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3D MODELING FOR ESTIMATION OF ENGINEERING-GEOLOGICAL CONDITIONS OF OPERATING MINERAL DEPOSITS

Abstract. The article is devoted to the nowadays actual problem - ensuring the safe and rational operations of mineral deposits in the underground working conditions of existing mining production. In recent years, progressive technologies have introduced actively to the mining industries with using the latest high-performance mining equipment, automation and complex mechanization of mining drift and stope. Their introduction was not sufficiently substantiated by specially conducted engineering-geological studies. As a result of such approaches, in areas operated with new technology using self-propelled equipment, were formed the vast zones of exposure of the roof and huge voids of the worked-out space with a large number of supporting interchamber pillars. On formalization of pillars were designed without taking into account the engineering and geological conditions of the underground excavation field, there were cases of their mass destruction, which led to the rock massifs collapse, shifting the overlying roof stratum under the built-up territory and environmental disasters.

As purpose to solve this problem, on researching works were made to quantify the engineering and geological conditions of thin-vein gold ore deposits using three-dimensional modeling on platform of modern computer technologies. The research used the results of the latest theoretical and methodological work in the field of engineering geology, as well as the results of a comprehensive survey of the state of the rock mass during exploration and operation on the example of the existing Beskempir gold deposit.

Key words: Engineering-geological conditions, 3D modeling, database, gold ore deposit, rock massif, stability of mine workings.

Introduction. The success of the development and exploitation at this level of the country's mineral resource base requires a modern and integrated approach to the operation of mineral deposits. In this regard safety, rationality, and the efficiency of mining ore bodies in the bowels play an important role. It is determined by the degree of knowledge and assessment of engineering and geological conditions of deposits, which in turn is also of great importance during mining operations in mining productions. This will let maximize the volume of ore mining and reduce dilution of the rock mass.

The main point of engineering and geological research conducted to address the assessment of the sustainability of the mine workings is determined by the principle and purpose of the work.

The fullness and self-sufficiency of studying and forecasting the engineering and geological conditions (hereinafter as EGC) of mineral deposits is achieved if these studies are synchronized with geological exploration at the stages of exploration and operation of the deposit. It should be borne in mind that the content, volume, accuracy and confidence level of the received data on EGC should be sufficient to solve the tasks. In the future, the obtained data will be used in the construction and operation of a mining production, its underground mine workings.

Engineering and geological studies were carried out at the Beskempir thin-vein gold ore deposit. The selection of the fundamental teaching methods and research methods, the combination of which will allow us to implement a rational set of field, laboratory and cameral studies of EGC. They are dictated by the need to solve the following problems:

– The study of EGC on the basis of special field geological studies and purposeful processing of the entire known information of geological database;

– Assessment of forecast parameters for the development of geotechnical conditions and processes during field operation. Achieving this goal will be based on 3D modeling of the geological environment, with the help of which the tasks of assessing the quantitative parameters of the EGC deposit will be successively solved.

Analysis and discussion of research results. An objective assessment of all the components that make up the Engineering and geological conditions of the Beskempir gold ore deposit makes it possible to make the most reliable and objective forecast of the stability of the rock massif. The main engineering and geological components of the selected ore bodies and host rocks are due to their petrographic composition, the presence of structural and tectonic elements, crushing zones with varying degrees of crushing of the rocks and the development of joint systems that form weakening zones, and physical-mechanical properties [1,6,7].

Geological and structural structure of the deposit. The Beskempir deposit is localized within the Akbakai ore field, located 3 km northeast of the Jambyl fault, one of the regional faults of the Jalair-Naiman geostucture [2-4]. It is clearly limited in space by the Kashkimbai Fault from the southwest, Kengir Fault from the northeast, Kyzyljartas Fault from the north and South-Kengir Fault from the south. The length of the Fault along the strike is 15 km with a width of 3.5-4 km. From the north-west, the ore field is overlapped by Devonian volcanics filling the Kyzyljartas graben-syncline.

