MINERALOGICAL COLLECTION | МІНЕРАЛОГІЧНИЙ ЗБІРНИК
2025. № 75. P. 43–56 | 2025. № 75. С. 43–56
ISSN 2078-6220 (print) | ISSN 2786-6556 (online)

UDC 552.3:551.21:549(477-924.52)

FEATURES OF THE MINERAL COMPOSITION OF ANDESITES FROM THE MATEKIVSKYI AND OBAVSKYI VOLCANIC COMPLEXES OF THE VYHORLAT-HUTYNSKE RIDGE (UKRAINIAN CARPATHIANS)

Iryna Poberezhska, *Candidate of Geological and Mineralogical Sciences, Associate Professor, Head of the Department of Mineralogy, Petrography and Geochemistry named after Professor Orest Matkovskyi*
iryna.poberezhska@lnu.edu.ua
https://orcid.org/0000-0001-5020-8326

Dmytrii Biruk, *Postgraduate Student of the Faculty of Geology*
https://orcid.org/0009-0005-7129-2244

Leonid Skakun, *Candidate of Geological and Mineralogical Sciences, Associate Professor at the Department of Mineralogy, Petrography and Geochemistry named after Professor Orest Matkovskyi*
https://orcid.org/0000-0002-2338-6562

Taras Brynskii

Yevheniia Slyvko, *Candidate of Geological and Mineralogical Sciences, Associate Professor at the Department of Environmental and Engineering Geology and Hydrogeology*
https://orcid.org/0000-0002-2731-0602

Anastasiia Pavlenko, *4th year student of the Faculty of Geology*
https://orcid.org/0009-0005-8038-2540
Ivan Franko National University of Lviv,
4, Hrushevskoho St., Lviv, Ukraine, 79005

The article provides information on the mineral composition of rocks that form the Matekivskyi and Obavskyi volcanic complexes, which are the part of the Vyhorlat-Hutynske Volcanic Ridge central segment in the Ukrainian Carpathians. Rocks from the quarries in the villages of Klenovets, Shelestove and Obava are described.

The quarry in Klenovets is composed of andesite-basalts, andesites and their porphyrites (total observed thickness reaches 30 m) which form columnar jointing and slab parting. The rocks are mediophyric, have dark grey colour and massive texture. Plagioclases, clino- and orthopyroxenes, and ore mineral predominate among the phenocrysts. The groundmass has hyalopylitic, andesitic or intersertal texture and is composed of acid volcanic glass, plagioclase, pyroxene and ore mineral.

The dome-shaped structure is clearly visible in the quarry of Shelestove. Volcanic rocks are represented by andesites, andesite-dacites and in the upper part of the section – often by tuffs or interbedding

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of andesites, andesite-dacites and tuffs. The results of the microprobe studies of the Matekivskyi volcanic complex rocks from quarries of the Klenovets and Shelestove (Kolchino) showed that plagioclases are represented by labradorite and bytownite, pyroxenes – by orthopyroxenes of the enstatite–ferrosilite series and clinopyroxenes (augite, diopside).

A powerful flow of medio- and magnophyric andesites and andesite-basalts is exposed in the Obava-village quarry; andesite tuffs occur at the bottom of the flow. Grey andesites contain phenocrysts of labradorite, orthopyroxenes of the enstatite–ferrosilite series and augite.

The trends of change over time of mineral composition (in the direction of the central part of the phenocryst → its peripheral part → the groundmass of the rock) in the studied rocks, determined by the results of microprobe analyses, are as follows: the content of Na and K increases in plagioclases, Fe – in pyroxenes and Ca – in orthopyroxene. The temperature regime of magmatic systems during the formation of volcanic rocks in the studied area covered the range of 1000–700 °C.

Key words: volcanic rocks, andesite, plagioclase, pyroxene, magmatic system, Neogene, Vyhorlat-Hutynske Ridge, Ukrainian Carpathians.

DOI https://doi.org/10.30970/min.75.03

Statement of the problem. Neogene volcanic rocks of Transcarpathia are part of the calc-alkaline volcanic belt of the Inner Carpathians, the time of formation of which is from 13.8 to 9.1 million years ago [2; 5; 9]. These rocks are widespread in the southwestern part of Transcarpathia, where (according to the identified by Ye. Malieiev phases of magmatism) they are today distinguished as three geomorphological structures: (1) Solotvynska Basin (eroded volcanoes and horizons of rhyolite and rhyodacite tuffs; the first phase of magmatism); (2) Berehivske Hill Country (stratovolcanoes, lava flows, tuffs from rhyolite to andesite-basalt composition, however, mainly acidic; the second phase of magmatism); (3) Vyhorlat-Hutynske Volcanic Ridge (stratovolcanoes, lava flows, horizons of tuffs of various composition – from rhyolites to basalts, however, with a significant predominance of andesites and andesite-basalts; the third and fourth phases of magmatism). This ridge is an essentially continuous series of «fused» volcanic edifices, which were formed as a result of the eruptive activity of nine central-type volcanoes, as well as a large number of their lateral craters (Fig. 1).

