МІНЕРАЛОГІЯ, ГЕОХІМІЯ ТА ПЕТРОГРАФІЯ

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MORPHOLOGICAL CHARACTERISTICS OF MAGNETITE AND QUARTZ IN THE PRODUCTIVE STRATA OF NORTHERN DISTRICT OF KRYVYI RIH BASIN

(Представлено членом редакційної колегії д-ом геол. наук, проф. О. В. Митрохиним)

Currently, the main task for the geological service of Hannivka deposit of the Northern Ore Mining and Processing Works is to ensure the Ore Mining and Processing Works with raw materials, which allows receiving high-quality iron ore concentrate that meets the requirements of the world market. It is only possible to meet this challenge taking into account the morphological features of the main rock-forming minerals, and as a consequence, the natural capabilities of the ores, their dressability by increasing the efficiency of the blending ores of various mineral varieties and of different technological potential, in order to achieve the optimal composition of the ore mixture, which is fed to the beneficiation plant.

Morphological studies of the main minerals in unchanged and metasomatically altered ferruginous quartzites were performed according to the standard method. Measurement of the magnetite and quartz grain sizes was carried out using an eyepiece micrometer mounted on a mineralographic microscope. The determining of their average indexes was carried out with the use of mathematical methods.

The results of the study of the main morphological characteristics of iron ore-bearing minerals and their variations, depending on the location within the unchanged and metasomatically altered ferruginous quartz of Hannivka deposits at Northern region are represented. The results of the study of the dihedral angles of magnetite and quartz crystals, changes in the particle size distribution of these minerals, depending on the imposed geological processes on the banded-iron formation of Kryvyi Rig basin are shown.

The scientific novelty consists in detailed conducting of mineralogical researches of the magnetite and quartz morphological features depending on their location in the section of the banded-iron formation of the Kryvyi Rih basin and in the further utilization of these results in topominerological mapping of the Northern region.

The obtained variability of the main minerals' morphology of the ore-bearing strata must be taken into account in the mineral mapping of the deposit and the Northern region of the Kryvyi Rih basin in general, when specifying the mineral-technological classification of ores and the blended mineral varieties of ores before feeding to the beneficiation plant.

Keywords: Ukrainian Shield, Kryvyi Rig basin, Hannivka deposit, ferrous siliceous formation, iron quartzite, magnetite morphology, quartz morphology.

Challenge problem. Iron ore deposits of the Kryvyi Rih basin have been developed since 1881. Extraction and beneficiation of low-grade magnetite ores started in the middle of the twentieth century. At the current time, mining operations are carried out by five iron ore beneficiation plants at nine deposits. One of these deposits is that of Hannivka. At Hannivka, it is mined open-pit located in the Northern iron ore region. Its raw material base is composed of the fifth and sixth ferriginous horizons of the Saksagan series. In the section of the series there are ten stratigraphic horizons. All of them are composed of non-economic magnetite-silicate quartzites and quartz-silicate schists.

The main task for the geological services of the mining enterprises of Kryvyi Rih basin is to supply the Ore Mining and Processing Works with raw materials, which makes it possible to obtain high-quality iron ore concentrate that meets the requirements of the world market. The solution of this task is only possible taking into account the morphological features of the main rock-forming minerals. As a result, the natural capabilities of the ores, their dressability, increase in the efficiency of blending ores of various mineral varieties with different technological potential in order to achieve the optimal composition of the ore material, which is fed to the beneficiation plants.

One of the main directions of solving this task is the mineralogical study of the morphology of minerals, the allocation of mineral varieties and the mineralogical mapping of the deposit. It will allow outlining the deposits of ores with different mineral composition and different technological parameters.

Research analysis. The issue of dependence of the morphological, chemical, physical and other characteristics of minerals on the mineral composition of ferruginous quartzites, their position in the sections of deposits was studied by many preceding researchers *(Belevtzev et al, 1962), (Gramenitskiy et.al, 2000), (Chernovskyi and Evtekhov, 1983), (Domarev, 1955), (Evtekhov and Poltavets, 1980), (Evtekhov et al., 1988), (Petrovskaya and Chuhrov, 1983), (Lepp, 1987), (Morris, 1983)*. The authors concluded that there are general patterns of variation of most mineralogical parameters in sections of ore deposits of different genesis (*Tikhlivets and Filenko, 2017).*

In Evtekhov's (*Evtekhov, 1992*) and Karpenko's works (*Karpenko, 2010*) it was noted that all geological processes (sedimentogenesis, metamorphism, weathering, metasomatism, etc.) influenced the morphological features of minerals in different ways. These processes occurred within the banded-iron formation of the Kryvyi Rih basin. In some authors' works *(Ilnitskaya,1969), (Pavlishin et al., 2003), (Pavlishin, 1984), (Tikhlivets and Filenko, (2018)* the information is given about the composition and morphology of minerals of unaltered iron ore strata. In other authors' works *(Belevtsev, 1986), (Domarev, 1955)* the influence of sodium metasomatism on the morphology of minerals is mentioned. Namely, under conditions of metasomatic changes in the rocks of the banded-iron formation, metasomatic zoning is superimposed on the primary autigene-metamorphogenic zoning and inherits largely its features. As a result, polygenic formations having complex structures and variable mineral and chemical composition (sedimentation + metamorphism + metasomatism) are often observed in these zones. The detection of a metasomatic component in the process of their genesis is often complicated. The generalization of the results of studies on the change in the morphology of the main rock-forming minerals of the banded-iron formation of the Northern region in dependence on their location has not been carried out.

