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Testing complex-structural magnetite quartzite deposits chamber system design theme

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Abstract

Development of iron ore by underground methods in terms of the Krivoy Rog iron ore basin is considered. The methods of the inclined pillars parameters calculation at level room-work of thick complex-structural magnetite quartzite are suggested.

Keywords: *quartzites, system development, class, pillar, rock inclusion*

The problem and its connection with the scientific and practical task

In Krivoy Rog iron ore basin rich and poor iron deposits are generally mined by open face development method or bulk-caving method (table 1).

Table 1 Development methods applied in enterprises with underground mining

Enterprise	Mine	Mining depth, m	Mining methods
PJSC “Krivbaszhelezrudkom”	Rodina	1315	sublevel ore caving
	Octyabrskaya	1190	sublevel ore caving, room and pillar caving
	Lenin mine	1275	
	Gvardeiskaya	1270	
PJSC “ArcelorMittal Krivoy Rog”	№1 Artem mine	1135	sublevel ore caving
PJSC “Evraz Sukha Balka”	Yubileinaya	1260	sublevel ore caving, room and pillar caving
	Frunze mine	1135	

The main efficiency indices of mining methods are production costs, which are largely determined by the level of ore losses, degree of waste rock clogging and the specific volume of the breakoff, table 2.

Table 2 Technical and economic indices of mining methods in Krivoy Rog iron ore basin

Indicator name	Mining methods		
	Level room-work	Sublevel room work	Sublevel ore caving
Specific weight in annual production, %	35.0	20.0	45.0
Specific volume of preliminary development	1.9-3.0	2.5-4.5	3.0-5.0

and breakoff m/th. t			
Ore losses, %	5.0-10.0 17.4-25.0	7.0-12.0 16.9-20.0	14.7-18.0
Ore clogging, %	4.0-7.0*) 13.0-16.0*)	4.0-6.0*) 11.4-14,0*)	16.5-18.0
Iron reduction in output in ore mass, %	0.5-2.0	0.3-1.5	1.5-3.0

Note: * - without pillar and ceiling recovery

Table 2 represents that the bulk-caving methods reduce iron ore content in ore output almost by two times in comparison with the room-work [1-3]. Taking into account that magnetite quartzite deposits are composed of very thick hard rocks technological advancement of their room-and-pillar methods is rather essential.

Investigation and publication analysis

Iron ore deposits in Krivoy Rog basin, reach the horizontal area of more than 1500 m^2 and strike length of more than 700 m, of ore bodies ranging in size from 50 to 500 m^2 and strike length from 10 to 75 m. The share of large deposits is 80% from the ore area in the basin. Their thickness varies from 20 to 150 m and more. The ore bodies are extended in the north-east direction and lie at angle from 20 to 80 degrees with the recovered grade of solid ore from 36 to 64%. Physical and mechanical properties of iron ore of Krivbass basin vary widely. Some mine fields have one or two parallel iron deposits containing about 70% of the reserves of the mine field, others have more than 20 separate ore bodies having a strike length from 150 to 500 m with the recovered grade of solid ore from 58 to 64% [2].

According to the deposit position iron ore deposits are divided into homogeneous and heterogeneous [3,4]. There are inclusions of dirt area or ores with low recovered grade quality of solid ore in heterogeneous deposits. The thickness of dirt areas vary from 3.2 m to 6 m in some areas to 10.6 m. The specific area of dirt area within the level (sublevel) is 10 ... 15-18%. The deposits with the presence of dirt area, are usually throw back with bulk mining, see table 1.

The problem statement

Application of traditional mining methods with ore bulk extraction at ore deposits mining, including dirt area inevitably leads to a decline of the recovered grade quality from 3 to 10%, which significantly affects the sale price of commercial products and increases the cost of extraction, transportation, hoisting of extracted rock mass and its dressing.

Thereby, the development of improved version of mining methods for deposits with dirt area inclusions, allowing to increase the quality of extracted ore mass, is an important scientific and technical task for enterprises with underground mining.

Material presentation and results

Ore deposits of Krivoy Rog iron ore basin according to their structure can be divided into five types: 1 - without dirt area inclusions, 2.3 and 4 - mining ore area has single, double and triple dirt area inclusions, 5 - ore area has combined dirt area inclusions, figure 1.