The Beskempir deposit is essentially the eastern flank of the Akbakai field, shifted 1800 meters eastward along the Beskempir post-ore fault and 300 m higher relative to Akbakai.The fault falls southward at an angle of 75-85° and borders the field at a depth of about 400-500 m (Porechin et all., 1986). The deposit area is composed of rocks of the Kyzyljartas (earlier-middle Devonian) gabbro-diorite complex, which is represented by several intrusive phases.

To the first phase of introduce includes sub-consonants with stratification, less often cutting small bodies, composed of diabases, diabase porphyrites, diabases and diorite porphyrites. A detailed study of these intrusives on the Olympic field showed that diabase porphyrites have a quenching zone in contact with diorite porphyrites of biotite and biotite-hornblende composition, i.e. the formation of these small-sized intrusions occurred in two stages.

They clearly differ in natural radioactivity. The second phase of introduce includes gabbro-diorites of intrusive appearance, which components of the Kengir stock. Actually, the Kyzyljartas intrusives completes the formation of the complex. It is composed of rocks that vary in composition from gabbro-diorites through quartz diorites and granodiorites to adamellites and granites. The main part of the intrusives is composed of granodiorites, on which siliceous-potassium metasomatism is imposed under the influence of Jeltau granites. According to previous studies, Kyzyljartas granodiorites are characterized by a higher potassium content in comparison with standard ones.

A dyke series of rocks consisted with the composition of microdiorites, diorite porphyrites and quartz diorite porphyrites is associated with the Kyzyljartas complex. Single dykes of this composition are known in the Kyzyljartas and Kengir stocks; their difference from later dykes is hornfelsification under the influence of Jeltau granites.

Two main and two secondary ore veins are known at the deposit. Main veins: Beskempir (acclivous dip), Surprise (steep dip). One of the secondary veins of Surprise-2 (steep dip) is controlled by dykes, and the other Berezitovaya (acclivous dip) is not connected with dykes and is distinguished by poor gold grade.

Engineering and geological particular qualities of the rock massif. Ore bodies are represented by veins of a quartz-berezite or substantially berezite composition, occurring in the contacts of diorite porphyrite dykes, less often in the dykes and ore-quartzed, chloritized dykes. A variety of ores is singled out that control sections of the rocker entry of ore-controlling dykes. In this case, the ore body is metasomatically quartz granodiorites, which have acquired a porphyritic appearance, dissected thin quartz veins with highly gold grade.

The contacts of quartz veins with berezites and berezites with host granodiorites or dykes are clear and often represented by tectonic seams with mirrors sliding. Ore bodies with steep (70-80°) and acclivous (40-55°) dip angles.

The host rocks and ores are characterized by high predictive indicators, that is, they are highly stable, with the exception of areas with weakened contacts of ore bodies with rocks. Almost all of the underground mine workings were completed without supporting of rock massif. Only in some rare cases, in areas of local increase in the thickness of the fracture crushing zone, rock stability was low. In such areas, was required continuous underground supporting of individual intervals of mine workings. Minor tectonic faults do not have a significant negative effect on rock stability [1,8-15].

Strength values coefficients of rock massif in deposit according the table prof. M.M. Protodyakonov are: for quartz ores – 16-18; berezites – 11-14; lamprophyre dykes – 11-12; granodiorites – 14-16; terrigenous rocks – 11-12. The weakest are the areas of interfacing of quartz veins, as well as their contacts with ore-controlling dykes.

Ores are not prone to caking, soaking, swelling, spontaneous combustion.

The natural radioactivity of the rocks is within the background values, mcR/h: diorite porphyrites – 10-15; granodiorites – 25-31; ore bodies – 20-30.

The volume mass of ores and host rocks varies from 2.69 to 2.83 t/m^3, the loosening coefficients are the same and is 1.6. The natural moisture content of ores and rocks does not exceed 1.5%. More detailed information about the physical-mechanical properties presented in table.

