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KARST MORPHOLOGY IN THE STRANDJA REGION BETWEEN THE VALLEYS OF MLADEZHKA AND VELEKA RIVERS

Abstract: The area, located northwest of the historic and protected site Petrova Niva between the valleys of Veleka and Mladezhka rivers, is among the most representative karst regions in Strandja Nature Park. In the region are placed perfectly developed forms of epikarst – limestone pavement, karst fields, sinkholes, ponors, etc., and of mesokarst – caves and precipices. Here is the longest and deepest cave in the Bulgarian part of the mountain – Golyama Vapa (450/-125 m).
The purpose of this research is to explore and precisely describe the surface and underground karst landforms in a representative karst region of the Bulgarian part of Strandja.
The proven uniqueness and high vulnerability of the study area requires strong limitation of the anthropogenic impact on the territory. The most vulnerable karst landforms are the sinkholes with active ponors. Therefore, they need to be marked with durable special signs due to the high afforestation of the area, in order to restrict forestry activity.

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Introduction

The karst area, covered by this research, is located in the Bulgarian part of Strandja mountain, within the same named nature park. It occupies the eastern part of the watershed ridge between Veleka and Mladezhka rivers. The area is 15 km north of the town of Malko Tarnovo and 40 km southwest of the regional administration center – the city of Bourgas. The main starting point is the village of Zvezdets, from which there is an asphalt road along the watershed ridge to the historical and protected site Petrova Niva.

The southern boundary of the region is distinguished by the highly meandering and deeply cut valley of Veleka river, along its stretch from the Varli Dol gully to the confluence with Mladezhka River. The northeast boundary is the deep valley of Mladezhka river, also known in the area as Karamlak river. The northwestern boundary is conditionally marked by the area of Cheshmenski Polyani on the watershed ridge, from where deep gullies descend towards the valleys of Mladezhka and Veleka rivers in the northwestern and southeastern directions.

The outlined boarders of the study area originate from erosion processes and cover a territory of 24.56 km^2 (Figure 1).

Although relatively small in area, the region is characterized by significant density of the karst landforms and relief displacement of more than 250 m. The lowest point is the confluence of the rivers Veleka and Mladezhka in St. Virgin Mary area – 96 m above sea level and the highest is Kosovo Peak (357.1 m above sea level).

According to the geomorphological zoning of Bulgaria, the study area falls within the boundaries of the Thracian-Strandja region. The relief is low-mountainous and belongs to the Dervent-Strandja area of Sakar-Strandja sub-region of the South Bulgarian (Thracian-Anadol) geomorphological province (Vaptsarov et al. 1997).

According to the karst zoning in Bulgaria of Popov (1982), the study area is part of subdistrict №310 of the Strandja Karst area of Sredna Gora-Thracian Region.

Figure. 1. Location and boundaries of the study area

The territory of the study area partly overlaps with Petrova Niva karst area, corresponding to the modern karst zoning of Strandja (Benderev and Ilieva 2015), but significantly exceeding its size.

The specific natural environment, caused by the special geographical location of the study area, together with the karst character of the territory, are a prerequisite for diverse karst landscapes formation. According to the landscapes zonation in Bulgaria, the karst massif is in the Fakia-Veleka area of the Strandja sub-region of the Inter-mountainous region of the southern Bulgarian lowlands and low mountains.

In terms of administrative-territorial division, the karst area is shared between the lands of the villages of Zvezdets and Stoilovo.

Material and Methods

For the analysis of specific karst morphology in the study area a complex approach was applied, using a number of geomorphology methods, listed below.

Description and mapping of surface and underground karst landforms. Characterization and mapping of karst landforms in the area was performed according to the established methods in karst geomorphology (White 1988, Ford and Williams 1989). In the description of the surface karst, the existing Bulgarian terminology of karst landforms was used with some variations (Popov and Stefanov 1980).

Method of statistical analysis of karst landforms (White 1988, Kostov 1999, 2017, Shanov and Kostov, 2015). This method, based on measurements with geological compass of the surface karst landforms (limestone pavement) orientation and the preferred direction of the cave galleries in the area, was applied. Charting was used to prove or reject the role of structural control in speleogenesis.

During field surveys in the summer of 2017, the karst fields of limestone pavement, sinkholes and part of the caves in the study area were visited. In the karst fields, with a geological compass, measurements of the fracture orientation of the karst morphological complex were made (46 measurements).

The preferred directions of 38 cave galleries from 11 caves were measured on available maps of caves in the area. The free software Yong Technology Inc. was used to compose the rose charts.