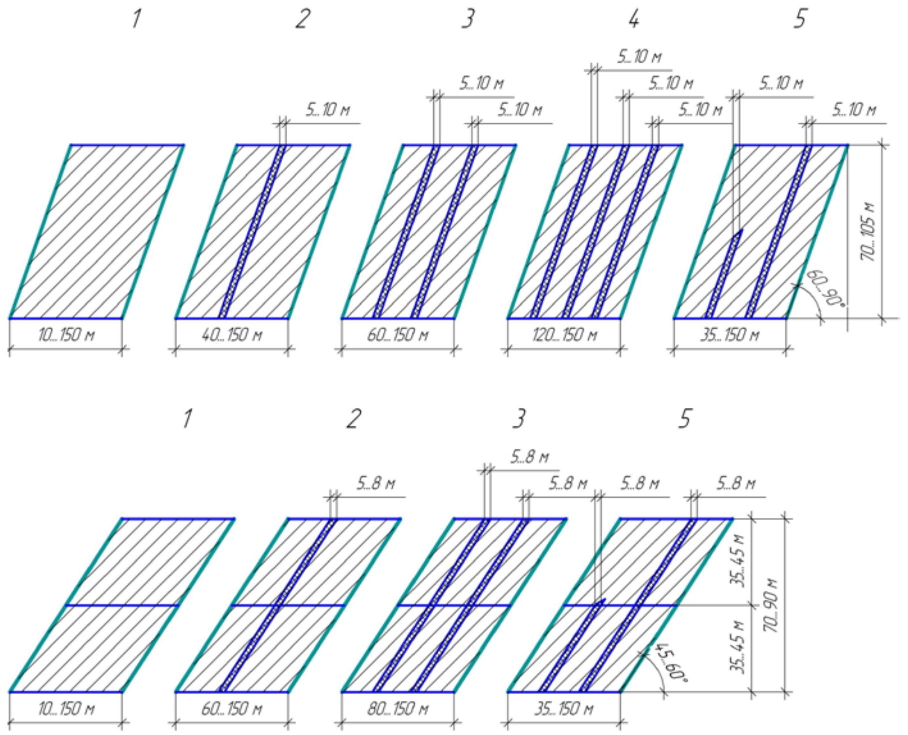

Figure 1 The structure of ore deposits of Krivoy Rog iron ore basin

The first type includes all single and parallel and contiguous deposits that don’t contain dirt area inclusions or the thickness of dirt area inclusions between the ore deposits is more than 15 m. In this case, it should be noted that the parallel and contiguous deposits are mined separately. Deposits which have one dirt area inclusion with the thickness of not more than 10 m belong to the second type. The third and the fourth type are ore deposits having two or more dirt area inclusions, the distance between dirt area inclusions vary from 15 to 35 m and more. The fifth type is ore deposits with dirt area inclusions of irregular shape.

Based on researches, the classification of ore deposits of Krivoy Rog iron ore basin tend to be mined by room and pillar systems is given, table 3.

Table 3 Morphological classification of ore deposits of Krivoy Rog iron ore basin

Name	Without dirt area inclusions	Single dirt area inclusions		Doubled by dirt area inclusion		Tripled by dirt area inclusion	Combined dirt area inclusions	
Deposit type	1	2		3		4	5	
Dip angle of ore deposits, degree	45-90	45-60	60-90	45-60	60-90	60-90	45-60	60-90
Thickness of ore deposits, m	10-150	60-150	40-150	80-150	60-150	120-150	35-150	35-150
Dip angle of dirt area inclusions, degree	—	45-90	60-90	45-60	60-90	60-90	45-70	60-90
Thickness of dirt area inclusions,m	—	5-8	5-10	5-8	5-10	5-10	5-8	5-10
Rigidity of ore	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-

body								
Rigidity of hanging wall rock	+	+	+/-	+	+	+	+	+/-
Rigidity of bottom wall rock	+	+/-	+	+/-	+	+	+/-	+
Rigidity of rock inclusions	—	+	+/-	+	+	+	+	+/-
Note: + hard ores or rock; - soft ores or rock								

For mining of iron ore deposits with dirt area inclusions (type 2-5) it is necessary to use selective extraction, leaving dirt area inclusions in the waste area [4]. This can be achieved by using level (sublevel) room and pillar systems with the pillars and ceiling caving or leaving. However, their use has a number of boundary conditions, which include: the minimum allowable thickness of dirt area and ore deposit, the amount of extraction panels, the thickness of slope dirt area inclusion [5].

The minimum allowable thickness of dirt area inclusion is conditioned by inclined pillar integrity support, normal conditions of ore crashing and determined by

$$m_n \geq 1{,}5 \cdot W, \qquad (1)$$

where m_n – is the minimum allowable thickness of dirt area inclusion, m; W – is the line of least resistance at longhole work, m.

