https://doi.org/10.15407/geotech2020.31.005
УДК 553.04-553.69 (477)

Yatsenko V.G., Zaborovska L.P., Zemskov G.O., Lyzhachenko N.M., Nikolaevskiy V.P.

Yatsenko V.G., Ph.D. (Geol), Leading Researcher, State Institution "The Institute of Environmental Geochemistry of National Academy of Sciences of Ukraine", vgyatsenko@gmail.com, https://orcid.org/0000-0002-8113-5702
Zaborovska L.P., Ph.D. (Geol), Researcher, State Institution "The Institute of Environmental Geochemistry of National Academy of Sciences of Ukraine", zaborovskayalp63@gmail.com, https://orcid.org/0000-0001-7848-5528
Zemskov G.O., Researcher, State Institution "Institute of Environmental Geochemistry of the National Academy of Sciences of Ukraine", zemskov-gennadii2020@gmail.com, https://orcid.org/0000-0002-7445-5329
Lyzhachenko N.M., Ph.D. (Geol), Senior Researcher, State Institution "Institute of Environmental Geochemistry of the National Academy of Sciences of Ukraine", albeet@ukr.net, https://orcid.org/0000-0001-8598-0551
Nikolaevskiy V.P., Chief geologist, Private joint stock company "Zavalivskiy Graphite Plant", nvp49ktv@gmail.com , https://orcid.org/0000-003-3180-3036

RATIONAL USING OF RAW MATERIALS DURING EXPLOITATION OF THE ZAVALIEVSKY GRAPHITE DEPOSIT

Based on the analysis of the Zavalivskyi graphite deposit exploitation prospects, the article outlines the ways of rational development and integrated use of its raw materials, which include transition to the underground and combined extraction of the graphite ores, improvement of the enrichment schemes, expanding of the range of the Zavalivskyi graphite plant's production, use of the spent quarry for overburden and tailings dumping. An important component of the rational exploitation of the Zavalivskyi graphite deposit is the integrated use of its raw materials: (1) the deposit is the only one in Ukraine which mines pomegranate ores, which have good prospects nowadays; in terms of the technical characteristics, the pomegranate concentrate from Zavalivskyi graphite deposit is not inferior to that from other world producers; (2) the plant does not use all possible amount of the overburden rock formations for building-stone production; (3) the overburden sands, clays and loam have high technological characteristics and the economic feasibility study of their selective development should be envisaged; (4) graphite ore flotation tailings need further study to be used in the building and glass industries; (5) use of mineral pigments (ocher, seladonite) is possible after selective extraction, special separate storage and development of an enrichment and preparation technology; (6) jasper, chalcedony and opal specimens from Zavalivskyi graphite deposit have high decorative, textural and consumer characteristics and are suitable for production of various jewellery and decorative items; (7) among the host rocks of Zavalivskyi graphite deposit there are veins of unique, rare mineral – grautite; also mineralogically interesting is the presence of barite, horsex, pyrite, galena, coarse-grained graphite clusters, etc. Selling of these specimens as collectibles and organization of mineralogical excursions can also give some economic effect. The introduction of rational methods of development and integrated use of Zavalivskyi graphite deposit will make this object strategically important for the economy of Ukraine.

Key words: *Ukrainian shield, Zavalivskiy graphite deposit, graphite ore, rational development of the deposit, integrated use of mineral resources.*

Introduction.

Scientifically substantiated rational mineral resources usage is based on the ideas of V.I. Vernadsky and A.E. Fersman [13, 14]. At present, the problem of integrated full-field development and rational use of mineral resources has not lost its significance, but gained its importance in terms of the enormous extraction and consumption of mineral resources. Formation of an effective system of subsurface use based on the integrated development and usage of the entire complex of subsoil resources, application of low-waste resource-saving technologies, cleaner production approach and competitiveness of the mineral resource complex production is a complicated scientific and technological task.

The main way of the rational use of mineral resources as raw materials and energy sources is to improve the production methods to increase their extraction from earth bowels during deposit exploitation, reduce waste during production and mineral processing, and completely utilize all useful components.

A complex use of raw materials is obviously a part of rational exploitation of deposits [20]. The optimal utilization of mineral resources envisages, on the one hand, detailed study during exploration of the deposits, additional exploration and exploitation, and selection of rational schemes for the most complete extraction of the useful components during mining and mineral processing, on the other hand, it requires complex use of mineral raw mate-

rials. In addition to extraction of all industrially valuable components from raw materials, their complex use requires utilization of the aggregate-mineralogical base of ores, that is, host and overburden rocks, as well as residual products formed during the mineral processing of raw materials – mining wastes. The volumes of loose and rocky materials, extracted during the underground or quarry mining of raw materials, annually exceed millions of tons in Ukraine alone [17, 21, 29].

Today, graphite is an important industrial raw material for many countries of the world. The United States, China and the European Union classify this mineral as a strategically important one. China producing the major quantity of graphite in the world has set a 20% export tax (plus 17% VAT) for the export of minerals from the country. Besides, China has established an export licensing system to reduce the raw materials export and thereby more efficiently provide its own industry.

Ukraine occupying one of the leading places in the world in terms of the total graphite reserves has now found itself in a difficult position because of the deficiency of crystalline graphite and its products. Graphite mining at the only developed Zavalivskyi deposit has sharply decreased in recent years. Zavalivskyi Graphite Plant having a design capacity of 50-60 thousand tons of graphite per year at present produces no more than 10-12 thousand tons of graphite concentrate.

The guidelines for the graphite industry development in Ukraine are outlined in the "National Program for the Development of the Mineral Resources Base of Ukraine for the Period until 2030". According to this program, the priority tasks are: to find active graphite reserves in the territory of the Ukrainian graphite-bearing province [28], to undertake assessment of the already found perspective areas and to modernize production at the Zavalivskyi graphite plant.

The aim of the work is to analyze the prospects for the use of the entire resource base of the Zavalivskyi graphite deposit, to consider ways of its rational development and integrated use of the raw materials.

Geological setting. The Zavalivskyi graphite deposit is located in the southwest of the Kirovograd region, near the town of Zavallia (Gaivoronskyi district), on both banks of the river Southern Buh.

The geological structure of the region is characterized by the presence of two distinct structural floors: the lower one, composed of intensely dislocated crystalline rocks and their weathering products, and the upper one, represented by almost horizontally lying rocks of the sedimentary cover. The rocks of the basement belong to the Archean and Paleoproterozoic. Sedimentary formations are represented by Neogene and Quaternary sediments.

In tectonic terms, the area of the Zavalivskyi graphite deposit is located within the southeastern part of the Ukrainian shield and is confined to the western border of the Holovanivskyi suture zone. The largest folded structures of the crystalline basement of the area are the Bandurivskyi and Pervomaisk-Holovanivskyi anticlinorias, separated by the Synytsivskyi syncline. The anticlinorias in the gravitational field correspond to significant anomalies of gravity in size and intensity.

