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Geo-values of the natural monument Markovi Kuli near Prilep

Геовредности на споменикот на природата Маркови Кули кај Прилеп

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Abstract

Located on the southwestern branches of Babuna Mountain, north of Prilep in North Macedonia is the Natural Monument Markovi Kuli – a geosite with an exceptional weathering landscape. It is a host to a vast variety of weathering landforms (boulders, pillars, weathering pits, tafoni, etc.), mainly due to the lithology where Proterozoic gneiss rocks are intruded by Late Paleozoic granitic rocks. In addition, landform development is also controlled by the local climate conditions. As a result of its geomorphological significance, in 2004 Markovi Kuli geosite was placed on the tentative list of UNESCO World Heritage, and in 2006 it was proclaimed as a Natural Monument, within the network of protected areas in Macedonia. However, despite its geodiversity being the cornerstone of its significance, not many geomorphological studies have been made so far. Considering that, and especially the necessity for the effective protection of the area, the results of the latest research are presented in this work.

Keywords: Markovi Kuli, geodiversity, weathering, protection.

Апстракт

Споменикот на природата Маркови Кули се наоѓа на југозападните ограноци на планината Бабуна, северно од градот Прилеп, Северна Македонија. Тоа е геолокалитет со извонреден денудациски релјеф (блокови, остенци, каменици, тафони и сл.), создаден главно како резултат на специфичната литологија, каде младо-палеозојските гранити се втиснати и пробиени низ протерозојски гнајсеви. Покрај тоа, важен фактор за формирање на денудацискиот релјеф имала и локалната клима. Поради геоморфолошките вредности што ги има, во 2004 година локалитетот Маркови Кули е ставен на привремената листа на УНЕСКО, а во 2006 година е прогласен за споменик на природата, како дел од мрежата на заштитени подрачја во Македонија. Сепак, без оглед на фасцинантниот геодиверзитет, досегашните геоморфолошки истражувања на овој простор се релативно скромни. Имајќи го во предвид тоа, како и потребата од ефикасна заштита, во трудот ги презентираме резултатите од најновите истражувања на овој геолокалитет.

Клучни зборови: Маркови Кули, геодиверзитет, денудација, заштита

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Introduction

Geoheritage is a widely recognized concept within science, outreach and conservation which underpins various activities undertaken at regional, national, and international level focused on protection, better understanding of the Earth history, bridging the gap between science and the public, and the development of sustainable tourism. Two global initiatives implemented under UNESCO, explicitly address the international significance of geoheritage, including UNESCO World Heritage, within which areas may be inscribed on the World Heritage List in recognition of the outstanding universal values of its geology and geomorphology, and UNESCO Global Geoparks, which requires from the aspiring geoparks to have "geological heritage of international significance" (Brilha, 2018; Migoń and Maia, 2020). Both these global undertakings have their limitations, and are unable to provide an adequate framework to protect all key geoheritage sites, thus another initiative is proposed nowadays, to work towards the network of Key Geoheritage Areas (KGAs) which would include localities selected purely on the basis of their significance for geosciences (Ju and Woo 2018; Woo et al. 2018). Although of relatively small area, North Macedonia has rich geodiversity and numerous geomorphological sites. Currently the network of protected natural sites includes 86 localities (covering 8.9% of the national territory), from which about 26 are geoheritage sites (Milevski and Temovski, 2018). One of them is the Natural Monument Markovi Kuli (in further text "NM Markovi Kuli") that covers the hilly-mountain area of Zlatovrv, named after its highest peak (1422 m). According to the number, variety, and representativeness of the weathering landforms in granitoid rocks the "NM Markovi Kuli" is one of the few exceptional in Europe and wider. The main factors for morphogenesis and morphological evolution of this richness of forms are the lithology, the climate, the topography, the biosphere, and the anthropogenic factor as well. The earliest geomorphological research of this area began in the early 20th century. The pioneering work of Radovanović (1928), that gives a detailed description, and an interpretation of the formation of various morphological forms, as well as their morphological classification, was of highest importance and it remained to this day the most important work on the geomorphology of this area. His study of the weathering landscapes of Markovi Kuli and the Selečka Planina for a long period was the basis for research on similar phenomena on the Balkan Peninsula. Later followed, several predominantly geological, studies of this area and the wider surroundings by Arsovski (1960), Stojanov (1974), Dumurdžanov (1985), Jančev (1991) and the others. Gavrilović (1965) contributed to the geomorphological knowledge of the microforms of this site, while Kolčakovski and Gjorgieva (2001) made a hierarchical classification of the site. In 2004, Jančev and Anastasovski gave an overview of the basic natural characteristics of the granite near Prilep, and Jančev (2008) prepared a detailed study for the "NM Markovi Kuli" in which he pays attention to the geological and geomorphological features of this area. However, regardless of the above-mentioned research, there is no adequate answer to many questions about the genesis, morphology, and evolution of weathering forms of NM Markovi Kuli.

