ISSN 2519–2620. Проблеми геоморфології і палеогеографії... 2019. Вип. 1 (9), 117–132

УДК 551.4; DOI 10.30970/gpc.2019.1.2806

MORPHOLOGIC CLASSIFICATION OF THE BESKIDS ROCKS IN THE UKRAINIAN CARPATHIANS

Galyna Bayrak
Ivan Franko National University of Lviv
g_bajrak@ukr.net; orcid.org/0000-0002-4802-2706

Abstract. The article deals with morphological classification of the sandstone rocks in the Ukrainian Carpathians Beskids. By the methods of field measurements and mathematical computations the rock peaks heights, their shape, basement lengths and strata thickness have been calculated. The highest rock peaks in the Beskids amounts 32–37 m. The classification from the morphological point of view on the base of rock forms studying has been done. All rocks are divided in two classes: the rocks-outliers and the rocks-outcrops. Among the rocks-outliers 4 types are defined: spire-shaped, chain-shaped, arc-shaped and combined. Spire-shaped rocks are divided into subtypes: tower, spoke and needle. Among the chain-shaped rocks 3 subtypes are defined: wall, bloc and slab. The rocks of combined form are divided into subtypes: 1) with defined form – those of the rocks which are similar to certain objects and 2) undefined forms (cliffs). Among the rocks-outcrops three types are defined: cliff-shaped, canyon-shaped and angular ones. The class of rocks-outliers occurs most often. Among the types the rocks-towers occur most often. They dominate in the rock formations of Urych, Yamelnytsia and Bubnyshche. Many bloc-shaped and plate-shaped rocks are located on the Kliuch Ridge, in Bubnys'ki Rocks, Yamelnytsia. There are rocks-walls of 50–60 m in Urych and Yamelnytsia. The longest rock-wall in Danylov tract near Yamelnytsia has been investigated. Its length is 150 m and height is 17 m. Some needle and spoke rocks are situated in Bubnys'ki Rocks (Odinets' Rock, Golets' Rock) and Urych (Hostryi Kamin' (Sharp Stone) Rock. Unique types are very rare. For instance: Bronenosets' Rock in Bubnys'ki Rocks (this rock has shape of sail), Sokil (Falcon) Rock in the Kliuch Ridge, mushroom-shaped rock in Yamelnytsia. There is also unique arc-rock in the Kliuch Ridge. In the class of rocks-outcrops the types of cliff and canyon occur equally. The angular-shaped rocks are rarer. The cliff-shaped rocks are situated near Sokolova Mountain, Pozhernytsia Mountain and Kniazhi (Princes) Rocks near Tyshivnytsia. Unique rocks-canyons, the effects of tectonic breaking and gravity-erosion processes, occur on the Kliuch Ridge. The worked out morphological classification of rocks can be used by ascertaining features of rock morphogenesis with education and scientific purposes as well as by assessment of safety level and protection possibilities. Morphological types of the rocks can be considered as valuable objects of geomorphologic heritage and attractions for geo-tourism.

Key words: rocks; morphology type of the rock; rock shape; Beskids of Ukrainian Carpathians.

МОРФОЛОГІЧНА КЛАСИФІКАЦІЯ СКЕЛЬ БЕСКИДІВ УКРАЇНСЬКИХ КАРПАТ

Галина Байрак
Львівський національний університет імені Івана Франка

Анотація. Наведено морфологічну характеристику пісковикових скель Бескидів Українських Карпат. Методами безпосередніх польових вимірювань та математичних розрахунків обчислено висоти найбільших скель, визначено їхні форми, довжину основи

і товщину відслонень пластів. Найвищі висоти скель у Бескидах становлять 32–37 м. На основі досліджень форм скель, виконано їхню морфологічну класифікацію. Всі скелі поділено на два класи: скелі-останці і скелі-відслонення. Серед скель-останців відокремлено чотири типи: шпилеподібні, пасмоподібні, аркові та складних форм. Підтипи шпилеподібних скель – вежа, шпиця, голка; пасмоподібних – стіна, блок, плита. Скелі складних форм поділено на два підтипи: визначених форм – ті, які нагадують певні предмети; невизначених форм (брилові). У класі скельних відслонень виокремлено три типи: урвищеподібні, ущелиноподібні і кутові. Найбільше розповсюджений клас скель-останців, а серед типів – скелі-вежі. Вони переважають у скельних комплексах Урича, Ямельниці і Бубнища. Багато скель-блоків і плит на хребті Ключ, у Бубнищі, Ямельниці. Трапляються скелі-стіни довжиною 50-60 м в Уричі та Ямельниці. Досліджено найдовшу скельну стіну, яка розташована в урочищі Данилова в Ямельниці довжиною 150 м і висотою 17 м. Небагато виявлено скель із загостреними вершинами у вигляді шпиць та голок: у Бубнищі (“Одинець”, “Голець”) та Уричі (“Гострий Камінь”). Унікальні типи поширені мало: скеля Броненосець у Бубнищі нагадує вітрило; на хребті Ключ є скеля “Сокіл”; в Ямельниці – грибоподібні скелі. На Ключі є також унікальна аркова скеля. У класі скельних відслонень однаково розповсюджені типи урвищ та ущелин, менше поширені типи кутових скель. Скелі-урвища знаходяться поблизу г. Соколова, Пожерниця та “Княжі скелі” поблизу с. Тишівниця. Унікальні скелі-ущелини, наслідки тектонічних розривів та гравітаційно-ерозійних процесів, найчастіше трапляються на хребті Ключ. Розроблену нами морфологічну класифікацію скель можна використати для з’ясування особливостей морфогенезу скель з освітньою та науковою метою, для оцінки ступеня збереженості з природоохоронною метою. Морфологічні типи скель можна розглядати як цінні об’єкти геоморфологічної спадщини і високо атракційні для геотуризму.

Ключові слова: скелі; морфологічні типи скель; форми скель; Бескиди Українських Карпат.

Introduction. Rocks in Beskids are attractive tourist and well-known environmental sightseeing places of the northeast area of the Ukrainian Carpathians. Many of them have the status of historical, cultural or natural preserve object and are one of the main attractions of tourist routes. Rocks are interesting for their morphological forms and the more varied and massive they are, the more attractive they are for sightseeing and research studies. Rocks are associated with historical events in the lives of rusychs (poetic name of the inhabitants of Kievan Rus’), opryshkas (mountain outlaws), Sich archers and Ukrainian rebels. They are studied by ethnographers, archaeologists, geologists, geomorphologists, ecologists and local historian scientists. This indicates the interest of the scientific community in these objects, and requires performing detailed modern surveys and providing typology of the Carpathian rock formations.

