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NEW DATA ABOUT THE KOSTALEVO FAULT (BULGARIA)

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ABSTRACT. In a limestone quarry situated south of the Cherepish monastery, on a large area on the recent quarry face, a fault plane crops out with a slickenside comprising well-expressed meso-structural indicators for the fault kinematics. The objective of this article is to document this phenomenon by photographs and structural measurements as well as to interpret the sense of movements by features overprinted on the fault plane. The new structural data indicate dextral strike-slip – reverse fault movement. Due to its location, trend and kinematics this fault plane is considered to be the southern continuation of the Kostalevo fault, representing the boundary between the Balkan and Fore-Balkan zones. The marls cropping along a narrow strip, south of Cherepish monastery, are interpreted as sedimentary lenses (intercalations) inside the Cherepish Fm squeezed and tectonized between the Plakalnitsa and Kostalevo faults.

НОВИ ДАННИ ЗА КОСТАЛЕВСКИЯ РАЗЛОМ (**БЪЛГАРИЯ**)

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РЕЗЮМЕ. Във варовикова кариера южно от Черепишкия манастир, на широка площ в настоящия забой на кариерата, се разкрива разломна повърхност с тектонско огледало (харнишова повърхност), включващо множество мезоструктурни индикатори за кинематиката на разлома. Целта на статията е да се документира този феномен чрез фотографии и структурни измервания, и да се интерпретира характера на движенията, запечатани върху разломната повърхност. Новите структурни данни показват дясноотседно-възседен характер на движенията. Местоположението, посоката и кинематиката на този разлом дават основание да се счита, че той представлява южно продължение на Косталевския разлом, представляващ тук граница между Белканската и Предбалканска зони. Мергелите, разкриващи се южно от Черепишкия манастир, са интерпретирани като седиментни лещи (прослойки) в Черепишката свита, изстискани и тектонизирани между Плакалнишкия и Косталевския разломи.

Introduction

General settings. Geographically, the area under discussion is situated around the Cherepish monastery at the Iskar Gorge. Structurally, 2 tectonic zones of Balkanides meet here: Balkan and Fore-Balkan (after Bonchev, 1971; Ivanov et al., 1971; Antonov et al., 2004; etc.) or West Balkan and Central Balkan – Fore-Balkan zones (after Ivanov, 1988; Angelov et al., 2009). Between Vratsa and south of the Iskar Gorge they are separated by the Kostalevo fault. Moreover, fragments of two units of the West Balkan zone (Vratsa and Berkovitsa units), separated by Plakalnitsa fault crop out here. The Vratsa unit represents a tectonic block (wedge) comprising an anticline (Zgorigrad), the eastern end of which is broken by the Kostalevo fault. The periclinal part of this anticline is displaced 7 km to south. Apart from the horizontal amplitude, the fault has a vertical amplitude, demonstrated by thrusting of the Vratsa tectonic block over the structures of the Fore-Balkan (Mezdra syncline and Lyutibrod anticline). The Kostalevo fault is traced between Vratsa and the Cherepish monastery in the Iskar Gorge. Its northern part is well expressed not only geologically, but also geomorphologically. It is a very distinct feature in the recent relief and could be observed on the airborne imageries (e.g. Google Earth satellite imagery). North of the Cherepish monastery the fault disappears in the uniform looking limestones of the Cherepish Fm. Therefore, its southern part is disputable. In the geological map of 1:100000 (Цанков и др., 1991) it is traced along the boundary between the Cherepish limestones (Fm) and the Lyutibrod Formation. In fact, this boundary represents a hardground surface (Nikolov, Chumachenko, 1992). Antonov et al. (1990; 2004), Antonov (2004), Angelov et al. (2009) traced the boundary to the south of Cherepish monastery along a marl formation considered to be a fragment of Mramoren Fm squeezed between Plakalnitsa and Kostalevo fault.

Objectives. There is a limestone quarry (“Dalbokidol” quarry) situated south of the Cherepish monastery. On a large area on the recent quarry face a fault plane crops out with slickensides comprising a number of meso-structural indicators for the fault kinematics. The objective of this article is to document this phenomenon by photographs and structural measurements as well as to interpret the character of the movements overprinted on the fault plane. In addition, the paper aims at discussing some problems linked to the lithostratigraphic affiliation and relationships of the rocks along the fault plane in this complicated tectonic knot, where the Kostalevo and Plakalnitsa faults meet each other.