Sedimentological analysis of cave sediments. The examinations of cave sediments were made in a borehole with a depth of 40 cm, done at the bottom of Varadat cave. For the purposes of this research, the samples from Varadat cave were analyzed in the Laboratory for Quaternary Research of Sofia University "St. Kliment Ohridski" and the University of Mining and Geology "St. Ivan Rilski". The granulometric analysis clarified the conditions for sedimentation in the cave.

Method of analysis of tectonic effect on the morphology of cave galleries. In some caves, indicators of modern tectonic movements are observed on elements of cave morphology. Such indicators could be the displaced sections in the cross section of the gallery due to rift movement, slickenside, presence of a tectonic breccia, spatial discordance in the couple of "stalactite - reciprocal stalagmite", or dislocated or inclined stalagnates. Kostov (2017), Shanov and Kostov (2015) and others present in detail the benchmarks for active tectonics in caves. Their analysis includes routine measurement of their parameters (side, slope, displacement amplitude, friction hatch analysis) with a geological compass. With this method, tectonic dislocations were found in two caves in the study area.

Results and Discussion

The conducted geological-structural studies in the area of Golyama Vapa cave (Benderev and Radulov 2008) link the karst morphological complex to a marble body enclosed in schist. The structural features of the marbles and their spatial relation with the schists control the location of the surface karst landforms and caves, the orientation and shape of their galleries. For example, the sinkhole entrance of Golyama Vapa cave is in the contact zone between the schists (in which the gorge is formed) and the marbles (in which the surface runoff of the gorge is transformed into an underground through the cave system) – a typical example of an allochthonous karst type (by Yakuch 1979).

Considering the general geomorphological development of the mountain and the specific features of the relief in the area, it is suggested that the cave system of Golyama Vapa as well as other caves in the area, are relatively young and their origin is associated with the Pleistocene. Evidence for the activity of karst processes is also the active construction of secondary cave formations in Golyama Vypa.

The tectonic fracture of the massif is one of the main factors for the formation of karst landforms. Benderev and Ilieva (2015) report the presence of a suspected rift along the line of Varadat cave within the study area, which was confirmed by our field work.

The results from the 46 measurements of fracture orientation in the karst complex with geological compass are shown on Fig. 3 and the results from the 38 measurements on maps of the preferred directions of cave galleries in 11 caves – on Fig. 4.

The comparison of both rose charts shows the clearly expressed structural control in karst genesis and the formation of limestone pavement and caves in the region by a fracture system 285º-315° and 60º.

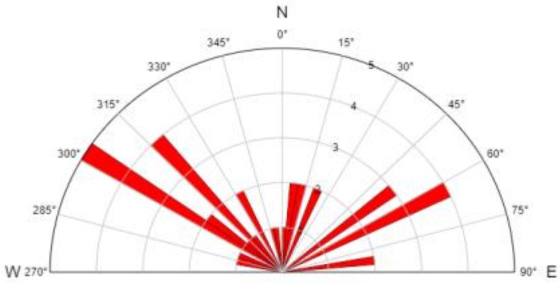

Fig. 3. Rose chart of limestone pavement in karst fields in the areas of Starite Plevni and Mogilite, based on 46 measurements

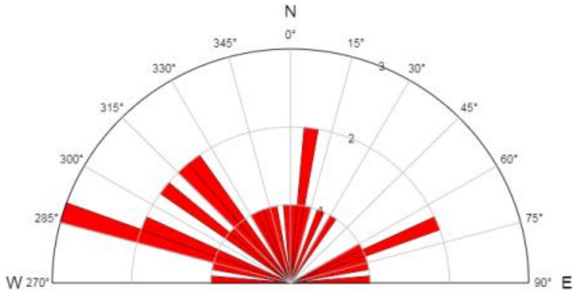

Fig. 4: Rose chart of preferred directions of cave galleries in the study area, based on 38 measurements

In the description of karst landforms in the study area, approved classifications in karst geomorphology of Popov (1980), White (1988), Ford and Williams (1989) and others were used. In order to fulfill the purpose and objectives of the study, precise mapping of the epi- and mesokarst landforms in the area was made, recording GPS coordinates.

The epikarst forms in the study area include different in shape, size and genesis limestone pavements and the karst fields formed by them, sinkholes with ponors, karst valleys, karst niches.

Limestone pavements and karst fields

Limestone pavements represent the early stage in the development of the karst process (White 1988). Within the study area, their distribution is over an area of about 1.5 km^2 and form two main karst fields northwest of the historical and protected site of Petrova Niva. Through field surveys in August 2017, all morphological types of limestone pavements were identified according to Popov's classification scheme (1980).

Ordinary (structural) limestone pavements follow the orientation of the tectonic fracture of the massif (Fig. 6 A). After measurements with geological compass, it is found, that they are formed along systems of tectonic fractures with predominant directions of 60º, 300º and 315º (Fig. 3-4). The depth of the limestone pavement furrows varies from a few centimeters (usually covered with weathered materials and soil) to 50 cm.