Characterization of the physical-mechanical properties of the Beskempir deposit rocks

Lithological type of rocks	Identified by laboratory tests			
	Density (volume mass), g/cm^3	Water absorption, %	The limit of compressive strength (in dry condition), MPa	Strength coefficient from-to
Loam with inclusion of gravel and crushed stone up to 15%	Density (volume mass) 2.73 t/m^3, coefficient of loosening 1.4-1.6			
Granodiorites	2,7	1,5	138	14-16
Hornfelsific sandstones	2,7	1,5	162,9	11-12
Quartz ore	2,73	1,5	170	16-18
Berezites	2,73	1,5	127,8	11-14
Lamprophyres	2,73	1,5	91,8	11-12

Estimation of jointing. The study of jointing is of great practical importance in the development of deposits since joints violate the continuity of rocks and reduce their strength in the massif. Under the conditions of the Beskempir deposit, the study of rock mass joints both in ore bodies and in host rocks in underground mines was carried out by visual inspection and using special tools (measuring tape, surveyor's compass, special laser equipment, etc.). In addition, such work was carried out on cores of geotechnical and production exploration holes. When performing work, special attention was paid to the following components of the engineering geological conditions: rock type, blocks of massif, number of joint systems, distance between joints, frequency, extent, thickness, filling and macro-roughness of joints, etc.

On the whole, the massif of rocks is moderately jointed, in some places there are crushing intervals, composed of rocks with rigid structural bonds belonging to the class of very strong and strong rocks. The regime of spatial variability of the properties of the massif can be attributed to stable both in strike and in dip. Tectonic structures control the degree of fragmentation of the massif and the intensity of fracturing, as well as the development of jointing systems in the rock massif. It should be noted that ore bodies are characterized by varying degrees of intensity, rock jointing, and ore-bearing granodiorites are mainly characterized by the lowest intensity of jointing. The main aspects that determine the formation of jointing and the development of their intensity, as well as the orientation of joints in the rock mass within the entire deposit, are ore-forming processes and tectonic faults, developed almost across the strike of ore bodies. This is evidenced by the existence of three main systems of jointing according to the fall and strike of ore bodies, and across their strike. In areas of discontinuous faults, joints are developed more intensely.

Joints breaking the massif of rocks, mostly oblique, chipped with mirrors and slip strokes. Joint fillers are: friction clay, vermiculite, chlorite, kaolinite. As a rule, processes of carbonatization, berezitization, sulfidization, and sericitization are developed along joints. Jointing system leads to anisotropy of the properties of the massif and block structure, for example joints of different orientations in the rock mass intersecting mutually add up different separate shapes (rectangular, prismatic, tiled, etc.) and sizes. The greatest joint voids are confined to the areas of development of tectonically disturbed rocks. The presence of weakened zones is the result of unloading of rock masses. A decrease in the average values of rock strength in weakened zones and zones of increased jointing is noted.

The database – fundamental basis of 3D modeling in assessing the engineering and geological conditions of deposits (the necessary source data for the formation of the database). The fundamental basis for creating a three-dimensional model of the geological environment, then using it to assess the engineering and geological conditions of the deposits, is the geological database and the database of engineering and geological conditions, which should be constantly updated on maintenance of mining operations. The formation of databases is carried out as a result of exploration and operational exploration work with data collection. These data reflect the actual state of the rock mass in accordance with specific systems. On documentation of core from hole, the aforementioned types of databases are created in one spatial coordinate field and their required tables collar (coordinate file) and survey (inclinometry file) should be the same.

A geological database is needed to build a 3D model of ore bodies and host rocks of the hanging and bedding walls in three-dimensional space. There are additional interval tables in this database such as assay (sample data file) and lithology (lithology data file) [10-15].

