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RECONSTRUCTION OF THE PLEISTOCENE GLACIERS OF MOUNT DURMITOR IN MONTENEGRO

REKONSTRUKCIJA PLEISTOCENSKIH LEDENIKOV NA DURMITORJU V ČRNI GORI

Predrag Djurović

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Bobotov Kuk (2522 m a. s. l.) is the highest peak of the Durmitor.
Bobotov Kuk (2522 m n. v.) je najvišji vrh Durmitorja.

Reconstruction of the pleistocene glaciers of Mt. Durmitor in Montenegro

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ABSTRACT: Mount Durmitor is situated in the southeastern part of the Dinaric mountain system in Montenegro. Throughout the Pleistocene there were many glaciers there, which descended to adjacent karst plateau. Types of glaciers, their number and direction of moving were mostly affected by geological structure (carbonate basis) and pre-glacial relief (karst and fluvial relief). During two phases of intensive glaciation, the surface that had been seized by glacial changes also changed. Over 54% of the surface of Durmitor was exposed to the glacial process of the stronger phase and about 36% of the weaker phase. Cirque type of glaciation dominated the third phase.

KEY WORDS: geography, glaciation, glacier reconstruction, Pleistocene, Durmitor, Dinaric mountains, Montenegro

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Contents

1 Introduction

Mount Durmitor lies in the western part of the Balkan Peninsula. It is situated in the southeastern part of the Dinaric Alps, in the northern part of the Republic of Montenegro. In the broader sense it belongs to the Drina River drainage basin, while in the narrower sense it represents the watershed between the rivers Tara and Piva.

Figure 1: Geographic position of Mount Durmitor.

Durmitor represents unique and clear morphological entirety, surrounded by high karst plateau from 1400 to 1600 m a. s. l. The line of the contact plateau of Jezerska površ and mountain mass represents the morphological border of Durmitor. It descends only in the northern part of the mountain up to 1100 m above the sea-level, to the basin of Lake Sušičko. The highest parts of the mountain exceed 2400 m a. s. l. (Bobotov kuk 2522 m a. s. l.) and they are from 900 to 1100 m higher than adjacent plateaus. The total area of Mount Durmitor is 123 km^2 (Djurović 1996, 21).

Lithological structure of Durmitor is rathher simple (Mirković 1983,108). Carbonate rocks of different structure and age participate in its structure, while clastic rocks appear only sporadically. Limestone is predominant among carbonate rocks, while there are fewer dolomites. They are mostly presented by massive limestone of Triassic and Cretaceous age. Limestone with nodular chert can often be seen in layered limestone. Cretaceous-Palaeogene sediments, the so called Durmitor flysch, take a special place in the carbonate complex of rocks. Those are layered limestone breccias, layered sandy limestone, marly limestone, marl and sandstone. Above this petrologic diversity, however, different kinds of carbonates prevail. Therefore, they do not differ much from other rocks of the carbonate complex. Clastic rocks were mostly formed during the Triassic, and they are presented in quartz sandstone, sandy limestone. They occupy small area on Mount Durmitor. Middle Triassic Andesites also belong to this complex. They appear in small areas below Crvena greda, near Bosača and Lake Barno (Živaljević et al. 1989).

Durmitor belongs to two major tectonic units. The southwestern part of the mountain belong to the Kuči tectonic unit (Prutaš, Vjetrena brda, Dobri do, Sedlena greda, Stožina, Ružica, Lojanik, Bolj), the rest part of the mountain belong to the Durmitor tectonic unit. The tectonic unit of Durmitor was overthrusted from the northeast over the sediments of the Kuči tectonic unit along the over trust of Ranisava (Živaljević et al. 1989).

Based on instrumental measuring (Weather almanacs) and statistical calculations, mean annual air temperature at Žabljak (1450 m a. s. l.) is 4.7 °C (period 1958–1993). Mean monthly air temperature in the coldest month (January) is 4.3 °C at Žabljak, while it is 14 °C in July. On the basis of temperature gradient

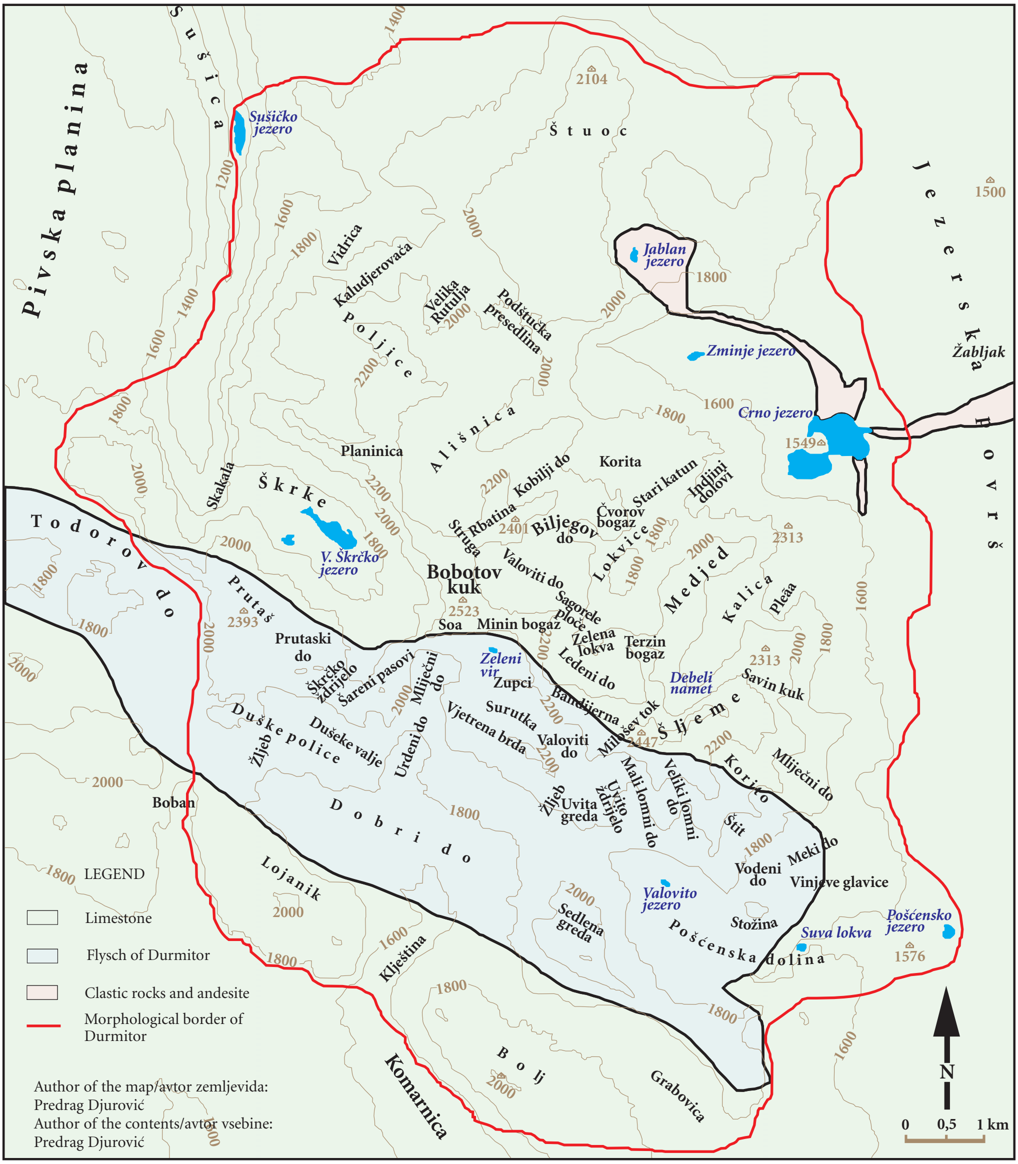

Figure 2: Toponyms and geological structure.

calculations, the contemporary mean annual air temperature is positive in the most part of the mountain. Mean annual temperature is negative only above 2450 m a. s. l., while it is –0.5 °C at the highest parts (Djurović 1996).

Based on 12 precipitation stations, the analysis of the precipitation amount has been done for the period from 1958 to 1993 (Djurović 1996). The position of the mountain, in relation to dominant direction of moist air masses, and altitude are considered to be the crucial factors for determining precipitation amount. These factors have even existed during the Pleistocene without more any significant changes difference. Recent distribution and spatial relations of precipitation amount are very important for understanding the formation of glaciers on Durmitor during the Pleistocene. Precipitation amount greatly increases in areas situated in the direction of dominant moist masses. Therefore, the southwestern slopes of Durmitor receive even 60% more precipitation than area of Jezerska površ and northeastern slopes of the mountain. As calculated, the central, highest parts of the mountain receive about 2600 mm of precipitation per year. Annual precipitation slightly decreases towards southwest to about 2000 mm, while it decreases more significantly towards karst plateaus that surround Durmitor in the east, west and north. In this areas, annual precipitation is about 1200 mm.

2 Methodology of reconstruction

Based on the results of both previous and contemporary researches, a picture of the extent of ice cover, moving direction and types of glaciers and the intensity of glaciation during the Pleistocene has been reconstructed. The reconstruction is done on the basis of glacial forms, preserved in the relief of Durmitor. These are, above all, the erosional forms – cirques and glacial valleys. Roches moutonnées, nunataks and glacial shoulders also served in the establishing the moving directions of glaciers and glacial phases. Glacial sediments and accumulation forms such as till (moraine material) and moraines were less significant for the reconstruction. There are very little of them on Durmitor, and the reasons are twofold. Glaciers descended off the mountain and spread over the mountain plateaus that surround Durmitor. Consequently, they are preserved only at some places on the mountain during the last phase of the existence of glaciers. The second reason lies in quick altering of glacial sediments into fluvial by which the possibility of exact genetic determination is lost, what significantly influence the final reconstruction. Aerial photo images were used for the identification of forms at a scale of 1 : 25 000, while for the survey of the spatial relations the topographic maps of the same scale were used. Nevertheless, all data, obtained by remote detection, were checked through direct terrain observation.

During the reconstruction of glaciers, significant attention was paid to factors that influenced the formation and modification of the Pleistocene ice cover of Durmitor. It is mainly the shape of the pre-glacial relief, geological structure of the terrain which was exposed to glacial process, type of glaciers, inclination of slopes, aspect of slopes, direction of wet air masses, rain shadow and postglacial processes. Special attention was paid to possible errors during establishing the genetics of analyzed forms and sediments (Djurović 2007).

3 Results of previous studies

Researching the Pleistocene glacial morphology of Durmitor, establishing the moving direction of glaciers, the extent of glaciation began at the end of the 19th century. Starting from 1888 and 1897 J. Cvijić made detailed researches of glacial traces on this mountain. Many papers published from 1899 to 1926 (Cvijić 1899; 1903a; 1903b; 1913; 1926) were the result of these researches. The results of Cvijić's studies on Durmitor glaciation can be summarized into several major theses:

- glacial traces on Durmitor belong to younger glaciation of this part of the Balkan Peninsula; he separated the Older glacial phase (Riss) and the Younger phase (Würm):
- there was one glacial period with three stadials what corresponds to the Würm of the Alps;
- there were three types of glaciers: valley, karst and piedmont.

Cvijić's »karst type of glaciers/glaciation« were developed on the terrains rich in limestone. The karst relief was formed in the pre-glacial period as well as in the interglacial phase or phases. By the change of the karst process with the glacial process, the glaciers were formed in the karst forms of relief. Uvalas for example greatly influenced the development of glaciers as they enabled ice accumulation, spreading of glaciers and their slow and inverse moving while coming out of them. Fractures were also frequent in the vertical profile of glaciers, as well as of glacial valleys formed during the motion. These fractures were the consequence of karst processes, not the glacial one (Cvijić 1889; 1913).

Another significant researcher of this area was B. Milojević. He also included the problems of the Pleistocene glaciation of Durmitor into many studies (Milojević 1937; 1950; 1950a; 1951). He gave the following results on glaciation of Durmitor:

- two glacial phases were present, older Riss and younger Würm;
- three stadials within the Würm glaciation can be found;

- during the two glacials, the piedmont glaciation of the whole Jezerska površ did not exist, but only by joining the glaciers of註išnica, Dobri do, Savin do and Korito, piedmont glacier was formed which moved towards the Tara as a valley glacier.

After long interruption, the researches of Durmitor glaciation continued at the beginning of the 1970s. A new methodological aspect in the study of glaciation was presented by using aerial-photo images. It was established that, above piedmont glacier that existed on Jezerska površ, the piedmont glacier of Todorov do also existed, which moved towards the Piva mountain (Marović and Marković 1972).

Detailed study on geological structure of Durmitor, Piva Mountain and Volujak also included the studies of the Pleistocene and Quaternary sediments (Mirković 1983). More detailed analysis of age and genesis of the youngest sediments of this area were missing.

During long geological researches for the elaboration of the basic geological map, a decent attention was paid to glacial sediments established mostly on Jezerska površ, while on the very Durmitor their determination was missing (Živaljević et al. 1989).