The minimum allowable thickness of ore body limited by the dirt area inclusion depends on the underground mining technology, height of level (sublevel) and is determined by

$$m_p \geq (0{,}1 \ldots 0{,}3) \cdot h \geq m_n, \qquad (2)$$

where m_p – is the minimum allowable thickness of ore body which is situated near dirt area, m, h – is the height of level, m.

The amount of extraction panels in the stope limited across by dirt area inclusions is determined from

$$N = \frac{M}{n} + 1, \qquad (3)$$

where N – is the amount of extraction areas in the stope limited across by waste rock inclusions; M – is the horizontal thickness of ore deposit, m, n – the amount of dirt area inclusions the thickness of which are ranged from 5 to 8…10m.

The thickness of the inclined dirt area inclusion that will ensure its stability for a period of the panel mining is determined by the conditions of the longitudinal compressive forces $P_{пр}$ in which there is no integrity. Side forces $P_б$, are directed towards the previously mined room filled with caved rocks [5]. The design formula for determining the width of the inclined interstall pillar is

$$b = \frac{P_{пр} \cdot K_д \cdot \xi \cdot \sqrt{\sigma_p \cdot h}}{n_ц \cdot \sigma_{сж} \cdot \sqrt{K_{зап} \cdot \gamma}} \geq m_n, \qquad (4)$$

where $P_{пр}$ – is the longitudinal compressive forces work along the inclined pillar; $K_д$ – is the ratio depending on the tensile stress and rock deformation; ξ – is the ratio of rock creeping; σ_p – rock tensile strength, kPa; $n_ц$ – the amount of longitudinal pillars for one room; $\sigma_{сж}$ – rock compressive strength; $K_{зап}$ –inclined pillar stability factor; γ – specific weight of rock, forming the inclined pillar, kg/m^3.

In the case when there is no tensile stress and deformation in the pillar K_d is 1.15 ... 1.41, when inclined pillar subjected to maximum deformation without affecting its integrity K_d is 1.41 ... 1.73, in the laminated fractured ground with possible or partial pillar caving K_d is 1.63 ... 2.0, and at crack initiation with the following caving K_d is 2.0 ... 2.44 [6].

So, the width of the inclined barren pillar defined by the expression (4) should be 1.5 times greater than the thickness power of barren area inclusion. As a result of researches an improved version of the level room mining methods with pillars and roof caving is developed.

A distinctive feature of the proposed version of the room mining method shown in Figure 2, from the traditional is the following. Mine section is divided into extraction panel according to the thickness. The first section is limited by hanging wall rock and hanging wall of dirt area inclusion, the last one is limited by hanging wall of dirt area inclusion and bottom wall. Section mining is carried out by extraction panel from hanging to bottom wall.