Spatial distribution of volcanic rocks in the western and central parts of the Vyhorlat-Hutynske Ridge has been controlled by the tectonic regime of the Transcarpathian deep fault. The volcanic massifs formed here (Poprychnyi, Antalovskyi, Syniak and Boryliv Dil) are composed of an association of such rocks as andesite-basalts, andesites, andesite-dacites, dacites, and rhyodacites. These are the Antalovskyi, Makovytskyi, Matekivskyi, Syniatskyi, Obavskyi, and Martynskyi volcanic complexes in the investigated territory. We studied volcanic rocks of the Matekivskyi complex (quarries in the villages of Klenovets and Shelestove) and Obavskyi complex (quarry in the Obava-village) (Fig. 2).

Research analysis. Various researchers conducted studies of volcanic rocks and complexes of the Vyhorlat-Hutynske Ridge: V. Sobolev, Ye. Lazarenko, E. Lazarenko, Ye. Malieiev, B. Merlich, S. Spitkovska, V. Zolotukhin, L. Danylovych, N. Koronovskyi, A. Honcharuk, Z. Liashkevych [10] and other scientists. The region was also studied by the employees of the Transcarpathian Geological Exploration Expedition (GEE). Among such studies, are the search for veined lead-zinc ores and metasomatic manifestations (Lazarenko, 1961), the valuation of gold-bearing prospects (Galakhov et al., 1977), the search and valuation of gold and silver ores, the prospecting for gold and polymetals using the method of geological-structural mapping on a scale of 1:10,000 (Krechkovskiy, 1990), etc. A significant contribution to the study of the geology of Transcarpathia, and the Vyhorlat-Hutynske Volcanic Ridge in particular, was made by M. Prykhodko [7; 12; 13].

Fig. 1. Location of central-type volcanoes of the of Vyhorlat-Hutynske Ridge [13]:
1 – Poprychnyi; *2* – Antalivskyi; *3* – Makovytsia; *4* – Trostianytsia (“Three-headed volcano”); *5* – Syniak; *6* – Dekhmaniv; *7* – Martynskyi Kamin; *8* – Buzhora; *9* – Tovstyi Verkh

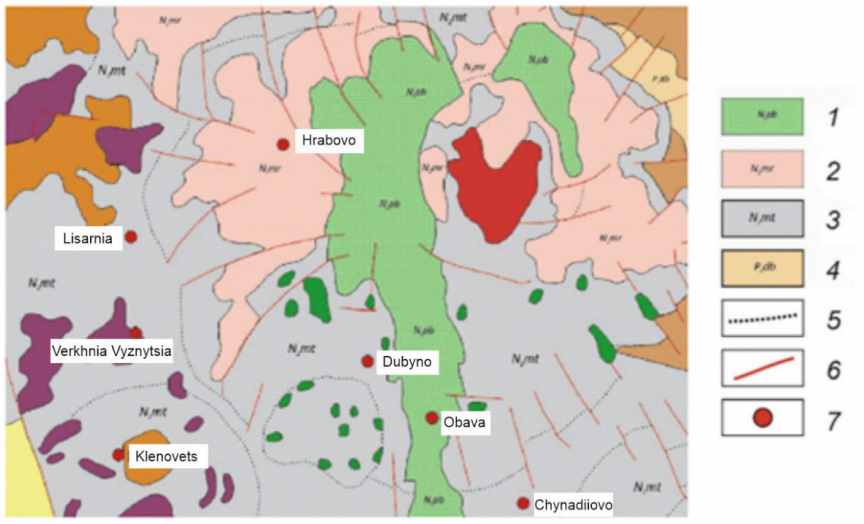


Fig. 2. Geological map-scheme of the research area [12]:
1–3 – volcanic complexes: *1* – Obavskyi, *2* – Martynskyi, *3* – Matekivskyi; *4* – Dibrovska suite; *5* – caldera contours; *6* – dislocations with a break in continuity; *7* – settlements

Geologists of the Transcarpathian GGE, together with researchers from Slovakia, Hungary, Romania, and Great Britain, selected over a hundred samples of volcanic rocks in the region at the end of the 20th century to determine their absolute age [2; 5; 6].

