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Decrease in coal losses during mining of contiguous seams in the near-bottom part at Vorkuta deposit

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Abstract. The problem of formation of extended zones with high rock pressure (HRP) from safety pillars at the boundaries of extraction pillars formed due to the mine layout of complex geometry is considered at the example of JSC Vorkutaugol mines. A detailed analysis of the remaining reserves of the near-bottom part of the deposit was carried out to estimate losses and the impact of HRP zones from the Chetvertyi protective seam to mining operations on the Troinoi upper seam along with the possibilities for the reduction of sizes of HRP zones at the account of expanding the underworked space. Due to research on the near-bottom part of the Vorkuta deposit, within the framework of the accepted layout, a zone at the Komsomolskaya mine and two zones at the Zapolyarnaya-2 mine were singled out, at which losses at the boundaries of the extraction pillars amount up to 13-22 % of the total resources of the mine field. The high volume of losses in these pillars indicates the relevance of research on the priority extraction impact of protective seams on the efficiency and safety of mining operations in the working area of underworked and HRP zones. Based on the analysis of foreign and Russian experience in the pillar cleaning-up at the boundaries of working areas and the methodical guidelines and instructions, a technological scheme was developed that allows increasing the coal mining recovery factor in the near-bottom part of the Vorkuta deposit from 0.75 to 0.9 without fundamental changing of the ventilation and transport networks and also without purchasing any additional mining equipment. The conducted economic calculations confirmed the effectiveness of implementing the new technological scheme for cleaning-up reserves at the boundaries of extraction districts. The economic effect is from 0.079 to 1.381 billion rubles of additional profit from coaxial extraction pillars, depending on the mining and geological conditions and the size of the pillars.

Key words: pillar; losses; contiguous seams; high rock pressure; technological schemes; Vorkuta deposit; extraction district; underworked zones

Introduction. In terms of the Vorkuta deposit development, the annually increasing depth of mining is accompanied by the increase of gas content in extraction districts, deterioration of conditions for the maintenance of the district workings and a growing risk of rock bursts [2, 5]. The need to localize mining operations on productive formations within the underworked zones has led to the fact that, despite the use of pillarless schemes for preparing extraction districts and schemes with protection of district gateways with yield pillars, the coal mining recovery factor for blocks in the near-bottom part of the geological basin does not exceed 0.75, which is associated with extended HRP zones at the boundaries of the extraction districts and with the mine layout of complex geometry [1, 9].

Formulation of the problem. The Troinoi and Chetvertyi seams are worked out at the Komsomolskaya and Zapolyarnaya-2 mines. Despite the priority development of the Chetvertyi protective seam, it is almost impossible to fully work out the entire mine field without leaving the pillars and forming zones of high rock pressure on the underworked seam. The existing mine layout does not allow working out reserves at the boundaries of the extraction pillars due to the rectangular shape of the extraction districts. The abandoned reserves in the form of triangles on the side of the installation and break-down chambers form the HRP zone for the Troinoi upper seam (Fig.1). HRP zones are projected at angles δ , which amount to 80 and 75 degrees for the working conditions of the Vorkuta coal deposit, which is the reason for the reduction of the longwall length along the Troinoi upper seam [6].

The task of implementing resource-saving technology when refining the reserves of the trough bend of the Vorkuta deposit part is quite urgent, since the reserves of high-quality coal of the Zh coal rank at the boundaries of the extraction pillars amount to up to 22 % for the block [3].

