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PERIGLACIAL RELIEF PHENOMENA ON MOUNT VARDENIK (SOUTHEASTERN SERBIA)

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Abstract: In the medium-high mountains of Serbia (1,000-2,000 m.a.s.l), sporadic periglacial relief forms occur, which is also the case with Mount Vardenik (1,876 m.high), a mountain in the southeast of Serbia. During reconnaissance, certain relict and sub-recent periglacial phenomena and landforms in the highest part of the mountain have been identified: block slides, rock flows, thermogenic landslides in springs, nivation-induced relief and in one location cryoplanation terraces. Sparsely clustered and individual occurrences of frost splitting and solifluction of the land surface and small areas with grass turf indicate contemporary signs of sporadically present seasonal frost and freeze-thaw cycles. Periglacial morphology and its processes have been recorded and investigated using a qualitative geomorphological procedure. The main problem is the origin of periglacial phenomena (occurrences and landforms) of the relief, considering that the analysis of the contemporary climate, geoecological properties and anthropogenic activities indicate that there are no conditions for the existence and development of a contemporary periglacial environment on the mountain. The problem was analyzed considering the climate change in general and, in particular, geoecological conditions created under the influence of human activities. Due to the observed sporadic relict and sub-recent periglacial relief on Mount Vardenik, in contemporary conditions the periglacial environment of this area can be considered as relict or as a phenomenon bordering the limits of differentiation. The relict property also results from the fact that on the mountain, due to the contemporary climate and changed geoecological conditions, the transition zone of the periglacial environment cannot be distinguished.

Key words: periglacial landforms and phenomena, periglacial environment, Mount Vardenik, southeastern Serbia.

1. INTRODUCTION

Mount Vardenik (1,876 m) belongs to the group of ten highest mountains in Serbia. Together with Gramad (1,721 m) and Čemernik (1,638 m), it forms the Vlasina Plateau, and with Besna Kobila (1,923 m) and Dukat (1,881 m), the vast mountainous area of Vlasina and Krajište, in the furthest southeast part of Serbia. The geotectonic area belongs to the Serbian-Macedonian massif. The area of Mount Vadenik is an area with remains of old land surfaces, elongated slopes, flattened peaks and deep valleys, which clearly divide the mountain massif.

Mount Vardenik was only partially investigated in geomorphological terms. On general geomorphologic maps, it stands out as an area with periglacial landforms or as a transitional periglacial zone (Ćalić et al., 2017). For the geomorphological presentation of the Vlasina and Krajište area, the representation of Vlasina moorland (F=10.5 km^2), i.e. the Vlasina mud, from the end of the 19th century is significant (Cvijić, 1896). In the middle of the 20th century, there were extensive and complex geomorphological investigations (Rakićević, 1964; Milić, 1984a, 1984b). Most of them were conducted because of the construction of the dam (1949), the formation of the Vlasina Lake (a water mirror - 16.5 km^2) and other large-scale infrastructure for inter-basin water transfer in a wider area. There is more recent research of the periglacial relief of this area (Milošević et al., 2007, 2015; Nešić et al., 2012). During the second half of the 20th century, this area experienced a most visible transformation of the landscape due to the formation of an artificial lake, and intensive depopulation as well.

For the purpose of protecting the Mount Vadenik area, during 2019, the terrain reconnaissance was conducted. On that occasion, various sporadic periglacial phenomena and landforms were observed (Figure 1). During the research, the idea of recording and processing the studied periglacial relief arose in order to distinguish the possible framework of the periglacial environment. Based on these principles, the aim of this article is to present the established periglacial landforms and phenomena in the context of determining the nature of the contemporary periglacial conditions of this area.

The foundation for determining the characteristics of the periglacial environment consists of climatological, geoecological and geomorphological criteria (Nešić & Milinčić, 2019). Inventory compilation of the periglacial relief is a part of this procedure. Research on Mount Vardenik confirmed the importance of all the indicated factors for the existence of the periglacial environment. Particularly, the importance of the anthropogenic impact on the contemporary lower limit of the periglacial climazonal belt was determined. During the field research, the classic geomorphological reconnaissance procedure was applied with the inventory compilation and morphometry of the identified landforms.

2. REGIONAL PRESENTATION

Mount Vardenik, with the highest peak Veliki Strešer (1,876 m), is mostly mentioned as the peripheral part of the Vlasin Lake basin, formerly Vlasina mooreland. According to hypsometric characteristics (altitude and slopes), Mount Vardenik belongs to the middle mountain area of Serbia within the altitude range of 1,001-2,000 m.a.s.l. (Ćalić et al., 2017).

The central morphological unit of the mountain is the Veliko Strešer mountain cone, from which the Bilo peak (1,741 m) extends to the northwest, and the Golemi Vrh (1,753 m) to the southeast. In the area between Strešer and Golemi Vrh, to the north and south, long and complex mountain ridges with a series of lower mountain peaks can be distinguished. With these slopes, Mount Vardenik is connected to the Vlasina Lake basin in the north and Besna Kobila (1,913 m) in the south. In the north, Ravnište (1,703 m), Beli kamen (1,573 m), Pandža's grave (1,664 m) and again Ravnište (1,663 m), are distinguished. From Ravnište, there is a slope towards Vlasina Lake. On the southern slope, the most important peaks are Prosenik (1,726 m) and Golema Ravnica (1,744 m).

The mountain has the shape of a spacious broken surface with elongated slopes, rounded and flat tops of the highest peaks, which dominates the surrounding terrain of Vlasinska Plateau. This morphology influenced previous researchers in the Mount Vardenik area to differentiate a series of high surfaces of 1,600-1,800 m and 1,400-1,500 m, above the Vlasina Plateau of 1,000-1,200 m (Cvijić, 1911; Milić, 1967, 1984a). Another feature of the mountain are deep valleys that dramatically divide the systems of the mountain surfaces. In the west, these are the valleys in the Vrla basin, and in the east in the Božička river basin.