Within detailed geomorphological researches of the high-mountain karst of Durmitor, the detailed studies of traces of the Pleistocene glacial forms were also done. By using aerial-photo-images and direct terrain research, the reconstruction of glacial forms was done and cirques and glacial valleys, as well as other glacial forms were determined on this mountain. Surfaces, exposed to a long-term and short-term influence of glacial process were determined, and all in the function of establishing the genesis of the high mountain karst on this mountain (Djurović 1996).

The basic characteristics of the contemporary glacial process are shown on this mountain by the detailed geomorphological map of the Debeli namet glacier and its direct surrounding. Two glacier pits and a glacier table which appeared on the glacier during the summer of 1993 were shown in the study. On the basis of holes in glacier, the depth of glacier was established. Vertical profile through glacier was also established (Djurović 1999).

Radiochemical methods, namely, gamma spectrometry and β activity measurements on the mass balance history and ice dynamism of the glacier (Debeli Namet) and cave ice (Ledena pecina) of Durmitor Mountains have been applied in these investigations. Gamma spectrometry did not satisfy the hopes for dating 1963 AD radiochemical reference horizons from the natural ice bodies of Durmitor Mountains (Kern et al. 2006).

Moraines of the Debeli namet glacier were subject of climate variation determination researches. As established by lichenometry, the last two moraines originated from 1878 and 1904 and they were the consequence of climatic variations, coinciding with average variations in the eastern Mediterranean (Hughes 2007).

The contemporary process of glaciation on Durmitor has been observed through the influence of extremely high summer temperatures in the period from 2003 to 2007. It was established that these summer temperatures influenced the reduction of the Debeli namet glacier, but not on its disappearance (Hughes 2008).

4 Glaciers of the Durmitor mountain

As established on the basis of the reconstruction, there were a great number of glaciers on Durmitor during the Pleistocene. Many glaciers joined and formed large glaciers among which the following stand out: Dobri do, Valoviti do, Sušica, Ališnica, Pošćenski glacier. There were also other smaller glaciers there. Glaciers differed by the type; many of them belonged to valley type, but there were also saddle and piedmont glaciers. Due to karst basis of the mountain and developed pre-glacial karst relief, a special type of glaciation was developed on Durmitor, which even J. Cvijić defined as karst type of glaciation. Glaciers were moving from the mountain into three major directions: towards Jezerska površ and the Tara canyon, Piva Mountain and the Piva canyon and Komarnica valley. During the glacial, almost the whole mountain was under ice cover wherefrom just the highest ridges and peaks protruded.

4.1 Dobri do Glacier

The Dobri do glacier was the largest glacier that ever existed on the area of Durmitor. It was formed in relatively opened pre-glacial basin, of Dinaric spreading direction (NW–SE), 5 km long and 2 km wide. The northern rim of the basin is fenced by high peaks of Prutaš (2393 m a. s. l.), Šareni Pasovi (2236 m a. s. l.),

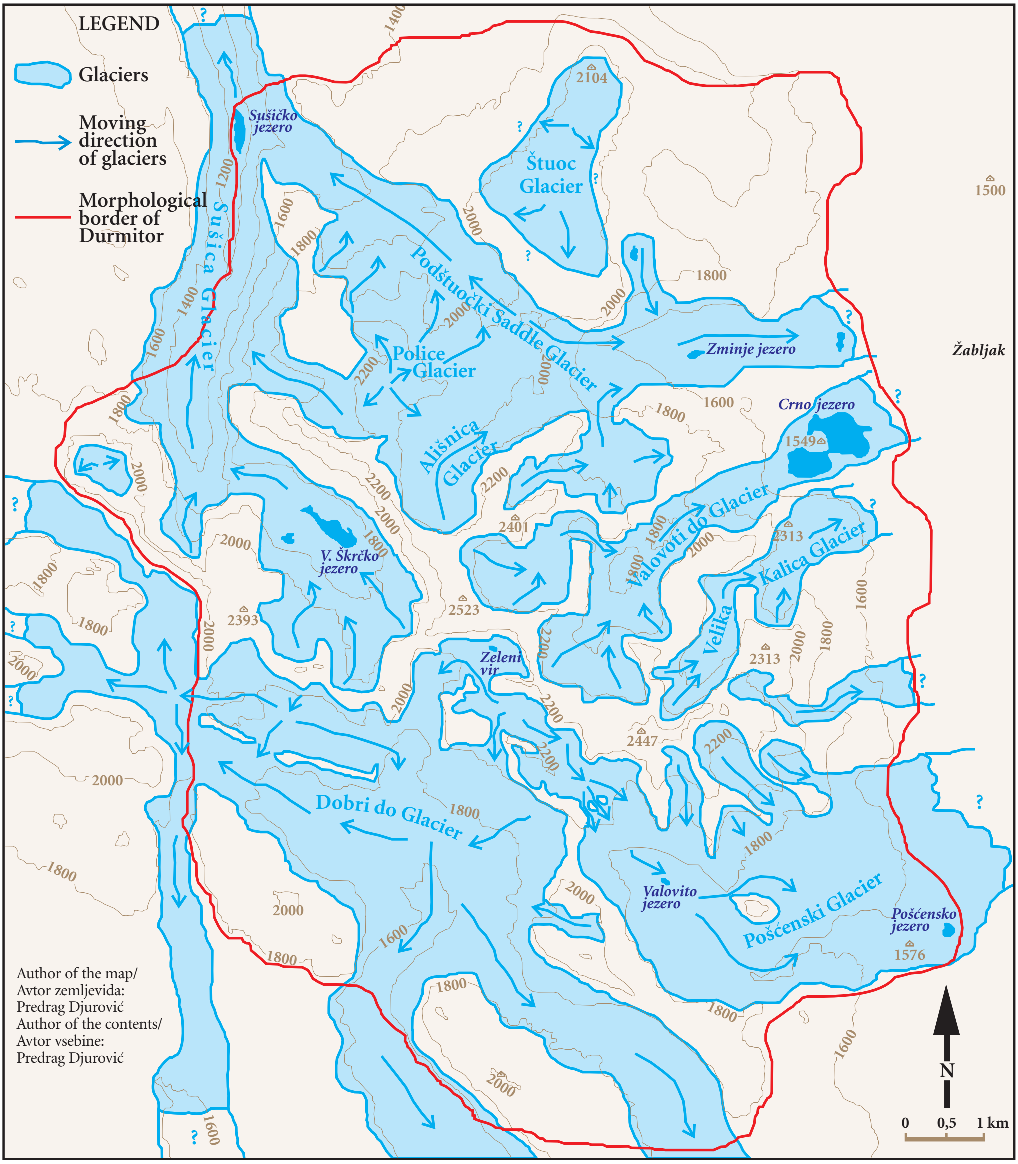

Figure 3: Older phase of glacier spreading.

Soa (2440 m a. s. l.), Zupci (2309 m a. s. l.), Bandjerna (2409 m a. s. l.) and Milošev tok (2426 m a. s. l.). The primary places of ice accumulation were formed, i.e. the primary glaciers beneath these peaks and ridges: the Duški lednik glacier and the Vjetrena brda glacier. They represent the highest branches of the Dobri do glacier. By joining these two glaciers, as well as ice of Lojanik, Bolj and Sedlena greda, an ice field was formed in the area of the present Dobri do. Glacial tongues were spreading from it and moving to different directions.

The **Duški saddle glacier** was formed beneath the southern slope of Prutaš on about 2050 m above the sea-level. It covered the whole karst area of Duška polica. The surface was trimmed in southern and western part by the erosion of western branch of glacier which separated from ice field in Dobri do. The eastern part of the karst surface was also cut by the erosion of the Zeleni vir glacier. Since the karst surface was cut, the ice mass was cracking and falling over Duške valje towards the Zeleni vir glacier, over Žljeb towards western branch of the Dobri do glacier, while in the western part directly towards Todorov do.

North of the Dobri do glacier, on the southern side of Šljeme–Bandjerna–Zupci ridge, the **Vjetrena brda saddle glacier** was formed on structural plateau (contact of Kuči and Durmitor tectonic unit). The ice mass piled from the mentioned ridge on the surface of about 2150 m a. s. l. Ice moved into three directions. During the stronger phase of glaciation the ice mass was feeding the Dobri do glacier and the Pošćenski glacier also, but insignificantly. During the weaker phase, the glacier moved only towards Dobri do.

The glacial branches of Zeleni vir, Surutka and Valoviti (južni) do divided from the saddle glacier of Vjetrena brda.

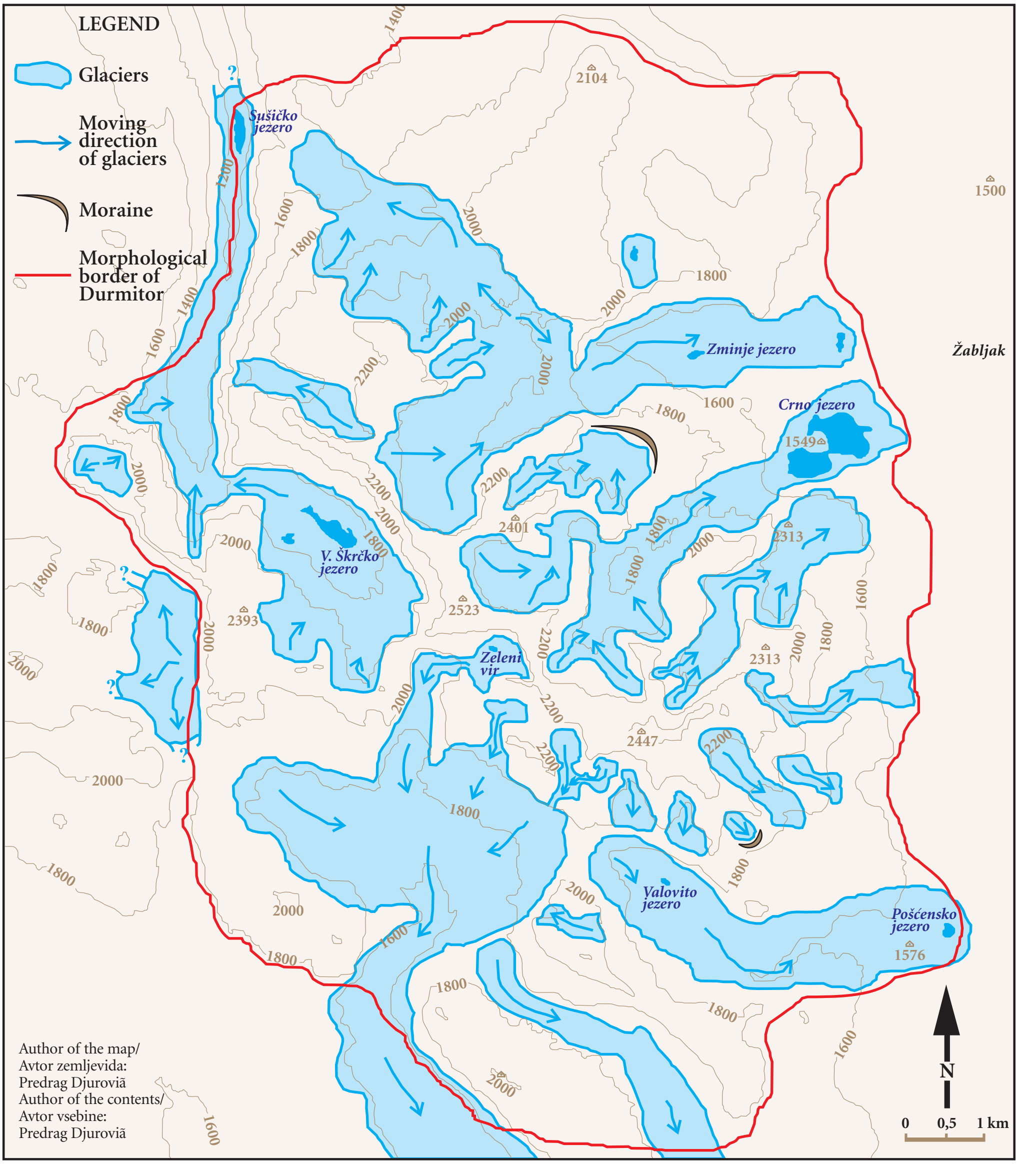

Figure 4: Younger phase of glacier spreading.

Glacial branch of Surutka (2050 m a. s. l.), breaking the ridge of Vjetrena brda, was cracking and falling on the shelf of Polica where it got into the structure of ice mass of the Dobri do glacier.

Glacial branch of Valoviti (južni) do (2100 m a. s. l.) had a very complex moving. The reason of this complexity lies in the change of the glaciation intensity as well as in the erosion of limestone basis and expanding and opening the new moving directions of ice. During stronger glaciation, the glacier first moved towards southeast and stroke Uvita Greda (2199 m a. s. l.). A smaller part of it was passing over the ridge and moving towards the Dobri do glacier. Greater part was turning east. By this separation of the mass of ice on the area of Uvita greda the formation of larger nunatak started. Under further motion the glacial branch was coming across several rocky peaks, splitting into many parts and making several smaller nunataks. One part was falling towards the Mali Lomni do glacier (1930 m a. s. l.) linking with it and moving further toward the central part of the Pošćenski glacier. Another part was moving through Uvito ždrijelo and coming down the source part of the Pošćenski glacier on the place of the present Lake Valovito.

