

Characteristics of volcanic mountains morphostructure of Transcarpathia, Ukraine

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Received on 30-04-2022, reviewed on 26-08-2022, accepted on 07-10-2022

Abstract

The study presents a detailed geomorphological characterization of the volcanic mountains of Transcarpathia. Materials of previous geological researches, including the Transcarpathian geological exploration expedition, supplemented by the results of our own field researches, are systematized. Based on the analysis of relief forms and taking into account geomorphological and tectonic factors, Vyhorlat-Gutyn morphostructure of the second order is divided into morphostructures of the third order: Poprychny, Antaliv-Synyatska, Velykyi Dil, Tupy and Oash, which in turn are divided into morphostructures of lower orders. The Mukachevo morphostructure of the second order is composed of the following morphostructures of the third order: Beregovo hills, Kosino-Biganski hills, volcanic remains (Shalanka, Chorna Gora). Based on a detailed analysis of the collected materials, it was determined that the main role in shaping the modern relief of volcanic mountains belongs to channel and temporary water flows and weathering processes; consequently, river valleys and weathering surfaces were formed, which are the most important morphosculptures. On the basis of morphological and structural-lithological approach, as well as own field research, a geomorphological map of the volcanic mountains of Transcarpathia on a scale of 1: 100,000 was compiled.

Keywords: *geological structure, morphology, morphostructures, andesites, basalts, liparites, Vygorlat-Gutyn ridge*

Rezumat. Caracteristicile morfostructurilor munților vulcanici din Transcarpatia, Ucraina

Studiul prezintă o caracterizare geomorfologică detaliată a munților vulcanici din Transcarpatia. Sunt sistematizate materiale ale cercetărilor geologice anterioare, inclusiv expediția de explorare geologică transcarpatică, care sunt completate cu rezultatele cercetărilor proprii de teren. Pe baza analizei formelor de relief și luând în considerare factorii geomorfologici și tectonici, morfostructura Vyhorlat-Gutyn de ordinul doi este împărțită în morfostructuri de ordinul al treilea: Poprychny, Antaliv-Synyatska, Velykyi Dil, Tupy și Oash, care la rândul lor sunt împărțite în morfostructuri de ordin inferior. Morfostructura Mukachevo de ordinul doi este compusă din următoarele morfostructuri de ordinul al treilea: dealurile Beregovo, dealurile Kosino-Biganski, vestigiile vulcanice (Shalanka, Chorna Gora). Pe baza unei analize amănunțite a materialelor colectate, s-a stabilit că rolul principal în modelarea reliefului actual al munților vulcanici revine văilor și cursurilor temporare de apă, precum și intemperior, care au format văile râurilor și suprafețele de modelare, care sunt cele mai importante morfosculturi. Pe baza abordării morfologice și structural-litologice, precum și a cercetărilor de teren proprii, a fost întocmită o hartă geomorfologică a munților vulcanici din Transcarpatia la scara 1: 100.000.

Cuvinte-cheie: *structura geologică, morfologie, morfostructuri, andezite, bazalte, liparite, creasta Vygorlat-Gutyn*

Introduction

Volcanic mountains of Transcarpathia are the youngest orographic formation in the system of the Ukrainian Carpathians and at the same time, in comparison with the neighboring territories, are insufficiently studied. During the 19th-20th centuries, researches of the geological structure of the territory were carried out, along with thematic works, such as geophysical research, developed stratigraphic schemes. This contributed to a detailed study of the mineralogical and petrographic composition of rocks. Subsequently small-scale and large-scale studies supplemented the materials on geological study, neotectonics and paleogeographic analysis of the territory. These materials have almost no information about geomorphological features and processes, landforms of volcanic mountains. Some information

about the geomorphological structure of individual territories or districts is partially reflected in scientific publications. The most important contribution to the study of Transcarpathian volcanism was made by Maleev (1964), Merlich and Spitkovskaya (1974). Geological and tectonic processes were studied by Hofstein (1995), Alfer'ev (1968), Merlich and Spitkovskaya (1974), Kostyuk (1961), Sobolev, Vartanova, Gorbachevskaya (1947), Yermakov (1948).

The practical significance of the results. The relevance of this work is due to insufficient development of the topic, the lack of a comprehensive geomorphological study of the volcanic mountains of Transcarpathia. Therefore, there is a need to systematize and supplement existing materials and knowledge. This study is also relevant because the geomorphological study of the territory today is mostly descriptive, moreover morphological characteristics and its connection with

the main factors of relief formation remain practically absent. A complex combination of volcanic structures and tectonic elements has determined the modern geomorphological structure of the territory, which by the specific nature of volcanic activity, structural and morphological features require a separate study.

The collected factual material on the research issues can be used in further geomorphological and paleogeographic studies in the region, the characteristics of relief assessment for engineering, environmental and recreational purposes, the development of anti-erosion measures and more.

Study area. The southernmost volcano of the Carpathian ridges is the powerful Vygorlat-Gutyn volcanic ridge, one of the links of the Neogene volcanic formations of the Carpathian Arc. Within Transcarpathia, the ridge stretches in a narrow strip from northwest to southeast, from Uzhgorod to Khust. The length of the strip is about 120 km, the width - from 8 to 25 km. Along the southern slopes of the Vyhorlat-Hutyn ridge, there is the Chop-Mukachevo alluvial plain, against which rises the Beregovo hills and island volcanic mountains. They are located west of Berehove, between the villages of Velyka Bigan and Zapson and near Vynohradiv (Fig. 1).

The structural-volcanic relief of the volcanic mountains of Transcarpathia was formed as a result of the interaction of oppositely directed endogenous and exogenous forces. The former significantly prevailed, forming the main geological structures. Morphostructure is understood as a complex of relief forms and geological structure, historically connected into a single unit by common conditions of development. According to Kruglov, Smirnov, Khyzhnyakov (1985), Palienko (1992), the East Carpathian morphostructure of the first order is divided into seven morphostructures of the second order, among which the Vygorlat-Gutyn and Transcarpathian morphostructures are distinguished (Palienko, Sokolovsky 1979), as well as Mukachevo and Solotvyno (Gerenchuk 1981).

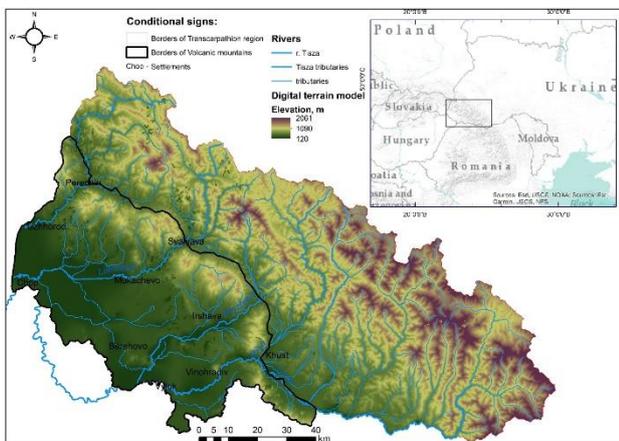


Fig. 1. Map of study area

Materials and Methods

During the study of the geomorphological structure of the volcanic mountains of Transcarpathia, a number of methods of both general and specific scientific knowledge were used. In close contact with the basic natural sciences, geomorphology makes extensive use of the methods of various natural sciences. However, more important in geomorphological research are certain methods that underline the sciences of the geological complex, and sciences that study the spheres of the Earth's outer shell.