Objective of research. The objective of the research is grounded on the need for mineralogical mapping of iron ore deposits of Kryvyi Rih basin. The research was conducted at the example of Hannivka deposit, which represents manifestations of all major varieties of the autigene-metamorphogenic zoning and superimposed secondary processes.

In the process of the mineralogical mapping of ferruginous siliceous formation of the deposit carried out by the authors, numerous signs of the variability of morphological and anatomical characteristics of the ore-forming, secondary and accessory minerals of ferruginous quartzites were recorded. Therefore, it was decided to study in detail the changes in morphology and dihedral angles of magnetite and quartz crystals that are the main rock-forming minerals of the iron ore strata. This will solve the task settled for geological services to increase the ore blending, and, as a consequence, to improve the quality of iron ore concentrate and its ratio.

Laying out the main material.

The autigene-metamorphogenic mineralogical zoning of the fifth and sixth ferruginous horizons of Hannivka deposit is due to a change of the quantitative correlation of ore-forming minerals (quartz, magnetite, micaceous-hematite and cummingtonite) in their sections, as well as the size and shape of their crystals. The author researched the ferruginous quartzites of all mineral varieties of both ferruginous horizons of the productive strata in order to detect possible patterns of variation of minerals' morphological parameters and to establish quantitative estimates of these parameters. 248 samples of ores were selected, 236 transparent and 278 polished microsections were made from their material. Minerals' quantification of morphological features was carried out using proved mineralogical and petrographic methods.

Magnetite and quartz form ore layers of unchanged magnetite quartzite, magnetite occasionally occurs in the form of small inclusions in non-ore layers, as well as in ore and non-ore layers of metasomatically changed ferruginous quartzites.

The results of microscopic studies have shown that the character of the aggregation of magnetite individuals naturally changes in the horizon section. Ribbon-shaped, more rarely block-shaped, dendrite aggregates of magnetite (fig. 1) are typical for the central zone of the fifth ferruginous horizon, which is represented by micaceous hematite quartzite; ribbon-shaped aggregates are less typical for magnetite and cummingtonite-magnetite quartzites in intermediate zones, they're dominated by the block-shaped and dendrite ones.

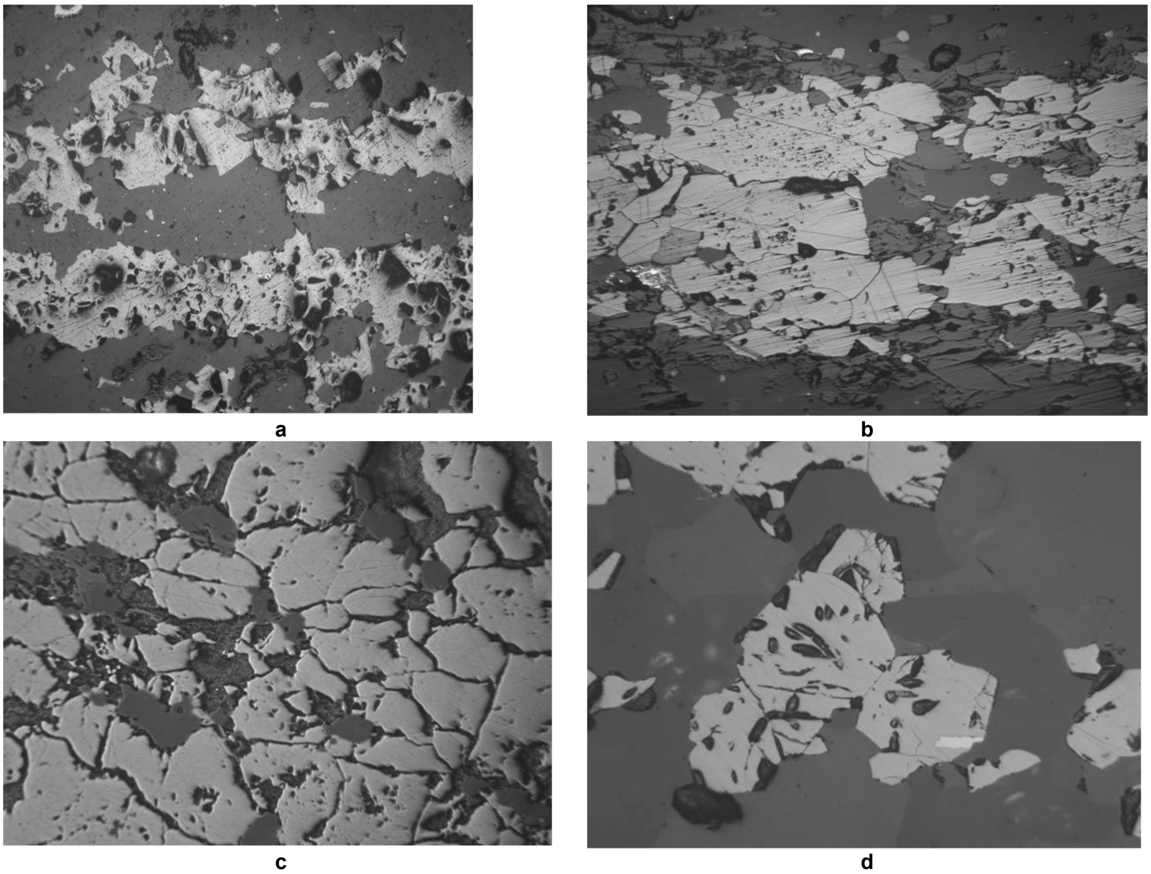


Fig. 1. The variability of magnetite aggregation in the mineral zones of the productive strata of Hannivka deposit:
a – ribbon-shaped aggregates of magnetite in micaceous-hematite-magnetite quartzites; b – block-shaped aggregates of magnetite in magnetite quartzites; c – dendrite aggregates of magnetite from cummingtonite-quartzites; d – subautomorphic individuals of magnetite from magnetite-cummingtonite quartzites. Microscopic observations in translucent light.
Nicol prism II. Magnification – 30^X; b-d – 50^X. Light grey colour – magnetite; dark grey colour – quartz

Larger individuals of magnetite are more typical for cummingtonite-magnetite quartzites. Large block aggregates and single large, subautomorphic individuals of magnetite are typical for the peripheral zones of magnetite-cummingtonite quartzites.

