MGPB

The influence of geology and ore deposit occurrence conditions on dilution indicators of extracted reserves

The Mining-Geology-Petroleum Engineering Bulletin
UDC: 622.013.364.3
DOI: 10.17794/rgn.2019.1.8

Original scientific paper

Mykhailo Petlovanyi[1]; Vasyl Lozynskyi[2], Serhii Zubko[3]; Pavlo Saik[4], Kateryna Sai[5]

[1] *Dnipro University of Technology, Mining Faculty, Underground Mining Department, Yavornytskoho Ave 19, UA-49005 Dnipro, Ukraine, https://orcid.org/0000-0002-8911-4973*

[2] *Dnipro University of Technology, Mining Faculty, Underground Mining Department, Yavornytskoho Ave 19, UA-49005 Dnipro, Ukraine, https://orcid.org/0000-0002-9657-0635*

[3] *PJSC "Zaporizhzhia Iron-ore Plant", UA-69061 Zaporizhzhia, Ukraine*

[4] *Dnipro University of Technology, Mining Faculty, Underground Mining Department, Yavornytskoho Ave 19, UA-49005 Dnipro, Ukraine, https://orcid.org/0000-0001-7758-1083*

[5] *Dnipro University of Technology, Mining Faculty, Underground Mining Department, Yavornytskoho Ave 19, UA-49005 Dnipro, Ukraine, https://orcid.org/0000-0003-1488-3230*

Abstract

The development of iron-ore deposits is accompanied by the excavation formation of considerable dimensions in the underground space and to ensure high technical and economic indicators of extraction, especially when developing high-grade iron ore, it is necessary to take into account the nature of the geological structure of the massif on the indicators of their dilution. It is established that when the chambers are worked out on a junction with hanging wall waste, the indices of ore dilution with the adjacent strata are 1.7 times higher than on a junction with the foot wall of the deposit. The tendencies and causes of variability of volume of extracted ore dilution with the adjacent strata in different geological structure parts of the ore deposits are revealed, the ore basin across the pitch is characterized by a general evolving trend of the rock strength of the hanging wall and ore basin angle of incidence decreasing and increasing the thickness of the deposit from the northern side to the southern one. It has been established that the concentration of hanging rocks caving and extracted ore dilution indices is enhanced by changing their morphological composition, reducing the strength and stability of these rocks, reducing the ore basin angle of incidence, and increasing the ore deposit thickness. The obtained results allow us to lay the foundations for optimizing the parameters of the development system and the rational procedure for breaking up ore reserves in the chambers under the changing mining and geological conditions of field development.

Keywords:
iron ore, deposits, mining, dilution, geological structure

1. Introduction

Underground mining is complicated by the influence on the technology of a complex of mining-geological factors **(Snihur et al., 2016)**. Especially geological factors are important in the excavation's formation of considerable dimensions in the underground space **(Sotskov and Saleev, 2013; Pivnyak and Shashenko, 2015)**, which is characteristic for the development of iron-ore deposits, which are worked out with extraction chambers in the established order. Such a property as rock mass staying during underground development is important, since it primarily depends on the mining operations' safety and the economic indices of mining as a result of mine destruction or rock caving, especially in the development of high-grade ores with high content of useful components **(Falaknaz et al., 2015; Basarir et al., 2018; Lozynskyi et al., 2018)**. For underground ores mining technology, factors such as the angle of incidence and ore deposit capacity, strength and fracture of the array, as well as the main indicators of output such as loss and dilution of ores, which testify to the efficiency of the accepted development system, are of great importance.

Mining in areas with increased rock fracturing is considerably complicated due to the decrease of their strength characteristics (**Lozynskyi et al., 2018; Dychkovskyi et al., 2018, a)**, the angle of deposit incidence influences the pressure of the hanging rocks, with its increase, the pressure decreases **(Chistyakov et al., 2012)**, and the power of the deposit on baring distance of stopes increases **(Tsarikovskiy and Sirotyuk, 2012)**. In such conditions, stopping operations is organized in two or more steps. Broken ore is dumped using feeders or slop-

Corresponding author: Vasyl Lozynskyi
lvg.nmu@gmail.com

ing the bottom of mine cars on the haulage horizon **(Dychkovskyi et al., 2018, b).**

Annually in the Ukraine, about 75 – 80 million tons of iron-ore are extracted, moreover about 15.0 million tons are extracted by 9th mines through the underground method **(Khomenko et al., 2017)**. A significant part of underground mining (25%) is occupied by PJSC "Zaporizhzhia Iron-ore Plant", which develops high-grade iron ore (iron content more than 60%) in the Belozerskyi iron ore region. For working ores, a highly-efficient developing chamber system is used in these conditions with the subsequent of filling mined-out space with consolidating stowing **(Kuzmenko and Petlovanyi, 2015; Kuz'menko et al., 2013; Kuz'menko et al., 2010)**, where stopes alternate in time with stowages in complex geological conditions. Complex conditions are determined by the aquifers' occurrence in ore-crystalline area in the roof, unstable hanging rocks in the southern part of the bank with a coefficient of strength on the scale of prof. M.M. Protodiakonov $f = 7 – 9$, the depth of development (640 – 940 m), fracture of the array. In such circumstances, mining technology requires continuous improvement under the influence of changing natural and man-made environment.

