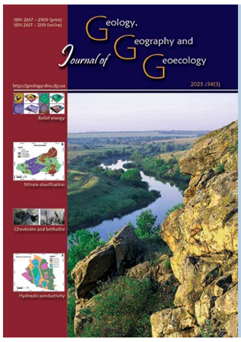

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph.
Geology,
34(3), 615-629
doi:10.15421/112552

Sodalite mariupolite occurrences in the Zhovtnevy Massif in the context of the development and usage of the raw material base of precious stones in Ukraine

Viktor A. Nesterovskyi[1], Kateryna I. Derevska[2], Volodymyr V. Manyuk[3], Kseniia V. Rudenko[4], Oleksandr V. Kovtun[5]

[1] Taras Shevchenko National University of Kyiv, Institute of Geology, Kyiv, Ukraine
[2] National University of Kyiv-Mohyla Academy, Kyiv, Ukraine, National Museum of Natural History at the National Academy of Sciences of Ukraine, Kyiv, Ukraine
[3]Oles Honchar Dnipro National University, Dnipro, Ukraine
[4] National Museum of Natural History at the National Academy of Sciences of Ukraine, Kyiv, Ukraine, *rudenkokseniiav@gmail.com*
[5] M.P. Semenenko Institute of Geochemistry, Mineralogy and Ore Formation of the NAS of Ukraine, Kyiv, Ukraine

Received 27.06.2024;
Received in revised form 16.08.2025;
Accepted 30.08.2025

Abstract. Data are presented on the historical aspects of geological research and the structural and mineral composition of rocks in the Zhovtnevy alkaline massif of the Azov region. The uniqueness of its structure and petrography, genetic characteristics, and the vast diversity of rock-forming minerals, textures, and rare-earth elements are highlighted. Polish researcher Yu. Morozevich describes mariupolite as an extreme alkaline facies of nepheline syenites, primarily composed of albite, nepheline, and aegirine. Therefore, it is commonly referred to as aegirine-albitic nepheline syenite. Other minerals that lead to the classification of mariupolites into different types include zircon, hastingsite, lepidomelane, and beckelite or cerium brytholite. Among the researchers studying the alkaline massif, A.S. Ginzburg stands out for his detailed examination of the composition and structure of mariupolites. He describes the components of these rocks and discusses their distribution. He also addresses the genesis of the Mariupol (Zhovtnevy) nepheline massif, suggesting that the formation of nepheline syenites results from the assimilation of limestones by magma and subsequent differentiation. The ideas of Yu. Morozevich were further developed by Liya Falkovna Einberg. Based on field research conducted by the Polish researcher between 1927 and 1929, Einberg created a detailed topographic map that illustrates the geological structure, relief elements, and names of streams and their tributaries – many of which have been lost on contemporary maps (Einberg, 1933). Structurally, the massif exhibits zonation: nepheline rocks are situated at the core, surrounded by nepheline syenites, with pyroxene-amphibole granites occurring on the periphery. Mariupolites are integral to the massif and form distinct zones and bodies of various shapes and sizes within it. The primary rock-forming minerals in mariupolites include nepheline, albite, aegirine, and lepidomelan, while secondary and accessory minerals consist of zircon, apatite, sodalite, amphiboles, calcite, cancrinite, zeolite, pyrochlore, brytholite, magnetite, and iron sulfides, among others. All rock complexes in the Zhovtnevy massif are largely ferruginous. Zirconium, rare earth elements, tantalum, and niobium mineralisation are associated with nepheline syenites, mariupolites, and albitites, which may have industrial significance in certain areas. Sodalite varieties of mariupolite are regarded as promising raw materials for the stone-working industry. The main decorative minerals found in them are sodalite, albite, and nepheline, occurring in various ratios and textural combinations. The ability of sodalite mariupolites to be processed, ground, polished, and utilised in producing jewellery, haberdashery, and souvenir items has been studied. The results of these tests have been positive, and the demand for products made from this material has exceeded expectations. The authors recommend that when planning the development of the Zhovtnevy massif deposits, an integrated approach should be taken, ensuring that the extraction of critically important minerals occurs alongside the harvesting of sodalite varieties of mariupolite for the stone-working industry.

Key words: sodalite mariupolite, Zhovtnevy massif, mineral and raw material base of Ukraine

Прояви маріуполіту Жовтневого масиву у контексті розвитку та комплексного використання мінерально-сировинної бази України

В.А. Нестеровський[1], К.І. Деревська[2], В.В. Манюк[3], К.В. Руденко[4], О.В. Ковтун[5]

[1] Київський національний університет імені Тараса Шевченка, ННІ Інститут Геології, Київ, Україна
[2] Національний університет «Києво-Могилянська академія», Київ, Україна, Національний науково-природничий музей НАН України, Київ, Україна
[3] Дніпровський національний університет імені Олеся Гончара, Київ, Україна
[4] Національний науково-природничий музей НАН України, Київ, Україна, rudenkokseniia@gmail.com
[5] Інститут геохімії, мінералогії та рудоутворення ім. П.М. Семененка НАН України, Київ, Україна

Анотація. Наведено дані про історичні аспекти геологічного дослідження, особливості будови і мінерального складу гірських порід Жовтневого лужного масиву Приазов'я. Показано його структурну і петрографічну унікальність, генетичну природу і широке розмаїття у світі породотвірних мінералів, текстури і рідкісноземельної специфіки. Польський дослідник Ю. Морозевич описує маріуполіт як крайню лужну фацію нефелінових сієнітів, складену переважно альбітом, нефеліном та егірином. Тож зазвичай його розглядають як егірин-альбітовий нефеліновий сієніт. Іншими мінералами, що зумовлюють розподіл маріуполітів на низку типів, є циркон, гастингсит, лепідомелан і беккеліт або церієвий бритоліт. Серед інших дослідників лужного масиву слід згадати А.С. Гінзбурга, який детально зупиняється на складі і структурі маріуполітів, дає опис складових цих порід та вказує їх поширення. Більш за те, він розглядає питання генезису Маріупольського (Жовтневого) нефелінового масиву і вважає, що виникнення нефелінових сієнітів є наслідком асиміляції магмою вапняків і подальшої їх диференціації. Справу Ю. Морозевича продовжила Лія Фальковна Айнберг і за матеріалами польових досліджень Маріпольського масиву проведених польським дослідником впродовж 1927 – 1929 рр., нею була складена мапа із детальними топографічними даними, що надають уявлення як про особливості геологічної будови території, елементи рельєфу, так і про назви балок і їх приток, що втрачені на сучасних мапах (Ainberh, 1933). В структурному відношенні масив має певну зональність – в ядрі знаходяться нефелінові породи, їх змінюють нефелінові сієніти, а на периферії залягають піроксен-амфіболові граніти. Маріуполіти є невід'ємною складовою масиву і формують в ньому певні зони і тіла різної конфігурації і протяжності. Для маріуполітів породоутворювальними мінералами є нефелін, альбіт, егірин, лепідомелан, другорядними і акцесорними – циркон, апатит, содаліт, амфіболи, кальцит, канкриніт, цеоліт, пірохлор, бритоліт, магнетит, сульфіди заліза тощо. Всі породні комплекси Жовтневого масиву в значній мірі озалізнені. До нефелінових сієнітів, маріуполітів, альбітитів приурочена цирконій – рідкісноземельна – тантал – ніобієва мінералізація, яка на певних ділянках має промислове значення. Содалітові різновиди маріуполіту розглядаються як перспективна неординарна сировина для каменеобробної промисловості. Головними декоруючими мінералами в них є содаліт, альбіт і нефелін, що знаходяться в різних співвідношеннях і текстурних комбінаціях. Содалітові маріуполіти було досліджено на їх здатність до обробки, шліфування, полірування і можливості виробництва прикрас, предметів галантерейного і сувенірного призначення. Результати цих випробувань є позитивними, а попит на вироби з цієї породи перебільшив наші очікування. Автори пропонують при плануванні робіт на розробку родовищ Жовтневого масиву врахувати комплексний підхід стосовно використання ресурсів і паралельно з видобутком критично-важливих мінералів видобувати содалітові різновиди маріуполіту для каменеобробної галузі.

Ключові слова: содалітовий маріуполіт, Жовтневий масив, мінерально-сировинна база України

Introduction

One of the rarest and most beautiful stones found in the East Azov area is mariupolite, a highly decorative gem that forms alongside nepheline syenites. This gem has become a symbol of the indomitable spirit and courage of Ukrainians. Ukraine is rich in various stone and gem raw materials, but their distribution is uneven across different regions due to their association with various tectonic structures. With adequate investment in geological prospecting and evaluation, it is possible to extract economically viable amounts of several types of raw materials, including mariupolite, rhodonite, pyrophyllite, marble onyx, jasper-like quartzites, jaspilites, and pegmatites. Most of these can be obtained through the extraction of ores, building materials, and other minerals. Since 2014, Ukraine's mineral and raw material base has experienced significant territorial losses due to the occupation of the eastern and southern regions of the country. Currently, dozens of deposits of decorative, industrial, and facing stones are located in the 20% of Ukraine's territories that remain occupied. This work aims to highlight the sodalite mariupolite of the Azov region, focusing on its mineralogical and gemological characteristics within the framework of the integrated use of Ukraine's raw material base during the post-war recovery period. This approach emphasises the economically beneficial use of primary and associated minerals found in the Zhovtnevy massif of the Azov tectonic block.