The database of engineering and geological conditions is designed to visualize the results of documentation and research on engineering and geological study of rock mass and their use in the interpolation of quantitative parameters into a block model (evaluation in a three-dimensional environment) with using modern computer technologies. This type of database is compiled in two forms, the first one is for documentation of underground mining workings (geotech_drive), and the other is for documentation of core samples frome hole (geotech_drillhole). To generate the geotech_drive and geotech_drillhole files, data are needed on the following important components of the engineering-geological conditions, which are used to interpolate (estimate) by the value of the Burton rating (figure 1):

– *Lithological code (ROCK).*

– *Water cut of the rock (Jw)*: 1 – no water inflow, dry rocks; 0.66 – wet rocks; 0.5 – casing, wet rocks; 0.33 – light water inflow; 0 – noticeable water inflow.

– *Water cut of the rock (Jw), Rat*, the value is determined depending on Jw: when Jw = 1 (Jw), Rat = "10", Jw = 0.66 (Jw), Rat = "7", Jw = 0.5 (Jw), Rat = "4", Jw = 0.33 (Jw), Rat = "0".

– *Rock strength (UCS)*, MPa, set by the device.

– *Strength category, the value is determined depending on the UCS*: within 1-5 MPa, the value is "R1" (very weak); 5-25 MPa value of "R2" (weak); 25-50 MPa value of "R3" (medium strength); 50-100 MPa value "R4" (durable); 100-250 MPa value "R5" (very strong); greater than 250 MPa, the value of "R6" (extremely durable).

– *Rock Quality Designation (RQD)* in m, the sum of the lengths of whole pieces over 10 cm in the documented interval.

– *RQD (Rat)*, the value is determined depending on (RQD), %: at (RQD), % 90-100 the value is "20", 75-90 the value is "17", the 50-75 value is "13", 25-50 value of "8", less than 25 value of "3".

– *Number of jointing systems (Jn):* 0.5 – no joint, 1 – random joints, 2 – one jointing system, 3 – one jointing system + random joints, 4 – two jointing systems, 6 – two jointing systems + random joints, 9 – three jointing systems, 12 – three jointing systems + random joints, 15 – four or more jointing systems, 20 – crushing zone.

– *Number of joints (NJ)* for a specific interval.

– *The distance between the joints (SD).*

– *The distance between joints (SD00) Rat*, the value is determined depending on (SD): with a smaller 0.06 value of "5", 0.06-0.2 value of "8", 0.2-0.6 a value of "10", 0.6-2 a value of "15", greater than 2 a value of "20".

– *Roughness of the walls of the joints (Jr):* 0.5 – polished flat, 1 – smooth flat, 1.5 – flat rough, 2 – smooth wavy, 3 – wavy rough.

– *Joint wall friction (Ja).*

– *Burton Rating Index (Q).*

– *Class category according to the Barton system*, the value is determined depending on Q: when Q is less than 1 – the value is "V", 1-4 – the value is "IV", 4-10 – the value is "III", 10 – 40 – the value of "II", 40-1000 – the value of "I".

– *Characterization of the massif* according to the Barton rating index (Q): when Q is less than 1, the value is "very unstable", 1-4 values are "unstable", 4-10 values are "medium-stable", 10-40 values – "stable", 40-1000 values – "very stable".

№ holes	From, m	To, m	length, m	Lithological code (ROCK)	Water cut of the rock (Jw)	Water cut of the rock (Jw), Rat	Strength category	Rock strength (UCS), MPa	UCS(Rat)	Rock Quality Designation (RQD), m	Rock Quality Designation (RQD), %	RQD(Rat)	Number of jointing systems (Jn)	Number of joints (NJ)	The distance between the joints (SD)	The distance between joints (SD00) Rat	Roughness of the walls of the joints (Jr)	Joint wall friction (Ja)	Burton Rating Index (Q)	Class category according to the Barton system	The characteristics of the array according to the rating index of Barton (Q)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
S_Bes_M37_GT_010	0	1	1	GRD	1	10	R4	86	7	0	0	3	12	4	0,02	5	1,5	2	0	V	**very unstable**
	1	2,5	1,5	GRD	1	10	R4	85	7	0,26	17	3	3	6	0,02	5	1,5	2	4,333	III	**medium-stable**
	2,5	2,9	0,4	LPH	1	10	R4	84	7	0	0	3	3	3	0,02	5	1,5	2	0	V	**very unstable**
	2,9	3,7	0,8	GRD	1	10	R4	75	7	0,28	35	8	9	8	0,15	8	1,5	2	2,917	IV	**unstable**
	3,7	8,4	4,7	GRD	1	10	R2	22,1	5	0,37	8	3	9	8	0,15	8	1,5	2	0,656	V	**very unstable**
	8,4	9,1	0,7	GRD	1	10	R3	40	4	0	0	3	20	3	0,02	5	3	2	0	V	**very unstable**
	9,1	10	0,9	GRD	1	10	R4	55	7	0,4	44	8	3	2	0,4	10	3	2	22,22	II	**stable**