The study of the morphological outlines of the rocks began with the study of the historical and cultural heritage of the region in the mid-nineteenth century. Thus, I. Vahylevych in 1843, studying the rocks in Urych, identified the following types of them: cliffs, towers, walls, crested rocks, spires, arches with piles (Vahylevych, 1993). V. Demetrykiewicz (1903) to define forms of rock formations on the slopes of the Carpathians used the terms “rounded boulders, peaks of billet-shaped form” (Demetrykiewicz, 1903).

The morphology of rock formations in the Karkonosha massif in the Polish Sudetes was carefully analysed by K. Mazursky (Mazurski, 1972). He identified four groups of

rocks: *a wall, a pillar, a slab and a block*. The formation of these types of rocks, according to K. Mazursky, was greatly influenced by the mutual relation of the plane of tectonic cracks and the direction of the ridge extensions: where the crack direction was transverse to the ridge extension, walls emerged; the longitudinal extension of cracks and ridges caused the formation of rock pillars or towers. In places of access to the surface of massive granites, where the role of tectonic cracks is insignificant, cubic shapes were formed: wide tables and angular bridges with flat tops. The chaotic blocks that result from the destruction of the previous three groups are common as well. By the shape of the base Mazursky distinguished such types: walls (with a "rectangular" base), towers (with a "square" base) and other irregular ones. Highly denuded forms are described as needles, towers or gates.

During the rock's studies of the Polish Carpathians and Sudetes S. Alexandrowicz (1989) distinguished the following forms of the rocks: wall, table, tower, ambo, sharp-topped rock or belveder, rock-ribs (Alexandrowicz, 1990). In her later works the simple forms of rocks were supplemented by the more complex ones: The Stone Town, The Spinner, The Tor Ship, Mushroom Stone, Cliffs, Pulpits (Alexandrowicz, 2008). She also divided the rocks into two groups: undetached from the base (all of the above) and detached from the base (block and cluster of blocks).

In Ukraine, in recent years, the rocks have been considered in scientific studies to be inventoried for environmental purposes (Zinko, 2003; Zinko, Ivanyk, 2016). They are partially described and included in the geotourism, local and educative routes (Bubnyak et al., 2014; Andreychuk, 2018). The peculiarities of rock formation and the influence of erosion, denudation and gravity processes on them are also investigated (Bayrak & Gavrilov, 2011; Urban, 2015). The morphometry of individual rocks have been investigated as well (Slutskyi, 1984; Rozhko, 1996; Bayrak & Zozulya, 2012). The other scientists studied the composition, structure, physical and chemical properties of the rocks they are composed of (Voloshyn, 2012; Gavryshkiv, 2008). However, many questions regarding the morphological structure and spatial location of the rocks are still topical. Obtaining geospatial data on groups and complexes of both known and little-known rocks of Beskids remains its relevance.

Research Methods. Research methods have been traditionally used are field research and cameral analysis. In the field, the coordinates were determined; the morphometric parameters of the largest rocks were measured. For the available rocks, the altitudes were found by using a long measuring tape and the GPS receiver altitude data on the mobile device, and the results were compared and the correct ones were selected. For rocks with inaccessible peaks the heights were calculated by the formula obtained from the trigonometric properties of right triangles:

$$(H - h)/b = tg\alpha,\ H - h = b \cdot tg\alpha,\ H = h + b \cdot tg\alpha;$$

H is the height of the rock, *h* is the height of a person some distance from the foot of the rock, *b* is the base or distance from the foot to the person, *tgα* is the angle between the top of the cliff and the point of view of the person, which is measured by a goniometer on a mobile device.

In the field, the morphological outlines of the rocks, their unique or typical features, the parameters of the base, the complexity of cracks of different genesis, and the sedimentation marks on the surface of the rocks were also studied. As a result of studies, the morphological typing of the Beskids' rock formations was performed.

In cameral conditions, GIS, analysis and synthesis methods were used. In the ArcGIS-10.3 software environment, horizontal digitization of topographic maps of 1:25 000 and 1:10 000 scales was carried out.

3D rendering of the terrain was performed, the angles of slope and exposure of the slopes the rocks are located on were found; the geospatial position of the rocks on the obtained digital terrain models were noted; the regularities in the local and regional distribution of the rocks were found.

Results. In Beskids there are about a dozen rock formations, the largest of them create the rock complexes. There are five of them in Beskids (from west to east): ***Uryts'kyi, Yamelnyts'kyi, Komarnyts'kyi, Kliuch-Kamianka, Bubnys'kyi Rock Complexes***. There are dozens of rocks-outliers or other rock formations in a given area. Rock formations include the detachment of rocks as upright walls on the slopes of beams or shores of the rivers, gorges gaps of solid rocks. Groups of rocks consist of several (5–8) shapes. Tyshivnyts'ki Rocks, Rozgirche are referred to groups of rocks.

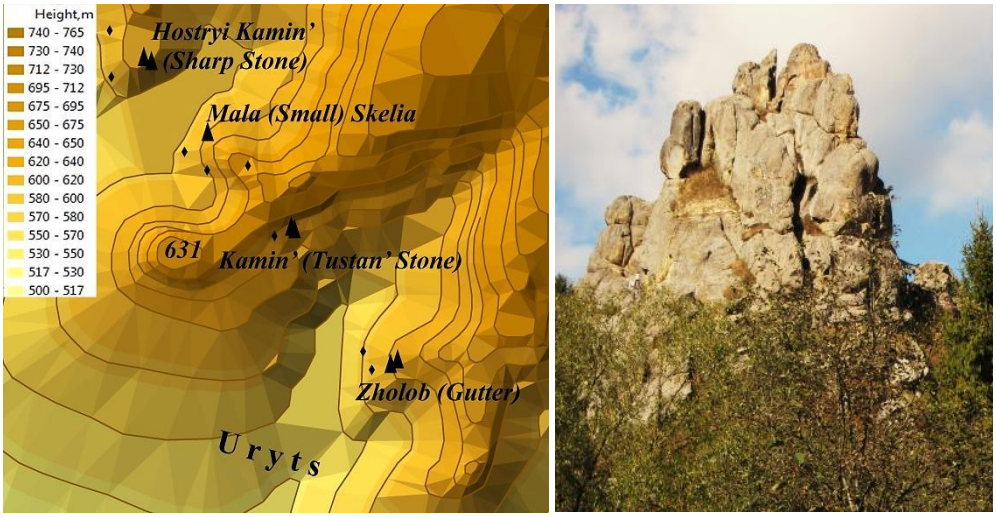
The rocks are composed of sandstones of the Yamna suite of the Palaeocene of the Lower Paleogene age (56–66 million years), with the exception of the Rozgirche rocks, which are formed by sandstones of the Vyhoda suite of Eocene (average Paleogene, 34–56 million years). The rocks were formed at a depth of 4800–5000 m during the existence of the ancient Tethys Ocean here; that is evidenced by coral remnants and sea turtles in the sandstones.