The influence of geological factors on the rock massif stability is noted in a number of scientific works **(Forster et al., 2007; Barba and Nordlund, 2013; Suglo and Opoku, 2012).** However, studies of the simultaneous influence of complex geological factors of the ore deposits occurrence on the rock massif stability in literary sources have not been adequately considered. Thus, the determination of the ore deposit geological environment influence on the rock massif stability is always a topical issue for mining science and production.

2. Technological features of the Southern-Bilozerka deposit development

Studies of the geological environment degree of influence on the baring stability and the quality of mined ore were carried out for the Southern-Bilozerka iron-ore deposit. Currently, iron-ore reserves with an iron content of more than 60% are being developed in the depth interval 305 – 940 m. The ore reserve excavation is carried out with high stopes with the subsequent filling of mined-out space with a consolidating mixture of man-made waste. The height of the chamber is 100 – 200 m, and the width is 30 m. Depending on the power fluctuations, 2 – 3 chambers are located in the transverse of the pitch, and the reserves are drilled from the hanging side to the foot and vice versa. Thus, in the development of pitch-dipping ore deposits with stowing, the rock massif is directly an ore deposit that is being developed, adjacent strata of the hanging and foot walls, as well as concrete block **(Russkikh et al., 2012; Russkikh et al., 2013)**.

With this mining technology of high-grade iron ore excavating, the natural massif is replaced with concrete blocks as time passes. The peculiarities of the development technology are that according to the "chamber-pillar" scheme, first-stage chamber reserves are extracted at first in the ore massif.

After they have been worked out (Stage I), the chambers are filled with a consolidating mixture and, after the required strength is set, the ore reserves are mined between the concrete blocks, while filling mass of former first-stage chambers.

Stopes, depending on the order of the work, can contact the ore massif, adjacent strata of the hanging and foot walls, a concrete block or a system of junctions. The greatest damage to the quality of mined ore is caused by a junction with the concrete block, since in case of its caving, the filling material does not contain a useful component and significantly reduces the average content of iron in the ore mined from the chamber. The junction of the stope with the adjacent strata also has a negative effect, but to a lesser extent, which is explained by their iron content of 25 – 30%. The junction of the stope with the ore massif, in principle, does not have a negative effect, since in the case of ore caving from the neighboring chamber with an iron content of 55 – 60%, the content of the useful component will not decrease, but this will change the shape of the chamber and make it difficult to develop its reserves in the future.

The stability of the natural rock massif barings in the ore extraction from the stopes, and, consequently, its quality depends primarily on the geological factors such as the structure and strength of the rocks, the fracture of the rocks, the angle of incidence and thickness of ore deposit, and the stability of concrete blocks depends to a greater extent on filling the massif formation technology and its strength properties **(Streltsov et al., 2017; Rudy, 2017)**.

3. Detection of stopes with increased extracted ore dilution with adjacent strata

Mined ore dilution occurs in the event of trouble in the actual contour of the stopes due to adjacent strata or concrete block caving. As a rule, in all mines, the cases of adjacent strata, ores and stowages caving in the work out chambers are fixed by the surveying service. It should be noted that even in the first-stage chambers, a concrete block from the bottoms of worked out chambers can cave from above **(Petlovanyi, 2015)**, and major cavings are also recorded in special inspection certificates.

The degree of geological factor influence can be characterized by comparing and scientifically analyzing the amount of ore dilution in the used-up chambers (with adjacent strata or concrete block) with the geological factors of these chambers' occurrence, while excluding the facts of concrete block caving.

To study the influence of geological factors on the massif stability and ore dilution, a deck of 640 – 740 m was adopted, the reserves of which have been developed at the present time by more than 80%. A detailed analysis of the deck development history in the period 2000 – 2013 made it possible to identify 42 chambers worked out in junction with the hanging (22 pcs.) and foot walls (20 pcs). Of the 22 chambers worked out on junction with the hangingwall rocks, in 6 chambers large concrete block caves were noted, with the largest ore dilution reaching 5%. While developing 20 chambers on junction with the footwall rocks, in 12 chambers large concrete block caves were marked, and the ore dilution with stowage reached 8% in some cases. From this it follows that when working out 16 chambers of hangingwall and 8 chambers of footwall, the key factor of ore dilution is the influence of the ore deposits geological structure.

Analysis of the average amount of dilution in 16 chambers, worked out on junction with the hangingwall and 8 chambers with footwalls in 640 – 740 m level deck, revealed an exaggeration of ore dilution developed in the chamber on hangingwall side over the chambers of the footwall by 1.7 (see **Fig. 1**). Used-up chambers in which dilution occurred with concrete block are excluded from analyses.

The increased chambers dilution in the hangingwall of the deposit (see **Fig. 1**) is explained by the fact that the chambers on the hangingwall side are subjected to the pressure of the whole rock column to the earth's surface. Strengthening the pressure of the hangingwall rocks as the chambers were worked out was also repeatedly noted in work **(Chistyakov et al., 2012)**.