In geomorphological science, depending on the organization of work, there are methods of field geomorphological research (expeditionary), which are based on route surveys of the territory and combined with geomorphological mapping and in-house methods aimed at processing field materials, their generalization and terrain modeling (Karpenko 2009).

The morphological method used in the current research was to determine the external features of the forms and types of the volcanic mountains relief of Transcarpathia. It was used to establish and describe narrow ridges, cone-shaped and domed peaks, hills, V-shaped river valleys, and so on. There is no doubt that this method of research was necessary to combine the analysis of morphology of ancient and modern relief creation processes in the study area, which allows to objectively assess the stability of relief elements.

The morphometric method of research, which is a variant of the morphological method, is based on quantitative information about geomorphological objects to identify and describe them. Based on this, specific morphometric descriptions are made, which are necessary for understanding the basic laws of formation and development of the relief of the earth's surface. For this purpose, morphometry uses any quantitative information about the relief of the study area. Morphometric indicators are needed primarily for the development of measures in areas with dangerous relief-forming processes.

For this research quantitative indicators of the relief were analyzed using GIS packages - ArcGIS and graphics editors CorelDraw and Adobe Photoshop. It was important to correctly build the technological process of vectorization of cartographic data. Preparation of raster cartographic materials was carried out according to the technological scheme proposed by Dziuba (2000).

Since the geomorphological structure of the volcanic mountains of Transcarpathia is inextricably linked with the geological features of the territory and tectonic structures, an important approach in the study of these relationships is the morphostructural method. The method is used to study the relationship between the irregularities of the earth's surface and the geological structure of the study area. The

morphoneotectonic research method was used to identify the links between landforms and geological deposits and to study the direction of tectonic movements and their reflection in geomorphological processes (erosion, accumulation, etc.). The morphodynamic method of cognition was used for the analysis of exogenous processes of the territory and their influence on the geomorphological structure.

On the territory of Transcarpathian volcanic mountains, reconnaissance routes were selected on the basis of topographic (scale 1:25,000, 1:50,000) and geological maps (1: 200,000), maps of quaternary deposits (1: 100,000) and stock materials of the Transcarpathian Geological Exploration Expedition. Due to the large size of the study area, key areas were selected for such routes, which represent the main elements and forms of relief of the volcanic mountains of Transcarpathia. Field geomorphological studies have been conducted for several years within the following areas:

1. route through the territory of the Poprychny massif;
2. study of the Antaliv-Synyatsky massif;
3. route through the Velykyi Dil massif;
4. field research of the Tupy ridge territory;
5. route through the territory of the Oash massif;
6. study of volcanic remains of the Chop-Mukachevo lowland (Fig. 2).

The purpose of the field research was to identify morphostructures, basic forms and types of relief, survey of natural outcrops, study river valleys and

their deposits as well as other elements. At the same time, attention was paid to the peculiarities of the expression of morphostructures in the relief and their comparative analysis was performed. The influence of hydrographic objects of the territory, soil and vegetation cover and economic development on the intensity and dynamics of modern geomorphological processes was also observed.

During the desk stage, a detailed analysis of the available materials was carried out, a geomorphological map of the volcanic mountains of Transcarpathia at a scale of 1: 100,000 was compiled (Fig. 3).

Results and Discussion

The study area is located within the Vyhorlat-Gutyn and Mukachevo morphostructures of the second order. The Vyhorlat-Gutyn morphostructure was formed as a result of powerful volcanic eruptions in the Upper Miocene and Pliocene. It is formed by Kuchavsky, Antalivsky, Makovytsky, Matekivsky, Sinyatsky, Obavsky, Martynsky and Buzhorsky volcanic complexes. They are composed mainly of andesites, andesite-basalts, andesite-dacites, basalts, and their tuffs.

Transverse terraced valleys of the Uzh, Latorytsia, Borzhava and Tisza rivers divide the volcanic ridge into separate massifs. West of the river Uzh there is the Vygorlat ridge, the main part of which is located within Slovakia.