The lithological foundation of the Mount Vardenik area basically consists of regionally and progressively metamorphosed crystalline schists of the Vlasina Complex, one of the oldest rocks in Serbia. The granitoids of Božica are embedded in them, and the largest in Serbia, the Surdulica granodiorite batholith (Mijović, 2014).

Within the regionally metamorphosed formation of the Vlasina Complex, mineralogical varieties of chlorite-sericite schists, as well as smaller occurrences of calxist, have been distinguished, whereas in the progressively metamorphosed rocks, lepidolites, mica schists and varieties of gneiss dominate (Babović et al., 1976). The granitoids of Božica are mostly made of gneiss granite and feldspathic and granitized schists, and hybrid or mixed rocks are also represented (Babović et al., 1977). The lithological foundation of the Surdulica batholith consists of rocks in which varieties of granodiorite, monzogranite and quartz diorite are distinguished. The batholith is intersected by dacite and andesite formations and dikes (Babović et al., 1977).

The structural foundation of the landscape consists of the Vlasina syncline and a large magmatic body known as the Surdulica batholith. In the Mount Vardenik area, the southwestern wing of the Vlasina syncline curves to the east and is intensively interspersed by dislocation zones, the most striking of which extends across Veliki Strešer (Babović et al., 1977). From a morphological point of view, the contact between the metamorphites and the Surdulica batholith is significant. Along the Surdulica batholith, the previously mentioned mountain slope stretches from Strešer to the south towards Besna Kobila.

These features of the relief and geological structure of Mount Vardenik, indicate that in addition to the tectonic uplift and fissures of the area, long-term denudation also dominated, which resulted in the senile morphology of mountain surfaces, plains and rounded mountain peaks. On the mountain, there are visible occurrences of thermal quartz that protrudes

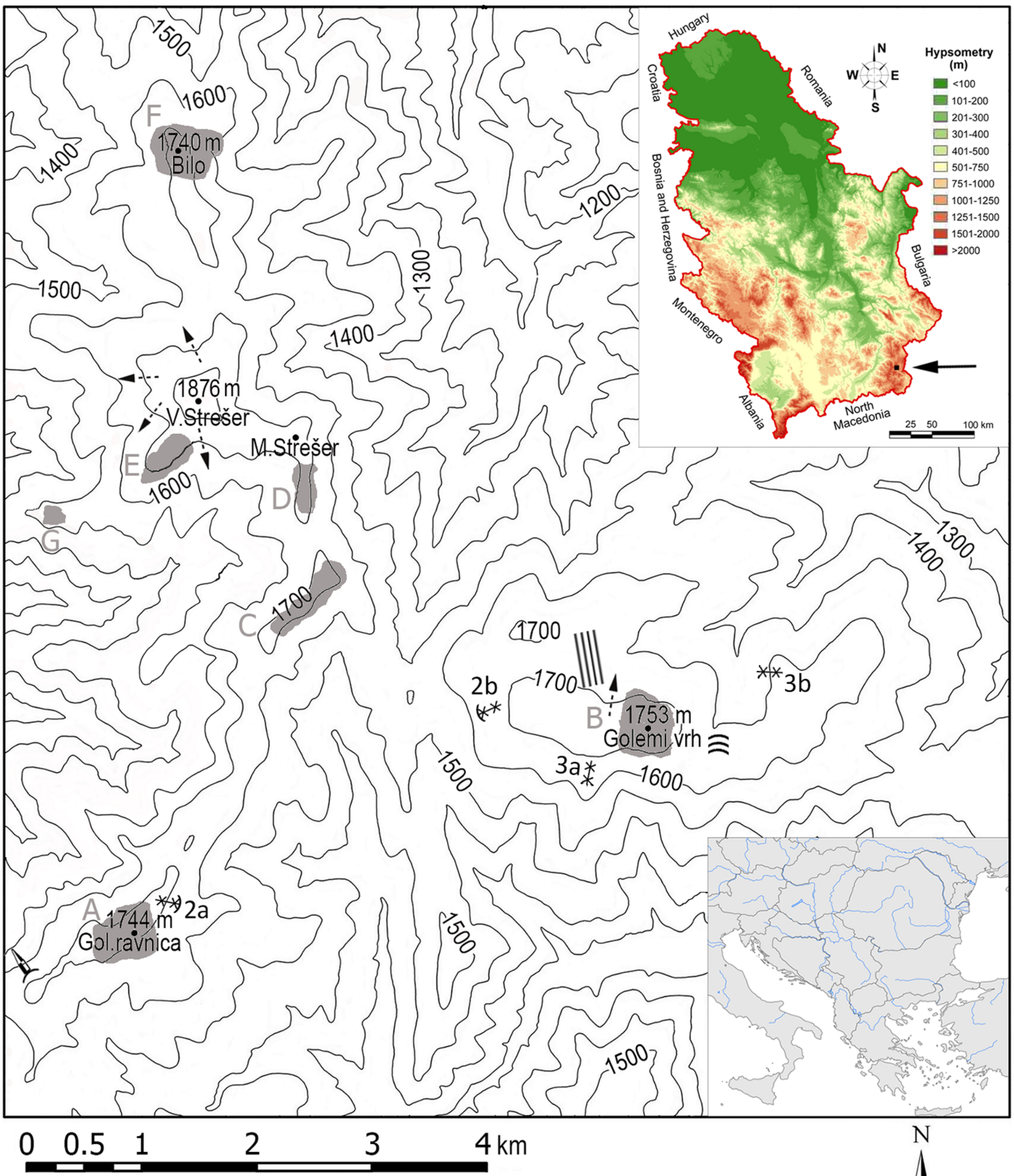

Figure 1. A general geomorphological map of Mount Vardenik mountain with its position in Southeast Europe. Legend: I - Contemporary periglacial phenomena (A, B, C, D, E, F, G): Relict periglacial relief: 1 - Block slides on Prosenik, 2 - Rock flows with a curved rampart (2a- Golema Ravnica, 2b- Golemi Vrh); 3 - Rock flows without arched ramparts (3a- Ržanska river basin and 3b- Stolovi); 4 - Solifluction at the spring; 5 - Cryoaplanation terraces near Veliki Stan and 6 - Nivation-induced relief.

in the form of isolated outcrops, which is an indicator of the relationship between total and selective denudation. Based on these characteristics of the space on Mount Vardenik, it is clear that denudation dominated, and with the development of the fluvial processes along the deep valleys during the general uplift of the massif, the secondary development of the colluvial and periglacial processes during the last stages of the Quaternary cooling, too.

