STRUCTURAL GEOLOGY OF THE CENTRAL PART OF KAMENITSA-RAKOVITSA FAULT ZONE

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ABSTRACT. Kamenitsa-Rakovitsa dislocation is well recognized as one of the most important structural elements in the Central Balkanides, yet, there is an obvious lack of structural studies and there are contrasting views on its kinematics. The presented here data are based on detailed mapping and structural studies of the central part of the zone, that is cropping out between the valley of Topolnitsa river and the area of the village of Kamenitsa. Here the hanging wall is built by Variscan metamorphic rocks and post-metamorphic granites, whereas the footwall includes Triassic dolomites and different Upper Cretaceous rocks. The trace of the fault zone in the strongly dissected relief indicate its steep dip (60-70o). With the help of small excavation the core of the fault zone was cropped out (west of the village of Kamenitsa). The core is composed of gauge and matrix-supported tectonic breccia with thickness 50-70 cm. A large number of meso-scale structures were documented in the strongly shortened immediate footwall that forms the overturned SW limb of Kayryaka syncline. Kinematic analyses of meso-scale imbrications, faults and folds, as well as cleavage-shear bands relations show consistent top N/NE shortening directions and allow interpretation of Kamenitsa-Rakovitsa dislocation as important Late Alpine compressional zone.

Keywords: Kamenitsa-Rakovitsa fault zone, Late Alpine tectonics, Upper Cretaceous rocks, tectonics, Central Balkanides

СТРУКТУРНА ГЕОЛОГИЯ НА ЦЕНТРАЛНАТА ЧАСТ ОТ КАМЕНИШКО-РАКОВИШКАТА РАЗЛОМНА ЗОНА

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РЕЗЮМЕ. Каменишко-Раковишката дислокация е отдавна разпозната като една от най-важните тектонски зони в Западното Средногорие. В литературата са изложени противоречиви данни за характера ѝ, като също така не са провеждани специализирани структурни изследвания. Изложените тук данни се основават на детайлно картиране и структурни изследвания на централната част на зоната, разкриваща се между долината на река Тополница и района на село Каменица. Тук висящият блок е изграден от Херцински метаморфити и пост-метаморфни гранити, докато лежащият включва пластини от триаски доломити и пъстър горнокреден разрез. Хода на разломната зона в разчленения ралеф индикира стръмния ѝ наклон (60-70^0) С помощта на разчистка бе разкрита тектонска зона (западно от с. Каменица). Дебелината ѝ е 50-70 сантиметра и е изградена от сиво-зелена тектонска глина и матрикс-подържана тектонска брекча. За кинематиката на срязванията в зоната може да се съди по структурите в лежащия блок, който в съседство със зоната се характеризира с интензивно съкращаване на разреза. Тук горнокредните последователности за засегнати от мезомащабни огъвания, срязвания и оформят преобърнатото бедро на Кайряшката синклинала. Установените в този силно деформиран домен структури (мезомащабни срязвания, кинематика на второстепенни разломни зони, асиментрични гънки) индикират насочени на С/СИ движения. Тези данни насочват към интерпретирането на Каменишко-Раковишката дислокация като важна Късноалпийска компресионна зона.

Ключови думи: Каменишко-Раковишка разломна зона, Късноалпийска тектоника, Горнокредни скали, тектоника, Централни Балканиди

Introduction

The Kamenitsa-Rakovitsa fault zone (KRFZ) has been recognized (Poushkarov (1927); Bončev (1940a); Karagyuleva et al. (1974); Ivanov (1998) as the most prominent tectonic feature in the western part of Central Srednogorie (Fig. 1). This is a NW-SE trending structure juxtaposing high-grade pre-Alpine basement with 4.5-9 km wide belt of deformed Upper Cretaceous sediments, volcanics and volcanoclastics of the Panagyurishte basin. Due to the lack of serious structural studies, at least two contradicting models for the kinematic and age of the fault zone have been proposed. Traditionally, the KRFZ has been regarded as a north, NE vergent, thrust (Boyadziev, 1940; Bončev, 1940; Karagyuleva et al., 1974). In the last twenty years another interpretation started to gain popularity. According to this new model the zone was reinterpreted as strike-slip fault (Ivanov, 1998)), where it was suggested (Rieser et al., 2008) that the KRFZ is a splay of the Maritsa shear zone.