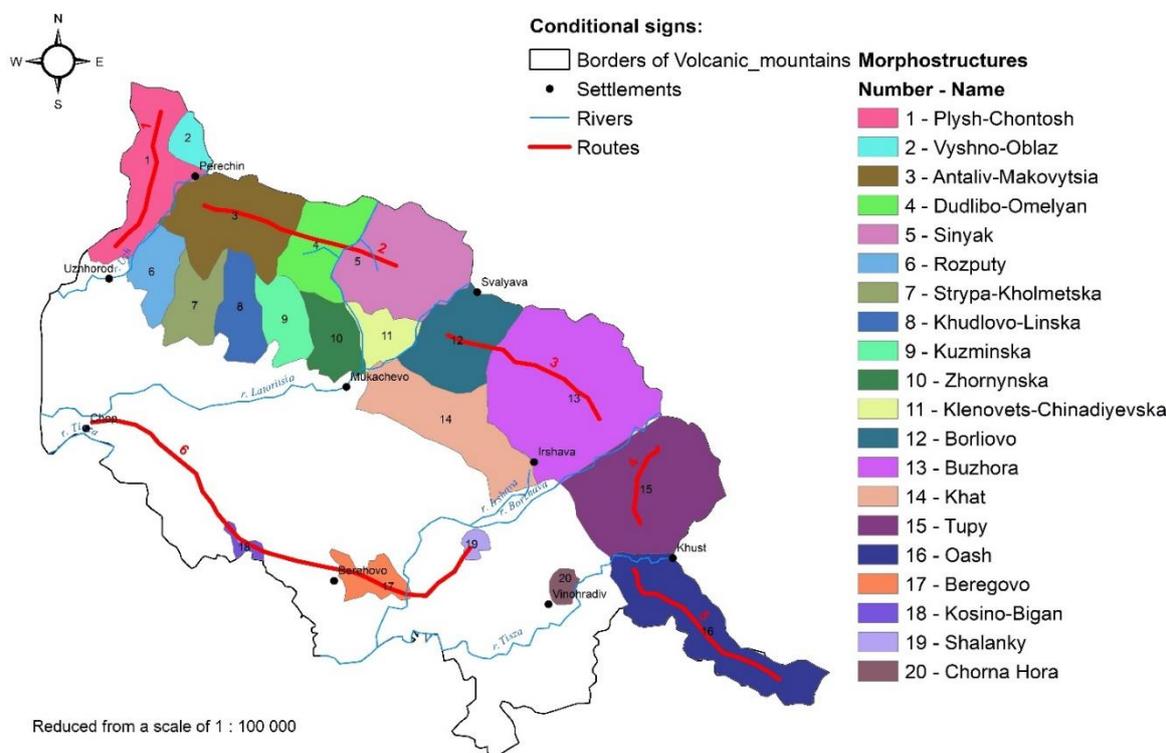


Fig. 2: Map of the morphostructures of the Volcanic mountains and survey routes

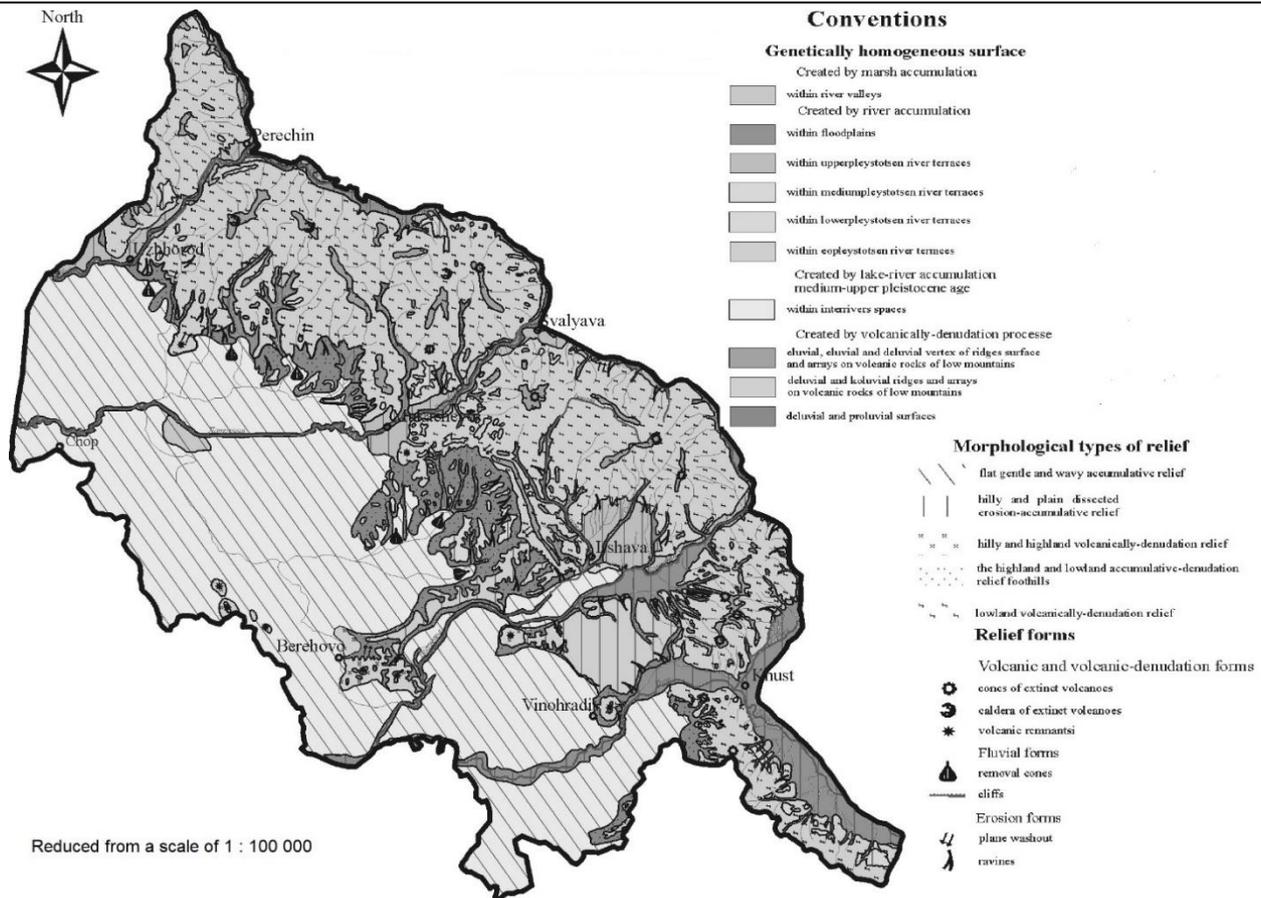


Fig. 3: Geomorphological map of Volcanic mountains of Transcarpathia, Ukraine

The group of mountains between the valleys of the Uzh and Latorytsia rivers is the Antalivska Polyana massif, or Makovytsia, with individual peaks close to 1,000 m (Makovytsia - 978 m, Pleska - 993, Serednya - 981 m). Between the Latorytsia and Borzhava rivers there is a massif Velykyi Dil with Mount Buzhora (1,086 m), which is the highest peak of the volcanic mountains within Transcarpathia. The Tupy massif, acquiring a meridional direction relative to the main ridge, is located between the valleys of the Borzhava and Tisza rivers. Dome-shaped peaks Klobuk (856 m) and Tupy (878 m) rise along the ridge. South of the city of Khust, behind the Tisza River there is the Oash massif, which stretches into Romania.

The morphology of the Vygorlat-Hutyn ridge is due to the multiphase of accumulative volcanic activity and long periods of erosion and denudation of the original forms of volcanic structures. As already noted, the most characteristic features of the ridge are its asymmetric structure: with short and steep northern, northeastern and eastern slopes and elongated and gentle opposites, which are oriented towards the plain. The highest peaks are located closer to the northern, northeastern and eastern edges of the Vyhorlat-Hutyn ridge, in particular, Poprychny (995 m), Antalivska Polyana (988 m), Makovytsia (976 m), Dunavka (1018 m), Dakhmaniv

(1016 m), Martynsky Kamin (970 m), Buzhora (1083 m), Bystra (1038 m), Tupy (778 m), Tovsty (819 m), Frasin (826 m), etc. These are volcanoes of the central type, which have preserved their characteristic conical shape and significant relative elevations (400-500 m) over the surrounding area with a classically pronounced radial hydro network. The tops and upper parts of the slopes of central volcanoes are sediments, smoothed, and flat watersheds are structural denudation surfaces of lava flows, which are prepared by denudation and somewhat eroded (Kamanin L, Ivanova 1954; Matskiv et.al. 2001).

Areas of tuff accumulation form wide watershed surfaces with absolute heights of 350-650 m and values of relative elevations up to 200-400 m. The slopes are generally smoothed, but dissected by a small bright system. Extruded tents, slag cones, subvolcanic and subintrusive rods, hypobisal bodies are well expressed in relief. They form conical vertices, the shapes of which are close to isometric, elliptical with sizes from 0.3-0.5 to 1.0-2.0 km.

The morphology of the river valleys that divide the Vygorlat-Gutyn ridge is determined by the lithology of blurred rocks. The valleys laid in massive lavas are deep, steep slopes with a V-shaped profile, while those in the tuffs are wide, trough-shaped.

The Mukachevo morphostructure is composed of Neogene molasses and Sarmatian volcanics, which are almost everywhere covered by quaternary sediments. The surface of the morphostructure is mainly a flat lowland alluvial plain, the absolute heights of which increase in the area near the Vyorlat-Gutyn ridge. In general, this area is a low terrace of the Tisza River and its tributaries, which rises above the current water level in rivers by an average of 5-6 m. The absolute heights of the plain are 115-120 m in the area adjacent to the Vyorlat-Gutyn ridge, descending to 105 m on the banks of the Tisza near the town of Chop.

The Mukachevo morphostructure is separated from the Vyorlat-Hutyn ridge by a strip of foothills, which in the Mukachevo-Irshava section form two flat spurs towards the lowlands. There are several ledges, which are inclined to the lowlands and divided by small tributaries of the rivers Latorytsia, Borzhava, as well as a number of shafts with wide, flat or domed peaks (Gerenchuk 1981). The relief of the morphostructure includes some dome-shaped volcanic mountains and remnants - Beregovo hills, Kosino-Biganski hills, Palanka, Drysinskaya, Chorna Gora (568 m), Shalanka (372 m) and others.

We propose to divide the Vyorlat-Gutyn morphostructure of the second order into morphostructures of the third order. From the north-west to the south-east, we distinguish the following morphostructures: Poprychny, Antaliv-Synyatska, Velykyi Dil, Tupy and Oash, which, in turn, are divided into morphostructures of lower orders.