Research history

In 1898, Polish geologist Józef Morozewych made a significant discovery while studying the

Azov Crystalline Belt in the Kalmius River Valley. He identified a small isolated outcrop of rocks that included alkaline granites and syenites, along with nepheline syenites (also known as foyaites) and unique rocks, which could be classified as a potassium-free variety of feldspar foyaite. He named this rock «mariupolite» in honour of the city nearby – Mariupol (Morozevych, 1902; Einberg, 1933; Biletskyi and Shpylovyi, 2007). The first accounts of the rocks forming the Mariupol alkaline massif, which is also referred to as the Azov, later the October, or Mazur massif, can be traced back to historical works by I. Ivanytskyi (Ivanytskyi, 1833), M. Klemm (Klemm, 1877), S. Kontkevych (Kontkevych, 1881), and P.V. Eremeev (Eremeev, 1897). These accounts are primarily general and of historical significance. Yu. Morozevych's studies of the alkaline rocks in the Azov region are regarded as the first detailed investigations (Morozevych, 1898a, 1898b, 1899, 1901, 1902, 1903, 1904, 1925, 1929, etc.). According to Morozevich and his followers, all other alkaline and basic magma intrusions are much younger than the ancient granite-gneiss complex of the Mariupol crystalline field.. He provides data on the gross composition of mariupolites and chemical analyses of individual components. Morozevich discovered new minerals, including taramite and beckelite (cerium britholite) (Fig. 2), and for the first time, he determined the composition of nepheline, which is now known as Morozevich nepheline (Fig. 1, 2).

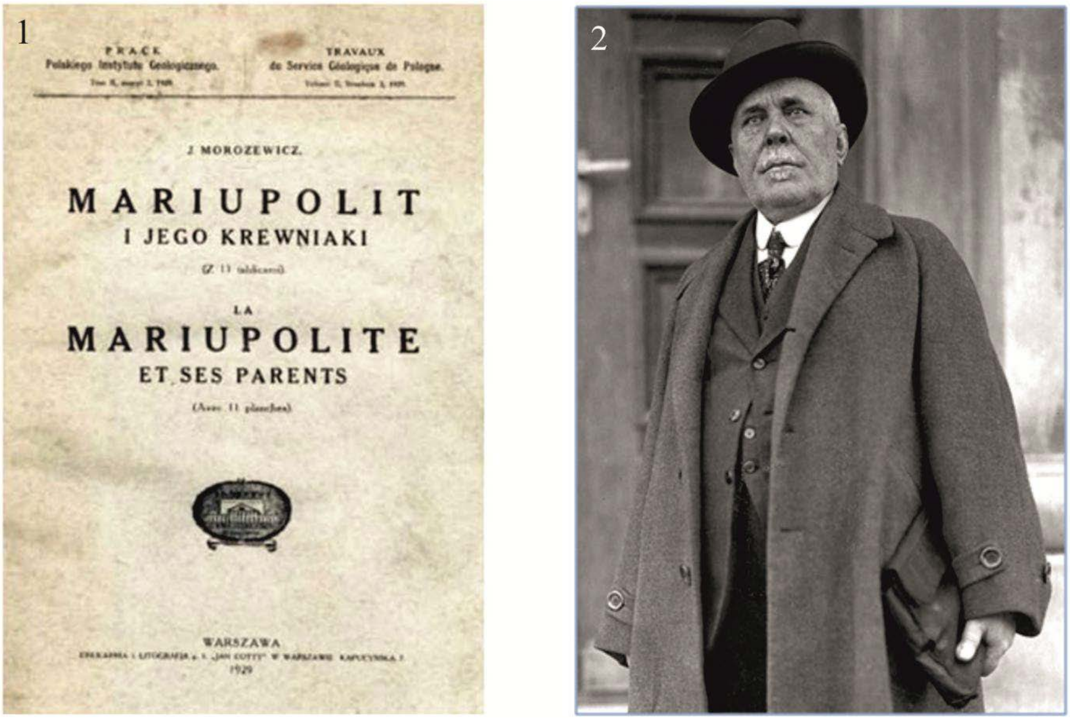

Fig. 1. Title page of the book «Mariupolite and its relatives» (1) and a portrait of its author, Yu. Morozevich (2)

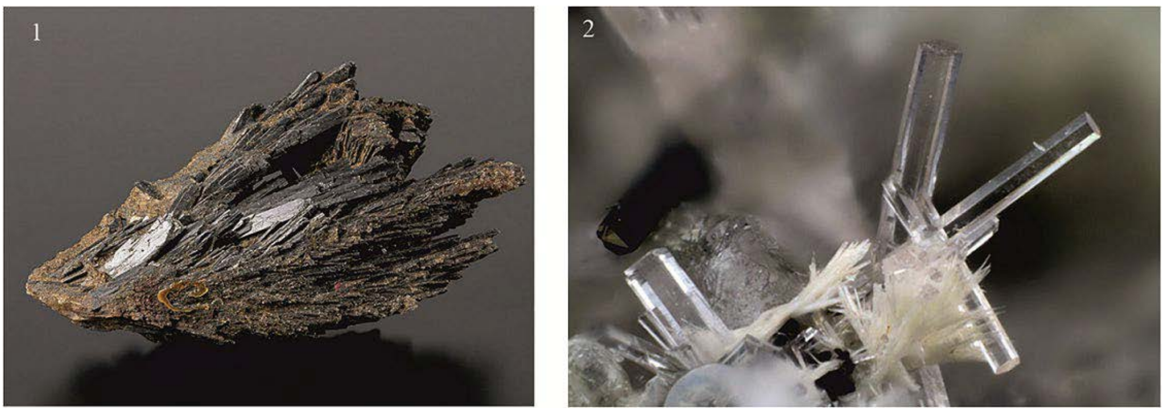

Fig. 2. Minerals: taramite (1) and beckelite or cerium britolite (2) (https://www.mineralpatriot.cz/taramit-a1110; https://www.mindat.org/min-775.html)

Yu. Morozevych describes mariupolite as an extreme alkaline facies of nepheline syenites, composed mainly of albite, nepheline and aegirine. Thus, it is commonly classified as an aegirine-albitic nepheline syenite. Other minerals, such as zircon, hastingsite, lepidomelane, and the previously mentioned beckelite or cerium brytholite, also play a role in distinguishing various types of mariupolite. Later, Morozevych broadened the definition of «mariupolite» to encompass various structural and mineral varieties. He identified eight types of mariupolite based on their genesis, which is described in detail in his work «On one extreme member of the family of nepheline syenites – mariupolite and related rocks of Mariupol district». (Morozevych, 1902).

Among other researchers of the alkaline massif, it is worth mentioning A.S. Ginzburg, who in his work on the petrography of the Azov region (Hynzburh, 1916) dwells in detail on the composition and structure of mariupolites, describes the components of these rocks and indicates their distribution. Furthermore, he explores the issue of the genesis of the Mariupol (October) nepheline massif, arguing that the formation of nepheline syenites results from the assimilation of limestones by magma and their subsequent differentiation.

Liya Falkovna Einberg continued Yu. Morozevich's work, utilizing field research materials on the Mariupol massif, gathered during 1927 – 1929, along with a thorough analysis of the Polish researcher's findings (Einberg, 1933, 1930).

This effort allowed her to compile the collected materials and provide a comprehensive description of the entire alkaline complex and the host rocks around the villages of Srytenky, Apostolske, Dmytrivka and Arkhangelske on an area of about 100 km^2. The map created by Einberg, which includes detailed topographic data, illustrates the geological features of the territory as well as its relief elements, along with the names of the streams and their tributaries that are not shown on modern maps (Fig. 3). According to her research, the area of the massif is characterised by the widespread presence of biotite granites and gneisses, alkaline pyroxene-hornblende granites with a subordinate group of diorites, alkaline quartz syenites, mariupolites, basic gabbro-peridotite rocks, and amphibolites.