Material and methodology

The fault surface is photo-documented and structurally investigated in three points (outcrops) inside the quarry. The 1st one is situated in the northern, the 2nd one in the middle and the 3rd one in the southern part of the quarry. The points localities are determined by GPS "Garmin" and their coordinates and related structural data are demonstrated in the Table 1. The structural data and relationship between the fault surface (F), bedding (ss), striation and/or mineral lineation (Ls) and intersection lineation (Lx) are demonstrated on stereographic projection using lower hemisphere of the equal areal Smidt net.

Results

"Dalbokidol" quarry is situated 2 km south of the Cherepish monastery in the valley of Dalbokidol river. It yields limestones from Cherepish Formation. The quarry is elongated approximately north-south. It is 400 m long and 160 m wide. The recent face of the quarry reveals a fault plane comprising a stunning slickenside on a large area (Photo-table I).

The recent quarry face is developed along the fault surface generally trending NNW-SSE. Although the mining activities are designed to go to ENE, now they are concentrated in a trench parallel to the fault surface in the hanging wall. There are two reasons for this: 1) very steep face and need to enlarge the quarry by benches of higher levels and 2) the limestones in the hanging wall are strongly disintegrated. In the footwall they are more compact or broken by distinct but rare faults oblique to the main fault surface with well-developed slickenside.

The most spectacular is the northern part of the quarry, where the mining is concentrated just now (Photo-table I, (3-6) and Table 1, point 1). Here, the quarry face coincides with a large slickenside. The fault plane trends NNW-SSE steeply dipping to WSW (F = 240/75). The fault surface is spotted - in places it is white, yellow or black. The white color is due to the calcite skin developed on the fault. The black color results from the black tectonic clay and the yellow color is related to the oxidation of pyrite included in the tectonic clay. Two types of lineation could be observed: 1) fibrous calcite slickenside lineation (mineral lineation) developed on thin (1-2 mm) calcite skin covering the fault plane and 2) striation lineation developed on the tectonic clay. They have common orientation (160/28) and demonstrate that the foot-wall is thrown down-right, i.e. the fault is dextral strike-slip – reverse fault. Very rare and unclear superposed lineation due to normal faulting is observed on this plane.

Cherepish limestones are massive to tick-layered here and the bedding is unclear (ss=137/35). The projected intersection lineation between the fault plane and bedding almost coincides with both the mineral and the striation lineations (Photo-table I, 6). Apart from the slickensides, the fault is featured by a tectonic breccia (Photo-table I, 5). It is from 10 cm to 2 m wide and developed in a zone on the hanging wall. The breccia clasts are represented by white angular limestone fragments of the Cherepish Fm, but the cement is black tectonic clay.

Pyrite is abundant in this zone – in places it is fresh but in places – oxidized. The eastern contact of the brecciated zone is sharp with the slickenside but the western one is transitional: breccias gradually turn into strongly disintegrated limestones but without black clay. A multitude of slickensides could be also observed here demonstrating thrusting or reverse-faulting.

In the middle part of the quarry (Photo-table I, 7-8 and Table 1, point 2) the same slickenside surface could be observed. Here, it is developed on a thin calcite skin. It is strongly weathered. The fault strike is similar to point 1 but the dip is steeper (F=243/80). Fibrous calcite slickenside lineation is developed here as well. Its orientation is 160/28 and demonstrates that the foot-wall is thrown down-right, i.e. the fault is dextral strike-slip – reverse fault. Bedding is well-expressed 30 m west of the point (ss=140/32). East of point 2 there is a big exposure of limestone with rusty color due to pyrite oxidation (Photo-table II, 2).

Between points 1 and 2 there is another exposure of the fault featured by thick black tectonic clay (Photo-table II, 1). Close to the slickenside it comprises clasts of limestones (pudding-like breccias) and the clay is loose and prevailing.

In the southern part of the quarry (Photo-table II, 5-6 and Table 1, point 3) the fault plane is almost vertical (225/86). The most representative slickenside is observed here (Photo-table II, 6). Calcite lineation plunges 145/26 and demonstrate that the eastern limb of the fault (foot-wall) is thrown down-right, i.e. the fault is dextral strike-slip – reverse fault. There is a number of oblique fractures developed next to the main fault surface. Black tectonic clay and fresh pyrite are also abundant here.

