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Justification of stripping and development of a modular mine site for a combined coal mining method in Kuzbass on the example Baikaimskaya mine site

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The article considers one actual method for development coal deposits in the Kuzbass by open-underground mining. The scientific and practical advantages of the proposed method due to the use of common infrastructure of coal mine and a modular mine site (subsequently transformed into a mining and technological structure operating according to the mine – longwall scheme) are presented. Currently, a development strategy for Kuzbass until 2035 has been developed. As part of the strategy, a draft program for subsoil use is being formed in the coal industry department. The program should take into account all the positive and negative aspects associated with coal mining in cities and municipal areas and also their prospects. In the Kuznetsk coal basin, 42 mines and 52 opencast mines are mining, of which 12 enterprises use partially unified infrastructure. According to the results of open-underground mining work conducted by the laboratory of the Institute of Coal and Coal Chemistry of the Siberian Branch of the Russian Academy of Sciences (Institute of Coal SB RAS), the list of sites includes favorable mining and geological conditions with incidence angles of up to 18 degrees. As open-pit coal production increases, many sites encounter such a parameter as maximum allowable (boundary) strip ratio. At the stage of preparing the feasibility study for the development of a coal deposit, this coefficient is calculated first of all, since duration of enterprise's work and its economic component depend on it. In order to increase parameters, it is necessary to carry out transition from open works to underground. As a result, coal mine will not work at a loss, providing production with an economically disadvantageous strip ratio.

***Key words*:** open-underground mining; coal deposits; strip ratio; modular mine site; related infrastructure

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Introduction. In order to increase production volumes and move to a new stage development of coal industry, we need new technologies that will increase the technical, economic and environmental indicators, which is possible with a more complete underground mining development. The article deals with one of the directions of open-underground mining operations, which can reduce the land-consuming of the mining and technological structure in general, while increasing the productivity of the enterprise due to a number of stripping and development parameters on coal formations using modular mine sites, which are later converted into a mine-longwall if necessary.

Formulation of the problem. The aim of this work is to generalize method of stripping and development modular mine sites during combined (open-underground) mining coal deposits. The objective of the study is to analyze the actual development of mining front of the technological structure "open-pit – modular mine site" with a sequential stripping.

Discussion. The modular mine site was developed at Mokhovsky open-pit mine, which was formed in 2009 by the merger of three mines – Mokhovsky, Sartakinsky and Karakansky. The Mokhovsky branch was founded in 1966. After 11 years, open-pits were merged into one enterprise located in the southwestern part of Leninsk-Kuznetsk district in Leninsky and Saltymakovsky geological and industrial regions of Kuznetsk coal basin. The mining depth and strip ratio reach maximum technical values for existing excavation and other mining equipment, economic indicators section is reduced. Upon reaching boundary ratio, the remaining coal formation at the license boundary refers to operational losses. To solve this problem, the strip and direct work out in cost-effective underground method are performed from the side surface of the mine. This method significantly

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improves the position of the open-pit on the basis of parameter estimates of coal mining of the open-underground method for different groups of geological conditions (in terms of thickness and dip angle of the formation). The conditions are met when the cost of open works and underground works is equal [17].

The formation has a synclinal structure, extending from northwest to southeast, asymmetric structure is a gently sloping southwestern wing and a steep northeastern wing. The fold has a wide bottom, up to 7 km. To the northwest, the fold gradually narrows and has only one wing, as its southwest wing has a violation. The axis of the fold sinks gently in a south-easterly direction. Disjunctive tectonics of the site is represented by a relatively small number of violations:

• violation I-I = a longitudinal dissonant upthrust with the fall displacer to south-west at an angle 20-40 ° and an offset amplitude 130-140 m; accompanied by a zone continuous crushing rocks with a thickness 10-30 m;

• violation II-II – longitudinal consonant upthrust with fall displacer to southwest at an angle of 20-40°; the amplitude displacement, measured along strike, is 40-100 m; violation is accompanied by a zone intense crushing rocks with a thickness of 10-40 m;

• Iganinsky upthrust – a consonant upthrust with fall of displacer to southwest, at an angle of 35-40°, with a stratigraphic amplitude of 220 to 560 m; has a crumpled rock zone with a normal thickness 40-60 m.

The field of Mokhovsky open-pit on which Baikaimskaya mine site is located, is characterized by a simple geological structure and, according to classification, belongs to the 1st group of deposits.

The tectonics of underground mining is sustained, the formation has a calm bedding, the dip angles vary between 14-20°, the Kuznetsky coal basin is rich in deposits with shallow bedding, as a result of which the transfer of open work to underground work using related mine infrastructure is widely used [16].

At the Baikaimskaya mine site, trenches from open-pit mining were used to construct the mouths of stripping workings. This is due to fact that at the initial stage of designing, the underground development was not provided and the need for internal dumping was forced. Nevertheless, this method of transition to underground mining with combined method is one of the most favorable, since workings open up formation immediately without passing through waste rock, which also increases economic performance of an enterprise.