L. Einberg emphasises the importance of distinguishing between various structural varieties of mariupolites (fine-grained melanocratic, dense hornblende leucocratic, gneiss, banded, pegmatite) and mineralogical (hastingsite, aegirine, zircon, micaceous and sodalite). She provides clear references to the distribution of each of the mentioned structural and mineral types, their detailed description, optical characteristics of individual minerals and results of chemical analyses (both her own and Yu. Morozevich's). In the work «Priazovskyi alkaline massif» L. Einberg characterizes all crystalline rocks found in the region, which include biotite granites and gneisses, pyroxene-amphibole granites (alkaline and dialagic), alkaline quartz syenites, amphibole (hastingsite) syenites, nepheline syenites (foyaites). The study highlights a significant variety of vein formations. They are represented by granite-aplites, granite-pegmatites, nepheline syenite-pegmatites and lamprophyres. Rocks of the lamprophyre series are represented by rather exotic camptonites and selvsbergites (Fig. 4). Camptonites are primarily composed of plagioclase (usually labrador) and brown amphibole (barkevikite); they also contain pyroxene (titanium-augite), biotite and olivine (Einberg, 1933). According to more recent data, phenocrysts of titanaugite and biotite (30%), barkevikite and kaersutite (around 30%), olivine (9%), titanomagnetite and apatite, are immersed in a holocrystalline groundmass. This groundmass is made up of labrador (up to 50%) and is often covered with crusts of albite or amphibole, pyroxene, apatite, calcite, zeolites, ore minerals, and with feldspars observed in some instances. Selvsbergite, as a vein analogue of alkali syenites, is characterized as a fine-grained or porphyritic igneous rock composed of alkali feldspar and aegirine or alkali amphibole. It is distinct from grorudite due to the absence of quartz.

L. Einberg draws attention to the fact that this rock complex has no contact with sedimentary rocks, particularly limestones, which would allow one to use Daly's theory of melting and assimilation (Daly, 1910) to explain the genesis of the alkaline massif. The zonal-concentric structure of the massif is quite apparent, featuring nepheline rocks at the core, which are surrounded by a broad field of alkaline syenites. These, in turn, are encircled by alkaline pyroxene-hornblende granites. The latter are bordered to the east by a strip of biotite granites. This undoubtedly connects the Azov (Zhovtnevy) alkaline massif with other massifs of the world. This is also stated by L. Einberg, relying on the works of Belyankin D.S. (1909, 1910), Quinsel P. (1913), Ramsey W. (1894) and others. Regarding the age of the mariupolites, L. Einberg (1933) suggests that the often veined and simultaneously pegmatite character of many varieties of mariupolite, as well as the heterogeneous texture and high alkali content, indicate their formation during the late pegmatite phase of the alkaline complex's development (Einberg, 1933).

In the work of Shpylyov L.V. and Biletsky V.S. (2008), which focuses on the history of the Mariupol zircon deposit, the research conducted by L. Einberg is not mentioned. Instead, the authors acknowledge the contributions of Yu. Morozevich, I. Ivanytsky and others. They suggest that the impetus for the revival of interest in the Mariupol massif was a detailed note by the mining engineer A.P. Dorofeev in 1933, which provides information on the industrial significance of zirconium occurrences known from literary sources.

At that time, this became the occasion for the organisation of exploratory geological exploration works for zirconium along the Mazurova ravine by the Institute of Geology of the All-Ukrainian Academy of Sciences. These surveys were conducted by geologist V.P. Amburher (Amburher, 1934). In 1937, further exploration of the deposit was undertaken by the Mariupol geological exploration party, led by P.V. Bystrov (Shpylyov and Biletsky, 2008). The result of the party's work included an assessment of zircon ore reserves along the Mazurov ravine, which was assessed at 4.5 million tons. The authors of the study provide a detailed account of subsequent exploration activities, trial operations, and the establishment and functioning of the ore mining enterprise, which are described in detail in the work of Shpylyovy and Biletsky (2008). The authors believe the Mariupol deposit of solid zirconium ores was developed for the first time in world practice.

The first monograph, titled «Coloured Stones of Ukraine», in which experts indicate the possibility of mining, along with nepheline syenites, mariupolite as a gemstone raw material, was published in 1974 (Semenchenko et al., 1974).

From 1962 to 1978, the nepheline complex of the Zhovtnevy alkaline massif was studied by a group of scientists under the leadership of A.A. Denisevich with the participation of employees of the Priazov Comprehensive Geological Expedition and the Institute of Mineral Resources (Simferopol). Based on geological observations and determination of the absolute age of rocks, the following sequence of rock types from younger to older has been established: albitites and intensively albitized rocks-alkaline pegmatites and rocks types from younger to older: albitites and intensively albitized rocks-alkaline pegmatites, mariupolites-foyaites and alkaline syenites-quartz syenites, granosyenites and coarse-grained Kateryniv granites-basic and ultrabasic rocks (Donskoi, 1982). In addition to a detailed examination of the petrology of the massif, the study also addressed its tectonics, weathering processes, and the geochemistry related to

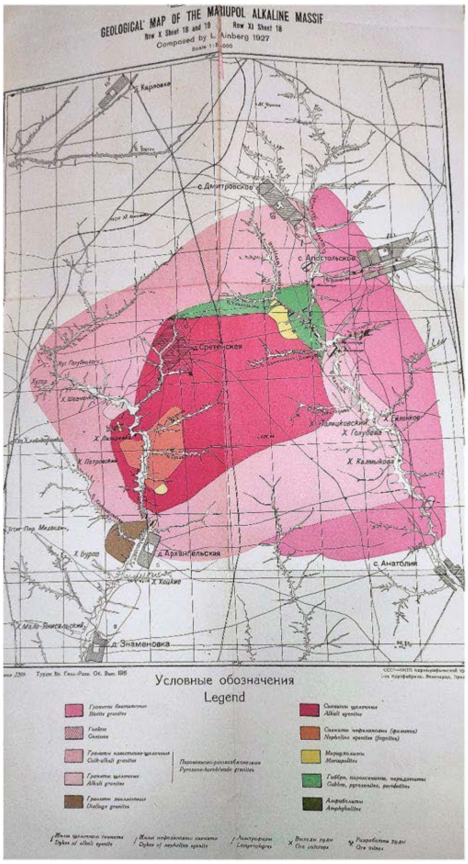

Fig. 3. Geological map of the Mariupol alkaline massif according to L. Einberg (Einberg, 1933)

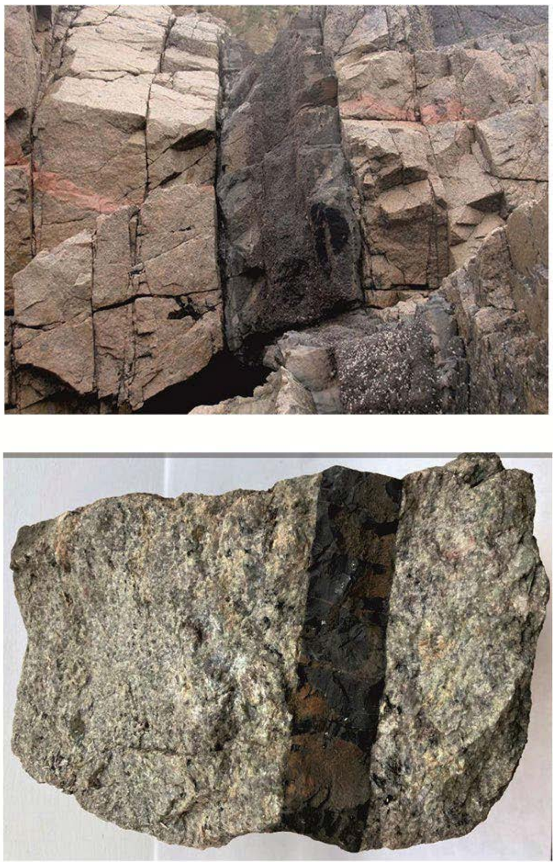

Fig. 4. Veins composed of camptonite (https://www.alexstrekeisen.it/vulc/lamprofiri.php)

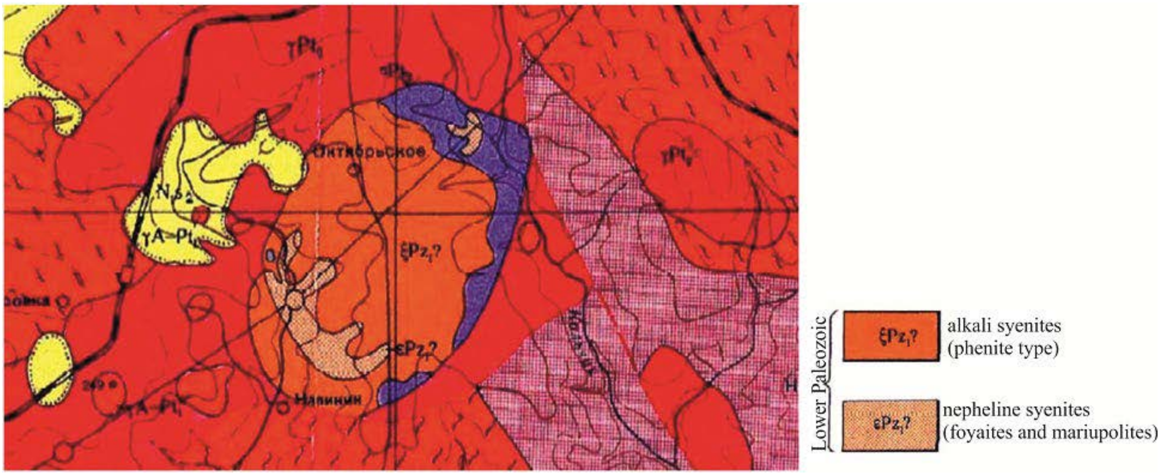

Fig. 5. The Zhovtnevy massif on the «Geological map of the USSR. Donbass series. L-37-II. 1958 (Heolohyia SSSR. Donetskyi bassein, 1944).

the distribution of individual elements, both for the deposit as a whole and its Northeastern and Southern section.