The breaking up ore reserves in the chambers is carried out successively from the centre of the deposit in the direction of the rocks of the hangingwall (**Fig. 2,a**), gradually exposing them to the formation of goaf while they are being extracted. The seismic impact of explosive blasting also affects the condition of the rocks of the hangingwall, especially if the rocks are characterized by low strength and stability. The combination of all these factors leads to the destruction of the rock mass of the hangingside, which leads to dilution of the extracted ore (**Fig. 2,b**).

The chambers of the footwall side of the deposit are located in reduced stress zone due to the protective (unloading) effect of above worked out and filled stopes stowage, as a result of which their structural elements are in the zone of reduced stresses and possess better stability. Therefore, in the chambers at the footwall side of the ore deposit, the dilution with rocks was observed less often or there were dumps of the stowage from the bottom of the above worked out and filled stopes. From this, it follows that the geological factors of the adjacent strata have a larger effect on chambers' dilution that are worked out on junction with hangingwall rocks than in

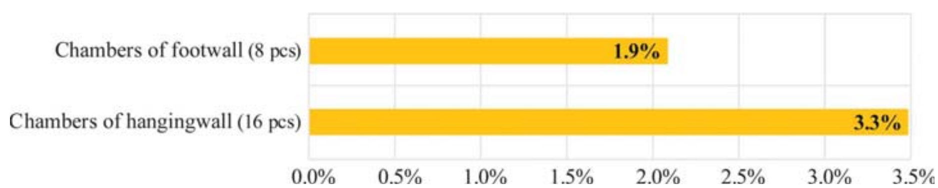

Figure 1: The average amount of ore dilution in the chambers worked out on junction with the hangingwall and footwall rocks.

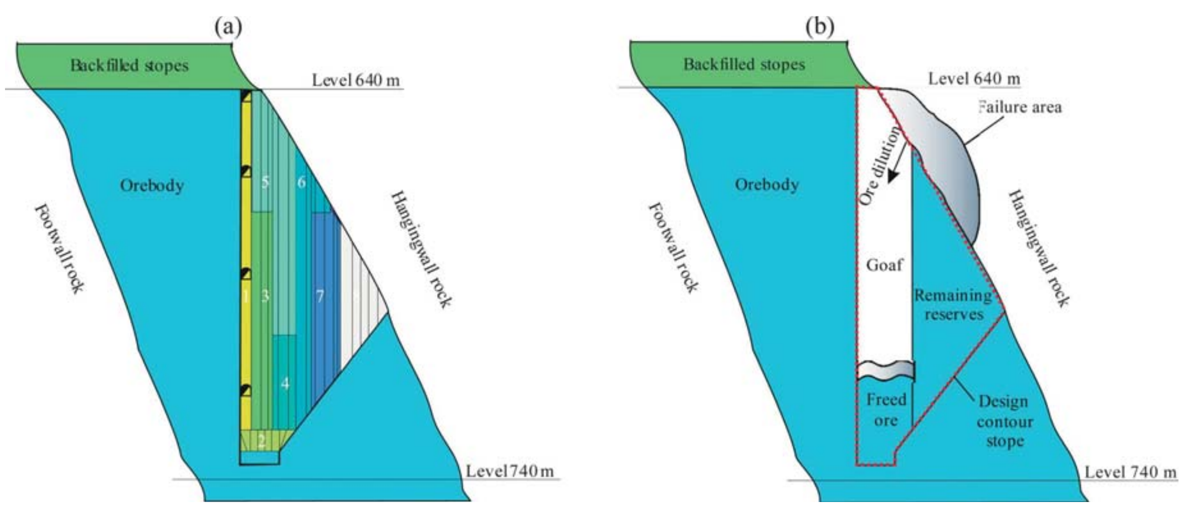

Figure 2: Schematic diagram of ore dilution with hangingwall rocks in the chamber: (a) the order of ore extraction in the chamber; (b) ore dilution from the chamber on junction with hangingwall; 1 – 8 numerical order

the footwall. Therefore, later on, the geological structure of the ore deposit and hangingwall rocks was studied.

Analysis of ore dilution amount in 16 chambers worked out on junction with hangingwall rocks made it possible to reveal the minimum and maximum interval of its values – 0.89 – 8.02%. The chambers were grouped according to the amount of ore dilution in intervals of 0.0 – 2.0; 2.0 – 4.0; 4.0% and (see **Table 1**) for the convenience of further determination of the degree of the geological environment influence on dilution.

Table 1: Grouping of stopes by amount of ore dilution with the hangingwall rocks

Amount of dilution	Areas with ore dilution
0.0 – 2.0	10n, 7n, 4n, 1n, 0, 11s
2.0 – 4.0	26n, 17n, 2s, 3s, 9s
4.0% and >	3n, 2n, 6s, 8s, 20s

To visualize the stopes worked out from the hangingwall side (see **Table 1**), it is proposed to isolate them on the horizon plan 740 m, where the pitch of the ore deposit is represented and note the groups of chambers in terms of dilution with special lines. The ore deposit "Holovna" across the pitch is divided into 3 sections: the northern part, the central part and the southern part. For effective planning of mining development, the ore deposit from the centre to the flanks is conditionally divided into the mine surveyor axis every 30 m with the notation "n" – north, "0" – centre, "s" – south. Mining unit – stopes are also numbered in the ranking, according to the mine surveying axis and the development order (for example, 1/3n, 2/3n). The parts of the ore deposit, where chambers are worked out on junction with the hangingwall sides, are plotted on the horizon of 740 m and marked with a palette of colors according to the degree of dilution, and according to grouping (see **Fig. 3**).