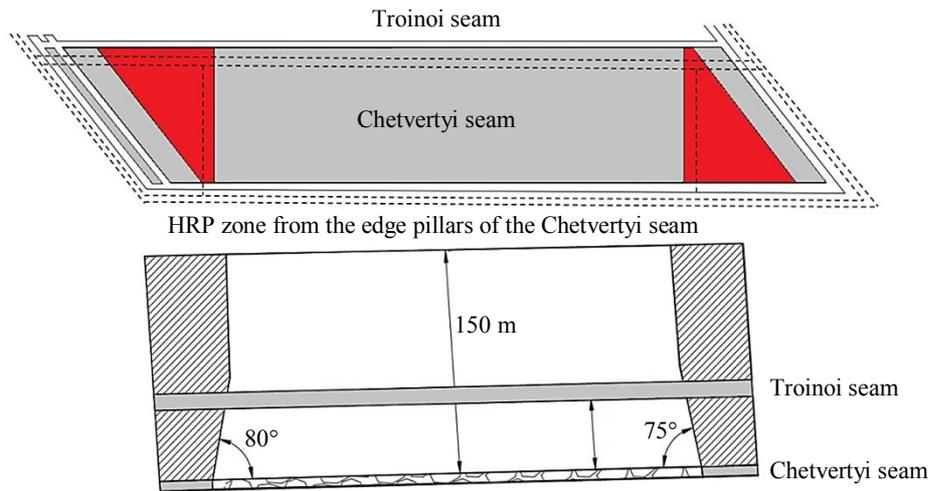


Fig. 1. The current technological scheme with leaving the pillars in the edge parts of the extraction pillars

The layout analysis of the near-bottom part of the Vorkuta geological basin revealed five blocks where it is planned to perform cleaning-up of the reserves. Three of the five blocks are characterized by large losses of reserves due to the complex geometry of the mine fields. The size of losses in pillars by area and volume are shown in table 1. The total stockpile of the reserves in the pillars at the boundaries of the extraction pillars with the existing mine layout is 4.6 million tons, which is equivalent to half of the annual business plan for coal production of JSC Vorkutaugol for 2018.

Table 1

Losses in the pillars on the boundaries of the extraction districts

Block number	Troinoi seam			Chetvertyi seam		
	By area, km ²	By volume, mln ton	From total stockpile in the block, %	By area, km ²	By volume, mln ton	From total stockpile in the block, %
1	0.31	1.13	15	0.23	0.51	13
2	0.4	1.25	22	0.3	0.65	20
3	0.2	0.7	21	0.16	0.34	19

As an example, the north-western block of the Zapolyarnaya-2 mine (district 2) can be singled out, where the total area of reserves at the boundaries of the extraction districts for both layers is 0.7 km² with the total volume of losses in the pillars amounting to 1.9 million tons of coal, which is 21 % of the total volume of coal planned for extraction in block № 2. The length of the extraction pillars in block № 2 does not exceed 1300 m in the Troinoi seam due to the extended HRP zone in the Chetvertyi seam. The pillar cleaning-up will increase the length of the extraction pillars along the upper seam by 5-10 %, which will affect the completeness of the resource extraction and increase the technical and economic mine indicators. Figure 2 shows a map extract of the plan of mining operations in the field of the Zapolyarnaya-2 mine, the losses in the pillars are highlighted in red.

Leaving pillars in a large area at the boundaries of extraction districts along the Chetvertyi seam leads to the formation of extended HRP zones, and despite the desire to develop only the underworked zones, extraction and tunneling districts fall into the HRP zones, as evidenced by recent accidents [4, 6]. As a result, the safety of mining operations decline, the technical and economic indicators of the enterprise drop, and operational losses increase.

The research results. Development of mine fields of complex structure with an increase of recovery ratio is a multifaceted technological task, especially in the conditions of contiguous seams development. Reducing the size of pillars at the boundaries of extraction districts by introducing a different technological scheme will improve the technical and economic indicators of the mine, i.e.,