Volcanism, magmatism and metallogeny of the Transcarpathian Inner Trough were studied by scientists of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine. The studies of M. Petrashkevych and P. Lozyniak (Petrashkevych, 1990 and others) were of great importance for the modern understanding of the stratigraphy of the Transcarpathian Trough basement rocks, and directly for the subdivision of the Vyhorlat-Hutynske Ridge volcanogenic strata – the works of V. Stepanov (1989 and others). Original views on the structure of individual volcanic structures were expressed by A. Radzyvill, V. Radzyvill, and V. Tokovenko (1986).

Thus, the geological structure of the Vyhorlat-Hutynske Ridge was studied quite thoroughly by our predecessors, specific volcanic structures and the most volcanic complexes have been identified. Despite this, the central segment of the Ridge in the Uzh–Latorytsia interfluve has been poorly studied. We have already published the results of our research on this topic [1; 8; 11 ;14] and continue to work on it.

Research purpose was to study the petrological features of the volcanic rocks from the Matekivskyi and Obavskyi complexes.

Presentation of the main material. We studied the volcanic rocks of the Matekivskyi complex in quarries near the villages of Klenovets and Kolchyno. This is, first of all, the well-known outcrop "Basalt Pillars", which is geographically located in the village of Zhborivtsi (we describe it as the Klenovetska quarry in this article). The second quarry – Shelestivska – is located within the boundaries of the Shelestivske andesite deposit (today the village of Shelestove does not exist, in 1960 it was merged with the village of Kolchyno). Rocks of the Obavskyi volcanic complex have been studied in the quarry of the Obava-village.

The Matekivskyi volcanic complex ($\alpha N_2 mt$) was identified by P. Koronovskyi (1963) in the Matekova-river basin, in the Syniak volcanic structure. In addition, its deposits are known in the volcanic structures of Dekhmaniv, Hotar, and Martynskyi Kamin, as well as in the Hat Ridge between the villages of Dilok and Siltse. The complex consists of andesites, andesite-basalts, their tuffs, lava breccias, and tuffites with a thickness of from the first to tens meters, rarely the first hundred meters.

The Matekivski deposits in the *quarry of Klenovets village* (up to 30 m thick) are represented by andesite-basalts, andesites and their porphyrites (Fig. 3). Columnar jointing and slab parting are observed in the quarry (Fig. 4).

Columnar jointing is developed in the middle and lower part of the lava flow outcrop, and slab parting – in the upper part. The columns have pentagonal or hexagonal cross-section, their size in diameter is from 30 to 50 cm. Orientation of the columns changes in the outcrop: they are located horizontally and oriented to the northwest in the western part, and are inclined to the north and northwest at an angle of 30–60° in the central part. The angles of dip of the columns increase from top to bottom. The columns gradually change their position in the eastern part of the wall from steeply sloping to almost horizontal with a sub-latitudinal orientation. Slab parting is developed in the upper part of the exposed lava flow. The thickness of the «tiles» decreases from bottom to top – from 10 to 3–1 cm.

The rocks are mediophyric, have massive texture and dark grey colour. The groundmass has hyalopylitic, andesitic or intersertal texture (Fig. 5, *a*).

Phenocrysts, which constitute up to 30% of the rock, range in size from 2 to 12 mm. Phenocrysts are composed of plagioclases (~ 50%), clinopyroxenes (25), orthopyroxenes (20) and ore mineral (~ 5%). Plagioclases and pyroxenes form glomeroporphyritic intergrowths. Such intergrowths together with phenocrysts visually constitute about 70% of the rock (see Fig. 5, *b*,

