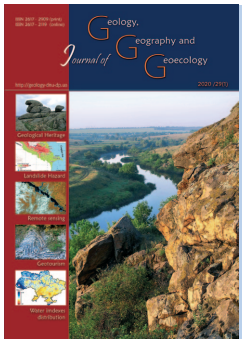


Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu-dp.ua

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

Journ.Geol.Geograph. Geology, 29(1), 188–195.
doi: 10.15421/112017

Mineralogical studies of amphibolite outcrops within the Kryvyi Rih Basin

Svitlana V. Tikhlivets, Valeriy D. Yevtiehov, Valentyna V. Filenko, Olena Y. Hrytsai

Kryvyi Rih National University, Kryvyi Rih, Ukraine, tikhlivets.svetlana@gmail.com, evtekhov@gmail.com, lenahrits@gmail.com

Received: 18.04.2019
Received in revised form: 06.05.2019
Accepted: 31.08.2019

Abstract. This study explores the mineralogical composition of the material of samples extracted from the outcrops of amphibolites located within the Kryvyi Rih Basin. Amphibolites of the Novokryvorizka suite of the Kryvorizka series are located in the area of Rodina mine of the Kryvyi Rih Iron Ore Enterprise (KRIOE) on the right bank of the Saksahan river, where the amphibolites crop out as an interrupted line. Over the recent years, industrial and geological tourism has been actively developing not only within Kryvyi Rih, but also in Ukraine in general. The Kryvyi Rih Basin has many objects which deserve the status of unique geological observation sites. One such site has amphibolites of the Novokryvorizka series, which rarely outcrop to the surface. Such an object is interesting and useful not only for interested tourists, but especially for geology students as an example of rocks that have been formed out of effusive eruption products during the geological process such as regional metamorphism. No other examples of their exposure have been observed in the area. The studied outcrops are unique, but recently, their reduction has been observed due to the poor level of their preservation. The relevance of this study is conditioned by necessity of conducting geological evaluation of the amphibolite outcrops with a view to the future use of this object for development of industrial and geological tourism within the Kryvyi Rih Basin. We studied all possible outcrops of the amphibolites within the surveyed territory, and analyzed the results of the previous studies on the topic. We developed a schematic image of the outcrops with consideration of their thicknesses. The mineralogical composition of all outcrops of the amphibolites was studied for further determination of the exact age of the amphibolites and opportunity of providing the amphibolite outcrops with the status of unique observation sites. For achieving the goal, we used the following methods of study: geological survey, selection of representative petrographic samples of the amphibolites, mineralogical and petrographic analyses, generalization of results of field and laboratory studies.

Key words: Ukrainian Shield, Kryvyi Rih Basin, geological tourism, outcrops of amphibolites.

Мінералогічні дослідження виходів амфіболітів в межах Криворізького басейну

С. В. Тіхлівець, В. Д. Євтєхов, В. В. Філенко, О. Ю. Грицай

Криворізький національний університет, Кривий Ріг, Україна, tikhlivets.svetlana@gmail.com, evtekhov@gmail.com, lenahrits@gmail.com

Анотація. Дана робота присвячена мінералогічному вивченню матеріалу проб, відібраних з відслонень амфіболітів, що розташовані в межах Криворізького басейну. Амфіболіти новокриворізької світи криворізької серії знаходяться в районі шахти «Родіна» Криворізького залізорудного комбінату (КЗРК) на правому березі річки Саксагань, де переривчастою смугою виходять на поверхню. В останні роки активно розвивається промисловий і геологічний туризм в межах не тільки Кривого Рогу, а й в Україні в цілому. В межах Криворізького басейну існує багато об'єктів, що заслуговують на статус геологічної унікальної точки спостереження. Одним з таких є амфіболіти новокриворізької серії, які рідко виходять на земну поверхню для спостережень. Такий об'єкт є цікавим і корисним не тільки для зацікавлених туристів, а й особливо для студентів-геологів у якості прикладу гірських порід, що утворились з ефузивів при такому геологічному процесі як динамотермальний метаморфізм. Інших прикладів наочності в межах Криворізького басейну не спостерігається. Досліджене відслонення є унікальним, але останнім часом спостерігається його скорочення у зв'язку з низькою збереженістю виходів амфіболітів. Актуальність даної роботи обумовлена необхідністю проведення геологічної оцінки виходів амфіболітів для подальшої можливості використання цього об'єкту для розвитку промислового і геологічного туризму в межах Криворізького басейну. Досліджено всі можливі виходи амфіболітів в межах вивченої території, проаналізовано результати попередніх досліджень з даної теми. Побудоване схематичне зображення їх відслонень з урахуванням потужностей. Вивчено мінеральний склад всіх виходів амфіболітів з метою подальшого визначення точного віку амфіболітів та можливості присвоєння виходам амфіболітів статусу унікальної точки спостереження. Для досягнення поставленої мети використовувались наступні методи досліджень:

виконання геолого-зйомних робіт, відбір представницьких петрографічних проб амфіболітів, виконання мінералогічних і петрографічних досліджень, узагальнення результатів польових та лабораторних досліджень.