Zavalivskyi graphite deposit is located at the junction of the Bandurivskyi and Synytsivskyi structures and is confined to the wings of a large synclinal folded structure of the second order that is a part of the Khashchevo-Zavalivskyi synclinorium. Within the deposit, the rocks form a synclinal fold of a sub-latitudinal strike with a length of 5 km and a width of up to 2 km, located in a field of migmatites and granites. The structure core is composed of carbonate rocks (calciphyres). The middle part is composed of biotite-graphite and biotite-garnet gneisses and quartzites and is a productive companion for graphite ores. The outer part of the southern wing of the structure is composed of biotite, amphibolite and pyroxene gneisses, which are converted into charnockites in the northern wing.

The graphite deposit is located in both wings of the syncline, forming two zones (Northern and Southern) of ore-bearing graphite-containing gneisses. The deposit's main part is located within the Northern wing of the syncline. The total length of the Northern ore zone is 3.7 km, and the thickness is from 150 to 390 m.

There are six ore areas within the deposit field: Northern ore zone – Pivdenno-Skhidna, Promizhna and Khutir Andriyivka areas, Southern ore zone – Pravoberezhna, Pivdenna polosa areas (Fig. 1, Table 1).

The ore zone is a rhythmic interbedding of quartzites, biotite-graphite and biotite-garnet gneisses, garnet-quartz skarnoids, as well as (to a lesser extent) sillimanite gneisses and calciphyres. All lithological varieties form laminate and lenticular bodies with thickening and pinching. The total strike of the ore zone is 290-300 °, its dip is almost vertical. Graphite is present in all rocks of the ore zone up to 1-2%, in biotite-graphite gneisses (graphite ores) its content varies from 1-3 to 24%.

The ancient weathering crust of areal and linear types is widespread in the deposit field. The weathering crust is developed everywhere, its thickness varies from 2 to 30 m. The linear weathering crust is confined to gneiss bodies and zones of discontinuous tectonic disturbances. The depth of development of the linear weathering crust is 100-150 m, but it exceeds 200 m in the Khutir Andriyivka area.

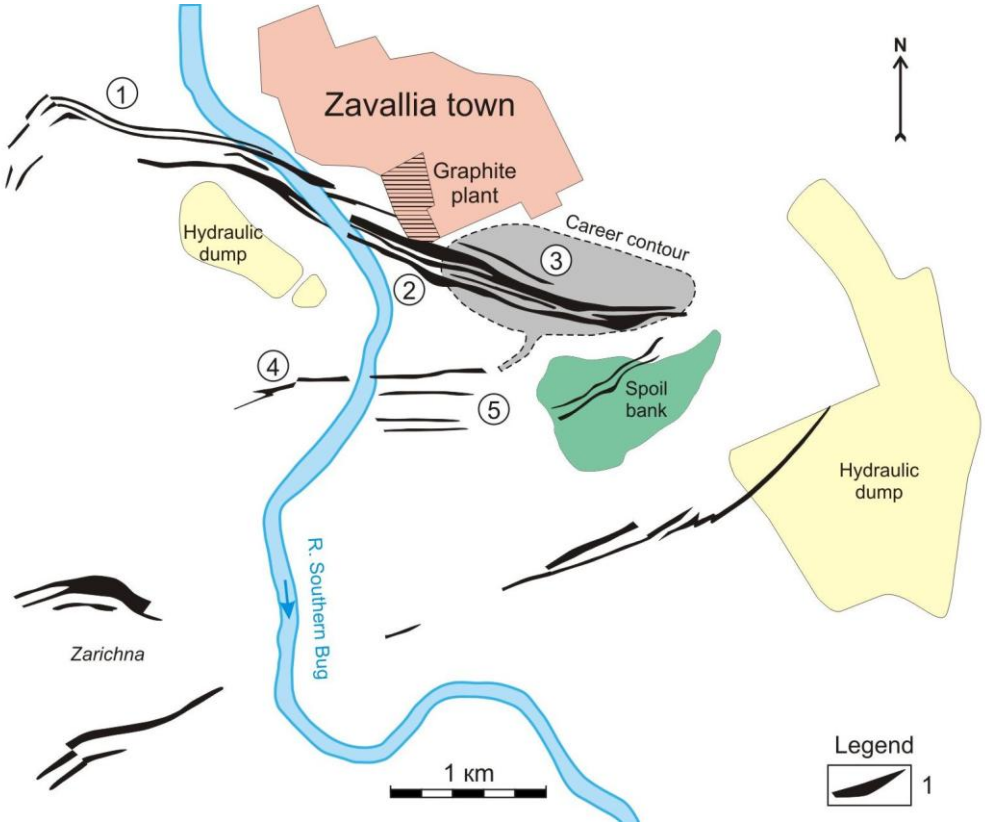

Fig. 1. Localization scheme of graphite-bearing areas of the Zavalivskyi graphite deposit:
1 – graphite ore bodies; numbers in circles – graphite-bearing areas: 1 – Khutir Andriyivka, 2 – Promizhna, 3 – Pivdenno-Skhidna, 4 – Pravoberezhna, 5 – Pivdenna polosa, 6 – Zarichna

Рис. 1. Схема локалізації графітоносних ділянок Заваллівського родовища:
1 – графітові рудні тіла; цифри в кружках – графітоносні ділянки: 1 – Хутір Андріївка, 2 – Проміжна, 3 – Південно-Східна, 4 – Правобережна, 5 – Південна полоса, 6 – Зарічна

The main raw material for the production of crystalline graphite is biotite-graphite gneisses, less used are biotite-garnet-graphite and sillimanite-garnet-graphite gneisses.

Depending on the degree of manifestation of hypergenic processes, three technological types of graphite ores are distinguished, which differ in material composition and physical and mechanical parameters:

– loose ores corresponding to the kaolinite and kaolinite-hydromica zones of the weathering crust;

– semi-loose ores corresponding to the disintegration zone;

– dense ores corresponding to gneisses that have not undergone weathering.

The boundaries between the types of ores are fuzzy and are not sustained hypsometrically.

Graphite in dense ores is typically metamorphic mineral; in loose and semi-loose ones, it belongs to residual (that remained after weathering) formations. Graphite is clearly crystalline, represented by a scaly variety with the flakes size of up to 10 mm. In dense ores, graphite is found in intergrowths with rock-forming minerals. Contacts between different types of ores are gradual.

The graphite content in the Northern ore zone varies from 4-6.5% (Pivdenno-Skhidna, Promizhna areas) to 10-12% (Khutir Andriyivka area), in the Southern ore zone – 6.6-7.5%. The average graphite content in the ore at the whole deposit is 6.86%. The distribution of graphite in the ore is mainly uniform; the scales of graphite are oriented according to gneissic banding. The ore bodies have a complex morphology and cannot always be traced along the profiles relative to each other.

At the Khutir Andriyivka area, 3 ore bodies of sublatitudinal strike were found; ore bodies thickness is from 18 to 80 m, length ~500 m. The average graphite content in the ore is 9.8%. The ore bodies are traced to a depth of 100-130 m. The intra-ore layers have a thickness of 15 to 30 m and are represented by quartzites, garnet gneisses and skarns.