Due to the unique geo-values that it has, this granitic complex, became a protected area as early as 1965, according to the "Law on Protection of Natural Rarities" at the time. In 1967, with the decision of the Republic Institute for the Protection of Monuments of Culture, the geo-complex "Markovi Kuli" was placed in the category of Natural Monuments. In 2004, "NM Markovi Kuli" was listed on the UNESCO World Cultural and Natural Heritage Tentative List, and in 2006 was proclaimed as a Natural Monument under the new "Law on Nature Protection".

Study area

Geoheritage site "NM Markovi Kuli" is hilly-mountain area located in the central part of North Macedonia, just north of the city of Prilep, and it is the southwest branch of the Babuna Mountain. Morphologically, Zlatovrv is bordered with the Stara Reka valley to the north, Prilepska Reka to the south, and Prilep Plain to the west and southwest, covering an area of 45 km^2. The whole site has an average height of 875 m, and it ranges from 650 m at the foot to 1422 m at the highest peak Zlatovrv (Fig. 1).

In the zone of strict protection, the highest area covers the terrain between 900 and 1000 m (23.5%), while in the zone of active management the terrains at a height between 800 and 900 m (37.8%). The sustainable use zone, along with the outer buffer zone, extends predominantly in the hypsometry zone from

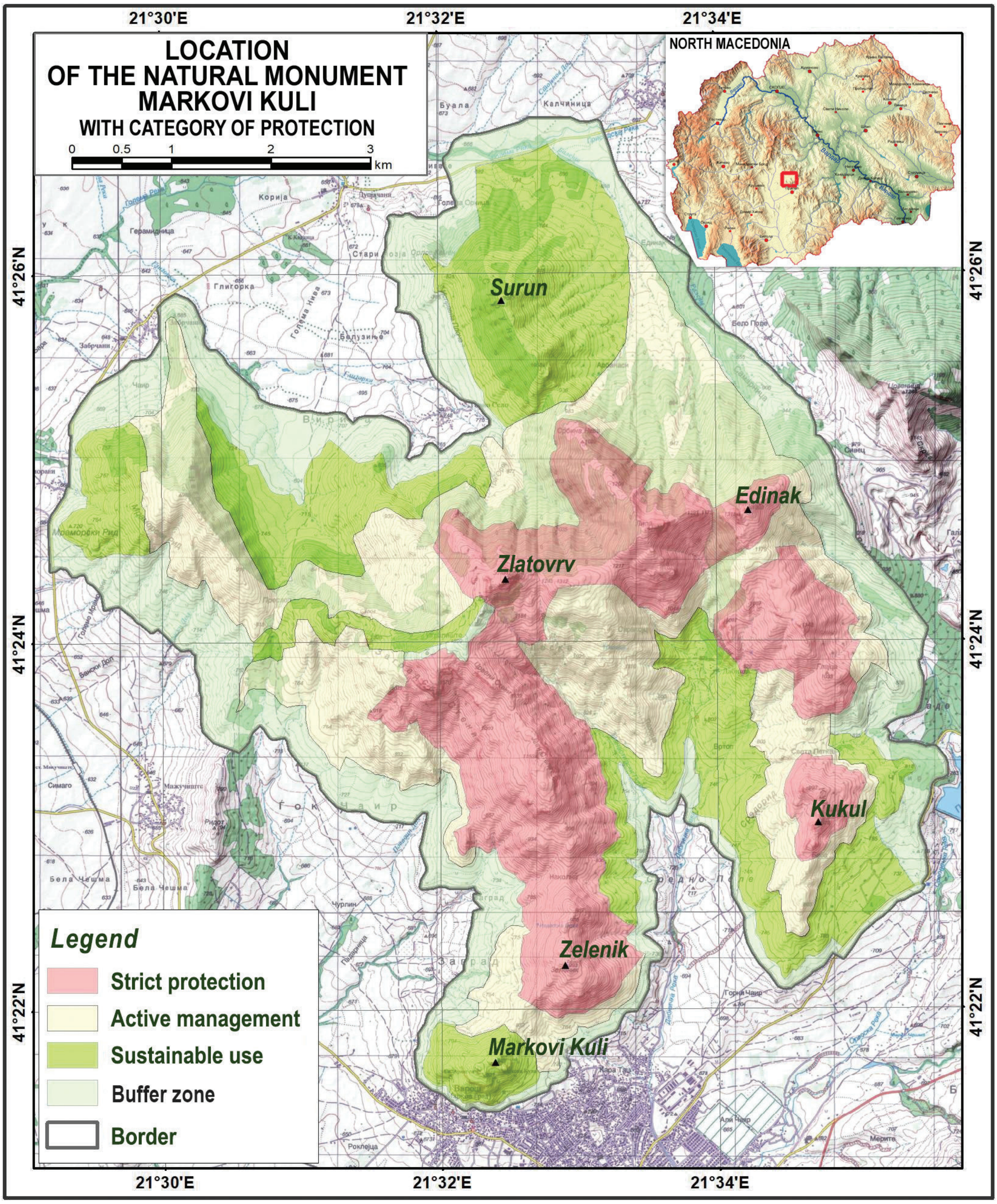

Figure 1. Map of the NM Markovi Kuli with the relevant categories (zones) of protection.