In this paper we address these problems as we present new evidence from field observation obtained during detailed mapping of the KRFZ in the area of Topolnitsa and Kamenitsa river valleys. Field studies were conducted for about three weeks in the period 2017-2020. The mapped territory is approximately 13 km^2 and covers the area around KRFZ, but mainly in its footwall from the hamlet of Srebrinovo to the area of Gorna Rakovitsa village. Outcrop conditions vary significantly, often limiting the possibility to document precisely the location of the contacts and collecting structural data. Much better outcropped are the area of Kamenishka river watershed and the area between Kamenitsa village and hamlet Kayryaka. Here, our detailed structural studies allowed us to construct several cross-sections along the well-outcropped traverses across KRFZ and Kayryaka syncline. Westward, in the watershed of Kalugeritsa river and in the area of Gorna Rakovitsa village the

outcrop conditions allow only roughly to delineate the unit contacts.

Local Stratigraphy

The complete stratigraphy of the study area is described in Katskov and Iliev (1993). For this study, most important is the stratigraphy of the Upper Cretaceous sequence that build up the footwall of KRFZ. A more recent stratigraphy overview of the Upper Cretaceous sequence is given in Vangelov et al. (2019).

The oldest rocks exposed in the study area are the rocks of the Central Srednogorie High-grade Metamorphic complex. Here this Variscan basement consists mainly of migmatitic paragneisses, that contain from meter- to hundreds of meters bodies of leucocratic orthogneisses and metagabbros. The rocks are well foliated, as the foliation is striking NW-SE. The dips are mainly to SW, but due to the presence of large-scale folds with NW-SE axes, there are domains with NE dip. Thus, KRFZ is in fact running parallel to the Variscan penetrative fabric. Pre-Turronian Mezosoic rocks are rare in the area. They occur either as tectonic slices in the immediate footwall of the KRFZ, or in the hanging wall of another prominent fault zone - Petrich fault (Fig. 1). The lowermost part of the Upper Cretaceous sequence is represented by the basal terrigeneous unit with Turonian age (Vangelov et al., 2019). This unit is cropping out only along the northern margin of the Panagyurishte basin, the hanging wall of Petrich fault or farther in the northernmost tip of the basin The intermediate parts of the sedimentary sequence are represented by voclanics and various volcaniclastic deposits (terminology of McPhie et al., 1993). Several magmatic centers (see also Popov et al., 2012) are defined - Golyama Rakovitsa, Vran kamak, Smolsko, as only for the first center there are solid geochronological data (89,47 ± 1,2 Ma - Nedkova et al., 2012). While the older studies (Karagyuleva et al., 1974)) interpreted the upper parts of the volcanic deposits as syn-eruptive products (pyroclastic deposits), in a recent re-evaluation they are described as epiclastic rocks (lower epiclastic unit - Vangelov et al., 2019). Most often these epiclastics underlie the regionally traceable unit in the Upper Cretaceous sequence - Mirkovo Formation of Santonian-Campanian age. This unit mark establishment of a stable marine basin with more or less unified carbonate sedimentation. The lateral consistency of this facies was recognized since first detailed studies (e.g. Boyadziev, 1940; Bončev, 1940) and since then these red beds are used as a marker to delineate large-scale folds in the Upper Cretaceous sequence. A turbiditic series of sandstones, siltstones, marls and rare limestones, denoted as Chugovitsa Formation (Moev and Antonov, 1978) is the youngest unit affected by Late Alpine tectonic overprint. For the area of Topolnitsa and Kamenishka river valleys, the Chugovitsa sequence is underlay by thick, up to tens of meters, siliciclastic rocks enriched in magmatic detritus. This subunit was denoted as Upper epiclastic (Vangelov et al., 2019).