Promizhna area is located in the northern strip of graphite rocks. The rocks strike is northwest, the ore bodies dip is subvertical (from 75 ° to 90 °); in some cases, ore bodies bends along the dip and along the strike are observed. The ore-bearing stratum is an alternation of

biotite-graphite and biotite-garnet gneisses with skarnoids, limestones and quartzites. The ore-bearing stratum thickness is 300–350 m. Industrial graphite concentrations are confined to the kaolinized and chloritized gneisses. Graphite is present as needle crystal aggregates or flake clusters from 0.1 to 1 mm in size. Ore bodies are called graphite-bearing gneiss layers and packs. The ore bodies thickness varies from 1-2 to 25.2 m.; their length varies from several tens of meters to 1.4 km. All bodies are subparallel, stratiform or, less commonly, lenticular in shape. Their thickness is unstable and they are separated by interlayers of various thicknesses and lenses of barren rocks. The ore bodies are often wedged out, connected to each other or bifurcated, as a result of which the number of ore bodies varies from 4 to 8. The ore bodies total thickness along exploration lines varies from 50 to 300 m, and the total thickness of intra-ore layers varies from 4 to 50 m. Traced inside the ore-bearing stratum, the skarnoid bodies have the same morphology as the ore bodies. The skarnoid bodies thickness ranges from 4 to 28 m in the west of the site and from 1 to 24 m in the east. The number of skarnoid bodies varies from 4 to 6. The average carbon content in the ore is 6.12% [26, 28].

Pivdenno-Skhidna area is characterized by the presence of 14 ore bodies of various thicknesses and lengths. All of them were opened by the current quarry and a significant part of them was worked down the dip to 30-130 m. All ore bodies lie subparallel, have a dip at high angle, a stratiform shape, variable thickness and morphology, and they are separated by interlayers of gneisses, skarns, and quartzites. The total thickness of ore bodies along exploration lines is from 25 to 190 m, the total thickness of barren interlayers is from 13 to 70 m. The average carbon content in the ore is 6.26%.

Pivdenna polosa area is located in the southern wing of the Zavalivskyi synclinal structure. The geological structure and ore content in the area are significantly different from Promizhna and Pivdenno-Skhidna areas. The total thickness of the ore-bearing stratum ranges from 60 to 160 m. There are up to 8 ore bodies within the area, however, the main reserves of graphite ore are concentrated within the ore body, which is closest to carbonate rocks. The ore-bearing stratum is oriented mainly along the azimuth of 60 °. The main features of the ore area are: the small thickness of the ore bodies, their simple structure, the prevalence of amphibole-containing rocks among the host ones. The total length of the ore-bearing stratum is 1450 m. The thickness of the ore bodies varies from 3 to 20 m. The average graphite content in the area is 6.75%. The ore content coefficient reaches 0.97.

Pravoberezhna area is characterized by a presence of the only ore body, the strike of which varies along the azimuth of 55 ° - 82 °. The ore body has a stratiform shape and sub-concordant bedding with the host rocks. The total length of the ore body is more than 1000 m.; its thickness along the strike varies from 16 to 34 m. The dip in the northern rhambes is 80 ° - 85 °. The graphite average content in the ore is 6.59%.

Zarichna area is one of the ore-bearing strata of the Zavalivskyi graphite deposit. The ore-bearing stratum adjoins to the lower horizon of graphite gneisses of the Lower Proterozoic Khashchevo-Zavalivskyi suite. The ore body is an ore-bearing stratum with the thickness of 80-120 m, and the length of 550 m. It lies subconcordantly with the host gneisses and pegmatites, and has a high-angle dip (75 °- 80 °) to the North. The ores are represented mainly by biotite-graphite gneisses, the less common are graphite-garnet ones. Areal and linear weathering crusts are above ore-bearing stratum. The thickness of the areal weathering crust ranges from 10 to 50 m, the thickness of the linear one along the tectonic faults reaches 200-250 m and more. In the northern part of the Zarichna area, there are several transverse tectonic disturbances that cut off the ore-bearing stratum in the East and West. The graphite average content in the ore is 5.3%

At the Zavalivskyi deposit, ore bodies displacement despite tectonic influences is practically not manifested, however, the complex morphology of the ore bodies and the variability of their thickness makes it possible to equate the ore deposit to a tectonically disturbed one. Based on the "National classification of reserves and resources of minerals of Ukraine", according to the degree of complexity of the geological structure, the field is assigned to deposits of complex geological structure.

The current deposit exploitation. Currently, the development of the Zavalivskyi graphite deposit is carried out by quarrying. Most of the industrial reserves of graphite are located in pillars under the Southern Buh River floodplain, the Processing Plant and Zavallia town. For further quarrying, it is necessary to construct a dam and a river channel, to transfer the working Processing Plant and to alienate 400 hectares of land. According to preliminary estimates, the total cost of these works significantly exceeds the cost of the transition to underground graphite mining. In this regard, it is planned to develop the deposit in a combined way, that is, completion of the quarrying and the transition to underground mining.

The presence of the quarry in the north in the Pivdenno-Skhidna area adjacent to the Promizhna area makes it expedient to conduct further development of the deposit in a combined way: the completion of the field in the Pivdenno-Skhidna area to the level of 19 m by quarrying and the transition to the underground mining method in the Promizhna area.

For the transition to underground mining, it is necessary to select opening schemes and methods for preparing the mine field, transporting ore and overburden rocks,

mine ventilation and environmental protection, justifying the possibility of filling the worked-out space chambers with enrichment tailings [1]. Given the conditions of ore bodies bedding and the relief, it is advisable to use one of the two main options for opening the Zavalivskyi deposit in the Promizhna area:

1. An inclined barrel and four adits traversed from the southwestern side of the quarry.
2. Three vertical trunks and four adits.

Further mining operations at the Zavalivskyi graphite deposit in a combined way, that is, refinement of the quarry and transition to underground mining, will ensure uninterrupted supply of the main consumers with graphite, preservation of employment of the population and the maximum possible preservation of the ecological balance of the region.