700 to 800 m, with 55.6 %. In terms of slopes, the entire site is dominated by steep slopes (20-40°), which account for 41.5%, while the average slope of the entire site is 19°. The dominance of the west and southwest aspects is noticeable, which together account for 32.8% of the total area. As sun-facing aspects, they have the longest exposure of granitic rocks to direct solar radiation, which in turn affects the decomposition and destruction process. Unlike sun-facing aspects (southeast, south, southwest, and west), which together account for 54%, north-facing (shaded) slopes occupy 46%. The most remarkable and most characteristic granitic landforms are located within the zone of strict protection, which covers the highest and steepest parts of the natural monument.

The area of "NM Markovi Kuli" is mostly built of granitic rocks (monzonite granites and granodiorites), which penetrate through the coarse-grained and porphyroblastic gneisses

(Rakičević et al., 1965; Stojanov, 1974: Dumurdžanov, 1986). The boundaries of the granitic rocks with the gneisses towards the west and northwest are unclear and gradual, while to the east they are sharp. The granitic rocks appear in the form of sills and dykes with a meter to decameter dimensions (Jančev, 2008). The granitoids are predominantly coarse-grained to porphyroid, with varieties having larger porphyroid feldspar minerals being found in the central part of the massif, around Zlatovrv (Fig. 2).

In the case of gneisses, coarse-grained varieties are predominantly represented. In the eastern part, mica-schists are in contact with gneisses. Regarding tectonics, "Markovi Kuli" geosite is a part of the Prilep anticline (Arsovski and Dumurdžanov, 1984; Arsovski, 1997) orientated in NW-SE direction, in which the central parts are built in granite, and the sides are in gneisses and mica-schists. It is cut with a system of fractures predominantly