Geometry of KRFZ

Mapping of the KRFZ is relatively easy even if the direct contact is not cropping out, because it separates very different lithologies. Our mapping indicate that the trace of the zone as delineated on the geological map (Iliev and Katskov, 1990; Katskov and Iliev, 1993) is rather precise. The zone strikes NW-SE as in several places is displaced by small-amplitude strike-slip faults. Our estimates of the dip of 50-70° - are based on detailed structural profiles, trench data as well as digital calculation of best fit plane for a set of points. A characteristic deviation from NW-SE trend is observed in the area of Gorna Rakovitsa village, where the presence of Turonian magmatic center strongly influenced local structural pattern. Despite our efforts to find outcrops of the fault (approx. 15 km along the KRFZ were checked in areas with deeply incised relief) no direct contact was found. At several places in the area of Kamenitsa village the hanging-wall (gneisses, Variscan granites) and the footwall (Triassic dolostones, Cretaceous sediments, volcanics and volcanoclastic) are separated by 1-5 m slope deposits. At one of these localities (E 23.9232, N 42.58751) the covered interval between the Variscan granites and Triassic dolostones is less than 1 m wide, so a small trench was excavated along the fault zone core. Both hanging-wall and footwall rocks are strongly brecciated, as in the proximity of the contact there are 0.2-0.5 m thick matrix-supported tectonic breccia. The core of the zone is represented by thick, up to 0.6 m gauge with colors varied from orange (next to the hanging-wall granites) to green (next to the dolostones). The gauge is often rich in survival grains with size up to several centimeters. No pronounced and consistent striations have been observed.

KRFZ related deformation

While the trench data clearly indicate strong localization of deformation within the fault core, our field data indicate that there are structural features, more pronounced in the footwall, that can be related to the movements along KRFZ.

KRFZ hanging wall

Deeply incised valleys of Redutin dol (SW of Kayryaka hamlet) and Golyamata reka (SW of Kamenitsa village) provide good possibility to study the structures within the hanging wall. The Variscan high-grade fabric is unevently affected by brittle overprint, as no major fault zones can be defined. Well-defined kinematics was determined only for a set of shallow dipping to SW shear planes, bearing quartz fibers indicating top-to-the NE transport.

KRFZ-related fabric in the footwall

Mandev (1940) was first to recognize the existence of syncline front of the KRFZ to which later Karagyuleva et al. (1974) gave the name Kayryaka syncline. This structure is well defined for approx. 18 km from the hamlet Srebrinovo (to the SE) to the area NE of Golyama Rakovitsa village (to the NW). The syncline trends NW-SE and only NE of Golyama Rakovitsa the trend changes to approx. E-W, following the strike of KRFZ (Fig. 1, 2). It represents a tight fold with overturned SW limb and shallowly dipping NE limb. Both limbs of the syncline show differences in the lithologies, their thickness, but most pronounced are structural differences (Fig. 3A). The normal limb, as observed, along the Kamenishka river valley is devoid of meso-scale folds and shear planes and provides one of the best sections of the Cretaceous sequence (Vangelov et al., 2019). On the contrary, the SW limb is strongly shortened and overturned and provides wealth of meso-scale structures

allowing to constrain the character of shearing along KRFZ and its structural evolution.

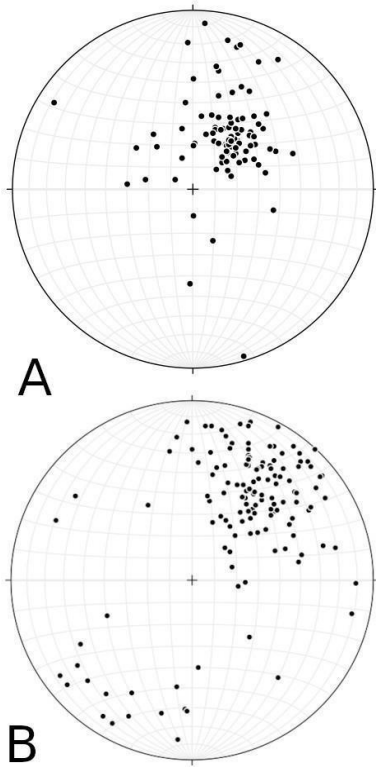

Fig. 2. Bedding orientations for normal (A) and overturned (B) limb of Kayryaka syncline, displayed on equal-area lower-hemisphere stereoplots