Table 1. Average monthly and annual air temperatures at the stations Vlasina (1,260 m.), Vranje (433 m.) and Bosilegrad (830 m) for the period 1961-2010 (°C) (data source Republic Hydrometeorological Service of Serbia - RHMZ).

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yr.
Vlasina	-3.7	-2.9	0.7	5.4	10.3	13.3	14.8	14.7	11	7	2.5	-1.9	5.9
Vranje	-0.3	2	6.2	11.1	15.8	19.2	21.5	21.2	16.8	11.7	6	1.1	11
Bosilegrad	-2.2	-0.3	3.6	8.4	13.1	16.7	18.8	18.2	14.4	9	3.9	-0.9	8.5

The climate is especially important for the development of contemporary periglacial phenomena and the possible reconstruction of the periglacial environment of Mount Vardenik. Rakićević (1980) classifies the area of Vlasina and Krajište in a separate Vlasina climate region (marks II-16), which according to Köppen's climate classification is equivalent to D climate or moderately cold, boreal climate (snow forest climate with cold winters). According to the more recent classification of the climate in Serbia, the area of Vlasina and Krajište, and according to Köppen, belongs to the area of boreal or snow forest climate that is constantly humid with a warmer variant up to 1200 m.a.s.l. (Dfb) and colder (Dfc) above this height (Milovanović et al., 2017).

According to general climatological research in Serbia, the average annual air temperature below 3°C is recorded only at the highest parts of high mountains: Stara Planina, Kopaonik, Šar Planina and Prokletije. The area of Mount Vardenik belongs to the zone of average annual air temperature of 3-4°C (Milovanović et al., 2017). The analysis of the thermal gradient from the profiles of Vranje (433 m) and Bosilegrad (830 m), (for the observation period 1961-2010) shows that the average annual air temperature at the height of 1,730 m is around 3°C, which is the lower limit of the climatological framework of the periglacial environment (French, 2007). Measurements from Kopaonik at 1,710 m show that the average annual air temperature is over 3°C (Nešić & Milinčić, 2019). However, the climate of the highest parts of the researched area should also be observed in the light of the trend of climate cooling, as this is the only area with a slight cooling of the climate in Serbia, on the Bosilegrad – Kukavica profile (Milovanović et al., 2017). Regardless of the projections of the average annual air temperature on Mount Vardenik, the fact is that the climatic coverage of the periglacial environment, if it exists, would cover only the part of the mountain above 1,730 m above sea level. The rudimentary presence of periglacial phenomena on the mountain is partially confirmed by the findings of rare periglacial occurrences presented in this paper. The area of Mount Vardenik is in the isohyet range of 800-1,000 mm of annual precipitation (Milovanović et al., 2017), which is within the reconstructed altitudinal gradient of precipitation from 920 mm at 1,500 m above sea level, to 1,000 mm at the top of Veliki Strešer.

In the context of the contemporary climate, the position of the isotherm of 10°C, for the warmest month, is considered as the upper limit of tall trees and can be expected above 2,000 m above sea level (Milovanović et al., 2017). Based on this, in natural conditions, Mount Vardenik (1,876 m) would be completely covered by tall trees, with the probable appearance of an orographic forest border in the parts of the relief exposed to the wind.

The contemporary upper limit of tall trees on Mount Vardenik is entirely anthropogenic, created under the influence of long-term cattle breeding, and probably primitive mining as well (Milošević et al., 2007) (Figure 2). At the beginning of the 19th century, this area was one of three areas on the territory of Serbia where the mining activities and ore processing still continued since the ancient and medieval times (Milinčić, 2001). Large and highest mountain areas are covered with pastures, which is one of the main features of the Mount Vardenik landscape. The contemporary upper limit of tall trees consists of beech forests at an average altitude of 1,600 m above sea level, and within the zone 1,520-1,670 m, and in some places, forests descend even lower on certain slopes. Forests are present along river valleys and on the lower parts of mountain slopes, often in the form of fragments. Parts of forests or smaller conifer forests were planted on pastures, in some places over the highest mountain slopes, such as north of the Golema Ravnica (1,744 m), on Bilo (1,741 m) or Golemi Vrh (1,732-1,753 m).

The conditions for the development of seasonal frost and freeze-thaw cycles, as one of the features of the transitional periglacial environment, on the pastures of Mount Vardenik occur during frosty and icy days without snow cover. Such longer periods of time lead to more intensive freezing of the land surface. Such weather conditions are rare on Mount Vardenik

3. METHODOLOGY

Methodology involves the classic procedure of qualitative geomorphology with terrain reconnaissance, differentiation and determination of landforms and their morphometry. The procedure implied taking data about the location with a standard GPS device, determining the inclination and exposure of slopes,