Tabl. 1. Mineral reserves on the Zavalivskyi graphite deposit
Табл. 1. Балансові запаси корисних копалин по Заваллівському родовищу графіту

Area	Mineral reserves				
	Graphite ore graphite, thousand t	Overburden rock, thousand m^3	Garnet ore garnet, thousand t	Clay, loam million m^3	Black earth, thousand m^3
Khutor Andriyivka	6305 597				
Promizhna	41300,9 2546,0	70705	16300 2808		
Pivdenno-Skhidna	22594,3 1481,8	52722,2	4014,5 615,5		
Pravoberezhna	5177 322,9	6032			
Pivdenna polosa	5028,1 310				
Zarichna	18949,6 1052,2	33962			
All over the field	99354,9 6309,8	163421,2	20314.5 3423,8	2,0	
In addition, in a special dump			1739,2 271,8		19,0

Rational deposit exploitation. The rational exploitation of the Zavalivskyi graphite deposit involves:

1. Transition to underground and combined production of graphite ores, which will increase the volume of active reserves of Zavalivskyi deposit graphite ores available for mining, without environmental degradation of production;

2. Improvement of the graphite mineral processing schemes at the Zavalivskyi mineral processing plant that will allow significant reduction of the raw materials loss, and use of flotation mineral processing tailings that contain significant additional graphite volumes;

3. Increasing of the assortment of the plant's graphite products using the technical innovations, which will improve its competitiveness;

4. Creation, in addition to the Zavalivskyi deposit exploitation, of a network of subsidiary small and medium-sized enterprises, where graphite mineral will be processed close to the place of graphite ore extraction. Such enterprises produce 85% of graphite in the world.

5. Use of the former quarry of the Pivdenno-Skhidna area for the storage (disposal) of overburden dumps and mineral processing tailings.

6. Integrated use of raw materials.

One of the most important components of the rational development of the Zavalivskyi graphite deposit is the integrated usage of its raw materials.

Integrated using of raw materials. At present, in the Zavalivskyi graphite deposit, in addition to graphite, quarry stone is mined. There are also reserves of garnet raw materials and a number of other minerals. Thus, the deposit is considered as a complex facility, the raw material potential of which is far from exhausted [15].

Building stone (crystalline rocks). At present, in the Zavalivskyi graphite deposit only rocky overburden rocks as associated minerals are quarried. They are represented by carbonate-silicate (calciphyres, skarnoids, dolomitic rocks) and silicate (charnockites, migmatites, gneisses, quartzites) rocks, which occur in the form of large enough

massifs (charnockites, calciphyres) or stratiform bodies of predominantly sub-latitudinal strike and a high-angle dip (sub-vertical), interbedded with ore bodies. Of many varieties of crystalline rocks, homogeneous strata of calciphyres (Buh series) and migmatite-charnockitoids (Pobuzh ultrametamorphic complex) are of practical interest as building stone. Among these rocks, non-weathered and slightly weathered differences are distinguished by the degree of surface weathering. Calciphyres are the most common group of carbonate rocks. Within the Pivdenno-Skhidna area, they border the strata of graphite rocks on the southern flank and form the central part of the Zavalivskyi structure. Together with calcifiers, with gradual transitions, small lenses of calcite-dolomite marble lie. The stratum thickness in the central part is 1500-1800 m, in the eastern part it decreases sharply to 50 m.

Charnokitoids (charnockite-migmatites and enderbit-migmatites) occur in the northern and north-eastern part of the Pivdenno-Skhidna area.

Skarnoids, calciphyres, quartzites, biotite-garnet gneisses lying in the ore zone between graphite gneisses can also be used as raw materials for rubble and crushed stone.

Laboratory examination (mineralogical, physical-mechanical, petrographic, etc.) of overburden rock samples determined the possibility of using non-weathered and slightly weathered rocks for building industry – for rubble and crushed stone production.

In the Zavalivskyi graphite deposit, the building stone total reserves, which were calculated for four areas (Promizhna, Pravoberezhna, Zarichna and Pivdenno-Skhidna), reach over 160 million m^3 (Table 1). The existing production of crushed stone from the Zavalivskyi deposit rocks has a capacity of 60 thousand m^3 / year.

In addition to the building stone rocks from the Zavalivskyi deposit, in the region there are enterprises for production of crushed and buta stone – "Gayvoronsky special quarry" and LLP "Charnokity", which have significant open reserves of high-quality rock and the necessary development infrastructure.

Garnet. In the productive stratum of the deposit, along with biotite-graphite gneisses, biotite-garnet gneisses are widespread. They have been studied and evaluated as a source of abrasive garnet. Garnet-biotite gneisses are developed in the ore zone in the form of lens strips (up to 1 km long, from 1-2 to 100 m thick), often of complex configuration; they contact with graphite gneisses, charnockites and skarnoids. The garnet content in the ore ranges from 6 to 300 kg / t (average 167 kg / t). Reserves of biotite-garnet gneisses (for abrasive) in the Zavalivskyi graphite deposit are estimated at 26.8 million tons. Besides at present 1740 thousand tons of garnet ore (Table 1) are stored in a special storage on the territory of the Zavalivskyi deposit, with the beneficiation of which 267 thousand tons of garnet concentrate can be produced.

Garnet is an essential mineral for industrial production in the advanced countries of the world. According to US Geological Survey (USGS), total world industrial garnet production was estimated to be about 1.2 Mt in 2019. The leading global producers were Australia, 400,000 t; China, 310,000 t; South Africa, 190,000 t; India, 150,000 t; the United States, 93,000 t; and other countries, 60,000 t. Russia and Turkey have mined garnet in recent years, and small garnet-mining operations are also located in Canada, Chile, Czechia, Pakistan, South Africa, Spain, Thailand.

Modern industries that consume garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, glass polishing, the petroleum industry, shipbuilding and maintenance, structural steel fabrication and maintenance, textile stonewashing, water filtration plants, and wood-furniture-finishing operations. For instance, major end users of garnet in the United States in 2017 were estimated to be abrasive blasting (50%), water-jet cutting (35%), and water filtration media (10%), with the remainder used as abrasive powders, as an additive in nonslip coatings, in sandpaper, etc.

Most industrial garnet is used as an abrasive because of its hardness, which ranges from 6 to 7.5 on the Mohs scale. High-quality, high-value garnet grain has been used principally for such applications as optical lens grinding and plate-glass grinding for more than a century. In recent years, industrial garnet powders have been used for high-quality, scratch-free lapping of semiconductor materials and other metals. Garnet is a good alternative to silica sand as a natural abrasive blasting media because it does not have the health risks associated with the inhalation of airborne crystalline silica dust, and it is a safer abrasive for the environment.

Petroleum industry is one of the leading garnet-consuming industries, using garnet for cleaning drill pipes and well casings. Oil and gas producers also use garnet as reservoir-fracturing proppant.

The aircraft manufacturing and shipbuilding industries use garnet for blast cleaning and for finishing metal surfaces. Similar uses include the cleaning and conditioning of aluminum and other soft metals, as well as metal cleaning by structural steel fabrication shops. Garnet entrained in high-pressure streams of water also is used to cut many different materials. Garnet powders are used for antiskid surfaces, antislip paints, and glass and ceramic polishes.

Water-jet cutting is the process combining water under ultrahigh pressure with entrained abrasive grit to cut a wide variety of materials. Materials cut using this process range from soft leather and fabric to hard steel, titanium, and other metals. Water-jet cutting makes it possible to

carve extremely complex shapes with computer-assisted cutter control. Almandine-pyrope garnet is excellent for this application because it strikes the necessary balance between cutting productivity and equipment wear. The use of abrasives for water-jet cutting began to develop slowly in the late 1980s and early 1990s, and it has grown at a faster rate in the past 20 years. Future growth is expected to remain steady as use of this technology expands in existing areas and enters new applications. Garnet materials most preferred for water-jet-cutting applications remained in tight supply.