The Mukachevo morphostructure of the second order includes the Beregovo mountain range, the Kosino-Biganski hills, volcanic remains (Shalanka, Chorna Gora), which respectively are lower order morphostructures.

The Poprychny morphostructure occupies the area between the state border with Slovakia and the valley of the Uzh river. It was formed on the homonym volcano, which is composed of andesites, andesite-dacites, rhyolites and their tuffs of the Antalivsky volcanic complex. The territory of the morphostructure is characterized by low-mountainous volcanic-denudation relief. From the west, along the state border, the watershed ridge Poprychny Verkh with domed, sometimes elongated peaks can be clearly seen (mountains Golytsia - 983.1 m, Vitrova Skala - 1024.9 m, Poprychny Verkh - 995.2 m, Chertezh - 903.8 m). The slopes of the ridge are mostly convex. The exception is the northeastern slope, which has a complex convex-concave transverse profile. The steepness of the slopes' averages 9-20° and more. The ridge is composed of fine-porphyry andesites and their tuffs with a thickness of 260 m, which are overlapped by periclinal lava flows (up to 200 m) of various porphyry andesites. It is divided by the upper reaches of the

rivers Syrova, Benyatinska Voda, Kamenichka, Syry Potok, where deep erosion predominates. River valleys are characterized by steep slopes, V-shaped transverse profile, there are no floodplains. In the southern part of the Poprychny morphostructure, from the Poprychny Verkh ridge to the Uzh river valley, two low-mountain ridges with Plyshka (693.4 m) and Yavorova (701.1 m) peaks stand out, forming the fourth-order Plysh-Chontosh morphostructure. The maximum absolute heights of the morphostructure range from 440-700 m. The main characteristic of the lithological features of this morphostructure, as well as that of Poprychny, is the dominance of sediments of the Antalivsky volcanic complex, represented by andesites, andesitic basalts, andesitic dacites and their tuffs. The south-eastern part of the morphostructure differs, where eruptive bodies of fine-porphyry andesites stand out on the left bank of the Syry Potok. The Chontosh and Plyshka ridges are separated by the Syry Potok river, which flows in a south-easterly direction and flows into the Uzh river near the village of Kamenitsa. The river valley is narrow, with steep (more than 20°) slopes. The ridges are strongly dissected by tributaries of the Syry Potok river. Their slopes are mostly convex, sometimes concave, with a steepness of 8-20°.

The interfluvium of the Domarach and Dvernytsky rivers is occupied by the Vyshno-Oblaz morphostructure of the fourth order, which is represented in the relief by a highly dissected ridge with steep northern slopes (maximum absolute heights 358.8 m, 331.6 m) and a domed mountain Vyshny Oblaz (357.2 m).

The Antaliv-Synyatska morphostructure occupies the interfluvium of the Uzh and Latorytsia rivers. Its length is up to 43 km, width - 25-27 km. Orographically, it is characterized by short and steep northern, northeastern slopes in the direction of the Turya River valley and gentle and elongated southern, southwestern slopes in the direction of the Chop-Mukachevo lowlands. The highest absolute heights are in the northern and north-eastern part of the morphostructure, the growth of which can be traced from the north-west (from the Uzh river valley) to the south-east (to the Latorytsia river valley).

From the valley of the Uzh river to the Koblyky tract, we find the ridge Sinatoriya (691.9 m; mountains Rozhok - 546.4 m; Sokolych - 812.0 m), the Lypova Skelya ridge (896.0 m), mountain Makovytsia (976.0 m). The southern part of this ridge is characterized by conical peaks (Antalivska Polyana - 968.3 m, Dil - 793.5 m). The ridges are strongly dissected, massive and mostly sub-latitudinal. The surfaces of the peaks are rounded, wide, flat and are structural denudation surfaces of lava covers and streams, modelled mainly by deep erosion. Slopes are usually convex, concave, convex-concave with steepness from 3-5° (top surfaces) to 35° (near the

tops of the Klokotyva stream). The north-eastern slopes of the ridges are divided by numerous streams of the Verkhniy, Velyka Ruzha, Kostylyv, Bystryk, south-eastern slopes - the valleys of the streams Tsygany, Solotvinsky, Stara and their numerous tributaries.

In the upper reaches of the Vyznytsia (tributary of Latorytsia) and Poluy rivers (tributary of Mala Latorytsia) the absolute heights decrease to 570-700 m (tracts Koblyky, Podklykuchky, Omelyany, Yavornyk). The area is dominated by medium-divided massive ridges with narrow elongated peaks (Podklikuchka tract, the interfluvium of the Polyuy and Vyznytsia rivers). Convex, convex-concave slopes with a steepness of 3-7° on flat top surfaces up to 30° in the valley of the Vyznytsia river predominate.

The highest part of the Antaliv-Synyatska morphostructure is located between the valleys of the Vyznytsia river with the tributary Lamovani and the valley of the Latorytsia river. It is represented by the Tovsty, Shiyka, Plyshka and Sinyak ridges, which extend almost meridionally. The Tovsty, Shiyka and Plyshka ridges include the following peaks: Chalovisty, 860.0 m; Neck, 702.9 m; Plyshka 992.0 m; Obavsky Kamin, 979.2 m. The Sinyak ridge includes the Biliy Kamin, 961.0 m; Dunauka, 1018.8 m; Solochynskyi Dil, 980.7 m; Serednyi Verkh, 980.7 m. These ridges are divided by deeply incised valleys of the rivers Vyznytsia, Obava, Matekova, Tysanyk, Oblazny, Luh, Bystra, which in very large areas have very steep and steep slopes. Apical surfaces are rounded, wide and wavy.

The southern and southwestern part of the Antaliv-Synyatska morphostructure is divided by numerous tributaries of the Latorytsia river into elongated ridges from north to south, where absolute heights of 300-500 m predominate. Absolute and relative heights, as well as the steepness of the slopes gradually decrease with the approach to the Chop-Mukachevo plain. Against the background of these ridges, dome-shaped peaks rise, the structure of which involves powerful strata of andesites and andesite-dacites (Kravchuk, 2008).

Sediments of the Kuchavsky (southeastern part), Antalivsky, Makovytsky, Matekivsky, Synyatsky, and Obavsky volcanic complexes take part in the construction of the Antaliv-Synyatska morphostructure. These are andesites, andesite-basalts, rhyodacites, dacites, andesite-dacites and their tuffs. The total thickness of the deposits of each complex is from 400 to 700 m.

Within the Antaliv-Synyatska morphostructure of the third order, the following morphostructures of the lower order can be distinguished: Antaliv-Makovytska, Dudlibo-Omelyanska, Tovsty-Sinyak, Rozputy-Chinadiyevska.