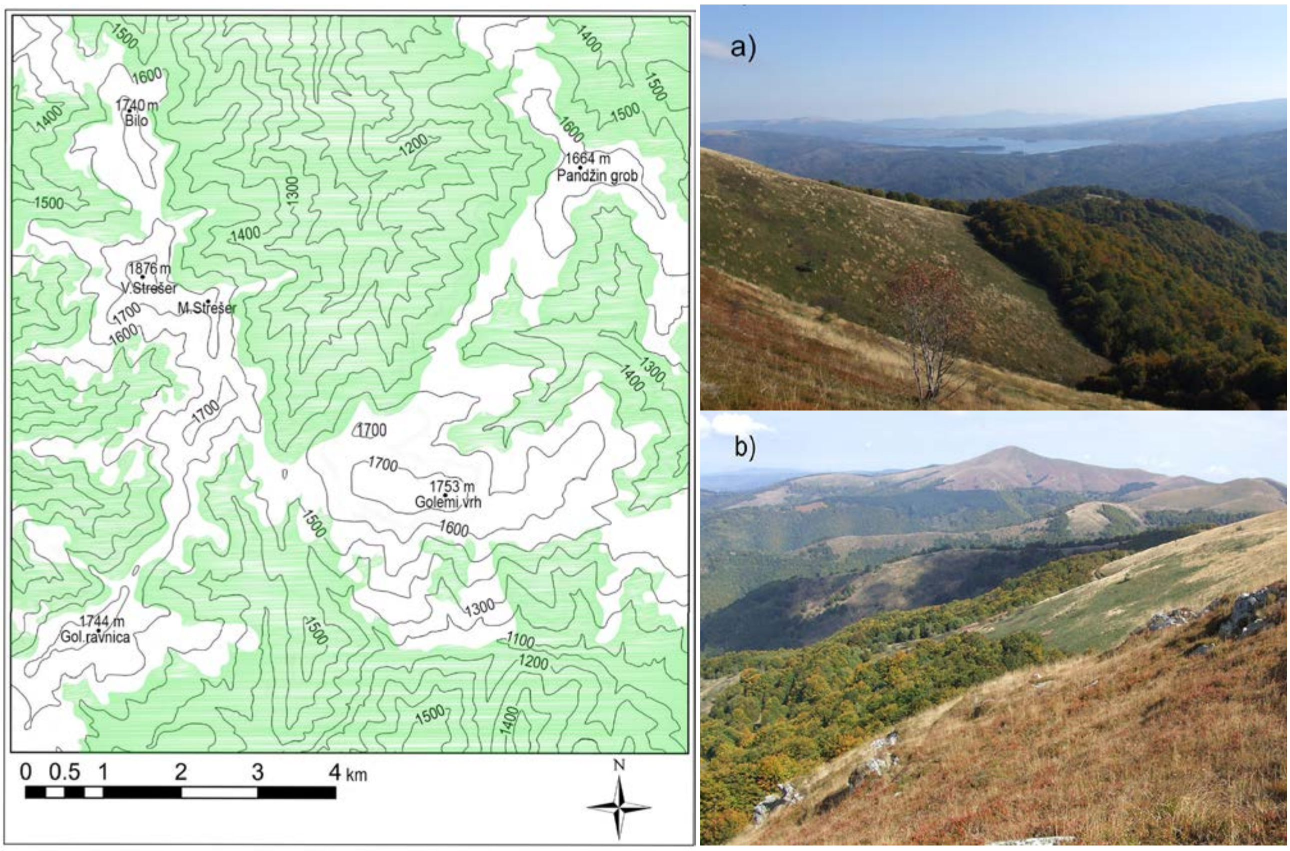

Figure 2. Areas under forests with the upper limit of tall trees on Mount Vardenik
a - Forests on the eastern slopes of Bilo (1,630-1,660 m.) above Topli Dol
b - Forests on Prosenik, Velika Ravnica, Mali and Veliki Strešer

the type of rock base and a general description of the appearance of the isolated morphology.

Periglacial landforms and phenomena were determined by comparison with the known morphology in the mountains of Serbia (Nešić & Milinčić, 2004; Nešić, 2009; Nešić et al., 2012) or with equivalent relief known in the world, for example cryoplanation terraces (Demek, 1969; Reger & Péwé, 1976; Czudek, 1995; French, 2007). The procedure involved differentiation of landforms based on their morphology, position and mutual relationship in the relief. Then, determination of parameters for the expected geomorphological processes of recent or relict origin.

During the processing of the results, various remote sensing methods were applied and the analysis of basic topographic and other thematic maps (e.g. geological map). The classic procedure of climatological calculations of air temperature and precipitation gradients was applied. Determination of the upper limit of tall trees was done by obtaining data from the map and through direct field observation and locating. Data on the average height of the line of tall trees were determined through statistical calculations with several observing points.

4. RESULTS

4.1. Contemporary Periglacial Phenomena

Contemporary periglacial phenomena on Mount Vardenik are of marginal importance and cannot be distinguished as a relief. Their spatial distribution is significantly conditioned by the orography, exposure and climate. These phenomena present the frost splitting and solifluction processes of the soil and grass cover, and the grass turf surfaces (Figure 3), whereas rudimentary solifluction phenomena are difficult to prove based on qualitative indicators.

The frost splitting and solifluction of the soil and grass cover occurs on the pastures of the protruding parts of mountain slopes, i.e. directly below them on the slopes with higher inclination (10-30°). Occurrences of splitting of eluvium with grass cover were recorded on the highest mountain slopes at the height between 1,650-1,740 m: Obržina, Golemi vrh, Prosenik and Bilo. This developmental regularity was recorded only on the slope below Šiljegarnik near Zanoga at about 1,545 m above sea level.

The phenomena of soil splitting were described as grass rings (Nešić, 2009; Nešić et al., 2012). This is probably the process of splitting the soil and grass