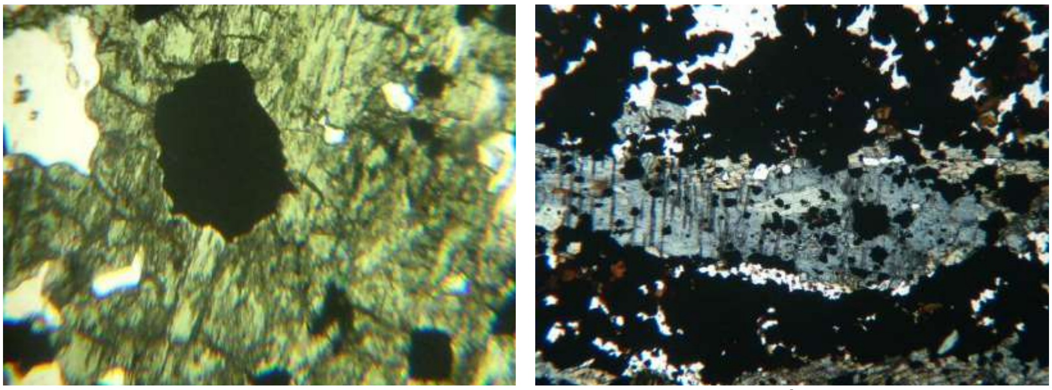
The change in the morphology of aggregates in mineralogical zones was also revealed for magnetite from sodium metasomatites bodies. Monomineral aggregates (ribbon-shaped, block-shaped) are typical for zones of riebeckitization. The aggregates of more complex morphology are typical for zones of aegirinization and silification of ferruginous quartzites, they are dendrite-block shaped, dendrite, and also impregnated ones (fig. 2). In the author's opinion, the reason for this is an active replacement of individuals and aggregates of magnetite with newly formed aegirine (alkaline metasomatizing solutions) and quartz (acidic solutions).

The zones of riebeckitization were formed by the influence of neutral solutions. These solutions contributed to the recrystallization of magnetite, which was accompanied by consolidation of its crystals and formation of aggregates. These aggregates were close in composition to the monomineral ones (fig. 2, b).

The tendency towards simplification of crystal form, approaching it to the crystallographically perfect form, can be illustrated by a decrease of the dihedral angles divergence from 120° at triple points of the magnetite aggregates *(Zhabin, 1979).*

The dihedral angle measurements were performed by the author with the use of mineragrafical microscopes in polished sections after pickling them for a short-time (30-40 sec.) in the hydrochloric acid steam. Measurements of three dihedral edges around triple points of contacts of magnetite crystals were performed for each microsection. The calculations were made for magnetite from unchanged and metasomatically changed ferruginous quartzites. The obtained results in the generalized form are given in the table 1 and 2.

According to the data obtained, the divergence of the dihedral angle from the ideal (120°) naturally and gradually decreases from micaceous-hematite-magnetite to magnetite-cummingtonite quartzites, that is to say, from the central to the peripheral productive strata zones of ferruginous horizons. The index of the mean square deviation of the dihedral angles is also reduced in this direction.



a b

Fig. 2. Magnetitemorphologyby mineral zones of sodium metasomatites of Hannivka deposit:
a – inclusions of magnetite crystals in the zones of aegirinization; b – monomineral aggregates of magnetite in zones of riebeckitization; Microscopic observations in translucent light. Nicol prism II. Magnification of 50^X. Legend: white colour – quartz; black colour – magnetite; blue colour– riebeckite; green colour– aegirine; brown colour- tetraferrousbiotite

Table 1

Morphological characteristics of magnetite from unchanged ferruginous quartzites of the productive strata of Hannivka deposit

№	Mineral varieties of ferruginous quartzites	Dihedral angles around triple points ± (120°–α)		
		n	x	S_x
1	micaceous-hematite-magnetite quartzites	18	10,1	6,1
2	magnetite quartzites	13	9,7	5,5
3	cummingtonite-magnetite quartzites	10	9,3	5,6
4	magnetite-cummingtonite quartzites	7	8,6	4,5

Studying the same indexes for mineralogical zones of metasomatic formations showed that in the zones of riebeckitization the growth of magnetite individuals is the closest to the ideal one (120°) comparing tothe zones of aegirinization and silification. This is confirmed by the above mentioned conclusion about the active dissolution and substitution of the magnetite crystals in the zones of aegirinization and silification, which determined their xenomorphism (fig. 2, a).