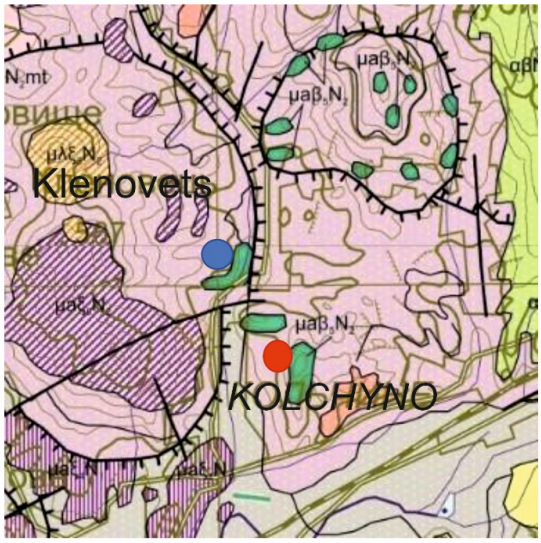
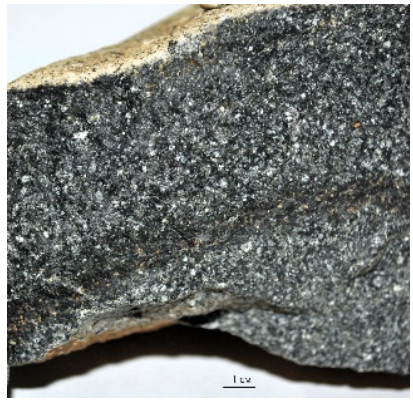


Fig. 3. Location of quarries in the villages of Klenovets (blue circle) and Kolchyno/Shelestove (red circle)

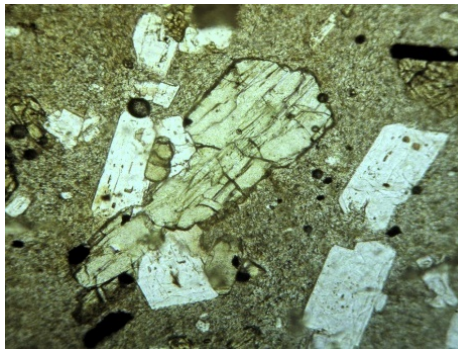
Fig. 4. Quarry in the Klenovets-village

c). The groundmass is composed of acid volcanic glass (71.5–73.0 at. % SiO_2), plagioclase laths, pyroxene and ore mineral.

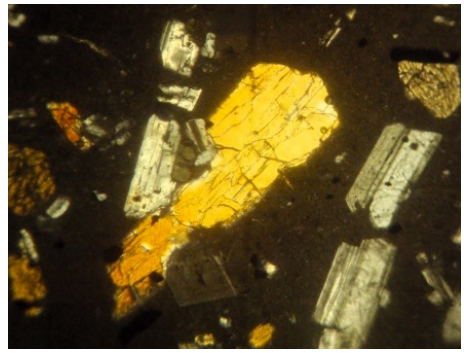
Shelestove andesite deposit (Fig. 6) is located 1 km northeast of the village of Kolchyno (part of the former village of Shelestove). The dome-shaped structure is clearly visible in the quarry. There is primary fracturing, which has a vertical dip, and fluidity in the central part of the eruption centre. The primary fracturing is inclined towards the eruption centre with distance from it,



a



b



c

Fig. 5. Andesite from a quarry in the village of Klenovets:
a – rock sample; *b*, *c* – phenocrysts of pyroxene and plagioclase (thin section, polarizing microscope):
b – plane-polarised light (PPL), *c* – cross-polarised light (XPL), × 75

which determines the fan-shaped structure of the extrusion. The angle of inclination of the joints decreases further from the eruption centre, and their dip becomes almost horizontal. Volcanic deposits are represented by andesites, andesite-dacites, and often by tuffs or interbedding of andesites, andesite-dacites and tuffs in the upper part of the section. Brown, brownish-grey tuffs up to 18.8 m thick occur in the western and southwestern parts of the deposit.

Andesites, which reach a thickness of 4.8 m, are usually weathered; they are common only in the south-eastern part of the studied area. Andesite-dacites are dark grey, fine-grained, massive rocks with a vitreous microtexture (Fig. 7, *a*). Plagioclase microliths are present against the background of the non-crystallized groundmass. Andesites contain phenocrysts (about 40% of the rock) of plagioclase, orthopyroxene, clinopyroxene and ore mineral. The groundmass is composed of acidic volcanic glass (71.5–73.0 at. % SiO_2), plagioclase laths, pyroxene and ore mineral (see Fig. 7, *b–e*).

The results of the microprobe studies of the volcanic rocks from quarries of the Klenovets and Shelestove (Kolchino) showed the following (Fig. 8, 9).

Plagioclases are represented by labradorite and bytownite. The content of the anorthite component varies from 51% in the groundmass to 79% in phenocrysts. The trend of change in the composition of plagioclases in the direction of the central part of the phenocryst → its peripheral part → the groundmass indicates an increase in the content of Na and K over time (see Fig. 9, *A*).