Hangingwall chamber distribution across the pitch of the ore deposit in the deck of 640 – 740 m (see **Fig. 3**)., according to the ore dilution amount, shows ore deposit areas where the rock massif tends to cave, but detailed analysis of its geological structure will identify and formulate causes of increased ore dilution in these chambers.

4. Analysis of the rock massif geological structure across the pitch of ore deposit

The high-grade haematinic martite ores of the Southern-Bilozerka deposit (Fe > 60% content) occur in complex geological and hydrogeological conditions. Complex conditions are characterized by the occurrence of aquifers in the roof of the ore-crystalline massif, as well as by water content of massif, partial instability of hangingwall rocks, and the fracturing of the massif. The main deposit size across the pitch on the horizon 740 m is about 1500 meters and down dip ore reserves have been explored up to 1500 m. The fall of ferruginous quartzite, shale and ore is pitch-dipping: North East and East in the southern part of the deposit and the South East in the northern part. The angle of incidence increases from south to north – from 60 – 65° to 80 – 85°.

Mining and geological conditions of "Holovna" ore deposit occurrence are characterized by significant variability across its pitch. The northern, central and southern parts differ in the composition of ores and adjacent strata, the content of iron in the ore, the hardness, the

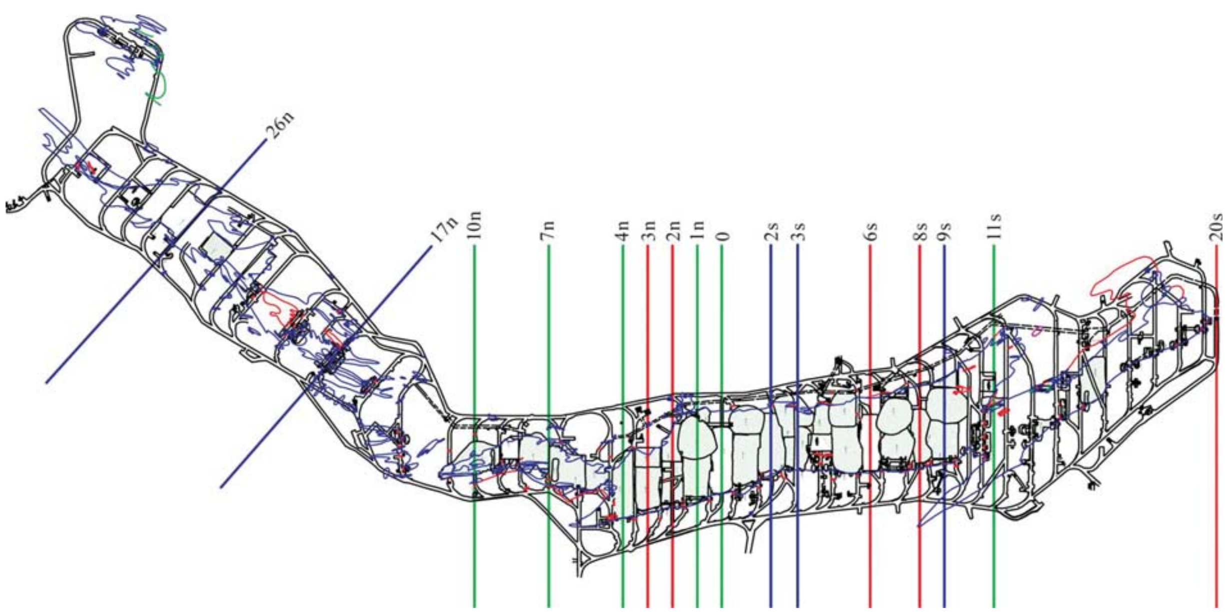

Figure 3: Distribution of hangingwall chambers by the dilution amount in the deck of 640 – 740 m. The amount of ore dilution in the chambers: □ <2.0%; □ 2.0-4.0%; □ >4.0%

fracture, the thickness of the deposit and the angle of its incidence. Furthermore, the characteristic geological features for each part of the deposit are considered.

The northern part of the deposit according to the ore bodies morphology and the adjacent strata composition differs considerably from the southern and central part of the deposit and extends 650 m from the mine surveyor axis 30n to 8n. The thickness of the ore deposit varies from 20 to 60 m. The average ore hardness is $f = 9.5$. The ore deposit of the northern part is cleaved into several dykes, they are separated by quartzites, mainly haematinic martite composition with a thickness of 7 – 15 m with reduced iron content. The adjacent strata of the footwall is mainly quartzites of haematinic martite composition with hardness $f = 14 – 15$. From the hangingwall, the adjacent strata are also quartzites, mainly of haematinic martite composition with hardness $f = 14 –$ 15, medium stability and fracturing. There are areas of strong fracturing of the rocks of the hanging wall, cracks of the I-III order, multidirectional, intersecting, forming a block structure. The contact of the ore body with the enclosing rocks has a folded shape, interlayering of ore and rocks is observed that reduces stability.