Table 2

Morphological characteristics of magnetite from sodium metasomatites of the productive strata of Hannivka deposit

№	Mineral varieties of metasomatites, formed in	Dihedral angles around triple points ± (120°–α)		
		n	x	S_x
	micaceous-hematite-magnetite quartzites			
1	Coarse-crystallin eriebeckite-magnetite-aegirine metasomatites	15	7,4	3,7
2	Micaceous-hematite-riebeckite-magnetitequartzites	13	6,7	2,1
3	micaceous-hematite-magnetite quartzites silicified	13	8,2	3,5
	magnetite quartzites			
4	Coarse-crystallineriebeckite-magnetite-aegirine metasomatites	15	7,8	3,7
5	Riebeckite-magnetite quartzites	7	7,4	1,8
6	Magnetite quartzites silicified	14	8,2	2,7

Notes: n – number of definitions; x is the average value of the indicators; Sx – standard deviation.

According to the study of magnetiteparticle size distribution, because of the mineralogical zoning of the fifth and sixth ferruginous horizons, the size of its crystals also naturally changes. Measurement was made with an eyepiece micrometer installed on a mineralographic microscope. Polished microsections were pretreated with concentrated HCl for determining individuals' boundaries in magnetite aggregates *(Ilnitskaya et al., 1969)*. Measurements of the magnetite crystals' size were carried out in two directions (along and across lamination of magnetite quartzites).The average size of the crystals was determined as the arithmetical mean of these two indexes. Accuracy of determination is 0,001 mm. About 150 determinations of the crystals' size were made for each polished section. The average value corresponded to the average size of the magnetite crystals of the corresponding sample. The research was carried out in polished sections of 27–38 samples of each mineral variety of ferruginous quartzites. The results are shown in fig. 3.

For more detailed analysis of the variability of the magnetite crystals size in sections of the ferruginous horizons, the recalculation of the obtained data (table 3) was also carried out after five granulometric classes of crystals (–0,02; +0,02-0,05; +0,05-0,1; +0,1–0,2; +0,2 mm).

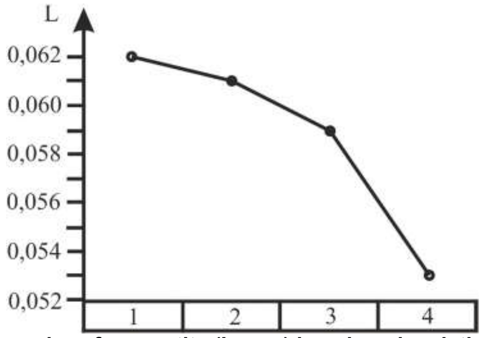


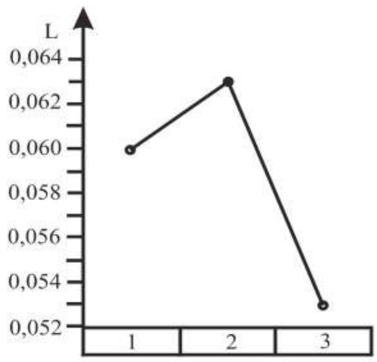
Fig. 3. Change in the average size of magnetite (L, mm) by mineral varieties of ferruginous quartzites in the productive strata of the deposit:
Mineral varieties of quartzite: 1 – micaceous-hematite-magnetite; 2 – magnetite; 3 – cummingtonite-magnetite; 4 – magnetite-cummingtonite

Table 3

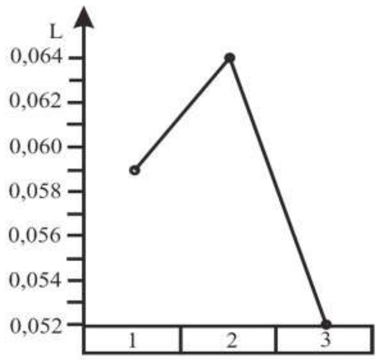
Particle size distributionof magnetite from the initial unaltered ferruginous quartzites of Hannivka deposit productive strata

№	Mineral varieties	Content (vol. %) of individuals and aggregates of magnetite in size, mm					average	Number of definitions (thin sections)
		less 0,02	0,02–0,05	0,05–0,1	0,1–0,2	more 0,2		
1	micaceous-hematite-magnetite quartzites	19,2	33,7	26,1	15,3	5,7	0,062	26
2	magnetite quartzites	21,8	31,1	26,0	14,6	6,5	0,061	27
3	cummingtonite-magnetite quartzites	27,7	25,7	24,2	13,4	9,0	0,059	24
4	magnetite-cummingtonite quartzites	29,2	21,9	23,6	9,7	10,1	0,053	21

There was a persistent tendency of increase in number of magnetite crystals that are less than 0.02 mm in size and more than 0.1 mm in size(the smallest and largest of them) in the direction from the central to the peripheral zones of both ferruginous horizons. The formation of the large crystals, in the author's view, can be explained by the magnetite accumulative recrystallization during cummingtonization of ferruginous quartzites in the contact areas of the horizons. This recrystallization was accompanied by the bimetasomatic phenomena at the progressive stage of dinamothermal metamorphism of ferruginous rocks. Bimetasomatosis was also accompanied by the active substitution of fine-grained magnetite with cummingthonite. This process resulted in the presence of a large number of small relict magnetite aggregates of the size up to 0.02 mm in the composition of magnetite-cummingtonite and cumingtonite-magnetite quartzites.



a



b

Fig. 4. The change in the average size of magnetite crystals (L, mm) in mineralogical zones of sodium metasomatites bodies, formed in micaceous-hematite-magnetite (a) and magnetite (b) quartzites of the fifth ferruginous horizon:
мineralzones: 1 – zone of aegirinization; 2 – zone of riebeckitization; 3 –zone of silification

A different tendency is typicalfor other bodies of sodium metasomatites (table 4): the number of crystals of the size of more than 0,1 mm increases in the zones of riebeckitization; individuals of less than 0,05 mm are dominant in the central and peripheral areas. Therefore, the magnetite from the riebeckitized zones has larger average size than that from the zones of aegrinization and silification.