Fig. 6. Shelestivske andesite deposit

Pyroxenes are represented by orthopyroxenes of the enstatite–ferrosilite series and clinopyroxenes (augite, diopside). They form phenocrysts up to 2 by 3 cm in size. The orthopyroxenes composition varies from enstatite $En_{0.68}Fs_{0.31}Wo_{0.01}$ in phenocrysts to hypersthene $En_{0.42}Fs_{0.42}Wo_{0.16}$ in the groundmass; composition of augite-diopside in phenocrysts is $Wo_{0.45}En_{0.40}Fs_{0.15}$.

The trend of change in the composition of pyroxenes in the direction of the central part of the phenocryst → its peripheral part → the groundmass indicates an increase in the content of Fe over time and increase in the content of Ca in orthopyroxene (see Fig. 9, *B*).

The Obavskyi volcanic complex ($\alpha\beta N_2 ob$) records the final process of lava flow in the Syniak volcanic structure (Koronovskiy, 1963). The rocks of the complex also form the apical part of the Dekhmaniv shield volcano; some of their outcrops are recorded on the southern slope of the volcano and in the Hat range, where they occur with a stratigraphical break on the Syniatskyi and Matekivskyi complexes.

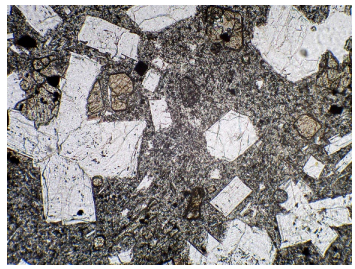
The Obavska quarry is located within the volcanic belt of the same name of Dacian-Romanian age (Fig. 10). The outcrop is composed of a powerful flow of medio- and magnophyric andesites and andesite-basalts, at the base of which andesite tuffs occur (Fig. 11).

Andesites are grey in colour, contain phenocrysts (about 35% of the rock) of plagioclase (~ 60%), ortho- (20) and clinopyroxene (17), ilmenite (~ 3%) and their glomeroporphyritic intergrowths (Fig. 12). The groundmass is composed of quartz, plagioclase and potassium feldspar (up to 90%), clinopyroxene and hornblende laths occur, as well as ilmenite and titanomagnetite.

Microprobe studies of volcanic rocks from the Obava village quarry have shown the following (Fig. 13, 14). Plagioclase phenocrysts (2.0 × 0.5 cm) are represented by labradorite with a high Ca content. The content of the anorthite component varies from 52% in the groundmass to 66% in phenocrysts. The trend of change in the composition of plagioclases in the direction of the central part of the phenocryst → its peripheral part → the groundmass indicates an increase in the content of Na and K over time (see Fig. 14, *A*).

Pyroxenes are represented by orthopyroxenes of the enstatite–ferrosilite series and by clinopyroxenes (augite). They form phenocrysts up to 0.5 by 1.00 cm in size. The orthopyroxenes composition varies from enstatite $En_{0.60}Fs_{0.30}Wo_{0.04}$ in phenocrysts to hypersthene $Fs_{0.64}En_{0.33}Wo_{0.03}$ in the groundmass; composition of augite in phenocrysts is $Wo_{0.43}En_{0.33}Fs_{0.26}$. The trend of change in the composition of pyroxenes in the direction of the central part of the phenocryst → its peripheral part → the groundmass indicates an increase in the content of Fe over time and Ca in orthopyroxene (see Fig. 14, *B*).

a



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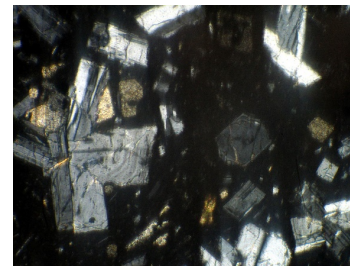

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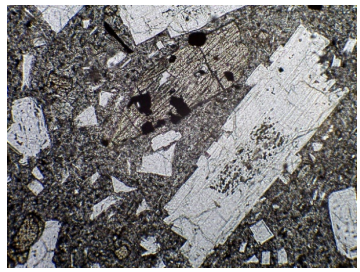

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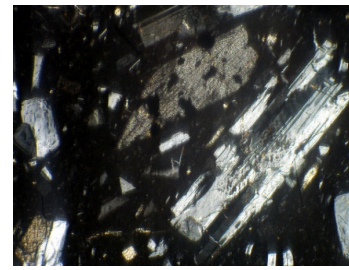
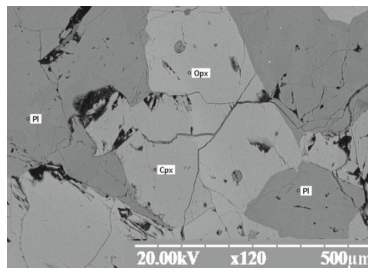


e

Fig. 7. Andesite from Shelestivske deposit:
a – rock sample; *b*, *c* – phenocrysts of pyroxene and plagioclase: *b*, *d* – PPL, *c*, *e* – XPL; × 75



