

УДК 551.4 (477.8); DOI [10.30970/gpc.2025.1.4882](https://doi.org/10.30970/gpc.2025.1.4882)

Protection of relief of the Ukrainian Carpathians: state and prospects

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Abstract. The aims of the study are to analyze the current state of protection of various relief types within reserves, national parks, and regional landscape parks (RLPs) and geomorphological sites, as well as geomorphosites of the Ukrainian Carpathians. Additionally, the study aims to develop proposals for optimizing relief protection and its use for environmental, scientific, natural, and recreational purposes. The methodology involves a general geomorphological analysis of the relief in nature conservation territories of the Ukrainian Carpathians, based on systematization and comparison of up-to-date cartographic and descriptive materials. This includes comparing the map “Geomorphological structure (morphostructure and morpho-sculpture) of the Ukrainian Carpathians” (Hnatyuk et al., 2007), borrowed cartographic materials from projects on the organization of reserves and national parks within the region, and information on regional landscape parks, nature reserves, and natural monuments from the cadastres of the nature reserve fund of the administrative regions of the Carpathian region. The special representativeness of relief types was obtained using QGIS.

The authors assessed the degree of representativeness of relief types within the territories of reserves and national parks, presenting their findings in dedicated tables and maps. Additionally, maps depicting the locations of reserves, national parks, geomorphological sites, and regional landscape parks within the geomorphological zoning of the Ukrainian Carpathians were created. The character of protection for various geomorphological areas of the mountain and foothill parts of the region was clarified.

Within the territories of reserves and national parks, the mid-mountain relief and geological structure of the Polonynsko-Chornohirska, Skibova, Vododilno-Verkhovyna geomorphological regions, and the Marmarosh crystalline massif are the best represented. Conversely, the relief of the Zakarpattia Plain is the least protected. In total, seven relief types are unprotected within reserves and national parks – two common in the mountainous areas and five in the foothills of the Ukrainian Carpathians. The highest regional geomorphological representativeness is found in the Carpathian Biosphere Reserve (BR), Carpathian National Park, and Cheremoshsky RLP, while the typological representativeness is highest in Hutsulshchyna National Park and the Carpathian BR. The Synevyr NNP and Carpathian NNP have somewhat lower typological representativeness, with the lowest diversity observed in the relief of the Zacharovany Krai NNP. The Prytysyansky and Chernivtsi Regional Landscape Parks, due to their cluster structure, significantly improve the protection status of foothill relief types and the typical and unique relief forms of the Ukrainian Carpathians. An analysis of landforms with protected status shows that the highest concentration of geomorphological sites is in the Skiba Carpathians (64 sites), dominated by rocks (37) and waterfalls (19), and in the Polonynsko-Chornohirske Carpathians (31 sites), dominated by rocks (12), caves (11), and relict glacial formations.

Proposals have been developed for optimizing the protection of the region’s relief and its utilization for environmental, scientific, natural history, and recreational purposes. To enhance the protection of relief types, it is recommended to establish national parks within the Beskid

Predkarpattia, Zakarpattia Plain, Verkhnyaya Tysenskaya Depression, and Vygorlat-Gutynsky Volcanic Ridge.

Key words: Ukrainian Carpathians; geomorphological regions; geomorphosites; types of relief; reserve, national park, regional landscape parks.

Охорона рельєфу Українських Карпат: стан і перспективи

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Анотація. Метою дослідження є аналіз сучасного стану охорони типів рельєфу Українських Карпат у межах територій заповідників, національних природних парків (НПП) і регіональних ландшафтних парків (РЛП) та окремих геоморфологічних утворень, а також розроблення пропозицій щодо оптимізації охорони рельєфу регіону та його використання у природоохоронних, наукових, природно-пізнавальних і рекреаційних цілях. Методика містить загальний геоморфологічний аналіз рельєфу заповідників, національних парків і регіональних ландшафтних парків Українських Карпат та геоморфологічної будови і районування регіону досліджень на основі систематизації та порівняння найновішого картографічного й описового матеріалу. Типологічну репрезентативність заповідних територій отримано у середовищі QGIS при порівнянні карти “Геоморфологічна будова (морфоструктура та морфоскульптура) Українських Карпат” (Гнатюк та ін., 2007) та запозичених картографічних матеріалів з Проектів організації території заповідників і національних парків цього регіону та інформації про регіональні ландшафтні парки, заказники і пам’ятки природи з кадастрів природно-заповідного фонду адміністративних областей Карпатського регіону.

Встановлено ступінь регіональної та типологічної геоморфологічної репрезентативності заповідних територій, укладено відповідну карту та складено таблиці. Додатково укладено карти розташування заповідників і національних парків та геоморфологічних об’єктів і регіональних ландшафтних парків на тлі геоморфологічного районування Українських Карпат та з’ясовано характер охоплення охороною різних геоморфологічних областей гірської і передгірної частин регіону.

На території заповідників і національних парків найкраще представлений середньогірний рельєф та геологічна будова Полонинсько-Чорногірської, Скибової, Вододільно-Верховинської геоморфологічних областей та Мармароського кристалічного масиву. Найменше охоплений охороною рельєф Закарпатської рівнини. Взагалі не забезпечені охороною у межах заповідників і національних парків сім типів рельєфу, з яких два поширені у гірській, а п’ять – у передгірній частинах Українських Карпат. Найвищу регіональну геоморфологічну репрезентативність мають Карпатський біосферний заповідник (БЗ), Карпатський НПП та РЛП “Черемошський”, а типологічну репрезентативність – НПП “Гуцульщина” та Карпатський БЗ. Дещо нижчу типологічну репрезентативність мають НПП “Синевир” і Карпатський НПП, а найменшою різноманітністю відзначається рельєф НПП “Зачарований край”. Регіональні ландшафтні парки “Притисянський” і “Чернівецький”, завдяки кластерній структурі територій, суттєво покращують стан охорони передгірних типів рельєфу, типових і унікальних форм рельєфу Українських Карпат. Аналіз поширення форм рельєфу з заповідним статусом засвідчує, що найбільшою насиченістю геоморфологічними об’єктами вирізняються Скибові Карпати (64 об’єкти) з

домінуванням скель (37) і водоспадів (19) та Полонинсько-Чорногірські Карпати (31 об'єкт) з домінуванням скель (12), печер (11) і реліктових льодовикових утворень.

Розроблено пропозиції щодо перспектив оптимізації охорони рельєфу регіону та його використання у природоохоронних, наукових, природно-пізнавальних і рекреаційних цілях. Для покращення стану охорони типів рельєфу необхідно створити національні парки у межах Прибескидського Передкарпаття, Закарпатської рівнини, Верхньотисенської улоговини та Вигорлат-Гутинського вулканічного пасма.

Ключові слова: Українські Карпати; геоморфологічні області; форми і типи рельєфу; заповідник; національний природний парк; регіональний ландшафтний парк.

Introduction. Genetic types of relief and individual geomorphosites (such as rocks, caves, waterfalls, etc.), according to the current Law of Ukraine “On the Nature Reserve Fund” (1992), are protected within protected areas and objects of comprehensive (natural and biosphere reserves, national nature parks, regional landscape parks, landscape reserves (zakaznyky), complex natural monuments, protected tracts) and special protection (general geological, paleontological, karst-speleological, and hydrological reserves, geological and hydrological natural monuments) categories. Areas designated for comprehensive protection typically cover large territories (ranging from several hundred to tens of thousands of hectares), while areas of special protection are smaller in size (ranging from several to a few hundred hectares).