Ключові слова: Український щит, Криворізький басейн, геологічний туризм, відслонення амфіболітів.

Introduction. One of the most interesting geological objects of the Ukrainian Shield is the Kryvyi Rih Structure. This is explained not only by the localization of unique reserves of iron ores below the ground, but also by a specific structure determined by the history of the geological development of the region, which reflects all the main stages of formation of the Ukrainian Shield.

According to the modern point of view, the Kryvyi Rih Structure is a complex geological structure developed by metal-volcanic-sedimentary of the Upper Archean, Lower, Middle and the Upper Proterozoic and Cenozoic Periods (Stepanuk,e.a., 2011). The structure includes deposits of the Kryvorizka series made up of Novokryvorizka, Skeliuvatska, Saksahanska, Hdantsivska and Hleiuvatska suites (Akimenko, et. al., 1957; Belevtsev, et. al., 1991).

The Novokryvorizka suite has been studied most substantially within the Saksahan and South iron ore regions of the Kryvyi Rih Basin, where it is embedded with angular and stratigraphic unconformity on the Konkska series. In its basal part, amphibolites, products of regional metamorphism of the covering basalts, are dominant. The initial effusive nature of the amphibolites is indicated by the presence of lensed amygdules of quartz in their structure (Gritsay, e. a., 1975). In the upward direction along the section of the suite, there is an increase in content of metaclastolites – quartz-chlorite, sericite-quartz-chlorite, quartz-sericite-chlorite (area of manifestation of green schist facies of metamorphism) or quartz-bimicaceous, quartz-hornblende-biotite (areas of epidote-amphibolite facies) of the schists. In a small amount, the upper section of the suite contains feldspar-quartz meta-sandstones and meta-gritstones with chlorite, quartz-chlorite cement, formed by interlayers of 1-2 m thickness, and also schist meta-conglomerates. Within the central part of the Saksahan iron ore region, where the deposit of the Rodina Mine is located, the thickness of the suite equals 150-200 m.

The Skeliuvatska suite is conformably embedded on the Novokryvorizka suite. It contains rocks of three subsuites: lower, middle, and the upper. Total thickness of the suite ranges from 40-50 to 340-360 m.

The Saksahanska suite is a productive iron ore thickness of the basin, and is embedded on the Skeliuvatska suite. Its complete section includes seven iron ore and seven schist horizons. The horizons range in number and thickness along the Kryvorizka Structure. The most complete section is within the deposit of the V. I. Lenin Mine. There, its thickness reaches 1,300 m. In the section of the suite of the deposit of the Rodina Mine, the seventh schist and seventh ferriferous horizons are absent. By petrographic content of the stratigraphic horizons, the Saksahanska suite is divided into the lower, middle, and lower subsuites.

The terminating part of the Kryvorizka series is the Hdanivska suite which is embedded with angular and stratigraphic unconformity on the rocks of the Saksahanska suite. Its structure comprises sericite-plagioclase-quartz-chlorite, graphite-sericite-quart-chlorite schists, oligomictic meta-sandstones and meta-conglomerate-breccia (green schist facies) or quartz-plagioclase-biotite, staurolite-andalusite-quartz-biotite, graphite-quartz-micaceous, quartz-biotite-hornblende schists, biotite, hornblende-biotite quartzites, and also ferriferous quartzites of different composition, initially clastogenic metamorphosed rich iron ores (products of rewashing of the weathering rind of the ferriferous rocks of the Saksahanska suite), quartz-carbonate rocks and dolomite marbles. The average thickness of the suite within the Inhulets iron ore district is 30-50 m, Saksahan and South districts – 700-1,000 m, North district – up to 2,000-2,500 m, does not exceed 1,500 m on average.

Rocks of the Hleiuvatska suite form the central part of the Kryvorizka Structure. The structure of the suite comprises polymictic meta-conglomerates, quartz-fieldspar and fieldspar-quartzitic metasandstones, quartz-biotite, plagioclase-quartz-biotite, garnet-quartz-biotite, garnet-hornblende-quartz-biotite schists and shists of other composition. The total thickness of the suite in the northern part of Saksahan and Northern iron ore districts is up to 2,000-2,500 m. Towards the north, this parameter significantly decreases, the suite outcrops in the south part of the Saksahansk district, and the suite is absent within the Southern and Inhuletsk districts.