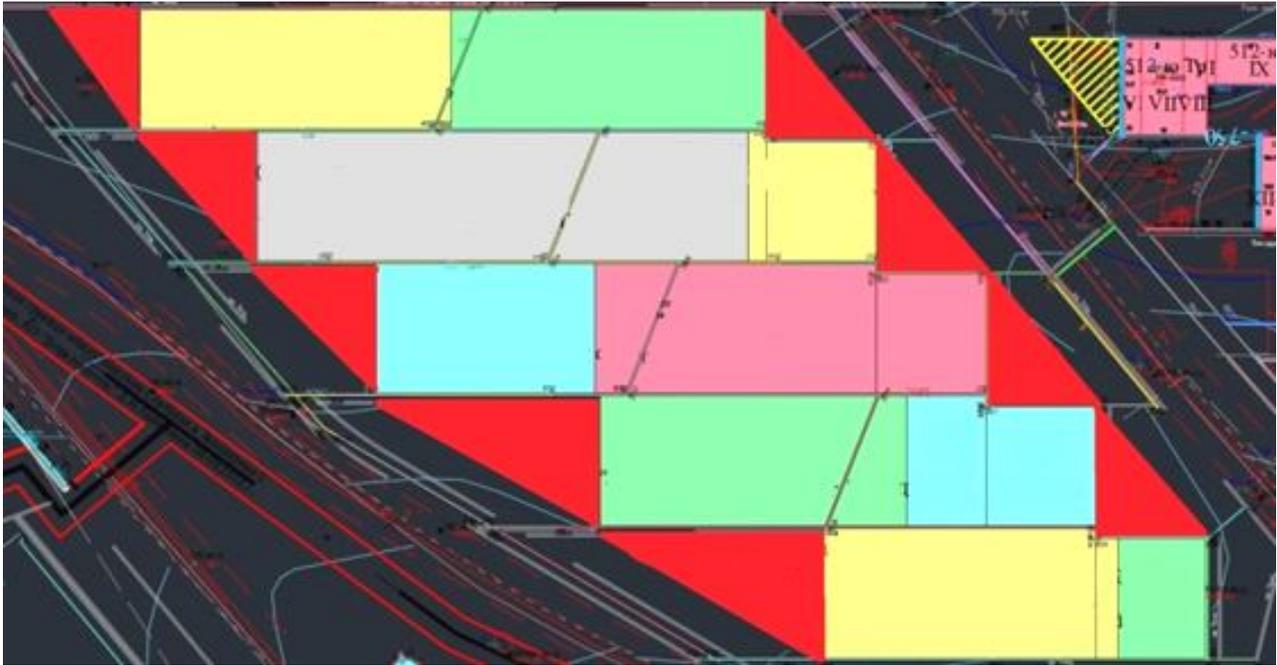


Fig.2. North-western block of the Zapolyarnaya-2 mine, the Chetvertiy seam

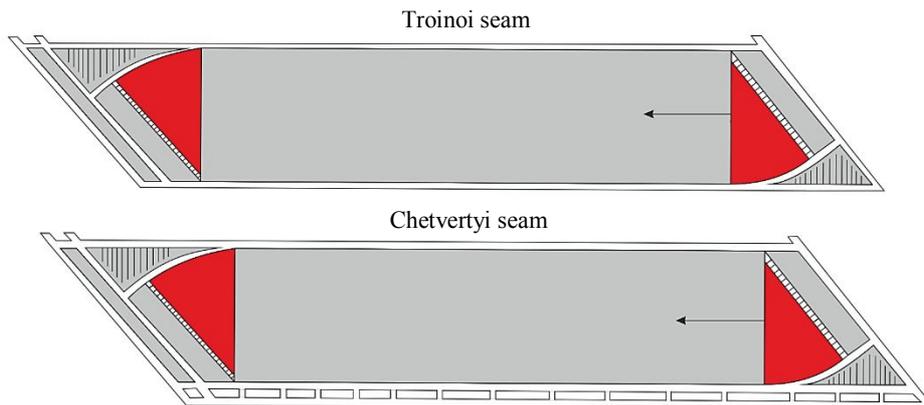


Fig.3. The proposed technological scheme

increase the coal mining recovery factor and the safety of mining operations [12, 13]. Various options for complete extraction of reserves at the boundaries of the extraction pillars were considered, including augering, chamber mining, and room-and-pillar methods. For a number of reasons, mining-geological and mining-technical conditions of the near-bottom part of the Vorkuta field do not allow to implement these methods cost-effectively and safely, including the tendency of layers to dynamic manifestations, large depth of the development, an unstable main roofing and the high cost of tunneling [9].