There are more than 1,400 protected areas and sites in the Ukrainian Carpathians. Their number and area are unevenly distributed across the administrative regions of the Carpathian region. As of 2022, the protected area coverage is 8.15% in Lviv region, 15.16% in Zakarpattia region, 15.97% in Ivano-Frankivsk region, and 12.80% in Chernivtsi region. The region hosts 15 nature conservation institutions of national and international significance: Gorgany Nature Reserve (NR), Carpathian Biosphere Reserve (BR) and Carpathian, Synevyr, Vyzhnytskyi, Skolivski Beskydy, Uzhanskyi, Hutsulshchyna, Halytskyi, Zacharovany Krai, Synohora, Verkhovynskyi, Cheremoskyi, Boykivshchyna, and Royal Beskydy National Nature Parks (NNP). Additionally, there are 8 local protected areas, including regional landscape parks (RLP): Nadsyanskyi, Verkhniodnistrovski Beskydy, Polyanitsky, Syniak, Prytysyansky, Hutsulshchyna, Chernivtsi, and Cheremosh. These large protected areas, along with smaller protected sites such as nature reserves (zakaznyky), natural monuments, and protected tracts, are unevenly distributed within the study area. Consequently, different types of mountain and foothill relief, as well as valuable geomorphological formations of the Ukrainian Carpathians, are protected to varying degrees.

Some studies have considered the state of protection and use of geomorphological sites of the Ukrainian Carpathians in general and its specific regions (Zinko et al., 2004; Bayrak & Teodorovych, 2020, 2023; Stetsiuk et al., 2024), individual reserves and national nature parks (Stoyko et al., 1993; Krychevska, 2004; Brusak & Kobziak, 2008; Brusak & Bayunova, 2012; Hnatiuk & Brusak, 2014; Bayrak & Generalova, 2024) and recreational assessment of the Ukrainian Carpathians (Kravchuk et al., 2006). An attempt has been made to assess the state of protection of the relief types of the Ukrainian Carpathians within reserves and national parks (Brusak V. et al., 2022, 2023). However, it is worth noting that special comprehensive studies to establish the state of protection of relief types and valuable geomorphological formations of the Ukrainian Carpathians have not yet been conducted. This is the scientific novelty of this study. It should be

noted that the works of botanists, foresters and zoologists traditionally focus on the state of protection of flora, vegetation and fauna within specific reserves and national parks with regard to the diversity of flora and fauna species and plant communities common in the Ukrainian Carpathians (Stoyko et al., 1982, 1993; Andrienko & Onyshchenko, 2003). There are some studies on the state of protection and ecosystem and landscape representativeness of individual protected areas (Stoyko et al., 1991, 2004), as well as the state of protection of natural vegetation types, old-growth forests and virgin forests of the Ukrainian Carpathians (Angelstam et al., 2017; Smaliychuk, 2019).

The *aim* of our study is to assess the current state of protection of the relief types in the Ukrainian Carpathians within the territories of reserves, national nature parks, regional landscape parks, and individual geomorphological formations with protected status. Additionally, the study seeks to develop proposals for optimizing the protection of the region's relief, as well as its sustainable use for environmental, scientific, natural history, and recreational purposes.

Materials and methods of research. The methodology includes a general geomorphological analysis of the relief of reserves, national parks, regional landscape parks and individual geomorphological formations of the Ukrainian Carpathians and the geomorphological structure of the study area based on the systematisation and comparison of the latest cartographic ("Tectonic map of the Ukrainian Carpathians", 1986; "Geological structure (up to the Quaternary section) of the Ukrainian Carpathians", 2007; "Geomorphological structure (morphostructure and morphosculpture) of the Ukrainian Carpathians", 2007; "State Geological Map of Ukraine", 2009), descriptive material (Kruglov, 1986; Hofshsteyn, 1995; Kravchuk, 1999, 2005, 2008, 2021; Slyvka, 2001; Kravchuk & Khomyn, 2011; Kravchuk & Chalyk, 2015; Kravchuk et al., 2016) and information on regional landscape parks, nature reserves (zakaznyky), natural monuments and other protected sites from the cadastres of the nature reserve fund of the administrative regions of the Carpathian region.

To clarify the regional and typological geomorphological representativeness of reserves, national parks, regional landscape parks, and geomorphological formations with protected status, the following maps were compiled: "Location of Reserves and National Nature Parks on the Map of Geomorphological Zoning of the Ukrainian Carpathians", "Location of Regional Landscape Parks and Geomorphological Formations with Protected Status on the Map of Geomorphological Zoning of the Ukrainian Carpathians", and "Location of Reserves and National Nature Parks Against the Background of Different Types of Relief of the Ukrainian Carpathians". The latter was used to calculate the proportion of various relief types common in the Ukrainian Carpathians and their share within the territories of each protected area. For this analysis, the "Geomorphological Zoning of the Ukrainian Carpathians" map (Rudko and Kravchuk, 2002) and the "Geomorphological Structure (morphostructure and morphosculpture) of the Ukrainian Carpathians" map (Hnatiuk et al., 2007) were employed. The boundaries of nature reserve territories were superimposed onto these maps, based on official cartographic materials from reserve and NNP organization projects, forest management maps, and cadastres of the nature reserve fund of the administrative regions within the Carpathian region, at a scale of 1:25,000–1:50,000. Using these maps, an area calculator was employed to determine the percentage representation of different geomorphological types within each protected area.

Research results and discussion. Large-scale nature conservation institutions of national, international and local significance in the Ukrainian Carpathians are represented by 23 sites created and expanded in 1968–2022, differing in size, territory structure and location of settlements within their boundaries (Tables 1, 2, Figs. 1, 2).

The Gorgany NR and most of the NNPs (Carpathian, Synevyr, Vyzhnytskyi, Uzhanskyi, Zacharovany Krai, Synihora and Verkhovyna) are represented by one large area. The Carpathian BR and Skolivski Beskydy, Hutsulshchyna, Halychyna, Cheremoshky, Boikivshchyna and Royal Beskydy NNPs have a cluster structure (consisting of several separate areas).

The NNPs of the Ukrainian Carpathians are funded by the state budget, have special administrations, and consist of territories provided to the NNP for permanent use and plots of land included in their composition without being withdrawn from other land users. The features of the relatively “young” NNPs such as Skolivski Beskydy, Hutsulshchyna, Galician, and the “youngest” NNPs such as Zacharovanyi Krai, Cheremosh, Verkhovyna, Boikivshchyna and Royal Beskydy are that their boundaries do not include settlements. Among the national parks in the region, Hutsulshchyna NNP has the largest share of land of other users (76.5%).

Regional landscape parks are protected areas of local significance that may have special administrations and are funded by regional or municipal budgets. Landscape parks are organised on the lands of other users, so the RLP administrations are not granted permanent use of the land. Out of the 8 RLPs in the Ukrainian Carpathians, only three have special administrations – Nadsianskyi, Verkhniodnistrovski Beskydy and Syniak (Table 2). The protection of natural complexes and objects on the territory of landscape parks is entrusted to the main land users (mainly forestry enterprises). Among the RLPs, Nadsianskyi, Polianytskyi and Syniak are the only large areas, while the rest of the parks have a cluster structure.