Beingore-forming mineral, **quartz** is present in the ferruginous quartzite of all mineral varieties of both stratigraphic horizons of the productive strata. This mineral forms the main volume of non-metallic layers (85–99 vol. %) and as a minor mineral it is present (10–40 vol. %) in the ore layers.

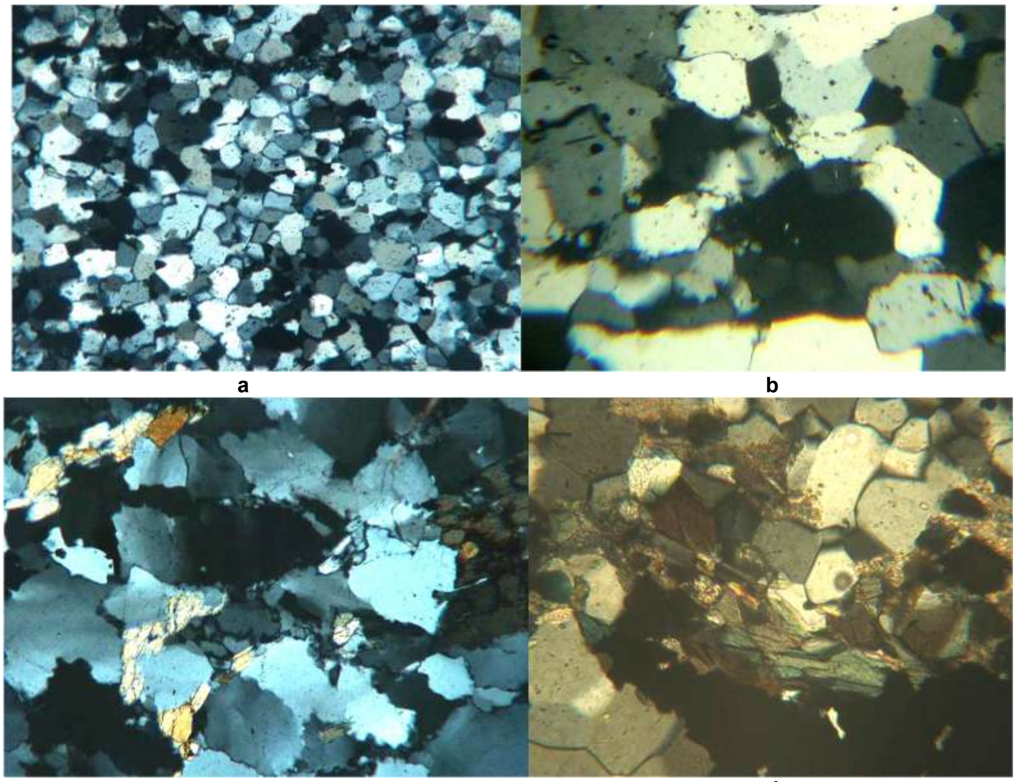
In order to establish the laws for changing the morphology of individuals of quartz, their particle size distribution, the author conducted mass determinations of the corresponding indexes in 466 polished microsection using petrographic microscopes and methods. These methods are similar to those used for morphological investigations of magnetite. The ferruginous quartzites, which form the autogenic zonation of ferruginous horizons and zonation of bodies of sodium metasomatites, were studied.

There exists a clear tendency towards simplifying the shape of quartz crystals in the sections of the ferruginous horizons in the direction from their central zones, consisting ofmicaceous-hematite-magnetite quartzites, through the intermediate ones, composed of magnetite and cumintonite-magnetite quartzites, to the peripheral zonesrepresented by magnetite-cummingtonite quartzites. This is manifested the most clearly in non-ore layers of ferruginous quartzites. Fine-grained aggregates of quartz with complex boundaries of individualsgrowth, numerous poikiloblasts of small (0,001–0,01 mm) scale crystals of micaceous-hematite are typical for micaceous-hematite-magnetite quartzites (fig. 5, a). In non-ore layers of magnetite quartzite, xenomorphic porphyroblastic quartz is rare. Aggregates of quartz without poikiloblasts of micaceous-hematite are quite common.The polymodality of quartz individuals is more characteristic for non-ore layers of cummingtonite-magnetite and magnetite-cummingtonite quartzites (fig. 5, b). This can be explained by the accumulative recrystallization of quartz aggregates which accompanied the synmetamorphic bimetasomatic processes in the contact zones of the ferruginous and schistose horizons (*Evtekhov, 1992*).

Table 4

Particle size distributionofmagnetitefrom sodium metasomatites of the productive strata of Hannivka deposit

№	Mineralvarietiesof metasomatites, whichwere formedin	Content (vol.%) of individuals and aggregates of magnetite of size, mm					average	Number of definitions (thin section)
		less 0,02	0,02–0,05	0,05–0,1	0,1–0,2	more 0,2		
	micaceous-hematite-magnetite quartzites							
1	Coarse-crystalline riebeckite-magnetite-aegirine metasomatites	21,3	28,2	32,9	11,0	6,6	0,060	23
2	Micaceous-hematite-riebeckite-magnetite quartzites	19,5	28,5	29,1	13,7	9,2	0,063	29
3	Micaceous-hematite-magnetite quartzites silificate	28,2	31,7	26,6	10,8	2,7	0,053	23
	magnetite quartzites							
4	Coarse-crystalline riebeckite-magnetite-aegirine metasomatites	21,8	27,9	33,1	10,9	6,3	0,059	24
5	Riebeckite-magnetite quartzites	21,5	25,7	31,3	15,1	6,4	0,064	32
6	Magnetite quartzites silificate	28,8	31,8	25,9	9,8	3,7	0,052	25



a b

c d

Fig. 5. Morphology of quartz in non-ore layersof the ferruginous quartzites of Hannivka deposit:
a – small crystals of quartz in micaceous-hematite-magnetite quartzites; b – crystals of quartzinnon-orelayers of the cummingtonite-magnetite quartzites; c, d – quartz in sodium metasomatites. Microscopic observations in translucent light. Nicol prism X. Magnification 50^X. Colour from white to black – quartz; brown colour – tetraferrousbiotite; yellow colour-cummingtonite