According to earlier researchers (Stepanuk,et. al., 2011), outcrops of amphibolites occur also in the area of the Inhulets River, east of Rahmanivka village. They are dark-grey with greenish tone, and of fine-average grained structured texture. According to the mineral composition, they differ: amphibole represented by actinolite and hornblende, - 45-55%, acid plagioclase – 30-50%, quartz – up to 10%, biotite and chlorite – up to 5%, rarely – epidote and carbonate. Accessory minerals are represented by zircon,

apatite, ilmenite, tourmaline, rutile, and leucoxene. In these amphibolites, pyrite and pyrrhotite ore minerals rarely occur. According to the result of study of the age of the zircon in these amphibolites (Stepanuk, e. a., 2011), it was determined that they belong to the Konsk series (Paranko, e.a., 2007).

The objective of this paper was conditioned by active development of industrial tourism (Samoylenko, Dubytska, 2012) within the Kryvyi Rih Basin. The amphibolites of the Kryvorizka suite are unique as a geological object (Nesterovskyy,Krynutska, 2006), especially for Geology students as an example of rocks formed from effusive eruption products during regional metamorphism. Unfortunately, recently as a result of abandoning of this territory, low level of maintenance, the outcrops of amphibolites have lost their esthetic attractiveness. The study was performed in scope of the scientific topic (Gritsay, 2017) ordered by the open joint stock company Kryvyi Rih Iron Ore Enterprise.

Analysis of previous studies. The amphibolites within the Ukrainian Shield have been researched in several stages (Sukach, 2015). The first stage of studying the amphibolites was conducted by I. S. Usenko in 1940s, when the general picture of their distribution and peculiarities of composition was described. The second stage occurred after the 1950s, when complex scientific-research studies were conducted. According to the latter, the main areas of distribution of amphibolites within the Ukrainian Shield were designated and documented. The third stage was related to the studies of geochronology and geologic-formational orientation, which resulted in the obtaining of data on the age of the amphibolites (Sukach, 2015).

The amphibolites of the Novokryvorizka suite within the Kryvorizkyi Basin are exposed in natural outcrops on the slopes of the Inhulets and Saksahan rivers and slopes of the ravines which fall into these rivers. In the northern part of the Kryvbas, on the right slope of the Saksahan, natural outcrops with amphibolites of the Novokryvorizka suite are known, which border with concessions of the M. V. Frunze and Yuvileina mines. In the northern part of the Kryvbas, these amphibolites are exposed in outcrops on the left slope of the Inhulets River near the Quarry of the Northern Mining and Processing Enterprise and on the left slope of the Inhulets River near Lativka village.

There are several technogenic outcrops of amphibolites of the Novokryvorizka suite in the mine workings of quarries and mines. The most representative of them is located on the eastern capital pit side of the Quarry of the Inhulets Mining and Processing Enterprise.

Studies on the outcrops of amphibolites as a geological relic were performed by different organizations at different periods (Gritsay, 2017; Manyuk Vad., Manyuk Vol., 2011; Manyuk Vol., Manyuk Vad., 2018). The studies were conducted for clarifying the petrographic composition, area of distribution, coordinates of location and possibility of preserving the amphibolite outcrops as a geological relic (Manyuk Vol. V., Manyuk Vad. V., 2018). The study by Manyuk Vol. V., Manyuk Vad. V., 2018 provided information regarding relationship between amphibolites and spilite-keratophyre formation, where the amphibolites are the products of metasomatic transformation of paleotypic basalts or spilites. In their study, these scientists proved that the amphibolites are derivatives of the basalts of an ancient volcano, which is unique for the Kryvyi Rih Basin.

Methods of field surveys. The examined outcrops of amphibolites in the administrative aspect are located in the Saksahan districts of Kryvyi Rih, 500 m east of the Rodina Mine (Kryvbaszalizrudkom PJSC).

The outcrops of amphibolites are located on the steep slope above the Saksahan River. The outcrop was accurately examined (Fig. 1). According to the data of observations made by the authors, the amphibolite outcrops occurred only on the slope of the river as a narrow strip (around 97 m) of separate outcrops overgrown by bushes, trees and covered by shifted fractures of loams and soil-plant layer. Currently, the area of the outcrops of amphibolites is 12,500 m^2 (1.25 ha). Outcrops of the amphibolites are designated by two poles marked on Fig. 1.