Biogenic limestone pavements have usually oval shape. For their formation contribute the root systems of the plants, which widen and form micro-tectonic cracks (Fig. 6 B).

Small limestone pavements (also known as streamers) are typical for steep karst slopes and such were found north of the great meander of Veleka river on a surface with a slope of 44º within the boundaries of the study area (Fig. 6 C).

A B C

Fig. 6. Ordinary (structural) limestone pavements and karst field (A), biogenic (B) and small limestone pavements (C) in the study area

Sinkholes

Sinkholes are one of the most representative and emblematic karst forms. About twenty sinkholes, different in genesis and morphological features according to the terminology of Popov (1980), are developed in the area. Distinctive for this karst area in Strandja are both ordinary (funnel-shaped) sinkholes and rocky sinkholes with vertical walls. Some of the sinkholes are open at the bottom and are cave entrances.

The biggest sinkhole in the whole area is the one with the entrance to Golyama Vapa cave. It is located in one of the tributary valleys (blind karst valley) of Sahov Dol (Bazov Dol). The frontal shape of the sinkhole is oval, and in profile it is asymmetric conical. Its total area is 0.49 ha (0.049 km^2), narrowing to 25 m^2 in the lowest parts. At its base, the narrow ponor entrance of the precipitous Golyama Vapa cave opens.

An interesting geomorphological phenomenon is the cave Izvornata. Its description, made during the Strandja`86 expedition, gives the reason this cave to be classified as a ponor-spring, i.e. estavela in karst terminology. These types of forms are typical for young, actively developing karst genesis with shallow groundwater – at high levels they overflow through the ponors and form karst springs.

Underground karst landforms

The forms of the mesokarst include caves (horizontal, sloping, cascading), precipitous caves and precipices. They form complex underground systems and together with inaccessible karst cavities, build the structure of underground karst in the area.

Within the study area, 11 caves were explored and mapped. Only three of them are over 200 m in length: Golyama Vapa (450 m), the Cave with two entrances (208 m) and Labirintnata (201 m).

Sedimentological analysis in borehole in Varadat cave

The results of the granulometric analysis of the sediment samples from the borehole at the bottom of Varadat cave are shown in Table 1.

From the analysis of the collected data, we can conclude that gravel and rubble materials are located at most 20 cm in depth. This fact may indicate a frost weathering, caused by the considerable size of the cave entrance and the difference in temperature conditions before the sediments accumulate and close some of the entrance parts. It is important to know that the blockage is located at the southern end of the cave, with positive displacement, and the main gallery developing from the entrance has a negative one. Therefore, we assume that it was probably a passage cave and at some stage of its development, a major cataclysm occurred. It was probably a tectonic event, at which the collapse processes began. The presence of a rift with considerable dislocation between the hanging and the lying wing supports this assumption. In support of this assumption is the amount of clay material in the borehole profile, which decreases from the surface to its bottom. This indicates that a periodic stream penetrates the cave, washes the clay from the surface and send it in depth.

Table 1. Granulometric analysis of cave sediment from a borehole in Varadat cave

Лазар I — 5000 ml — 8 бр. кофи

кол в-во в цил. ml — изх. т = … 140

40000 : 25 k 1600 %

40 cm повърхностна

		пелит (от - до в мм)			алеврит (от - до в мм)				псамит (от - до в мм)					гравий (- - мм)	чакъл (от - до в мм)		
		<0.001	0.001-0.002	0.002-0.004	0.004-0.008	0.008-0.016	0.016-0.02	0.02-0.063	0.063-0.125	0.125-0.25	0.25-0.50	0.50-1.0	1.0-2.0	2.0-4.0	4.0-8.0	>8.0	
тегло g x…….k*	1600	0	0	0	0	0		20,37	9,65	2,43	1,67	2,27	4,58	5,64	4,95	3,43	
кумулативен %		100	100	100	100	100	100	54,99	34,62	24,97	22,54	20,87	18,6	14,02	8,38	3,43	
% съд. в изх. т		0	0	0	0,00	0,00	45,01	14,55	6,89	1,74	1,19	1,62	3,27	4,03	3,54	2,45	
Σ % в изх. т		0			59,56				14,71					4,03	5,99		84,29