The central part of the deposit extends 400 m and is located between the axes of 8n and 5s. The ore body thickness in this part is quite high and fluctuates within 100 – 120 m, the average ore hardness decreases and reaches $f = 7.0$. In the hangingwall and footwall overlie quartzite $f = 14 – 15$, give way as they approach the southern part to shales quartz-chlorite-sericite, quartz, chlorite, sericite, quartz and hematite-chlorite composition with hardness $f = 7 – 9$ to 8 – 10 of medium stability and fracturing.

The southern part of the deposit extends 450 m and is located between the axes of 5s and 20s. The ore body occupies almost the entire iron ore horizon, here the thickness of the deposit increases from the centre to the south from 60 m to 150 m, and the ore hardness is $f =$ 6.5. As in the hangingwall and in the footwall adjacent strata is quartz-chlorite schists; sericite, quartz, chlorite; sericite, quartz and haematinic martite composition with hardness $f = 7 – 9$ to 8 – 10 and medium stability and fracturing. With depth of ore body occurrence, an increase in semi-stable quartz-chlorite-sericite schists of low hardness f = 6-9 in the scope of distribution of the hangingwall rocks in the southern part of the deposit is observed, which is 60 m at a depth of 400 m; 150 m at a depth of 640 m; 330 m at a depth of 740 m; and 600 m at a depth of 840 m.

It should be noted anomalously high and developed fracturing, which occurs locally in the northern and the southern part of the deposit and forms areas of low stability of the array, breaking it into blocks. The ore deposit junction with adjacent strata is rugous, which also contributes to ore dilution.

Such significant changes in the geological structure of the ore deposit are also responsible for changes in mining technology. Thus, for example, in the northern part of the deposit, due to the insignificant thickness of the deposit (30 – 50 m), there is one stope transverse of the pitch at its thickness, and 2 – 3 stopes are located in the central and southern parts, where the thickness reaches more than 100 m transverse of the pitch. When working out the chambers of the last stage, this leads to an increase in the number of junctions with the concrete block, which, when diluted, causes more damage to the quality of the mined ore.

With increasing development depth, the useful ore area of the deposit is also reduced. Thus, the ore area of the southern flank at a depth of 253 m is 95 thousand m^2, which is reduced by 5 thousand m^2 with a deepening for every 100 m. On the northern flank, the degree of mineralization is much less than in the southern flank, but with depth it will increase. This circumstance makes it possible to compensate for the decreasing power of the southern flank with an increase in the development depth **(URL, 2018)**.

Thus, the heterogeneous geological structure of the deposit and rock massif determines the different amount of ore dilution when extracting it from the stopes as the extraction works developing in the area of the ore deposit.

5. The nature of geological structure influence and ore deposit occurrence conditions on the extracted ore dilution

Due to the increased extracted ore dilution on junctions with adjacent strata of the hangingwall, a detailed analysis of changes in their hardness, the angle of incidence and thickness of the ore deposit was made for each mine surveying axis (30 m) across the pitch of the ore deposit at 1500 m. As a result, graphs of geological factors variance were obtained (see **Figure 4**). It can be noted that the distribution of the deposit is characterized by a general evolving trend of decreasing hangingwall rocks hardness and the angle of incidence of the ore deposit and increasing the thickness of the deposit from north to south.

Analysis of the graph in **Figure 4** allows us to establish trends and causes of extracted ore dilution, amount changes in different geological structure ore deposits. It was revealed that for the examined timeframe of 16 chambers working in the hangingwall of the deposit, the main intensity of cavings and dilution of ore with the adjacent strata of the hangingwall is confined to the central and southern part of the ore deposit “Holovna” from the mine surveying axis 7n to 11s in length 550 m, where there were 70% cases of ore dilution with rocks.

The smallest ore dilution with caved ground at the level of 0.0 – 2.0% is observed when the quartzite, especially of haematinic martite composition, is predominant