A significant contribution to the study of alkaline massifs, in particular Zhovtnevy, was made by I.D. Tsarovsky. For over 20 years, he explored issues related to the geology, petrology, and genesis of these massifs. Tsarovsky identified two periods of intrusive activity, the first of which is linked to the formation of alkaline granites, syenite-pegmatites and albitites, and the second one is associated with foyaites, microcline-nepheline pegmatites, and mariupolites (Tsarovsky, 1947, 1954). In later works, he emphasised the importance of the role of metasomatic processes and the single-phase development of the massif. I.D. Tsarovsky attributed the diversity of alkaline rocks to metasomatic phenomena such as fenitization and marupolitization, which occur under the influence of foyaite intrusion (Tsarovsky, 1960, 1964). He classified the alkaline rocks of the Zhovtnevy massif to the granitoid-syenite-foyaite series, thereby rejecting the idea of a comagmatic relationship with their basic and ultrabasic rocks.

Later, Kryvdik S.G. highlights the original conclusions of Rudenko S., according to which the entire variety of textural and structural types, and spatially related pegmatites-mariupolites arose during the transformation of the initial fine-grained mariupolites (Kryvdik and Tkachuk, 1990; Rudenko, 1962). Donskoi O.M. (Donskoi and Donskoi, 2011) noted the great practical importance of albitites of the Zhovtnevy massif, among which he distinguished three types: 1) zircon-pyrochlore; 2) pyrochlore on syenites; 3) zircon on granites. Within the massif, he also identifies three primary deposits of complex ores: Mazurova Balka, Kalynino-Shevchenkivske and Vili-Tarama and provides their description.

The publication «On the Genesis of Alkaline Metasomatites of the Ukrainian Shield» (Kryvdik, 2013) represents one of the first efforts to compare all known types of alkaline metasomatites, as well as certain igneous rocks regarded as metasomatites, within the Ukrainian Shield.

Recent works by Shpylovyi K.L. (Shpylovyi and Shpylovyi, 2012; Shpylovyi et al., 2023) provide a modern and comprehensive overview of the discovery, further study, and utilization of the Zhovtnevy massif as a mineral deposit. It is particularly noted that the integrated use of all minerals of the Mazuriv deposit greatly enhances its development potential. Given the current increasing interest in rare metals, there is an opportunity to significantly reduce reliance on imported concentrates, such as niobium and tantalum. Additionally, advancing research into the geological, economic, technological, engineering, and environmental aspects of the Mazuriv deposit is crucial for lowering the production costs of domestic ferroalloy and rare metal products, as well as establishing a local raw material base for nepheline-feldspar materials (Shpylovyi et al., 2023). The potential for using mariupolite not only as a gemstone raw material is obvious and undeniable. For example, within the Mazurivka section of the Zhovtnevy massif, pyrochlore ores with an average Nb_2O_5 content of 0.13% were discovered, confined to mariupolites (nepheline-feldspar syenites). The tantalum-niobium mineralization present in mariupolites and feldspar metasomatites shows promise as well. Additionally, complex zirconium-rare-earth ores are concentrated in this area.

A group of scientists, including Tsymbal S.M., Voznyak D.K., Sharygin V.V., Kryvdik S.G., Dubyna O.V. and others, during 2010-2015, shed light on the processes of sodalitization of pegmatoid mariupolites in their publications (Kryvdik and Tkachuk, 1990; Kryvdik 2002; Kryvdik et al., 2012; Kryvdik et al., 2015 and others). At the same time, the genesis of Palaeozoic alkaline rocks of the Eastern Azov region and minerals of alkaline rocks of Ukraine are being studied. The composition and geochemical features of nepheline syenite-porphyries of the Azov region are being analysed in detail, as a new type of rock in Ukraine (Donskoi and Donskoi 2011; Kryvdik et al., 2015).

In September 2010, the Institute of Geochemistry, Mineralogy and Ore Formation named after M.P. Semenenko, together with the Mineralogical Society of Poland, organised a conference «Alkaline rocks: petrology, mineralogy, geochemistry». This event was held in memory of Yu. Morozevich and included a field trip to the Zhovtnevy massif.

The conference materials and references to related publications were compiled under the title «Alkaline Rocks from the Mariupol Massif (South-Eastern Ukraine)» and can be found on the Mineralcollection-blog online resource (Alkaline rocks…, 2025). The information provided includes well-illustrated details on the structure of the Zhovtnevy massif, as well as the petrology and mineralogy of both alkaline and host rocks (Fig. 6).

The conference sparked increased interest in alkaline rocks among Polish geologists. This is evidenced by an initial joint article with Ukrainian gemologists (Dumańska-Słowik et al., 2011) and several independent articles published between 2015 and 2019. These articles addressed significant topics such as the geological structure of the massif, its petrology and mineralogy, geochemistry, and the evolution of mariupolites as potential carriers of niobium-zircon-rare-earth mineralization. They also explored fenitization processes and the ultramafic and mafic rocks found in the outer rim of the massif (Dumańska-Słowik et al., 2015(a); Dumańska-Słowik et al., 2015(b); Dumańska-Słowik and Heflik, 2016; Dumańska-Słowik et al., 2019, etc.).

Fig. 6. Remains of the exhausted Don quarry (1) and mariupolites from it: 2 – aegirine-albite-nepheline syenite; 3 – blue sodalite, yellow cancrinite and black aegirine in nepheline pegmatite (mariupolite) (Alkaline rocks from Mariupol massif (SW Ukraine), https://mineralcollectionblog.wordpress.com/tag/mariupolite).

Features of the geological structure of mariupolite deposits.

In the south of the Ukrainian Shield within the Azov tectonic block, alkaline rocks (syenites, nordmarkites, nepheline syenites, foyaite, granosyenites, etc.) are commonly found. These rocks cover a significant area and form large massifs (Shpylovyi et al., 2023). Among them, within the East Azov area, the following are distinguished: 1) South Kalchyk massif (Cherdakly deposit); 2) Kalmius massif; 3) Gruzskyi Yelanchyk massif; 4) Zhovtnevy massif.

The Zhovtnevy alkaline massif represents an ancient platform manifestation of nepheline magmatism within the Ukrainian Shield, with an absolute age estimated to be around 1.8 billion years (Donskoi, 1982). The massif has a circular shape, somewhat elongated in the northeast direction, measuring approximately 7–8 km in length and up to 6 km in width (Fig. 7). Spatially, the Zhovtnevy alkaline massif is a part of the Zhovtnevy ore field, which is situated in the northwestern part of the East Azov block of the Ukrainian Shield. The megablock is predominantly composed of granitoids and syenites of the Anatolian, Khlibodarov and South Kalchyk complexes. Structurally, the massif is localised at the intersection of the deep fault zones, including the northeastern (Volodarsk and Don), northwestern strike – Oktyabr (Kryvyi Rih-Pavliv tectonic zone), and sublatitudinal Konka (Shpylovyi et al., 2023).

According to the authors of the work «Petrology of alkaline rocks of the Ukrainian Shield» (Kryvdik and Tkachuk, 1990), the Zhovtnevy massif is unique in the world, as it possesses a complete range of gabbro-syenite formation rocks, from gabbro-pyroxenites to agpaitic nepheline syenites. The massif has an autonomous internal structure and is asymmetrically positioned relative to the surrounding granitoid body. The trachytoidity of alkaline and nepheline-containing syenites exhibits a more gentle dip directed into the massif and emphasises the concentric structure and structural independence of the massif.