The structure of the territory of nature reserves has a significant impact on the ability to ensure an appropriate environmental protection regime and the degree of landscape, geological, geomorphological and biotic representation of protected areas. The cluster structure of the territory significantly increases the regional representativeness of the protected area, but due to the “island” effect, it requires more costs to ensure protection.

In the nature conservation literature (Stoyko et al., 1982; Tkachyk, 1996; Brusak, 2006), the assessment of the representativeness of protected areas is primarily reduced to the evaluation of the characteristic (typical) nature of their flora, fauna and vegetation in terms of quantitative and qualitative indicators in relation to similar indicators of regions of different taxonomic ranks within which a particular protected area is located. In a broader sense, the term “representativeness” was introduced into nature conservation by T. L. Andrienko, who, in contrast to the term “uniqueness”, uses it to assess the socio-ecological significance of protected areas (Andrienko et al., 1991). Supporting the opinion of V. P. Tkachyk (1996), we believe that representativeness is a method of knowing the representation of certain protected objects (species of animals and plants, phytocoenoses, genetic forms of relief, landscape complexes) within protected areas, as well as the self-sufficiency of protected objects, territory and conditions necessary to ensure their conservation over time. At the same time, the size of the protected area is important for biotic components to ensure the spontaneous course of their life and evolution (Brusak, 2006).

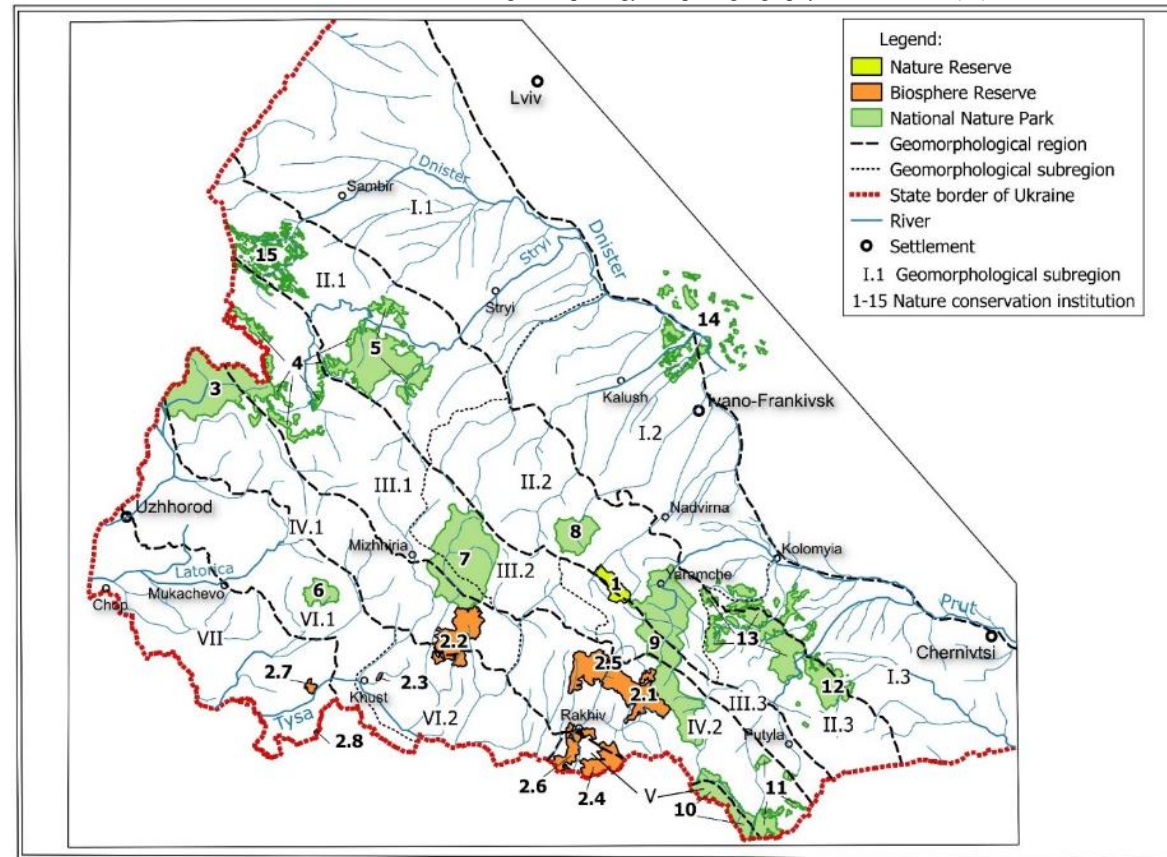


Fig. 1. Location of nature reserves and national nature parks on the map of geomorphological zoning of the Ukrainian Carpathians (Brusak V., et al, 2022 with additions)