Geometry of the overturned limb

An overturned sedimentary sequence, often displaying evidences for faulted contacts between different rock units is characteristic for the immediate KRFZ footwall. In the northern tip of the zone below the Variscan basement there is a discontinuous layer of dolostones (Iskar Carbonate Group, Fig. 1), occurring as thin lenses (up to 30-50 m width in map view, not shown on Fig. 1). Where present, they are underlying coherent magmatics or directly the limestones of Mirkovo Formation. These relations are clearly documented in the deeply incised relief W and SW of Kamenitsa village. In most of the cases the Variscan basement is in direct contact either with Cretaceous magmatics or with Mirkovo Formation. The magmatics crop out as areally extensive, elongated parallel to the KRFZ, strongly faulted and fractured rock volume or as rather thin (up to several meters, not shown on Fig. 1) strip. Neither in the dolostones nor in the magmatics clear primary fabric can be recognized. In a few cases a rough cataclastic foliation (formed by closely spaced joints) or marked by black ultracataclastic levels occurs, oriented sub-parallel to the main surface of KRFZ. Field data unambiguously indicate that the basement and the volcanics structurally overlie the upper most parts of the Cretaceous sequence (Fig. 3B, 3C).

NE and N of the KRFZ the Mirkovo Formation limestones are the best regionally traceable unit. Most often they are represented by vertical, strongly folded by upright folds and cleaved sequence of pinkish and grey limestones, sometimes containing intercalations of whitish wacke sandstones. Where observed, the lower structural contact of these limestones is always faulted. They are juxtaposed with moderately SW dipping (50-40°), strongly faulted and altered thin (up to few tens of meters) fine-grained dark rocks, most probably representing Upper epiclastic sequence (Vangelov et al. (2019).

Structurally lowermost position in the overturned limb occupies the turbiditic sequence of Chugovitsa Formation. There is no sharp break between the overturned and normal limb of Kayryaka syncline. The transition occurs within the monotonous turbidite intercalation of sandstones, silts, pelites, marls and clayey limestones. As criteria to delineate both limbs of Kayrya syncline we used features as: lack of meter-scale folds and cleavage and synsedimentary way-up structures indicating normal polarity - for the normal limb; and: strong meso-scale folding, cleavage development and inverted polarity, indicated by synsedimentary fabric. Thus our data point to about 0.5 km wide in map view deformed rock volume, situated in the intermediate footwall of KRFZ. There are field data, as well as reasoning related to regional-scale tectonics are grounds to propose existence of thrust zone, more or less following the axial plane of Kayryaka fold (Fig. 3A).

Meso-scale features in the overturned limb

Structurally below the rigid block made of Variscan basement and Turonian magmatics, the low-strength sediments of Mirkovo and Chugovitsa Formation are unevenly, but most often strongly deformed. A well-outcropped section along Dobri dol river valley (Fig. 3C) allows to document the style and sequence of the deformation, that we relate to the movements along KRFZ. A fault sets (minor fault arrays) are most widespread meso-scale features in this rock volume. Unfortunately in most of the cases indicators of the sense of relative movement (Petit, 1987) are missing. North of Kamenitsa village small-displacement thrust faults are rather common (Fig. 4A). Meter-scale folds are affecting the whole volume of Mirkovo Formation, and are also common in Chugovitsa Formation. They can be observed only in steep valley walls, while in cases of lack of vertical sections their presence is indicated by the steep attitude of beding. These folds are not omnipresent; some decameter-scale domains are devoid of folds and dip monoclinaly to the NE (Fig. 3C). As previously documented by Boyadziev (1940), upright folds are typical (Fig. 4B). The folds are mostly similar with rounded and thickened hinge zones and often N-vergent.