To the south of the quarry the fault plane is cut by Plakalnitsa fault. To the north it is traced to the western part of a large landslide (Photo-table II, 8).

Results and interpretation

South of Cherepish monastery the Kostalevo fault goes inside the Cherepish limestones (Fm). The best fault outcrops are in the limestone quarry of "Dalbokidol". The new structural data indicate dextral strike-slip – reverse fault movement along the fault surface and confirm the kinematics, previously established during the regional geological investigations for the northern part of this fault.

Discussion

The main reasons to consider that the fault plane, with the well developed slickensides exposed in "Dalbokidol" quarry, represents the southernmost continuation of Kostalevo fault are its location, trend and kinematics. As mentioned in the Introduction, from the Cherepish monastery to the „Dalbokidol" quarry, the Kostalevo fault is traced along the boundary between the Cherepish limestone Formation and the Mramoren marl Formation (Антонов и др., 1990; Antonov, Synnyovsky, Jelev, 2004; Angelov et al., 2009). Moreover, the Mramoren Fm is considered to be a tectonic wedge inserted in the Cherepish limestones along the junction zone of the Plakalnitsa thrust and the Kostalevo strike-slip – thrust faults.

Having in consideration that in the normal stratigraphic sections Mramoren Fm is above Cherepish and below Lyutibrod Fms (Nikolov et al., 1972; Angelov et al., 2009; etc.) it is unclear why a higher stratigraphic level (Mramoren Fm) is thrust over lower ones (Cherepish Fm). A possibility to explain this situation exists if these marls are correlated with similar marl lens cropping east of Dalbokidol quarry just above the Cherepish limestones (Цанков и др., 1991). At first glance the marls of both outcrops are similar. Moreover, both of them include thin layers of dark limestones. However this model requires normal fault kinematics. In fact, on the described slickenside surfaces there are striations demonstrating such kinematics but they are rare and unclear. Moreover, the most significant deference between both marl lenses is that the marls and limestone intercalations east of the quarry are abundant in foraminifers. That is why they are referred to Lyutibrod Fm (Antonov et al., 2004; Angelov et al., 2008; 2009).

So, we are inclined to accept that the marl lens south of Cherepish monastery as well as similar but smaller lenses in the old (abandoned) quarry represent sedimentary lenses (intercalations) inside Cherepish Fm, squeezed and tectonized between Plakalnitsa and Kostalevo faults. Their chronostratigraphic range confirms such an interpretation, because they overlap in the interval of Valanginian-Barremian (Антонов и др., 1999; Sinnyovsky, Valchev, 2004; Angelov et al., 2009).

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Table 1. *Structural data*

Point №	Coordinates (UTM, WGS84, 35N)		Bedding (ss)	Fault (F)	Lineation (Ls)	Fault kinematics	Notes
	X (east)	Y (north)					
1	713395	4773587	137/35 (unclear)	240/75	160/28	dextral strike-slip - reverse	superposed lineation result of normal faulting (unclear)
2	713397	4773553	140/32	243/80	162/25	dextral strike-slip - reverse	-
3	713440	4773486	125/40	225/86	145/26	dextral strike-slip - reverse	-