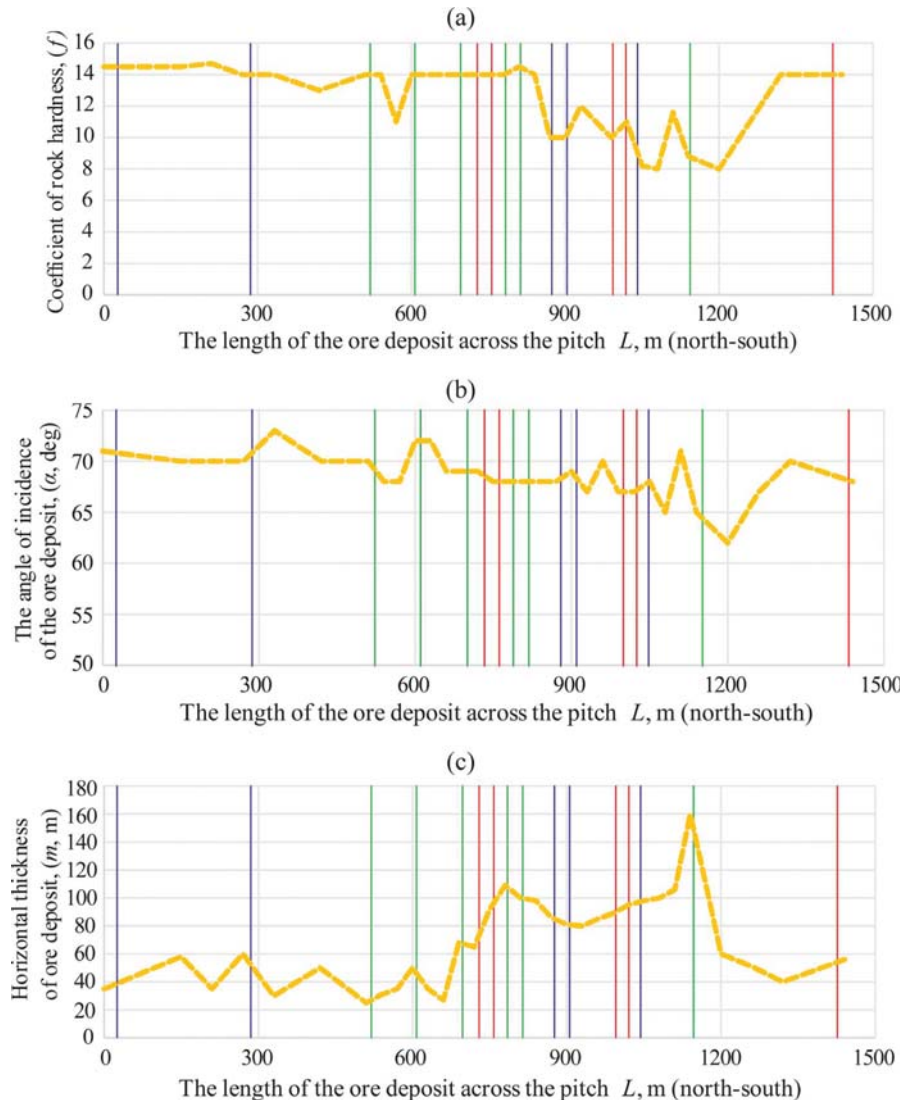

Figure 4: Nature of geological parameters variance across the pitch of the ore deposit: hangingwall rock hardness (a), the angle of incidence of the ore deposit (b), and ore deposit thickness (c)

in the hangingwall, with equal hardness of *f* = 14, with an insignificantly fluctuating angle of incidence of the ore deposit 68 – 70° and in 65% cases comparatively inconsiderable horizontal thickness of deposit up to 60 m.

Ore dilution at the level of 2.0 – 4.0% is noted in the northern, central and lesser in southern part of the deposit. In the northern part in the axes 26n and 17n, we assume that the increased dilution is caused by the presence of an ore deposit with adjacent strata (quartzites) of rugous form on the junction, and also that, due to the pressure of the roof strata weight, it contributes to ore dilution. There is high rock fracturing in the northern-most sections of the deposit, which reduces the strength and stability of rocks. Dilution is also facilitated by the splitting of the deposit into a number of thin veins and the presence between them of quartzite interlayers with a reduced content of iron. In the central and early southern part of the deposit, dilution occurred in comparison with the conditions at 0.0 – 2.0 with the replacement of quartzites of haematinic martite composition at hardness *f* = 12 with quartz-chlorite-sericite schists of reduced hardness *f* = 8 – 10 and stability, reducing of angle of incidence of deposit to 65 – 68° and increasing of the ore deposit horizontal thickness from 80 to 100 m.

The greatest dilution at the level of 4.0 – 8.0% is observed in the central and southern part of the deposit in 80% cases when quartzite of haematinic martite composition with hardness *f* = 14 is replaced with quartz-chlorite-sericite schists of reduced hardness *f* = 8 and stability, reducing of angle of incidence to 70 to 65° and increasing of the ore deposit horizontal thickness from 70 to 100 m.

It should be noted that the dilution intensity in the chambers increases markedly with an increase in the horizontal thickness of the deposit. So in the northern part, it varies from 20 to 60 m, averaging 35 – 40 m. In such cases, one stope by the thickness of the deposit is located transverse of the pitch. In the southern part, the power varies from 80 to 150 m, averaging 100 – 120 m. In this case, the deposit has two, sometimes three, stopes. Under such conditions, it is necessary to increase the average length of the chamber, which involves an increase in the horizontal span of the chamber, which in turn increases the possibility of hangingwall rock caving and spalling. The northern part is characterized by the length of stopes 25 – 40 m, for the central and southern parts – 40 – 60 m.

Thus, tendencies and reasons for the change in the amount of extracted ore dilution on junction with adjacent strata in heterogeneous geological structure of the ore deposit are revealed. To increase the probability of the ore deposits geological environment influence on the degree of ore dilution, it is recommended to investigate a larger number of chambers and the conditions for their working out.

6. Conclusions

Sections of the ore deposit with increased ore dilution with adjacent strata are identified by scientific and technical analysis. The average amount of dilution in 16 chambers worked out on junction with the hangingwall and 8 chambers with a footwall in deck of 640 – 740 m revealed the exaggeration of the ore dilution in the chambers from the hangingwall by the chambers of the footwall by 1.7 times.