The Antaliv-Makovytsia morphostructure of the fourth order in the west and northwest is limited by

the valley of the Uzh river, in the north and northeast - by the valley of the river Turya, on the east - by the upper reaches of the rivers Bystryk (tributary Turya) and Stara (tributary Latorytsia), and in the south-west and south - by the line of villages Orikhovytsia - Yarok - Verkhne Solotvino - Antalovtsi. In its western part there is the Sinatoria ridge with the peaks of Rozhok (546.4 m), Sokolych (812 m), Antalovetska Polyana (968.3 m), Dil (793.5 m). To the east stretches the ridge Lypova Skala with the peaks of Makovytsia (976.0 m) and Zakruzhy (687.0 m). The northern and north-eastern slopes of the ridges are strongly dissected by the tops of numerous tributaries of the Uzh and Turia rivers (Vorocheva, Verkhniy, Klokotyva, Velyka Ruzha). Convex and convex-concave slopes with a steepness of up to 35° predominate. The southern and southwestern slopes are less dissected than the northeastern ones. Their steepness does not exceed 15-20°. The slopes are mostly convex, although straight. The apical surfaces of the ridges are rounded, often wide and bumpy. River valleys that divide ridges are narrow, sloping, symmetrical, often V-shaped. The Antaliv-Makovytsia morphostructure is composed of deposits of the Antalivsky and Makovytsky volcanic complexes. The Antalivsky complex, represented by andesites and their tuffs, andesite-dacites, rhyolites and their tuffs, forms the Sinatoria ridge and the lower part of the Lypova Skala ridge. The Makovytsky complex forms the upper part of the Lypova Skala ridge. It is composed mainly of medium porphyry diopside andesites, less of andesite-basalts, tuffs of andesites, which with angular mismatch lie on the Paleogene rocks of the Magura flysch, and with a stratigraphic break - on the rocks of the Antalivsky complex.

The Dudlibo-Omelyan morphostructure. The western and northwestern borders of this morphostructure are the interfluvium of the Stara and Bystryk rivers, the northern border runs along the valley of the Turia river, the northeastern border runs along the valley of the Mlynska river and the valley of the Lamovani river (a tributary of the Vyznytsia). Vyznytsia, and south-west - along the villages of Goydosh-Lintsi-Patskanyovo-Rostovyatytsia-Bobovyshche-Ilkovytsia-Lesarnia. Maximum absolute heights range from 600 to 780 m, relative heights from 150 to 180 m. In the relief there are low mountain ranges and ridges with elongated and domed peaks, extending in accordance with the general direction of the study area, ie from northwest to southeast. They are divided by numerous valleys of streams. The steepness of the slopes is mostly 2-7°, sometimes increasing to 15°. The flow valleys embedded in the andesites are characterized by a V-shaped structure and in tuffs by a U-shaped structure. The western and central parts of the Dudlibo-Omelyan morphostructure include andesites, andesite-dacites, andesite-basalts and their tuffs of

Antalivsky, Makovytsky, Matekivsky volcanic complexes superimposed on each other. The north-eastern part of the morphostructure is formed by dacites, rhyodacites, andesite-dacites, andesites and their tuffs of the bruise complex. The thickness of the complexes does not exceed 700 m. In the southern part of the morphostructure volcanic rocks are covered with deluvial and deluvial-proluvial deposits up to 10 m thick.

The morphostructure of Sinyak occupies the interfluvium of Vyznytsia and Velyka Pina. In the northwest, its border runs along the watershed between the Lamovani Valley (left tributary of the Vyznytsia) and the Mlynsky Valley (left tributary of the Turia). In the south and south-east, the boundary of this fourth-order morphostructure runs along the line of the villages of Klenovets-Obava-Chinadiyevo and the valley of the Latorytsia river. Its length from north to south is about 24 km, from west to east - 17 km. In the western part of the morphostructure in the relief there are ridges of almost meridional extension: Tovsty, Shiyka and Plyshka (mountains Chalovisty, 860.0 m; Shiyka, 702.9 m; Plyshka, 992.0 m; Obavsky Kamin, 979.2 m). The eastern part of the morphostructure is the Sinyak ridge with the Krugla (744.2 m), Dunauka (1018.8 m), Solochynsky Dil (943.0 m), Serednyi Verkh (980.7 m) and Zvesna (722.3 m) peaks. The central part of the morphostructure Sinyak is divided by the valley of the river Matekova and its numerous tributaries. The valley is well defined, narrow at the top with a V-shaped profile, and below the Fokova tract in the relief there is a floodplain. The slopes of the valley are convex, often straight, with a steepness of more than 25°. In the western part of the morphostructure, the absolute heights decrease to 500-680 m, and elongated and conical peaks stand out in the relief (mountains of Berdo, 678.4 m; and Shkitena, 530.3 m). The steepness of the slopes compared to the eastern part is also reduced and is 4-9°, and in the tract Yavornik does not exceed 3°. The shape of the slopes is mostly convex, convex-concave. In general, the morphostructure has the form of a stratovolcano, prepared by the erosion of watercourses. The morphostructure of Sinyak is formed by andesites and their tuffs of Antalivsky, Makovytsky, Matekivsky, Sinyatsky and Obavsky volcanic complexes, which were formed as a result of several eruptions that occurred at more or less equal intervals.

The Rozputy-Chinadiyev morphostructure of the fourth order is distinguished in the south-western part of the Antaliv-Synyatsky morphostructure of the third order. It occupies the interfluvium of the Uzh and Latorica rivers. Its northern and north-eastern border runs along the line of the villages of Orikhovytsia – Yarok – Verkhne Solotvyno – Antalivtsi – Kiblyary – Lintsi – Patskanyovo – Rostovyatytsia – Mykulyntsi – Shchaslyve – Lesarnia – Klenovets – Obava –

Chinadiyevo. The south-western border coincides with the border of the Chop-Mukachevo lowland. It is characterized by high-altitude accumulative-denudation relief. The maximum absolute heights of the morphostructure range from 400-560 m. The highest peaks are located in the central and eastern parts of the morphostructure: Zhornyna (543.4 m), Khudlivska (551.7 m). The structure of the morphostructure involves volcanic rocks of various volcanic complexes, which are sometimes covered with a thick crust of weathering of andesites and deluvial-proluvial deposits. The Rozputy-Chinadiyev morphostructure is characterized by smoothed outlines of ridge surfaces with a predominance of dome-shaped peaks and rather wide valleys of the main rivers with declining slopes. In fact, these valleys divide the Rozputy-Chinadiyev morphostructure into Rozputsky (Uzh and Tsygany interfluvium), Strypo-Kholmetsky (Tsygany and Stara interfluvium), Khudlyovo-Linska (interfluvium of the Stara and its tributaries), Kuzmyska (Stara and Polyuy interfluvium) and Zhornynska (the interfluvium of the Polyuy and Vyznytsia rivers) and the Klynovets-Chinadiyev (interfluvium of the Vyznytsia and Matekova rivers) morphostructures of the fifth order.

The Rozputy morphostructure is represented by a wide ridge with dome-shaped elongated peaks (m. Rozputy, 291.0 m). Its north-eastern border runs along the line of the villages of Orikhovytsia-Yarok. The south-western part of the morphostructure is strongly dissected by streams flowing into the Uzh river and the reclamation canals of the Chop-Mukachevo plain. Absolute heights up to 140 m decrease in the same direction. Convex and straight slopes with a steepness of 1-7° predominate.

The Strypa-Kholmetska morphostructure on the interfluvium of the Tsygany and Stara rivers is distinguished by four ridges and a dome-shaped massif, which are strongly dissected by tributaries of the Tsygany and Stara rivers. The north-eastern border runs along the Strypa-Khudlyovo line. The maximum absolute heights are 330 m and gradually decrease to 195 m in the direction of the Chop-Mukachevo lowlands. An exception is the massif with dome-shaped peaks (301.0 m; 302.5 m) south of the village Hlyboke, which is composed of sub-intrusive bodies of acidic composition. For strands that stretch from north to south, elongated narrow surfaces, convex slopes with a steepness of 3-7° are characteristic. The domed massif is characterized by convex, convex-concave slopes with a steepness of 7-18°.