In total, 44 ore bodies were discovered at the deposit (Mazuriv ore node), including within the detailed area – 10. The distribution of natural ore varieties within the ore bodies is as follows: mariupolites account for 54%, nepheline pegmatites make up 24%, feldspar metasomatites represent 20%, and the host rocks and their alteration products constitute approximately 1.6-2%. For substantial ore bodies, these formations have been traced over significant distances, often exceeding 1000 meters. Most bodies are wider than 300 meters, with thicknesses ranging from 1 to 45-80 meters. The boundaries between ore bodies and host rocks are distinct and clearly defined, as evi-

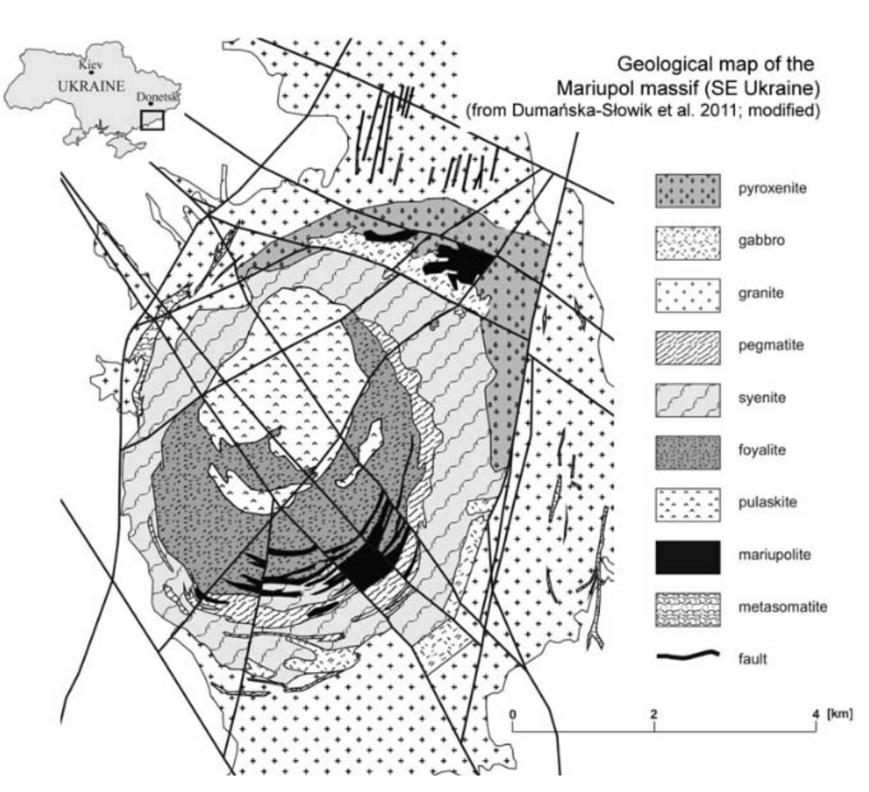

Fig. 7. Geological map of the Mariupol (Zhovtnevy) massif (after Dumanska-Slowik et al., 2011)

denced by visual mapping in the cores of wells (Shpylovyi et al., 2023).

The rock complex consists of subalkaline basic and ultramafic rocks (gabbro, pyroxenites, peridotites), alkaline and nepheline syenites (foyaites, mariupolites). The rock-forming components of mariupolites are nepheline, albite, aegirine, and sometimes microcline (Zahnitko et al., 2017). The zirconium-rare-earth-niobium ore complex is confined to the massif of nepheline syenites, particularly in areas where mariupolites and albitites are found (Mykhailov, 2023; Shpylovyi et al., 2023). However, despite the high resource potential of rare metals, Ukraine is not one of the leading countries in this field.

As of the beginning of the 21st century, the following ore objects are promising: Perga beryllium, Yastrebetske fluorite-zircon-rare earth, Malyshiv ilmenite-zircon, Polokhivka, Shevchenkivske and Stankovatske lithium, Azov zircon-rare earth, Zhovtorichenske scandium-vanadium, Mazurivka nepheline-feldspar-rare metal, Verbynske molybdenum, Novopoltavske apatite-rare earth, Fedirivska, Kropyvnytske, Stremyrhorod apatite-titanomagnetite-rare metal.

The Mazurivka deposit is currently regarded as a reference object for developing a systematic approach to solving the problem of studying and rational industrial development of rare-earth metal deposits in Ukraine. Within its boundaries, pyrochlore ores with an average Nb_2O_5 content of 0.13% were discovered confined to nepheline-feldspar syenites (mariupolites). Tantalum-niobium mineralisation in mariupolites and feldspar metasomatites was also detected here (Shpylovyi et al., 2023). Balance reserves of zirconium are taken into account in five placer deposits – Mazurivka, Vovchansk, Krasnokutsk, Tarasivska, Voskresensk, and off-balance reserves in the Mokry Yaly and Mariupol deposits. The ores of the Mazurivka deposit contain rare-earth metals of the cerium group. The main mineral-concentrator, which concentrates up to 70-80% of rare-earth metals in rocks, is brytholite (Fig. 8-2). In addition, rare-earth metals are found in pyrochlore, zircon, apatite and chevkinite (Fig. 8-1). Brytholite appears as irregular grains and well-formed pseudogonal prismatic crystals. The composition of rare earths (in wt% of TR) is typical for brytholite: lanthanum – 21.8; cerium – 41.1; praseodymium – 5.8; neodymium – 19.4; samarium – 3.9; europium – 0.5; gadolinium – 4.4; terbium – 0.2; dysprosium – 1.2; erbium – 0.5; ytterbium – 1.0. The highest concentrations of these minerals are observed in mariupolites and di-spar metasomatites, where the amount of rare-earth metals ranges from 0.02 to 0.32% (Shpylovyi et al., 2023).

As indicated above, the Zhovtnevy deposit is the first discovered zirconium deposit in Ukraine, where in the process of prospecting work conducted by the Institute of Geology of the All-Ukrainian Academy of Sciences in the northern part of the Zhovtnevy massif, during the study of the rocks of the planar crust of weathering of alkaline-basic rocks, along the Mazurivka Balka and the Maly Kalchyk River, the first work on the search and evaluation of loose zircon ores of the upper deposit was carried out, and their industrial value was established: the average thickness of the mariupolites was 7 m, and the average content of zirconium dioxide (according to 82 analyses) was 0.4%. Ore reserves are estimated at 21,642 tons (Amburher, 1934). It is evident that the production of rare-earth metal products in Ukraine can only have good prospects if a domestic raw material base is established.

According to the research conducted by Polish followers of J. Morozevich, the presence of sodalite, natrolite, cancrinite, fluorite, and some other secondary minerals containing rare-earth metals in the pegmatite variety of mariupolite indicates the post-magmatic activity of this region (Dumanska-Slowik et al., 2011; Dumańska-Słowik et al., 2015; Dumańs-

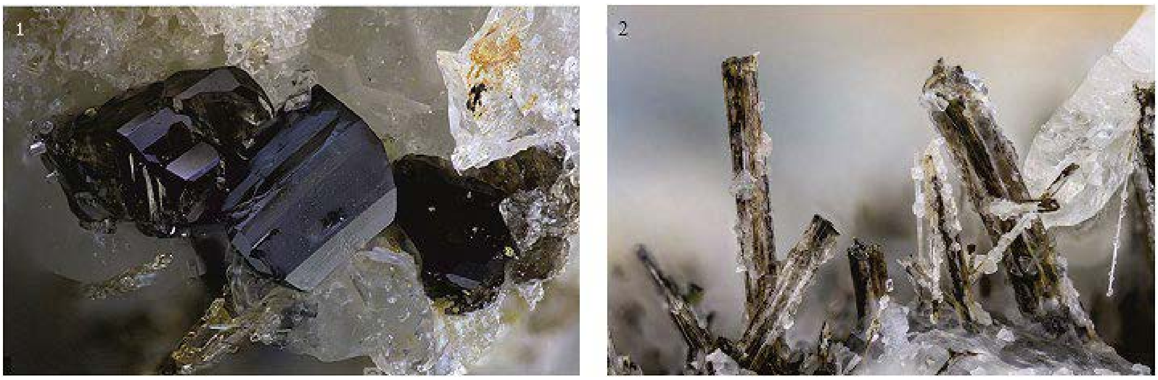

Fig. 8. The main rare-earth metal concentrating minerals of the Mazurivka deposit: chevkinite (1) and brytholite (2)

ka-Słowik et al., 2016; Dumańska-Słowik and Heflik, 2016). Metasomatic fluids that flowed through tectonic zones were enriched in Na^+, Ca^{2+}, REE^{3+}, Cl^-, HCO^-, F^- and depleted in SiO^2. They replaced nepheline syenites and deposited secondary minerals. With a decrease in salinity of post-magmatic fluids, cancrinite, sodalite, natrolite and fluorite were formed, mainly due to nepheline, and partly albitite. Two generations of sodalite have been identified: the first generation (older) presents as irregular, mottled forms of various sizes with dark blue, pink, or purple hues. The second generation (younger) mainly fills veins or forms borders through substitution or growth on albite, exhibiting a light blue colour. The concentration of metasomatic minerals along weakened tectonic zones creates a general pattern for the distribution of sodalite and albitite locations, which lend white or blue colours to nepheline syenites.

In August 2023, during a revision survey of geological monuments of the nature of Donetsk region, one of the authors of this article examined the mariupolite outcrop in the exhausted quarry of the village of Donske. Based on the results of monitoring, observations, mineralogical and petrographic studies of selected samples of mariupolite and a generalization of existing scientific publications, it was proposed to grant the status of a geological monument of nature of national importance, as a unique petrological and mineralogical object of the geological heritage of Ukraine (Fig. 9, 10) (Manyuk, 2006; Geological landmarks (geosites) of Ukraine, 2011).

Results

Mineralogical and gemological features of mariupolite. According to the list of minerals of the Cabinet of Ministers of Ukraine (No. 747 of August 16, 2005), mariupolite is classified as a productive raw material (Perelik korysnykh kopalyn…, 2005). The reserves of nepheline-feldspar-rare metal ores, calculated from five productive deposits of the Mazurivka deposit to a depth of 280 m, are classified as C_1 and C_2 and amount to a total of 11,242 thousand tons of ore (Shpylovyi et al., 2023).