During the younger phase, Uvito ždrijelo was widened and enabled the whole glacial branch to pass towards the present basin of Lake Pošćensko, so that the inflow of ice to the Mali lomni do glacier stopped. This glacial branch deposited moraine material and lateral moraine in the present basin of Lake Valovito and below it. However, the final change of the moving direction of Valoviti do glacial branch was done by the complete cutting of the ridge of Uvita greda in the area of Žleb. Since then the feeding of the Pošćenski glacier stopped, while the motion of the whole mass of glacial branch of Valoviti (južni) do was directed towards the Dobri do glacier. During the last phase the glacial branch was falling over the slope (–200 m) situated at the end of Žljeb. The glacier could not regenerate and continue further motion, but it melted there. On the place of its melting (1950 m a. s. l.) the dispersed deposits of moraine material were preserved. In the contemporary relief on the area of Valoviti (južni) do and Uvita greda the remnants of great valley glacier were preserved, which corresponds to stronger glaciation and smaller valley glacier, which is carved into it, originated during the weaker phase of glaciation.

From the northern part of the saddle glacier of Vjetrena brda, the glacial branch separated, whereof in the area among the peaks of Zubci (2309 m a. s. l.), Minin bogaz (2387 m a. s. l.) and Lučin vrh (2394 m a. s. l.), an independent **glacier of Zeleni vir** was formed on about 2030 m a. s. l. It was turning south from the present basin of Lake Zeleni vir and over three bends and Mliječni and Urdeni do joined the Dobri do glacier.

An ice field was formed of glaciers that were flowing from different sides on the area of the present basin of Dobri do. The individual glaciers separated and moved from it (Figure 3). The first one moved west, over the saddle of about 1880 m a. s. l. towards Todorov do and further towards the Piva canyon. The second branch of the Dobri do glacier moved south between Bolj and Lojanik towards the present Komarnica valley. Breaching through the narrowest part (Klještine), it entrenched the glacial shoulders on both glacial sides. It moved on about 1750 m a. s. l. The third branch of the Dobri do glacier moved southwest between Bolj and Sedlena greda. It moved over the saddle on about 1700 m a. s. l. towards Grabovica. The saddle is the highest on the west and the ice mass moved over it only during the strongest glaciation, i.e. relatively short time period. The motion of ice is oriented towards lower saddles on the south and southeastern side. By the reduction of the intensity of glaciation, the glacier near Klještina started entrenching the new glacial valley, while the former bottom of the glacial valley remained on 250 m relative height. At that time the motion of ice towards Grabovica stopped.

4.2 Valoviti do Glacier

The Valoviti do glacier existed north to ridges of Sljeme (2447 m a. s. l.), Zupci (2309 m a. s. l.), Soa (2440 m a. s. l.). It was formed in the central part of the mountain (Figure 3). It made a cirque of irregular circular shape on about 2020 m above the sea-level and sides of 2400 m a. s. l. in the north, 2480–2520 m a. s. l. in the west and 2200 m a. s. l. in the east. The cirque is partially opened in the northeastern part by the saddle which is on 2160 m a. s. l., i.e. on about 70 m relative height. When the accumulation of ice reached the critical height, i.e. the height of the saddle the ice mass began to move. It moved over Biljegov do, and then turned southeast towards Lokvica where it joined the *Lokvički glacier*. The *Ledeni do glacier* joined the mass of glaciers of Valoviti do. It was formed beneath the high ridges of Minin bogaz (2387 m a. s. l.), Bandjerna (2409 m a. s. l.), Milošev tok (2426 m a. s. l.) and Terzin bogaz (2303 m a. s. l.) Change in the intensity of glaciation was established on the basis of glacial shoulder which is on 150 m relative height. The *Lokvički glacier* joined the ice mass of the Valoviti do and Ledeni do glaciers. The glacier, originated by connecting

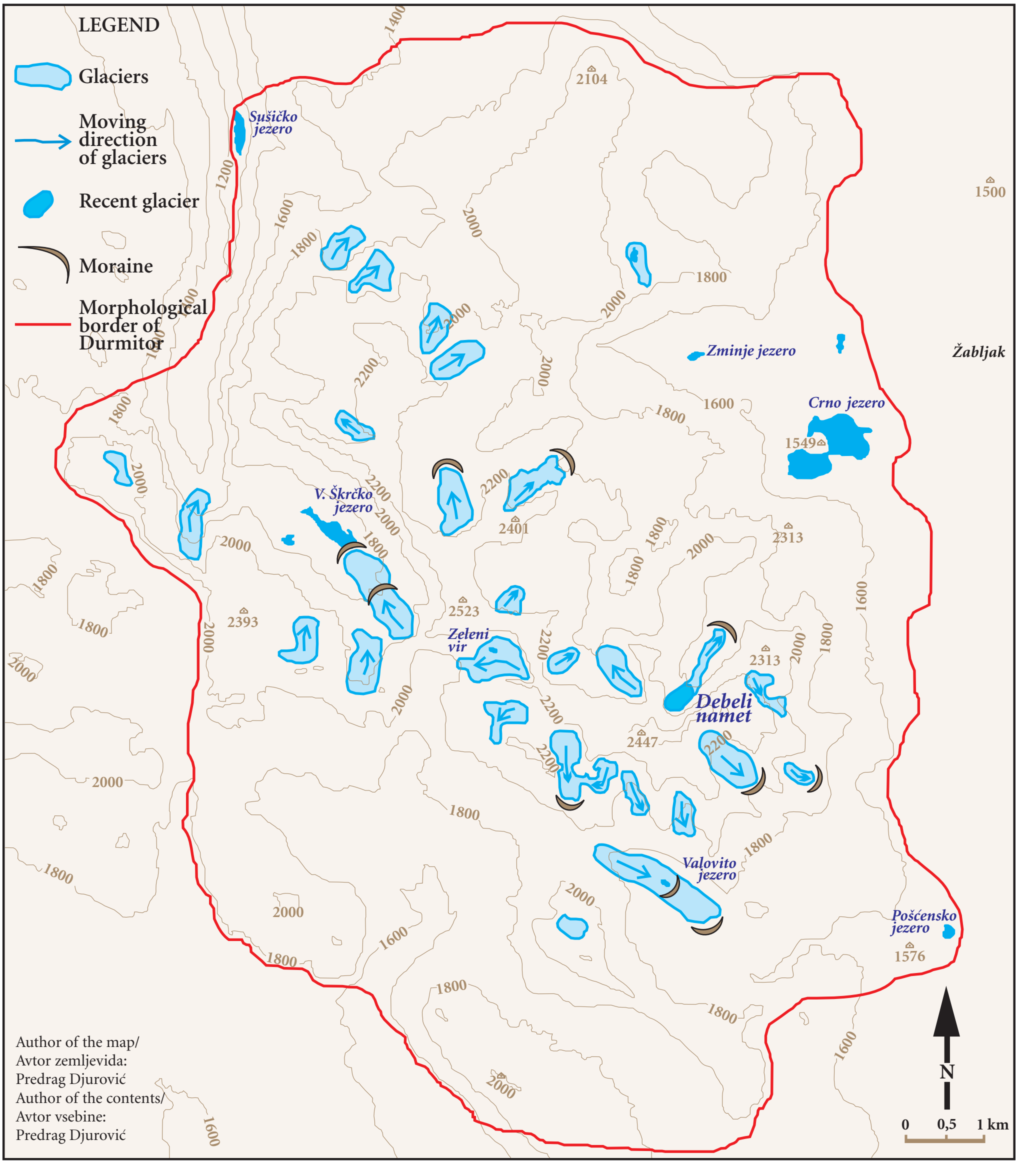

Figure 5: Cirques and recent phase glacier spreading.

these three glaciers, continued further moving towards northeast and by slope of 300 m it descended towards the present basin of Lake Crno and Jezerska površ.

4.3 Sušica glacier

The Sušica glacier was one of the longest glaciers in Durmitor. It was formed in a cirque 2.5 km long and 1.5 km wide, on altitude ≈ 1680 m. The cirque is opened in the northwestern part, and fenced on all other sides by high ridges of Planinica (2330 m a. s. l.), Soa (2523 m a. s. l.), Šareni pasovi (2248 m a. s. l.) and Prutaš (2293 m a. s. l.). The size of the cirque is not only the consequence of the glacial erosion process, but the

Figure 6: The Sušica glacier.

structural relations, i.e. the existence of great over trust of the Kuči and Durmitor tectonic unit. The glacier came out of the cirque in the northwestern part, near Skakala and moving towards the Tara it descended lower than 1100 m (Figure 6). The Sušica glacier was a valley-type glacier (Figure 3). The ice mass was coming from two short glaciers to the major glacier. They were formed on the northern side of the Prutaš–Šareni pasovi ridges, in Prutaški do (2010 m a. s. l.) and Škrčko ždrijelo (1950 m a. s. l.). The *glacier from Škrčko zdrijelo* left a series of moraines beneath the cirque, on about 1850 m a. s. l. In relation to the Sušica glacier, both glaciers were hanging glaciers (Figure 4).

4.4 Poljice glacier

The plateau glacier of Poljice was formed in the area of Donja and Gornja Poljice, was formed on about 2250 m a. s. l. on a limestone plateau. Ice mass moved from the limestone surface towards the Sušica and Ališnica glaciers. When moving, the glacier did not develop the glacial morphology. The adjacent glaciers cut this surface by strong erosion and additionally differentiated it in relation to the surrounding terrain (Figure 3).

4.5 Štuoc glacier

Another plateau glacier of Štuoc was formed at the utmost northern part of Durmitor, on about 2150 m above the sea-level, on old karst plateau that had been formed during the Pliocene. Ice mass moved off this surface to all directions and fed the adjacent glaciers.

4.6 Podštuoc saddle glacier

Podštuoc saddle (1900–2000 m a. s. l.) is situated between the plateau glaciers of Poljice and Štuoc. Its spreading direction is Dinaric. It is opened towards the glacial valley of the Sušica glacier in the northwestern part (1600 m a. s. l.), and towards the glacial valley of the Ališnica glacier in the southeast (1900 m a. s. l.). The Podštuoc saddle glacier was formed in this area. It originated partially by the accumulation of ice of the atmospheric precipitation, while mostly by ice mass of two adjacent higher plateau glaciers (Poljice and Štuoc). During stronger glaciation (Figure 3) the ice mass moved in two directions: toward the Sušica and Ališnica glaciers. During weaker glaciation the saddle glacier significantly reduced and several small glaciers were formed: *Kaludjerovača* (1690 m a. s. l.), *Vidrica* (1850 m a. s. l.), *Velika Rutulja* (1940 m a. s. l.), *Valoviti (severni) do* (2050 m a. s. l.) (Figures 3 and 4). These glaciers were formed in the northwestern part of the saddle where there were, due to exposition, more suitable conditions for ice accumulation.

4.7 **Ališnica glacier**

The Ališnica glacier was formed in a cirque, clearly fenced by Rbatine ridge (2401 m a. s. l.) and Planinica (2330 m a. s. l.) on the southwest. The border is not limited by ridges on the north, but it represents a wide karst plateau wherein the cirque is partially entrenched. The bottom of the cirque is on 2040 m above the sea level and sides of relative height from 180 to 360 m. The cirque is opened in the northeastern part so that glacier descended through the opening towards Lake Zminje and Jezerska površ where it melted there. The Ališnica glacier represented complex valley glacier of icefalls up to 250 m high. The Ališnica glacier enlarged its mass in the upper part by ice of the plateau glacier of Poljice (Figure 3). Lateral glaciers came to Ališnica from many sides, lower on the area of the present Lake Zminje. The *Jablan hanging glacier*, which existed on the place of the present basin of Lake Jablan, came from the north. Due to southern exposition and relatively small height (about 1790 m a. s. l.) it did not have greater ice mass, so it remained as hanging in relation to the Ališnica glacier. Ice mass of the *Podstuoc saddle glacier* came from the northwest, while the Kobilji do glacier from the southwest. This glacier originated in a cirque on 2070 m a. s. l. Ice masses of the *Korita piedmont glacier*, which was formed on the northeastern slopes of Obla glava–Čvorov bogaz ridges, came to Ališnica from the south. The glacier deposited moraine material on the area north to Čvorov bogaz, today preserved as dispersed piles of moraine material. Throughout the later phase, the Korita glacier did not descend off the shelf but it melted on it (Figure 4). During the cirque phase of glaciation, the Ališnica glacier deposited a series of small head moraines in the highest part of the cirque (2200 m a. s. l.) (Figure 5).

4.8 **Velika kalica glacier**

The Velika Kalica glacier belongs to valley glacier group. The glacier originated out of two cirque glaciers: *Previja* (2050 m a. s. l.) and *Debeli namet* (2050 m a. s. l.). The Debeli namet glacier is still preserved, presenting the area of the recent effects of glacial processes (Figure 5) (Djurović 1996, 202; 1999, 579). The Velika Kalica glacier originated from these two joined cirque glaciers. At the exit from the mountain mass of Durmitor, the shorter *glacier of Pleća* joined the glacier from the south. It was formed on the northern slopes of Savin kuk on about 1820 m a. s. l. Soon, Velika Kalica glacier descended on Jezerska površ where it overspread on broad area. During the retreat the glacier deposited several moraines in the glacial valley, in the area between Medjed and Savin kuk.

