized major groups of faults and fault zones in the study area. One trending generally NW-SE, another striking N-S to NNW-SSE and individual faults oriented NE-SW and WNW-ESE.

NW-SE trending fault zones

The Pernik fault zone is up to several kilometers wide zone of localized brittle deformation which consists of prominent set of NW-SE trending faults (Figs. 2 and 3, Kostadinov, 1971). They are developed mostly in the Upper Cretaceous sediments or along their contact with the Tithonian-Berriasian carbonates of the Lyubash monocline and can be traced almost continuously from Bankia to the area of Breznik (Fig. 2). Northwest of Bankia, in Serbia, this zone probably continues along the contact of the Upper Cretaceous sediments and the Tithonian-Berriasian carbonates. Most of the faults of this zone are steep and in several cases fault planes bear slikenfibres that indicate dextral-strike slip movement (Fig. 3). However, previous authors have reported some exhumation of the Lyubash monocline along this zone describing it as a horst-monocline (e.g. Kostadinov, 1977).

Previously the Tran-Kosharevo fault was described as a structure generally bordering the Lyubash monocline from the SW and trending N-S from the area of Tran to Ezdemirtsi, where changing to SE direction (Kostadinov, 1977; Marinova et al., 2010a, b). Our new field data, as well as the analysis of the maps indicate that this supposedly single structure actually encompasses, at least, two different faults. The Kosharevo fault, which is striking NW-SE, could be clearly followed along the western boundary of the Lyubash monocline from Kosharevo northward to Banishte where it ends up in the NNW-SSE trending structure which we are attributing here to the Timok fault.

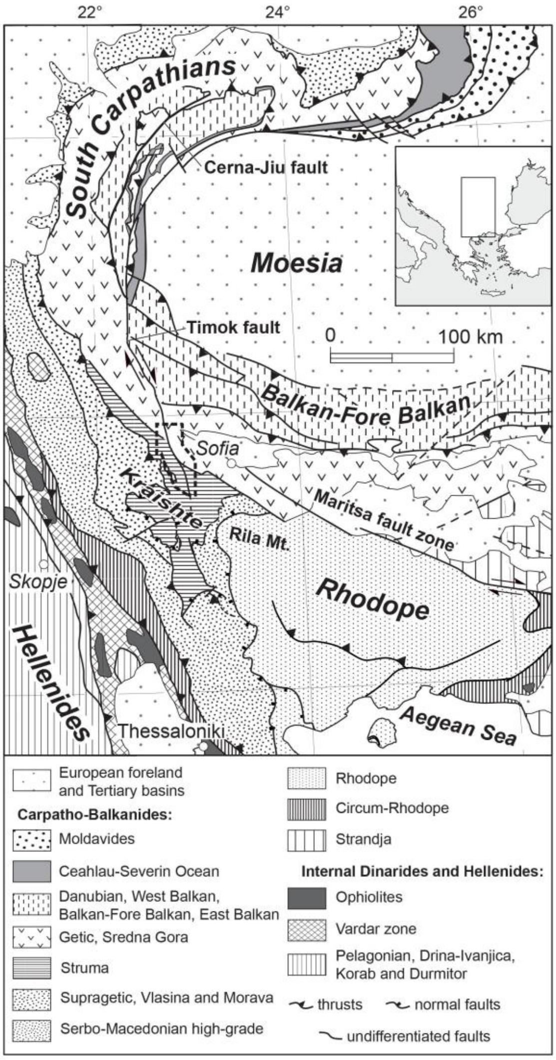

Fig. 1. Tectonic map of part of Balkan Peninsula (after Schmid et al., 2008). Box outlines Figure 2