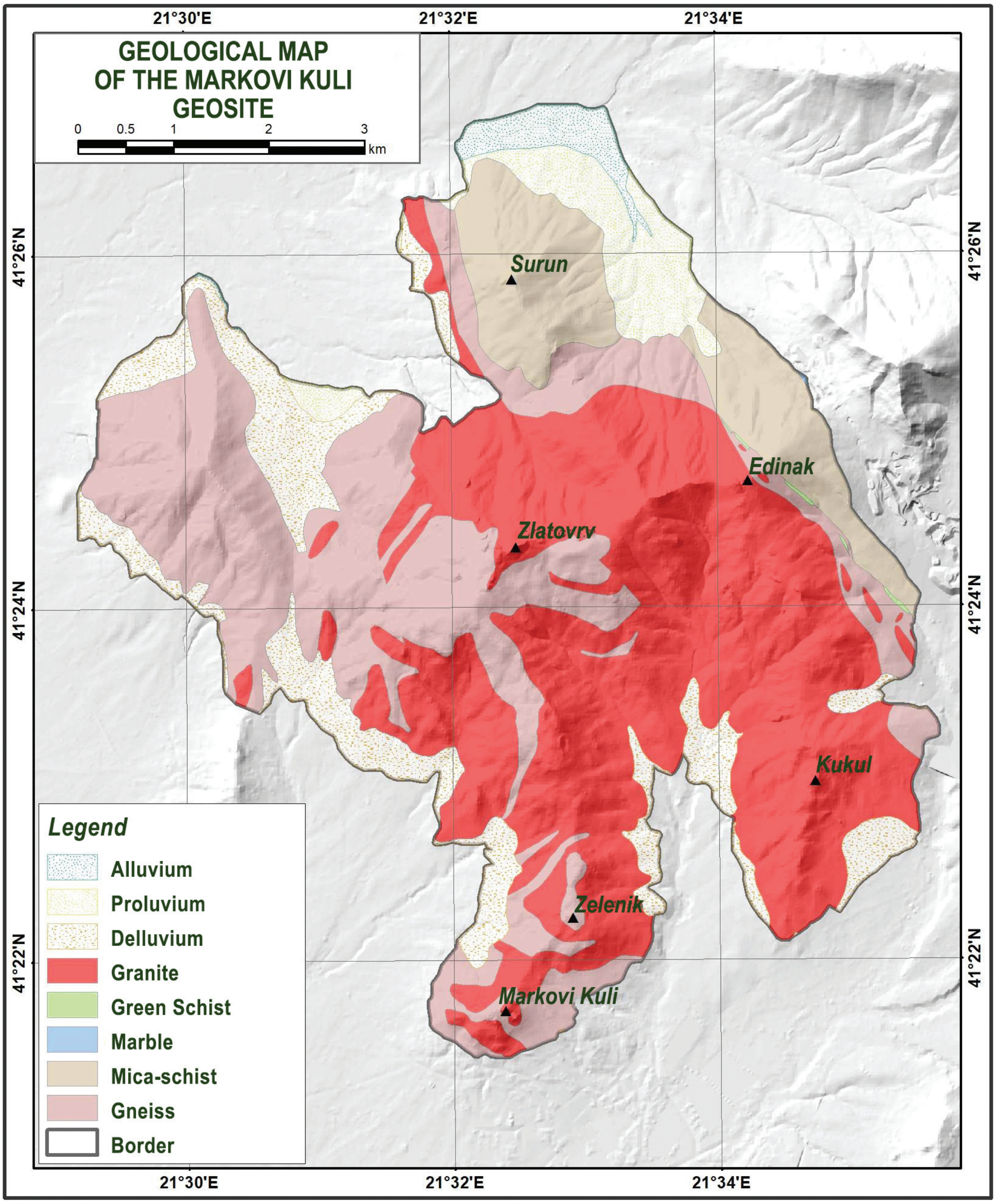

Figure 2. Geology of the NM Markovi Kuli (according to Rakićević et al., 1965).

of NNW-SSE and E-W direction, which in combination with the curved fracture systems formed during the embossing of the magma, partitioned the entire geosite in smaller boulders (Jančev and Anastasovski, 2004).

Climate in this area is temperate with relatively cold winters with temperatures around 0°C, and warm and dry summers with temperatures around 30°C. Long-term average temperature in this area is around 11°C, with extreme values between -25°C and 40°C, while average precipitation sum is about 500-600 mm/y.

Vegetation is represented mostly by grasslands and individual trees and bushes, while soils are poorly developed with leptosols, regosols etc.

Methodology

During the initial phase of this work, the available relevant bibliography considering weathering landforms of Markovi Kuli area and the similar sites worldwide (in the form of papers, reports, topographic and geological maps, etc.) was collected and analyzed. After that, several field prospections, recordings, and measurements were made of various morphological features to get a better idea of their genesis and evolution. During the field research, numerous terrestrial and aero (drone) recordings were performed, with the help of which a more precise digital altitude model was made and an ortho-photo recording was obtained. The collected materials from the field helped for further analysis of the denudation forms over the entire space of the „NM Markovi Kuli". A summary of the obtained results is presented in this paper.

Results

The main natural value and uniqueness of this site is the excellent diversity of weathering forms, which is mainly due to the terrain lithology, represented by granitoid rocks (Prilep granitoid complex) imprinted and protruded through the older gneiss. Because of the heterogeneous mineralogical composition they have, these rocks are susceptible to significant underground and surface selective erosion. In the territory of Macedonia, more significant granitoid complexes are the base of several mountains, such as Ogražden, Selečka Planina, Golak, Bejaz Tepe, etc. However, unlike Markovi Kuli, in these mountains, the diversity, abundance, and the number of the forms are far smaller. This is because apart from the lithology, several other factors (e.g. tectonic, climate, biogenic) acted in optimal combination, which allowed the occurrence of fascinating and unique weathering landforms.

Recent work on the geomorphology of granite landscapes classifies the landforms appearing on granite terrains by size into two general groups: primary and secondary (Migoń, 2006). Inselbergs, tors, and boulders are considered as primary forms. Their distinction and classification are not always easy and simple. Small weathering forms, such as weathering pits, tafoni, alveoes, granite karrens, and flare slopes, are considered as secondary ones. This basic classification of granite rock weathering forms does not differ much from the classification of Radovanović (1928), which in addition to the class of "gramada" (that directly compares to inselbergs) as the largest form, classifies the smaller ones as: piles of boulders; groups of boulders; isolated and covered pillars and boulders; and identifies smaller depressions in gneiss rock (nest-like holes and gneiss caves).