4.9 **Pošćenski lednik glacier**

The Pošćenski lednik glacier was a complex glacier which significantly changed the characteristics in dependence of the intensity of glaciation. During the strongest glaciation, the highest branch of the Pošćenski lednik glacier originated from the plateau glacier of Vjetrena brda (Figure 3). It was falling towards the present basin of Lake Valovito, getting into the structure of the main mass of the Pošćenski lednik glacier that was formed beneath the saddle of Sedlo (1910 m a. s. l.). Lateral glaciers, formed on the southeastern slopes of Durmitor were joining the Pošćenski lednik glacier.

Several shorter glaciers were coming from the northern side to the Pošćenski lednik glacier. Ice mass from the Vjetrena brda glacier reached the *Mali lomni do glacier* during stronger glaciation. Under weaker glaciation the inflow of ice from the Vjetrena brda glacier stopped, while the Mali lomni do glacier began existing independently. Ice mass was formed at the bottom of the cirque of about 2100 m above the sea-level. The *Veliki lomni do glacier*, similarly to former one, was hanging in relation to the Pošćenski ledni glacier. It was formed in cirque on about 2500 m a. s. l. and sides up to 2200 m a. s. l. At the exit from the cirque,

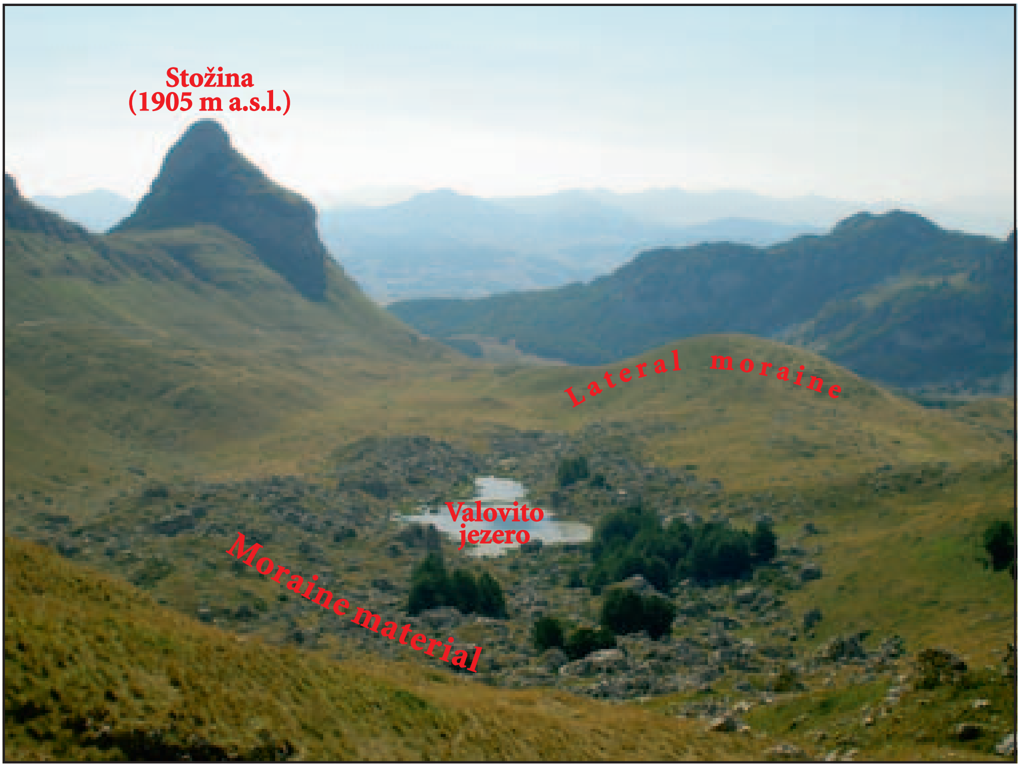

Figure 7: The Pošćenski lednik glacier.

the glacier was breaking over the slope and falling towards the Pošćenski lednik glacier. The *Pod Štitom glacier* was formed in cirque on 1850 m a. s. l. During the older glaciation phase, the Pod Štitom glacier was coming out of the cirque and moving over Vodeni do (1660 m a. s. l.), wherefrom it kept rising on the saddle between Stožine and Vinjeva glavica (1705 m a. s. l.), and while breaking, it was falling from north towards the Pošćenski lednik glacier. In the last phase of existence, the glacier could not succeed to pass over the saddle, but it stopped below it and melted there. Thus this glacier made moraine material on inverse part of the shallow glacial valley. The *Korita glacier* was formed directly near the Pod Štitom glacier. It formed a regular cirque on about 2070 m a. s. l. Ice moved southeast with frequent vertical breaks. It descended over Meki do on Jezerska površ where it melted away. In the last, weaker phase, the glacier retreated and only reached Meki do (Figure 4). It deposited moraine material there, today preserved as dispersed piles of blocks. Coming across the rocky obstacle of Stožina, the Pošćenski lednik glacier divided in two parts on the way to Jezerska površ. Passing Stozina it built a nunatak of it (Fig 7). Smaller part of the glacier crossed Meki do and Vinjeva glavica and descended towards Jezerska površ. Greater part of the glacier proceeded towards Jezerska površ over Suva lokva and the area of the present basin of Lake Pošćensko jezero. When the intensity of glaciation became reduced, the Pošćenski lednik glacier lost its highest branch that was coming from the Vjetrena brda glacier. Due to ice mass reduction, the glacier did not reach Stožina, but it passed by its south side, and over Suva lokva and Lake Pošćensko jezero it reached Jezerska površ (Figure 4).

4.10 Glaciers in the eastern side of Durmitor

During the younger glaciation phase, the following four short glaciers were formed on the eastern slopes of Durmitor: Mlečni Do glacier, Savin kuk glacier, the Pod Štitom glacier and the Korita glacier (Figure 8).

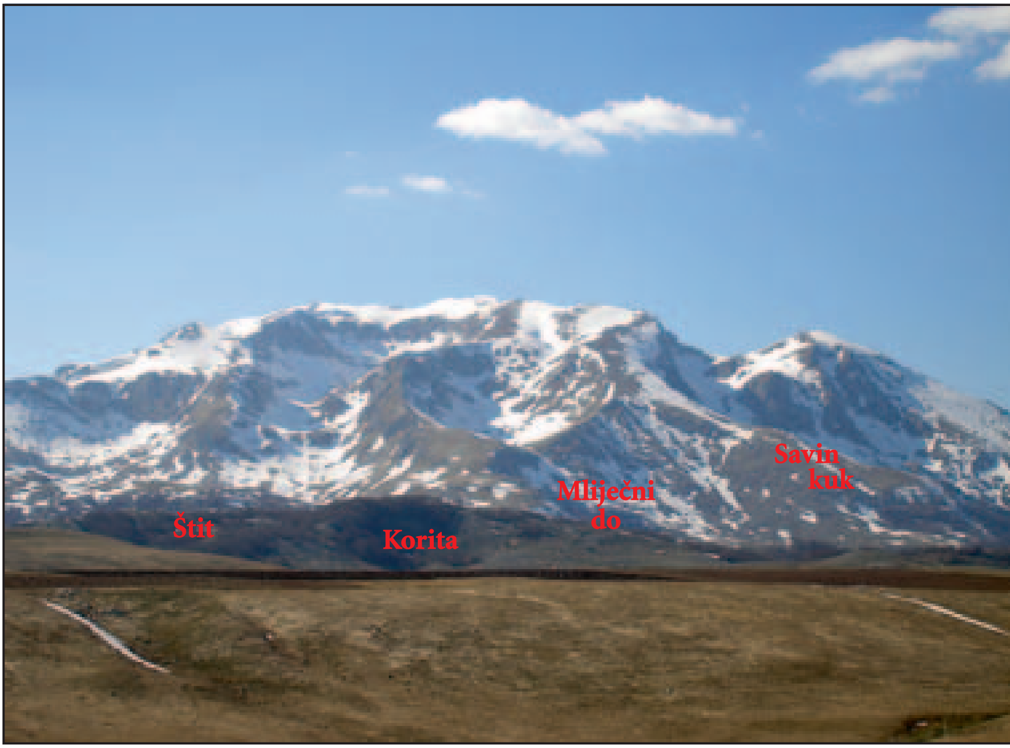

Figure 8: The glaciers of the eastern side of Durmitor.

During older glaciation, the last two glaciers flowed towards the Pošćenski lednik glacier. However, during younger glaciation, it came to shortening of their length and the reduction in the extension of the Pošćenski lednik glacier. The formation of four independent glaciers is the result of it. After coming out on Jezerska površ, they overspread and disappeared.

The *Mlečni do glacier* was formed in cirque with the bottom on about 1880 m a. s. l. After leaving the cirque, the glacier was falling down on the Jezerska površ. The *Savin kuk glacier* was formed in a cirque on about 2090 m above the sea-level. Due to very steep eastern slopes of Šljeme, the glacier possessed high kinetic energy, so that it hollowed out a deep glacial valley, while after coming out on Jezerska površ it overspread on it.

5 Discussion

The basic morphological and hypsometric characteristics, as well as their typology have been presented in the previous reconstruction of glaciers on Durmitor. In order to make the complete reconstruction of the Pleistocene glaciers on Durmitor it is also necessary to describe their chronology, i.e. to establish the time periods in which the glacial phases developed. Since the dating of the age has not been done yet, the glacial chronology can be analyzed by the correlation with the mountains on which the age of the glacial phases was established. It is possible to compare certain glacial phases of Durmitor with the phases of the adjacent mountains (Figure 1), considering that they are of the similar heights, distances from the sea and latitudes.

Three glacial phases were developed on a group of Maglić (2386 m a. s. l.), Volujak (2336 m a. s. l.) and Bioč mountains (2397 m a. s. l.) (Milivojević 2007, 122). It is established that the glaciers occupied the area from 30 to 35 km^2 (Menković et al. 2004, 384) on the Šar planina Mt. (2748 m a. s. l.). Older moraines situated at the end of the glacial valleys, moraines on lower heights than cirques and cirque moraines are ascertained on this mountain (Menković 1977/78, 101; Menković 1990, 64). There were older and younger moraines on the Kosovo and Metohia part of the Prokletije (Djeravica 2656 m a. s. l.). On the basis of moraine material in the cirques, it can be concluded that there were also the third, youngest phase of glaciation which developed only in cirques (Menković 1994, 141). As it has also been established, three glacial phases existed (Milivojević et al. 2008, 115) in the central parts of the Albanian Prokletije (Maja e Jezerce 2697 m a. s. l.). There were only one glacial phase (Menković 1994a, 30) in the northeastern part of the Prokletije (Hajla 2403 m a. s. l., Žljeb 2381 m a. s. l.). The existence of only one glacial phase has also been established on Mount Lovćen (1748 m a. s. l.), which is understandable in accordance with the height of the mountain and closeness of the sea (Menković and Djurović 1993, 23). Three glacial phases have also been established on the Pindus Mountains in Greece (Hughes 2006, 51).

The comparison of the equilibrium line altitude (ELA) value is also significant for establishing the glacial chronology of Durmitor.

During the older glacial phase the ELA was 1600 m a. s. l. on the northern parts of Durmitor (Štuoc), 1600 m a. s. l. near Crno jezero Lake, 1600 m a. s. l. in the eastern parts of the mountain (Šljeme), it descended to 1400 m a. s. l. in the southern part of the mountain (Komarnica), while it was about 1500 m a. s. l. in the northwestern part (the Sušica canyon). The average value of ELA for this glacial phase is 1540 m a. s. l.

During the younger phase of glaciation ELA had average value of 1850 m a. s. l. on Štuoc, 1900 m a. s. l. at Lokvice, 1850 m a. s. l. on the eastern slopes of Šljeme, 2000 m a. s. l. on Vjetrena brda, 2000 m a. s. l. below Prutaš, 1700 m a. s. l. on Škrke. The average value of ELA for the younger glacial phase is 1880 m a. s. l.

The cirque phase of glaciation marked the increase of the ELA value. The ELA was 1950 m a. s. l. in the northern part of the mountain (Vidrica, Kaludjerovača, Velika Rutulja), 2100 m a. s. l. in the eastern part (Debeli namet, Savin kuk, Korito, Mliječni do), 2080 m a. s. l. in the southern part of the mountain (Surutka, Vjetrena brda, Mali lomni do, Veliki lomni do, Zeleni vir), while it was 1950 m a. s. l. in the western part (Škrke, Škrčko ždrijelo). The average value of ELA for this glacial phase is 2020 m a. s. l.

For the central part of the Prokletije Mt., ELA was 1750 m a. s. l. for the first glacial event, 1942 m a. s. l. for the second and 2123 m a. s. l. for the third one (Milivojević et al. 2008).

On the Pindus Mts., the value of ELA is 1700 m a. s. l. for the lowest unit, 1890 m a. s. l. for the next glacial unit, while it is 2125 m a. s. l. for the last cold stage (Hughes 2006, 51).