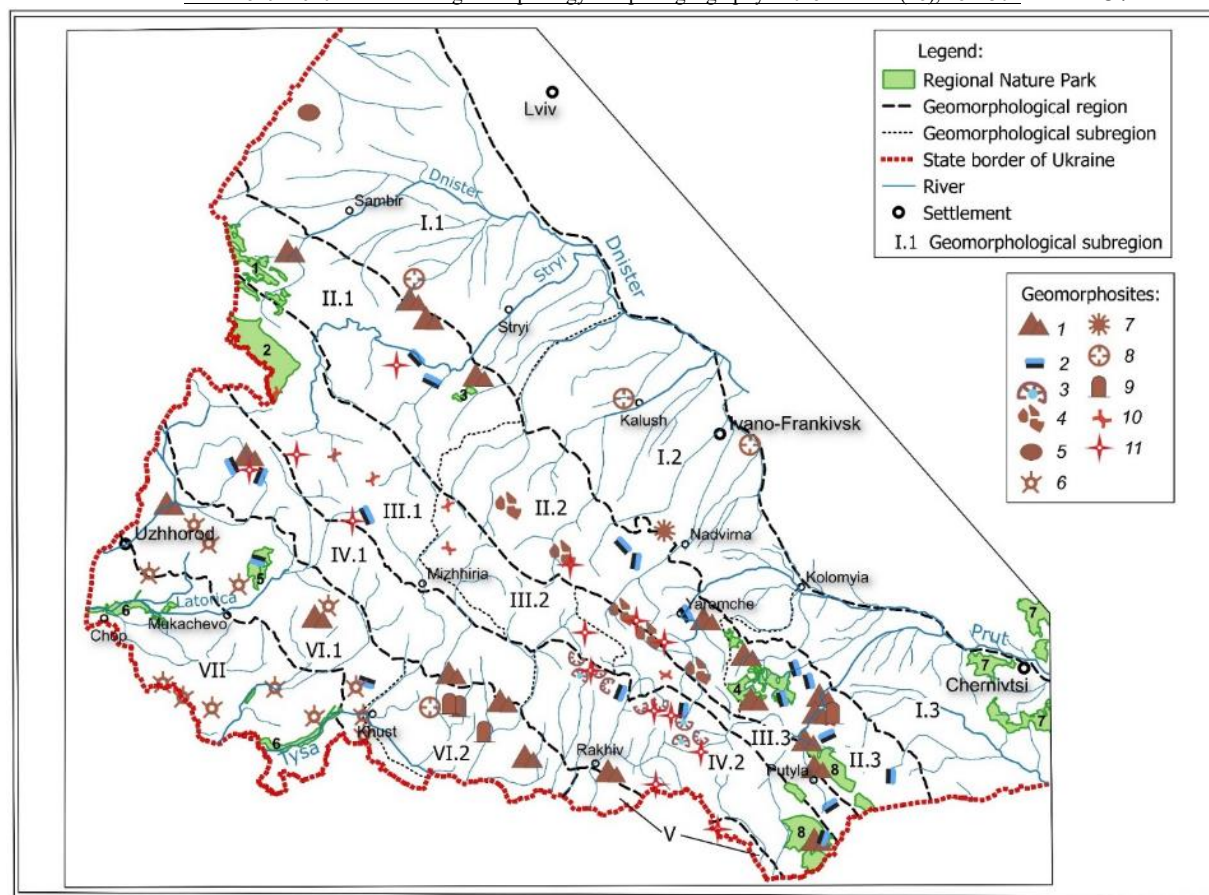


Fig. 2. Location of regional landscape parks and geomorphosites on the map of geomorphological zoning of the Ukrainian Carpathians

Legend to Fig. 1:

Nature conservation institutions: 1. Gorgany Nature Reserve, 2. Carpathian Biosphere Reserve (massifs: 2.1 Chornohora, 2.2. Uholsko-Shyrokoluzhanskyi, 2.3. Khustskyi (Valley of Daffodils), 2.4. Marmaroskyi, 2.5. Svydovetskyi, 2.6. KuziyTrybushanskyi, 2.7. Chorna mountain, 2.8. Yulivska m tain), 3. Uzhanskyi NNP, 4. Boykivshchyna NNP, 5. Skolivski Beskydy NNP, 6. Zacharovanyi Krai NNP, 7. Synevyr NNP, 8. Synohora NNP, 9. Carpathian NNP, 10. Verkhovyna NNP, 11. Cheremoskyi NNP, 12. Vyzhnytskyi NNP, 13. Hutsulshchyna NNP, 14. Halytskyi NNP 15. Royal Beskydy NNP

Legend to Fig. 2:

Regional landscape parks: 1. Verkhniodnistrovski Beskydy, 2. Nadsianskyi, 3. Polianytskyi, 4. Hutsulshchyna, 5. Syniak, 6. Prytysyanskyi, 7. Chernivetskyi, 8. Cheremoskyi.

Geomorphosites: 1. Rocks and rock complexes, 2. Waterfalls, 3. Glacial kar and kar lakes, 4. Stone placers, 5. Glacial boulders, 6. Volcanic forms, 7. Pseudo-volcanic forms (mud volcanoes); 8. Surface karst forms. 9. Caves, 10. Remarkable mountain passes; 11. Remarkable peaks.

Legend to Fig. 1 and Fig. 2:

Geomorphological zoning of the Ukrainian Carpathians (Rudko & Kravchuk, 2002 with changes):

I. Region of the Precarpathian Upland. *I.1.* Precarpathian-Prebeskydy denudation-accumulative upland with glacial and water-glacial forms, *I.2.* Precarpathian-Pregorgany denudation-accumulative upland, *I.3.* Precarpathian-Pokuttia-Bukovyna statum-denudation-accumulative upland.

II. Region of thrust-folded low-mountains and medium-mountains of Skybovi Carpathians. *II.1.* Monoclinally-folded low-mountains of Beskydy Massif, *II.2.* Monoclinally-folded low- and medium-mountains of Gorgany Massif, *II.3.* Anticlinally-folded low- and medium-mountains within Pokuttia and Bukovyna.

III. Region of structural-denudated low- and medium-mountains of the Vododilno-Verkhovynski Carpathians. *III.1.* Structural-denudated low-mountains of Verkhovynskyi Massif, *III.2.* Anticlinally-block medium-mountains of Pryvododilni Gorgany, *III.3.* Erosive low-mountains of Yasinia, Vorokhta, and Putyla.

IV. Region of fault-block medium-mountains of the Polonynsko-Chornohirski Carpathians. *IV.1.* Fault-block medium-mountains with remnants of the weathering surface of Polonyna Ridge, *IV.2.* Fault-block medium-mountains within Svydovets and Chornohora Ridges with ancient glacial forms.

V. Region of the block-arch medium-mountains of Marmarosy crystalline massif.

VI. Region of denudated low-mountains of the Vylkanichni (Volcanic) Carpathians. *VI.1.* Vygorlat-Gutytskyi erosive low-mountains, *VI.2.* Verkhnyotytsenska hollow with denudation-accumulative and structural-erosion relief.

VII. Region of Zakarpattia alluvial plain with insular volcanic hills.

Therefore, the assessment of the *regional* and *typological representativeness* of the nature conservation institution consists in comparison with, the qualitative characteristics of its nature with similar characteristics of the regions within which it is located. The peculiarity of the assessment of *geographical representativeness* (GR) of nature reserves or national parks is to determine their place in the system of natural regional and typological units by a set of features. This assessment should be carried out primarily on the basis of typological features at the level of taxa of a certain rank according to different zoning schemes. The need to establish GR of nature and biosphere reserves is due to one of the main requirements for their functioning, to be specific, they should represent the natural features of regions of a certain taxonomic rank. It is a physical-geographical land (province) for NR (Stoyko et al., 1982; Tsaryk, 2009) as well as it is a biogeographical region according to the zoning scheme of Udvardy (Udvardy, 1975) for BR.

The highest *regional geomorphological representativeness* in the studied region is provided by the Carpathian BR, Cheremoshsky RLP and Carpathian NNP due to the cluster structure of the territory and transverse extension relative to the arc of the Ukrainian Carpathians (see Figs. 1, 2). The Carpathian BR represents the peculiarities of the geological and geomorphological structure of four geomorphological regions of the Ukrainian Carpathians, and the Carpathian NNP and Cheremoshsky RLP – three regions (Tables 3, 4).

The relief and geological structure of the four geomorphological regions of the Ukrainian Carpathians are best represented on the territory of reserves and national parks: Polonynsko-Chornohirska, Skibova, Vododilno-Verkhovyna and Marmarosh crystalline massif. The least protected relief is that of the Zakarpattia Plain with its island volcanic hills (Table 3). The relief of the Skibovy and Vododilno-Verkhovynski Carpathians is best represented in the regional landscape parks (Table 4). It should be noted that the RLPs significantly improve the state of protection of the relief of the Peredkarpatska Upland and Zakarpattia Plain.

The highest *typological geomorphological representativeness* due to the cluster structure of the territory is in the Hutsulshchyna NNP and the Carpathian BR, where nine and eight relief types are distributed respectively (Fig. 3). The Synevyr NNP and the Carpathian NNP, which are large in area and represented by a single massif, have a somewhat lower representation, with seven and six relief types, respectively. However, within the majority of protected areas, three to five types of relief are common (Table 5). The least diverse relief is within the Zacharovanyi Kray NNP (two types). Among the regional landscape parks, the highest typological geomorphological representativeness due to the cluster structure of the territory is in the Hutsulshchyna and Chernivtsi RLPs, which have five and four relief types, respectively. It should be noted that 48.5% of the territory of the Chernivtsi RLP is located outside the foothills of the Ukrainian Carpathians.