The inverse character of the evolution of the morphology of quartz individuals is determined for bodies of sodium metasomatites. The most perfect polygonal forms are characteristic for the central metasomatic zones, represented by aegirine metasomatites. The increased alkalinity of metasomatizing solutions caused here not only the substitution of quartz by aegirine and accumulating recrystallization of its crystals from polygonal aggregates formation (fig. 5, c) but also, this process was active in the intermediate zones of riebeckitization. In the peripheral zones of silification, quartz is represented by fine-grained aggregates of xenomorphic individuals (fig. 5, d).

The values of the dihedral angles at triple points of quartz aggregates (table 5 and 6) are closely related to the morphology of its individuals.

In the general case, the value of deviation of this index from 120° decreases significantly from polygonal aggregates to xenomorphic crystal ones. As a result, this tendency can be observed in the zones of the authigenic rhythms in the direction from the central to the peripheral zones of the ferruginous horizons and in the zones of metasomatic bodies in the opposite direction – from the peripheral to the central zones.

Table 5

Morphological characteristics of quartz from unchanged ferruginous quartzites of the productive strata of Hannivka deposit

№	Mineral varieties of ferruginous quartzites	Dihedral angles around triple points ± (120°–α)		
		n	x	S_x
1	micaceous-hematite-magnetite quartzites	27	12,7	7,2
2	magnetite quartzites	24	12,3	7,1
3	cummingtonite-magnetite quartzites	21	11,8	6,9
4	magnetite-cummingtonite quartzites	18	11,4	6,7

Notes: n – number of definitions; x is the average value of the indicators; Sx – standard deviation.

Table 6

Morphological characteristics of quartz from sodium metasomatites of the productive strata of Hannivka deposit

№	Mineral varieties of metasomatites, which were formed in	Dihedral angles around triple points ± (120°–α)		
		n	x	S_x
	micaceous-hematite-magnetite quartzites			
1	Coarse-crystalline riebeckite-magnetite-aegirine metasomatites	43	6,4	1,7
2	Micaceous-hematite-riebeckite-magnetite quartzites	67	5,3	1,0
3	micaceous-hematite-magnetite quartzites silificate	36	6,1	1,9
	magnetite quartzites			
4	Coarse-crystalline riebeckite-magnetite-aegirine metasomatites	43	6,4	1,7
5	Riebeckite-magnetite quartzites	35	4,8	1,1
6	Magnetite quartzites silificate	29	6,3	2,4

From the data of table 5 and table 6 it is clear that metasomatic quartz is characterized by a more significant approximation to the equilibrium shape of crystals. This is likely to be due to a more active effect ofalkaline solutionson the morphology of quartz in comparison with metamorphogenic one.

The particle size distributionof quartz was determined according to the method described above for the magnetite. 100–150 determinations of the size of quartz crystals were made for each thin rock section. For each mineral variety of ferruginous quartzites (table 7) and metasomatites (table 8), measurements were fulfilled in transparent thin sections made from material of 27–38 samples.

Recalculating of the obtained data for a more detailed analysis of the variability of the size of quartz crystals in the sections of the ferruginous horizons, similar to that for the magnetite, was made for five granulometric classes of crystals (–0,02; + 0,02–0,05; + 0,05 – 0,1; + 0,1 – 0,2; + 0,2 mm). The results of calculations are shown in fig. 6.

Table 7

Particle size distribution of quartz from the initial nonchanged ferruginous quartzites of the productive strata of Hannivka deposit

№	Mineral varieties	Content (vol. %) of individuals and aggregates of magnetite in size, mm					average	Number of definitions (thin sections)
		less 0,02	0,02–0,05	0,05–0,1	0,1–0,2	more 0,2		
1	micaceous-hematite-magnetite quartzites	36,2	37,9	22,8	2,9	0,2	0,039	26
2	magnetite quartzites	30,1	40,8	24,8	3,9	0,4	0,042	27
3	cummingtonite-magnetite quartzites	28,4	41,5	25,3	4,3	0,5	0,043	24
4	magnetite-cummingtonite quartzites	25,3	42,2	26,5	4,8	1,2	0,046	21

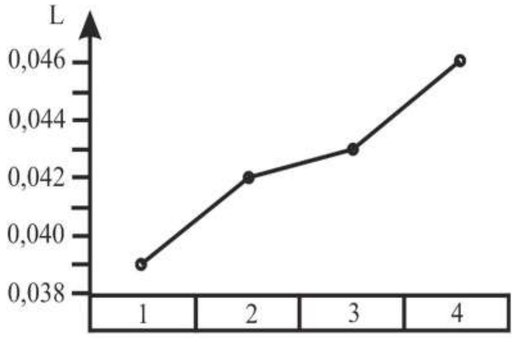


Fig. 6. Change in the average size of quartz crystals (L, mm) by mineral varieties of ferruginous quartzites in the fifth ferruginous horizon:

мineral varieties of quartzites are as follows: 1 – micaceous-hematite-magnetite; 2 – magnetite; 3 – cummingtonite-magnetite; 4 – magnetite-cummingtonite

According to the data obtained, the number of the smallest crystals of metamorphogenic quartz (to 0,02 mm) is noticeably reducedin the direction from the center to the periphery of the ferruginous horizons. In the same direction, the number of its individuals of other granulometric classes (more than 0,02 mm) increases. This can be explained by the manifestation of quartz accumulating recrystallization, which accompanied bimetasomatic cummingtonization of ferruginous quartzites in the contact zones of the ferruginous horizons.