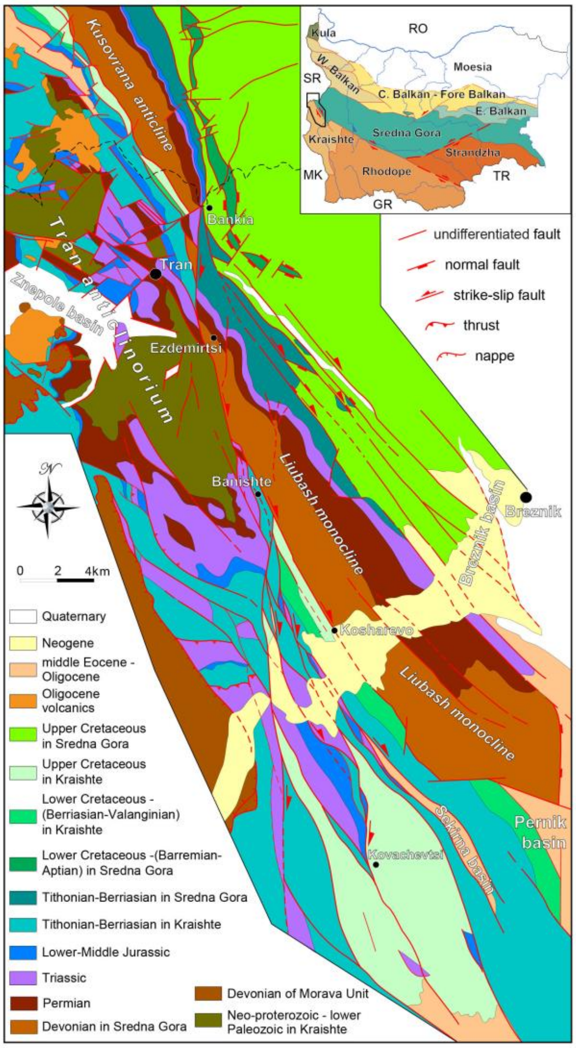

Fig. 2. Geological map of the study area (after Marinova et al., 2010a,b; Kräutner and Krstić, 2003)

As a logical continuation of the Tran-Kosharevo fault, north of Tran, we suggest the fault bordering to the southwest the Lower Paleozoic sediments of the Lyubash monocline and its continuation, the Kusovrana anticline in Serbia, named here as Tran fault (Figs. 2 and 3).

N-S to NNW-SSE trending fault zones

This fault system of N-S to NNW-SSE trending faults have been previously described in the study area (Karagyuleva, 1970; Kostadinov, 1971, 1977). In the light of our field observations the N-S fault between Bankia and Banishte, previously regarded as a part of the Tran-Kosharevo fault, is now considered as an independent fault representing a direct continuation of the Timok fault in Bulgaria. This is in agreement with the existence of N-S trending faults in neighbouring Serbia (Fig. 3, Kräutner and Krstić, 2002). South of Banishte, the Timok zone can be traced along previously recognized Sekirna fault (Karagyuleva et al., 1980; Marinova et al., 2010a). There is not enough field data to document the continuation of the Timok zone south of Bunovo (south of the study area), as suggested by Karagyuleva et al. (1980). It could be proposed that the fault zone ends up in a horsetail splay of faults, which could be clearly observed south of Kosharevo in the southern part of the study area (Figs. 2 and 3).

Field observations, combined with analysis of existing geological maps and satellite images clearly shows that Timok fault cuts the older Tran-Kosharevo fault (Figs. 2 and 3). This is evident by the ~2.5 km offset of the Lyubash monocline along the Timok fault between Bankia and Ezdemirtsi (Fig. 2). It is important to notice that amount of strike-slip displacement along the Timok fault decrease from 50 km in northeastern Serbia (Sikošek, 1955) to ~2.5 km in the Kraishte zone suggesting dying out of the structure in the area.

NE-SW and WNW-ESE oriented individual faults

Another distinct fault group, in the study area, is presented by NE-SW and WNW-ESE structures which are generally characterized by their relatively short length. These faults clearly cut the faults of the other two groups and are mostly developed in the core of the Tran anticlinorium (Figs. 2 and 3). Southwest of Bankia such NE-SW trending dextral strike-slip fault is offsetting both the Tran and Timok faults (Figs. 2 and 3).