Inselbergs

Inselbergs are the largest forms in the granitic complex of Markovi Kuli. These are characteristic, relatively isolated rocky hills with steep sides, which rise abruptly from relatively flat or slightly inclined terrain. Due to the strength (resistance) of the rocks from which they are built, the inselbergs are strikingly stiff in the landscape and are characterized by steep (> 20°), mainly rocky sides. According to Migoń (2006), in terms of dimensions, they can have a diameter of several tens of meters, up to several km, and the height is usually from 50 to 500 m. In that sense, observed as a whole, the entire granitic complex Markovi Kuli can be considered as a huge inselberg that rises from the Prilep Plain. If considered in detail, then a dozen separate, relatively large inselbergs can be identified, grouped in two parallel sequences with the general direction of SE-NW. In the western line are the inselbergs: Markovi Kuli (945 m), Zelenik (993 m), Javi Steni (1153 m), Zagradski steni (1231 m) and Mramorski Rid (988 m). In the eastern line, from the south to the north are the inselbergs: Kukul (992 m), Glavica (1033 m), Edinak (1303 m), and Surun (1077 m). The two chains of inselbergs are separated from each other by the valleys

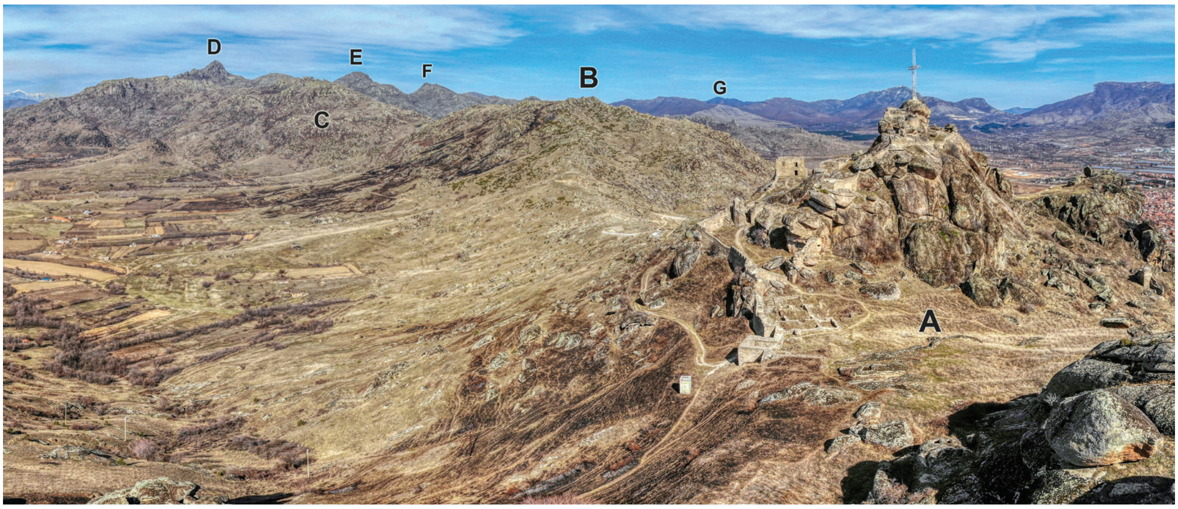

Figure 3. Primary inselbergs: A. Markovi Kuli (945 m); B. Zelenik (993 m); C. Javi Steni (1153 m); D. Zlatovrv (1422 m); E. Lipa (1392 m); F. Edinak (1303 m); G. Kukul (992 m).

of Dabnička Reka (in the south) and Gligorka (in the north), while in the middle part they are connected with the highest inselbergs of this area, Zlatovrv (1422 m) and Lipa (1392 m), which extend into transverse direction SW-NE (Fig. 3). All of these inselbergs have a diameter of about 1 to 3 km and a relative height of 200 to 500 m. Within the above-mentioned inselbergs, which we can consider as primary, smaller or secondary inselbergs

Figure 4. Part of the characteristic tors along the sides of the Markovi Kuli hill (inselberg).

can be identified, having a diameter of 50-300 m. Thus, only the Markovi Kuli hill has 8 secondary inselbergs with a diameter between 50 m and 100 m and a height of 20 m to 80 m on which numerous tors, boulders, and microforms appear. Regarding the above, the inselbergs can be considered not only as of the largest and most distinctive forms of the granitic complex Markovi Kuli, but also as the primary forms structurally constrained by the original emplacement of magma in the surrounding rock masses.

Tors

Tors are smaller rocky hills that are abruptly rising from the surrounding terrain, that is, from the inselbergs of which are most often "inoculated". According to the dimensions, they usually have a diameter of 20 to 30 m and a height that rarely exceeds 15 m. Their shape is formed mainly by the system of dominant fractures along which distinct parts separate. In the tors of the Markovi Kuli area, two vertical and horizontal fracture systems are dominant. Depending on the shape, and as a result of the lithology, the direction and the extensions of the fractures and the evolutionary stage, several types of tors can be distinguished here: castellated, dome-like, tower-like, lamellar tors. In the castellated tors, the fracture density and pattern is quite regular, in the tower-like tors, vertical cracks are dominant, and in the lamellar tors, horizontal cracks dominate (Fig. 4).