The reverse tendency is typical for quartz from metasomatic zones: the number of the smallest individuals (granulometric fractions up to 0,02 and 0,02–0,05 mm) increases in the direction from the central zone of aegirinization to the peripheral zone of silification. The number of larger individuals (more than 0,05 mm in size) decreases in this direction. This can also be explained by the fact that along with replacement of quartz with the newly-formed minerals (aegirine, riebeckite) in alkaline medium of metasomatic solution, relict quartz accumulating recrystallizationtook place, which was accompanied by consolidation of its crystals.

Table 8

Particle size distribution of quartz from sodium metasomatites of the productive strata of Hannivka deposit

№	Mineral varieties of metasomatite bodies, whichwere formedin	Content (vol.%) of individuals and aggregates of magnetite in size, mm					average	Number of definitions (thin sections)
		less 0,02	0,02–0,05	0,05–0,1	0,1–0,2	more 0,2		
	micaceous-hematite-magnetite quartzites							
1	Coarse-crystallineriebeckite-magnetite-aegirine metasomatites	19,4	19,7	39,4	11,2	10,3	0,065	23
2	Micaceous-hematite-riebeckite-magnetite quartzites	21,3	26,4	35,4	8,5	6,4	0,057	29
3	micaceous-hematite-magnetite quartzites silificate	24,9	32,1	34,1	7,4	2,7	0,053	23
	magnetite quartzites							
4	Coarse-crystallineriebeckite-magnetite-aegirine metasomatites	20,1	20,7	39,2	10,9	9,1	0,064	24
5	Riebeckite-magnetite quartzites	22,6	23,9	36,6	8,3	4,6	0,056	32
6	Magnetite quartzites silificate	19,2	36,8	35,2	7,2	1,6	0,054	25

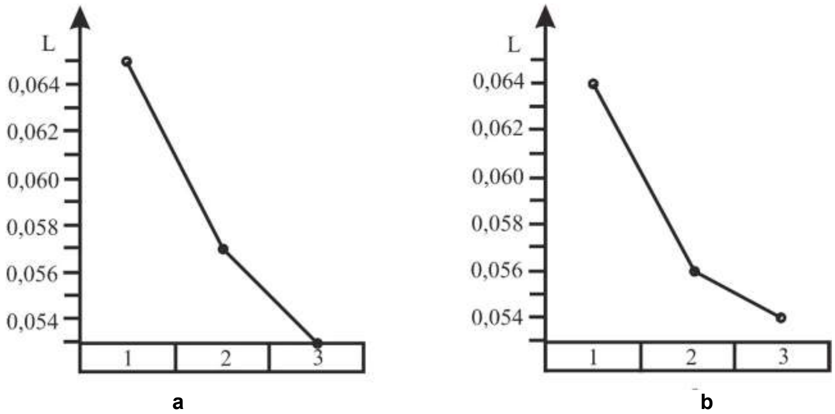


Fig. 7. The change in the average size of quartz crystals (L, mm) in mineralogical zones of bodies of sodium metasomatites, formed in micaceous-hematite-magnetite (a) and magnetite (b) quartzites of the fifth ferruginous horizon:
мineralzones: 1 – zone of aegirinization; 2 – zone of riebeckitization; 3 – one of silification

The index of idiomorphism of crystals of rock forming minerals (magnetite and quartz) increasesin the direction from the central to the peripheral zones of the autigene mineralogical zoning of the productive strata, the size of the magnetite crystals decreases (from 0,062 to 0,053 mm), and that of the quartz increases (from 0,039 to 0,046 mm). The regularity of variability of morphological indices is also typical for bodies of epigenetic formations: rock-forming minerals from intermediate zones, which are composed of riebeckitizedvarieties of ferruginous quartzites, have the most ideal growth patterns and the maximum sizes of crystals.

Conclusions. Research of the morphological features of magnetite showed that it forms ribbon-shaped, rarely block-shaped, dendriteaggregatesin unchanged ferruginous quartzites,depending on its location in the section of the productive strata. In metasomatically changed rocks, an ore mineral forms monomineral aggregates (ribbon-shaped, block-shaped) that are typical for the riebeckitization zones, and those of more complex morphology (dendrite-block-shaped, dendrite) aggregates that are more typical forzones of aegirinezation and silification of the ferruginous quartzites.

Regularities were also observed when quartz was studied. For unchanged ferruginous quartzites, the change in quartz aggregates from fine-grained with complex boundaries of individuals' growth to medium-grained ones, is typical. Inverse evolution character of morphology of quartz individuals was determined for bodies of sodium metasomatites. Their most perfectpolygonal forms are typical for the central metasomatic zones represented by aegirine metasomatites. In the peripheral zones of ferruginous quartzites silification, quartz is represented by fine-grained aggregates of xenomorphic individuals.

The values of dihedral angles at triple points of magnetite aggregates and quartz are closely related to the morphology of their individuals. The results of studying the angles confirm the conclusions about the variability of morphological features of the main minerals in the productive strata of the deposit.