Low-quality industrial garnet, which has lower hardness and is more highly fractured, is used as a high-density medium in water filtration systems because of its relative inertness and resistance to chemical degradation. Garnet is well suited for water filtration and treatment because it is relatively heavy and chemically stable.

Ukraine has one of the most powerful raw material bases of garnets in former USSR countries and Europe [4, 12]. Garnets reserves have been explored at a number of sites in the Kirovograd (Zavalivskyi graphite deposit with associated garnets reserves) and Vinnytsia (Slobidske granite deposit with associated garnets reserves) regions. Significant volumes of garnet raw materials can be mined as a by-product during the exploitation of Kryvyi Rih iron ore deposits [2, 11, 25].

At present garnet raw materials in Ukraine are not mined. The country's own needs for garnet concentrate are satisfied mainly with exported raw materials from the Czech Republic, Australia and India, although research results indicate that Ukrainian garnets are a promising abrasive raw material; in their technical properties they are not inferior to garnets from world producers and are competitive in the world market [7, 9, 18].

Garnet raw materials of Zavalivskyi graphite deposit have great prospects. In mineralogical terms, the concentrate of the Zavalivskyi deposit is: almandine (over 90%), individual pyrope grains, grossular, quartz in splices (2-3%), hornblende (1-2%). The garnet abrasive hardness is from 6.5 to 7.5 on the Mohs scale. According to industry requirements, fracturing is one of the important physical and mechanical properties of garnet. A study of the garnet fractures from the concentrate of the Zavalivskyi graphite deposit shows that it is characterized by low values of fracturing (0.550-0.590 mm-1), which indicates the high quality of the garnet concentrate by this indicator [7].

In addition, imported garnet concentrates may be of low quality, in particular, in terms of radioactivity, due to the presence in the concentrates of poorly recoverable radioactive impurities, primarily, thorium-bearing monazite, zircon (malacone) and apatite. Garnet-bearing rocks in the Zavalivskyi deposit are garnet-biotite gneisses characterized by a low content of radioactive minerals, which leads to the production of a pure (in terms of radioactivity) garnet concentrate without laborious and expensive post-treatment operations [7].

Thus, based on the level of garnet ore reserves and the possibility of establishing industrial production of high-quality garnet concentrate, the Zavalivskyi graphite deposit is capable of providing Ukraine with its own high-quality garnet raw materials for various purposes, that serves Ukraine's national interests.

*Clays and loams***.** The bulk of overburden rocks in the Zavalivskyi graphite deposit are clay rocks, which are represented by Neogene clays and Quaternary loams. Macroscopically, bottom up the geological section, the following varieties can be distinguished [1]:

– greenish-grey and grey, viscous, dense, plastic clay (Baltic age, Neogene). The layer thickness – 0.5-6.5 m. The clay is distributed in the Pivdenno-Skhidna area;

– red-brown and brown clay, overlapping the Baltic one almost everywhere. The clay is sandy, viscous, containing carbonate cohesions. The layer thickness – 1-20 m;

– red-brown and brown loams (Lower-, Mid-Quaternary Age), dense, with limestone screed. The layer thickness – 13-188 m;

– pale yellow, microporous, carbonaceous and with small calcareous cohesions, loess-like loams (Upper Quaternary). The layer thickness – 3-12 m.

All of these varieties belong to low-melting, less – to refractory raw materials with an average and low content of carbonates. According to the results of loam tests, they can be used as raw materials for brick production. The bricks of light terracotta colour (grades – 100, 125, 150) were made by the method of plastic molding. Loams can be used in the production of ceramic materials as an additive or as the main raw material (with additives of other components) for the production of expanded clay. Almost all varieties of clay raw materials can be used for production, including the reconstruction of hydraulic structures and road construction. The total loam reserves are over 2 million m^3.

Thus, the results of a study of the technological properties of overburden clay rocks in the Zavalivskyi graphite deposit corroborate a high quality of products from this raw material and low cost, given their associated mining during the graphite ore mining.

*Sands***.** In the Zavalivskyi graphite deposit, sands in the form of lenses (thickness – 1-10 m) are widespread among the rocks of the Baltic suite of the Neogene age and Quaternary sediments. In addition, a significant amount of sand mass (more than 50 million tons) is concentrated in technogenic waste from flotation processing of graphite ore. The sands are fine-grained, with a large admixture of clay material. Studies, conducted in 1982 year, did not reveal ways of their economically attractive usage. Today, it will be appropriate to test the

sands in accordance with the new regulatory requirements. The sands can be used as the basis or component of mixtures in the road construction, as ballast material for landscaping and planning works, as a fine concrete filler (heavy, light, fine-grained, special-purpose and other concretes), for mortar, dry mixes, filler and component for the silicate concrete production of dense structure, autoclaved and autoclave-free cellular concrete, silicate bricks, stones, pressed products, etc.

Mineral pigments. The prospects for the economic use of certain types of overburden rocks of the Zavalivskyi graphite deposit as natural pigments are currently insufficiently researched. At the Khutir Andriyivka area, during geological exploration and subsequent development, the weathering crust of ferruginous quartzites of ocher-red colour was revealed. Within the Northern ore zone, in the quarry, a number of areas with clay-micaceous, siliceous-seladonite rocks of grey-green and green colour have been identified. Preliminary laboratory studies have shown satisfactory qualitative characteristics of these natural pigments. The possibility of their use for the manufacture of dark-water emulsion paints was established. This implies the selective extraction of these rocks, their special separate storage and development of technology for their mineral processing.

Coloured stones. In the Zavalivskyi graphite deposit, epigenetic low-temperature processes are widely manifested – chloritization, kaolinization (argillization), opalization, silicification, pyritization, limonitization. Currently, there is evidence that these processes are not only due to the development of an extensive linear and areal weathering crust, but also are a consequence of superimposed hydrothermal processes that were manifested at the final stages of the development of the Zavalivskyi structure [5, 26, 28]. Intensive "weathering" is due to the permeability of the zone for solutions and the nonequilibrium nature of the rocks, accumulated in it [30]. As a result, a peculiar complex of rocks and minerals was formed in local areas of intensive hydrothermal processing and weathering of gneisses, skarnoids and calciphers, which are of interest both as raw materials for jewellery making and as valuable collectible mineralogical material. This decorative raw material is represented by jasper and agate.

The manifestations of jasper in the Zavalivskyi graphite deposit are confined to discontinuous disturbances, according to which extensive weathering crusts of a linear and areal type were formed [23, 24].