The most common type of relief on the territory of the protected areas, as well as within the Ukrainian Carpathians, is fluvial (33.4% of the region's area). In particular, in the mountainous part, the most widespread is the 24th type of relief – floodplains and a complex of low undivided or weakly divided terraces (10.6% of the region's area). This type of relief is common in all protected areas, except for Galician NNP and Prytysyansky RLP; within the national park, almost 60% of its territory is covered by the 26th and 25th types of fluvial relief, and the entire territory (100%) of the RLP is covered by the 26th type of relief. It should be noted that Galician NNP is located in the contact zone of the southwestern margin of the East European Plain and the Carpathian Mountain structure, respectively, and is represented by the upland and river-valley relief of the Prygorgan Predkarpattia and Opillya (western part of Podillia). The Opillya part of the Halychyna NNP accounts for almost 40% of its area.

The best protected areas within the nature reserves are the boulder-folded midlands (types 2a and 2b) with hill-anticline massifs composed of Cretaceous and Paleogene sediments and the folded-sliding midlands (type 4b) with anticline and monocline mountain ranges composed of Cretaceous and Paleogene flysch. The boulder-folded midlands are protected primarily within the Chornohora and Svydovets massifs of the Carpathian BR and Carpathian NNP (type 2a, covers 6.3% of the region), as well as the Uholsko-Shyrokoluzhanskyi massif of the Carpathian Biosphere Reserve, Uzhanskyi and Cheremoshskyi NNPs and Cheremoshskyi RLP (type 2b, 5.1%). The folded-over midlands (type 4b, 4.3%) are protected within the Carpathian NNP, Skole Beskydy NNP and Synohora NNP, and Polyanitsa RLP (see Fig. 3, Table 5).

It should be noted that the most protected Folded-block medium-mountains are composed of Proterozoic and Paleozoic sediments (type 1), which are limited in distribution in the Ukrainian Carpathians (0.8% of the region). The midlands of crystalline rocks are distributed within the Marmarosh and Kuziy-Trybushansky massifs of the Carpathian BR and Verkhovyna NNP (Table 5).

Table 1. The structure of the territory of nature reserves and national natural parks of the Ukrainian Carpathians (Brusak V., et al, 2022 with additions)

Nature protection institution	Year of foundation	Total area, ha	The area provided for permanent use		The area of other land users		Territory features
			ha	%	ha	%	
Gorgany Nature Reserve	1996	5344.6	5344.6	100	–	–	One allotment, a protection zone (3712.89 ha) is created around the NR
Carpathian Biosphere Reserve	1993 (1968)	58035.8	39485.8	68.0	18550	32.0	Cluster, the BR does not include settlements
Carpathian NNP	1980	50495	38322	75.9	12173	24.1	One allotment, the NNP includes settlements
Synevyr NNP	1989	41073.8	32294	79.5	8402	20.5	One allotment, the NNP includes settlements
Vyzhnytskyi NNP	1995	11238	8246.2	73.4	2991.8	26.6	One allotment, the NNP does not include settlements
Skolivski Beskydy NNP	1999	35261.2	24369.2	69.1	10892	30.9	Cluster, the NNP does not include settlements
Uzhanskyi NNP*	1999	39159.3	21892.6	55.9	17266.7	44.1	Two allotments, the NNP includes settlements
Hutsulshchyna NNP	2002	32248	7581	23.5	24667	76.5	Cluster, the NNP does not include settlements
Halytskyi NNP	2004	14209.1	11826	83.2	2383.1	16.8	Cluster, the NNP does not include settlements
Zacharovanyi Krai NNP	2009	10451.4	9999.4	95.7	452	4.3	One allotment, the NNP does not include settlements
Synohora NNP	2009	10866	10866	100	–	–	One allotment, the NNP does not include settlements
Cheremoskyi NNP	2009	7117.5	5556	78.1	1561.5	21.9	Cluster, the NNP does not include settlements
Verkhovynskyi NNP	2010	12022.9	12022.9	100	–	–	One allotment, the NNP does not include settlements
Boykivshchyna NNP	2019	12240	10623	86.8	1617	13.2	Cluster, the NNP does not include settlements
Royal Beskydy NNP	2020	8 997	8 691	96.6	306	3.4	Small-clustered, the NNP does not include settlements

Table 2. The structure of the territory of regional landscape parks of the Ukrainian Carpathians

Regional landscape parks	Year of foundation	Total area, ha	Territory features
Verkhnodnistrovski Beskydy	1997	8356.0	Cluster, the PLP does not include settlements; has an administration
Nadsyanskyi*	1997	19428.0	One site, the boundaries of the RLP include settlements; has an administration
Prytysyanskyi	2009	10330.7	Cluster, the PLP does not include settlements
Syniak	2011	4631.3	One site, the PLP does not include settlements; 350.0 ha of land provided to the administration for permanent use

Polyanitskyi	1996	1032.0	One site, the PLP does not include settlements
Hutsulshchyna	1996	17729.0	Cluster, the PLP does not include settlements
Chernivetski	1996	21487.5	Cluster, the PLP does not include settlements
Cheremoshski	1997	14985.8	Cluster, the PLP does not include settlements

* In 1998, the Uzhanskyi NNP and Nadianskyi RLP became part of the Eastern Carpathians International Biosphere Reserve (Poland, Slovakia, Ukraine).

Table 3. Regional geomorphological representativeness of nature reserves and national natural parks of the Ukrainian Carpathians
(Brusak V., et al, 2022 with additions)

Geomorphological zoning (Rudko & Kravchuk, 2002 with changes)	1	2. Carpathian Biosphere Reserve								3	4	5	6	7	8	9	10	11	12	13	14	15
		2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8													
<i>I. Precarpathian Upland</i>																			+	++	++	
<i>II. Skybovi Carpathians</i>	++										+	++			++	++			++	++		++
<i>III. Vododilno-Verkhovynski Carpathians</i>	+									++	++			++		++						+
<i>IV. Polonynsko-Chornohirski Carpathians</i>		++	++		+	++	+			++				+		++	+	++				
<i>V. Marmaroski Carpathians</i>					++		++										++	+				
<i>VI. Vylkanichni Carpathians</i>			+	+									++									
<i>VII. Zakarpattia Plain</i>								+	+													

Nature protection institutions: 1. Gorgany Nature Reserve, 2. Carpathian Biosphere Reserve (massifs: 2.1 Chornohora, 2.2. Uholsko-Shyrokoluzhanskyi, 2.3. Khustskyi (Valley of Daffodils), 2.4. Marmaroskyi, 2.5. Svydovetskyi, 2.6. Kuziy-Trybushanskyi, 2.7. Chorna mountain, 2.8. Yulivska mountain), 3. Uzhanskyi NNP, 4. Boykivshchyna NNP, 5. Skolivski Beskydy NNP, 6. Zacharovanyi Krai NNP, 7. Synevyr NNP, 8. Synohora NNP, 9. Carpathian NNP, 10. Verkhovyna NNP, 11. Cheremoskyi NNP, 12. Vyzhnytskyi NNP, 13. Hutsulshchyna NNP, 14. Halytsky NNP, 15. Royal Beskydy NNP.