According to the field identification, the rocks which formed the outcrops are represented by amphibolites of dark grey to black colour with green tone. The instrumental connection of the points of sampling was made using a GPS navigator. Macroscopic study included geological description of the outcrops and their schematic framing, macroscopic characteristic of rocks, formation of geological objects. We identified and macroscopically studied all the local outcrops of rocks and measured their sizes (length, width, height). It was determined that the amphibolite outcrops are not systematic, the size of the largest outcrop is around 9 x 2 m (Fig. 2a), all the rest are of much smaller size.

The amphibolites are characterized by different extent of schistosity, fracturing and hypergenic alteration (Fig. 2b). They are practically ubiquitously overlain by loess-like loams and soil-vegetative cover.

As a result of geological surveys, a schematic image of the amphibolite outcrops was developed (Fig. 3). The image was developed with consideration

Fig. 1. Location of the points of observation of the amphibolite outcrops.
Modern outcrops of amphibolites, marked by points "Pole 1" and "Pole 2"
A-1, A-2 … A-11 – points of extraction of the samples

of the layers of outcrops that are visible on the earth surface.

Microscopic studies (diagnostic of minerals, quantitative mineralogical calculations in standard preparations, microphotography) were undertaken in the laboratories of the Geology and Applied Mineralogy Department of the Kryvyi Rih National University using the standard methods with serial petrographic and mineralogic microscopes (NU, POLAM, MP-4, MP-6).

Mineralogical and petrographic composition of amphibolites. Within each of the local amphibolite outcrops, ordinary petrographic samples were extracted, the total number of which was 11. In the laboratories of the Kryvyi Rih National University, we performed cutting of the selected samples, out of which lumps of 6 x 9 cm were prepared for the following mineralogical studies (Fig. 4).

Out of the material of each sample, transparent and polished thin sections were prepared for microscopic mineralogical studies in the standard preparations and for performing quantitative mineralogical calculations, clarification of the textures and structures of the amphibolites and the pattern of spatial interrelation of the minerals. In correspondence to the obtained data, in structural and texture aspects,

а б

Fig. 2. Outcrops of amphibolites around the Saksahan River
a – amphibolite outcrop of maximum size (9 x 2 m);
b – schisted, fractured, intensely weathered amphibolites (1.1 x 0.8 m).

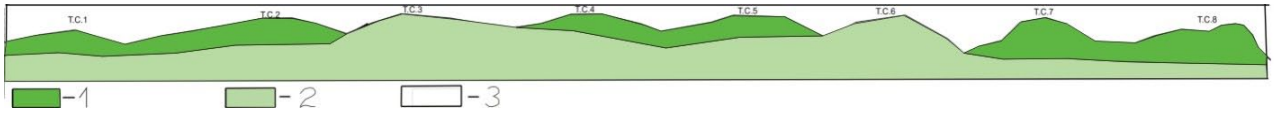


Fig. 3. Schematic image of amphibolites within the studied area of the Kryvorizkyi Basin.
1 – chloritized amphibolites; 2 – unchanged amphibolites; 3 – vegetative cover;
OP1-…..-OP8 – observation points.

the examined amphibolites are characterized by non-homogeneity, which is manifested by schistosity and fracturing. Rarely manifestations of massif texture of amphibolites were observed. Their colour changes from dark grey, dark green to grey-green, brown-green. The amphibolites have obtained a brown tone from numerous transversal veinlets of iron hydroxides.

biotite crystals. Size of the crystals is 2 mm to 0.7 mm in length (Fig. 5, c, d). Most of them are represented by simple twins. Cleavage is perfect to prism.

Biotite occurs in the form of small (0.1-0.3 mm) flat plaque-like, scale-like crystals which have lower level of idiomorphism compared to plagioclase crystals (Fig. 6). Its content ranges 5 to 30 % vol.

a b

Fig. 4. Lumps of ordinary samples 8 (a) and 2 (b) of amphibolites.

According to the microscopic studies, it was determined that rock-forming minerals are hornblende, plagioclase, quartz and biotite.

Hornblende (Fig. 5a) is present in the composition of amphibolites in amount from 35 to 65% vol. Significant fluctuations of the content are related to the variability of the chemical composition of the initial basaltoids and amount of additional clastic material in the compound of the effusive products. It forms elongated flat plaque-like xenomorphic and hypidiomorphic crystals, the size of which is up to 1.5-2 mm at maximum measurement (Fig. 5, a, b). Sometimes simple twins occur.

The colour of the mineral is grey-green with a bluish tone, pleochroism is from blue-green on Ng to light yellow on Np. Cleavage is perfect to prism with the angle between the surfaces measuring 55°. The extinction angle is up to 15°. The weathered types of amphibolites were observed to have heightened fracturing of the crystals of the hornblende.