Figure 1 – An example of a geotech_drillhole filled file

After the database was formed in the conditions of the Beskempir field it was checked for integrity, systematical errors, etc. in the mining and geological information system Micromine. Further, all possible errors are eliminated using the software. As a result of the work performed, we obtained a reliable database, which, in turn, was used in modeling and interpolation of quantitative parameters in three-dimensional space.

3D modeling and with its help an estimate the engineering and geological conditions of the Beskempir gold ore deposit. When three-dimensional modeling was taken into account the features of the geological and structural structure of the deposit, its knowledge degree and geological exploration methods. Then, in the Micromine software were used standard 3D modeling methods and techniques of ore mineralization within the deposit. The order of execution of the work consisted of the following steps:

– Loading the geological database. Successfully implemented the creation 3D models of ore bodies and host rocks of the hanging and bedding walls.

– Visualization of the results of engineering geological mapping. Constructed 3D models of discontinuous faults in three-dimensional space;

– Block modeling. At this stage, realized the creation of a blank block model within the boundaries of the deposit and coding of the block model with structural domains (ore bodies, enclosing rocks, discontinuous violations);

– Import a database of engineering and geological conditions. The data was visualized and verified in three-dimensional space in order to verify the readiness of the base for interpolating the quantitative parameters of the components of the engineering and geological conditions of the field into a block model.

– Estimation of engineering and geological conditions of the deposit. To carry out the estimate, was used inverse distance weighting – IDW interpolation method, beacause this method is most suitable for the Beskempir deposit. There is a clear structural control of mineralization, and the breakdown into structural domains was carried out only according to geological criteria. For this, of course is used the IDW-method (inverse distance weighting). Difference from other methods, here the weighting coefficient is calculated not only to the nearest indicator, but also to all neighboring indicators. In this case, the weighting coefficient is inversely proportional to the distance raised to a power from a point to a neighboring indicator. Naturally, the nearby indicator will have the high weight, the influence of other indicators is also taken into accounting.

As results, we obtained an experimental 3D block model of the deposit, which clearly shows the engineering and geological conditions of the geological environment in real time in three-dimensional space (figure 2).