Location of a part of the nature reserve area within the geomorphological zone: ++ main part, + insignificant part.

Table 4. Regional geomorphological representativeness of territory of regional landscape parks of the Ukrainian Carpathians

Geomorphological zoning (Rudko & Kravchuk, 2002 with changes)	1	2	3	4	5	6	7	8
<i>I.</i> Precarpathian Upland							++	
<i>II.</i> Skybovi Carpathians	++		++	++				++
<i>III.</i> Vododilno-Verkhovynski Carpathians	+	++						+
<i>IV.</i> Polonynsko-Chornohirski Carpathians								++
<i>V.</i> Marmaroski Carpathians								
<i>VI.</i> Vylkanichni (Volcanic) Carpathians					++			
<i>VII.</i> Zakarpattia Plain						++		

Regional landscape parks: 1. Verkhnodnistrovski Beskydy, 2. Nadsyanskyi, 3. Polyanitskyi, 4. Hutsulshchyna, 5. Syniak, 6. Prytysyanskyi, 7. Chernivetski
8. Cheremoshski

Table 5. Typological geomorphological representativeness in nature reserves and national natural parks of the Ukrainian Carpathians
(Brusak V., et al, 2022 with additions)

Types of relief (see the Fig. 3)									The percentage of relief type within the protected nature territory (transcript of numbers see in the Fig. 1), %							
№	within the Ukrainian Carpathians, %	1, %	2, %	3, %	4, %	5, %	6, %	7, %	8, %	9, %	10, %	11, %	12, %	13, %	14, %	15, %
<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>	<i>15</i>	<i>16</i>	<i>17</i>
<i>1</i>	0.8		18.0								62.1	7.3				
<i>2a</i>	6.3							10.1		28.8	2.5					
<i>2б</i>	5.1		31.8	29.8				4.3			8.3	74.8				
<i>3</i>	1.7		29.3					39.8								

Закінч. табл.5

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
4a	2.8	65.4						0.4	63.1	20.9				2.5		
4б	4.3				8.4	77.7			20.8	9.3				8.1		
5	1.4											4.9		1.7		
6	7.9					9.7				0.2			79.5	48.6		77.4
7	3.1			47.4	21.5	2.5		4.6								
8	2.4			0.1	64.9											9.5
9	0.3													5.5		
10	1.1															
11	3.8	20.6						17.2		13.8		1.3				
12	0.6		3.7													
13	1.4			0.8												
14	0.2															
15	1.7						97.7									
16	1.6						2.1									
17	4.1		0.2											18.7		
18	0.3															
19a	1.0		1.4													
19б	8.0												12.9		59.8	
20	1.5															
21	1.5															
22	2.4															
23	1.3															
24	10.6	14.0	14.7	21.9	5.3	10.1	0.2	23.6	16.1	27.1	27.1	11.7	2.8	12.5		13.1
25	4.7												0.7	1.8	26.6	
26	18.1		0.8										4.1	0.6	13.6	

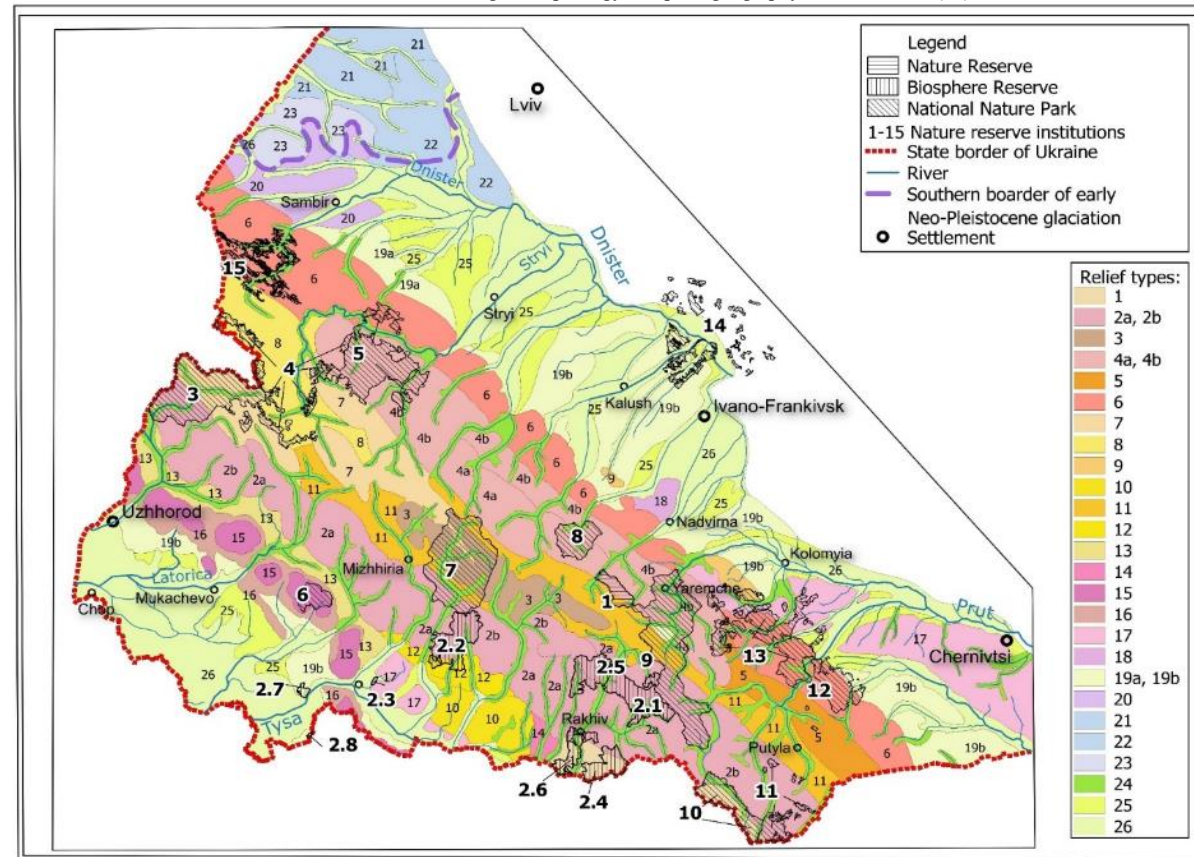


Fig. 3. Location of nature reserves and national nature parks within different types of relief of the Ukrainian Carpathians (Brusak V., et al, 2022 with additions)

Legend to Fig. 3:

Protected nature territories (see the Fig.1):

Types of relief (Hnatiuk et al., 2007):

Mountain structures created by the latest differentiated movements of the earth's crust*Denudation-tectonic mountains formed in the conditions of active uplifts and horizontal movements of the earth's crust*