The formation of the tors is related to the selective weathering of the granitoid bedrock along the fracture systems under the surface, forming a so-called mantle of decomposition (Migoń, 2006). The weathering proceeds under the action of exogenous agents after exposure at the surface of the weathered front. However, certain tors may also occur by decomposition of the inselbergs along vertical cracks systems. With the further weathering process, tors can be disintegrated in the form of pillars, but also completely torn off and fall into the base in the form of boulders. Thus, on numerous tors there are striking traces of freshly broken boulders usually collapsed at the foot.

Boulders

Granite boulders represent independent, partially rounded rocks, poorly connected or generally unrelated to the parent rock at the base and with a diameter usually greater than 1 m. They occur in isolation or groups, on flat or sloping terrain, and are often "scattered" along the sides of themselves inselbergs (Fig. 5). Accordingly, the main difference from tors is their poor connection to the bedrock and the absence of major primary fractures (Twidale, 1982). Due to the complex and long-lasting process of formation, numerous cubical, mushroom-like boulders, etc. have been observed in the area of Markovi Kuli. Usually,

Figure 5. Various forms of boulders on the NM Markovi Kuli.

they have a diameter between 1 and 5 m, but there are also larger ones.

Radovanović (1928) identified three morphological groups of boulders: piles of boulders, groups of boulders, and isolated boulders. Additionally, in the forested parts of Kajmakčalan, further to the south, he defines a fourth group, hidden (covered) boulders, buried by a weathered mantle of gneiss gruss. Their position is tied to the general morphology of the terrain, with the piles of boulders generally located at the steep sides of high ground (e.g. ridges), where the erosion is the strongest. Boulder groups and isolated boulders appear generally on slightly sloping and flat terrains. This classification of Radovanović (1928) corresponds well to the contemporary understanding of the genesis and evolution of tors and boulders (Migoń, 2006), that follows the erosion of the weathering mantle formed along fractures systems around more resistant granite parts, i.e. corestones.

Isolated boulders are common in the area, with quite diverse morphology that mainly follows a combination between polyhedron and oval forms (egg, elliptical). Thus, numerous isolated boulders that are flat-topped, mushroom-shaped, pillar-like and castellated can be found, while the most common form being spherical and cuboid shape. The genesis and evolution of boulders have not been fully understood yet. It is generally thought that the boulders have a »double« genesis, i.e. many of them begin to form below the surface, mainly by the selectively weathering of the fracture-separated rocky cores at the initial tors, with a weathering mantle formed around them (Migoń, 2006). With the gradual, slow erosion of the mantle and their exposure at the surface, the evolution continues with the action of external agents, i.e. denudation processes, flaking, fragmentation, and disintegration of the less resistant parts.

Small weathering forms

Secondary or micro-relief landforms encountered in the granitic complex near Prilep, are the various hollows in granitoid rocks. They give the characteristic microstructure of the larger forms and result from the different resistance to weathering of the minerals from which the rocks are composed. Thus, potassium feldspars, as more soluble, are more quickly eroded than the parts in which quartz minerals prevail, allowing the formation of tafoni, weathering pits, etc. The difference occurs in the fact that some of the shapes appear on a vertical or steep surface and others on a flattened to a horizontal surface.

Weathering pits

Among the most typical small landforms on exposed horizontal granite surfaces are depressions with a circular, elliptical or irregular shape, the diameter of which is 20 cm and up to over 2 m. In literature, they are known also as "kamenica" (Gavrilović, 1965). In the area of Markovi Kuli, there are a huge number of weathering pits whose diameter reaches up to 3 m. However, it should be noted that some of them have an anthropogenic origin, carved in the past for the collection of atmospheric water or the as graves (Fig. 6). Typical weathering pits are created on horizontal or nearly horizontal surfaces where there are suitable conditions (unevenness) for longer retention of rain water.

The initial hollows are the result of local lithologic differences on the rock or the surface removal of weathered rocky parts. The water in such places, with its chemical influence, slowly and permanently decomposes the bedrock minerals, so that, with the breakdown of less-resistant parts, the bond between the other minerals weakens. From the decayed minerals, clay is formed at the bottom of the weathering pit, while from the more resistant gruss-like (clastic) sediment is formed, which is transported in the nearby environment by the action of winds and water. With the constant repetition of this process, the weathering pit is deepened and, in this way, various shapes are formed. Lithophytes (lichens and mosses) also actively participate in their formation, either through biochemical processes or by contributing to the retention of water and thus facilitating the weathering process.