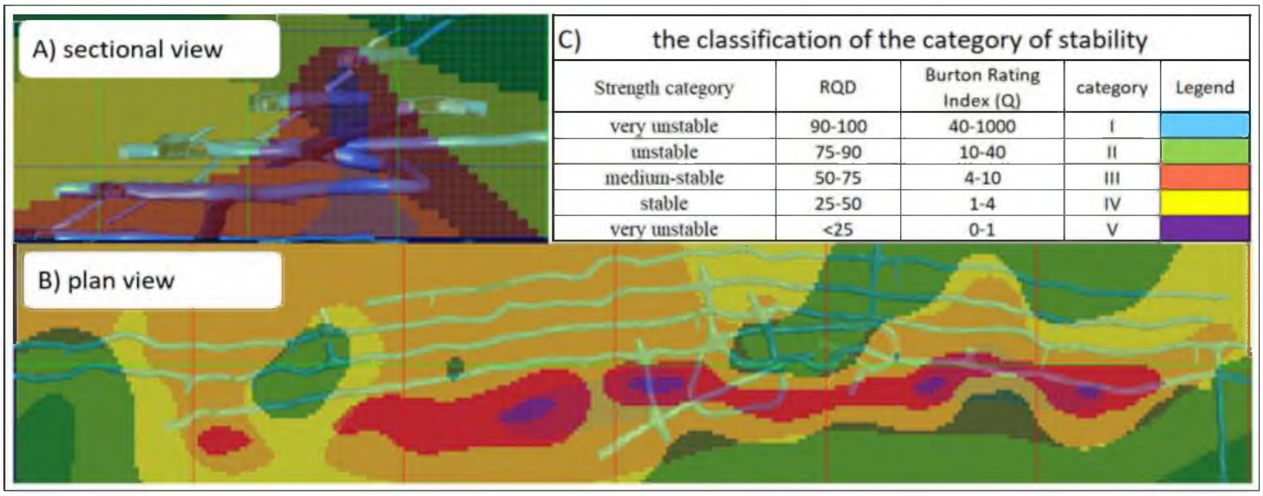

Figure 2 – Fragment of a 3D block model: A) sectional view; B) plan view;
C) the classification of the category of stability according to the Barton system with certain colors

Conclusion. In mine workings, engineering-geological phenomena include the following: deformation of rocks in the walls and at the bottom of mine shafts, swelling (blowing, extrusion) of rocks in the soil of workings, displacement and various types of rock collapse in the roof (inrushing, creating domes, collapsing of the false roof), emissions of rocks and minerals, inrushing and caving in zones of low stability and at the borders of changing stability classes, etc.

To prevent the occurrence of hazardous processes, it is necessary to use effective methods that ensure the safe and rational conduct of underground mining. In general, predicting the development of engineering-geological processes during field development under certain geological conditions, with a limited amount of information available, is a very difficult task due to the ambiguity and versatility of mutually affecting factors.

Nowadays, to solve the above problems, an estimation of the engineering and geological conditions of the Beskempir deposit has been implemented based on 3D modeling of the geological environment. During the work, data were collected on real criteria formulated according to the results of a comprehensive analysis of the geological, structural-tectonic, engineering-geological features of the deposit. A 3D model of the engineering and geological conditions of the deposit at the mine will serve as valuable material in the way of achieving the maximum safe, rational and efficient mining of ore bodies in the bowels.

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ӨНДІРІСТЕГІ КЕН ОРНЫНЫҢ ИНЖЕНЕРЛІК-ГЕОЛОГИЯЛЫҚ ЖАҒДАЙЫН БАҒАЛАУҒА АРНАЛҒАН 3D МОДЕЛДЕУ

Аннотация. Ғылыми жұмыс бүгінде өзекті мәселеге – пайдалы қазба кен орындарын қауіпсіз және ұтымды өндіру және жұмыс істеп тұрған кен өндірісі саласындағы өнеркәсіптің жерасты кен үңгімелері тұрақтылығын қамтамасыз етуге арналған. Әсіресе, соңғы жылдары кен өндірісі саласына жаңа жоғары өнімді кен техникаларын қолдану арқылы прогрессивті технологиялар белсенді енгізілді, жерасты кен үңгімелерін қазу және тазалау жұмыстары кешенді механикаландырылды және автоматтандырылды. Жаңа технологиялардың өндіріске енгізілуі инженерлік геологиялық зерттеулер негізінде жеткілікті негізделмеді.

Нәтижесінде жаңа технологияларды қолдану арқылы жер қойнауының бөлікшелерінде тау жыныс массиві жабынының ауқымды аймақта ашылуы және өндіру жұмыстарынан кейін көптеген камерааралық тіреуіш кентіректері бар үлкен бос кеңістігі қалыптасты. Өндіріс алаңының инженерлік-геологиялық жағдайын есепке алмай камерааралық тіреуіш кентіректердің дайындалуы олардың жаппай бұзылуына негіз болды, ал оның салдары тау жыныс массивінің опырылып құлауына, жогаргы қабатының жердің беткі қабатына жылжуына және экологиялық апаттарга әкелді.