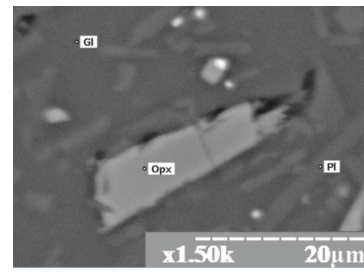
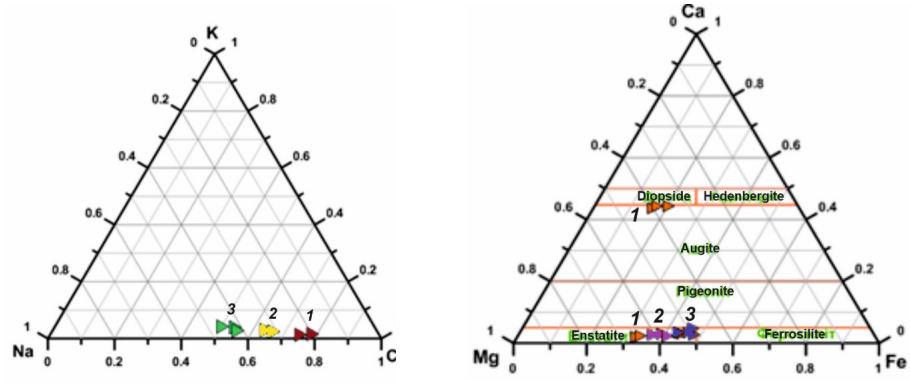


Fig. 8. Phenocrysts of plagioclase (Pl), orthopyroxene (Opx), clinopyroxene (Cpx) and volcanic glass (Gl) in andesite of Klenovets-quarry, BSE image



A *B*

Fig. 9. Variations in the chemical composition of plagioclases (*A*) and pyroxenes (*B*) in andesites of the villages of Klenovets and Shelestove in the direction of the central part of the phenocryst (*1*) → its periphery (*2*) → the groundmass of the rock (*3*)

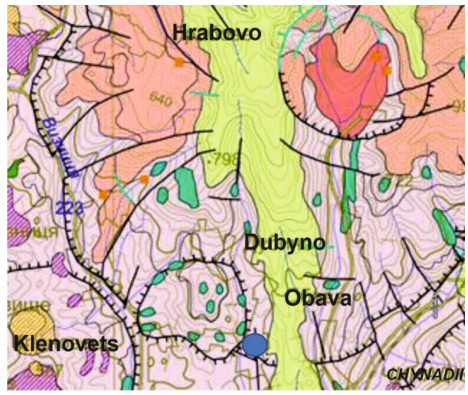
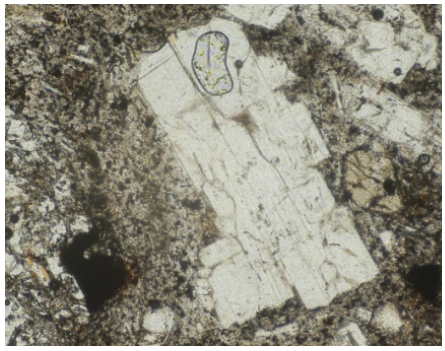


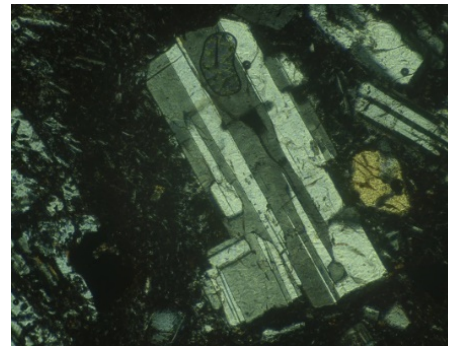
Fig. 10. Location of quarry in the village of Obava (blue circle)