Table 1: Glacial Phases on the Durmitor mountain.

Older phase glaciation	Younger phase glaciation	Cirque phase glaciation	Recent phase glaciation
67 km^2 54% surface	44 km^2 36% surface	3.9 km^2 3.2% surface	0.05 km^2 0.04% surface

The ELA value is always a little higher on the Durmitor mountains than on the Pindus and central part of the Prokletije. The coincidence of the number of the phases and approximate ELA values of the Durmitor, Pindus and Prokletije enables a very reliable correlation, and thus the establishment of the glacial chronology on Durmitor, too. As the indirect dating of the age of the glacial phases was done for Prokletije (Milivojević et al. 2008), so the correlation of the glacial phases and the establishment of their age has only been possible with the Pindus Mountains. The lowest glacial unit on Mount Pirin (Mount Tymphi, 2497 m a. s. l.) has been dated (secondary carbonates (calcite) formed within glacial deposits) by using uranium-series dating to > 350,000 cal. years BP (Woodward et al. 2004; Hughes 2004). The next glacial unit formed by glaciers that reached mid-valley positions, has been dated to before the last interglacial in Greece prior to 137,000 cal. years BP. The late-glacial on Mount Tymphi radiocarbon dating (slackwater flood deposits) indicates a period between c. 14,310 ± 200 and 13,960 ± 260 ^{14}C years BP (Woodward et al. 2001).

On the basis of the correlation it can be concluded that the oldest glacial phase of the Durmitor mountains could have taken place during the early or middle Würm, the younger glacial phase during the Last Glacial Maximum, while the Cirque phase could have taken place in the Younger Dryas.

6 Conclusion

Many glaciers existed on the Durmitor mountains during the Pleistocene. The former pre-glacial karst relief, as well as the position in relation to moist mass moving, influenced both the formation and size of ice cover on this mountain and the moving directions of glaciers. Karst type of glaciation caused that valley glaciers had many source branches. The cause of such condition lies in the existence of many pre-glacial karst forms that were transformed into cirques during glaciation, i.e. into sources of glaciers. Large karst pre-glacial forms caused not only the convergence of glaciers towards them but also the ice mass over-spreading out of them and glacier moving to different directions. Also, the parts of old plateaux from the Pliocene are preserved in the relief of Durmitor causing the formation of small saddle and plateau glaciers during glaciation. Ice mass from these glaciers moved to different directions.

During two phases of glaciation (older stronger and younger weaker), glaciers continually covered great parts of the mountain. Glaciers were preserved only in cirques in the last (cirque) phase. The consequence of the reduction in the intensity of glaciation was that glaciers stopped passing over the high saddles. Therefore, the moving of ice mass was directed in one direction, but not in several, as it was the case in the previous phase. By the reduction in the intensity of glaciation, the extension of glacier spreading also reduced. That had a consequence of forming a greater number of shorter glaciers that by their length and mass were considerably more modest than glaciers of the previous stronger phase. The area under ice during the stronger phase was about 54%, while during the weaker one it was 36% of total surface of Durmitor. After two phases of continuous glaciation of Durmitor, the phase of cirque glaciation came, where glaciers were kept at the bottom of the cirques formed in the previous phases, and the extension of which depended on the local conditions (exposition, etc). This phase has been preserved until today and it is presented by only one cirque glacier – Debeli namet.

7 References

Cvijić, J. 1889: Glacijalne i morfološke studije o planinama Bosne, Hercegovine i Crne Gore. Glas SKA LVII 1/21. Beograd.
Cvijić, J. 1903a: Novi rezultati o glacijalnoj eposi Balkanskog poluostrva. Glas SKA LXV 1/25. Beograd.
Cvijić, J. 1903b: Balkanska, alpska i karpatska glacijacija. Glas SKA 67. Beograd.
Cvijić, J. 1913: Ledeno doba u Prokletijama i okolnim planinama. Glas SKA 91. Beograd.
Cvijić, J. 1926: Geomorfologija II. Beograd.
Djurović, P. 1996: Visokoplaninski kras Durmitora – geomorfološka studija. Ph. D. thesis. Geografski fakultet. Beograd.
Djurović, P. 1999: Natural and anthropogenic influences as threats to pits in the Debeli namet glacier, Durmitor National park, Montenegro. Contribucion del estudio cientifico de las cavidades karsticas al conocimiento geologico. Malaga.
Djurović, P. 2002: New Approach in study of the extent of Pleistocene glaciation in the southwest part of Balkan peninsula. International Scientific Conference in Memory of Prof. Dimitar Jaranov-Varna 2. Sofija.
Djurović, P. 2007: Prilog rešavanju problema determinisanja morena i plavina. Zbornik radova 60. Beograd.
Hughes, P. D. 2004: Quaternary Glaciation in the Pindus Mountains, Northwest Greece. Ph. D. thesis. Univesity of Cambridge. Cambridge.
Hughes, P. D. 2007: Recent behaviour of the Debeli namet glacier, Durmitor, Montenegro. Earth Surface Processes and Landforms 32. Chicester. doi: 10.1002/esp.1537
Hughes, P. D., Woodward, J. C., Gibbard, P. L. 2006: The last glaciers of Greece. Zeitschrift für Geomorphologie 50-1. Stuttgart
Hughes, P. D. 2008: Response of a Montenegro glacier to extreme summer heatwaves in 2003 and 2007. Geografiska Annaler, Physical Geography 90-4. Stockholm. doi: 10.1111/j.1468-0459.2008.00344.x
Kern, Z., Surányi G., Molnár M., Nagy B., Balogh D. 2006: Investigation of natural perennialice deposits of Durmitor Mts, Montenegro. Proceedings of the 2nd international Workshop on ice Caves. Liptovský Mikuláš.
Marović, M., Marković M. 1972: Glacijalna morfologija šire oblasti Durmitora. Geološki anali Balkanskog poluostrva 37-2. Beograd.
Menković Lj. 1977/78: Glacijalni i nivacioni reljef severozapadnog dela Šar-Planine. Vesnik 35/36. Beograd.

Menković Lj. 1990: Opština Štrpce (Sirinićka župa) – Geomorfološke karakteristike. Geografski institut »Jovan Cvijić« SANU 37-1. Beograd.
Menković Lj. 1994: Tragovi glacijacije u području Djeravice – Prokletije. Geografski godišnjak 30. Kragujevac.
Menković Lj. 1994a: Glacijalna morfologija u gornjem slivu Ibra. Srpsko geografsko društvo. Beograd.
Menković Lj., Djurović P. 1993: Detaljna geomorfološka karta – osnova za vrednovanje prostora Nacionalnog parka »Lovćen«. Glasnik Srpskog geografskog društva 72-2. Beograd.
Menkovic M. Markovic M., Čupkovic T., Pavlovic R., Trivic B, Banjac N., 2004: Glacial morphology of Serbian, with comments on the Pleistocene Glaciation of Monte Negro, Macedonia and Albania. Quarternary Glaciations – Extent and Chronology. Amsterdam.
Milivojević, M. 2007: Glacijalni reljef na Volujku sa Biočem i Maglićem. Geografski institut »Jovan Cvijić« SANU 68. Beograd.
Milivojević, M., Menković, Lj., Ćalić J., 2008: Pleistocene glacial relief on the central part of Mt. Prokletije (Albanian Alps), Quaternary International 190. Amsterdam. doi:10.1016/j.quaint.2008.04.006
Milojević, B. Ž. 1937: Visoke planine u našoj Kraljevini. Beograd.
Milojević, B. Ž. 1950: O kanjonskoj dolini durmitorske Komarnice. Glas SKA 196-2. Beograd.
Milojević, B. Ž. 1950a: O kanjonskoj dolini durmitorske Sušice. Rad JAZU 280. Zagreb.
Milojević, B. Ž. 1951: Durmitor – regionalno-geografska istraživanja. Zbornik radova SAN 9-2. Beograd.
Mirković, M. 1983: Geološki sastav i tektonski sklop Durmitora, Pivske planine i Volujka Geološki glasnik 5. Titograd.
Woodward, J. C., Hamlin, R. H. B., Macklin, M. G., Karkanas, P., Kotjabopoulou, E. 2001: Quantitative Sourcing of Slackwater Deposits at Boila Rockshelter: A Record of Lateglacial Flooding and Palaeolithic Settlement in the Pindus Mountains, Northwest Greece. Geoarchaeology 16. Chicester. doi: 10.1002/gea.1003
Woodward, J. C., Macklin, M. G., Smith, G. R. 2004: Pleistocene Glaciation in the Mountains of Greece. Quaternary Glaciations Extent and Chronology 1 – Europe. Amsterdam.
Živaljević, M., Vujučić, P., Stijović V. 1989: Tumač za list Žabljak K 34-27. Osnovna geološka karta 1 : 100 000. Beograd.

Rekonstrukcija pleistocenskih ledenikov na Durmitorju v Črni Gori

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IZVLEČEK: Durmitor leži v jugovzhodnem delu dinarskega gorstva v Črni Gori. V pleistocenu so bili na njem številni ledeniki, ki so se spuščali k sosednjim kraškim planotam. Na vrsto ledenikov, njihovo številčnost in smeri gibanja sta najbolj vplivala geološka sestava (karbonatna osnova) in predledeniški kraški in delno fluvialni relief. V dveh obdobjih intenzivne poledenitve se je spreminjala površina, ki so jo preoblikovali ledeniški procesi. V obdobju močnejše poledenitve, so ledeniki pokrivali 54 % ozemlja, medtem ko so ob šibkejši poledenitvi zavzemali okrog 36 % površine Durmitorja. V zadnjem obdobju poledenitve je prevladoval krnični tip poledenitve.

KLJUČNE BESEDE: geografija, poledenitev, rekonstrukcija ledenikov, pleistocen, Durmitor, Dinarsko gorstvo, Črna Gora

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Vsebina

1 Uvod

Gora Durmitor leži v zahodnem delu Balkanskega polotoka (Slika 1). Sodi v zahodno cono mlajših nagubanih gorovij, dinarske skupine. Leži v jugovzhodnem delu Dinarskega gorstva, v severnem delu Republike Črne Gore. V širšem smislu pripada povodju reke Drine, v ožjem pa predstavlja razvodje med rekama Taro in Pivo.

Slika 1: Lega Durmitorja.
Glej angleški del prispevka.

Durmitor je edinstvena in jasno opredeljena morfološka celota, ki jo obdajajo visoke kraške planote višine od 1400 do 1600 m n. v. Meja planote in gorskega masiva je obenem tudi morfološka meja Durmitorja, ki se le v severnem delu gore spusti do 1100 m n. v., do kotanje Sušiškega jezera. Najvišji deli gore presegajo višino 2400 m n. v. (Bobotov kuk 2522 m n. v.), oziroma so višji od okoliških planot od 900 do 1100 m. Tako opredeljena gora Durmitor ima površino 123 km^2 (Djurović 1996).

Litološka sestava Durmitorja je precej enostavna (Mirković 1983) (Slika 2). Sestavljajo ga karbonatne kamnine različne sestave in starosti, klastične kamnine pa so večinoma le redek pojav. Med karbonatnimi kamninami najpogostejši je apnenec, v manjši meri pa se pojavljajo tudi dolomiti. Najbolj pogosto so predstavljeni z masivnimi in plastnatimi apnenci triasne in kredne starosti. V plastnatih apnencih je pogost rožnati apnenec tipa *scaglia rossa*. V karbonatnem kompleksu kamnin posebno mesto zasedejo kredno-paleogeni sedimenti, takoimenovan durmitorski fliš. To so ploščaste in plastnate breče apnenca, plastnati peščeni apnenci, laporasti apnenci, laporji in peščenjaki. Kljub tej petrološki raznovrstnosti vseeno prevladujejo različne vrste karbonatov, ki se bistveno ne razlikujejo od drugih kamnin karbonatnega kompleksa. Klastične kamnine so nastale največ med triasom, predstavljene pa so s kremenovimi peščenjaki, peščenimi apnenci in podobno. Na Durmitorju zavzemajo malo površine. Temu kompleksu pripadajo tudi andeziti, srednje triasne starosti. Prisotni so na manjšem prostoru in sicer pod Crveno gredo, pri Barnem jezeru in pri Bosači (Živaljević in ostali 1989).

Slika 2: Toponimi in geološka zgradba Durmitorja.
Glej angleški del prispevka.

Durmitor pripada k dvema tektonskima enotama. Njen jugozahodni del gore sodi k Kučki tektonski enoti (Prutaš, Vjetrena brda, Dobri do, Sedlena greda, Stožina, Ružica, Lojanik, Bolj) in Durmitorski tektonski enoti, ki obsega ostali del gore. Prek sedimentov Kučke tektonske enote od severovzhoda reversno se je gibala Durmitorska tektonska enota vzdolž vznožja Ranisave (Živaljević in ostali 1989).