Uryts'kyi Rock Complex includes three groups of rocks: Kamin' (Stone) or the Tustasn's'kyi Kamin' (Tustan' Stone), Hostryi Kamin' (Sharp Stone), the Zholob (Gutter) and the single rocks Mala (Small) Skelia, Gulka, Khrest (Cross) and Bezymianna (Nameless) (Fig. 1,*a*). Most of them are the rocks-outliers.

The Rock Massif *Kamin'* is located in a valley of a small river of sub-meridional extension, at the foot of the southern exposure slope. It consists of two rock walls (southwestern and northeastward), connected by a rocky lowering in the form of a platform (princely court territory) (Zinko, 2008). The height of the highest hill of Tustan's'kyi Kamin' is 37 m. The massif is of a complex morphology; it accommodates a combination of rock walls and spire forms form (Fig. 1,*b*). The plan is somewhat reminds the letter "H", which is expanded and extended in the direction of 330°. The north-eastern part of the massif is twice as thin as the southwestern, but 10 m longer, is called Velyke Krylo (The Big Wing). Its height is 15 m, length is 60 m and width is 5 m. According to researchers there was Detynets of medieval fortress Tustan' (Rozhko, 1996). The layered structure of sandstones causes horizontal closed cracks, which together with the vertical ones, form characteristic mattress-like free-standing forms. Vertical cracks in the lower parts are expanded by water erosion and form grottoes with their proper names ("Chotyry Veletni" (Four Giant), "Try Paltsi" (Three Fingers), "Chotyry Spysy" (Four Spears), "Orel" (Eagle). On the rocks there are round-shaped depressions up to 50 cm in diameter, which are a consequence of the heterogeneity of the sandy rocks and were used by ancient people as altars. There are also many petroglyphs of different periods on the surface of the rocks, and they complete the largest collection of rock images in Europe (Vahylevych, 1993).

The rocks *Hostryi Kamin'* are on the opposite slope of the valley, on the ridge, so the sharp peaks are notable on its background. Their height is about 25 m. The rocks are morphologically needle-shaped. The Zholob rock group is located on the southeast of Kamin', on the valley side of the slope. This rock, like the previous ones, has a two-

tiered structure: is an elongated wall at the bottom there, and there are two peaks shaped like spires at the top. The height of the rock is up to 20 m. Among the small boulders the cube-shaped ones are common. There are also unique rocks, for example, one rock in the tract Mala Skelia resembles an altar.



a *b*

Fig. 1. Uryts'ki rocks: *a* – a three-dimensional relief model, scale 1: 25,000; *b* – the tower-shaped rock Velykyi Kamin' (Big Stone)

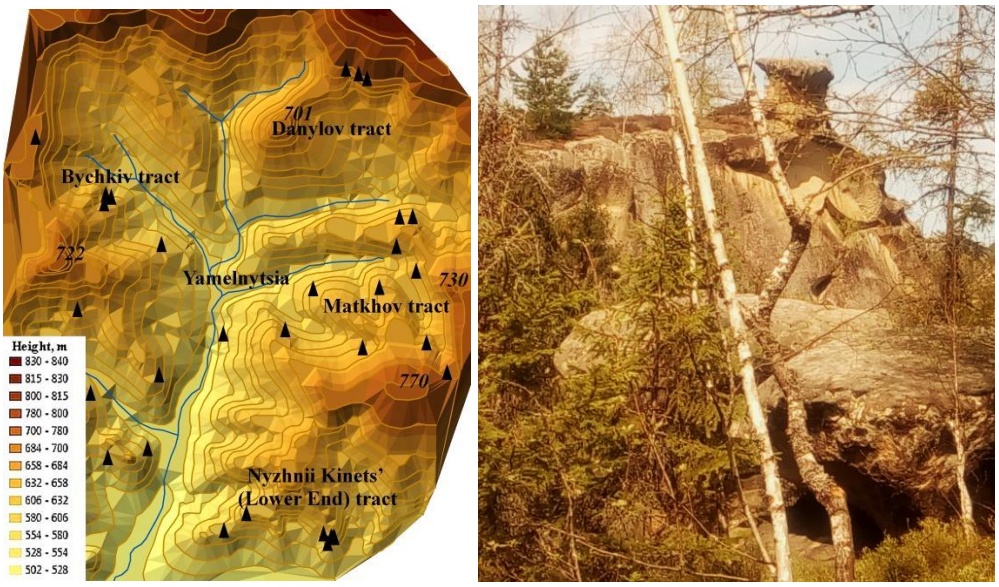
Yamelnyts'kyi Rock Complex. It is located to the east of Uryts'ki rocks, between the villages of Pidhorodtsi and Krushelnytsia (Skole district of Lviv region). The complex brings together five groups of rocks, that are located on 2–5 km one from another. The following groups of rocks should be distinguished: the south-western, north-western (Bychkiv tract), northern (Danylov), eastern (Matkhov) and south-eastern (Nyzhnii Kinets' (Lower End) tract) (orientation is from the centre of the village Yamelnytsia) (Fig. 2,*a*). Here are the rocks-outliers and rocks-outcrops. Rock wall-shaped morphological types are common among the rocks-outliers; the tower-shaped and cube-shaped single rocks are rare.

The north-western group of Yamelnyts'kyi Rocks Complex (Bychkiv tract) are the highest. The mushroom-shaped and tower-shaped rocks-outliers, as well as canyon and angular rocks, are common here. The highest is the Shiata Rock, 35 m high, in the form of a massive tower with a chimney-shaped top (Fig. 2,*b*). This tower is at the same time an angular rock and the end of a massive wall extending from the base of the slope. Further into the slope, together with the opposite vertical wall, it forms a canyon. Its length is 80 m; depth is 28 m; thickness of exposed rocks up to 20 m; azimuth of extension 240º.

The northern group of the Yamelnyts'kyi Rocks Complex near Danylov Mountain is a rock wall located in the middle of the ridge's slope. It is the longest of all the rocks-outcrops of the Beskids. Its total length is about 150 m, height 15–17 m, and thickness 9–12 m. Extension azimuth is 280º. There are also angular rocks. The strip of rocks is broken up by deep vertical cracks into free-standing forms, and that is why this

type of rock wall is called ribs. The more dismembered rocks-outcrops are situated the lowest to the valley.