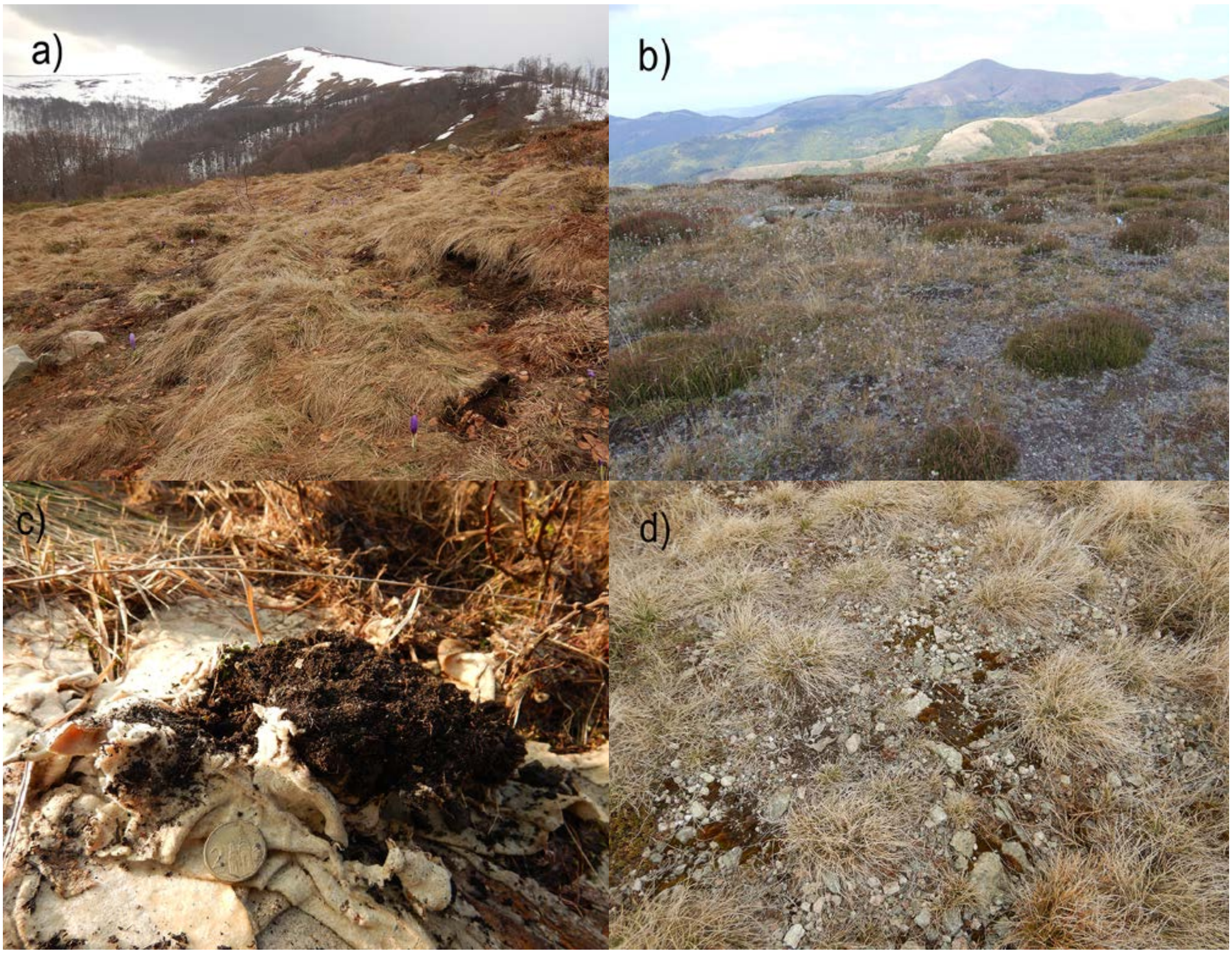

Figure 3. Contemporary periglacial phenomena on Mount Vardenik
a) Frost splitting and solifusion of the soil and grass cover at the location of Zanoge (1,545 m.a.s.l.) - April 2, 2019.
b) Grass turfs on the Golema Ravnica peak (1,730-1,740 m.a.s.l.) - October 1, 2019.
c) Rudimentary freezing of the soil on the northern slope of Veliki Strešer - April 2, 2019 and
d) Settling of debris between grass turfs due to frost - April 17, 2019.

cover under the influence of freezing, uplifting and solifluction of the land surface. The cracked parts appear as irregularly distributed grass turfs, or as shorter grass arcs (rings), and in further development, they appear as continuous and long (several meters long) grass turfs. On Mount Vardenik, the first stage of this frost splitting and solifluction degradation of soil occurs in the form of irregularly distributed grass turfs or smaller cracked surfaces (Figure 3). The process of soil splitting is followed by the settling of fine debris between the grass turfs, which is considered as a consequence of the frost process and a low denudation rate. The frost splitting of the land surface is interpreted in the context of seasonal frost and freeze-thaw cycles on the protruding parts of the relief that are freed from the snow cover more quickly, which allows freezing of the shallow soil and grass surface.

Land surfaces with grass turfs occur mainly on leveled mountain tops and the parts of mountain slopes with inclination of up to 10°. Genetically, they belong to small deflation zones where the soil surface is blown away by the wind. On small areas with grass turfs, the land surface is prone to more intensive freezing with settling of fine debris and limited denudation due to frost. On Mount Vardenik, such phenomena were observed on the highest parts of the mountain: Mali Strešer (1,710-1,730 m.a.s.l), Veliki Strešer (1,800 m.), the peaks of Golema Ravnica (1,730-1,740) and Bilo (1,740 m). Smaller zones with grass turfs are characterized by thinned fragmental (skeletal) soil or bedrock, which is associated with intensive denudation and deflation on the outcrops.

4.2. Relict Periglacial Relief

A relic periglacial relief is distinguished as a relief where periglacial processes do not take place or if they occur, they are sub-recent, probably from the last Holocene cooling, the Little Ice Age (LIA). At that time, low grass cover contributed to the freezing of the ground caused by intensive grazing. Degree of relictness of the sub-recent relief is derived on the basis of qualitative research and can be corrected if the quantification of the process proves its recentness. Within this relief, the following landforms are distinguished: block slides, block/debris streams, relict solifluction, relict cryoplanation terraces in one location and forms of nivation-induced relief.

The occurrence of block slides has been described in the periglacial environment of high mountains of Serbia (Gavrilović, 1990; Belij & Ćukić, 1990; Nešić, 2009). Block slides derive from the active solifluction process and frost intermittent uplifting of land surface with sudden, bouncy movements of block slides down a slope. This phenomenon belongs to the domain of massive scattering of slide blocks and debris, which is created by frost decomposition of the land surface in a periglacial environment.

On Mount Vardenik, block slides were found at one place on the northern slope of Prosenik in the altitude zone of 1,650-1,720 m. On this slope, with the inclination of 25-32°, about 15-20 blocks were observed. They push material in front of them and create a soil and grass fold, and since they leave no trace of movement, they belong to the type of creeping block slides (Belij, & Ćukić, 1990). According to the geological map (Babović, & Cvetković, 1976), the rock base of Prosenik consists of granitized schists resistant to erosion, which through decomposition form coarse debris.

