

## GEOLOGICAL FEATURES OF THE MESOZOIC SECTION BETWEEN THE VILLAGES OF STARO SELO AND STUDENA IN THE GOLO BARDO MOUNTAIN, WESTERN BULGARIA

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**ABSTRACT.** The subject of this study is the Mesozoic section exposed on the road escarpment of the Struma highway that intersects the Golo Bardo Mountain between the villages of Staro Selo and Studena. The incision is predominated by Triassic, Jurassic and Lower Cretaceous sedimentary rocks which relate to the Formations of Svidol (Upper Olenekian), Mogila (Upper Olenekian – Lower Anizian), Pancharevo (Upper Olenekian – Lower Anizian), Bosnek (Anisian), Radomir (Anisian - Ladinian), Rusinovdel (Carnian-Norian), Gradets (Aalenian), Poletintsi (Middle Aalenian - Lower Bathonian), Gintsi (Lower Kimmeridgian), Drugan (Middle Kimmeridgian), Neshkovo (Middle-Upper Kimmeridgian), Kostel (Upper Kimmeridgian-Middle Tithonian) and a breccia conglomerate unit (Middle Oligocene). Structural-geological observations and interpretations of the obtained data were carried out, with special attention paid to the discontinuities of the sedimentary sequence. The normal superpositional relations are disturbed by a fault and fold tectonics, marking significant tectonic deformations related to several tectonic stages: the Late Kimmerian (T-J), the Austrian (K<sub>1</sub>-K<sub>2</sub>), the supposed Laramide (K<sub>1</sub>-Pg), the Sava (Pg<sub>3</sub>-N), and the Neotectonic (N-Q) stage.

**Keywords:** Mesozoic section, Golo Bardo, tectonic deformations

### ГЕОЛОЖКИ ОСОБЕНОСТИ НА МЕЗОЗОЙСКИЯ РАЗРЕЗ МЕЖДУ СЕЛАТА СТАРО СЕЛО И СТУДЕНА В ГОЛО БЪРДО, ЗАПАДНА БЪЛГАРИЯ

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**РЕЗЮМЕ.** Обект на изследване на настоящата работа е мезозойският разрез, който се разкрива в шкарпа на автомагистрала Струма, пресичаща планината Голо бърдо между селата Студена и Старо село. В разреза преобладават триаски, юрски и долнокредни седиментни скали, отнесени към Свидолска (горен Оленек), Могилска (горен Оленек-долен Аниз), Панчаревска (горен Оленек – долен Аниз), Боснекска (Аниз), Радомирска (Аниз – Ладин), Русиновделска (Карн – Нор), Градецка (Аален), Полатенска (среден Аален – долен Бат), Гинска (долен Кимеридж), Друганска (среден Кимеридж), Нешковска (среден – горен Кимеридж), Костелска (горен Кимеридж – среден Титон) свити и брекчо-конгломератна задруга (среден Олигоцен). Извършени са структурно-геоложки наблюдения и интерпретация на получените данни, като специално внимание е обърнато на прекъснатостите в разреза. Нормалните суперпозиционни отношения са нарушени от гънкови и разломни тектонски деформации, свързани с няколко тектонски фази: Къснокимерска (T-J), Австрийска (K<sub>1</sub>-K<sub>2</sub>), предполагаема Ларамийска (K<sub>1</sub>-Pg), Савска (Pg<sub>3</sub>-N) и Неотектонска (N-Q).

**Ключови думи:** Мезозойски разрез, Голо бърдо, тектонски деформации

## Introduction

The main purpose of this work is to establish the nature of the relations between the lithostratigraphic units found in the Golo Bardo area. For this purpose, a section along the Struma highway, from the southern end of the village of Studena to the village of Staro Selo, is described. The article is a natural continuation of the problems discussed in our previous work – Ilieva, Zhelev (2010) and Ilieva, Dimitrov (2011).

In the first article, a new unit for the region was introduced – a brecco-conglomerate group with a continental, alluvial-proluvial-lymical character, which is a correlate of the Paleogene (Priabon - Oligocene) from the Pernik graben. It is a tectonic wedge in the dolomite limestones of the Middle Triassic Bosnek Fm, formed after the Paleogene during the Sava orogenesis.