The south-eastern group of the Yamelnyts'kyi Rocks Complex in the tract Nyzhnii Kinets' has been formed from small rocks of 1.5–3.0 m (cube-shaped, slab-shaped, undefined ones) and two rock walls. The western part of the wall is smaller, 20 m in length and 12 m height, and the eastern part is larger, 50 m in length and 15 m in height. The thickness of the rocks exits is 4–7 m.



a *b*

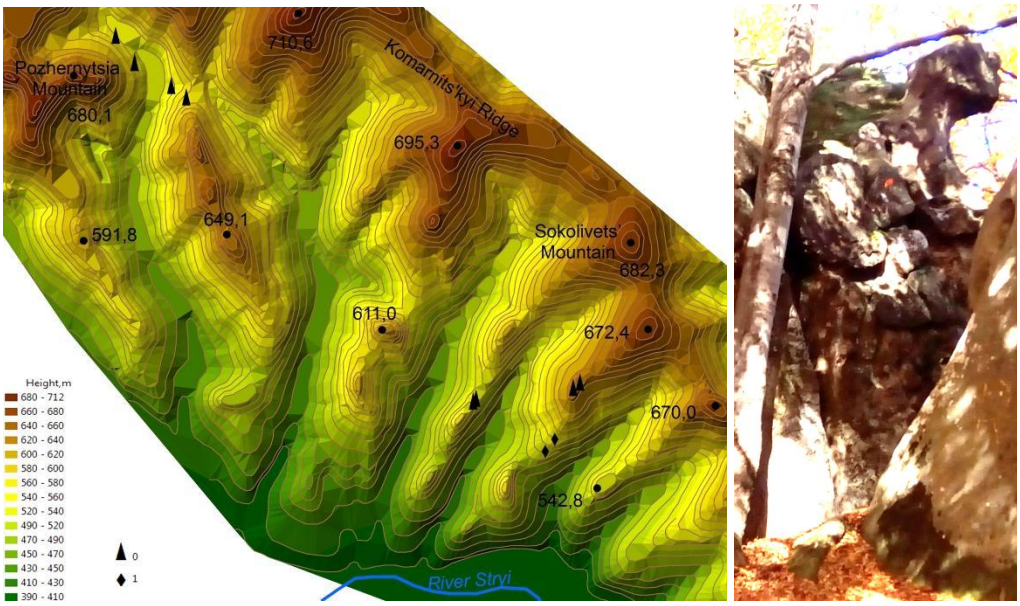
Fig. 2. Yamelnyts'kyi Rocks Complex : *a* – a three-dimensional relief model, scale 1: 50,000; *b* – Shiata Rock in Bychkiv tract

Komarnyts'kyi Rock Complex includes groups of rocks near the local mountain Ridges of Sokolivets' and Pozhernytsa (Fig. 3). According to morphology, there are rocks-outcrops, rock-towers and cube-shaped formations. There are three groups of rocks near Sokolivets' Mountain: north-west, south-east, and north-east (Bayrak & Zozulya, 2012). Sandstone detachments in the form of upright walls extend from the middle section of the slopes to ridges for from 35 to 70 m long. They are dissected by transverse cracks into massive cliffs, numbering 7–12. Azimuth of extension of all three groups is 320-340º. On ridges the rock walls turn into the rocks-outliersof tower-shaped forms. The maximal rock height in the north-eastern group is 23 m, in the north-western is 19 m, and in the south-east is 12 m. On the surface of the south-eastern cluster of rocks, there are interesting cells of cellular weathering, which are huge in size and have a unique columnar Ridgement.

There are several groups of rocks near the Pozhernytsia Mountain (680 m) in Komarnyts'kyi Rock Complex. There are three tower-shaped rocks, 10–12 m high and rocks-outcrops, up to 30 m long. The height of the rocks does not exceed 15 m.

The Tyshivnytsia rocks group is a detachment of massive sandstones near the river-bed of the Stryi river by the village of Tyshivnytsia (Skole district); the rocks group is broken down into separate cliffs. The massive rocks that rise above the river are called

Kniazhi (Princes). They are located in the lower part of the slope of the northern exposure (Fig. 4,*a*). The height of the highest Kniazha (Prince) Rock is 34.5 m, the



a *b*

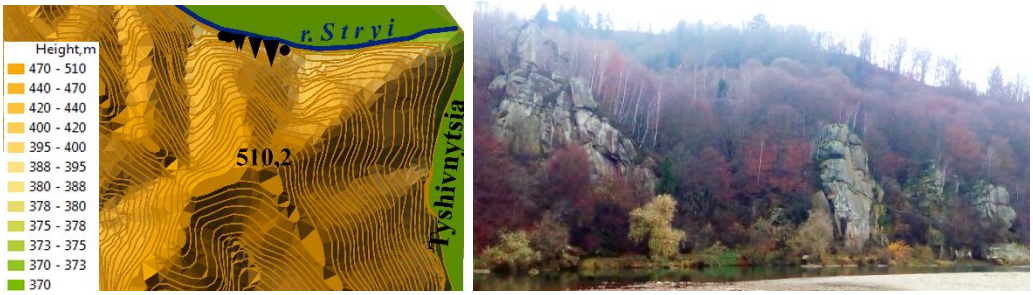
Fig. 3. Rock groups near Sokolovets' and Pozhernytsa: *a* – a three-dimensional relief model scale 1: 50,000 (symbols: *0* – rocks-outliers, *1* – low rocks); *b* – rock near Sokolovets'

height of the next one Yaroslavna Rock is 26.3 m; the lowest one is Khans'ka (Khan) Rock 14.5 m high. Azimuth of extension is 280°. The slope angle is 54°. The shape of the rocks in the profile is trapezoidal: the lower part is wider than the upper one several times (Fig. 4,*b*). Width of the lower base of Kniazha Rock is 19.5 m, the width of the upper base is 5.5 m; the width of the lower base of Yaroslavna Rock is 15.0 and the width of its upper base is 7.0 m; the width of the lower base of Khanska Rock is 13.0 and the width of its upper base is 3.3 m.

To the northeast of the Kniazhi Rocks the group of Rosgirche rocks is situated (Bayrak & Teodorovych, 2018). These rocks are located at the foot of the low ridge and are represented by the sandstone outcrop of the Eocene Vyhoda suite. There are three rather large rock cliffs and a few smaller ones. The largest is a 10 m high rock, located in a corner ledge of the slope. It has a wide base, a flat top, and stepped facade construction. Two large rooms with doors and windows are carved in the rock. A small cave monastery was located directly in this place in the Middle Ages.