Fig. 11. Quarry in the Obava-village

a

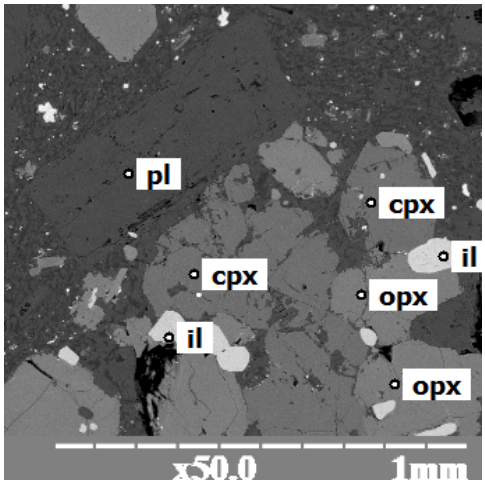


b



c

Fig. 12. Andesite from a quarry in the village of Obava:
a – rock sample; *b*, *c* – phenocrysts of pyroxene and plagioclase: *b* – PPL, *c* – XPL, × 75



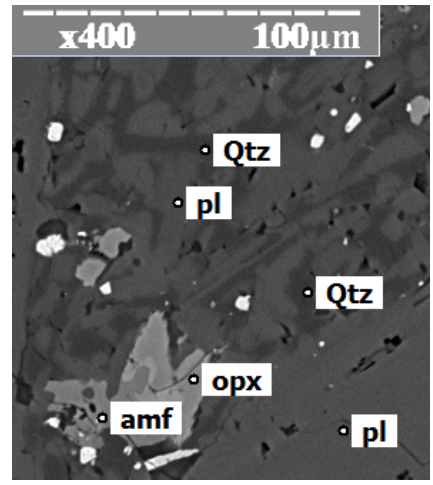
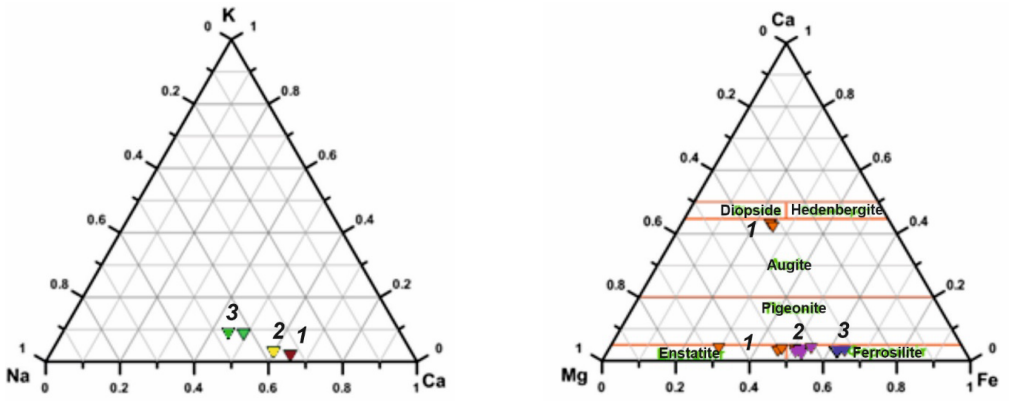


Fig. 13. Phenocrysts of plagioclase (pl), orthopyroxene (opx), clinopyroxene (cpx), ilmenite (il), amphibole (amf), quartz (Qtz) in andesite of Obava-quarry, BSE image



A *B*

Fig. 14. Variations in the chemical composition of plagioclases (*A*) and pyroxenes (*B*) in andesites of the Obava-quarry in the direction of the central part of the phenocryst (*1*) → its periphery (*2*) → the groundmass of the rock (*3*)

We used thermometer diagrams [3; 4] to determine the temperature of mineral formation at a pressure of 0.505 mPa for phenocrysts and 0.101 mPa for interstitials. The conclusion has been made that the temperature regime of magmatic systems forming volcanic rocks in the quarries of Klenovets, Shelestove, and Obava villages was 1000–700 °C.

Phenocrysts of plagioclases and pyroxenes from andesites of volcanic complexes of the Vyhorlat-Hutynske Ridge contain melt inclusions. Previous studies have shown [14] that melt inclusions in phenocrysts of both minerals differ in the degree of crystallization. The inclusions in plagioclases are crystallized, they have a predominantly acidic composition, and contain a lot of quartz and alkali feldspar. The inclusions in pyroxenes originate around small crystals of pyroxenes, plagioclases, apatite, ilmenite, and are predominantly non-crystallized, vitreous.

Conclusions and prospects for further research. We studied volcanic rocks of the Matekivskyi and Obavskyi volcanic complexes from the quarries in the villages of Klenovets, Shelestove and Obava (the central segment of the Vyhorlat-Hutynske Volcanic Ridge). The chemical composition of volcanic rocks varies from andesite-basalt to rhyolite, the alkalinity of the rocks – from normal to subalkaline.