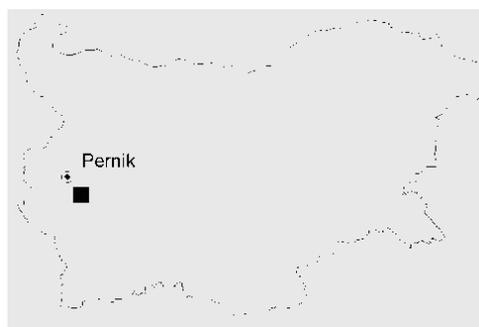


Fig. 1. Location of the Studena – Staro selo section.

It was found that the Mesozoic rocks in the area of the Golo Bardo mountain participate in large upright and open regional folds with the NW-SE direction of their axis (Ilieva, Ivanov, 2011). The new structural-geological observations show that the superpositional sediment relationships are not preserved anywhere, but a reversed layer of early bedding is observed.

## Material and methodology

The presented study is based on structural and geological mapping of the outcrops along the Struma highway from the southern end of the village of Studena to the northern end of the village of Staro Selo (Fig. 1, Fig. 3). Planar and linear structural elements were measured and geometric modeling was performed using CAD software and stereographic software.

In the next stage, the observations of the section Studena - Staro Selo should be linked with observations in other outcrops from the region so that the regional distribution of already established structural relations could be confirmed.

## State of the problem

The first information about Golo Burdo was given by E. Bonchev (1931), G. Bonchev (1936), S. Dimitrov, and Ts. Dimitrov (1931) who examined the tectonic structures of the Retro-Vitosha region. The research of Stefanov (1928, 1932, 1936a, b, 1943) is focused on the Triassic fauna as well as the Triassic lithostratigraphy of the Golo Bardo mountain. Detailed geological and structural-geological studies specific to the area are covered in the works of Moev (1967a, b). More recently, modern tectonic notions about the area are presented in the works of Zagorchev (1980, 1981, 1984, 1994, etc.) and Zagorchev et al. (1991). Sapunov et al. (1985) offer several distinct cross sections for the area associated with the Callovian-Upper Jurassic sediments. Subsequently, Budurov et al. (1995) elaborated detailed key sections for the Golo Bardo area, exploring for foraminifera and conodonts. The authors provided a large amount of paleontological data and significantly detailed the age intervals of the lithostratigraphical units in the area. The latest regional and geological ideas for the region were covered by Boudurov et al. (2009).

Palaeozoic, Triassic, Jurassic, Paleogene and Quaternary rocks are revealed in the studied area (Fig. 2). The stratigraphy of the area is considered in a number of literary sources. Within the boundary of the cross section belongs the Strouma diorite Fm (Stefanov, Dimitrov, 1936) of Neoproterozoic-Cambrian age. The subdivision of the Triassic lithostratigraphic units is given in detail in the works of Tronkov (1968, 1975, 1981, 1983).

The Triassic sediments in Golo Bardo are incorporated in several groups: the Petrohan Terrigenous group, the Iskar Carbonate Group, and a very limited Moesian Terrigenous-Carbonate Group, which is out of the area of the section. Jurassic sediments are discussed in numerous scientific publications by Sapunov (1969), Sapunov et al. (1985), as well as by Nikolov, Sapunov (1970), Dodekova et al. (1984), and others.

The Jurassic system is represented by the Gradets and Polaten Fm, the Neshkovo and Kostel Fm which are united in the Central Balkan Flish Group, while the Gintsi and Drugan Fm are united in the West Balkan Carbonate Group.