1. Folded-block medium-mountains (below 1800–1900 m) formed on Proterozoic quartzites, shales, gneisses, Paleozoic shales, and limestones ($N_2 - P$)
2. Folded-block medium-mountains (*a* – below 1900–2000 m; *b* – below 1600–1700 m) with horst-anticline massifs on Cretaceous and Paleogene argillites, limestones, marls, sandstones, Paleogene sandstones, argillites ($N_2 - P$)
3. Folded-block medium-mountains (below 1700–1800 m) on Cretaceous and Paleogene sand-clay sediments ($N_2 - P$)
4. Thrust-folded medium-mountains (*a* – below 1600–1800 m; *b* – below 1300–1400 m) with anticlinal and monoclinic mountain ranges on Cretaceous and Paleogene argillites, sandstones, limestones, marls ($N_2 - P$)
5. Thrust-folded medium-mountains (below 1300–1400 m) with monoclinic ridges on Cretaceous and Paleogene argillites, sandstones, limestones, marls ($N_2 - P$)
6. Thrust-folded low-mountains (below 900–1100 m) with monoclinic and anticlinal ridges on Paleogene argillites, limestones, marls, partly on Cretaceous argillites, limestones, marls ($N_2 - P$)

Structural-denudation mountains formed in conditions of less active and medium uplifts

7. Medium-mountains (below 1300–1400 m) on Upper Oligocene and Lower Miocene medium- and thin-rhythmic flysch (Krosnenska Suite) ($N_2 - P$)
8. Low-mountains (below 900–1000 m) with separate anticlinal ridges on Upper Oligocene and Lower Miocene, medium- and thin-rhythmic flysch (Krosnenska Suite) ($N_2 - P$)
9. Anticlinal-block low-mountains (below 800 m) on Eocene-Miocene sandstones, argillites
10. Anticlinal-block low-mountains (below 800 m) on Eocene-Miocene marls, clays

Denudation mountains formed in conditions of medium and low uplifts

11. Medium-mountains (below 1200–1300 m) with ancient valley forms and denudation plains on Paleogene sandstones, argillites ($N_2 - P$)
12. Fault-block low-mountains (below 800 m) on dissected Jurassic limestones ($N_2 - P$)
13. Low-mountains (below 1000 m) with ancient valley forms on Paleogene sandstones, argillites ($N_2 - P$)
14. Low-mountains (below 1000 m) on Paleogene sandstones, argillites ($N_2 - P$)

Volcanic and volcanic-denudation mountains formed in conditions of medium uplifts

15. Low-mountainous (below 900–1000 m) volcanic massifs, ranges, ridges ($N_2 - P$)
16. Low-mountainous (below 600–650 m) volcanic plateau-like mountains, the foothills of volcanic massifs ($N_2 - P$)

Premountain uplands, hills, and plains formed in the conditions of differentiated uplifts within the premountain troughs*Stratum-denudation uplands*

17. Denudation-erosion uplands and intermountain hollows with fragments of Pliocene-Pleistocene terraces ($N_2 - P$)
18. Denudation-erosion strongly dissected hills ($N_2 - P$)
19. Denudation-erosion uplands: *a*) with a wavy, slightly dissected relief (depth of dissection up to 60 m); *b*) strongly dissected plateau-like ($N_2 - P$)
20. Denudation-terrace uplands transformed by the activity of the Oka glaciation and water-glacial streams, sometimes with loess cover ($N_2 - P$)

Stratum-accumulative plains

Glacial and water-glacial plains

21. Strand-wavy moraine-water-glacial plains (P_I)
22. Bumpy-wavy moraine-water-glacial plains with a powerful loess cover (P)
23. Bumpy-hilly alluvial-moraine-water-glacial plains with loess cover (P)

Fluvial

24. River valleys with a complex of terraces of different ages
25. Complex of medium-high medium- and weakly-dissected terraces with loess cover ($P_I - P_{II}$)
26. Floodplains and the complex of low undissected or weakly dissected terraces ($P_{III} - H$)

The thrust-folded medium-mountains (type 4a, 2.8%) with anticlinal and monoclinic mountain ranges composed of Cretaceous and Paleogene flysch are well protected within the Gorgany NR and Carpathian NNP. The thrust-folded low-mountains with monoclinic and anticlinal ridges composed of Paleogene, partly Cretaceous sediments (type 6, 7.9%), and folded-block medium-mountains on Cretaceous and Paleogene sand-clay sediments (type 3, 7%) are also well-conserved protected. The thrust-folded low-mountains are protected mainly within the Hutsulshchyna NNP and Vyzhnytskyi NNP, Verkhnodnistrovski Beskydy RLP and partly protected by Skolivski Beskydy NNP and Polyanytskyi RLP as well as the folded-block medium-mountains are protected within the Synevyr NNP (see the Table 5).

Medium-mountains with ancient valley forms and denudation plains on Paleogene sediments (type 11, 3.8%) which are distributed within Carpathian NNP and Synevyr NNP, as well as low-mountainous volcanic massifs formed in conditions of medium uplifts (type 15, 1.7%) are relatively less protected. The volcanic low-mountains are protected within Zacharovanyi Krai NNP, which has expanded by 4350.4 hectares in 2019 and Syniak RLP.

Other relief types are widespread in the mountainous (types 5, 8, 9, 12, 16) and pre mountainous (types 17, 19a) parts of the region, and are protected only moderately. The state of protection of the folded-over midlands (type 5) in the Pokuttya-Bukovyna Carpathians is significantly improved by the Cheremoshkyi and Hutsulshchyna RLPs, the lowlands with separate anticline ridges (type 8) of the Stryj-Sianska Upland are enhanced by the Nadsianskyi RLP, and denudation-erosion uplands with fragments of high terraces (type 17) in the Bukovyna Predkarpattia are enhanced by the Chernivetskyi RLP. Meanwhile, the low-mountains with ancient valley forms on Paleogene sandstones and argillites are protected unsatisfactory (type 13, 1.4%).

Seven types of relief are not protected at all within reserves and NNPs, two of which are common in the mountains and five in the premountain part of the Ukrainian Carpathians (see the Table 5). There are no national nature parks within the uplands and plains of Precarpathian Upland, which covered areas of denudation-terrace uplands transformed by the activity of Oka glaciation and water-glacial streams, (type 20, 1.5%), glacial and water-glacial plains (types 21, 22, 23, respectively 1.5%, 2.4%, 1.3%). More than a third of the territory of the Hutsulshchyna RLP is occupied by a highly fragmented denudation-erosion hill (type 18, 0.3%), which is extremely rare in the foothills.

In the mountainous part of the region, anticline-block low-mountains on Eocene-Miocene marls and clays (type 10, 1.1%). Low-mountains on Paleogene sandstones and argillites (type 14), which are rare for the Ukrainian Carpathians, are not protected at all. Types 10 and 14 are common only within Verkhnyotysenska (Solotvynska) hollow. It should be noted that types 14 and 18 are the least common in the studied region and occupy only 0.2% and 0.3% of the region, respectively.

In this regard, in order to improve the state of protection, the issue of organization of national nature parks within Precarpathian-Prebeskyds, as well as the Zakarpattia Plain is topical. There are no protected nature territories of the significant area and a high level of protection within the denudation-accumulative upland with glacial and water-glacial landforms near the Beskidy Massif.

There are only two small territories such as Chorna Mountain and Yulivska Mountain, which are parts of Carpathian BR, within Zakarpattia alluvial plain with the island

volcanic uplands. Within the special reserves of lower significance called “zakaznyky” the volcanic hills are protected. However, the dominant relief of Zakarpattia plain which is the floodplains and the complex of low undissected or weakly dissected terraces (type 26) is protected within the Prytysyanskyi RLP and partly within Velykodobrunskyi zoological reserve of general state importance (1736 ha). This type of relief, which is one of the most common, both in the studied region (18.1%) in general and in the premountain part of the Ukrainian Carpathians, is quite well protected on the territory of Halytskyi NNP and partially in Hutsulshchyna NNP and Vyzhnytskyi NNP.