Most of the jasper rocks formed in the linear weathering crust are confined to the kaolinite and kaolinite-chlorite-hydromica type of this weathering crust, which develops by biotite-graphite and biotite-garnet gneisses. Jasper is found in the form of veins, veinlets and lenses with a thickness of 5-40, sometimes up to 80 cm or more. The colour of jasper is mainly greenish-brown and white-brown-green. The mineral composition of jasper: chalcedony (80-95%), quartzine (up to 10%), iron hydroxide (2-5%), celadonite (1-2%). In the linear weathering crust, highly decorative jasper was predominantly formed with spherulitic and spherulitic-streaky textures. Colour is mainly brown-yellow-green, dark green, white-yellow-brown and other. Jasper is well processed and requires a mirror polish. Based on the size and colour of the jasper samples, it can be used both for the jewellery manufacture (cabochons, inserts, beads, etc.), decorative products (balls, eggs, pyramids, table decorations), and as a collection material.

The second type of jasper is associated with the area weathering crust, which was formed by calciphyres. Such jasper is found in the form of streaks of siliceous-ferrous composition with a thickness of 1 to 10 cm. Fantastic and streaked-interspersed texture patterns prevail in the jasper of the areal weathering crust. The colour of jasper is mostly brown, tan. Like the jasper from the linear weathering crust, the jasper from the areal weathering crust lends itself well to processing and takes a mirror polish. This jasper can be used for the manufacture of cabochons, various inserts, as collection samples, less often for the manufacture of small items [3, 19, 27].

Thus, jasper of the Zavalivskyi graphite deposit has a high texture and decorative characteristics (nice colour and texture pattern, significant sample size) and is well processed. Due to this, jasper of the Zavalivskyi graphite deposit has excellent consumer characteristics and is suitable for the manufacture of various jewellery and decorative items.

In addition to jasper, in the zones of superimposed low-temperature processing and weathering crust in the quarry walls and dumps, highly decorative agate that can be used as ornamental stone and collection material is found [10].

Collection mineralogical material. Among the host rocks of the Zavalivskyi graphite deposit, there is a unique mineral, rare in the whole world – grautite [8, 22]. The presence of barite, horseixite, pyrite, galena, clusters of coarse graphite, etc. is also of mineralogical interest. The collection and sale of samples of these minerals as collection material and the organization of mineralogical excursions can also have some economic effect [6, 16].

Conclusions.

Integrated use of raw materials is one of the most important components of the rational exploitation of deposits. This is also relevant for the Zavalivskyi graphite deposit, since the potential for the integrated use of its raw materials is far from exhausted (Table2):

(1) the garnet raw material of the deposit has great prospects at present, since the Zavalivskyi Processing

Plant is the only one in Ukraine developing garnet ores; in terms of technical characteristics, the garnet concentrate of the Zavalivskyi graphite deposit is not inferior to the garnets of world manufacturers;

(2) not the whole volume of the rocky overburden is used for the building stone production;

(3) sands, clays and loams of the overburden rocks are characterized by high technological parameters and need further study of the economic feasibility of their selective development;

(4) graphite ore flotation tailings can also be considered (after required study) for using in the building materials and for glass production;

(5) the use of mineral pigments (ocher, celadonite) is possible provided their selective extraction, special separate storage and mineral processing development;

(6) jasper, chalcedony and opal formations of the Zavalivskyi graphite deposit have high decorative-textural and consumer characteristics and are suitable for the manufacture of various jewellery and jewellery-decorative items;

(7) mineralogy of interest is a unique mineral – grautite, as well as, barite, mountainseixite, pyrite, galena, clusters of coarse-grained graphite, etc. Collection and sale of samples of these minerals, as well as the organization of mineralogical excursions can also have a certain economic effect. Introduction of rational development methods and integrated use of raw materials from the Zavalivskyi graphite deposit allows us to consider this object as strategically important for the Ukrainian economy

Tabl. 2. Prospects for rational usage of raw materials during Zavalivskyi graphite deposit development
Табл. 2. Перспективи раціонального використанна сировини при розробці Заваллівського родовища графіту

Raw materials	Localization of raw materials types						Promising Applications	Economic importance	Recommendations for rational usage of raw materials
	Crystalline wall rocks	Secondary alteration zone	Weathering crust	Overburden rocks	Waste of ore concentration	Spoil			
Graphite	●	●	●		●		Refractories, electrodes for metallurgy, rechargeable electric batteries, fuel cells, products for nuclear plants	Countrywide	Product range expansion. Optimization of enrichment schemes
Garnet sand	●		●			●	A wide range of abrasives, drinking water filtration	Countrywide	Innovations in enrichment technology
Rubble stone	●					●	Crushed stone, rock debris	Local	Increase in production
Sands				●	●		Ballast material in construction, silicate brick, concrete	Local	Testing according to new regulatory requirements
Clays, loams				●			Ceramic materials: brick, expanded clay	Local	High quality raw materials of low cost
Quartz-feldspar raw materials					●		Glass industry	Local	Additional testing of dump materials
Ocher, Seladonite		●	●				Mineral pigments for construction	Local	Development of enrichment technology
Jasper, Opal, Agate, Grautite		●	●			●	Jewelry and decorative products; collectible mineralogical materials	Aesthetic	Trial batch of products
Black earth						●	Reclamation of dumps and spoil	Local	Reclamation plan development

References

1. Бузило В.И., Савельева Т.С., Савельев В.А. и др. Разработка научных основ по добыче графитовых руд комбинированным способом на базе Завальевского месторождения графита. Materialy Konferencyjne Szkoly Eksploatacji Podziemnej. Instytut Gospodarki Surowcami Mineralnymi i Energia, PAN, Krakow, 2011. С.392–400.

2. Бызов В.Ф., Губин Г.В., Гурин В.А. Использование гранатовых сланцев Анновского и Первомайского месторождений СевГОКа . Разработка рудных месторождений: науч.-техн. сб. Кривой Рог, 1996. Вып. 59. С. 22-26.

3. Виртуальная коллекция камней и минералов. Клуб любителей камня [Электронный ресурс]. URL: http://www.kievstone.zzz.com.ua/trips2.php (дата обращения: 16.12.2019).

4. Гурський Д.С. [и др.]. Металічні і неметалічні корисні копалини України / Д.С. Гурський, К.Ю. Єсипчук, В.І. Калінін, Є.О. та ін. , Київ-Львів: Центр Європи, 2006. 551 с.

5. Дубына И.В. Графитовые месторождения Украинской ССР / И.В. Дубына, Харьков: ГОНТИ, 1939. 208 с.

6. Елина А.Б., Лях О.А. Минералогический туризм как перспективное направление современного туризма Чита: Забайкальский гос. университет, 2018. 103–108 с.

7. Калашник А.А., Коврижкин Н.А., Ковалев С.Г. О защите интересов Украины на отечественном рынке гранатового концентрата. Мінеральні ресурси України. 2012. № 3. С. 19–22.

8. Квасниця В.М., Науменко Є.В. Кристаломорфологія граутиту (α-MnOOH) із Заваллівського родовища графіту (Український щит). Мінерал. журн. 2017. № 1 (39). С. 11–18.

9. Ковальчук Л.Н. Трещиноватость частиц граната из концентратов некоторых месторождений мира. Геолого-мінералогічний вісник. 2001. № 1. С. 106–109.