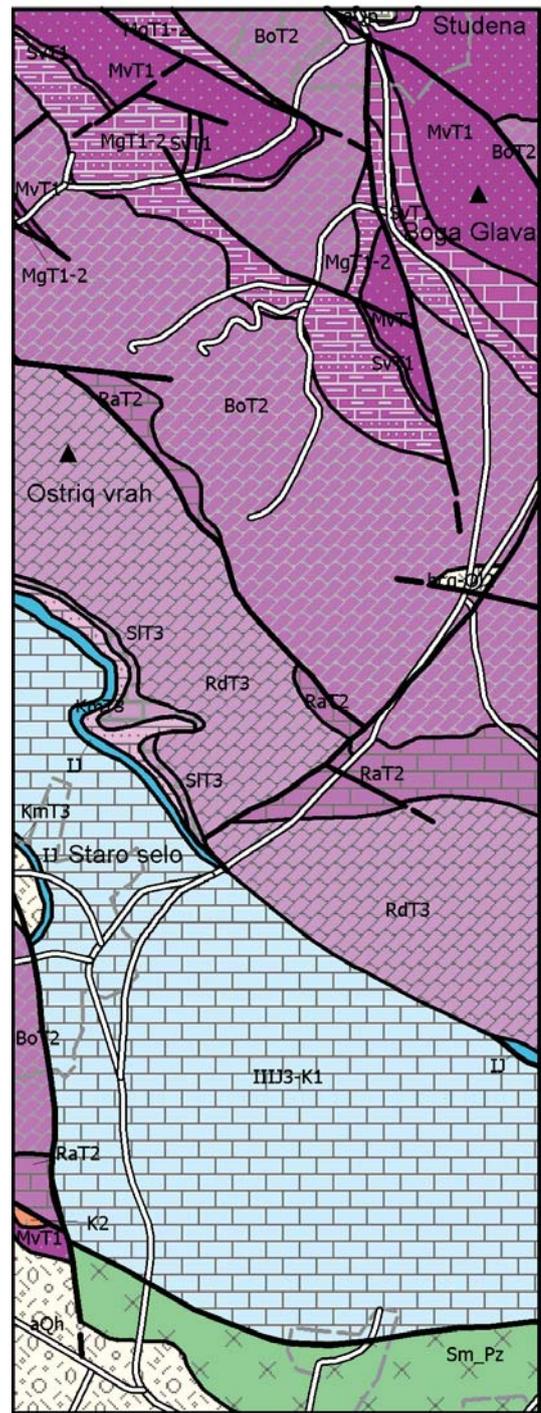


Fig. 2. Geologic map, scale 1:50 000 with amendments and supplements (Antonov et al., 2011 a, b). SmPz – Strouma diorite Fm, SvT<sub>1</sub> – Svidol Fm, MgT<sub>1-2</sub> – Mogila Fm, PaT<sub>1-2</sub> – Pancharevo Fm, BoT<sub>2</sub> – Bosnek Fm, RaT<sub>2</sub> – Radomir Fm, RdT<sub>3</sub> – Rusinovdel Fm, KmT<sub>3</sub> – Komshtitsa Fm, SIT<sub>3</sub> – Slaveeva Fm, IJ – Gradets, Polaten, Gintsi, Drugan Fm, IIIJ<sub>3</sub>-K<sub>1</sub> Cenralbalkan Flish Group – Neshkovo and Kostel Fm, K<sub>2</sub> – granodiorite porphyry, bcg Ol<sub>2</sub> – breccia-conglomerate Fm, aQh – alluvial sediments.

## Results

### Description of the cross section

This section is located along the Struma highway, starting from the southern end of the village of Studena and ending at the village of Staro Selo (Fig. 3). The starting point (km 0 + 000) has the following coordinates: 675202 E and 4711063 N in WGS 84 coordinate system, UTM projection, zone 34. The western escarpment of the highway is mostly documented where the outcrops are more representative, and in some typical cases the eastern one also. The section shown on Figure 4 is drawn from south to north and represents the geological features of the Mesozoic section between the villages of Studena and Staro Selo. The geological description of the Mesozoic section between the villages of Studena and Staro Selo is given in Table 1.

Several cross sections from different authors have been done on the territory of the Golo Bardo mountain. The stratigraphic relations among Triassic, Jurassic and Cretaceous rocks revealed in the area are discussed in the work of Budurov et al. (1995), which describes three incisions in the area of Bosnek and Radomir. Investigating the geological development and the paleo-dynamics of Bulgaria through the Mesozoic and the Tertiary, they prove lateral

differences in each cross section in Golo Bardo. It was found that the Jurassic sediments are transgressive and discordant with significant hiatus on the Triassic rocks.



Fig. 3. Location of the Studena – Staro selo section with the waypoints.