It should be noted that at the present time the low-mountainous relief of the Upper Dnister Beskids is insufficiently protected. Here the eponymous regional landscape park (RLP) is located. As of 2020 announced the new NNP called Korolivski Beskydy (8997 ha) in the Starosambir district of Lviv oblast.

It is also important to create a NNP or RLP in the territory of the Makovytsia mountain massifs within the Vygorlat-Gutynskiy Ridge, as well as within the Verkhnyotysenska (Solotvynska) basin for protection of the low-mountainous relief.

The creation of new protected nature territories will significantly improve the state of protection of usual and unique types and forms of relief in the mountainous and premountainous parts of the Ukrainian Carpathians. The creation of national nature parks as well as granting the status of *geoparks* to the most geologically and geomorphologically valuable nature reserves of Western Ukraine (Manyuk, 2007; Bogucki, et al., 2012) will also help to create conditions for organizing recreation in the natural environment and opportunity to acquaint park visitors with typical and unique landforms of the region, which is extremely important in the context of the formation of the ecological network of the Ukrainian Carpathians (Brusak et al., 2009).

An important element of terrain protection, which is also a catalyst for organised and sometimes “wild” recreation in the natural environment, is the picturesque landforms with the status of reserves (zakaznyky), natural monuments, and protected tracts, which are also unevenly distributed in the Ukrainian Carpathians (Table 6). Some aesthetically and recreationally valuable geomorphological formations have been incorporated into national parks and regional landscape parks, retaining the protected status of natural monuments and reserves.

Table 6. Distribution of geomorphosites with protected status in the geomorphological regions of the Ukrainian Carpathians (Zinko et al., 2004 with additions)

Geomorphological zoning (Rudko & Kravchuk, 2002 with changes)	Cliffs	Caves	Kary	Water-falls	Other*	In total
<i>I.</i> Precarpathian Upland	2	–	–	1	3	6
<i>II.</i> Skybovi Carpathians	37	–	2	19	6	64
<i>III.</i> Vododilno-Verkhovynski Carpathians	4	2	–	2	3	11
<i>IV.</i> Polonynsko-Chornohirski Carpathians	12	11	2	4	2	31
<i>V.</i> Marmaroski Carpathians	3	–	1	–	2	6
<i>VI.</i> Vylkanichni (Volcanic) Carpathians	4	3	–	3	3	13
<i>VII.</i> Zakarpattia Plain	–	–	–	–	3	3

*Prominent peaks, extinct volcanoes and pseudo-volcanoes, stone placers, landslides, karst funnels, river valley areas, moraine strands, and glacial boulders.

The analysis of the distribution of landforms with protected status within the geomorphological regions and districts of the Ukrainian Carpathians shows that among the geomorphological regions, the highest saturation of geomorphological formations (objects) is in the Skibovy Carpathians (64 sites) with the dominance of rocks (37) and waterfalls (19) and the Polonynsko-Chornohirsky Carpathians (31 sites) with the dominance of rocks (12), caves (11) and relict glacial formations. The least number of geomorphological sites with protected status within the foothills is found in the Zakarpattia Plain and the Precarpathian Upland and in the small Marmarosh crystalline massif (Table 6). At the level of geomorphological regions, a significant number and diversity of landforms with protected status are distinguished by: 1) Skole Beskydy area (cliffs – 7, waterfalls – 2), 2) eastern part of Skibovi Gorgany (cliffs – 7), 3) Pokutsko-Bukovyna area (cliffs – 5, waterfalls – 7), 4) Polonyna Ridge area (14 sites) – caves (8) and cliffs (4), 5) areas of Svydovets and Chornohora midlands (10 sites) – rocks (5), glacial forms (karls, carlings, glacial lakes, moraine strands), canyon-like river valleys, 6) area of Rocky ridges of the cliff zone (5 sites) – caves (3), rocks; 7) Vyhorlat-Buzhorsky volcanic area (6 sites) – rocks, waterfalls.

Conclusions. On the territory of reserves, national parks and regional landscape parks, the relief and geological structure of the Polonyna-Chornohora, Skiba, Vododilno-Verkhovyna geomorphological regions and the Marmarosh crystalline massif are best represented. The least protected relief is the Zakarpattia Plain with its island volcanic hills. The highest regional geomorphological representativeness in the Ukrainian Carpathians is in the Carpathian BR, the Carpathian NNP and the Cheremoshsky RLP, and the highest typological representativeness is in the Hutsulshchyna NNP and the Carpathian BR. The Synevyr NNP and the Carpathian NNP have a somewhat lower typological representativeness, and the lowest diversity is observed in the relief of the Zacharovanyi Krai NNP. Due to the cluster structure of the territories, the Prytysyanskyi and Chernivtsi RLPs significantly improve the state of protection of foothill relief types, typical and unique landforms of the Ukrainian Carpathians.

Several types of relief have the highest level of cover by protected nature territories. There are folded-block medium-mountains formed on Proterozoic and Paleozoic sediments (type 1), folded-block medium-mountains with horst-anticline massifs on Cretaceous, Paleogene, and Paleogene sediments (types 2a, 2b), and thrust-folded medium-mountains with anticlinal and monoclinic mountain ranges on Cretaceous and Paleogene flysch (type 4b).

The thrust-folded medium-mountains with anticlinal and monoclinic mountain ranges composed of Cretaceous and Paleogene flysch (type 4a), the thrust-folded low-mountains with monoclinic and anticlinal ridges composed of Paleogene, partly Cretaceous sediments (type 6), and the folded-block medium-mountains on Cretaceous and Paleogene sand-clay sediments (type 3) are fairly well protected.

Seven types of relief are not protected at all, in particular, two in the mountains and five in the premountain part of the Ukrainian Carpathians. Territories of denudation-terrace uplands transformed by the activity of Oka glaciation and water-glacial streams (type 20), glacial and water-glacial plains (types 21, 22, 23) are not protected by institutions within Precarpathian Upland. On the territory of Hutsulshchyna RLP extremely

rare in the premountain part strongly dissected uplands by denudation and erosion (type 18) are protected. The floodplains and the complex of low undissected or weakly dissected terraces (type 26) are protected within Prytysyanskyi RLP. The low-mountainous relief in the mountainous part of the region (types 10 and 14) which is common only within Verkhnyotysenska (Solotvynska) basin also needs nature reservation.

The analysis of the distribution of landforms with protected status shows that the geomorphological areas of the Skibovi Carpathians (64 sites) with the dominance of cliffs (37) and waterfalls (19) and the Polonyna-Chernohiria (31 sites) with the dominance of rocks (12), caves (11) and relict glacial formations are the most saturated with geomorphological formations.

The creation of new national nature parks within Precarpathian-Prebeskydy, Zakarpattia Plain, and the Vygorlat-Gutynskiy Ridge will improve the state of protection of typical and unique types and forms of relief of the Ukrainian Carpathians.

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Стаття надійшла в редакцію 30.04.2025

Прийнято до друку 30.05.2025

Дата публікації 16.07.2025