Kliuch-Kamianka Rock Complex. Various forms of formations are common here: low tower-shaped rocks, arch-shaped rocks, clusters of massive cliffs, single cube-shaped blocks and rock-slabs, as well as rocks-outcrops in the form of vertical walls that resemble canyons. Such diversity of rock formations can be explained by the fact that the central and eastern part of the Kliuch Ridge is made up of a powerful (up to 200 m) horizontal stack of massive sandstones that extend to the bottom. Blocks and slabs can be found everywhere on the tops and surface slopes of the ridge. Most of the rock formations are located at the intermediate peak elongated from the southwest to

the northeast, located to the west of the main peak (Kliuch Mountain, 929.7 m) (Fig. 5).



a *b*

Fig. 4. Rocks Tyshivnytsia: *a* – a three-dimensional relief model, scale 1:25,0000; *b* – the photo

The group of rocks is located at the southern end of the top. There are three rocks there: two tower-shaped, west and east, and cube-shaped, south. The height of the largest rock, western one, is 6 m. The surface of the rocks is strongly eroded, as sand layers of fine-grained and medium-grained structure are alternated. One of these rocks with a unique peak got the local name "Sokil" (Falcon).

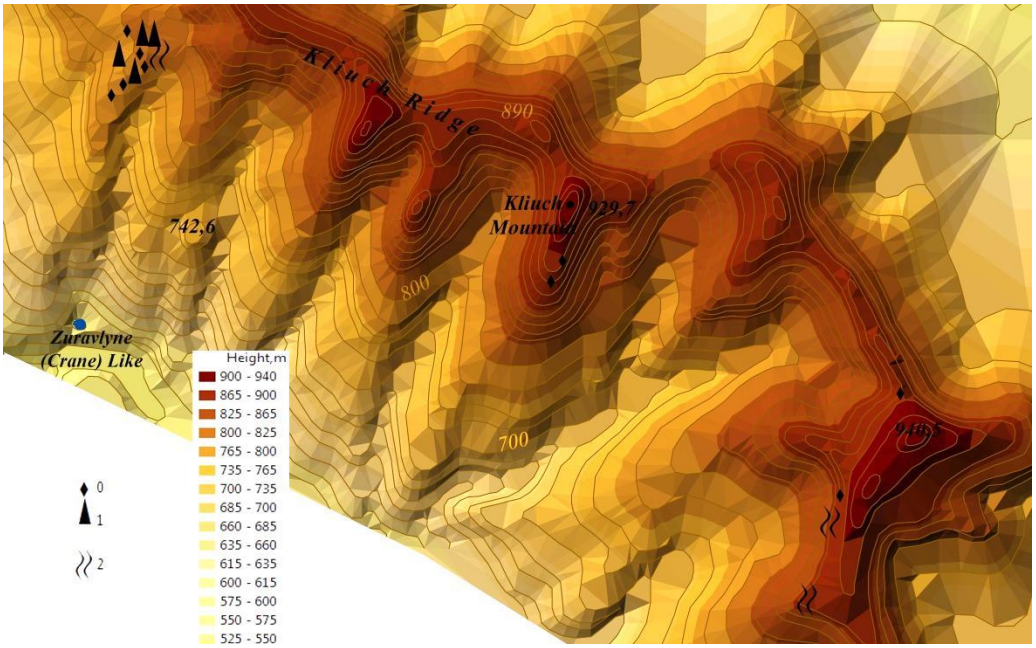


Fig. 5. Rocks on the Kliuch Ridge (a three-dimensional terrain model; scale 1: 50,000). Symbols: *0* – scattering of stones, *1* – rocks-outliers, *2* – canyon

The largest group of the rocks, located at the north-eastern end of this elongated peak, is called Ostriv Pasky (Easter Island) Rock. This is a chaotic cluster of blocks of different shapes. Therefore they are also called "Igroteka" (Games Store).

There are about 10 rock blocks in the area of 25 m^2. The height of the highest formation is 8 m. On the south side of this group is a short, 10 m long canyon with

smooth walls. Depth of the formation is 5 m, width of it is 2.5 m (Fig. 6,*a*). It is of tectonic-gravity-erosion genesis.

In the Kliuch-Kamianka Rock Complex the unique single rocks are common, for example, an arch-shaped. Such a rock is located at a distance of 100 m to southwest of "Igroteka". Its height is 4 m. Two rock pillars have an overlap and a small (1.8 × 2 m) passage with a semi-circular arch. To the northwest of the "Arch" there are rock blocks formed as a result of gravitational processes, in particular, the subsidence of blocks. These are two pairs of rocks, 4–5 m in height. The gravitational crack divided them into two parts (Fig. 6,*b*).

a *b*

Fig. 6. Rock formations on the Kliuch Ridge: *a* – canyon by the Ostriv Pasky (Easter Island) Rock, *b* – rocks as a result of the block dropping

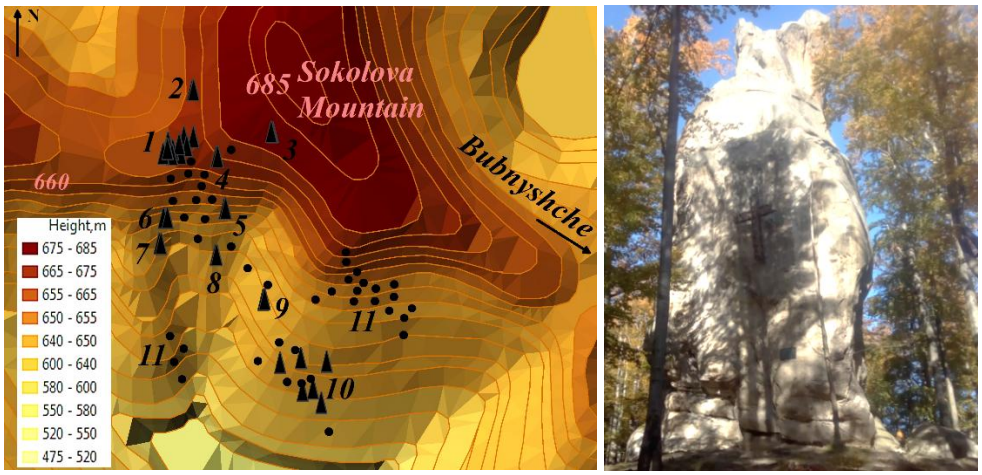
In the southeast direction from the main Kliyuch peak, in the crested parts of the slopes, there are two canyons with the vertical slopes composed by thick sandstone strata. They are of tectonic origin and are the result of settling and erosion processes. The tectonic genesis is indicated by a smooth sandstone surface, as well as a major cleft with transverse cracks. The length of the largest canyon is 80 m. The azimuth of the extension of its shorter segment (30 m) is 330°, and of the longer segment (50 m) is 360°. Its depth is 12–15 m, its width at the bottom is 2–5 m, and along the edge is 5–8 m.