Plagioclase is represented by andesine-labradorite. Its content ranges from 30 to 60 %vol. It is present in the form of flat plaque-like crystals, the level of idiomorphism is slightly higher compared to the

The mineral is yellow-brown with pleochroism from dark brown on Ng to light yellow on Np. Cleavage is perfect to the pinacoid.

Chlorite is present as an epigenetic mineral which in the process of weathering replaced biotite (Fig. 6b). Its amount ranges from 0 to 10 %vol. It has inherited the size and shape of initial xenomorphic plastic individuals of biotite. The colour of the mineral is light green, pleochroism is low. Cleavage is perfect to pinacoid. The interference colours are different tones of grey.

Apart from the silicates, amphibolites contain a small amount of ore minerals represented by magnetite, goethite and martite.

Magnetite, usually, occurs as separate small additions of isometric shape of 00.1 mm to 0.05 mm size (Fig. 7a). Content of the mineral is around 0.1 % vol.

Martite product of weathering of magnetite is represented by xenomorphic aggregates which have morphologically inherited the forms of the initial magnetite. We observed hypergenic replacement of magnetite by goethite (Fig. 7b). The size of the magnetite ranges from 0.1 mm to 0.6 mm.

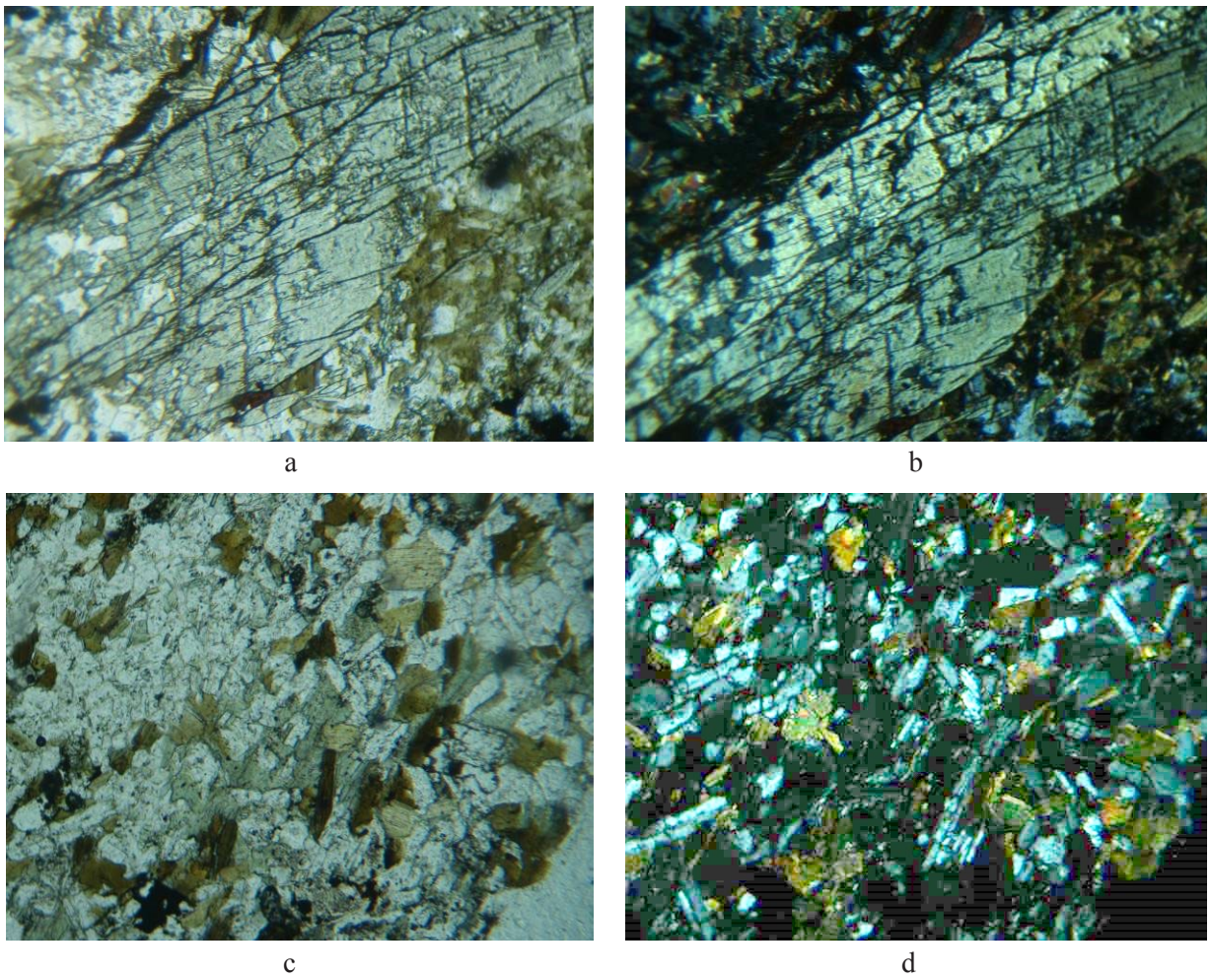


Fig. 5. Peculiarities of the structure and mineral composition of the amphibolites.
a-b – elongated large flat plaque-like crystals of the hornblende
c-d – flat plaque-like crystals of plagioclase (c – white; d – different tones of grey).