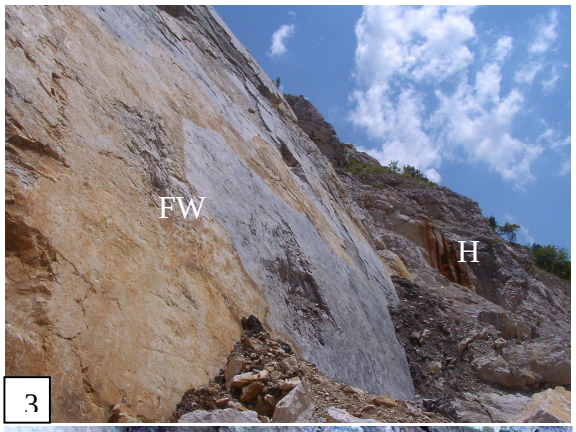
PHOTO-TABLE I

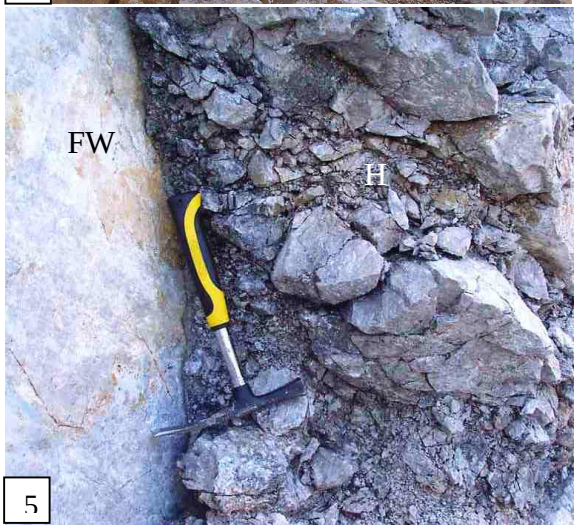
(1-2) – general view of the Kostalevo fault: 1 – look to North, demonstrating the fault in the northern part of the quarry (in the foreground where point 1 is situated) and west of Chelopek village (in the background), 2 – look to South, where in the southern part of the quarry trench point 3 is situated; (3-6) – pictures at point 1: 3 – close view of the footwall (FW) and hanging wall (HW) of the main fault surface (look to south), 4 – detail of the slickenside surface including mineral lineation and striation (the arrow demonstrates the sense of movement of the footwall – look to east), 5 – tectonic breccia developed in the hanging wall of Kostalevo in Cherepish limestone Formation, 6 – stereographic projection (lower hemisphere of equal area Smidt net) demonstrating the relationship between the fault surface (F), bedding (ss), striation and/or mineral lineation (Ls) and intersection lineation (Lx) at point 1; (7-8) – fault slickenside at point 2: 7 – general view (look to SE), 8 – close view of the same surface.

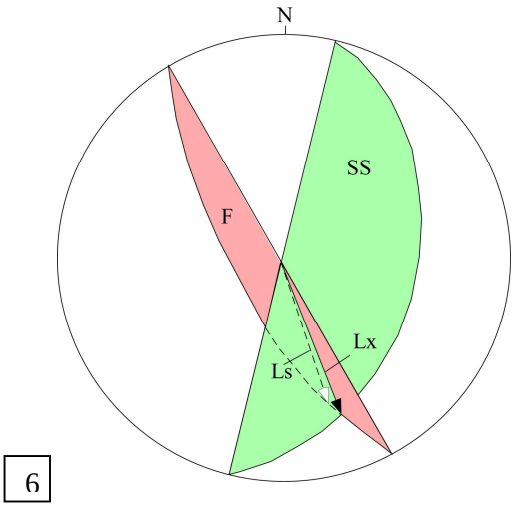
PHOTO-TABLE II

(1-4) – fault features between point 1 and 2: 1 – black tectonic clay and breccia developed along the fault surface north of point 2, 2 – rusty colors are due to an oxidized sulfide mineralization developed along the main fault surface and its subordinate structures, 3 – close vies of oxidized pyrite in the matrix of tectonic breccia, 4 – stereographic projection (lower hemisphere of equal area Smidt net) demonstrating the relationship between the fault surface (F), bedding (ss), mineral lineation, striation (Ls) and intersection lineation (Lx) at point 2; (5-7) – fault features at point 3: 5 – general view of the fault, 6 – close view of the slickenside, 7 – stereographic projection (lower hemisphere of equal area Smidt net) demonstrating the relationship between the fault surface (F), bedding (ss), striation and/or mineral lineation (Ls) and intersection lineation (Lx) at point 3; 8 – tectonic breccia in the eastern end of the 2nd tunnel east of the Cherepish inn (western end of a large landslide).

PHOTO-TABLE I







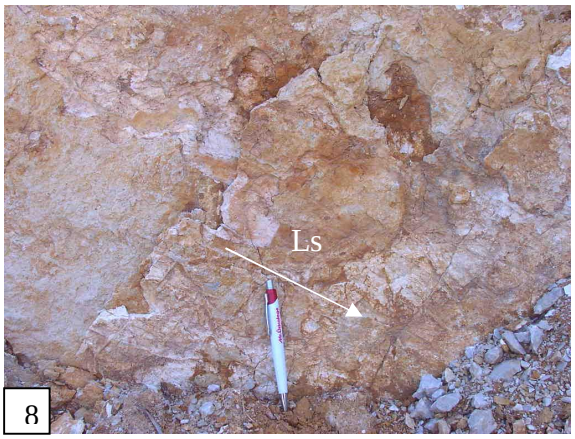


PHOTO-TABLE II