The Khudlovo-Linska morphostructure is represented by a ridge with a conical peak (551.7 m), stretching from northeast to southwest and a wide massif with elongated and domed peaks, which gradually decreases in the southern direction to the Chop-Mukachevo lowlands. A strand of the array

separates the Lyn stream. The apical surfaces of the ridge are mostly elongated and wavy. North-western, southern and south-eastern slopes of the ridge are straight, steeply 5-18°. The slopes are dissected by a large number of ravines formed on yellow-gray loams.

For a wide massif located in the southern part of the morphostructure, lower absolute heights and steeper slopes are characteristic compared to the ridge. Absolute heights decrease from north to south from 270 m to 189 m, respectively. Apical surfaces are wide, bumpy. Convex slopes with a steepness of 2-7° predominate. The array is strongly divided by ravines, which are concentrated in the southern part. The morphostructure consists of andesites of the Antalivsky and Makovytsky complexes and sub-intrusive bodies of acidic composition (dacites), which form the apical surfaces. In the southern part of the morphostructure, the thickness of volcanic rocks decreases towards the Chop-Mukachevo lowland, while the thickness of quaternary sediments, represented by pebbles of ancient terraces, which are covered with clays and yellow-brown loams with a thickness of 2 to 20 m.

The fifth-order Kuzminska morphostructure occupies the interfluvium of the Stara and Polyuy rivers. Its northern and northeastern border runs along the line of the villages of Lintsi-Patskanyovo-Rostovyatytsia-Mykulyntsi-Bobovyshche, and its southern line runs along the Polyuy valley. In relief it is expressed by low ridges elongated from north to south with wide, elongated and rounded peaks, which are strongly dissected by tributaries of the Stara and Polyuy. In the same direction, the absolute heights decrease from 340.4 m to 161.3 m. The relative heights are 120-180 m. The slopes of the strands are mostly convex, with a steepness of 2-5°, sometimes exceeding 7°. In the southern part of the morphostructure, below the villages of Kuzmino and Kopynovtsi, ravines up to 10 m wide and 2-3 m deep stand out well in the relief. The morphostructure is partially formed by andesites, andesite-basalts of Kuchavsky, Antalivsky and andesite-dacites of Sinyatsky volcanic complexes, which are covered with pebbles of ancient terraces and a thick layer of deluvial and deluvial-proluvial deposits.

The Zhornynska morphostructure on the interfluvium of the Polyuy and Vyznytsia rivers has the form of an elongated ridge from north to south with narrow, conical peaks (453.8 m; 567.0 m; m. Zhornyna, 543.4 m). Its northern border runs along the line of the villages of Bobovyshche – Ilkovytsia – Lesarnia, south-western and southern - along the line Ruske – Ivanivtsi – Klyachanovo and the valley of Latorytsia. The slopes of the ridge are strongly dissected by tributaries of Polyuy and Vyznytsia, as well as ravines formed in yellow-gray loams. Straight and concave slopes with a steepness of 5-15° prevail. The morphostructure consists of andesites, andesite-

basalts, andesite-dacites of the Kuchavsky and Matekivsky complexes, which in the south-western part are covered with terrigenous deposits, pebbles of ancient terraces and deluvial-proluvial deposits.

The fifth-order Klenovets-Chinadiyevska morphostructure occupies the interfluvium of the Vyznytsia and Matekova rivers. The northern border runs through the villages of Klenovets and Obava, and the southern border runs through the valleys of the Obava and Latorytsia rivers. The morphostructure has the form of a small massif, in places with dome-shaped peaks, strongly dissected by tributaries Vyznytsia, Obava and Matekova. The maximum absolute heights are characteristic of the north-eastern part and are 291.8 m. The slopes of the massif are mostly convex, with a steepness of 1-7°, although in the southern part of the morphostructure the steepness of the slopes reaches 17°. In the area of the villages of Obava and Klenovets, the relief features a large number of negative forms, represented by beams and ravines. The ravines are 15 m wide and 5 m deep. The morphostructure is formed by andesites, andesite-basalts, andesite-dacites of the Matekivsky and Sinyatsky volcanic complexes, in the southern part covered by alluvial deposits of the second terrace of Latorytsia and deluvial loams.

The morphostructure of Velykyi Dil, which is dominated by low-mountainous volcanic-denudation relief, occupies the interfluvium of the Latoritsa and Borzhava rivers. Its geomorphological structure is similar to the structure of the Antaliv-Syniatskaya morphostructure. In the northwestern part there is the Borliovy Dil massif with the Dehmaniv peak (1017.6 m). Numerous branches diverge radially from it, separated from each other by deeply incised valleys of many streams. The largest massif in the northern and north-western directions is fixed by the peak of Kichera (737.2 m), the other is located between the two sources of Bystryy (over 600 m). In the southern direction it is a branch of the Kryvulya tract (822.7 m). The massif has the appearance of a well-preserved stratovolcano (Kravchuk 2008). Dominated by straight slopes, which in the lower part become concave. The steepness of the slopes average between 15 and 20°. To the south-east the Velykyi Dil ridge stretches, which is separated from the Borliov Dil massif by the valley of the Irshava river and the upper reaches of the Kvasny Stream (left tributary of the Dusynka river). The highest peaks are Shelelovsky Verkh (729.1 m), Zlobsky (832.1 m), Buzhora (1085.5 m, the highest peak of the Volcanic range), Kamin (957.2 m), Sinyak (1035.2 m), Bystra (1002.5 m). The north-western part of the ridge is divided by the Irshava river. On its left bank there is an arched ridge with the top of Kryvulya (591.3 m), which from the east, southeast is surrounded by domed massifs with the peaks of Smologovytsky Dil

(807.1 m), Martynsky Kamin (989.0 m), Berehovy Dil (926.3 m) and Yavir (717.0 m). The morphostructure of Velykyi Dil is formed by the superimposed deposits of the Kuchavsky (southwestern part), Matekivsky, Synyatsky, Obavsky, Martinsky, and Muzhorsky volcanic complexes. They are represented by andesites, andesite-basalts, their tuffs, lava breccias, tuffites and basalts. Within the morphostructure of the Velykyi Dil, which belongs to the third order, we distinguish three morphostructures of the fourth order: Borliovo, Buzhorsk and Khat.

The fourth-order Borliovo morphostructure is bounded on the northwest by the valley of the Latorica River, on the north and northeast by the valley of the Dusynka river, on the east by the upper Kvasny stream (a tributary of the Dusynka river) and the Irshava river valley, and on the southwest by a line of villages Olkhovytsia – Letsovytsia – Babichi – Klenovytsia – Zagattya. In the relief the morphostructure is expressed by the cone-shaped mountain massif Borliov Dil with the Dehmaniv peak (1017.6 m). The massif has a round shape with a diameter of about 10 km, which divides a large number of streams flowing into the rivers Latorytsia, Dusynka, Irshava. The streams are characterized by deeply incised valleys, in most of the slopes with a V-shaped structure. The upper and middle parts of the slopes are mostly straight, with a steepness of 15-30°. The lower part of the slopes is characterized by a concave profile, with a slope steepness of up to 8°. The southern slopes of the massif are elongated in the direction of the Kryvulya river valley, their steepness does not exceed 5°. The Borliovo morphostructure is composed of deposits of the Kuchavsky, Matekivsky, Synyatsky, and Obavsky volcanic complexes. The Kuchavsky complex is formed by andesites, andesite-basalts, their tuffs, which occur in the basin of the Irshava river and in the south of the morphostructure. It is overlain by andesites, tuffites and lava breccias of the Matekivsky complex. Above the sediments of the Matekivsky complex in the central and eastern part of the morphostructure lie dacites, andesite-dacites, and their tuffs of the Bruise complex. The Obavsky complex is represented by large porphyry andesites and andesite basalts, which form the apical part and the southern slopes of Dehmaniv.