Without measuring the movement processes, the block slides on Prosenik leave the impression of being immobile. A similar phenomenon was observed on the block slides of the Babin zub site on Stara Planina (Gavrilović, 1990). With the absence of large-scale animal husbandry on the mountain, large pasture areas grow into tall grass. Seasonal renewal and accumulation of this plant mass creates an insulating layer that, together with the snow cover, protects the ground from freezing. Hence, this makes it possible that the block slides on Prosenik are a sub-recent phenomenon. They were probably active during the period of mass animal husbandry in the middle of the 20th century, but also during the last Holocene cooling in these areas, which ended in the middle of the 19th century.

Block streams (Wilson et al., 2017; Serban et al., 2019, etc.) are also distinguished as block/rock streams (Wilson, 2013). They are the product of mass decomposition of rocks in a periglacial environment with the concentration of blocks/debris in elongated zones down the slope under the influence of colluvial and periglacial processes (Tyurin et al., 1982). It is also common to see frontal arc accumulation of debris in the front part in the direction of the block streams.

On Mount Vardenik, several sporadic block streams have been recorded. In the area of Golema Ravnica and Mačita, a group of six block streams has been identified. Near the top of the Golema Ravnica, on the southeastern exposure, there are two shorter streams. On one of them, there was a 0.5 m (Figure 4a) high, sub-recent arc accumulation of blocks and debris. On the mountain slope in the area of Mečita, three shorter block streams have been observed, which are more difficult to notice because of the dense conifer forest. On the western slope of Golemy Vrh, in the altitude zone of 1,600-1,650 m, a group of 10-11 such streams were observed. On one of them, there is a frontal arc rampart with a height of up to 0.8 m. The appearance of the accumulated material indicates its sub-recent nature, and once very active periglacial processes (Figure 4b).

On Stolovi, east of Golemy Vrh, in the height zone between 1,590-1,620 m above sea level, there is a complex rock stream of convergent (merging) type (Serban et al., 2019). Here, two rock streams, each 10 m wide, merge into a single stream with a width of 20-25 m, and a total length of 40 m along the longer merging side. To the north of this stream, there is another shorter one, 7-8 m long, with a frontal arc accumulation of debris.

Similar occurrences of block streams have been observed in places on other lower parts of the mountain slopes. Larger zones with blocks and debris in addition to the ones previously described have been found on the southern slope of Golemi Vrh towards the Ržanska river basin. There are also occurrences of scattered blocks and debris in the area of certain mountain peaks, such as at the Zadružna Farma, at Vrteno Kamenje and others.

In general, block streams on Mount Vardenik are a sporadic phenomenon visible in the described locations. On the senile morphology of the mountain built of erodible rocks of crystalline schists in the Vlasina Complex, apart from these sporadic, there were no lithological conditions for the formation of larger areas with blocks and debris. Large areas of the mountain are under pastures without significant zones of massive periglacial scattering of decomposed rocks.

The described block streams on Mount Vardenik are relict, i.e. without movement under the influence of periglacial processes. Occurrences of arc accumulation of blocks and debris on some streams indicate sub-recent activity. In general, the block streams on Mount Vardenik, although sporadic, can present the subject of more detailed qualitative research.

Occurrences of larger relict solifluctions in springs have been observed at the springs near Zadružna Farma and Mali Stan, east of Golemi Vrh.

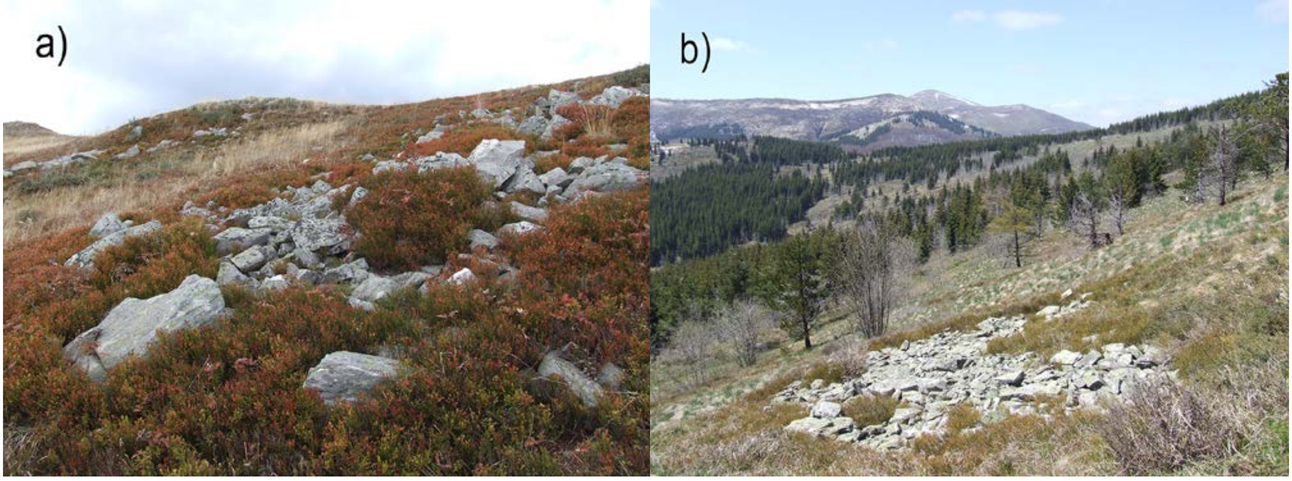

Figure 4. Arc accumulation of rubble in the block streams themselves;
a) South-eastern slope of the Golema Ravnica mountain peak; b) The western slope of Golemi Vrh