Fig. 9. Mariupolite from the collection collected during the inventory of the geological heritage of Ukraine (author's photo)

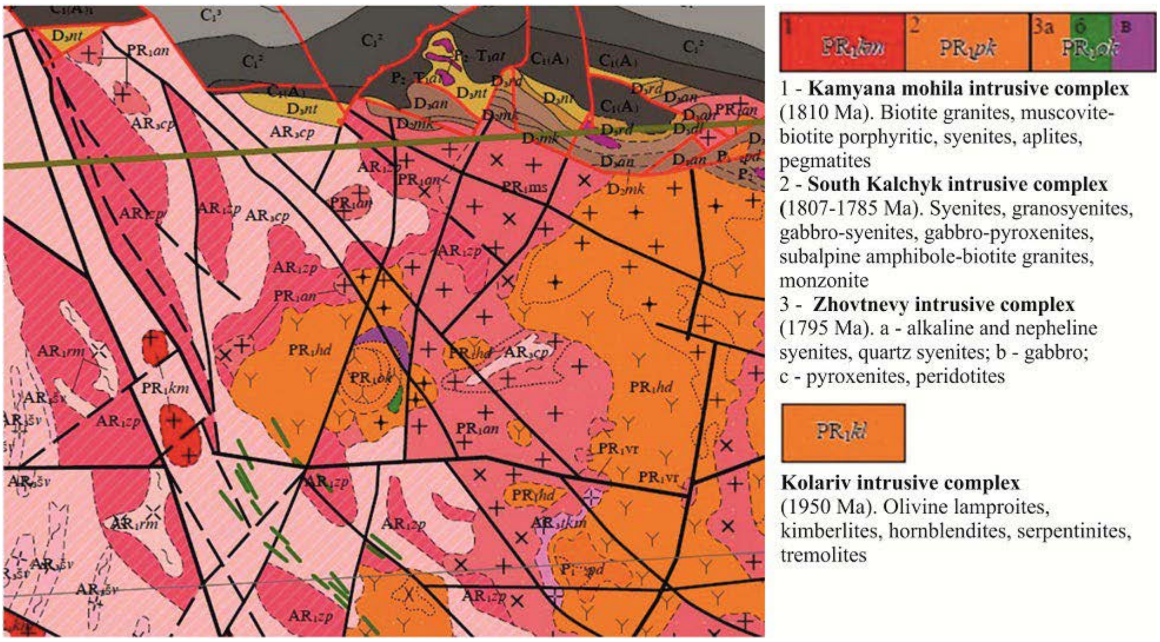

Fig. 10. Position of the Zhovtnevy massif on the modern map of pre-Mesozoic formations

Mariupolite is an alkaline rock consisting of 74% albite, 13% nepheline, 7% aegirine, 4% lepidomelane, 2% zircon, apatite, as well as minor minerals (sodalite, amphibole, calcite, cancrinite, zeolites), accessory minerals (pyrochlore, zircon, brytholite, magnetite, iron sulfides, etc.).

It is characterised by the almost complete absence of $K[AlSi_3O_8]$ and the presence of Na_2O. Mariupolite of the Mazurivka deposit contains impurities of rare refractory elements (Morozevych, 1902; Einberg, 1933; Kryvdik et al., 2012; Shpylovyi and Biletskyi, 2019; Shpylovyi et al., 2023). Nepheline syenites, foyaites, pegmatites and mariupolites have high decorative properties and are characterised by bright colour and original pattern.

The main elements of mariupolite, which give it decorativeness, are sodalite, albite and nepheline. These minerals are unevenly distributed in the volume of the rock, and in each case, they are distributed in different quantities, resulting in diverse patterns in each case. The spatial and quantitative variations create a distinctive structural pattern of the rock. Notably, the presence of sodalite imparts a blue colour to the Azov mariupolite, making it a highly decorative stone and setting it apart from other rocks with similar compositions (Fig. 11).

Sodalite is a sodium aluminosilicate mineral with a framework structure that includes an additional anion Cl^-. It was first discovered by Europeans in Greenland in 1811. The name sodalite, which is related to the word «soda» for the high sodium content in the mineral, was given by the Scottish chemist Thomas Thomson in the same year (Biletskyi et al., 2018). Sodalite typically occurs as granular or massive aggregates or scattered grains within silica-poor alkaline igneous rocks and pegmatites. It often forms rims around nepheline crystals, and less frequently, it appears as independent grains (Nesterovskyi and Derevska, 2024).

Mariupolite exhibits a range of colour and appearance , including light blue, grey, pink-grey, blue-grey, and greenish-grey. The rock is unevenly grained, featuring fine, medium, and coarse grains with a massive, sometimes banded texture.

According to Dumanska-Slowik et al. (2011), the main decorative varieties of sodalite mariupolite are considered. Sodalite, albite and nepheline, which are not equally located in the volume of the rock, create

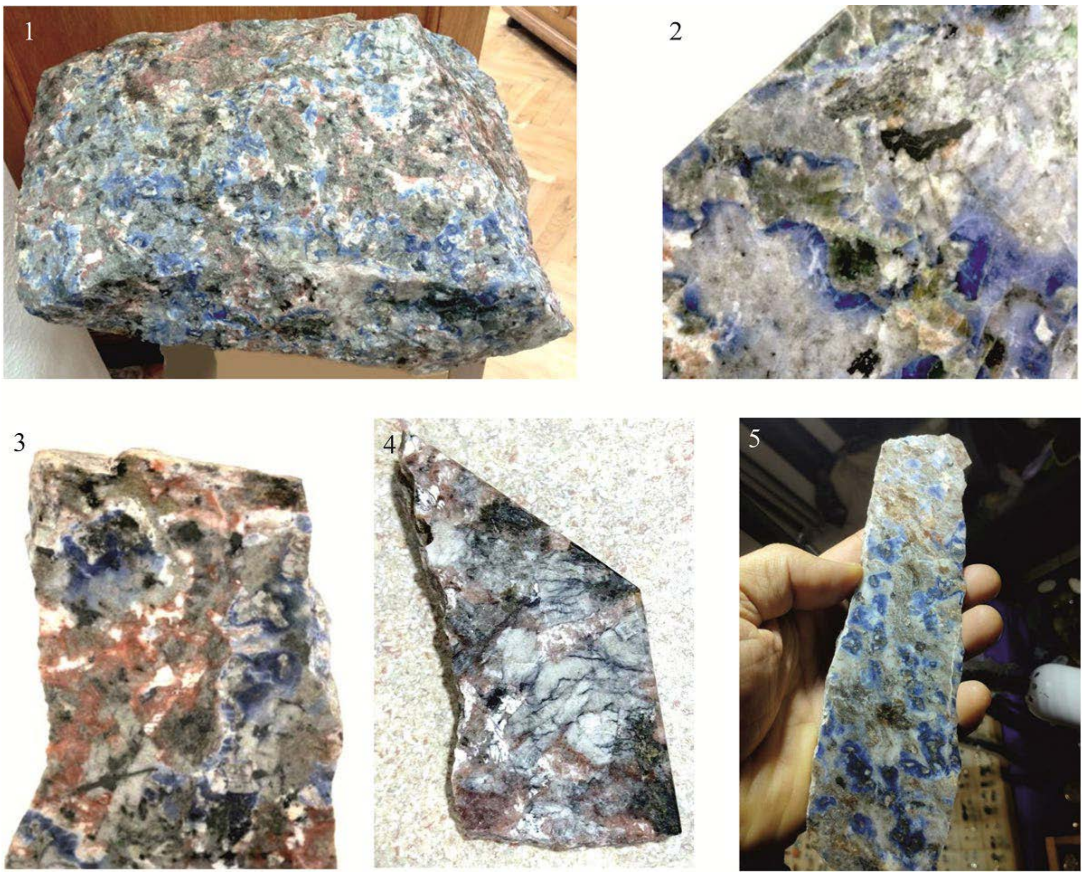

Fig. 11. Mariupolite from the deposits of the East Azov area: 1 – a sample from the funds of the Geological Museum of Taras Shevchenko National University of Kyiv (weight 200 kg). Photo by Nesterovskyi V.A.; 2 – 3 – samples from the funds of the Geological Collection of the Ukrainian State Geological Institute (size 3 – 8 x 12 cm, 2 – 7x5 cm); Author's photo. 4 – a sample from a private collection. Photo by Nurmamedov L. R. (size 9 x 4 cm); 5 – a sample from a private collection. Photo by Sytnyk A. (size 10 x 3 cm).

different types of textures depending on the generation of sodalite (see Fig. 11):

1. Dark blue sodalite forms separate large (up to 5 cm) clusters among light grey or white albite and forms a spotted texture.

2. Light blue sodalite creates thin (up to 1-2 mm), almost continuous borders around crystals and grains of albite in the rock, manifesting as a spheroidal texture.

3. Irregularly grained (up to 0.5 cm) various shades of blue sodalite are mosaically distributed throughout the rock and form a mottled texture.