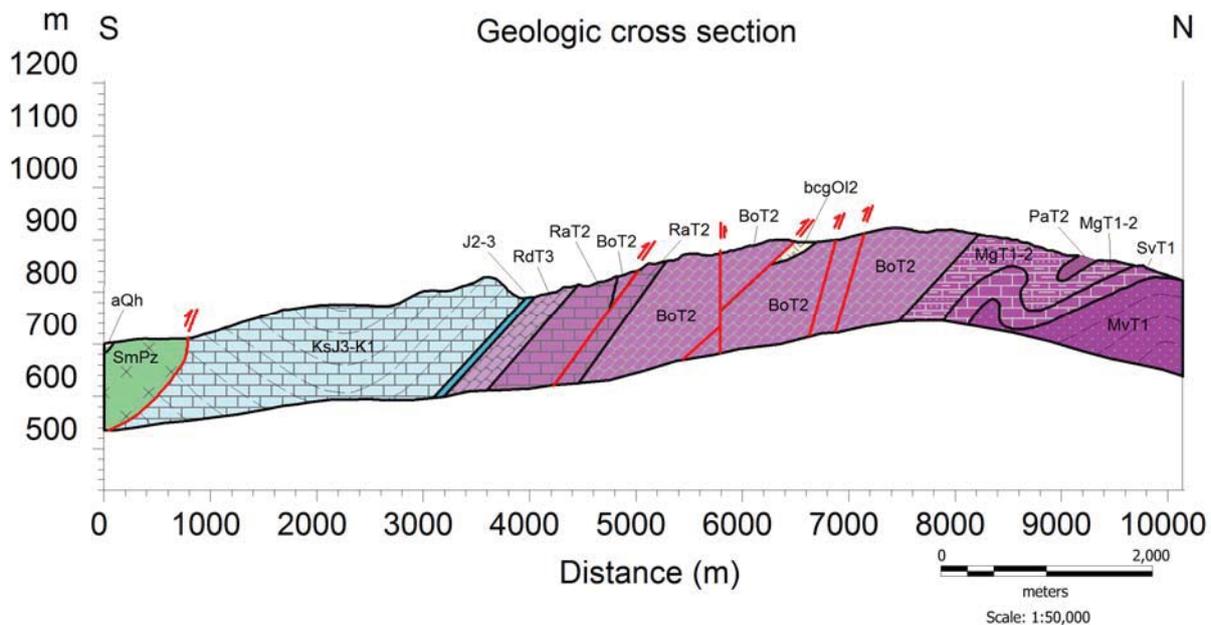


Fig. 4. Geologic cross section, scale 1:50 000. SmPz – Struma diorite Fm, SvT<sub>1</sub> - Svidol Fm, MgT<sub>1-2</sub> - Mogila Fm, PaT<sub>1-2</sub> – Pancharevo Fm, BoT<sub>2</sub> – Bosnek Fm, RaT<sub>2</sub> – Radomir Fm, RdT<sub>3</sub> - Rusinovdel Fm, KmT<sub>3</sub> – Komshtitsa Fm, SIT<sub>3</sub> – Slaveeva Fm, IJ - Gradets, Poletintsi, Gintsi, Drugan Fm, IllJ<sub>3</sub>-K<sub>1</sub> Cenral Balkan flish group – Neshkovo and Kostel Fm, K<sub>2</sub> - granodiorite porphyry, bcgOl<sub>2</sub> – breccia-conglomerate Fm, aQh – alluvial sediments, red line – fault.

Figure 5 shows a geological map comprising the lithostratigraphic units and the fracture structures observed along the incision. It has been found that the Svidol Fm, described in the works of Goranov et al. (2002) and Antonov et al. (2011a, b), differs substantially from the initial description of Chatalov (1974) where it is characterized by an alternation of red, cream or gray carbonate rocks. According to Tronkov (1983), its lateral analogue - the Lyubash Fm, consisting of thin-layer allevolite and sandy marls, limestones and limy sandstones - is observed in the abandoned quarry south of the village of Batanovtsi.

In the beginning of the section, beige sandy limestones and striped sandy limestones with muscovite (Fig. 7, d) are revealed which are not parts of the characteristic lithology of either the Svidol or the Lyubash Fm. Most likely, this is a multifacial lateral analogue that could be identified as an independent formation.

This requires more in-depth research, which will be reflected in a subsequent work. In this article, these rocks are described conditionally as Svidol? Formation.