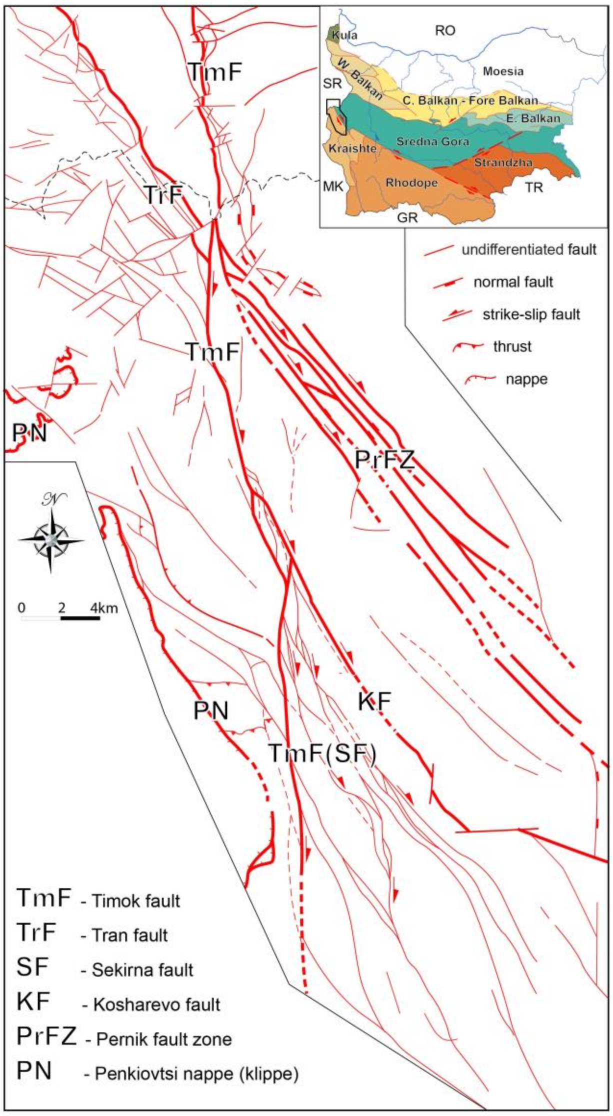

Fig. 3. Tectonic sketch map of the study area. Thicker lines represent the major faults discussed in the text

Discussion and conclusions

The time of the activities along the first two groups of faults could be well constrained by the age of the youngest sediments which they cut and the oldest which are sealing them. These are, respectively, the Late Oligocene - Early Miocene sediments of the Pernik and other smaller basins from the southern part of the study area and the Late Miocene-Pleistocene sediments filling small basins such as Znepole and Breznik (Fig. 2). These sedimentary sequences give a very narrow age span of activity between the Early and the Late Miocene. Only the NE-SW and WNW-ESE oriented faults seem to be active even during the Quaternary.

It was previously proposed that the formation of the Late Oligocene-earliest Miocene NW-SE elongated continental basins in Kraishte such as Sekirna, Pernik and Bobov Dol was related to dextral strike-slip tectonics during SSE-NNW transtension (Moskovski, 1971; Kounov et al., 2011). The evolution of the sedimentary basins was obviously controlled by the NW-SE oriented faults, of the first group, in releasing bend zones or at their terminations (Kounov et al., 2011). It must be noticed that activation of this fault group was facilitated by the fact that often they present a set of already existing inherited structures. The observed local thrusting of the basement rocks onto the Cenozoic sediments and their folding may have developed in restraining bend zones where permutation of the $\sigma 1$ and $\sigma 2$ stress axes has occurred (Kounov et al., 2011). It could be supposed that a NE-SW oriented $\sigma 1$ major stress axes was responsible for the formation of the NNW-SSW to N-S dextral strike-slip faults of the second group. Strike-slip tectonics in the Kraishte area was already explained by the processes of northeastward lateral extrusion and rotation of continental fragments around the western boundary of the Moesian platform (Boccaletti et al., 1974; Tapponnier, 1977; Burchfiel, 1980; Schmid et al., 1998; Fügenschuh and Schmid, 2005; Kounov et al., 2011). On the other hand the NE-SW oriented middle Miocene compression in the Balkans was related to the arrival of the Kruja crustal fragment at the north Hellenic trench in Albania (Burchfiel et al., 2008).

In line with the ideas of previous researchers (e.g. Kostadinov, 1970, 1977; Zagorchev, 2001) it could be suggested that the localization of the main fault systems is a result of structural inheritance from Variscan and Early Alpine weak zones. The most striking example is the southwestern margin of the Lyubash monocline, where there are clear evidence that tectonic activities along the precursors of the Kosharevo fault had controlled the sedimentation in the area since the Paleozoic (e.g. Kostadinov, 1970).

Our data also give some arguments for questioning the proposed link between the NNW-SSW to N-S trending steep fault zones in western Bulgaria and the fault segments that form the Maritsa fault zone (Bojadjiev et al., 1971). The strongest arguments are the overall geometry of the fault systems in this part of Bulgaria and the lack of robust data for supporting the connection between Pernik and the Maritsa fault zones. The main trace of the Maritsa zone is running along the Iskar River valley between Iskar dam and the Pancharevo (east from the study area), whereas farther northwest the zone is buried below the sediments of the Quaternary Sofia graben (Fig. 1, Gerdjikov et al., 2015). Furthermore, Gerdjikov et al. (2015) reported Eocene magmatic rocks sealing the fault zone. On the other hand, the suggested trace of Maritsa zone along northeastern footstep of Rila Mountain (Fig. 1) and northeast rim of the Palakariya graben (e.g. Ivanov, 1998) is very poorly documented and there is no reliable data for exact geometry, kinematics and timing of the movements along the fault segments. Taken together these facts rule out the possibility of direct continuation of Maritsa fault zone in the Kraishte area. Furthermore, our data suggest that the Tran-Kosharevo fault is not a single fault structure whereas its generally N-S trending part belongs to the Timok fault. Unlike the classical area in Eastern Serbia (Sikošek, 1955), in this southern part the translations along the dextral fault zone are much smaller – probably of less than few kilometres.

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