It was revealed that for the examined timeframe of 16 chambers working in the hangingwall of the deposit, the main intensity of cavings and dilution of ore with the adjacent strata of the hangingwall is confined to the central and southern part of the ore deposit “Holovna” from the mine surveying axes 7n to 11s in length 550 m, where there were 70% cases of ore dilution with rocks.

Tendencies and reasons for the change in the amount of extracted ore dilution on junction with adjacent strata in heterogeneous geological structure of the ore deposit are revealed. Across the pitch of the ore deposit, it is characterized by a general evolving trend of decreasing hangingwall rock hardness and the angle of incidence of the ore deposit and increasing the thickness of the deposit from the northern flank to the southern one. Comparing zones of dumps, hangingwall rock dilution and geological factors change along the ore deposit length. It was established that the concentration of rock caving is enhanced by replacing ferruginous quartzites with quartz-chlorite-sericite schists, reducing hardness from $f = 12 – 14$ to $f = 8 – 11$ and the stability of adjacent strata of the hangingwall, reducing the angles of incidence of the ore deposit from 73 – 69 to 68 – 62 degrees, a twothreefold increase in the ore deposit thickness from 30 – 60 to 80 – 100 m, and the dilution parameters vary within 2.0 – 8.0 %.

In the local parts of the deposit, predominantly in the northern part, higher levels of ore dilution with adjacent strata have been identified under the high rock strength, which is explained by the abnormally high and developed fracturing of the hangingwall rocks, which forms low stability of the massifs, breaking it into blocks, and junctioning the ore deposit with the adjacent strata has a rugous form, and the presence of intercalations of quartzites with a lower iron content also contributes to the ore dilution.

The obtained results allow us to lay the foundations for optimizing the parameters of the development system and the rational order for the ore reserves, cutting in the chambers under the changing mining and geological conditions of deposit development.

Acknowledgment

This work was supported by the Ministry of Education and Science of Ukraine, grants No.0116U008041 and No.0117U001127.

7. References

Barba, T.F.V. and Nordlund, E. (2013): Numerical analyses of the hangingwall failure due to sublevel caving: study case. International Journal of Mining and Mineral Engineering, 4, 3, 201-223. https://doi.org/10.1504/ijmme.2013.053168

Basarir, H., Bin, H., Fourie, A., Karrech, A. and Elchalakani, M. (2018): An adaptive neuro fuzzy inference system to model the uniaxial compressive strength of cemented hydraulic backfill. Mining of Mineral Deposits, 12, 2, 1-12. http://dx.doi.org/10.15407/mining12.02.001

Balter, B., & Faminskaya, M. (2018): Noosphere as Optimal Control. Part 2. Reflective Noosphere. Philosophy and Cosmology, 20, 56-73. https://doi.org/10.29202/phil-cosm/20/5

Chistyakov, E., Ruskih, V. and Zubko, S. (2012): Investigation of the geomechanical processes while mining thick ore deposits by room systems with backfill of worked-out area. Geomechanical Processes During Underground Mining, 127-132. https://doi.org/10.1201/b13157-23

Dychkovskyi, R.O., Lozynskyi, V.H., Saik, P.B., Petlovanyi, M. V., Malanchuk, Y. Z. and Malanchuk, Z. R. (2018, a): Modeling of the disjunctive geological fault influence on the exploitation wells stability during underground coal gasifi cation. Archives of Civil and Mechanical Engineering, 18, 4, 1183-1197. https://doi.org/10.1016/j.acme.2018.01.012

Dychkovskyi, R., Vladyko, O., Maltsev, D., and Cabana, E.C. (2018, b): Some aspects of the compatibility of mineral mining technologies. Rudarsko Geolosko Naftni Zbornik, 33, 4, 73-82. https://doi.org/10.17794/rgn.2018.4.7

Falaknaz, N., Aubertin, M. and Li, L. (2015): Numerical investigation of the geomechanical response of adjacent backfilled stopes. Canadian Geotechnical Journal, 52, 10, 1507-1525. http://dx.doi.org/10.1139/cgj-2014-0056

Forster, K., Milne, D. and Pop, A. (2007): Mining and rock mass factors influencing hangingwall dilution. Rock Mechanics: Meeting Society's Challenges and Demands, 1361-1366. https://doi.org/10.1201/noe0415444019-c169

Kabwe, E. (2017): Mining Sequence Deformation and Failure Behaviour Analysis in the hangingwall and Orebody Rock Formations; A Continuum Approach. Geotechnical and Geological Engineering, 35, 4, 1453-1473. https://doi.org/10.1007/s10706-017-0187-y

Khomenko, O., Kononenko, M. and Myronova, I. (2017): Ecological and technological aspects of iron-ore underground mining. Mining of Mineral Deposits, 11, 2, 59-67. https://doi.org/10.15407/mining11.02.059

Kuz'menko, A., Furman, A. and Usatyy, V. (2010): Improvement of mining methods with consolidating stowing of iron-ore deposits on big depths. New Techniques and Technologies in Mining, 131-136. https://doi.org/10.1201/b11329-22

Kuz'menko, O., Petlyovanyy, M. and Stupnik, M. (2013): The influence of fine particles of binding materials on the strength properties of hardening backfill. Annual scientific-technical collection "Mining of Mineral Deposits", 45-48. https://doi.org/10.1201/b16354-10