One of the rational ways to cleaning-up reserves at the boundaries of extraction districts is to tunnel the installation and break-down chambers parallel to the protected main workings, followed by turning the upper or lower part of the longwall (Fig.3). The use of this technological scheme is possible for both seams; it will reduce the length of the HRP zones of the Chetvertiy seam and, as a result, increase the length of the extraction pillars for the Troinoi productive seam. The use of this technological scheme can increase the coal mining recovery factor from 0.75 to 0.9 per block. For its implementation, an additional tunneling will be required, which will allow the installation of a mechanized stoping complex parallel to the main development and turn the breakage face without changing the length of the longwall. It is proposed to carry out tunneling after the main delineation of the extraction district.



Depending on the angle of rotation of the stoping mechanized complex (SMC), longwall lengths and seam thickness, the possible amount of afterextract can at the Chetvertyi seam can vary from 32 to 104 thousand tons and at the Troinoi seam, from 50 to 175 thousand tons. This volume is estimated for the reserves cleaned-up on one side of the extraction district. The afterextract volume can be increased by 1.5-2 times, if the mining and geological and mining and technical conditions allow to implement the technological scheme on both sides of the extraction pillar. The current trend to increase the longwall length up to 300-350 m in the conditions of JSC Vorkutaugol will contribute to an even greater increase in additional profit when implementing this technology [9].

The Troinoi and Chetvertyi seams are classified as hazardous for dynamic and gas-dynamic phenomena, so the use of a new technological scheme requires preventive measures in the form of well unloading. The parameters of the well unloading are determined by the instructions for conducting mining operations on seams that are hazardous with rock bursts. Preliminary well unloading of the remaining pillar (as far as the hypsometry of the district allows) will be required for additional tunneling [10]. Further on, during the tunneling of additional workings, if necessary, well unloading will be carried out from the drifting face itself (Fig.4).

Table 1 presents possible volumes of afterextract and additional profit with the account of the mining and geological conditions of the seams, the feasibility study, the pillar sizes at the boundaries of the extraction pillars, and the working seam options for the joint application of the current and proposed technological schemes for cleaning-up reserves at the boundaries of the extraction pillars. We can conclude that the greatest economic effect is achieved when applying the technological scheme with the swing of the mechanized complex both in the Troinoi and Chetvertyi seams. Mining and geological conditions cannot always ensure the use of mechanized complex swing along coaxial seams on both sides of the extraction district, so different variations suggest different afterextract volumes of the reserves at the boundaries of the extraction districts [15, 16].

For effective implementation of the proposed technological scheme, it is necessary to justify the parameters of the mechanized complex operation in the swing zone. It is recommended to determine the parameters of SMC operation using existing methods [8]. The load on the stoping face is reduced by 10-15 % due to the complexity of work in the swing zone. For the conditions of the near-bottom part of the Vorkuta field, the degradation factor of the combine was calculated; when the complex is turned, it is equal to 0.84, 0.86, 0.88 for longwall lengths of 200, 250, 300 m. The study considers technological maneuvering with a step-cyclic scheme of the contour of the swing, since the task is not to safely pass geological disturbances, but to maintain the specified position of the stoping mechanized complex relating to the preparatory workings.

In the case of roof falls in the trampling zone of the mechanized complex, it is recommended to carry out preventive measures in the form of borehole chemical strengthening along with the movement of support sections with active roof support [11, 14]. These measures have proven themselves positively both in Russia and abroad.