The rocks of Matekivskyi complex in the quarry of Klenovets are represented by andesite-basalts, andesites and their porphyrites, and in the quarry of Shelestove deposit – by andesites, andesite-dacites, and often by tuffs or interbedding of andesites, andesite-dacites and tuffs in the upper part of the section. The outcrop in the Obavska quarry is composed of a powerful flow of medio- and magnophyric andesites and andesite-basalts, at the base of which andesite tuffs occur.

Studies of the mineral composition of rocks from the Matekivskyi and Obavskyi volcanic complexes have shown that, regardless of the acidity of the rocks, the phenocrysts in them are represented by rhombic and monoclinic pyroxenes and by plagioclases of the labradorite–bytownite composition. These phenocrysts contrast with the groundmass of the rock, which contains rhombic pyroxene, plagioclase of the labradorite–andesine composition, alkali feldspar, amphibole, and quartz.

The trend of change in the composition of plagioclases in the direction of the central part of the phenocryst → its peripheral part → the groundmass indicates an increase in the content

of Na and K over time. The trend of change in the composition of pyroxenes in the same direction indicates an increase in the content of Fe over time and Ca in orthopyroxene.

Volcanic rocks in the investigated quarries have been formed in the temperature range of 1000–700 °C.

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Стаття надійшла до редакції 29.05.2025
Стаття прийнята до друку 10.06.2025

ОСОБЛИВОСТІ МІНЕРАЛЬНОГО СКЛАДУ АНДЕЗИТІВ МАТЕКІВСЬКОГО Й ОБАВСЬКОГО ВУЛКАНІЧНИХ КОМПЛЕКСІВ ВИГОРЛАТ-ГУТИНСЬКОГО ПАСМА (УКРАЇНСЬКІ КАРПАТИ)

Ірина Побережська, Дмитрій Бірук, Леонід Скакун, Тарас Бринський, Євгенія Сливко, Анастасія Павленко
iryna.poberezhska@lnu.edu.ua
Львівський національний університет імені Івана Франка,
вул. Грушевського, 4, Львів, Україна, 79005

У статті наведено інформацію про мінеральний склад порід, що утворюють матеківський та обавський вулканічні комплекси в центральному сегменті Вигорлат-Гутинського вулканічного пасма (Українські Карпати). Описано породи з кар'єрів у селах Кленовець, Шелестове й Обава.

У кар'єрі в с. Кленовець відслонені андезибазальти, андезити та їхні порфірити загальною потужністю до 30 м із характерною стовпчастою та плитчастою окремістю. Породи середньопорфірові, мають темно-сірий колір і масивну текстуру. Серед фенокристалів переважають плагіоклази, кліно- та ортопіроксени, а також рудний мінерал. Основна маса має гіалопілітову, андезитову або інтерсертальну структуру і складена з кислого вулканічного скла, плагіоклазу, піроксену й рудного мінералу. У кар'єрі Шелестівського андезитового родовища чітко помітно куполоподібну будову. Вулканічні породи представлені андезитами, андезидацитами, а у верхній частині розрізу – часто туфами або перешаруванням андезитів, андезидацитів і туфів. Результати мікрозондових досліджень порід матеківського вулканічного комплексу з кар'єрів у селах Кленовець та Шелестове (Кольчино) засвідчили, що плагіоклази представлені лабрадором і бітовнітом, а піроксени – ортопіроксенами ряду енстатит-феросиліт і клінопіроксенами (авгіт, діопсид).

У кар'єрі с. Обава виявлено потужний потік середньо- та великопорфірових андезитів і андезибазальтів; у підошві потоку залягають андезитові туфи. Сірі андезити містять вкраплення лабрадору й ортопіроксенів ряду енстатит-феросиліт і авгіту.

Тренди зміни із часом складу мінералів (у напрямі центральна частина фенокристала → периферійна його частина → основна маса породи), визначені за результатами мікрозондових аналізів, такі: у плагіоклазах збільшується вміст Na та K, у піроксенах – Fe, в ортопіроксені – Ca. Температурний режим магматичних систем під час формування вулканічних порід у досліджуваному районі охоплював діапазон 1000–700 °C.

Ключові слова: вулканічні породи, андезит, плагіоклаз, піроксен, магматична система, неоген, Вигорлат-Гутинське вулканічне пасмо, Українські Карпати.