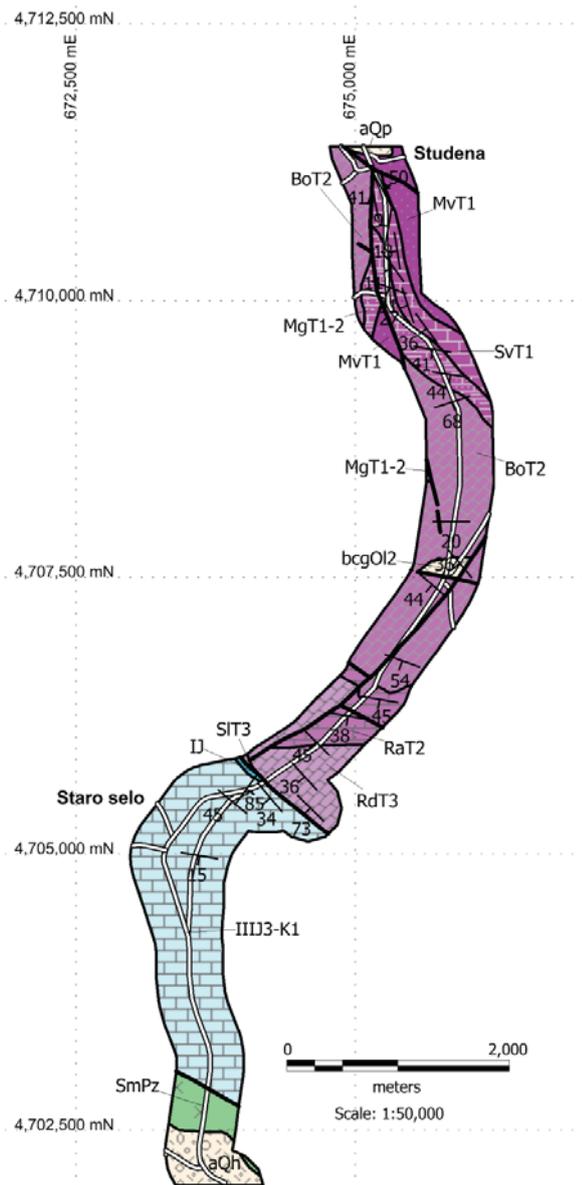


Fig. 5. Plan of the main structural elements observed at the Studena – Staro selo cross section, scale 1:50 000. SmPz – Strouma diorite Fm, SvT<sub>1</sub> – Svidol Fm, MgT<sub>1-2</sub> – Mogila Fm, PaT<sub>1-2</sub> – Pancharvevo Fm, BoT<sub>2</sub> – Bosnek Fm, RaT<sub>2</sub> – Radomir Fm, RdT<sub>3</sub> – Rusinovdel Fm, KmT<sub>3</sub> – Komshtitsa Fm, SIT<sub>3</sub> – Slaveeva Fm, IJ – Gradets, Polaten, Gintsi, Drugan Fm, IIIJ<sub>3</sub>-K<sub>1</sub> Cenral Balkan Flish Group – Neshkovo and Kostel Fm, K<sub>2</sub> – granodiorite porphyry, bcgOl<sub>2</sub> – breccia-conglomerate Fm, aQh – alluvial sediments. Bold line – fault.

Data from the conducted study showed that the tectonic contact between the black limestones of the Radomir Fm and the sugary dolomites of the Bosnek Fm, described by Zagorchev et al. (1991, 1994) and Antonov et al. (2011b), are not faulty. The observed folds (mainly in the Radomir Fm) of the contact between the two units are most probably the result of inter-formal slip in the process of tectonic deformation due to

the different rheological properties of the rocks (Fig. 7, c). In places close to the contact, the limestones of the Radomir Fm are folded into isoclinal folds, but in most cases the contact is normal. The dolomites of the Bosnek Fm, on the other hand, are slightly fractured.

### Structural-geological setting

The study revealed a complex picture of a folding interference in which folding events of different ages are partially co-axially overlaid so that later events mask the earlier effects.

Several tectonic stages have been set up in the Golo Bardo area. The demarcation of the Eo-Cimmerian tectonic stage from the Austrian is possible due to the pronounced azimuthal and angular unconformity between the Triassic and Jurassic-Lower Cretaceous stratigraphic sequence. The Laramide tectonic stage is not proven here because of the lack of Upper Cretaceous rocks, but it is established in the western parts of Golo Bardo. In the section where the research was carried out Sava tectonic stage was also found, through which a tectonic wedge of the breccia-conglomerate group was formed, which is all described by Ilieva, Zhelev (2010). The Neotectonic stage is manifested mainly by late faults that displace the structures, which have been already formed.

In a previous publication (Ilieva, Dimitrov, 2011), in two outcrops of the flish sediments of the Kostel Fm, the hinge of a lying fold was observed and the assumption of more such folds on a regional scale was made. In the present study, lying folds or a reversed layering was found. This means that the fold described is a local phenomenon, and on a regional scale the bedding can be considered normal.

Such folds of a lower order were found in the Pancharvevo Fm PaT<sub>1-2</sub> (Fig. 7a, b). They have a high orientation of limbs 240 to 250° and a direction of the axis – WNW-ESE. The type of the contact between the Pancharvevo Fm and the older Mogila Fm (Fig. 7e) is normal lithological.