Na podlagi instrumentalnih merjenj (Hidrometeorološka letna poročila) in statističnih izračunov je bilo ugotovljeno, da je srednja letna temperatura zraka v Žabljaku (1450 m n. v.) 4,7 °C (obdobje med 1958–1993). Srednja mesečna temperatura zraka v Žabljaku v najbolj mrzlem mesecu januarju je –4,3 °C, v najtoplejšem mesecu juliju pa 14 °C. Na podlagi izračunov (temperaturnega gradienta) smo ugotovili, da je sodobna srednja letna temperatura zraka na največjem delu gore pozitivna. Šele na višinah čez 2450 m n. v. srednja letna temperatura je negativna, za najvišje predele pa znaša –0,5 °C (Djurović 1996, 91).

Na podlagi podatkov iz 12 padavinskih postaj smo analizirali količine padavin za obdobje med letoma 1958 in 1993 (Djurović 1996, 100). Najbolj odločilna dejavnika, ki določata količino padavin, sta položaj gore glede na prevladujočo smer vlažnih zračnih gmot in nadmorska višina. Ta dejavnika sta brez pomembnejših sprememb obstajala tudi med pleistocenom. Sodobna razporeditev in prostorska razmerja količin padavin so zelo bistveni za razumevanje nastanka ledenikov na Durmitorju v pleistocenu. Na območjih, ki ležijo v smeri prevladujočih zračnih gmot, se v veliki meri povečuje količina padavin. Zaradi vsega navedenega, prejemajo jugozahodna pobočja Durmitorja tudi do 60 % več padavin kot območje Jezerske planote in severovzhodnih pobočij gore. Za osrednja, najvišja gorska območja, je bilo izračunano, da prejmejo letno okoli 2600 mm atmosferskih padavin. Letna količina padavin se rahlo zmanjšuje v smeri proti jugozahodu in sicer do okoli 2000 mm, količina padavin pa je še nižja na kraških planotah, ki obdajajo Durmitor na vzhodu, zahodu in severu. Tu letno pade okoli 1200 mm padavin.

2 Metodologija rekonstrukcije

Na podlagi rezultatov iz predhodnih raziskovanj, kakor tudi na podlagi rezultatov sodobnih raziskovanj, je bila rekonstruirana podoba obsega ledeniškega pokrova, smeri gibanja in tipov ledenikov ter intenziteta glaciacije tekom pleistocena. Rekonstrukcija je opravljena na podlagi ledenišnih oblik, ki so ohranjene v reliefu Durmitorja. To so predvsem erozivne oblike – krnice in valovi. Razen njih, so bile pri ugotavljanju gibalne smeri ledenika in glacialnih faz, koristne tudi mutonirane kamnine, nunataki (več vrhov, ki se dvigujejo nad ledenikom) in ledeniški sedimenti. Za rekonstrukcijo so veliko manj pomembni ledeniški sedimenti in akumulacijske oblike: til oziroma morenski material in ledeniške morene. Za to sta dva vzroka: v zadnjem obdobju obstoja so ledeniki lezli z gora in so se razlivali čez gorske planote, ki obdajajo Durmitor, zato so na gorovju ohranjeni samo na posameznih mestih. Drugi razlog je v hitrem lateralnem spreminjanju ledeniških sedimentov v fluvialne, s tem pa se izgubi možnost za natančno genetsko opredelitev, to pa bistveno vpliva na končno rekonstrukcijo. Za identifikacijo oblik smo uporabili aero-foto posnetke v merilu 1 : 25 000, za prikaz prostorskih razmerij pa so uporabljene topografske karte v enakem merilu. Polega tega smo z neposrednim terenskim opazovanjem preverili vse podatke, ki so bili dobljeni z daljinskim zaznavanjem.

Ob rekonstruiranju ledenika smo posebno pozornost posvetili številnim dejavnikom, ki so vplivali na nastanek in spreminjanje pleistocenskega ledeniškega pokrova na Durmitorju. To pa je, predvsem, izgled preglacialnega reliefa, geološka sestava terena, ki pa je bila podvržena glacialnemu procesu, tipu ledenika, naklon pobočij, ekspoziciji pobočij, smeri gibanja vlažnih zračnih gmot, naklonu padavin, postglacialnim procesom ipd. Posebno pozornost smo posvetili možnim napakam ob določanju genetske pripadnosti analiziranih oblik in sedimentov (Djurović 2007, 5).

3 Rezultati dosedanjih raziskav

Raziskave pleistocenske ledeniške morfologije Durmitorja, ugotavljanje smeri gibanja ledenika, obsega poledenitve so se začele na koncu 19. stoletja. Prve raziskave o sledovih poledenitve na tem gorovju je med letoma 1897. in 1888. opravil J. Cvijić. Izidi teh raziskovanj so številni prispevki, ki so bili objavljeni med letoma 1899. in 1926. (Cvijić 1899; 1903a; 1903b; 1913; 1926). Rezultate Cvijićevih preučevanj poledenitve Durmitorja lahko strnemo v nekaj glavnih tez:

- sledovi poledenitve na Durmitorju sodijo med mlajšo poledenitev tega dela Balkanskega polotoka;
- na Durmitorju je bilo ena poledenitveno obdobje s tremi stadiji, kar ustreza virmski poledenitvi na Alpah;
- so na tem območju trije tipi ledenikov: dolinski, krniški (ledeniške kape) in pobočni (ledeni pokrovi).

Cvijićev »krniški tip ledenika/poledenitve« je prisoten na območjih, ki jih sestavlja apnenec. V odbodbju pred poledenitvijo je nastajal kraški relief. Ko pa je poledenitveni proces zamenjal kraškega, so nastali ledeniki v kraških reliefnih oblikah. Med kraškimi oblikami so uvale najbolj vplivale na razvoj ledenika, saj je v njih prihajalo do kopičenja ledu, širjenja ledenika, do njihovega upočasnjenega gibanja in pa do inverznega gibanja ledenika pri izhodu iz uval. Prav tako so bili pogosti prelomi v vzdolžnem prerezu ledenika, kakor tudi valovi, ki so nastali zaradi gibanja ledenika. Ti prelomi niso posledica poledenitvenega, temveč kraškega procesa (Cvijić 1889,1913), ki se je prek ledenika odslikoval na površje.

Drugi pomemben raziskovalec tega prostora je bil B. Milojević, ki je v študijah zajel tudi probleme pleistocenske poledenitve Durmitorja (Milojević 1937; 1950; 1950a; 1951). Posredoval je naslednje ugotovitve o poledenitvi Durmitorja:

- ugotovil je, da sta bili dve poledenitvi, starejša riška in mlajša würmska;
- v okviru würmska poledenitve so bili trije stadiji;
- med dvema poledenitvama ni bilo krniške zaledenelosti celotne Jezerske planote, temveč je krniški ledenik nastajal le z združevanjem ledenika Ališnica, Dobri do, Savin do in ledenika Korito, ki se je gibal proti Tari kot dolinski ledenik.

Za tem obdobjem je nastopila dolga prekinitev raziskav poledenitve Durmitorja in šele v 70-tih 20. stoletja so spet nadaljevali raziskave. K preučevanju poledenitve so pristopili z novega metodološkega stališča in z uporabo aero-foto posnetkov. Ugotovili so, da je poleg krniškega ledenika, ki je obstajal na Jezerski planoti, obstajal tudi krniški ledenik Todorov, ki pa je tekel proti Pivi (Marović in Marković 1972).

Podrobna študija o geološki sestavi Durmitorja, Pivske gore in Volujka je zajela preučevanja tudi pleistocenskih in kvartarskih sedimentov (Mirković 1983, 81). V njej pa manjka podrobna razčlenitev starosti in nastanka najmlajših sedimentov na tem prostoru.

Med obsežnimi geološkimi raziskavami za potrebe izdelave osnovne geološke karte so skromno pozornost posvetili ledeniškim sedimentom, ki so jih največ ugotovili na Jezerski planoti, medtem ko jih na Durmitorju niso našli (Živaljević in ostali 1989).

Zato smo v okviru obsežnih geomorfoloških raziskav visokogorskega krasa Durmitorja smo opravili tudi podrobna preučavanja sledov pleistocenskih ledeniških oblik. Z uporabo aero-foto posnetkov in z neposrednim terenskim raziskovanjem smo opravili rekonstrukcijo ledeniških oblik in smo izločili krnice in ledeniške grbine kakor tudi druge ledeniške oblike na tem gorovju. Izločili smo površine, ki so bile podvržene dolgotrajnemu in kratkotrajnemu vplivu poledenitvenega procesa, da bi pojasnili nastanek visokogorskega krasa na tej gori (Djurović 1996, 53).

Na podrobni geomorfološki karti ledenika Debeli namet in njegovega neposrednega okolja smo prikazali osnovne lastnosti sodobnega ledeniškega procesa na tej gori. V okviru te študije smo pokazali dve ledeniški razpoki in ledeniško mizo, ki so se pojavili med letom 1993 na ledeniku. Na podlagi razpok v ledeniku smo ugotovili debelino ledenika. Prav tako smo naredili navpični prerez (Djurović 1999, 579).

Z radiometrijsko metodo raziskovanja, z gama spektrometrijo in z beta aktivnimi merjenji smo z lahko stari del ledenika razlikovali od njegovega dinamičnega, premikajočega se dela ter od ledu v jami (Ledena) na Durmitorju. Z gama spektrometrsko metodo nismo mogli potrditi obdobje 1963. AD radiometrijske reference horizonta iz naravne ledene mase lednjaka Debeli namet (Kern in ostali 2006, 70).

Morene ledenika Debeli namet so bile predmet raziskovanj in ugotavljanja podnebnih sprememb. Z lihenometrično metodo smo ugotovili, da sta poslednji dve moreni iz 1878 in 1904 leta in da sta nastali zaradi podnebnih sprememb. Naše ugotovitve se ujemajo s podatki o povprečnih spremembah v vzhodnem Mediteranu (Hughes 2007, 1593).

Sodobni ledeniški proces na Durmitorju smo obravnavali preko vpliva ekstremno visokih poletnih temperatur med letoma 2003. in 2007. Ugotovili smo, da so visoke poletne temperature vplivale na zmanjšanje obsega lednika Debeli namet, ne pa tudi na njegovo izginjanje (Hugnes 2008, 259).

4 Ledeniki na Durmitorju

Z rekonstrukcijo smo ugotovili, da je na Durmitorju v pleistocenu obstajalo več ledenikov. Manjši ledeniki so se združili in so oblikovali velike ledenike med katerimi posebej izstopajo: ledenik Dobri do, ledenik Valoviti do, ledenik Sušica, ledenik Ališnica in Pošćenski ledenik. Prav tako so obstajali tudi drugi krajši ledeniki. Ledeniki so se med seboj razlikovali po tipu. Največ je bilo ledenikov dolinskega tipa, bili pa so tudi ledeniki v obliki pokrova ali kape. Zaradi apnenčaste sestave gorovja in razvitega predledeniškega kraškega reliefa je bil na Durmitorju pogost poseben tip poledenitve, ki jo je že J. Cvijić opredelil kot kraški tip poledenitve. Ledeniki so se z gora gibali v treh glavnih smereh in sicer: proti Jezerski planoti in soteski Tare, proti Pivski gori in soteski Pive ter proti dolini Komarnice. Gorovje je med poledenitvijo skoraj povsem pokrivala ledena odeja iz katere so štrleli le najvišji grebeni in vrhovi.

4.1 Ledenik Dobri do

Ledenik Dobri do je bil največji ledenik na Durmitorju. Oblikoval se je v relativno odprtem predledeniškem prostoru dinarske smeri lege. Bil je 5 km dolg in okoli 2 km širok. Severni obod kotline gradijo visoki vrhovi Prutaš (2393 m n. v.), Šareni Pasovi (2236 m n. v.), Soa (2440 m n. v.), Zupci (2309 m n. v.), Bandjerna (2409 m n. v.) in Milošev tok (2426 m n. v.). Pod temi vrhovi in grebeni se se oblikovala primarna mesta akumulacije ledu, oziroma primarni ledeniki: Duški ledenik in ledenik Vjetrena brda, ki sta najvišja kraka ledenika Dobri do. S spojitvijo teh dveh ledenikov, kakor tudi ledu z Lojanika, Bolja in Sedlene grede na območju današnjega Dobrog dola je nastalo ledeno polje iz katerega so se ledeniški kraki gibali v različne smeri.

Pod južnim odsekom Prutaša se je na višini okoli 2050 m n. v.oblikoval sedelni **Duški lednik**, ki je prekrival celotno kraško planoto Duške police. Planoto je v južnem in zahodnem delu erodiral zahodni krak ledenika, ki se je ločil od ledenega polja v Dobrem dolu, njen vzhodni del pa je erodiral ledenik Zeleni vir. Zaradi erodiranosti roba kraške planote so se ledeniške gmote z nje lomile in je padale čez Duških valj proti ledeniku Zeleni vir, čez Žljeb proti zahodnemu kraku ledenika Dobri do, v zahodnem delu pa neposredno proti Todorovemu Dolu.