Bubnys'ki Rocks (Dovbush Rocks) are the highest and most massive of all the rocks described above. In this complex there are about a dozen compactly arranged groups of rocks, a few single rocks and three more groups located some distance away. Tall and massive cliffs over 15 m high, several cliff blocks 5–10 m high, small cliffs 2–3 m high and scattering of small fragments around them stand out in the groups. The high cliffs have their proper names, they are 14. The entire massif extends for 1.0 km from northwest to southeast. Azimuth of extension is 330–345°. The complex of rocks belongs to the top and surface slopes of Sokolova Mountain (685 m) of south-western exposition (Fig. 7,*a*). Its width reaches 200 m. According to the morphology, the plateau group of rocks, tower-shaped, spike-shaped, needle-shaped, cube-shaped rocks and rock-canyon can be distinguished.

The plateau group is called the Main Massif because it is the largest solid rock massif not only of Bubnys'ki Rocks, but of all the Carpathian rocks. Its width is 70 m, length is 150 m, and height is 30–34 m. It is pierced by four cracks, up to 1 m wide, extending from west to east and one longitudinal crack, extending from north to south, forming seven blocks. The massif is longitudinally and transversely divided by open and closed cracks of different directions and angles of incidence, so that the surface is divided into large and small free-standing forms. For example, on the east side, due to

the predominance of closed cracks, there are distinct "edges" and on the top there are "boulders field" and "karst plateau". Open through cracks up to 1.5 m wide split the Main Massif into massive tower-shaped boulders. On the north side, the massif forms a semicircle with a plane in the middle. There are three man-made caves and one natural cave, the stairs to the top. It was area that Dovbush opryshkas favoured as a rest area during their long hikes. The top of the massif is slightly inclined, broken by deep cracks into square pieces, with several cliffs hanging on it. It is available for people with average physical fitness, and opens view on Kliuch Mountain, Parashka Mountain, Bezimenna (Nameless) Rock, and the Bronenosets' Rock that soars above the forest.

The Bronenosets' rock is considered to be the highest among Bubnys'ki rocks, its height is 46 m according to S. Slutskyi (Slutskyi, 1984). According to our information, its height is 37 m. It has an elongated shape extended from east to west, so it is also called "sail". The massive tower-shaped rocks are the Bezimenna Rock (32 m), the Vid'ma (Witch) Rock (25 m), the Kin' (Horse) Rock (14 m). The tower-shaped rocks are the Golets' Rock (16 m), the Shurshun Rock (15 m), the Mala Austriyka Rock (8 m), and the Khrest (Cross) Rock (8 m). Spitz-shaped rocks are Odinets' Rock (18 m) (Fig. 7,*b*), Tiulpan (Tulip) Rock (13 m), Lialka (Doll) Rock (10 m). The needle-shaped top is Velyka Austriyka Rock (10 m). The cube-shaped rock is the Kolobok Rock (6 m) and other small rocks that form clusters to the southeast of the Main Massif.



a *b*

Fig. 7. Bubnys'ki rocks: *a* – a three-dimensional relief model, scale 1:25 000. Figures indicate rocks: *1* – Main Massif, *2* – Golets' Rock, *3* – Odinets' Rock, *4* – Tiulpan (Tulip) Rock, *5* – Vid'ma (Witch) Rock, *6* – Kin' (Horse) Rock, *7* – Alaska Rock, *8* – Bezimenna (Nameless) Rock, *9* – Bronenosets' Rock, *10* – low rocks, *11* – scattering of different blocks; *b* – Odinets' Rock

To the south of the Main Massif a small valley stretches, the upper part of which form a canyon. The depth of the canyon is about 3 m, the width of the bottom is up to 1 m. The canyon widens down the slope, the walls decrease, they are thinned until they pass into separate cube-shaped cliffs. The length of the canyon is about 20 m.

Discussion. The wide researches on the massive sandstone outcrops of the Skole and Upper Dnister Beskids, forming a variety of rocks, allows us to identify two of their classes: rocks-outliers and rocks-outcrops. The first class of the rocks are isolated stone blocks or humps. The second class of the rocks are the outcrops in the form of solid vertical walls.

The rocks-outliers are divided into four types: spire-shaped, chain-shaped, arc-shaped and combined. The first two types are the most common in the Beskids, so we distinguish their subtypes.

Spire-shaped rocks are divided into subtypes: 1) tower – a rock with a cross-sectional area, that is practically unchanged from the base to the top; 2) spoke – a rock with a cross-sectional area, that is decreases with height; 3) needle – a kind of spoke with a narrow pointed apex; 4) mushroom – a rock, the cross-sectional area is unchanged or decreases, and the top is several times wider than the base.

Among the chain-shaped rocks 3 subtypes are defined: 1) wall (ribs, fence, gate) is a chain-shaped form; its height is bigger than the width of the base. Belonging to a particular subtype depends on the length of the form and its continuity – the wall is more solid than the ribs; 2) block (table) – a cube-shaped form; its height and width are approximately the same; 3) slab – an elongated shape; its width of base is greater than its height.

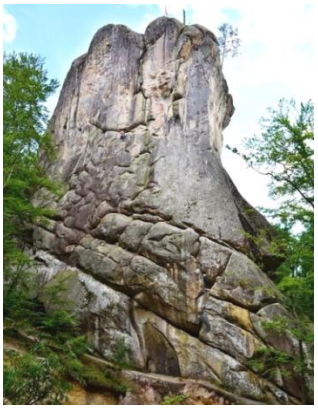
The rocks of combined form are divided into subtypes: with defined form – those of the rocks which are similar to certain objects (a ship, a sail, an animal, etc.); and cliffs – the rocks of undefined forms, clusters of massive boulders of various shapes.

Among the *rocks-outcrops* three types are defined: bluff-shaped, canyon-shaped and angular ones. All of them are the vertical end of a slope composed of crystalline rocks. The bluff-shaped rocks are ten-meter-long ledges on the slopes of a mountain in the form of a solid wall of long extension or its trapezoidal or rectangular free-standing forms. The canyon-shaped type is the rocks with parallel slopes. Types of angular rocks have the appearance of corner large stones on the lateral sides of the slope (Tab. 1).