The diagrams of the cyclographic traces (Fig 6a, b) and the polar statistical diagrams of surface measurements in Triassic and Jurassic (Fig 6c, d) show values for their maxima, respectively,  $s_0-78$  to  $81/72^\circ$  for Triassic sediments and  $s_0-46/50^\circ$  for Jurassic ones. The difference in the dip directions is  $23 - 35^\circ$  and  $18 - 22^\circ$  in the dip. This indicates the existence of a clear azimuthal and angular unconformity between the Triassic and Jurassic-Lower Cretaceous tectonic stages.

The restoration of the primary geometry and age of the folds is associated with a certain difficulty because of the incompleteness of the outcrops. For this purpose, it is necessary to make a correlation of the structures on a regional scale and to use indirect data about the age of analogous deformations from other outcrops.

Table 1.

Geological description of the Mesozoic section along the Struma Highway between the villages of Studena and Staro Selo. The description is from north to south.

From (km)	To (km)	Lithostratigraphic unit	Index	Lithographic description	Layering orientation
0+000	0+088	Bosnek Formation	BoT <sub>2</sub>	Strongly carced gray to dark gray dolomites and dolomite limestones of the Bosnek Fm	Unclear elements-
0+088	0+993	Svidol Formation?	SvT <sub>1</sub> ?	Beige sandy limestones, alternating with black sandy limestones with muscovite with multiple calcific lenses and veins	S <sub>0</sub> -280/18°
0+993	1+436	No outcrops	-	No outcrops	-
1+436	1+678	Mogila Formation	MgT <sub>1,2</sub>	Dark gray micritic limestones in places brecciated	S <sub>0</sub> -241/38°
1+678	1+766	Pancharevo Formation	PaT <sub>1,2</sub>	Light gray, hydrothermally altered sandy limestones with isoclinal metric folds. In the eastern escarpment of the road, under the limestones, are observed middle-layered, white to light gray, mica, quartz sandstones to gravelites	S <sub>0</sub> -229/36°
1+766	2+020	Mogila Formation	MgT <sub>1,2</sub>	Black intraclastic limestones	S <sub>0</sub> -210/49°
2+020	2+406	Bosnek Formation	BoT <sub>2</sub>	Light gray, striped dolomites	S <sub>0</sub> -170/25°.
2+406	3+706	Bosnek Formation	BoT <sub>2</sub>	Cracked, brecciated dolomites, forming screens	S <sub>0</sub> -200/45°
3+706	3+786	Breccia-conglomerate Formation	bcgOl <sub>2</sub>	Breccia-conglomerates and clays with lenticular layers of acidic tufts and limestones	S <sub>0</sub> -200/45
3+786	4+886	Bosnek Formation	BoT <sub>2</sub>	Bright, massive, locally striped, sugary dolomites	S <sub>0</sub> -190/45°;
4+886	5+109	Radomir Formation	RaT <sub>2</sub>	Dark limestones with abundant, but focused on separate levels, detrital component and bivalve fossils	S <sub>0</sub> -190/36°
5+109	5+229	Bosnek Formation	BoT <sub>2</sub>	Sugary, massive to striped dolomites of the Bosnek Fm on a contact with the black limestones of Radomir Fm	S <sub>0</sub> -190/38°
5+229	5+637	Radomir Formation	RaT <sub>2</sub>	Medium- to heavy-bedded sandy, bio-detrital light gray limestones with rare fine alevrolite layers. They are alternated with thin-bedded, carbonate, brownish alevrolite and black, aphanitic limestones	S <sub>0</sub> -190/45°;
5+637	6+124	Rusinovdel Formation	RdT <sub>3</sub>	Striped dolomites, medium-bedded, light and dark gray	S <sub>0</sub> -225/45°
6+124	7+624	Kostel Formation (Central Balkan fish group)	KsJ <sub>3</sub> -K <sub>1</sub> (IIIJ <sub>3</sub> -K <sub>1</sub> )	Flish alternation of medium-grained, fine-striped limey sandstones, alevrolites and argillites	S <sub>0</sub> -220 /45°