4. Dark blue sodalite fills microcracks (up to 1 mm) in white albite, forming a striped texture.

The overall volume-quantitative distribution gives the rock a characteristic mixed structural pattern. Sodalite distinguishes mariupolite from many other rocks of similar composition from deposits around the world and is the calling card of this region. Its main mineralogical properties are as follows: hardness – 5.5-6; density – 2.1-2.4 g/cm^3; brittle; perfect cleavage; glassy lustre, glassy along the cleavage plane, oily on the fracture, uneven fracture; crystals are rare; in one direction; colour – blue of various shades, reddish.

As is known, in polycrystalline rocks, to which mariupolite belongs, the strength is determined by the forces of mutual adhesion of directly touching crystalline grains and depends on their strength and morphology. Therefore, this rock has astrength of about 350 MPa. Due to its mineralogical and physicochemical properties, sodalite mariupolite is well cut, ground and polished with diamond tools. Common products made from this material include beads, cabochons, jewellry inserts, boxes, candlesticks, rotational figures, haberdashery, and souvenir items (Fig. 12).

Fig. 12. Products from Ukrainian and Czech mariupolite and sodalite. Samples from various sources of storage (photos by the authors and https://pebblebead.com/ida72789.html)

Due to its unique textural patterns, mariupolite is gaining popularity in Ukraine and European Union countries. It is actively used in the creation of highly artistic stone works and decorative elements. Additionally, samples of mariupolite are considered valuable collector's items and are in high demand.

Conclusions

1. Mariupolites have been extensively studied by various Ukrainian and foreign geologists. While they are considered well-researched, their genetic nature is still a topic of debate..

2. Sodalite mariupolite is a distinct variety of alkaline igneous rock found in the Azov block. Its unique mineral composition, structure, texture, and appearance give it a special significance within the Zhovtnevy massif.

3. The mariupolites of the Zhovtnevy massif are notable for their industrial potential, particularly in the extraction of rare-earth elements such as zirconium, tantalum, and niobium, making them an important raw material for future processing.

4. Due to its gemological characteristics, sodalite mariupolite is promising for use in the stone-working industry. This stone-coloured raw material can compete with jaspers and other opaque varieties of precious stones on the world market.

5. The main components for promoting sodalite mariupolite as a new type of gemstone raw material are creating a positive image, helping to develop several interesting design projects, and popularising them.

6. When preparing and implementing projects and business plans to develop rare-earth metal deposits in the Zhovtnevy massif, an integrated approach that will ensure the concomitant extraction of sodalite mariupolite for the stone processing industry must be considered.

References

Alkaline rocks from Mariupol massif (SW Ukraine) part I, II. On 15 December 2016. Mineralcollectionblog. (2025). https://mineralcollectionblog.wordpress.com/tag/mariupolite

Amburher, V.P. (1934). Kratkyi predvarytelnyi otchet o rabote tsyrkonovoi partyy Ynstytuta Heolohyy VUAN za 1934h. [Brief preliminary report on the work of the zircon batch of the Institute of Geology of the Ukrainian Academy of Sciences in 1934]. Geoinform. 3251, 1-2. (In russian).

Beliankin, D.S. (1909). Ocherki z petrohrafii Ilmenskykh hir. [Essays on the petrography of the Ilmen Mountains]. Part 1, 2. Izvestia St. Petersburg. Polytechnic Institute, XII-XIII. (In Ukrainian).

Biletskyi, V. S., Shpylovyi, L. V. (2007). Polskyi doslidnyk Pryazovskykh nadr. [Polish researcher of the Azov subsoil]. Geological and Mineralogical Bulletin of the Kryvyi Rih State Technical University, 2 (18), 82–90. (In Ukrainian).

Biletskyi, V.S., Omelchenko, V.H., Horvanko, H.D. (2016). Mineralohichnyi slovnyk. [Mineralogical Dictionary]. Mariupol: Eastern Publishing House. (In Ukrainian).

Biletskyi, V.S., Suiarko, V.H., Ishchenko, L.V. (2018). Sodalit. Mineraloho-petrohrafichnyi slovnyk. [Sodalite. Mineralogical and petrographic dictionary]. Kharkiv: NTU «KhPI», Kyiv: FOP Khalikov R.Kh. 1- 444. (In Ukrainian).

Daly, R.A. (1910). Origin of the Alkalin Rocks. Journ. Geol. Soc. Amer., XXVI, 97-134.

Donskoi, A. N., Donskoi, N. A. (2011). Metallohenyia nefelynovykh seryi yuho-zapadnoi chasty Vostochno-evropeiskoi platformy. [Metallogeny of the nepheline series in the southwestern part of the East European platform]. Geochemistry and Ore Formation. 29, 30-43. Retrieved from: http://jnas.nbuv.gov.ua/article/UJRN-0000093721(In russian).

Donskoi, A.N. (1982). Nefelynovyi kompleks Oktiabrskoho shchelochnoho massyva. [The nepheline complex of the Oktyabrsky alkaline massif]. Kyiv, Nauk. dumka. (In russian).

Donskoi, A.N., Kulysh, E.A., Donskoi, N.A. (2004). Nefelynovye porody Ukrayny – kompleksnye aliumynyi-hlynozemnye y redkometallnye rudy. [Nepheline rocks of Ukraine – complex aluminum-alumina and rare metal ores]. Kyiv, Logos. (In russian).

Dumańska-Słowik, M., Baranov, P., Heflik, W., Natkaniec-Nowak, L., Shevchenko, S., Tsotsko, L. (2011). Mariupolite from the Oktyabrsky Massif (SE Ukraine) – a less known rock in the gemstone trade. Z. Dt. Gemmol. Ges. 60/1-2, 37-48 (In Polish).

Dumańska-Słowik, M., Heflik, W., Kromska, A., Sikorska, M. (2015). Sodic fenites of the Oktiabrski Complex exposed in the Khlibodarivka quarry (East Azov, SE Ukraine): reconstruction of their growth history. N. Jb. Geol. Paläont. Abh.:275/3: 269–283. https://doi.org/10.1127/njgpa/2015/0471(In Polish)

Dumańska-Słowik M., Heflik W. (2016). Skały ultrazasadowe i zasadowe z otoczenia mariupolitów występujących w alkalicznym Masywie Oktiabrskim (SE Ukraina) – badania wstępne. [Ultrabasic and basic rocks from the vicinity of mariupolites occurring in the alkaline Oktyabrsky Massif (SE Ukraine) – preliminary studies]. Gospodarka surowcami mineralnymi – Mineral Resources Management: 32 (2), 63–78. (In Polish).

Dumańska-Słowik, M., Heflik W., Sikorska, M. (2016). Skały ultrazasadowe i zasadowe z otoczenia mariupolitów występujących w alkalicznym Masywie Oktiabrskim (SE Ukraina) – badania wstępne. Gospodarka surowcami mineralnymi – Mineral resources management: 32 (2), 63–78. (In Polish).

Dumańska-Słowik, M., Heflik, W., Pieczka, A., Sikorska, M., Dąbrowa, Ł. (2015). The transformation of nepheline and albite into sodalite in pegmatitic mariupolite of the Oktiabrski Massif (SE Ukraine). Spectrochimica Acta. Part A: Molecular and Biomolecular Spectroscopy. 150, 837-845. https://doi.org/10.1016/j.saa.2015.06.039 (In Polish).

Dumańska-Słowik, M., Pieczka, A., Heflik, W., Sikorska, M. (2016): Cancrinite from nepheline syenite (mariupolite) of the Oktiabrski massif, SE Ukraine, and its growth history. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy: 157: 211-219. https://doi.org/10.1016/j.saa.2016.01.007 (In Polish).

Dumańska-Słowik, M., Powolny, T., Heflik, W., Morgun, V. (2019). Mineralogical and geochemical constraints on the origin and evolution of albitites from Dmytrivka at the Oktiabrski complex, Southeast Ukraine. https://doi.org/10.1016/j.lithos.2019.03.024 (In Polish).

Einberg, L.F. (1930). Rohovye obmanky Maryupolskoho luzhnoho masyvu. [Hornblende of the Mariupol alkaline massif]. Izvestiya geolog. upravl. 5,44-52, 75-102. (In russian).

Einberg, L.F. (1933). Pryazovskyi luzhnyi masyv. [Priazovian alkaline massif]. NKTP, Proceedings of the All-Union Geological Exploration Association, Leningrad, 196, 48-64. (In Ukrainian).

Eremeev, P.V. (1897). Ob auerbakhyte y zakliuchaiushchei eho hornoi porode. [About auerbachite and its concluding rock]. Izv. Academy of Sciences St. Petersburg, VII, 2. (In russian).

Geological landmarks (geosites) of Ukraine. (2011). A team of authors, in 4 volumes, in Ukrainian and English. Edited by V.I. Kalinin and D.S. Gursky. Kyiv, IV, 46 – 47.

Heolohyia SSSR. Donetskyi bassein. (1944). [Geology of the SSSR .Donetsk Basin]. P.Y. Stepanov (Ed.), 7, 53-65. (In russian).