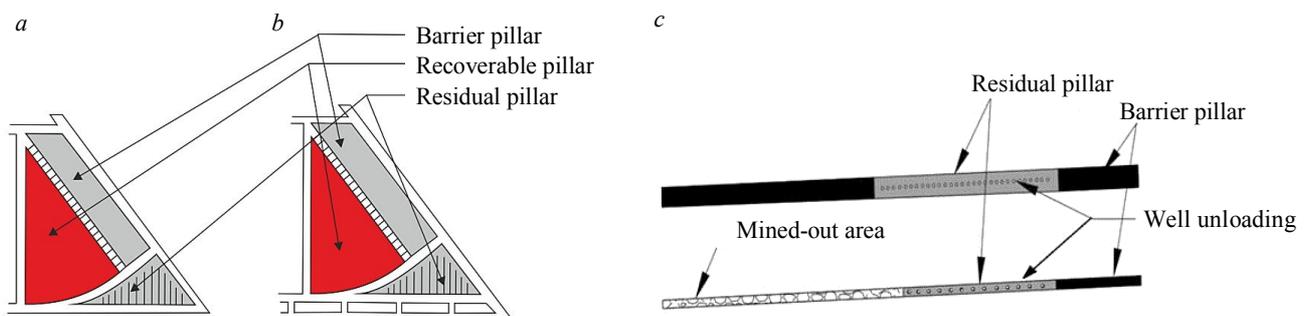


Fig.4. Concept scheme of the residual pillar unloading from the side of the installation chamber along the Troinoi seam:
a – designation of pillars for the Chetvertyi seam; b – for the Troinoi seam; c – vertical section



Table 2

Options for joint use of the current and proposed technological schemes

A pillar on the side of the installation chamber		A pillar on the side of the break-down chamber		Possible volumes of afterextract, thousand tons	Possible additional profit, billion rubles.
Troinoi seam	Chetvertyi seam	Troinoi seam	Chetvertyi seam		
SMK rotation	SMK rotation	SMK rotation	SMK rotation	164-558	0,403-1,381
SMK rotation	SMK rotation	Applied technological scheme	Applied technological scheme	82-279	0,203-0,690
Applied technological scheme	Applied technological scheme	SMK swing	SMK swing	82-279	0,203-0,690
Applied technological scheme	SMK swing	Applied technological scheme	SMK swing	64-208	0,158-0,513
Applied technological scheme	Applied technological scheme	Applied technological scheme	SMK swing	32-104	0,079-0,256
Applied technological scheme	SMK swing	Applied technological scheme	Applied technological scheme	32-104	0,079-0,256

In the proposed technological scheme, the coal mining recovery factor, depending on the parameters of the technological scheme at the boundaries of extraction districts, will vary from 0.79 to 0.9, which will increase the coal mining recovery factor at the near-bottom of the Vorkuta geological basin to 0.9.

Economic calculations have confirmed the positive effect of the introduction of a new technological scheme in the development of the near-bottom part of the Vorkuta geological basin. The profit from the sale of after-extract coal covers the necessary expenses (Fig.5) for additional development and well unloading for the safe implementation of the proposed technological solutions. The estimation of economic efficiency is linked to the selling price of coking coal and the total cost of a ton of coal after production and processing according to the data of JSC Vorkutaugol for the fourth quarter of 2018. The economic effect of implementing the proposed technological scheme for the Troinoi seam is 45 % higher than for the Chetvertyi seam, due to the greater capacity of the working seam and the lower cost of tunneling additional workings due to the lack of rock cutting.