Severno od ledenika Dobri do se je na južni strani grebena Šljeme–Bandjerna–Zupci oblikoval, na strukturno-kraški planoti (dotik Kučke in Durmitorske tektonkske enote) sedelni **Ledenik Vjetrena brda**. Iz omenjenega grebena se je zbirala ledena masa na planoti višine okoli 2150 m n. v. Led se je gibal v treh smereh. V obdobju močnejše poledenitve je ledena gmota vzdrževala ledenik Dobri do, v manjši meri pa tudi Pošćenski lednik. V obdobju manjše poledenitve se je ledenik gibal samo proti Dobremu dolu (Slika 3).

Iz sedelneg ledenika Vjetrena brda so se ločili trije ledeniški krakovi: ledeniški krak Zeleni vir, ledeniški krak Surutka in ledeniški krak Valoviti (južni) do.

Od severnega dela sedleneg ledenika Vjetrena brda se je ločeval ledeniški krak, iz katerega je prav tako nastal samostojni ledenik **Zeleni vir** na prostoru med vrhovi Zubci (2309 m n. v.), Minin bogaz (2387 m n. v.) in Lučin vrh (2394 m n. v.), na okoli 2030 m n. v. Od današnje kotanje jezera je Zeleni vir zavijal v južno smer in se prek treh pregibov ter Mliječnega in Urdenega dola zlival z ledenikom Dobri do.

Slika 3: Starejše obdobje poledenitve.
Glej angleški del prispevka.

Ledeniški krak **Surutka** (2050 m n. v.) se je lomil, potem ko je predrl greben Vjetrena brda in je tekel na polico Police, kjer pa se je pridružil ledeniku Dobri do.

Ledeniški krak **Valoviti (južni) do** (2100 m n. v.) se je zelo raznoliko gibal zaradi sprememb intenzitete poledenitve ter zaradi erozije apnenčaste osnove, ki je odpirala nove smeri gibanja ledu. Med močnejšo poledenitvijo se je lednik najprej gibal proti jugovzhodu, kjer je zadel ob Uvito Gredo (2199 m n. v.), manjši del pa se je prelival čez greben in se premikal proti ledenku Dobri do. Večji del je zavil proti vzhodu. S tem ločevanjem ledeniške mase na prostoru Uvite grede je začel nastajati večji nunatak. Pri nadaljnjem gibanju je ledeniški krak prilezel do nekaj kamnitih zobcev, potem se je razdrl na več delov in je oblikoval nekaj manjših nunatakov. Del ledu se je pomikal proti ledeniku Mali lomni do (1930 m n. v.), se zlil z njim in se pomikal proti osrednjemu delu Pošćenskega ledenika. Drugi del se je pomikal skozi Uvito ždrijelo do začetka Pošćenskega ledenika na mestu današnjega Valovitega jezera.

V mlajšem obdobju se je Uvito ždrijelo razširilo, zaradi česar se je ledeniški krak v celoti pomikal po njem proti današnji kotanji Pošćenskega jezera. S tem je prenehal dotok ledu do ledenika Mali lomni do. Ta ledeniški krak je v današnji kotanji Valovitega jezera pa tudi pod njim odložil morensko gradivo in bočno moreno. Vendar je do dokončne spremembe smeri gibanja ledeniškega kraka Valoviti prišlo z erozijo grebena Uvite grede na območju Žleba. Led ni več dotekal v Pošćenski ledenik, gibanje celotne gmote ledeniškega kraka Valoviti (južni) do pa se je usmerilo proti ledeniku Dobri do. V zadnjem obdobju obstoja ledeniški krak se je sesul čez odsek (–200 m), ki leži na koncu Žljeba. Ledenik ni imel moči, da bi se regeneriral in nadaljeval gibanje, pač pa se je tu stalil. Na mestu njegovega taljenja (1950 m n. v.) so ohranjene in razmetane plasti morenskega materiala. V sodobnem reliefu so na območju Valovitega (južnega) dola in Uvite grede ohranjeni ostanki velikega valova ki ustreza močnejši poledenitvi (starejše obdobje poledenitve) in pa manjšega valova, ki je vrezan vanj in je nastal med mlajše obdobje poledenitve.

Ledeniki, ki so pritekali z različnih strani, so na območju današnje kotanje Dobri do oblikovali ledeno polje. Pod njim se je led spet oblikoval v manjše krake (Slika 3). Prvi se je gibal proti zahodu, čez sedlo na višini okoli 1880 m proti Todorovemu dolu in naprej proti soteski Pive. Drugi krak ledenika Dobri do se je gibal proti jugu med Bolja in Lojanika proti današnji dolini Komarnice. Prebijajoč se skozi najožji del (Klještine) je vrezal ledeniška ramena z obeh strani valova. Na podlagi tega smo sklepali, da se je gibal na okoli 1750 m. Tretji krak ledenika Dobri do je tekel proti jugozahodu med Boljo in Sedleno gredo proti Grabovici čez preval na višini okoli 1700 m n. v. Preval na zahodu je najvišji in ledna gmota se je čezenj gibala le med najmočnejšo poledenitvijo, oziroma relativno kratek čas. Gibanje ledu je bilo usmerjeno proti nižjim predelom na južni in jugovzhodni strani. Z zmanjšanjem intenzitete poledenitve ledenik pri Klještinah začenja dolbenje novega valova, nekdanje dno valova pa je ostane na višini 250 m (ledeniška ramena). Tedaj je obenem prenehalo tudi gibanje ledu proti Grabovici.

Slika 4: Mlajše obdobje poledenitve.
Glej angleški del prispevka.

4.2 Ledenik Valoviti do

V osredju gorovja je bil severno od grebena Šljeme (2447 m n. v.)–Zupci (2309 m n. v.)–Soa (2440 m n. v.) ledenik Valoviti do. Oblikoval je krnica nepravilne okroglaste oblike z dnom na višini okoli 2020 m n. v.in s pobočji, ki na severu segajo 2400 m n. v.visoko, na zahodu so v višinah med 2480 m n. v. in 2520 m n. v. na vzhodu pa 2200 m n. v. V severovzhodnem delu je rob krnice za okoli 70 m nižji na višini 2160 m n. v. Ko je akumulacija ledu dosegla kritično višino, oziroma višino nižjega robu, je prišlo do prelivanja ledene gmote prek Biljegovega dola, zatem pa proti jugovzhodu proti Lokvicam, kjer se je združila z **Lokviškim ledenikom**. Ledeniku Valoviti do se je pridružil tudi ledenik **Ledeni do**, ki je nastal pod visokimi grebeni Mininega bogaza (2387 m n. v.), Bandjerne (2409 m n. v.), Miloševega toka (2426 m n. v.) in Terzinega bogaza (2303 m n. v.). Intenzivnost poledenitve smo lahko ugotovili na podlagi ledeniškega ramena, ki je za 150 m nižje od okolice. S spojitvijo ledenikov Valoviti do in Ledeni do je nastal Lokviški ledenik, ki se je pomikal proti severovzhodu in se je spuščal proti današnji kotanji Crnega jezera in Jezerski planoti.

Slika 5: Krnično in recentno obdobje poledenitve.
Glej angleški del prispevka.

4.3 Ledenik Sušica

Eden najdaljših ledenikov na Durmitorji je ledenik Sušica, ki je nastal v 2,5 km dolgi in 1,5 km široki krnici z dnom na okoli 1680 m n. v. Odprta je v severozahodnem delu, z ostalih strani pa jo obdajajo visoki grebeni Planinice (2330 m n. v.), Soe (2522 m n. v.), Šarenih pasov (2248 m n. v.) in Prutaša (2293 m n. v.). Velikost krnice ni le posledica ledeniške erozije, temveč tudi strukturnih razmer oziroma velikih narivov Kučke in Durmitorske tektonske enote. V severozahodnem delu, pri Skakalah, se je ledenik pomikal iz krnice proti dolini reke Tare in se je spustil do višine 1100 m. Ledenik Sušica je primer dolinskega tipa ledenika. K glavnemu ledeniku je dotekala led iz dveh kratkih ledenikov, ki sta nastala na severni strani grebena Prutaš–Šareni pasovi, in sicer v Prutaškem dolu (2010 m n. v.) in v Škrčkem ždrijelu (1950 m n. v.). Ledenik iz Škrčkega ždrijela je pod krnico, na višini okoli 1850 m n. v.pustil niz moren. Oba ledenika sta bila viseča v razmerju do ledenika Sušice (Slika 6).

Slika 6: Sušiški ledenik.
Glej angleški del prispevka.

4.4 Ledenik Poljice

Na območju Donje in Gornje Poljice na višini 2250 m n. v.je na apnenčasti planoti nastal planotasti ledenik Poljice. Led se je s planote spuščal proti ledenikoma Sušica in Ališnica. Ob gibanju ledenik ni močno preoblikoval površja, saj so sosednji ledeniki močno erodirali planoto in jo še dodatno ločili od okolice (Slika 3).

4.5 Ledenik Štuoc

Na skrajnjem severnem delu Durmitorja je nastal še eden planotasti ledenik – Štuoc. Nastal je na višini okoli 2150 m n. v.na pliocenski kraški planoti. Ledena gmota se je s te planote gibala v vseh smereh in je napajala sosedjne ledenike.

4.6 Podštuoški ledenik

Med planotastima ledenikoma Poljice in Štuoca leži Podštuoško sedlo (1900–2000 m n. v.). Razprostira se v smeri dinarskega gorstva. V severozahodnem delu (1600 m n. v.) je odprta proti valovu ledenika Sušica, jugovzhodu (1900 m n. v.) pa je odprta proti valovu ledenika Ališnica. Na tem območju je nastal Podštuoški sedleni ledenik. Deloma je na njegov nastanek vplivalo nabiranje ledu iz atmosferskih padavin, večji del pa so prispevale ledene gmote sosednjih višjih planotastih ledenikov Poljice in Štuoc. V obdobju močnejše poledenitve se je ledena gmota gibala v dveh smereh, in sicer proti ledeniku Sušica in proti ledeniku Ališnica. V času šibkejše poledenitve se je sedleni ledenik bistveno zmanjšal, nastalo je nekaj krajših ledenikov: Kaludjerovača (1690 m n. v.), Crvena stijena (1850 m n. v.), Velika Rutulja (1940 m n. v.), Valoviti (severni) do (2050 m n. v.). Ti ledeniki so nastali v severovzhodnem delu sedla, kjer so bile ugodnejše razmere za akumulacijo ledu.

4.7 Ledenik Ališnica

Ledenik Ališnica je nastl v krnici, ki je na jugovzhodu jasno omejena z grebenom Rbatine (2401 m), na jugozahodu pa s Planinico (2330 m n. v.). Na severu je ne omejujejo grebeni, temveč široka kraška planota, v katero je delno vrezana krnica. Njeno dno je na višini 2040 m n. v., pobočja pa so visoka med 180 in 360 m. V severovzhodnem delu je krnica odprta, tako da se je skozi to odprtino ledenik pomikal proti Zminjem jezeru in Jezerskoj planoti. Ledenik Ališnica je kompleksen dolinski ledenik, z ledenimi slapovi višine tudi do 250 m. V zgornjem delu je povečeval svojo maso z ledom planotskega ledenika Poljice. Nižje, na območju današnjega Zminjeg jezera, v smeri proti ledeniku Ališnica, so se mu pridružili številni bočni ledeniki: s severa na primer ledenik Jablan, ki je obstajal na mestu današnje jezerske kotanje v širšem smislu Jablan. Zaradi južne ekspozicije in relativno majhne višine (1790 m n. v.) ledenik ni imel velike mase in je kmalu obvisel glede na ledenik Ališnica. S strani severozahoda je prihajala ledena masa sedlenega Podštuočkega ledenika, z jugozahoda pa *ledenik Kobilji do*. Ta ledenik je nastal v krnici z dnom na višini 2070 m n. v. Z juga so se ledeniku Ališnica pridružile ledene gmote ovršnega *ledenika Korita*, ki je nastal na severovzhodnih pobočjih grebena Obla glava–Čvorov bogaz. Na območju severno do Čvorovega bogaza je ledenik nanesel morenski material. V poznejši fazi se ledenik Korita ni pomikal s planote, temveč se je na njen topil. Ledenik Ališnica je v najvišjem delu krnice (2200 m n. v.) v krniški poledenitveni fazi odložil niz majhih čelnih moren.

4.8 Ledenik Velika kalica

Ledenik Velika kalica spada med dolinske ledenike. Nastal je iz dveh krniških ledenikov: Previja (2050 m n. v.) in Debeli namet (2050 m n. v.). Ledenik Debeli namet je obstal do danes in je območje delovanja recentnih glacialnih procesov (Slika 5) (Djurović 1996, 202; 1999, 579). Po združitvi teh dveh krniških ledenikov je nastal ledenik Velika kalica. Na izhodu iz gorovja Durmitor se je ledeniku z juga priključil krajši *ledenik Pleća*, ki je nastal na severnih pobočjih Savinega kuka na višini okrog 1820 m n. v. Ledenik Velika kalica je dosegel Jezersko površ, kjer se je na široko je razlil. Pri umiku je ledenik v valovu med Malim Medjedom in Savinim kukom odložil nekoliko morenskih nasipov.