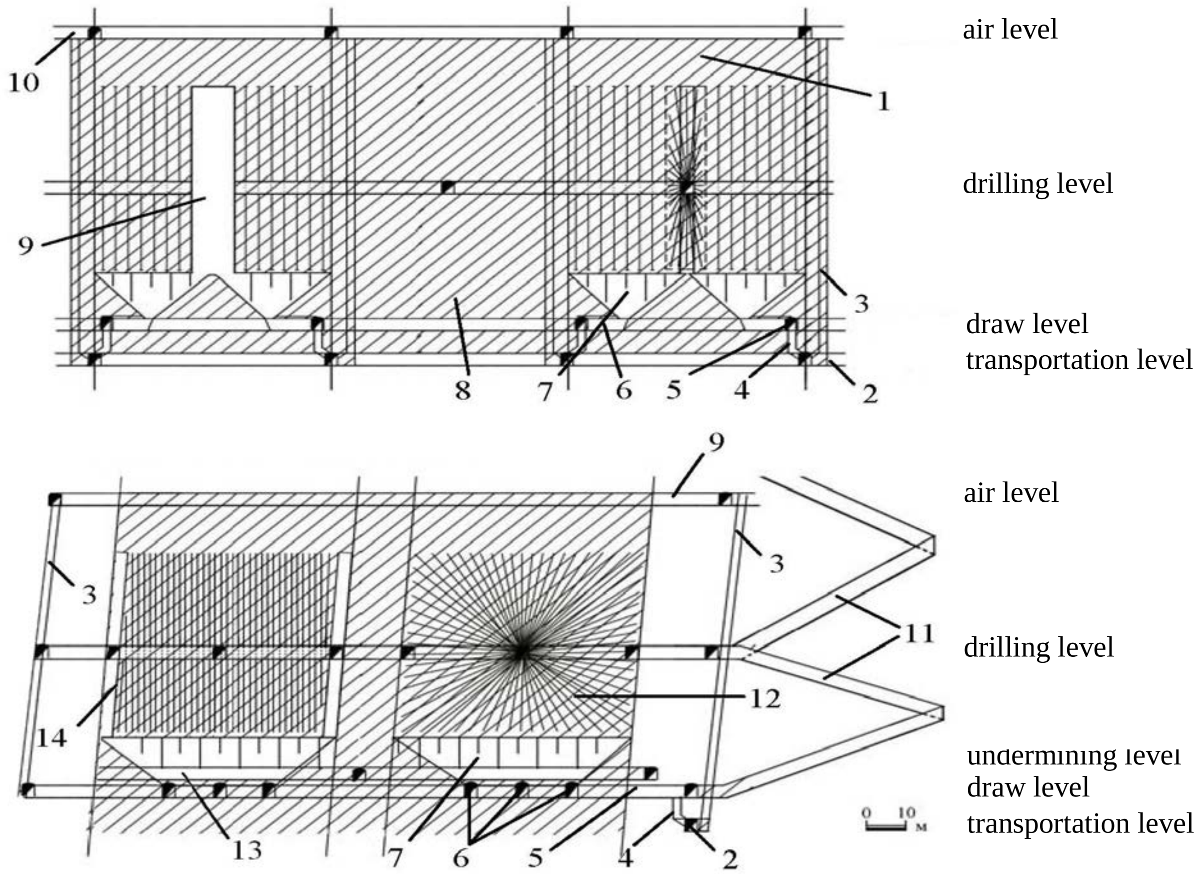

Figure 2 Level room development with dirt inclusions leaving in the section: I – primary stope (room); 2 –hauling roadway; 3, 4 – ventilation and manway raise , ore-pass; 5, 10 – draw entry; 6 – loading rooms; 7 – ditch undercutting; 8 – stope of the second turn (room fender); 9 –vertical compensation room; 11 spiral ramp; 12 rings of block caving deep holes; 13 –cutoff ditch ort; 14 – cut raise.

The panels are processed separately by level, (sublevel-) room and pillar system with the formation of a separate compensation space, drilling and receiving levels. Between the extraction panels the inclined pillar consisting of dirt inclusion is left. Interpanel inclined pillars (dirt inclusions) are not developed but remain unaffected between panels. Ore pillars and ceiling development is carried out according to the traditional technology. The results of calculation of improved mining method application compared with traditional technologies are shown in table 4.

Table 4 Technical and economic indices of development methods at mining of deposits with dirt area inclusions

Name	Room and pillar mining without pillar caving	Ore and cover caving methods	Proposal room and pillar mining method
Block (panel) parameters			
Block strike length, m	50	50	50
Extraction thickness, m	100	100	80
Level height, m	90	90	90
Dirt inclusion thickness , m	10	10	-
Dip angle of ore deposits, degree	80	80	80
Dirt inclusions amount, pieces	2	2	-
Mined blocks (panels) amount,	1	1	3

pieces			
Ore volume weight, t/m^3	2.8	2.8	2.8
Dirt inclusions volume weight, t/m^3	2.2	2.2	-
Ore mass reserve in the block, th.. t	1206	1206	1008
- ore reserve in the block, th. t	1008	1008	1008
- dirt inclusion reserve in the block, th.t	198	198	-
Recovered grade, %:			
- in ore	46.0	46.0	46.0
- in rock	24.0	24.0	24.0
- in dirt inclusionsв	16.0	16.0	-
Specific rate of preliminary development and breakoff, m/th.	2.8	36	3.8
Ore output per hole meter run, ton/m	21	20	25
Output per man-shift, t/ per shift	136.2	1548	155.72
Recovered grade of extraction block (panel) %	40.0	40.0	46.0
Ore loss, %	10.0	16.0	10.0
Ore clogging, %	7.0	15.0	7.0
Ore body amount, th. t	1084.5	1191.8	975.5
Recovered grade of extracted ore body, %	38.9	37.6	44.5

Conclusions and directions of further research

Performed researches have determined that the use of inclined pillars consisting of dirt area inclusions allows to increase the iron content in the mined ore body from 37.6 ... 38.9% to 44.5%, and to reduce drilling, output and minerals processing costs. Thus, the ore output is reduced by 10-18%, which significantly reduces the rock processing and haulage costs.

The given method of pillars determination is applicable under condition when the calculated width of inclined pillars is equal to or less than the dirt inclusion thickness. In the case when the calculated width of the inclined pillar is more than the dirt inclusion thickness, the traditional ore and cover caving method is applied.

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