Penetrative cleavage is unevenly present, and it is best documented along Dobri dol section (Fig. 3C). It is marked by closely spaced (several mm) fractures and it is most pronounced in marly lithologies. Except in the vicinity of the main faults, cleavage is associated with folds and shows divergent cleavage fan geometry. Within the strongly shortened by upright folds limestones and marls of Mirkovo Formation the steeply dipping cleavage is cut by subhorizontal to shallowly dipping to the SW shear planes (Fig 4C). Sliken-fibre lineations on the shear surfaces (Fig. 4D) indicate top-to-the NE sense of shear. This sense of shear is also confirmed by the curvature of the cleavage toward shear planes (in section orthogonal to the cleavage/shear planes and parallel to the lineation).

Cross faults

The main NW-SE structural grain is dissected by a set of sub-vertical faults, mainly with NE strike. Nowhere in the field

these faults are well outcropped, yet, the displacement of beds faults and contacts indicate their strike-slip kinematics.

Conclusions

In the studied area KRFZ represents a NW-SE trending steep brittle fault zone along which Variscan metamorphic basement is emplaced over different levels of Upper Cretaceous sedimentary sequence. Within the fault zone, often meter- to decameter scale tectonic lenses of strongly brecciated Triassic dolostones were observed. When observed the main contact is marked by approx. 1 m thick gauge and matrix-supported tectonic breccia formed at the expense mainly of the Variscan metamorphics and granitoids.

Often along its immediate footwall, boudinaged layers of coherent volcanics with intermediate composition are cropping out. No particular structures were observed in both, dolostones and the magmatics which are generally affected by strong cataclasis. The Variscan metamorphic basement along with the competent dolostones and magmatics can be regarded as a buttress front of which the layered and less competent sequences of Mirkovo and Chugovitsa Formations were strongly deformed.

These units outline a strongly asymmetric footwall syncline with overturned SW limb. Based on detailed mapping the width of the overturned domain is about 0.5 km. Within this domain a number of features (upright folds, cleavage, meso-scale faulting) indicate significant shortening of the sequence.

Our data support the original ideas about the compressional character of KRFZ. Main arguments for this are: 1/ dip and stratigraphic offset across the fault zone; 2/ geometry and kinematics of small-scale faults in the vicinity of the zone; 3/ locally penetrative cleavage-shear bands associations; 4/ overall geometry of the deformed rocks from the footwall.

A single protracted compressional event can explain all the observed along the KRFZ structures. There are no data suggesting several contractional events (e.g. Pyrinean as suggested) or significant strike-slip reactivation.

The studied area represents one of the best outcropped sections along the inverted Upper Cretaceous basin. Our data indicate rather uneven distribution of the Late Alpine shortening within the Cretaceous belt: compression-related structures are localized in the footwalls of the main fault zones: KRFZ, Petrich fault and Negushevo dislocation.