The described types of rocks are represented in various ways in the rock complexes of Beskids. The class of rocks-outliers occurs most often, and among its subtypes tower and spoke are the most widespread. They occur in almost all rock complexes of the Beskids.

Low rock blocks are widely distributed, both at the root bed and detached from the base, destroying processes. The subtype of rocks in the form of a wall is found in Urych and Yamelnytsia. Subtypes of complex cliffs are represented in the western part of the Kliuch Ridge, in the western part of the tract Nyzhniy Kinets' in Yamelnytsia, as well as in the central large massif in Bubnys'kyi Rock Complex. There are unique types of rocks that resemble different objects, such as a sail, a bird or a mushroom. The least common subtype is the "needle". In the class of rocks-outcrops, the types of bluff-shaped and canyon-shaped rocks observed in the groups of rocks Sokolivets', Pozhernytsa, Tyshivnytsia, Klyuch, in Bychkiv tract in Yamelnytsya are equally widespread. A bright example of the angular rocks is the rock cave monastery in Rozgirche.

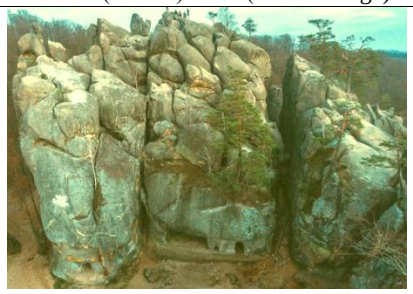
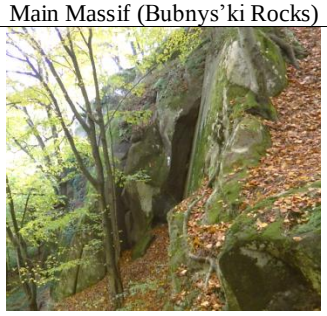
Table 1. The morphological classification of rocks of Beskid Mountains

Clas-ses	Ty-pes	Sub-types	Rock names/locations	An example of a typical rock
1	*2*	*3*	*4*	*5*
The rocks-outliers	**Spire-shaped**	**Tower**	"Velykyi Kamin' (Big Stone)", " Malyi Kamin' (Small Stone)" (Urych); Shiata Rock, north-western group, Matkhov, Nyzhnii Kinets' (Lower End) (Yamelnytsia); single rocks by Sokolivets' Mountain and Pozhernytsa Mountain; Golets' Rock, Bezimenna (Nameless) Rock, Shurshun Rock, Vid'ma (Witch) Rock, Mala Austriyka Rock, Khrest (Cross) Rock (Bubnys'ki Rocks).	 Bronenosets' Rock (Bubnys'ki Rocks)
		Spoke	Okremyi Kamin' (Separate Stone), Zholob (Gutter) rock group, Mala (Small) Skelia Rock (Urych); south-west, Matkhov tract (Yamelnytsia); Odinets' Rock, Tiulpan (Tulip) Rock, Lialka (Doll) Rock (Bubnys'ki Rocks).	 Mala (Small) Skelia Rock (Urych)
		Needle	Hostryi Kamin' (Sharp Stone) Rock (Urych); Velyka Austriyka Rock (Bubnys'ki Rocks).	 Hostryi Kamin' (Sharp Stone) Rock (Urych)

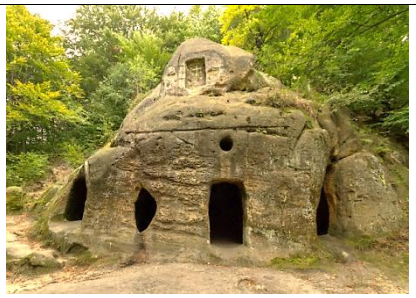
Continuation of Tab. 1

1	*2*	*3*	*4*	*5*
		Mushroom	Bychkiv tract, Nyzhnii Kinets' (Lower End) tract (Yamelnytsia).	 Bychkiv & Nyzhnii Kinets' tract (Lower End)
	Chain-shaped	**Wall**	Velyke Krylo (The Big Wing), Male Krylo (The Small Wing) (Urych); Danylov tract, Eastern part of Nyzhnii Kinets' (Lower End) tract (Yamelnytsia).	 Velyke Krylo (The Big Wing) (Urych)
		Block	Mala (Small) Skelia Rock (Urych); south-western group, single rocks on Danylov tract, Matkhov tract, Nyzhnii Kinets' (Lower End) tract (Yamelnytsia); rocks by Sokolivets' Mountain and Pozhernytsa Mountain; Vorota (Gate) Rock (Rosgirche); Kliuch Mountain; Kolobok Rock etc. (Bubnys'ki Rocks).	 Nyzhnii Kinets' (Lower End) tract (Yamelnytsia)
		Slab	"Altar" (Urych); single rocks of Nyzhnii Kinets' (Lower End) tract (Yamelnytsia); Kliuch Ridge; (Bubnys'ki Rocks).	 "Altar" (Urych)

Continuation of Tab. 1

1	*2*	*3*	*4*	*5*
	Arc-shaped		Kliuch Ridge; arched elements on the rocks (Bubnys'ki Rocks and Yamelnytsia).	 Arch-shaped rock, Kliuch Ridge
	Combined	**With defined form**	"Sokil" (Falcon) Rock (Kliuch Ridge); Bronenosets' Rock (Bubnys'ki Rocks).	 "Sokil" (Falcon) Rock (Kliuch Ridge)
		Cliffs	Western rock, Nyzhniy Kinets' (Lower End) tract (Yamelnytsia); Ostriv Pasky (Easter Island) Rock (Kliuch Ridge); Main Massif, Kin' (Horse) Rock (Bubnys'ki Rocks).	 Main Massif (Bubnys'ki Rocks)
The rocks-outcrops	**Bluff-shaped**		South-eastern group of Sokolivets' Mountain; by the Pozhernytsa Mountain; Kniazhi (Princes) Rocks (Tyshivnytsia).	 South-eastern group of Sokolivets' Mountain
	Canyon-shaped		Bychkiv tract (Yamelnytsia); Kliuch Ridge; segment of the river Kamianka; South of Main Massif (Bubnys'ki Rocks).	 Canyon to the east of Kliuch Mountain

End of Tab. 1

1	*2*	*3*	*4*	*5*
	Angular		Bychkiv tract, Danylov tract (Yamelnytsia); rock-monastery in Rozgirche; (Yamelnytsia); Kliuch Ridge.	 Rock in Rozgirche

Conclusions. In any science, classification is the first step to an in-depth study of the research subject. Proper classification gives an adequate idea of the nature of the studied objects, methods and origin of their formation. The presented morphological classification of rocks is an attempt to systematize the various rock formations of the Beskids. The classification allows to determine their value as an objects of geological and geomorphological heritage, to highlight the urgency of their protection and preservation, whereas many rocks are included in the nature conservation associations: Skole National Park (Kliuch-Kamyanka), natural landscape reserved area (Bubnys'ki Rocks), or historical and cultural reserved area (Tustans'kyi Kamin'). The scientific classification allows us to determine the degree of rock's weathering by the exogenous factors and, accordingly, the stage of rock formations development. Classification can be used in geo-tourism because it reflects the uniqueness or typical features of the Beskid rock formations and thus determines the degree of attractiveness and the priority of the tourist flows directions.