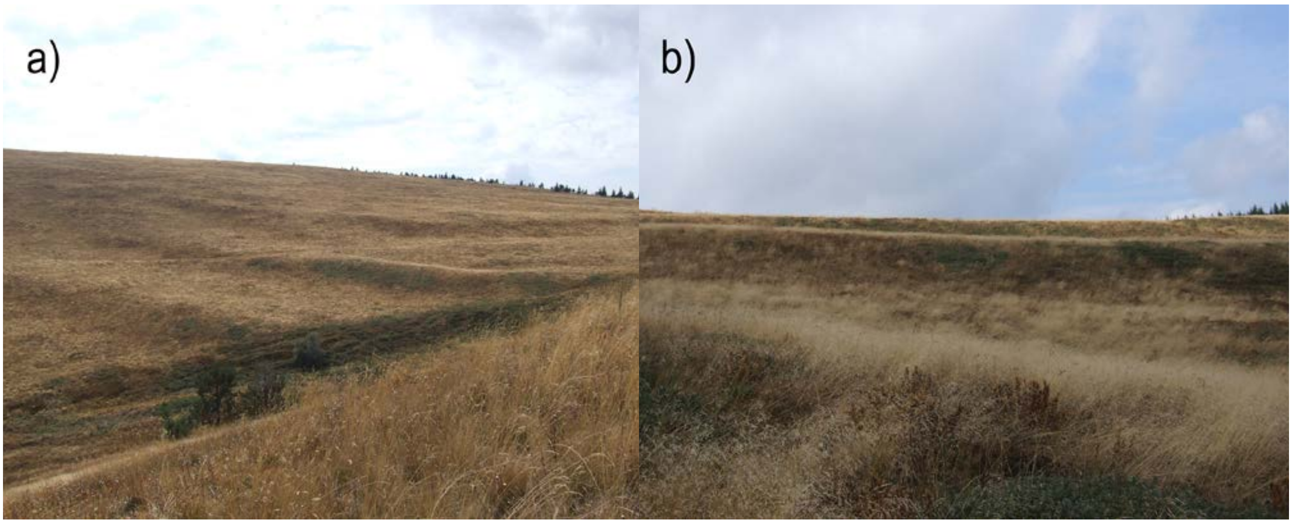

Figure 5. Relict terraces at the source of a creek near Veliki Stan
a) Parts of three terraces (the highest is the longest)
b) A detail of the section of the second terrace

Large, elongated zones of fine debris and soil were differentiated as solifluctions, because similar phenomena of thermogenic landslides, i.e. solifluctions, were recorded on Kopaonik (Nešić, & Milinčić, 2004). It is assumed that in the zones of increased moisture of the ground around springs, favourable conditions are created for thermogenic or solifluctional sliding of accumulated skeletal eluvium. Some of these phenomena are active on Kopaonik, but it seems that there is no such activity on Mount Vardenik.

At the source of a creek near Veliki Stan, a series of three terraces perpendicular to the river bed was observed (Figure 5). The valley is asymmetrical at this location, and the less inclined side with terraces is the northern slope of Golemi Vrh. According to their morphology, the terraces are equivalent to cryoplanation terraces as described in the periglacial environment (Demek, 1969; Reger & Péwé, 1976; Czudek, 1995; French, 2007). The question of the genetic origin of these landforms is burdened by the fact that they were found only in this place on the mountain and that they are spatially related to the fluvial relief. It is possible that the terraces were created during the succession process of intensive denudation and the development of the fluvial process, or that they present classic relict cryoplanation terraces of periglacial environments. If they were of cryoplanation origin, it would be the second finding of this kind in the relief of Serbia, taking into account that such phenomenon has been observed only on Kopaonik (Nešić et al., 2017). The first terrace is 135 m. long and has a relative height of 6-7 m. The second terrace is 175 m long and 5-7 m high, whereas the third is the longest - 300 m and 5 m high. The third terrace has a complex morphology, with two secondary terraces 1-1.5 m high, and one shallow closed depression. In general, the area with terraces has a complex relief that requires detailed research and measurements.

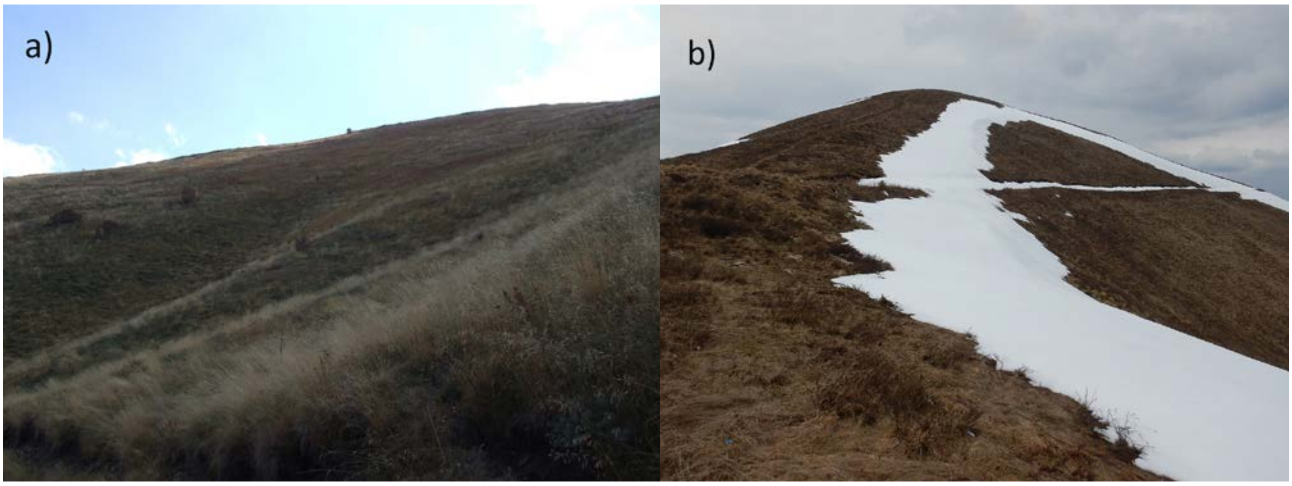

Figure 6. Nivation-induced relief and phenomena on Mount Vardenik
a) Relict nivation relief
b) Contemporary snow accumulation

Nivation-induced (snowbank) relief is by far the most common form of periglacial relief on Mount Vardenik. It is mostly relict, and partly recent due to short retention of snow cover on the mountain. The nivation process is complex and contains several morphogenetic processes (Christiansen, 1998). Elongated nivation hollows/depressions connected to sources of waterways are present. Downstream, fluvial (normal) river valleys develop, and along slopes, nivation-induced valleys develop in the direction of elongated periodic snowbanks. In the relief, most of these forms are on the southern and western slopes of Strešer (Figure 6), but they are also found sporadically on other parts of the mountain, mostly around the spring of the Božička River. Contemporary nivation-induced erosion on these landforms is difficult to quantify due to the short retention of snowbanks along these depressions. In the future, these morphologically complex phenomena on the northern slope of Golemi Vrh towards Veliki Stan should be investigated.