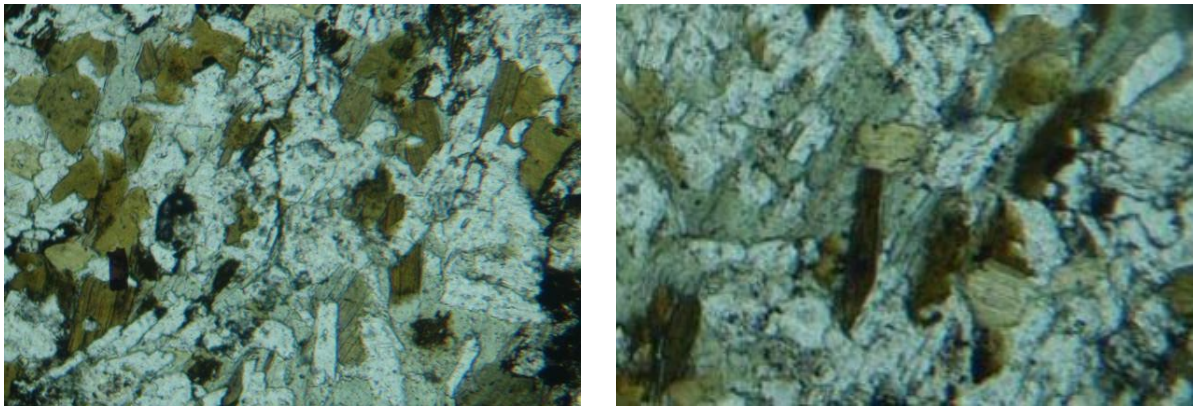
Goethite is present in the compound of amphibolites which were the most affected by weathering . It forms films along the fractures of the containing rocks, and also has metasomatically replaced all ferriferous minerals, mainly martite.

Results of the macro- and microscopic examinations of the materials of samples extracted from the outcrops confirm the stratigraphic confinement of these metabolites to the Novokryvorizka suite of the Kryvorizka series.

The uniqueness of the geological object. Currently, amphibolites have outcrops on the steep right slope of the Saksahan River in the form of a narrow, interrupted strip – this is a result of manifestation of shift of the loams and the soil-vegetation layer of the Quaternary period and sodisation, and overgrowing by shrubs and trees. The outcrops of amphibolites are represented by separate small rocky formations. The results of examinations of recent years indicate that the size of the amphibolite outcrops has a tendency towards reduction.

Furthermore, currently due to insufficient preservation of the relic, the continuity of the section of the Novokryvorizka suite has been lost. The upper parts of the fragmented outcrop are represented chiefly by weathered amphibolites; their slightly weathered or non-weathered types covered by shifted material and vegetation. Mineralogical, petrographic, geochemical variability of the section was not observed due to the non-systematic character of formation of outcrops of the rocks.

However, the outcrops have a certain scientific value determined by: 1) presence of several mineral types of amphibolites in the structure; 2) presence of layers and lenses of metaclastolites of different initial granulometric composition among them; 3) manifestation of vertical mineralogical zoning of the weathering rind – from intense hypergenically altered to initial amphibolites not affected by weathering; 4) textural non-homogeneity of amphibolites: manifestation of massif, layered, schisted, fractured, veinlet textures.



a b

Fig. 6. Shape of biotite crystals (brown) and chlorite (green) and peculiarities of their spatial interrelations with individuals of other crystals of amphibolites. Incident light; without analyzer; 50^x zoom.

The relic could be much more attractively displayed if the amphibolite outcrop site were cleared of vegetation, debris and intrusive manmade structures with the use of additional equipment. Currently private houses are located at the distance of around 100 m above the amphibolites; some of the houses are not inhabited and ruined. Near the houses (upper part of the slope), construction waste is deposited. Near the outcrops, there is a territory of the preventorium of the workers of the Rodina Mine, which is currently unused and under guard. Its premises are partly ruined, overgrown by shrubs and trees, and look unattractive. On the opposite, left slope of the river, there is a zone of a former park and a recreation house which borders it. The river near the suspension bridge, located south of the amphibolite outcrops, is completely overgrown by shrubs and its slopes have become swamped. Between the bridges, there is a stream pool of the river. During the summer, significant algae blooms occur. Therefore the esthetic attractiveness of the territory is low.