Our field observations indicate that the coarse-grained granitic rocks, that have approximately horizontal upper surface, are most common places for the initiation of the weathering pits. Generally, it is considered that the wind (deflation) is a very important agent for the removal of the weathering residue from the hollow. However, recent research shows that this is only the case when the hollow is very shallow, and as it becomes deeper, the effect of the wind becomes minor to insignificant (Migoń, 2006). This means that the rate of deepening of the weathering

Figure 6. Typical weathering pits filled with water under Zlatovrv inselberg.

pit diminishes with its increasing depth, as it is becoming progressively more difficult to remove the weathering residue. Therefore, in the area of Markovi Kuli, the weathering pits rarely have a depth greater than 10 to 20 cm. In the initial phase of formation, the weathering pits generally have circular, elliptical, trough-like or similar shape. As far as the age of these forms is concerned, it is difficult to estimate without detailed radiometric dating, but if they are naturally formed and larger than a few tens of cm, it can be assumed that they are probably at least several tens of thousands of years old. In any case, the speed of their creation depends on the mineralogical composition of the rocks, climatic conditions, and biogenic impacts.

Tafoni

Contrary to the weathering pits that appear on predominantly horizontal surfaces, the tafoni are depressions that usually occur on predominantly vertical sides of the granitoid rocks (Fig. 7). They usually have a spherical concave appearance, with a diameter of 10 to 30 cm, and appear in groups of several to a dozen. Accordingly, tafoni can be defined as spheroidal depressions on steep to vertical

Figure 7. Tafoni and alveoles under the Markovi Kuli hill (left) and Kukul (right).

rocky sides, with an arched, concave hollow upper side where traces of spalling and flaking of the rock are observed (Migoń and Maia, 2020). At the Markovi Kuli site, this phenomenon is quite common, especially on the tors and larger boulders. Regarding local distribution, there is no pronounced regularity, although it can be said that they are often noticed on the south-, southwest- and west-exposed sides. Regardless of the numerous studies carried out so far in various parts of the world, the origin of these forms hasn't been fully clarified yet. Two opinions about their formation prevail (Migoń, 2006). According to one, the tafoni were initially cavities filled with non-resistant material, which can hardly be confirmed. Most likely they are the result of selective erosion of a locally less-resistant rocky part or a pegmatite vein, forming a shallow hollow, which then increases due to the action of exogenous agents (rain, wind, living organisms). It means that the initial condition in the development of the tafoni is the heterogeneity in the composition of the rock and the greater susceptibility to denudation in certain places.

The second explanation is that the initial tafoni formation begins in sub-surface conditions due to strong selective erosion at contact with the wet soil. Additional mechanism that can be identified is the spalling and flaking of a rocky surface that is firmer, exposing the softer and less resistant parts of the rock that erode much faster than the part covered by a compact and sturdy "rocky crust". As for the rate of tafoni formation in the NM Markovi Kuli, based on other examples throughout the world, this process is going very slowly. This can be deduced from the absence of such forms at very old buildings from granite rock (megaliths) and even from granite boulders exposed to atmospheric influences after the last glaciation, about 12,000 years ago (Migoń, 2006). Accordingly, probably the tafoni in the area have an age of at least a few thousand years.

Alveoles are shallow ditches that occur in groups of several dozen so that they give a honeycomb appearance on a part of the rock (honeycomb decay). Similar to the previous microforms, they are assumed to be the result of selective erosion due to the heterogeneous mineralogical composition and the difference in the resistance of the rock (Twidale and Romaní 2005). In the area of the Markovi Kuli alveoles are observed at numerous sites in the form of groups of small cavities whose number is above one hundred.

Flare slopes

Characteristic phenomena in several tors in the Markovi Kuli area are the presence of flare slopes or concave sides toward the base of the rock. This is a concave part of the sides of the granitic rock, whereby the concave slope is usually typical for the entire side of the rock or only for its lower part. The occurrence of such concave slopes is considered to be the result of selective erosion while exhuming the rock to the surface and in the presence of a large amount of moisture in that area (Twidale, 1982). This means that such a concavity is formed at the near-surface part of the land, in the contact with the

Figure 8. Characteristic flare slopes of exposed granitoid boulders.

weathering mantle, when the rock is not yet fully exposed at the surface. This is evident from the field where it is seen that such concave sides continue under surface into the soil. By exposing the tor to the surface, the process continues with mechanical, chemical, and biogenic weathering, and the concavity increases further (Fig. 8).