по Munsel 5YR4/4 червеникавокафяв

Лазар III — 5000 ml — 7 бр. кофи

кол в-во в цил. ml — изх. т = … 150

35000 : 25 k 1400 %

10 cm

		пелит (от - до в мм)			алеврит (от - до в мм)				псамит (от - до в мм)					гравий (- - мм)	чакъл (от - до в мм)		
		<0.001	0.001-0.002	0.002-0.004	0.004-0.008	0.008-0.016	0.016-0.02	0.02-0.063	0.063-0.125	0.125-0.25	0.25-0.50	0.50-1.0	1.0-2.0	2.0-4.0	4.0-8.0	>8.0	
тегло g x…….k*	1400	0	0	0	0	0		17,88	11,26	2,98	1,9	2,22	4,04	6,94	6,81	31,03	
кумулативен %		100	100	100	100	100	100	85,06	67,18	55,92	52,94	51,04	48,82	44,78	37,84	31,03	
% съд. в изх. т		0	0	0	0,00	0,00	14,94	12,77	8,04	2,13	1,36	1,59	2,89	4,96	4,86	22,16	
Σ % в изх. т		0			27,71				16,00					4,96	27,03		75,70

по Munsel 5YR5/6 жълтеникавокафяв

Лазар IV — 5000 ml — 10 бр. кофи

кол в-во в цил. ml — изх. т = … 150

50000 : 25 k 2000 %

0 cm

		пелит (от - до в мм)			алеврит (от - до в мм)				псамит (от - до в мм)					гравий (- - мм)	чакъл (от - до в мм)		
		<0.001	0.001-0.002	0.002-0.004	0.004-0.008	0.008-0.016	0.016-0.02	0.02-0.063	0.063-0.125	0.125-0.25	0.25-0.50	0.50-1.0	1.0-2.0	2.0-4.0	4.0-8.0	>8.0	
тегло g x…….k*	2000	0	0	0	0	0		22,44	10,01	2,41	2,13	2,9	4,69	4,78	3,89	8,28	
кумулативен %		100	100	100	100	100	100	61,53	39,09	29,08	26,67	24,54	21,64	16,95	12,17	8,28	
% съд. в изх. т		0	0	0	0,00	0,00	38,47	16,03	7,15	1,72	1,52	2,07	3,35	3,41	2,78	5,91	
Σ % в изх. т		0			54,50				15,81					3,41	8,69		82,42

по Munsel 5YR4/4 червеникавокафяв

Лазар II — 5000 ml — 7 бр. кофи

кол в-во в цил. ml — изх. т = … 150

35000 : 25 k 1400 %

20 cm

		пелит (от - до в мм)			алеврит (от - до в мм)				псамит (от - до в мм)					гравий (- - мм)	чакъл (от - до в мм)		
		<0.001	0.001-0.002	0.002-0.004	0.004-0.008	0.008-0.016	0.016-0.02	0.02-0.063	0.063-0.125	0.125-0.25	0.25-0.50	0.50-1.0	1.0-2.0	2.0-4.0	4.0-8.0	>8.0	
тегло g x…….k*	1400	0	0	0	0	0		18,15	3,72	6,31	2,5	3,91	4,01	7,58	5,5	27,95	
кумулативен %		100	100	100	100	100	100	79,63	61,48	57,76	51,45	48,95	45,04	41,03	33,45	27,95	
% съд. в изх. т		0	0	0	0,00	0,00	20,37	12,96	2,66	4,51	1,79	2,79	2,86	5,41	3,93	19,96	
Σ % в изх. т		0			33,33				14,61					5,41	23,89		77,24857

по Munsel 5YR4/4 червеникавокафяв

The results show the conservation significance of the explored karst sites as part of the Bulgarian geodiversity and geological heritage and testify to their formation respectively as continual complex physical and chemical processes, similar to other geological sites preserved by the national Protected Areas Act (Anonymous 1998, Bancheva-Preslavska 2018a). Although, in case of erosion processes, efforts are usually directed towards afforestation (Zakov and Marinov 2006, Zakov 2016, Bancheva-Preslavska 2017, 2018b), in this case vegetation would affect the features of surface karst forms and their uniqueness.

The research justifies the studied and described emblematic karst region of the Bulgarian part of Strandja to be protected, as a typical and remarkable non-living natural site in the nature park, because of its inherent rarity, representative and aesthetic qualities, and its importance for science and culture. It supports the proposal to declare Bazov Dol karst geosystem as a natural monument, which is still not approved, but submitted already in 2009 to the Regional Inspectorate of Environment and Water – Burgas and the Ministry of Environment and Water (Milchev et al. 2014).

Conclusion

This text is based on geomorphological studies in karst terrains in Strandja Nature Park. The study area, located northwest of the historical and protected site of Petrova Niva, is one of the most representative karst areas in the Bulgarian part of the mountain.

The proven uniqueness and strong vulnerability of the explored area suggests that the anthropogenisation on this territory should be minimized. The most vulnerable areas are the sinkholes with active ponors. This requires marking them with permanent special signs due to the high afforestation of the area in order to restrict forestry activity.

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