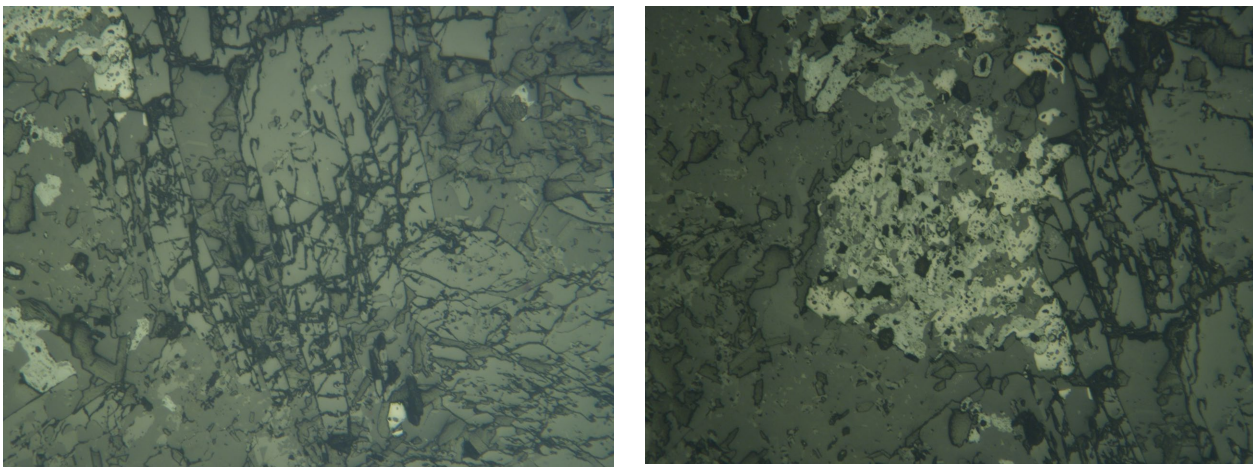
Conclusions.

1. Amphibolite outcrops are observed near the Rodina Mine of the Kryvbaszalizrudkom PJSC (Saksahan iron ore region of the Kryvyi Rih Basin).

2. Amphibolite outcrops are located on the western (right) slope of the Saksahan River in the form of a chain of small rocky outcrops of total length measuring 97 m. The size of the separate outcrops does not exceed a few meters. Maximum sizes of outcrops are up to 9 x 2 m.

3. According to the field observations, the amphibolites are characterized by non-homogeneity, which is manifested by schistosity, fracturing. Rarely, there was observed manifestation of massif texture of amphibolites. Their colour changes from dark grey, dark green to grey-green, brown-green. The brown tone of the amphibolites is caused by numerous transversal veinlets of iron hydroxides. Locally, presence of quartz was observed.

4. According to the data of microscopic studies, it was determined that rock-forming minerals are



a b

Fig. 7. Peculiarities of morphology of individuals and aggregates of ore minerals.

a – isometric crystal of magnetite (light grey); b –porous aggregate of martite (light grey) with manifestation of replacement with goethite (grey); Dark grey – silicates, black – pores. Reflected light; without analyzer; 75^x zoom.

hornblende, plagioclase, quartz and biotite. Ore minerals are represented by magnetite, martite and goethite.

5. The scientific significance of this study and the educational value of the amphibolites are limited due to their low preservation level, their insufficient level as a representative object of mineralogical, geochemical, petrographic studies, and local history observations. However, after performing necessary measures for clearing the territory from shrubs, construction wastes, etc, and taking into account both data obtained by the authors of this paper and results of the studies conducted earlier, more detailed study on amphibolites of the Kryvyi Rih Basin is needed.

References

Akimenko, N.M., Belevtsev Ya.N., Goroshnikov B.I.; Belevtsev Ya.N., 1957. Geologicheskoye stroyeniye i zheleznyye rudy Krivorozhskogo basseyna [Geological structure and iron ores of Kryvyi Rig basin] Moscow, 280. (in Russian).

Belevtsev Ya.N., Kravchenko V.M., Kulik D.A., e. a., 1991. Zhelezisto-kremnistyye formatsii dokembriya Yevropeyskoy chasti SSSR. Genezis zheleznykh rud [Iron-siliceous formations of the Precambrian of the European part of the USSR. The genesis of iron ores]. Kyiv: Naukova Dumka, 215 (in Ukrainian).