Formation of the Markovi Kuli's geosite

The main factor for creating of such typical weathering forms on the Markovi Kuli site is the lithology. Studies in different parts of the world show that on the exposed granite rocks, characteristic landforms and complexes are usually created, which can't be found on other types of rocks. The granitic rocks in the Markovi Kuli area were created mostly by melting the deepest parts of the lithosphere, and later followed by a process of their imprint and protruding through the older gneisses. In this process, by reducing the internal pressure and relaxation of the intruded mass, there was a fracturing of the granites and the creation of numerous systems of spheroid (relaxation) fractures. This means that the primary form of the granite mass is created deep in the lithosphere in the form of arches and large embedded bodies. With their further evolution, through their tectonic uplift towards the surface, they became exposed to sub-surface weathering along fault and fracture structures of different directions. After the surface of the granite rock was exposed, the surface denudation begins. In those micro-sites on the granite where there are locally increased concentrations of potassium feldspar (orthoclase, microcline, etc.) in the form of lenses or veins, various depressions are created (Twidale and Romani, 2005). Namely, potassium feldspar is the least resistant to exogenous processes due to the removal of potassium from the crystal lattice, which is taken as a soluble cation from surface and groundwater. Due to this chemical dissolution and destruction of the crystalline lattice of potassium feldspar, the surface of the rocks is becoming more brittle, disintegrating, and the granite is locally partially changing to a thin scaly shell that is slowly consumed due to the transformation of feldspars into clay minerals. Due to the same process, some of the mineral constituents from which the rocks are formed (quartz, feldspar and mica), lose their connection, forming a coarse-grained material, i.e. granite gruss. In parallel with the chemical decay, the process of physical degradation (thermal and biogenic disintegration) takes place. Recent experimental studies (e.g. Allison & Goudie, 1994) indicate that fires can also have an effect on disintegration of granite rocks, with also severe weather events (lightning, sudden changes in time, hail) likely having an effect.

The presence of Pliocene lacustrine sediments in the vicinity at up to 900 m of elevation, show that during Neogene, and possible also part of Quaternary, part of the granite complex in Markovi Kuli was covered and only small area raise above, in the form of island, within the large Pelagonian lacustrine basin. The low slope terrains within the area, at the elevation of 800-900 m, likely correspond to former coastal terraces. Only after the draining of the Pelagonian Lake in Early-Middle Pleistocene the lacustrine sediments were eroded, exposing underlying granitoid rocks to surface processes. In this sense, the forms that we see today were successively exposed at the surface, and that process with erosion and transport of sediments and less-resistant rocks around the granitic complex will continue in future.

Conclusion

Given the abundance of various denudation landforms in the granitoid rocks, and on the basic of the available literature, it follows that NM "Markovi Kuli" is unique and highly valuable geosite in this part of Europe. Here, in a small area of only 45 km^2, almost all landforms typical for terrains built of granitic rocks, such as primary and secondary inselbergs, tors, boulders, tafoni, alveoles, weathering pits, flare slopes, etc., are found. This diversity intrigued earlier researchers, with initial research of this area starting in the early 20th century, especially with the important work of Radovanović (1928). However, his knowledge hasn't been significantly increased to date, especially from a geomorphological aspect, and what has been done is not adequately presented to the wider international scientific public. In that sense, more detailed research is needed, in which the latest approaches and technologies will be used. In parallel with further scientific research, it is also necessary to promote this Natural Monument as a unique geosite. At the same time, functional protection of this unique natural monument is necessary, with strict adherence to the

"Law on Proclamation of Natural Monument “Markovi Kuli" and the restrictions regarding the defined protection zones. Meanwhile, a number of degradation processes are observed in the area of this geosite. Namely, a number of clearly visible graffiti, signs, etc. are drawn on more remarkable forms, leaving a negative impression and affecting the micro-erosion processes (Fig. 9). To prevent this, it is necessary to educate the local population about the importance of preserving the natural appearance of the forms, as well as to indicate such information and warnings on locally placed information boards. Additional degradation are the small landfills located near the boulders and tors in the lower elevation zone of the area. Another issue is the length of the paved roads and the number of trekking paths on Markovi Kuli which is relatively large, especially considering the total area.

In that sense, it is necessary to reduce the number of roads that are actively used, to select and arrange the most appropriate ones according to the weight of movement and thematic subject. The roads should be arranged in such a way that they do not significantly change the landscape or cause further erosion. In addition to the above, anthropogenic degradation include driving with off-road vehicles and cross motorcycles, various other activities that are not appropriate for the size or capacity of this space and lead to its degradation. It should also be mentioned that the unplanned and unregulated expansion of the settlements around Markovi Kuli, moving closer to the borders of the protected area, as well as the pressure for granting concessions for quarries are also an increasing threat. On the other side, outdoor activities that are environmentally sustainable, and at the same time they promote the remarkable features of the landscape, such as rock climbing and bouldering, paragliding, mountain running and orienteering, should be further developed. The ultimate goal would be for NM »Markovi Kuli« to become UNESCO World Heritage site, UNESCO Geopark, or at least Key Geoheritage Area. Further studies will show which category is most suitable and most possible for this geoheritage site.

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Figure 9. Examples of degradation of the weathering landforms in NM "Markovi Kuli".

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