4.9 Pošćenski ledenik

Pošćenski ledenik je kompleksen ledenik, ki se je zelo spreminjal glede glede na intenzivnost poledenitve. Med najmočnejšo poledenitvijo je najvišji krak Pošćenskega ledenika nastajal pod ledenikom Vjetrena brda (Slika 3). Spuščal se je k današnje kotanje Valovitega jezera, kjer se je pridružil Pošćenskemu ledeniku, ki se je pritekal od Sedla (1910 m n. v.). Pošćenskemu ledeniku so se pridružili tudi bočni ledeniki na jugovzhodnih pobočjih Durmitorja, nekaj krajših ledenikov pa je pritekalo tudi s severa. Ledeniku *Mali lomni do* je med najmočnejšo poledenitvijo dotekal led iz ledenika *Vjetrena brda*. S slabenjem glaciacije je dotok ledu iz ledenika Vjetrena brda prenehal, ledenik Mali lomni se je ločil od drugih. Ledena gmota je obstala na dnu krnice v višini okrog 2100 m n. v. Tudi ledenik *Veliki lomni do* je bil viseči ledenik glede na Pošćenski ledenik. Nastal je v krnici z dnom na višini okrog 2500 m n. v. Pred izhodom iz krnice se je ledenik lomil in padal k Pošćenskemu ledeniku. *Ledenik pod Štitom* je nastal v krnici z dnom na višini 1850 m n. v. V starejši fazi glaciacije ledenik je pod Štitom segal iz krnice in se pomikal prek Vodenega dola (1660 m n. v.), od tam pa med Stožinami in Vinjevo glavico (1705 m n. v.), kjer se je s severa lomil proti Pošćenskemu ledeniku. V zadnji fazi obstoja ledeniku ni uspelo, da bi dosegel drugo stran sedla, ampak se je zaustavil pred njimin in ustvaril morenski material. Ledenik *Korita* je nastal tik ob Ledeniku pod Štitom. Ustvaril je pravilno krnico z dnom na višini okrog 2070 m n. v., iz katere se je led gibal proti jugovzhodu in se pogosto navpično prelamljal. Preko Mekega dola je dosegel Jezersko površ, kjer se je razprostrl. V zadnji fazi je ledenik dosegel samo do Mekoga dola (Slika 5), kjer je odložil morensko gradivo, ki je danes ohranjeno v obliki razmetanega kupa kamnitih blokov. Na poti k Jezerski površi se je Pošćenski ledenik, pri kamniti oviri Stožina, razdelil na dva dela. Ob premikanju okoli Stožine je iz ustvaril nunatak (Slika 7). Manjši del ledenika se je prek Mekega dola in Vinjeve glavice spuščal k Jezerski površi, njegov večji del pa je preko Suve lokve in današnje kotanje jezera nadaljeval pot proti Jezerski površi. Z zmanjševanjem glaciacije je Pošćenski ledenik izgubil najvišji krak, ki je prihajal od ledenika Vjetrena brda in z zmanjševanjem ledne mase ni več dosegel Stožine, temveč je obstal na njegovi južni strani in čez Suvo Lokvo in Pošćensko jezero segel do Jezerske površi (Slika 4).

Slika 7: Pošćenski ledenik.
Glej angleški del prispevka.

4.10 Ledeniki vzhodnega Durmitorja

Na vzhodnih pobočjih Durmitorja so v mlajši fazi glaciacije nastali štirje kratki ledeniki: Mlečni Do, Savin kuk, ledenik Pod Štitom in ledenik Korita (Slika 8). Zadnja dva ledenika sta med starejšo poledenitvijo dosegla Pošćenski ledenik, med mlajšo poledenitveno fazo pa so se skrajšali, obseg Pošćenskega ledenika pa se je zmanjšal. Nastali so štirje neodvisni ledeniki, ki so se končali na Jezerskem površu.

Ledenik Mlečni do je nastal v krnici cirku z dnom na višini okrog 1880 m. Po izhodu iz krnice je globoko padal in se razlival po Jezerski površi. Ledenik *Savin kuk* je nastal v krnici na višini okrog 2090 m n. v. Zaradi velike strmine vzhodnih pobočij Šljemena je imel veliko kinetično energijo, zato je izdolbel globoki valov, po izhodu na Jezersko površ pa se je tudi ta razprostrl po njej.

Slika 8: Ledeniki na vzhodni strani Durmitorja.
Glej angleški del prispevka.

5 Razprava

V dosedanji rekonstrukciji ledenikov Durmitorja smo prikazali njihove temeljne morfološke in hipsometrične lastnosti, kot tudi njihovo tipologijo. Za popolno rekonstrukcijo pleistocenskih ledenikov na Durmotorju bi morali nujno prikazati tudi njihovo kronologijo, oziroma ugotoviti časovna obdobja, v katerih so se dogajala obdobja poledenitve. Z ozirom na to, da na Durmitorju ni bilo opravljeno datiranje starosti glacijalnih sedimentov, lahko glacialno kronologijo opravimo le s posrednimi metodami, na primer s pomočjo korelacije z gorovji, za katera je bila starost obdobij poledenitve že ugotovljena.

Obdobja poledenitve na Durmitorju je mogoče primerjati tudi s pomočjo poledenitvenih faz na podobno visokih in od morja oddaljenih sosednjih gorstvih (Slika 1). Na gorski skupini Maglić (2386 m n. v.), Volujak (2336 m n. v.) in Bioč (2397 m n. v.) so bila razvita tri obdobja poledenitve (Milivojević 2007, 122). Za Šar planino (2748 m n. v.) je bilo ugotovljeno, da so ledeniki zavzemali površino od 30 do 35 km^2 (Menković in ostali 2004, 384), ugotovili pa so tudi obstoj starejših moren na koncu valov, moren pod krnicami in krniških moren (Menković 1977/78, 101; Menković 1990, 64). Tudi v Kosovsko-metohijskem delu Prokletij (Djeravica 2656 m n. v.) so ugotovili, da obstajajo starejše in mlajše morene. Na podlagi morenskega gradiva v ledeniških dolinah lahko sklepamo, da je obstajala tudi tretja, najmlajša faza poledenitve, ki se je dogajala le v dolinah (Menković 1994, 141). Tri poledenitvena obdobja so obstajal tudi v osrednjem delu albanskih Prokletij (Maja e Jezerce, 2697 m n. v.) (Milivojević in ostali 2008, 115), v severovzhodnem delu Prokletij (Hajla, 2403 m n. v.; Žljeb, 2381 m n. v.) pa so potrdili le eno poledenitveno obdobje (Menković 1994a, 30). Na Lovćenu (1748 m n. v.) je bilo prav tako le eno poledenitveno obdobje, kar je razumljivo z ozirom na višino gore in na veliko bližino morja (Menković in Djurović 1993, 23). Tudi na gori Pind v Grčiji so potrdili obstoj treh poledenitvenih obdobij (Hughes 2006, 51).

Razen obdobij poledenitve je za ugotavljanje poteka poledenitve na Durmitorju pomembno tudi primerjanje vrednosti ravnovesne meje ledenikov (angleško *equilibrium line altitude*, ELA).

V starejšem poledenitvenem obdobju je bila ELA na severnih delih Durmitorja 1600 m n. v.visoko (Štuoc), pri Črnem jezeru na višini 1600 m n. v., v vzhodnih delih gore na 1600 m n. v. (Šljeme), v južnem delu gorovja (Komarnica) se je spustila do 1400 m n. v., v severozahodnem delu pa je bila na okoli 1500 m n. v. (soteska Sušice). Povprečna vrednost ELA za to obdobje poledenitve je bila 1540 m n. v.

V mlajšem obdobju poledenitve je imela ELA povprečno vrednost na Štuocu 1850 m n. v., v Lokvicah na 1900 m n. v., na vzhodnih pobočjih Šljemana 1850 m n. v., na Vjetrenih brdih 2000 m n. v., pod Prutašem 2000 m n. v., v Škrkah 1700 m n. v. Povprečna vrednost ELA je bila v času mlajše poledenitve 1880 m n. v.

Z večjo višino ELA v mlajšem obdobju je povezan nastanek krnic. V severnem delu gorovja (Vidrica, Kaludjerovača, Velika Rutulja in dr.) je bila ELA na 1950 m n. v., na vzhodnem delu (Debeli namet, Savin kuk, Korito, Mliječni do in dr.) pa na 2100 m n. v. V južnem delu gorovja (Surutka, Vjetrena brda, Mali lomni do, Veliki lomni do, Zeleni vir) je bila ELA na 2080 m n. v., v zahodnem delu (Škrke, Škrčko ždrijelo) pa na 1950 m n. v. V tem poledenitvenem obdobju je bila povprečna vrednost ELA 2020 m n. v.

V osrednjem delu Prokletij je bila ELA v prvem obdobju poledenitve na višini 1750 m n. v., v drugem na višini 1942 m n. v. in v tretjem na višini 2123 m n. v. (Milivojević in ostali 2008).

Na gori Pind je vrednost ELA za najstarejši glacial 1700 m n. v., v naslednjem obdobju poledenitve je bila ELA na višini 1890 m n. v., v zadnjem poledenitvenem obdobju pa na višini 2125 m n. v. (Hughes 2006, 51).

Preglednica 1: Obdobja poledenitve na Durmitorju.

starejše obdobje poledenitve	mlajše obdobje poledenitve	obdobje krnične poledenitve	sodobno obdobje poledenitve
67 km^2 54 % površine Durmitorja	44 km^2 36 % površine Durmitorja	3,9 km^2 3,2 % površine Durmitorja	0,05 km^2 0,04 % površine Durmitorja

Na Durmitorju je bila vrednost ELA zmeraj nekoliko višja kot na gori Pind in v osrednjem delu Prokletij. Število obdobij in približne vrednosti ELA so na Durmitorju, na gori Pind in na Prokletijah precej podobne, kar omogoča ugotavljanje ledeniške kronologije na Durmitorju. Tako kot je bila za Prokletije opravljena indirektna datacija starosti poledenitvenih obdobij (Milivojević in ostali 2008), je korelacija glacialnih obdobij in določanja njihove starosti možna le z goro Pind. Najnižjo poledenitveno enoto gorovja Pind (Tymphi, 2497 m) so datirali z uporabo uranovih izotopov in ugotovili starost večjo od 350.000 let (Woodward in ostali 2004; Hughes 2004). V naslednjem poledenitvenem obdobju so ledeniki segali do osrednjih delov dolin. To je bilo pred zadnjim interglacialnim obdobjem v Grčiji, to je pred 127.000 leti. Staroste zadnje poledenitve je bila na gori Tymphi ugotovljena z radioogljikovo metodo in sicer na 14.310 ± 200–13.960 ± 260 ^{14}C let BP (Woodward in ostali 2001).

Na podlagi korelacij, lahko sklepamo, da je bila najstarejša poledenitev Durmitorja v zgodnjem ali srednjem Würmu, mlajše poledenitveno obdobje tekom zadnjega poledenitvenega maksimuma in pa obdobje krnične poledenitve v mlajšem drijasu.

6 Sklep

V pleistocenu so na Durmitorju obstajali številni ledeniki. Predhodni, preglacialni kraški relief, kakor tudi položaj v razmerju do gibanja vlažnih zračnih gmot so odločilno vplivali na nastanek in obseg ledenega pokrova na tem gorovju, kakor tudi na smeri gibanja ledenika. Kraški tip glaciacije je vplival na to, da so imeli ledeniki dolinskega tipa veliko pritokov. Vzrok za tako stanje je obstoj večjega števila predglacialnih kraških oblik, ki so bile med poledenitvijo spremenjene v krnice oziroma. Velike kraške preglacialne oblike so pogojevale ne le konvergenco ledenika k njim, temveč tudi razlivanje ledene gmote iz njih in gibanje ledenikov v različne smeri. Prav tako so v reliefu Durmitorja ohranjeni deli starih (pliocenskih) planot, ki so med poledenitvijo vplivale na nastanek malih krniških in planotastih ledenikov. Ledena gmota iz teh ledenikov se je gibala v različnih smereh.

Ledeniki so v dveh obdobjih poledenitve (starejše močnejše in mlajše šibkejše) nenehno prekrivali velike dele gorovja. V zadnjem obdobju so se ledeniki ohranili samo v krnicah. Zmanjšanje intenzitete poledenitve je vplivalo na ustavitev pretoka ledenika preko visokih sedel, zato se je gibanje ledene gmote usmerilo v eno smer, ne pa v več smeri, kot se je dogajalo prej. Z zmanjšanjem intenzitete poledenitve se je zmanjšal tudi obseg razprostiranja ledenika, zaradi tega pa je nastalo večje število manjših ledenikov, ki so bili po svoji dolžini in masi veliko skromnejši kot ledeniki v predhodnem močnejšem obdobju. Poledenela površina je bila v starejšem obdobju okrog 54 %, potem pa okoli 36 % skupne površine Durmitorja. Po dveh obdobjih kontinuirane poledenelosti Durmitorja je nastopilo obdobje krnične poledenelosti, ko so se ledeniki zadrževali na dnu dolin prej nastalih krnic. Njihov obseg je bil odvisen od krajevnih razmer (lega). Take razmere so se obdržale do danes, in jih predstavlja le en dolinski ledenik – Debeli namet.

7 Literatura

Glej angleški del prispevka.