Белгілі бір уақыт аралыгында жетекші әлемдік компаниялар геологиялық барлау және кен өндірісі салаларында үшөлшемді модельдеуді қолдану арқылы өндіру жұмыстарының тиімділігін көтеруге, аналитикалық және статистикалық есептерге кететін уақыттың үнемделуіне, геологиялық және өндірістік барлау жұмыстары бойынша дерекқордың дұрыс қалыптасуына және толыгуына, сонымен қатар зерттелетін аймақтың инженерлік-геологиялық жағдайын толыгырақ багалауга қол жеткізді.

Соңгы жылдары кен-геология саласында компьютерлік технологиялардың қолданылуы елімізде де кеңінен орын алып келеді. Кен орындарын ашық және жерасты тәсілдермен өндіру барысында кен денелерін 3D модельдеу сәтті жүзеге асырылуда. Дегенмен, бүгінгі күні кен орындарын максималды қауіпсіз және ұтымды игеру жолында үлкен практикалық мәнге ие 3D модельдеу арқылы геологиялық ортаның инженерлік-геологиялық жағдайларын багалауга толыгымен қол жеткізілмеді.

Үшөлшемді ортада қазіргі компьютерлік технологияларды қолдану арқылы кен орындарының инженерлік-геологиялық жағдайларын бағалау бойынша шетелдік мамандардың тәжірибесі зерделенді. Біз осындай жұмыстарды Бескемпір алтын кен орнында жүргіздік және мақсатымыз геологиялық ортаның (кен денелері, сыйыстырушы тау жыныстар, тектоникалық жарылымдар және т.б.) 3D моделін қолдану арқылы осы кен орнының инженерлік-геологиялық жағдайларын бағаладық.

Атқарылган жұмыстар кен-геологиялық ақпараттық жүйеде үшөлшемді модельдер тұргызуда және кен орнының инженерлік-геологиялық жагдайларын бағалау кезінде үлкен маңызга ие төмендегідей зерттеу сатыларын қамтиды: жұмыс ауданының геологиялық-тектоникалық құрылысы кен орнының геологиялық ерекшеліктерін зерттеу; кен үңгімелеріндегі құрылымдық тектоникалық элементтерді; тау жыныс массивінің инженерлік-геологиялық ерекшеліктері; кен және сыйыстырушы тау жыныстардың заттық құрамы және олардың физикалық-механикалық қасиеттері жайлы деректерді жүйелеу және жинақтау; тау жыныс массивінің кернеулік күйін тексеру; жарықшақты багалау; жерасты кен үңгімелерінде тау жыныс массивінің опырылу, бұзылу жагдайын бағалау; жарықшақ жүйесінің тау жыныс массивінің тұрақтылыгына әсері және оны есепке алу; деректер қоры – кен орындарының инженерлік-геологиялық жағдайларын бағалаудағы 3D модельдеудің іргелі негізі (деректер қорын құру үшін қажетті мәліметтер); жерасты кен үңгімелерін және геотехникалық, өндірістік барлау ұңғымаларының кернін инженерлік-геологиялық құжаттау; Бартон жүйесі бойынша тау жыныс массиві жіктеліміндегі класты анықтау; талдау және модельдеуге деректер дайындау – геологиялық және инженерлік-геологиялық деректер қорын құру.

Бескемпір кен орнының жерасты үңгімелерінде жүргізілген гылыми-зерттеу жұмыстары нәтижесінде геологиялық ортаны 3D модельдеу арқылы кен орнының инженерлік-геологиялық жағдайларын багалауга қол жеткізілді. Кен өндіру өнеркәсібінде осы модель кен орнын максималды қауіпсіз, ұтымды және тиімді игеру жолында құнды материал ретіде қызмет етеді, сонымен қатар басқа ұқсас кен орындары үшін дайын тәжірибе түрінде қолдануга ұсынылады.

Түйін сөздер: инженерлік-геологиялық жагдай, 3D модельдеу, мәліметтер базасы, алтын кен орны, тау жыныс массиві, тау-кен қазбаларының тұрақтылыгы.