The results of studying the particle size distributionof magnetite and quartz have shown that for unchanged quartzites, the average size of magnetite and quartz is, accordingly, 0,059 and 0,043 mm, for metasomatically changed ones it is 0,059 and 0,058 mm. The obtained data ought to be used in the compilation of mineralogical recommendations when selecting the methods for preparing ore for beneficiation.

The obtained results are the basis for topominerological studies of banded-iron formations of the Kryvyi Rih basin. The results of topomineralogical and technological studies were the basisfor compiling mineralogical and technological maps of the deposit and the Northern region in general, which are used for operational and long-term mining planning, in the development of flowsheet for optimal iron ores blending before being sent to beneficiation plants, for constant monitoring of ore mining sectionsaccording to their mineralogical and technological parameters. The implementingof these measures will contribute to improving thequality of iron ore concentrate, increasing the concentrate yield and reducing the iron losses in the beneficiation waste.

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МОРФОЛОГІЧНІ ОСОБЛИВОСТІ МАГНЕТИТУ ТА КВАРЦУ ПРОДУКТИВНОЇ ТОВЩІ ПІВНІЧНОГО РАЙОНУ КРИВОРІЗЬКОГО БАСЕЙНУ

На сьогоднішній день перед геологічною службою Ганнівського родовища Північного ГЗКу стоїть завдання забезпечення гірничозбагачувальних комбінатів сировиною, яка дозволить отримувати високоякісний залізорудний концентрат, що відповідає вимогам світового ринку. Вирішення цього завдання можливо з урахуванням морфологічних особливостей головних породотвірних мінералів, і як наслідок, природних можливостей руд, збільшення ефективності усереднення руд різних мінеральних різновидів, які мають різний технологічний потенціал, з метою отримання рудної сировини, що подається на збагачувальні фабрики.

Дослідження морфологічних особливостей головних мінералів у незмінених і метасоматично змінених залізистих кварцитах проводились за стандартною методикою. Вимірювання розмірів зерен магнетиту та кварцу проводилось за допомогою окуляр-мікрометра, який встановлюється на мінераграфічному мікроскопі. При визначені їхніх середніх значень використовувались математичні методи.

Наведено результати вивчення морфологічних особливостей головних мінералів залізорудної товщі, їхню варіативність залежно від розташування в межах незмінених і метасоматично змінених залізистих кварцитів Ганнівського родовища Північного району. Показано результати вивчення дігедральних кутів кристалів магнетиту та кварцу, зміна гранулометричного складу цих мінералів залежно від накладених геологічних процесів на залізисто-кременисту формацію Криворізького басейну.

Наукова новизна обумовлена детальним проведенням мінералогічних досліджень морфології магнетиту та кварцу залежно від їхнього розташування в розрізі залізисто-кременистої формації Криворізького басейну, а також у подальшому використанні цих результатів при топомінералогічному картуванні Північного району.

Отримані результати необхідно врахувати при мінералогічному картуванні родовища і Північного району Криворізького басейну загалом, при уточненні мінерально-технологічної класифікації руд і усередненні мінеральних різновидів руд перед подачею на збагачувальні фабрики.

Ключові слова: Український щит, Криворізький басейн, Ганнівське родовище, залізисто-кремениста формація, залізисті кварцити, морфологія магнетиту, морфологія кварцу.

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МОРФОЛОГИЧЕСКИЕ ОСОБЕННОСТИ МАГНЕТИТА И КВАРЦА ПРОДУКТИВНОЙ ТОЛЩИ СЕВЕРНОГО РАЙОНА КРИВОРОЖСКОГО БАССЕЙНА

На сегодняшний день перед геологической службой Анновского месторождения Северного ГОКа стоит задача обеспечения горнообогатительных комбинатов сырьем, которое позволяет получать высококачественный железорудный концентрат, соответствующий требованиям мирового рынка. Решение этой задачи возможно только с учетом морфологических особенностей главных породообразующих минералов и, как следствие, природных возможностей руд, их обогатительных свойств, повышение эффективности усреднения руд разных минеральных разновидностей, имеющих различный технологический потенциал, с целью получения оптимального состава рудной смеси, подающейся на обогатительные фабрики.

Изучения морфологических особенностей главных минералов в неизмененных и метасоматически измененных железистых кварцитах проводились по стандартной методике. Измерения размеров зерен магнетита и кварца проводилось с помощью окуляр-микрометра, установленного на минераграфическом микроскопе. При определении их средних значений использовались математические методы.

Приведены результаты изучения морфологических особенностей минералов железорудной толщи, их вариативность в зависимости от расположения в пределах неизменных и метасоматически измененных железистых кварцитов Анновского месторождения Северного района. Показаны результаты изучения дигедральных углов кристаллов магнетита и кварца, изменения гранулометрического состава этих минералов в зависимости от наложенных геологических процессов на железисто-кремнистую формацию Криворожского бассейна.

Научная новизна состоит в детальном проведении минералогических исследований магнетита и кварца в зависимости от их расположения в разрезе железисто-кремнистой формации Криворожского бассейна. А также в дальнейшем использовании этих результатов при топоминералогическом картировании Северного района.

Полученные данные по вариативности морфологии главных минералов железорудной толщи необходимо учитывать при минералогическом картировании месторождения и Северного района Криворожского бассейна в целом, а также при уточнении минерально-технологической классификации руд и усреднении минеральных разновидностей руд перед подачей на обогатительные фабрики.

Ключевые слова: Украинский щит, Криворожский бассейн, Анновское месторождение, железисто-кремнистая формация, железистые кварциты, морфология магнетита, морфология кварца.