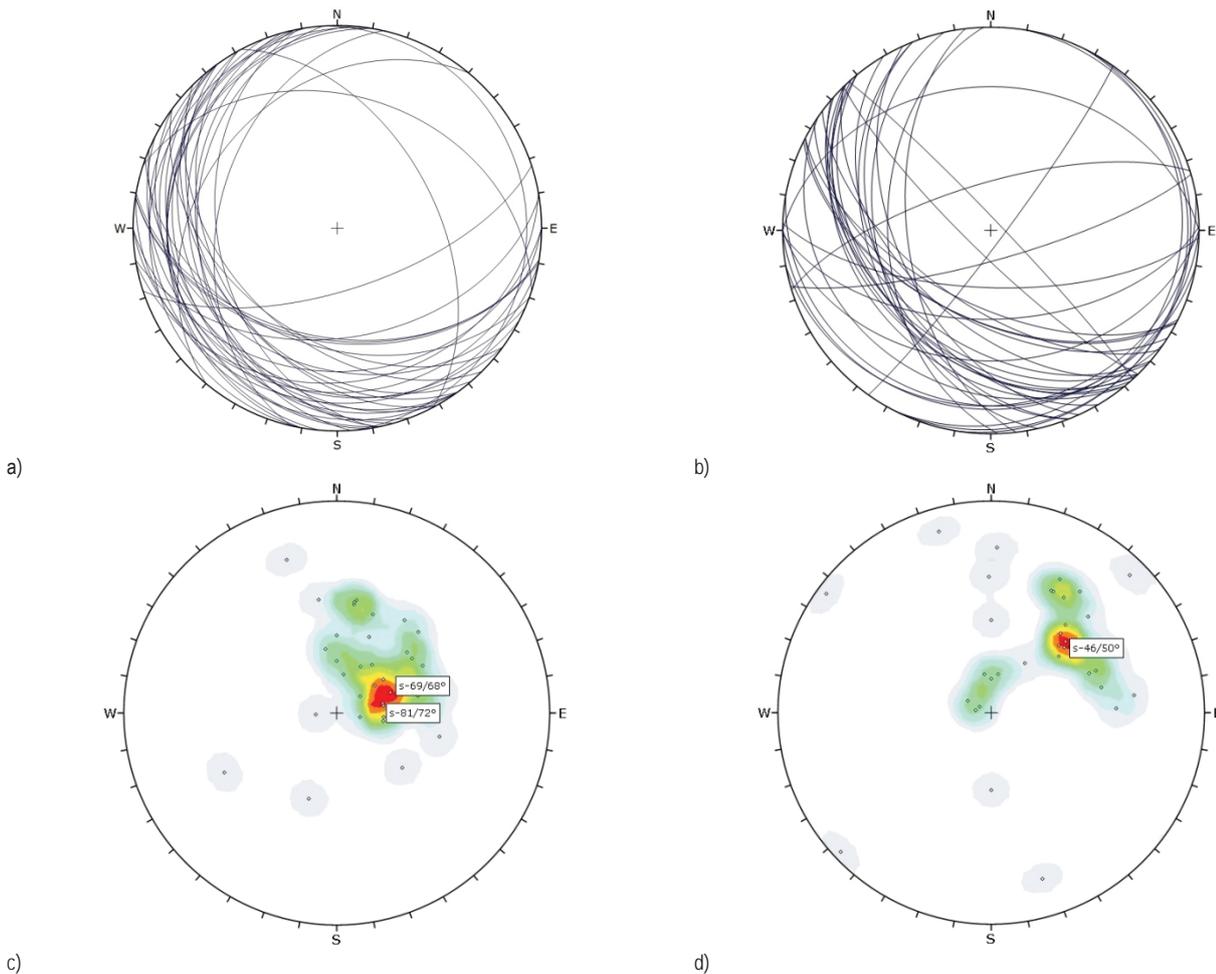


Fig. 6. a) Diagram of the cyclographic traces of 37 planar surfaces in the Triassic sediments, b) Diagram of the cyclographic traces of 36 planar surfaces in the Jurassic sediments, c) Density diagram of poles of 37 planar surfaces in the Triassic sediments with the maxima, d) Density diagram of poles of 37 planar surfaces in the Jurassic sediments with the maxima