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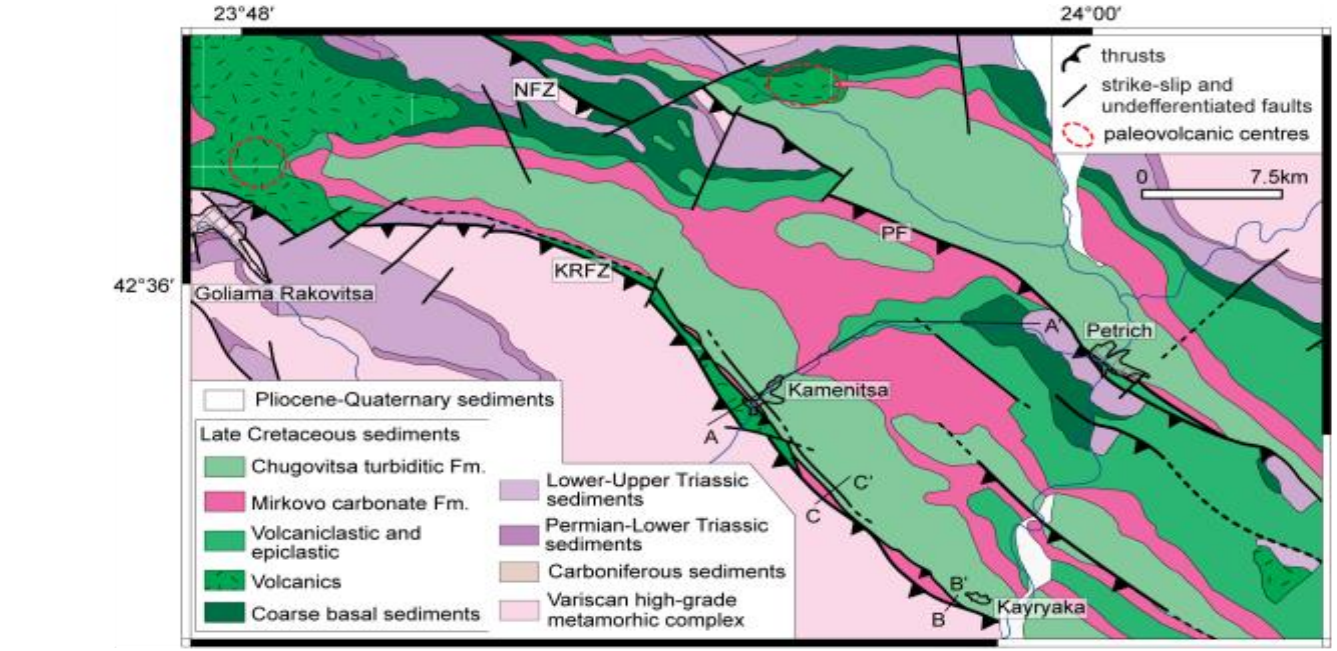

Fig. 1. Geological map of the studied area between the valleys of Topolnitsa and Kamenitsa rivers. Modified after Katskov and Iliev (1993).

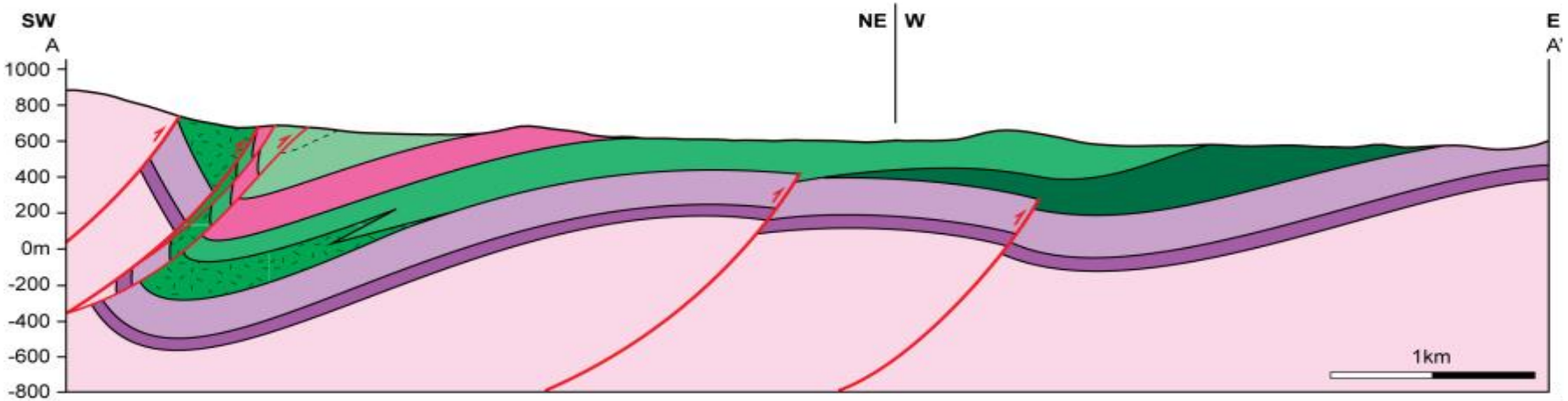

Fig. 3. Geological cross-sections. A. Kamenitsa river valley.