5. DISCUSSION

Contemporary rudimentary periglacial phenomena and rare relict landforms of periglacial relief have been recorded on Mount Vardenik. On the basis of the observed contemporary appearance and relict periglacial morphology, and in relation to the state of contemporary climate and geoecologic conditions, it is possible to distinguish certain features related to the state of the periglacial environment in the area of Mount Vardenik.

Contemporary climate on Mount Vardenik shows that the average annual air temperature is about 3°C at altitudes above 1,730 m, which indicates that only a small part of the mountain belongs to the lower boundary framework of the transitional periglacial environment or the lower climazonal periglacial belt. In the general framework of climate in Serbia, the expected position of the isotherm of the warmest month of 10°C is over 2,000 m above sea level (Milovanović et al., 2017). This indicates that the upper limit of tall trees on Mount Vardenik is above the highest mountain peaks. Under normal conditions, the whole of Mount Vardenik would be covered with tall trees, with the development of an orographic border of the forest on protruding parts of the relief. Such climatic and geoecological conditions significantly limit the development of seasonal frost and freeze-thaw cycles on the mountain, to the level of the absence of a periglacial environment. The conditions are similar on pastures under anthropogenic influence, where periglacial, rudimentary and relict landforms and occurrences were recorded. However, the described phenomena classify Mount Vardenik as a mountain with a periglacial relief.

Contemporary rudimentary periglacial phenomena occur above the height of 1,650-1,700 m, except for one occurrence at 1,545 m. (Figure 3a). Relict periglacial phenomena are most often present above the height of 1,600 m, although they are noticeable, but also more difficult to distinguish at lower altitudes in the forest zone. The established facts raise the question of the origin of the described periglacial phenomena.

The answer is relatively simple. On Mount Vardenik, the upper limit of tall trees was anthropogenically created under the influence of a long period of intensive livestock farming (with shorter interruptions of 1,000-2,000 years), and also the exploitation of forests due to extensive mining and metallurgy activities (Milošević et al., 2007). In such conditions, large areas of pastures were created on the mountain, which were partially reforested during the 20th century. On pasture areas with low grass, under the conditions of intensive grazing, certain periglacial phenomena such as block slides and rock streams developed. This condition could have lasted during the LIA, and possibly for some time after it. Certain rock streams or rare fields of debris have an older chronological origin. Some forms of relief date back to Pleistocene age, such as nivation-induced relief and cryoplanation terraces.

To understand the problem, the period of large-scale cattle breeding in the middle of the 20th century is of particular importance. Intensive grazing does not allow tall grass to grow, which is an important factor that affects the distribution and intensity of seasonal frost and freeze-thaw cycles. That is why the block slides and some rock streams on Mount Vardenik were distinguished as sub-recent, because before the reduction of animal husbandry there were conditions for their genetic activity.

The facts indicate that the periglacial environment on Mount Vardenik is relict, and that contemporary periglacial phenomena are azonal. The existence of a former periglacial environment is indicated by relict and subrecent landforms and relief phenomena. This environment was active or restored in some parts under the influence of the last Holocene cooling of the LIA. Anthropogenic activity on changing the upper limit of tall trees and a greater volume of livestock breeding contributed to the activation of the periglacial environment, which now has a relict quality.

Certain phenomena such as block slides and rock streams are sub-recent from the last Holocene cooling and a period after it. Detailed research and the quantification of the activity process of these phenomena should verify this assumption.

6. CONCLUSION

The characteristics of the climate and the geoecological conditions of Mount Vardenik indicate that the contemporary periglacial environment, i.e. its lower limit, is difficult to determine. The periglacial phenomena and landforms observed on the mountain are azonal and relict, developed under the anthropogenic influence that conditioned upper limit of tall trees at an average of 1,600 m above sea level, with extensive pastures above this altitude (Figure 2).

Drastic reduction of cattle breeding, restoration of grass vegetation, reforestation and contemporary climate dynamics reduced the seasonal frost and freeze-thaw cycles to a marginal phenomenon. In such circumstances, the activities of the observed block slides and individual rock streams probably ceased and were therefore recognized as sub-recent phenomena. The above-mentioned periglacial phenomena had conditions for activity during the last Holocene cooling, and probably sometime after it, when during lower air temperatures, the land surface, unprotected by tall grass and in the absence of snow, froze more intensively.

Some earlier observations of the cessation of periglacial processes at medium heights of 1,000-2,000 m on the mountains in Serbia due to cessation of pastoral cattle breeding (Gavrilović, 1990), were confirmed by research on Mount Vardenik. This directly indicates the influence of human activities on the development of recent periglacial processes, phenomena and landforms (Nešić, & Milinčić, 2019), which was introduced in one of the first studies of the periglacial environment in Serbia (Gavrilović, 1970). In these circumstances, the Mount Vardenik area can be distinguished as a relict periglacial environment that is under significant influence of human activity. As a transitional periglacial environment, defined by the climate criterion of an average annual air temperature below 3°C (French, 2007), it is at the level of an unreliable statistical thermal gradient.

Based on the previously presented data, it is evident that human activity is a significant factor in contemporary periglacial processes on the medium-high mountains of Serbia, especially on its lower border. The importance of these activities is equivalent to the influence of climate and geoecological conditions as the main determinants of the periglacial environment. The focus of future research of Mount Vardenik and Vlasinska Visija should be on the relict properties of the periglacial relief and the environment in which it was created. Hence, it is recommended to study these areas as areas of relict periglacial environment and relief.

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