Hynzburh, A. S. (1916). K petrohrafyy Pryazovskoi krystallycheskoi polosy. [Towards the petrography of the Azov crystalline zone]. Izv. Petersburg Polytechnic. inst., XXV, issue 1-2. (In russian).

Ivanytskyi, I. (1833). Heohnostychnyi opys Mariupolskoho povitu. [Geognostic description of Mariupol district]. Mountaineering Journal, Kh. (In Ukrainian).

Kontkevych, S. (1881). Heolohichni doslidzhennia u hranitnii smuzi Novorosii zi skhidnoho boku Dnipra. [Geological research in the granite strip of Novorossia on the eastern side of the Dnieper]. Mining Journal, 1-2. (In Ukrainian).

Kryvdik, S.G. (2002): Metallogeny of Alkaline Complexes of the Ukrainian Shield. Mineral. Journ. (Ukraine). 24(2/3): 58-64.

Kryvdik, S.G. (2013). Pro henezys luzhnykh metasomatytiv Ukrainskoho shchyta [On the genesis of alkaline metasomatites of the Ukrainian shield]. Geochemistry and Ore Formation, 33, 3- 17. (In Ukrainian) https://doi.org/10.15407/mineraljournal.37.04.078

Kryvdik, S.G., Dubina, O.V., Amashukeli, Yu.A., Vishnevsky, O.A. (2015). Nefelinovyi siienit-porfir Pryazovia – novyi typ porid Ukrainskoho shchyta [Nepheline syenite-porphyry of the Azov region – a new type of rock of the Ukrainian shield]. Mineralogical Journal. 2015. 37, 4, 78-84. (In Ukrainian).

Kryvdik, S.G., Tkachuk, V.I. (1990). Petrolohyya shchelochnykh porod Ukraynskoho shchyta. [Petrology of alkaline rocks of the Ukrainian shield]. Kyiv. Nauk. Dumka. (In russian).

Kryvdik, S.H., Vozniak, D.K., Sharyhin, V.V., Dubyna, O.V. (2012). Minerals of alkaline rocks of Ukraine. [Mineraly luzhnykh porid Ukrainy]. Notes of the Ukrainian Mineralogical Society. 9, 1-34. (In Ukrainian).

Manyuk, V.V. (2006). Heolohichni doslidzhennia v Zaporizkii i Donetskii oblastiakh z metoiu obstezhennia, inventarizatsii i podalshoho zberezhennia heolohichnykh pamiatok pryrody. [Geological research in Zaporizhia and Donetsk regions for the purpose of survey, inventory and further preservation of geological monuments of nature]. Collection of scientific works dedicated to the 75th anniversary of Professor O.P. Fisunenko. Lugansk, Alma-Mater, 82-93. (In Ukrainian).

Morozevych, J. (1898a). O lytolohycheskom sostave Yuzhno-russkoi krystallycheskoi ploshchady, v predelakh Maryupolskoho uezda. [About the lithological composition of the Southern Russian Crystalline Area, within the Mariupol District]. Izv. Geol. com. for 1898, XVII, issue 3. (In russian).

Morozevych, J. (1898b). Heolohycheskye yssledovanyia, proyzvedennye v Maryupolskom uzde letom 1898. [Geological research conducted in Mariupol region in the summer of 1898]. Izv. Geol. com., XVII Q& 6. (In russian).

Morozevych, J. A. (1899). Heolohycheskye nabliudenyia, proyzvedennye v Berdianskom uezde letom 1899 h. [Geological observations made in Berdyansk district in the summer of 1899]. Izv. Geol. com., XVin. (In russian).

Morozevych, J. (1901). Heolohycheskye nabliudenyia, proyzvedennye v Aleksandrovskom uezde y Tahanrohckom okruhe letom 1901 h. [Geological observations made in Aleksandrovsky District and Taganrog District in the summer of 1901]. Izv. Geol. com., XX. (In russian).

Morozevych, J.A. (1902). Ob odnom krainem chlene semeistva eleolytovykh syenytov – maryupolyte y sviazannykh s nym porodakh Maryupolskoho uezda.

[About one extreme member of the family of eleolithic syenites – Mariupolite and related rocks of the Mariupol district]. Zapiski St. Petersburg Miner. Soc., 2, XXXIX, 44-51. (In russian).

Morozevych, Y. (1903). O nekotoryykh zhylnykh porodakh Tahanrohskoho okruha. [About some veins of the Taganrog district]. Proceedings of Geol. com., Nov. ser., 8. (In russian).

Morozewicz, J. (1904) Uber Beckelit ein Cero-Lantano-Didymo-Silikat vom Calcium. Bull. Inter. Acad. Sci. Cracovie. 485-492.

Morozewicz, J. (1925) Uber einige Eisenalkali-amphibole. Tschermaks mineralogische und petrographische Mitteilungen, 38, 210-222.

Morozewicz, J.A. (1929). Mariupolit i jego krewniaki. [Mariupolite and its relatives]. Prace Pol. Inst. Geol.:1 – 151. (In Polish).

Mykhailov, V.A. (2023). Vysokoperspektyvni obiekty MSB Ukrainy. [Highly promising objects of the Ukrainian MRB]. *Bulletin of the Taras Shevchenko National University of Kyiv. Geology*. 1(100), 73-85. (In Ukrainian).

Nesterovskyi, V.A., Derevska, K.I. (2024). Mariupolit – symvol ukrainskoi mitsnosti i nezlamnosti. [Mariupolite – a symbol of Ukrainian strength and invincibility]. Collection of materials of the 13th International Scientific and Practical Conference «Precious and Decorative Stones: Current Issues of Gemological Examination, Geology, Mining, Processing and Use». Kyiv, 22-24. DOI: https://doi.org/10.53036/2024-11. (In Ukrainian).

Perelik korysnykh kopalyn Kabinetu Ministriv Ukrainy (vid 16 serpnia 2005 r. № 747). [List of Minerals of the Cabinet of Ministers of Ukraine]. (No. 747 of August 16, 2005). Retrieved from: https://www.kmu.gov.ua/npas/20058044. (In ukrainian).

Rudenko, S.A. (1962). Henezys y strukturnye osobennosty maryupolytov. [Genesis and structural features of mariupolites]. Notes of the Leningrad Mining Institute. 13, 2, 3-25. (In russian).

Semenchenko, Yu. V., Ahafonova, T. N., Solonynko, Y. S., Lvova, T.V., Nazarenko V.V. (1974). Tsvetnye kamny Ukrayny. [Coloured stones of Ukraine]. Kyiv, 67-68. (In russian).

Shpylovyi, K.L., Shpylovyi, L.V. (2012). Stanovlennia tsyrkoniievoi promyslovosti Donbasu. Pytannia istorii nauky i tekhniky. [The formation of the zirconium industry in Donbass. Issues of the History of Science and Technology]. 3 (23), 22-31. (In Ukrainian).

Shpylovyi, L. V., Biletskyi, V.S., Cherniienko, N.M., Strekozov, S.M. (2023). Mazurivske ridkisnometalichne rodovyshche: Monohrafiia. [Masurian rare metal deposit: Monograph]. Lviv, Novyj Svit-2000, 1-283. (In Ukrainian).

Shpylovyi, L.V., Biletskyi, V.S. (2019). Istoriia stanovlennia vitchyznianoi tsyrkoniievoi promyslovosti. [History of the formation of the domestic zirconium industry]. Geotechnologies. Kharkiv, 2, 47-56. (In Ukrainian).

Shpylovyi, L.V., Biletskyi, V.S (2024). Tsyrkoniieva promyslovist Ukrainy: stanovlennia i rozvytok. [Zirconium industry of Ukraine: formation and development]. Lviv, New World-2000 Publishing House.

Tsarovsky, I.D. (1960). O zonalnosti v mariupolitizirovannyh shelochnyh porodah. [On zonation in mariupolitzed alkaline rocks]. *Dokl. Academy of Sciences of the USSR*. V. 130, Iss. 6, 1341-1344. (In russian).

Tsarovsky, I.D. (1947). O harakteristike ostatochnoj kristallizacii Oktyabrskogo (Mariupolskogo) shelochnogo massiva. [On the characteristics of the final crystallization of the October (Mariupol) alkaline massif]. *Dokl. Academy of Sciences of the USSR*. 57, №. 5, 489-491. (In russian).

Tsarovsky, I.D. (1964). Kriterii razlichiya yavlenij metasomatoza i magmatizma v shelochnih porodah [Criteria for distinguishing the phenomena of metasomatosis and magmatism in alkaline rocks]. In: Proishozhdenie shelochnyih porod. Moskow, Nauka,70-78. (In russian).

Zahnitko, V., Mykhailov, V., Kryvdik, S., Sydorchuk, V. (2017). Henetychni osoblyvosti ta resursy ridkisnometalevykh rodovyshch Ukrainskoho shchyta. [Genetic features and resources of rare-metal deposits of the Ukrainian Shield]. Bulletin of the Taras Shevchenko National University of Kyiv. Geology 1(76), 58–65. (In Ukrainian).