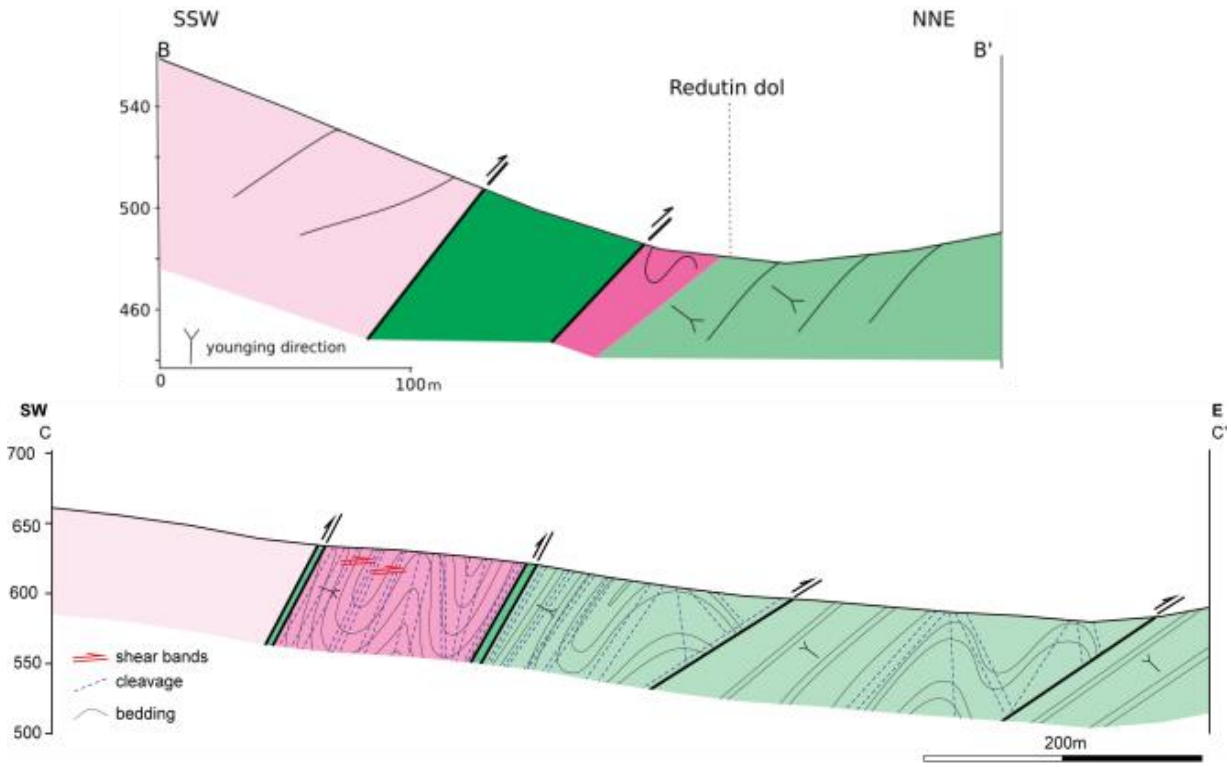

Fig. 3. Geological cross-sections. B. Kayryaka (Center: E 23.97805; N 42.55083) C. Dobri dol (SW: E 23.94886;N 42.56629; NE: E 23.95573 N 42.57191). Unit colors are the same as Fig. 1.

Fig. 4. A. Small-scale N vergent thrust, Chugovitsa Formation, North of Kamenitsa village (E 23,9113; N 42,6041). B. Upright anticline-syncline pair. Chugovitsa Formation, Dobri dol section (E 23,9530; N 42,5690). Width of the photo - 6 m. C. Vertical bedding and cleavage are dissected by a set of low-angle shear bands (arrows). Mirkovo Formation, Eastern cliff of Gradishteto peak (E 23,9477; N 42,5702). D. Calcite fibres with steps on the shear band surface indicate top-to-the NE shear sense. Same location as C.