The morphostructure Buzhora in the northwest is bounded by the upper reaches of the Kvasny stream (a tributary of the Dusynka river) and the Irshava river valley, in the north by the Dusynka river valley, in the northeast and southeast by the Borzhava river valley, and in the southwest by the Irshava river and Irshava basin. In its north-western part there is an arched ridge with the top of Kryvulya (591.3 m). It is characterized by elongated and rounded peaks, straight and convex slopes, which are strongly divided by the valleys of the rivers Irshava and Abranka. The

steepness of the north-western slopes is over 25°. To the east and south-east of this ridge there is a domed massif with peaks Smologovytsky Dil (807.1 m), Martynsky Kamin (989.0 m), Berehovy Dil (926.3 m) and Yavir (717.0 m). The massif is strongly divided by the rivers Abranka, Chorna Irshava and their numerous tributaries. The apical surfaces of the massif are wide, domed. The south-western slopes of the massif are mostly concave, with a steepness of 7-18°. The northern slopes are characterized by a convex profile, steepness from 3° in the apical parts to 30° in the valley of the Irshava river.

The largest ridge of the morphostructure, Velykyi Dil, stretches from the Kvasny stream to the Borzhava river valley. In the north-west it is separated from the dome-shaped massif described above by the valley of the Irshava River, and in the west by the valley of the Ilnychka river. The ridge is fixed by the peaks Shelelovsky Verkh (729.1 m), Zlobsky (832.1 m), Buzhora (1085.5 m, the highest peak of the Volcanic ridge), Kamin (957.2 m), Sinyak (1035.2 m), Bystra (1002.5 m). The apical surfaces of the ridge are mostly narrow, elongated, conical. The northern and northeastern part of the ridge is divided by numerous left tributaries of the Dusynka river and the right tributaries of the Bystry and Borzhava rivers. In this area, the slopes are characterized by a complex structure: the upper parts of the slopes are straight, steepness over 25°, the middle and lower part is mostly concave-convex, steepness 7-15°. In the southern part of the morphostructure is the Irshava basin, which is dominated by hilly-plain dissected relief. It is composed of layers of clay with layers of sandstones, siltstones and lignites of the Ilnytsya world (Panon). In its south-western part there are clay deposits with layers of tuffs and tuffites of the Almashi and Lukiv Sarmatians. Floodplains and low floodplain terraces within the basin occupy large areas, and the basin can be considered as a separate morphostructure of lower order. The andesite basalts of the Kuchavsky, Matekivsky, Synyatsky, Martinsky and Buzhorsk volcanic complexes take part in the construction of the Buzhora morphostructure.

The south-western part of the interfluvium of the Latorytsia and Borzhava rivers is occupied by the Khat morphostructure. From the northeast it is limited by the villages of Olkhovytsia-Babichi-Zagattya and the valley of the Irshava river, and from the south-west by the villages of Kuchava, Stanovo, Zavydovo, Negrovo, Ardanovo, and Siltse. The relief is represented by a ridge stretching from northwest to southeast. In this direction, the absolute heights recorded by the peaks of Velykyi Kamin (434.5 m), Velykyi Gorotan (407.6 m), and 260.5 m (near the village of Siltse) also decrease. The structure of the morphostructure is dominated by tuffs. Therefore, the tributaries of the Irshava, Borzhava and Latoritsa rivers divide the ridge into separate spurs of different

directions, ending mainly in small domed massifs (242.6 m, near the village of Bystritsa). The north-eastern slopes of the ridge are gentle, steeply 3-7° and more dissected. South-western slopes are convex-concave, steepness in the apical part up to 15°, and in the middle and lower - 3-5°.

The morphostructure Khat consists the deposits of Kuchavsky, Matekivsky and Obavsky volcanic complexes. In the north-western part of the morphostructure from the village Kuchava to the village of Negrovo there is a layer of andesite tuffs with a thickness of about 56 m from the Kuchavsky complex. The complex is covered with tuffs of andesite, andesite-basalt of the Matekivsky complex, which are common between the villages of Dilok and Silce. Sediments of the Obavsky complex are distributed on the south-western slope of the ridge, represented by erosive remnants of andesite-basalt up to 10-25 m thick.

The Morphostructure Tupy occupies the interfluvium of the Borzhava and Tisza rivers, its length is 16-18 km. The morphostructure is characterized by low-mountainous volcanic-denudation relief, which is represented by a meridional ridge with well-fixed peaks Maly Klobuk (568.2 m), Grabova (782.5 m), Tupy (878.5 m), Doschata (761.3 m), Tovsta (819.2 m), Irosla (598.6 m). Its north-eastern border runs along the valleys of the Dovhy and Lipche rivers, and its western border runs along the lines of the villages of Velykyi Rakovets-Vertep-Rokosovo. The ridge divides a large number of tributaries of the Borzhava and Tisza rivers, forming elongated massifs with cone-shaped and domed tops. The largest of them in the eastern, western and north-western directions are recorded by the peaks of Ilyka (758.2 m), Rorond-Tete (554.0 m), Kititsa (841.0 m), Yuritsa (630.2 m). The average absolute heights of the Tupy ridge are 100-150 m lower than those of the Velykyi Dil ridge. Apical surfaces are mostly narrow, wavy and rounded. The south-eastern slopes of the ridge, which are divided by tributaries of the Tisza River, are mostly straight with a steepness of more than 20°. The western slopes are characterized mostly by a convex profile, steepness of 15-20° at the top and 2-6° at the foot. In the interfluvium of Lipovets and Lipcha there is a decrease in absolute heights from 463.2 m to 294.4 m, and the steepness of the slopes does not exceed 11°.

Sediments of Kuchavsky, Matekivsky, Synyatsky and Obavsky volcanic complexes take part in the construction of the morphostructure. Andesites, andesite-basalts and their tuffs of the Kuchavsky complex lie in the southern part of the morphostructure near the "Khust Gate". They are covered with andesites, lava breccias, tuffs and tuffites of the Matekivsky complex, which are distributed throughout the morphostructure Tupy. The rocks of the Synyatsky complex form two layers

of sediments. The lower stratum, which is composed of tuffs of rhyolites, rhyodacites, andesite-dacites up to 240 m thick, lies directly on the sediments of the Matekivsky complex. The upper stratum is represented by andesite-dacites with low-thickness strata (up to 2-3 m) of psephytic tuffs, common in the southwestern part of the morphostructure. Andesite-basalts and basalts of the Obavsky complex are formed on the rocks of the Matekivsky and Synyatsky complexes, which form the top parts of the Tovsty, Kytytsia and Tupy mountains (Matskiv et al. 1996).