Kuzmenko, O., & Petlovanyi, M. (2015): Substantiation the expediency of fine gridding of cementing material during backfill works. Mining of Mineral Deposits, 92, 183-190. https://doi.org/10.15407/mining09.02.183

Lozynskyi, V., Saik, P., Petlovanyi, M., Sai, K. and Malanchyk, Ye. (2018): Analytical Research of the Stress-Deformed State in the Rock Massif Around Faulting. International Journal of Engineering Research in Africa, 35, 77-88. https://doi.org/10.4028/www.scientific.net/JERA.35.77

Petlovanyi, M. (2016): Influence of configuration chambers on the formation of stress in multi-modulus mass. Mining of Mineral Deposits, 10, 2, 48-54. https://doi.org/10.15407/mining10.02.048

Pivnyak, G.G., & Shashenko, O.M. (2015): Innovations and safety for coal mines in Ukraine. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 6, 118-121.

Rudy, M. (2017): Mineral and raw material base of agronomical ore in Kharkiv region. Visnyk of V.N Karazin Kharkiv national university-series geology geography ecology, 47, 56-63. https://doi.org/10.26565/2410-7360-2017-47-06

Russkikh, V., Yavors'kyy, A., Zubko, S., & Chistyakov, Y. (2013): Study of rock geomechanical processes while mining two-level interchamber pillars. Annual Scientific-Technical Colletion – Mining of Mineral Deposits, 149-152. https://doi.org/10.1201/b16354-26

Russkikh, V.V., Lapko, V.V., & Zubko, S.A. (2012): Development and adoption of new technical decisions for development of Yuzhno-Belozerskoye ore deposit under difficult mining and geological conditions. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 5, 34-38

Snihur, V., Malashkevych, D., & Vvedenska, T. (2016): Tendencies of coal industry development in Ukraine. Mining of Mineral Deposits, 10, 2, 1-8. http://dx.doi.org/10.15407/mining10.02.001

Sotskov, V., & Saleev, I. (2013): Investigation of the rock massif stress strain state in conditions of the drainage drift overworking. Annual Scientific-Technical Colletion - Mining of Mineral Deposits, 197–201. https://doi.org/10.1201/b16354-36

Streltsov, V., Evtekhov, V., & Evtekhova, A. (2017): Some mineralogical zoning features of iron ore riebeckite metasomatites in the Kryvyi Rih basin. Visnyk of Taras Shevchenko National University of Kyiv. Geology, 1, 76, 52-57. https://doi.org/10.17721/1728-2713.76.08

Suglo, R.S. and Opoku, S. (2012): An assessment of dilution in sublevel caving at Kazansi Mine. International Journal of Mining and Mineral Engineering, 4, 1, 1-16. https://doi.org/10.1504/ijmme.2012.047996

Tsarikovskiy, V.V. and Sirotyuk, C.V. (2012): Technology of the extraction excavation with self-destruction of the ore massif. Mining forum, 1, 104-112.

Internet sources:

URL: http://www.zgrk.com.ua/?page=about&t=product (accessed 2nd June 2018)

SAŽETAK

Utjecaj geologije na pojave opadanja koncentracija u rudnim ležištima

Rudarenje ležišta željezne rude povezano je s iskapanjem vrlo velikih količina stijena iz podzemlja. Na taj način osigurava se ruda za daljnju ekstrakciju. Nadalje, kod bogatih ruda željeza posebno su važni geološki odnosi rudnoga tijela i okolnih stijena, a koji utječu i na smanjenje koncentracije u prostoru. U radu je prikazano kako je u slučaju kada se rudarske komore usmjeravaju prema krovinskomu sloju s jalovinom opadanje koncentracije rude 1,7 puta veće nego kada se isti postupak radi prema podini. Takve pojave zabilježene su u različitim geološkim strukturama te su uglavnom posljedica razlike u čvrstoći stijena te nagibu i debljini slojeva (u analiziranome slučaju smjerom od sjevera prema jugu). Nadalje, dokazano je kako su pojave pukotina i opadanje koncentracije rude u krovini dodatno potaknute promjenom morfologije, smanjenjem čvrstoće, nagibom slojeva te općenito debljinom rudnoga ležišta. Na temelju rezultata bilo je moguće utvrditi vrijednosti optimizacije rudarskih radnji te iskapanje što većih količina rezervi.

Ključne riječi:
željezna ruda, rudarenje, opadanje koncentracije, geološke strukture

Authors' contribution

Mykhailo Petlovanyi (Associated Professor) provided the idea for research, participating in all stages of the research, developing a research methodology, analyzing data and formulating conclusions. **Vasyl Lozynskyi (Associated Professor)** – performed a study of the geological structure change in the ore deposit as well as enclosed rocks, allocation of characteristic sections of the ore deposit in similar geological conditions. **Serhii Zubko (Mining Engineer)** – provided a collection and detailed analysis of the geological structure of the ore deposit, features and indicators of ore dilution in chambers. **Pavlo Saik (Associated Professor)** – performed grouping of extraction chambers by the amount of ore dilution, a graphical representation of the material. **Kateryna Sai (Associated Professor)** – performed a determination of the geological structure influence and the occurrence conditions of ore deposits on the index of ore dilution.