10. Кравченко И. Агаты Завальевского месторождения графит. Севастопольский музей камня. URL: http://www.sevstone.ru/articles/agaty-zavaljevskogo-mestorozhdenija-grafita-kogda-neverojatnoe-stanovitsja-vozmozhnym/ (дата обращения: 26.11.2019).

11. Кушнірук Н.В., Жавнерик В.С. Отримання гранатового концентрату з розкривних руд Ганнівського родовища. Гірничо-металургійний комплекс: досягнення, проблеми та перспективи розвитку:.Матеріали міжнар. наук.-техн. конференції (Кривий Ріг, 12-16 .052009). С.271-272.

12. Лавров Д.А., Каневский А.Я., Гордеев Ф.М. Абразивные гранаты Украины М.: Наука, 1975. 90–94 с.

13. Ларичкин Ф.Д. Терминологические проблемы комплексного использования минерального сырья. Цветная металлургия. 2004. № 12. С. 29-36.

14. Ларичкин Ф.Д. Эволюция и формирование современной парадигмы (модели) комплексного использования минерального сырья. Вестник Кольского научного центра РАН. 2012. (4). С. 8–14.

15. Лижаченко Н.М., Ніколаєвський В.П. Перспективи використання ресурсної бази Заваллівського родовища графіту. Вісник Київського національного університету імені Тараса Шевченка. 2013. № 2(61). С. 41–44.

16. Матковський О.І. Визначальні чинники залучення нових мінералів у практичне використання. Надрокористування в Україні. Перспективи інвестування: Шоста міжнародна науково-практична конференція (Трускавець, 7–11 жовтня 2019 р). С. 9–14.

17. Мирзаев Г.Г. [и др.]. Экология горного производства / Г.Г. Мирзаев, Б.А. Иванов, В.М. Щербаков, Н.М. Проскуряков, М.: Недра, 1991. 320 с.

18. Мостыка Е.Н. Гранаты Украины как перспективное абразивное сырье. Науковий вісник НГУ. 2012. (1). С. 5-9.

19. Моя коллекция: породы и минобразования кремнезема. Минералы от Леонида [Электронный ресурс]. URL: https://www.leonmin.ru/moya-kollekciya-porody-i-minobrazovaniya-kremnezema/ (дата обращения: 16.12.2019).

20. Педан М.П., Мищенко В.С. Комплексное использование минеральных ресурсов / М.П. Педан, В.С. Мищенко, Киев: Наук. думка, 1981. 272 с.

21. Сивий М.Я. До проблеми раціонального використання мінерально-сировинних ресурсів регіону. Вісник Львівського університету. Серія географічна. 2009. № 37. С. 65–75.

22. Скакун Л., Манчур Б., Мартишин А. Граутит із Заваллівського графітового родовища (перша знахідка в Україні). Мінерал. зб. 2003. № 1–2 (53). С. 49–58.

23. Сурова В.М. Текстурно-колористичні особливості та гемологічні характеристики яшм Заваллівського родовища графіту. Scientific World [Электронный ресурс]. URL: https://www.sworld.com.ua/index.php/ru/geology-311/general-and-regional-geology-311/7881-teksturnokoloristichn-osoblivost-ta-gemologchn (дата обращения: 25.11.2019).

24. Сурова В.М., Ляшок В.І. Дослідження текстурно-колористичних і споживчих характеристик яшм та яшмоїдів з родовищ України. Коштовне та декоративне каміння. 2012. (3), с.8-11.

25. Тарасова Т.В. [и др.]. Промислові відходи в Україні. Проблеми та шляхи їх вирішення. ТВ. Тарасова, В.Г. Губіна, Л.П. Квашук, Б.О. Горлицький, М.В. Єременко, Київ: Логос, 2011. 199 с.

26. Шакіна К., Скакун Л. Мінеральні асоціації графіту на Заваллівському родовищі. Мінералогічний збірник. 2010. № 1 (60). С. 70–85.

27. Шар из яшмы, 56 мм. Камневеды [Электронный ресурс]. URL: https://kamnevedy.ru/category/shary_200/kupit-suveniry-shar-yashmy_21636/ (дата обращения: 16.12.2019).

28. Яценко В.Г. Геология, минералогия и генезис графита Украинского щита / В.Г. Яценко, Киев: Логос, 2008. 127 с.

29. Whoriskey P. In your phone, in their air. Washington Post URL: https://www.washingtonpost.com/graphics/business/batteries/graphite-mining-pollution-in-china/

30. Yatsenko V.G. Role of hydrothermal-metasomatic processes and weathering in formation of graphite deposits within the Ukrainian Shield. Florence – Italy – August 20-28, 2004. 881 с.

References

1. Buzilo, V.I., Savelyeva, T.S., Savelyev, V.A., Fomichev, V.V. (2011), *Instytut Gospodarki Surowcami Mineralnymi i Energia. PAN*. Krakow. RU. pp. 392–400 c.

2. Byzov, V.F., Gubin, G.V., Gurin, V.A. (1996). *Razrabotka rudnikh* mesgorozhdeniy: nauch.-tekhn. sb., 59. RU. pp.22-26

3. Virtual'naya kollektsiya kamney i mineralov. Klub lyubiteley kamnya. Available at: http://www.kievstone.zzz.com.ua/trips2.php .

4. Hurs' kyy, D.S., Yesypchuk, K.YU., V.I. Kalinin, YE.O. ta in. (2006). *Metalichni i nemetalichni korysni kopalyny Ukrayiny*, Kyyiv-Lviv: Tsentr Yevropy. UA. 551 p.