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3D МОДЕЛИРОВАНИЕ ДЛЯ ОЦЕНКИ ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ УСЛОВИЙ РАЗРАБАТЫВАЕМЫХ МЕСТОРОЖДЕНИЙ

Аннотация. Работа посвящена актуальной на сегодняшний день проблеме – обеспечению безопасной и рациональной разработки месторождений полезных ископаемых и устойчивости подземных горных выработок действующих горнодобывающих предприятий. Особенно в последние годы в горные отрасли были активно внедрены прогрессивные технологии с применением новейшей высокопроизводительной горной техники, автоматизация и комплексная механизация горнопроходческих и очистных работ. Внедре-

ние их не было достаточно обосновано специально проведенными инженерно-геологическими исследованиями. В результате таких подходов на участках, отработанных по новой технологии с применением самоходного оборудования, образовались обширные площади обнажения кровли и огромные пустоты выработанного пространства с большим количеством поддерживающих целиков. При оформлении междукамерных целиков без учета инженерно-геологических условий выемочного поля происходили случаи их массового разрушения, что привело к обрушению горной массы породного массива, сдвижению налегающей толщи до выхода на дневную поверхность и экологических катастроф.

На протяжении определенного времени ведущие мировые компании геологоразведочной и горнодобывающей сфер деятельности с применением объемного трехмерного моделирования достигли существенного повышения эффективности добычных работ и экономии времени на аналитические и статистические расчеты, корректности формирования и пополнения базы данных по геологоразведочным и эксплуатационно-разведочным работам, в том числе подробной оценки инженерно-геологических условий на изучаемом участке.

В последние годы компьютерная технология в горно-геологической сфере все шире применяется и в нашей стране. Успешно осуществляется применение 3D моделирования рудных тел при добычных работах как открытом, так и подземном способах разработки месторождений. На сегодняшний день пока полностью не реализована оценка инженерно-геологических условий геологической среды с помощью 3D моделирования. Моделирование в свою очередь имеет большое практическое значение для достижения максимально безопасной и рациональной разработки месторождений как открытым, так и подземным способом.

Изучен теоретический и практический опыт зарубежных специалистов по оценке инженерно-геологических условий месторождений в трехмерной среде с использованием современных компьютерных технологий. Нами такие исследования проведены на золоторудном месторождении Бескемпир. Цель работ заключалась в оценке инженерно-геологических условий месторождения с применением 3D модели геологической среды (рудных тел, вмещающих пород висячего и лежачего боков, тектонических нарушений и зон дробления и др.). Выполненные работы состояли из следующих важных этапов работ: Геолого-структурное строение района работ: изучение геологических особенностей месторождения; изучение структурно-тектонических элементов в пределах горных выработок. Инженерно-геологические особенности массива горных пород: обобщение, систематизация данных о вещественном составе руд и вмещающих пород и их физико-механических свойствах; обследование напряженного состояния массива горных пород (рудные тела, массивы в лежачем и висячем боках); Оценка трещиноватости: оценка обрушаемости, нарушенности горных пород в подземных горных выработках; учет и влияние систем трещиноватости на устойчивость массива горных пород; инженерно-геологическая документация подземных горных выработок и керна геотехнических и эксплуатационно-разведочных скважин; классификация и определение класса массива горных пород по системе Бартона; анализ и подготовка данных к моделированию, формирование баз геологических и инженерно-геологических данных; 3D моделирование и с его помощью оценка инженерно-геологических условий месторождений на примере золоторудного месторождения Бескемпир.

В результате научно-исследовательских работ, проведенных в горных выработках золоторудного месторождения Бескемпир, достигнута оценка его инженерно-геологических условий с применением 3D моделирования геологической среды. На горнодобывающем предприятии данная модель будет служить ценным материалом для достижения максимально безопасной, рациональной и эффективной отработки рудных тел, а также хорошим опытом для аналогичных месторождений.

Ключевые слова: инженерно-геологические условия, 3D моделирование, база данных, золоторудное месторождение, горный массив, устойчивость горных выработок.

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