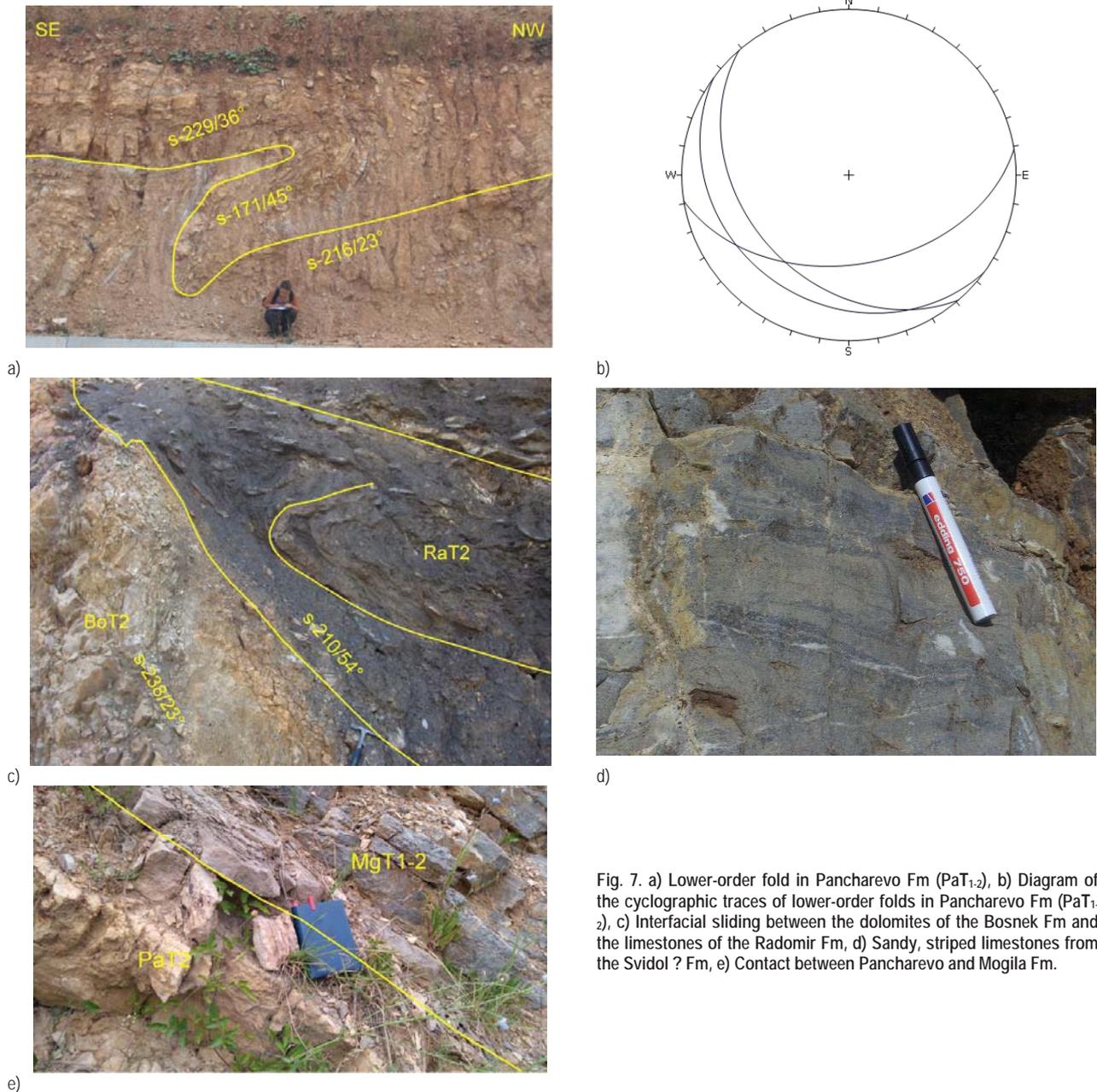


Fig. 7. a) Lower-order fold in Pancharevo Fm (PaT<sub>1-2</sub>), b) Diagram of the cyclographic traces of lower-order folds in Pancharevo Fm (PaT<sub>1-2</sub>), c) Interfacial sliding between the dolomites of the Bosnek Fm and the limestones of the Radomir Fm, d) Sandy, striped limestones from the Svidol ? Fm, e) Contact between Pancharevo and Mogila Fm.

## Conclusion

The described Studena - Staro Selo section revealed complex tectonic relationships between the lithostratigraphic units in the area. It has been found that Mesozoic sediments in the area are affected by several tectonic folding phases – Eo-Cimmerian, Austrian, Sava and Neotektonic. Regionally, the construction is dominated by large folds with NW-SE direction of the axes. The cross section shows the SW limb of a large conical to cylindrical fold that is refolded by younger folds. The demarcation of the Eo-Cimmerian tectonic stage by the Austrian stage is possibly due to the pronounced azimuthal and angular unconformity between the Triassic and the Jurassic-Lower Cretaceous tectonic stages.

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