5. Dubyna, I.V. (1939), *Grafitovyye mestorozhdeniya Ukrainskoy SSR*, Khar'kov: GONTI. RU. 208 p.

6. Yelina, A.B., Lyakh, O.A. (2018).. Zabaykal'skiy gos. universitet, Chita. RU. 103–108 p.
7. Kalashnik, A.A., Kovrizhkin, N.A., Kovalev, S.G. (2012). *Míneral'ní resursi Ukraíni,* 3. RU. pp. 19–22.
8. Kvasnytsya, V.M., Naumenko YE.V. (2017). Mineral. Journal. 1 (39). UA. pp. 11 – 18.
9. Koval'chuk, L.N. (2001). *Treshchinovatost' chastits granata iz kontsentratov nekotorykh mestorozhdeniy mira.* Geologo-míneralopchniy vísnik. 1. RU. pp. 106–109.
10. Kravchenko, I. *Agaty Zaval'yevskogo mestorozhdeniya grafita*. Sevastopol'skiy muzey kamnya. Available at: http://www.sevstone.ru/articles/agaty-zavaljevskogo-mestorozhdenija-grafita-kogda-neverojatnoe-stanovitsja-vozmozhnym/ (data obrashcheniya: 26.11.2019).
11. Kushniruk, N.V., Zhavneryk, V.S. (2009). *Materialy mizhnar. nauk.-tekhn. konferentsiyi (Kryvyy Rih, 12-16 travnya 2009).* UA. pp.271-272.
12. Lavrov, D.A., Kanevskiy, A.YA., Gordeyev F.M. (1975). *Abrazivnyye granaty Ukrainy*. Nauka, Moskow. RU. pp. 90–94.
13. Larichkin, F.D. (2004). *Terminologicheskiye problemy kompleksnogo ispol'zovaniya mineral'nogo syr'ya*. Tsvetnaya metallurgiya. 12. RU. pp.29-36.
14. Larichkin, F.D. (2012). Vestnik Kol'skogo nauchnogo tsentra RAN.4. RU. pp. 8–14.
15. Lyzhachenko, N.M., Nikolayevskyy, V.P. (2013). *Perspektyvy vykorystannya resursnoyi bazy Zavallivskoho rodovyshcha hrafitu.* Visnyk kyyivskoho natsionalnoho universytetu imeni Tarasa Shevchenka. 2(61). UA. pp. 41–44.
16. Matkovskyy, O.I. (2019). *Nadrokorystuvannya v Ukrayini. Perspektivy investuvannya: shosta mizhnarodna naukovo-praktychna konferentsiya (Truskavets, 7–11 zhovtnya 2019).* UA. pp. 9–14.
17. Mirzayev, G.G. Ivanov, B.A. Shcherbakov, V.M. i dr. (1991). Nedra: Moskow. RU. 320 p.
18. Mostyka, Ye.N. (2012). *Naukoviy vísnik NGU.* 1.RU. pp. 5-9.
19. Moya kollektsiya: porody i minobrazovaniya kremnezema. Mineraly ot Leonida. Available at: https://www.leonmin.ru/moya-kollekciya-porody-i-minobrazovaniya-kremnezema/
20. Pedan, M.P., Mishchenko, V.S. (1981). *Kompleksnoye ispol'zovaniye mineral'nykh resursov.* Nauk. Dumka:Kiev. RU. 272 p.
21. Syvyy, M.YA. (2009). *Visnyk Lvivskoho universytetu. Seriya heohrafichna.* 37. UA. pp. 65–75.
22. Skakun, L., Manchur, B., Martyshyn, A. (2003). *Mineralohichnyy zbirnyk*. 1–2 (53). UA. pp. 49–58.
23. Surova V.M. *Teksturno-kolorystychni osoblyvosti ta hemolohichni kharakterystyky yashm Zavallivs′koho rodovyshcha hrafitu*. Scientific World. Available at: https://www.sworld.com.ua/index.php/ru/geology-311/general-and-regional-geology-311/7881-teksturnokoloristichn-osoblivost-ta-gemologchn (data obrashchenyya: 25.11.2019).
24. Surova, V.M., Lyashok, V.I. (2012).*Koshtovne ta dekoratyvne kaminnya*.. 3. UA. pp. 8-11.
25. Tarasova, T.V, Hubina, V.H., Kvashuk, L.P., Horlytskyy, B.O i dr. (2011).. Lohos :Kyiv. UA. 199 p.
26. Shakina, K., Skakun, L. (2010). *Mineralohichnyy zbirnyk.*1 (60). UA. pp. 70–85.
27. Shar iz yashmy, 56 mm. Kamnevedy [Elektronnyy resurs]. URL: https://kamnevedy.ru/category/shary_200/kupit-suveniry-shar-yashmy_21636/.
28. Yatsenko, V.G. (2008). *Geologiya, mineralogiya i genezis grafita Ukrainskogo shchita*. Logos:Kyev, RU. 127 p.
29. Whoriskey, P. In your phone, in their air. Washington Post. Available at: https://www.washingtonpost.com/graphics/business/batteries/graphite-mining-pollution-in-china/.
30. Yatsenko, V.G. (2004*).* (Geol.Congress, Florence, August 20-28), 881 c.

РАЦІОНАЛЬНЕ ВИКОРИСТАННЯ МІНЕРАЛЬНОЇ СИРОВИНИ ПРИ РОЗРОБЦІ ЗАВАЛЛІВСЬКОГО РОДОВИЩА ГРАФІТУ

Яценко В.Г., канд. геол.-мін. наук, пров. н. с., ДУ «Інститут геохімії навколишнього середовища НАН України», vgyatsenko@gmail.com,
Заборовська Л.П., канд. геол. наук, н. с., ДУ «Інститут геохімії навколишнього середовища НАН України», zaborovskayalp63@gmail.com
Земсков Г.О., н. с., ДУ «Інститут геохімії навколишнього середовища НАН України», zemskovgennadii2020@gmail.com
Лижаченко Н.М., канд. геол. наук, ДУ «Інститут геохімії навколишнього середовища НАН України», albeet@ukr.net
Ніколаєвський В.П., головний геолог, ПрАТ «Заваллівський графітовий комбінат»", nvp49ktv@gmail.com

У роботі на основі аналізу перспектив використання ресурсної бази Заваллівського родовища намічено шляхи раціональної розробки і комплексного використання його сировини, що включає перехід на підземний та комбінований видобуток графітових руд, вдосконалення схем збагачення, збільшення асортименту графітової продукції комбінату, використання відпрацьованого кар'єру для відвалів розкривних порід та хвостів. Важливішою складовою раціональної розробки Заваллівського родовища є комплексне використання його сировини: (1) гранатова сировина родовища має на сьогодні значні перспективи, оскільки родовище є єдиним в Україні, що розробляє гранатові руди; за технічними характеристиками гранатовий концентрат Заваллівського родовища не поступається гранатам світових виробників; (2) підприємство не реалізовує всі обсяги скальних порід розкриву для виробництва будівельного каменю; (3) піски, глини та суглинки порід розкриття характеризуються високими технологічними показниками і потребують вивчення економічної доцільності їх селективної розробки; (4) сировина хвостів флотації графітових руд заслуговує на подальше вивчення з метою застосування в галузі будівельних матеріалів і для скляного виробництва; (5) використання мінеральних пігментів (вохри, селадоніту) можливе при селективній виїмці, спеціальному окремому складуванні та розробці технології збагачення та підготовки для подальшого використання; (6) яшми, халцедоніти та опалоподібні утворення Заваліського родовища мають високі декоративно-текстурні і споживчі характеристики і придатні для виготовлення різноманітних ювелірних та ювелірно-декоративних виробів; (7) серед вміщуючих порід Заваллівського родовища зустрічаються жили унікального, рідкісного у світі мінералу граутиту, мінералогічний інтерес представляє присутність бариту, горсейкситу, піриту, галеніту, скупчень крупнозернистого графіту, та ін. Збирання і реалізація їх зразків як колекційного матеріалу, організація мінералогічних екскурсій також можуть мати певний економічний ефект. Впровадження раціональних методів розробки і комплексного використання сировини Заваллівського родовища графіту дозволить розглядати цей обєкт як стратегічно важливий для економіки України.

Ключові слова: *Український щит, Заваллівське родовище графіту, графітова руда, раціональна розробка родовища, комплексне використання мінеральних ресурсів*