The morphostructure Oash stretches from the valley of the Tisza River to the border with Romania. The relief is represented by the northern part of the Gutyn ridge and its north-eastern slopes, which are divided by the left tributaries of the Tisza River into separate spurs with cone-shaped and dome-shaped peaks. The northern part of the ridge is fixed by dome-shaped peaks of Sarget (394.7 m), Kamin (347.1 m), Krzhivsky Verkh (390.8 m), Pinteva Studnya (467.7 m), Bagno (602.3 m) and Frasin 826.4 m). The northern and north-eastern slopes to the Tisza River valley are short, mostly straight and convex, with a steepness of 15-25°. The southern and southwestern slopes are concave and longer, with a steepness of up to 11°. The central part of the ridge is formed by andesite-basalts, and on the periphery - volcanic-conglomerates and tuff gravelites of the Matekivsky volcanic complex, which are covered with dacites, andesitic-dacites of the Synyatsky complex. The apical part of the ridge is formed by andesite-basalts, basalts and their tuffs of the Buzhorsky complex (Matskiv et al. 1984, Matskiv et al. 1996; Matskiv et al. 2001; Prikhodko M., Titov E. et al. 1980). Intrusive peaks Kruglyak (520.1 m), Maly Cherepovets (456.3 m), Shayan (440.0 m), Gostra (577.3 m), Fekete-Khed (769.4 m), Chorny Bor (699.3 m), Var-Khed (589.6 m) and Lysiy Kholm (665.3 m) can be traced between the villages of Velyatino and Yablunivka on the spurs of the Hutyn ridge. The slopes of the spurs are mostly concave, with a steepness of up to 15°, approaching the floodplain of the Tisza River. The structure of the peaks mainly involves panno-pont deposits, which are represented by andesitic porphyrites, diorites and diorite-porphyrates (Matskiv et al. 2001).

The Beregovo morphostructure of the third order with hilly volcanic-denudation relief is bounded on the west and south by the Verke Canal, on the southeast by the Borzhava river, and on the north and east by the Zatyshne-Kidosh-Velyki Berehy-Kvaso villages. In relief it is expressed by hills with maximum absolute heights of 298.5 m and 365.7 m. The length of the mountain range from northwest to southeast is about 13 km. The apical surfaces are domed, wide and wavy. The top parts of the slopes are mostly straight, steeply 7-13°. For the middle and lower parts of the slopes is characterized mainly by a concave profile,

steepness 2-7°. The slopes are divided by numerous ravines and beams, which end in powerful cones of removal of proluvial material. The Beregovo hills are the volcanic remnants of Sarmatian volcanoes, which are covered by thick sedimentary strata of Neogene and Quaternary sediments. They are composed of deposits of the Velykodobronsky and Barkasivsky volcanic complexes. The Velykodobronsky complex is located in the eastern part of the Berehovo hills. It is formed by andesites and their tuffs up to 400 m thick, which lie in the lower part of the mountain range (Matskiv et al. 1996).

Barkasivsky complex is the most common. With a stratigraphic break, it is deposited on the deposits of the Velykobronsky complex and sedimentary deposits of badenium. The lower and middle part of the complex is formed by rhyolite tuffs with layers of terrigenous rocks up to 950 m thick. In the upper part there are domes and streams of rhyolites, perlite, their lava breccias, tuffs and tuffs up to 350 m thick (Fishkin 1954; Matskiv et al. 2001).

The Kosino-Bigan morphostructure of the third order is located between the villages of Kosino and Velyka Bigan. The relief is represented by dome-shaped volcanic remains with relative heights of 100–120 m. In its northern part near the village Zapson is a volcanic remnant measuring 1.6 × 1.2 km with a maximum absolute height of 207 m. The slopes of the hill are convex, weakly dissected, with a steepness of up to 10°.

To the south of the village Zapson is a volcanic massif measuring 2 × 3 km, which is represented by domed, wide peaks with absolute heights of 223.0 and 200.0 m (m. Tipet). The eastern and southern slopes of the massif are straight, steeper than 15°. Western slopes are concave, moderately dissected, steeply 3-10°. To the east of this massif (near the village of Velyka Bigan) there are two volcanic remains, elongated in the south-eastern direction, which are fixed by the peak of Biganska (192.0 m) and the absolute mark of 171.6 m. The andesites of the Velykodobronsky complex, which are covered by thick strata of rhyolite tuffs of the Barkasivsky complex, take part in the construction of the morphostructure.

The Shalanky morphostructure of the third order is located between the villages of Shalanky and Velyki Komyaty. The relief is represented by a small (2.5 × 3.5 km) volcanic massif with the highest conical peak Shalansky-Helmets (368.6 m). The massif is characterized by short, straight and convex northern slopes up to 20°, which approach the channel of the Borzhava river. The western, southern and eastern slopes are concave, steep up to 12°, strongly dissected by ravines, the depth of which reaches 5 m. The morphostructure is composed mainly of layers of bipyroxene andesites and their tuffs with a thickness

of 580 m of the Chicoshsky volcanic complex (Matskiv 1996).

The morphostructure Chorna Hora is located to the east of Vynohradiv. Its northern and northeastern border runs along the valley of the Salva stream and the line of the willage Mala Komyata, and the eastern one - along the Tisza riverbed. The relief is expressed by an elliptical mountain, elongated in the meridional direction, 4.5 km long and 3-3.5 km wide. It is fixed by a conical narrow peak of Chorna Hora (565.0 m). The slopes of the mountain are mostly straight, steeply 13-18°. The exception is the eastern part of the mountain, which is washed away by the Tisza River, the steepness of the slopes here is more than 25°. This morphostructure is formed by andesites, andesite-basalts, dacites, rhyolites and their tuffs of the Matekivsky and Sinyatsky volcanic complexes (Matskiv 1984).

Conclusions

Taking into account the differences in the spatial arrangement of tectonic elements and volcanic structures as well as their emergence in the relief, Vygortat-Gutyn and Mukachevo morphostructures of the second order are divided into morphostructures of the third order. Structural and lithological features have determined the specific features of their relief, which are expressed by narrow ridges with dome and conical tops.

The highest absolute altitudes within the study area are characteristic of the Antaliv-Synyatsky and Velykodilsky massifs (900-1,085 m). Differences in the relief of the north-western and south-eastern parts of the Vygortat-Hutyn ridge are well traced, which is due to the lithological composition of the rocks. The ridges, which are dominated by andesites, are characterized by narrow conical apical surfaces, in contrast to the dome-shaped ridges and massifs composed of dacite intrusions. In the south-eastern part of the volcanic ridge and its spurs are less massive, their absolute heights decrease, there is a symmetry of the slopes.

It was found that the most important morphosculptures that form the relief of the study area are river valleys and leveling surfaces. The river valleys, which cut deep into the andesites, are characterized by a V-shaped cross-section profile, which causes a significant steepness of their slopes. At the exit of river valleys to areas that are composed mostly of tuffs, the valleys become wider and trough-like, with a general decrease in the steepness of the slopes.

The results of the study can be used in assessing the terrain for engineering, environmental and recreational purposes. Theoretical and practical developments can be used in complex geographical research and compiling a general geomorphological

map of Ukraine. The obtained quantitative indicators of the state of division of the territory can serve as an information base during the planning and design of anti-erosion and anti-flood measures within the Transcarpathian region.

Funding

This research received no external funding.

Author contribution

Conceptualization, methodology, writing – original draft, Mykhailo Mykyta; writing - review & editing, validation, Maryana Salyuk, Roman Slavik and Mykola Karabiniuk; data curation, Vasyl Leta. All authors have read and agreed to the published.

Conflicts of Interest

The authors declare no conflict of interest.

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