REFERENCES

Andreychuk, Ju., I. Knysh, Kremin', N. (2018). Geoturystychni ta navchal'ni perspektyvy Skolivs'kyh Beskydiv na prykladi basejnu r. Kam'janka [Geotourism and educational perspectives of Skole Beskydy on the example of the Kamianka river basin]. In *Geografija, ekonomika i turyzm: nacional'nyj i mizhnarodnyj dosvid*: materialy XII Mizhn. nauk. konf. L'viv, 6–21 (In Ukrainian).

Bayrak, G., Zozulia, M. (2012). Geomorphologichni osoblyvosti Mezybrods'kogo kompleksu skel' u Verhniodnistrovskih Beskydah [Geomorphological features Mezhibrodskogo of complex of rocks in Verkhnednisterskikh Beskidakh]. In *Problemy geomorfologii' i paleogeografii' Ukrai'ns'kyh Karpat i pryleglyh terytorij: Zbirnyk nauk.prac*. L'viv: LNU im. Ivana Franka, 125–132 (In Ukrainian).

Bayrak, G., Gavryliv, M. (2011). Formuvannja skel'nyh kompleksiv Beskydiv [Forming of rocky complexes of Beskyd]. In *Fizychna geografija ta geomorfologija*, 3(64). Kyi'v: Obrii', 63–72 (In Ukrainian).

Bayrak, G., Teodorovych, L. (2018). Skeli "Rozgirche" ta ihnje vykorystannja v geoturystychnyh ciljah [Rozhirche rocks and their use for geotourism]. In *Problemy geomorfologii' i paleogeografii' Ukrai'ns'kyh Karpat i pryleglyh terytorij: Zbirnyk nauk. prac*. L'viv: LNU im. Ivana Franka, 85–97 (In Ukrainian)

Bubnjak, I. M., Skakun, L. Z. (Eds.) (2014). Geoturyzm: praktyka i dosvid [Geotourism: practice and experience]. In *Materialy mizhnarodnoi' naukovoi' konferencii'*. L'viv: Karty i atlasy, 152 (In Ukrainian).

Vahylevych, I. (1993). Berdi v Urichi. In *Podorozhi v Ukrayinski Karpati : zbirnik*. Lviv, 102–113 (In Ukrainian).

Voloshyn, P. (2012). Inzhenerno-geomorfologichna harakterystyka Uryc'kyh skel' [The Urych roks engineer-geomorphologic characteristic]. In *Problemy geomorfologii' i paleogeografii' Ukrai'ns'kyh Karpat i pryleglyh terytorij: Zbirnyk nauk. prac*. L'viv: LNU im. Ivana Franka, 172–180 (In Ukrainian).

Gavrishkiv, G. (2008). Petrografiya paleotsenovih vidkladiv "ekzotichnih skel" Skibovoyi zony Ukrayinskih Karpat. [The petrography of paleocene deposits of the Skiba unit of the Ukrainian Carpathians]. In *Zb. nauk. prac Institutu geologIchnih nauk NAN Ukrayini*, 1, 67–69 (In Ukrainian).

Zinko, Ju., Gnatjuk, R., Shevchuk, O. (2003). Pidhody do pryrodoohoronnoi' pasportyzacii' skel'nyh utvoren' Podillja. [Formation of the International Geopark "Rocky Beskyds" as a Center for Geotourism]. Rol' pryrodno-zapovidnyh terytorij Zahidnogo Podillja ta Jury Ojcovs'koi' u zberezhenni biologichnogo ta landshaftnogo riznomanittja : *Materialy naukovoi' konferencii'*. Grymajliv, 165–178 (In Ukrainian).

Zinko, Ju. (2008). Formuvannja mizhnarodnogo geoparku "Skeljasti Beskydy" jak centru geoturyzmu. [Formation of the international geopark "Rocky Beskyds" as a center for geotourism]. In *Visnyk L'viv. un-tu. Serija mizhnarodni vidnosyny*, 24, 83–93 (In Ukrainian).

Zinko, Ju., Ivanyk, M. (2016). Inventaryzacija ta ocinka ob'jektiv geomorfologichnoi' spadshhyny Prydnisters'kogo Podillja dlja potreb geoohorony i geoturyzmu [Inventory and evaluation of the objects of geomorphologic heritage of Transdniestria Podillia for the purposes of geoprotection and geotourism]. In *Problemy geomorfologii' i paleogeografii' Ukrai'ns'kyh Karpat i pryleglyh terytorij: Zbirnyk nauk.prac*. L'viv: LNU im. Ivana Franka, 6, 291–302 (In Ukrainian).

Rozko, M. (1996). *Tustan' – davnjorus'ka naskel'na fortecja* [Tustan – Old Russian rocky fortress]. Kyiv: Naukova dumka, 240 (In Ukrainian).

Sluckij, S. (1984). *Bubnys'ki skeli* [Bubnisky rocks]. Retrieved from http://www.karpaty.com.ua/?chapter=12&item=374

Alexandrowicz, Z. (1990). Waloryzacja i funkcje srodowiska abiotycznego w systemie ochrony przyrody (na przykladzie opracowan z Karpat Polskich). In *Studia Natura*, 9–35 (In Polish).

Alexandrowicz, Z. (2008). Sandstone rocky forms in Polish Carpathians attractive for education and tourism. In *Przeglad geologiczny*, 56, 8/1, 680–687 (In Polish).

Demetrykiewicz, W. (1903). Groty wykute w skalach Galicji wschodniej, pod względem archeologicznym (z 6 tablicami). In *Materiały Antropologiczno-Archeologiczne I Etnograficzne*, VI, 51–91 (In Polish).

Mazurski, K.R. (1972). Skalne fantazje przyrody. In *Rocznik Jeleniogorski*, X, 65–81 (In Polish).

Urban J. (2015). The role of gravitational processes in shaping sandstone rock landforms in low mountains: Świętokrzyskie (Holy Cross) Mountains, central Poland. In *Zeitschrift für Geomorphologie*, 59, Suppl. 1: 35–79.