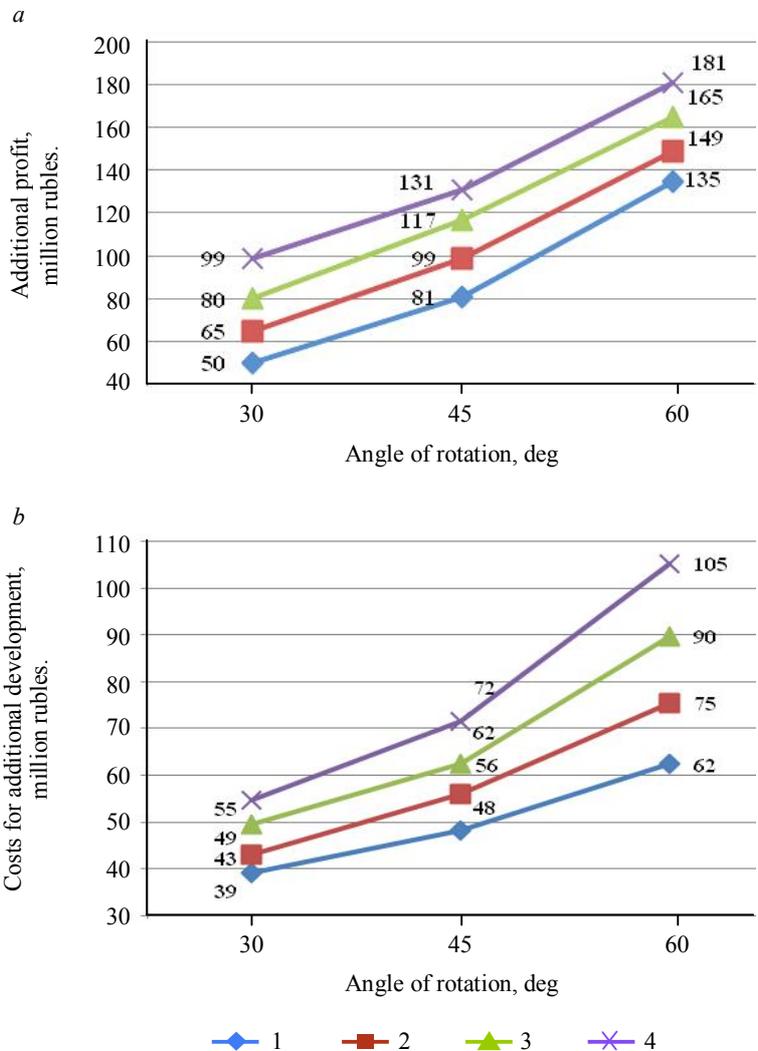


Fig.5. Dependence of additional received profit (a) and necessary expenses (b) at different angles of rotation of the stoping mechanized complex on the Chetvertyi seam

1 – longwall length 225 m; 2 – 250 m; 3 – 275 m; 4 – 300 m



Conclusions. The research made it possible to draw the following conclusions:

- The applied technological schemes of seam development provide for the reserves abandonment at the boundaries of the extraction districts, which leads to a significant reduction of the size of the mined-out areas and high losses (up to 22 % for the block).
- Expansion of the underworked areas is possible with the pillar cleaning-up at the boundaries of the extraction districts using the mechanized stoping complexes available at the mines.
- The most efficient and safe technological scheme is the one using with the swing of the mechanized complex at the boundaries of the extraction districts. At that, the afterextract pillar coefficient will amount to 0.72-0.9 and the coal mining recovery factor for the near-bottom part of the deposit will amount to 0.9.
- The costs of implementing the proposed technological scheme for refining reserves at the boundaries of the extraction districts will be covered by the profit from the sale of afterextract coal.
- The economic effect of the proposed technological schemes implementation varies from 0.079 to 1.381 billion rubles of additional profit from coaxial extraction pillars, depending on the mining and geological conditions and the pillars size.
- Since the Troinoi and Chetvtyi seams are classified as hazardous for dynamic and gas-dynamic manifestations, the implementation of the proposed technological scheme involves the use of preventive measures in the form of well unloading, the parameters of which are determined using the instructions for conducting mining operations on seams that are hazardous with rock bursts.
- For the most efficient implementation of the technological scheme with a mechanized complex swing, high work culture is a must, since the work cyclogram of the stoping face in the swing zone is undergoing significant changes.

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