Diznaysya bil′she pro zapovidni terytoriyi!» [Learn more about the protected areas!], 2009. "NGO" National Ecological Center of Ukraine ". Kyiv, 6. (in Ukrainian).

Gritsay O.Yu., 2017. Zvit pro naukovo-doslidnu robotu «Detal′ne obstezhennya heolohichnoyi pam″yatky pryrody mistsevoho znachennya «Vykhody amfibolitiv» (m.Kryvyy Rih, Saksahans′kyy rayon): utochnennya yiyi polozhennya na mistsevosti, ploshcha poshyrennya amfibolitiv, vidbir prob dlya utochnennya petrolohichnoho ta mineral′noho skladu z metoyu vyznachennya heolohichnoyi tsinnosti ob'yektu. Na osnovi provedenykh doslidzhen′ sklasty ekspertnyy vysnovok pro podal′shu dolyu pam″yatky pryrody PAT «Kryvbaszalizrudkom» v 1-3 kvartalakh 2017 roku» (tema № 14-17 dohovir №493 vid 19.04.2017 r.) [Report on research work "Detailed survey of the geological nature monument of local significance" Outcrops of Amphibolites" (Kryvy Rih, Saksagansky district): clarification of its position in the area, the area of distribution of amphibolites, sampling for refining petrological and mineral composition for the purpose determination of the geological value of the object. On the basis of the conducted researches, to draw up an expert opinion on the further fate of the nature monuments of PJSC "Kryvbaszalizrudkom" in 1-3 quarters of 2017 "(theme № 14-17 contract №493 dated 19.04.2017)] NDGRI KNU, 35. (in Ukrainian).

Gritsay Yu.L., Pedan M.V., Dmitriev E.V., Shaposhnikov V.A., 1975. Tsiklichnost' v porodakh zhelezistykh gorizontov sredney svity Krivbassa [Cyclicity in the rocks of the ferruginous horizons of the middle suite of Krivbass]. Prospects for the development of rich iron ores of the Krivoy Rog iron ore basin to the depth. Kyiv: Naukova Dumka, 19-26. (in Ukrainian).

Manyuk Vad. V., Manyuk Vol. V., 2011. Pam'jatky pryrody Dnipropetrovs'koi' oblasti: navchal'nyj dovidnyk. [Nature monuments of Dnipropetrovsk region: study guide]. Dnipropetrovsk, 37–53.

Manyuk, Vol. V., Manyuk, Vad. V., 2018. Zvit pro naukovo-doslidnu robotu «Obstezhennya heolohichnoyi pam″yatky pryrody mistsevoho znachennya «Vykhody amfibolitiv» (dohovir №488 (617). (Report on research work "Survey of the geological nature monument of local significance "Outcrops of Amphibolites" (contract №488 (617)). Oles Gonchar Dnipropetrovsk National University, 50. (in Ukrainian).

Nesterovskyi V., Krynytska M., 2006. Heolohichni pam″yatky: ekolohichni aspekty [Geological sites: environmental aspects]. Bulletin of Kyiv National University named after. Taras Shevchenko. Kyiv, 36, 20-22. (in Ukrainian).

Paranko I.S., Stetsenko V.V., Butyrin V.K., Kozar M.A., 2007. Putivnyk heolohichnykh ekskursiy [Guide to geological excursions]. IV Scientific and production meeting of geologists-surveyors of Ukraine (October 8-12, 2007). Dnipropetrovsk, 62. (in Ukrainian).

Samoylenko L.V., Dubytska A.V., 2012. Klasyfikatsiya heolohichnykh pam″yatok za inzhenerno-heolohichnymy oznakamy [Classification of geological monuments by engineering and geological features]. Geological Journal, №1, Kyiv, 91-98. (in Ukrainian).

Stepanyuk L.M., Bobrov O.B., Paranko I.S., Ponomarenko O.M., Serhyeyev S.A., 2011. Henezys ta vik tsyrkonu iz amfibolitu novokryvoriz′koyi svity kryvoriz′koyi seriyi [Genesis and age of zirconium from amphibolite of the Novokryvorizh suite of the Kryvorizh series]. Mineralogical Journal, 33, №3, 69-76. (in Ukrainian).

Sukach V.V., 2015. Petrohenezys amfibolitiv aul′s′koyi seriyi baseynu r. Bazavluchok, Seredn′oprydniprovs′kyy mehablok Ukrayins′koho Shchyta [Petrohenesis of amphibolites of aulian series of the River Basavluchok, Middle Dnipro megablock of the Ukrainian Shield]. Mineralogical Journal, Mineralogical Journal, 37, №1, 69-85. (in Ukrainian).