It should be noted that stripping and development project provides for mining operations that extended along the boundaries of the mine field. The protection of mine workings that contour mine field is carried out by coal pillars, while following options are possible in related territory:

1) mining was not carried out and future mining is not expected;
2) mining was not carried out, but mining is not excluded in future;
3) there are development mine workings in operation;
4) there are offset development mine workings;
5) near the boundary of mine field, the stoping works have been carried out and there is a worked out site.

In our case, this is the first option, when development and stripping mine workings can be carried out directly along mine lease boundary, without leaving pillars, while ensuring most complete extraction of the mineral resources located on the mine lease territory, since the completeness of reserves extraction is one of the main requirements of mineral resources protection.

However, if there are development or stoping mine workings in neighboring site, the size of barrier pillars should provide reliable aero- and waterproofing of the existing mine workings from mining operations of the related enterprise.

At the borders with mining operations of a related enterprise and contouring underground mine workings, a barrier coal pillar must be left. The pillar width is determined according to instructions for safe mining operations in flooded workings:

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$$B_p = 0.05H + 5m + \Delta l \geq 20.0 \text{ m}, \quad (1)$$

где H – pillar depth from earth's surface, m; m – development thickness (height of the ward working), m; Δl – mine position error, m.

Then (Fig.1), the location of the contouring mine at boundary with open-pit is determined. By measurement the distance between the mine lease boundary and the related outlining workings is located $B_p(l)$. If mining operations were not conducted below the lower boundary of the mine field, then it should not be excluded that they can be conducted, so the lower parallel gate way should be carried out at a distance from the border equal to half the calculated width of the barrier pillar.

The location of the contouring workings in development is determined by the method of construction at the shift angles (Fig.1, *b*)

$$B_{pI} = B_p + M/\text{tg}(\Delta), \quad (2)$$

when Δ – complete shift angle along strike formation, deg.

Such mining operations are dynamically progressing abroad, in such developed countries as Australia, USA and Canada, where scientists pay great attention to effectiveness of combined method and safety [18-21]. In domestic practice, at Sibirginsky coal open-pit, one of the first similar processes was conducted back in 1999 [14].

At the Institute of coal SB RAS there was developed a dependence (Fig.2), based on which [15], it can be seen that the less maintain workings in the mine are carried out, the less its entropy is. Thus, the dependence shows high production indicators for such coal mining complexes as modular mine sites. This dependence becomes relevant when there is a rational use of the existing infrastructure of the mining enterprise.

Reducing the length of maintain workings is known to improve the work of all production mine systems, which creates conditions for achieving a high load on the stope and development faces. At the same time, the number of jobs is minimized, labor productivity and wages are growing, and the cost of production is decreasing. The technical and economic indicators of the Baikaimskaya mine site of the Mokhovsky open-pit significantly exceed similar indicators of a representative group of Kuzbass mines at the construction stage.

Using the experience accumulated at the Institute of Coal SB RAS and the global experience of similar solutions [3-12], a wide range of technologies for stripping and development a

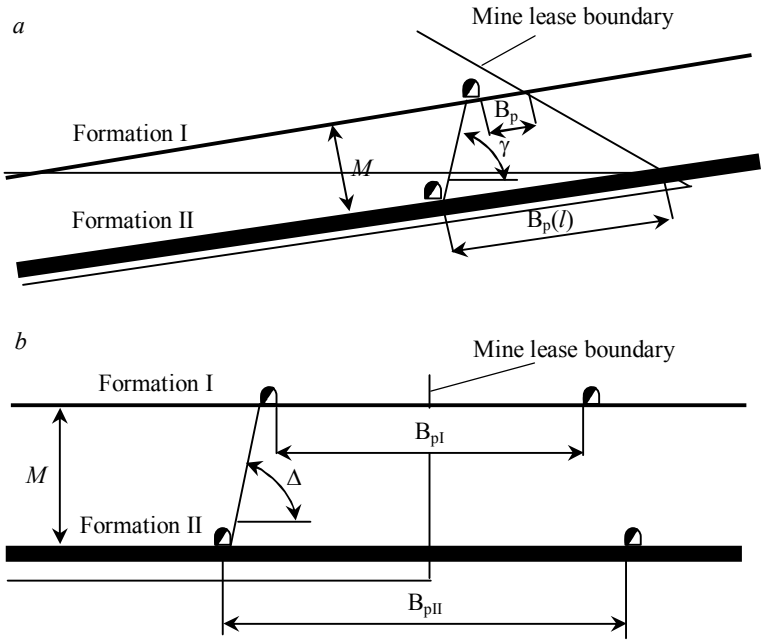


Fig.1. Scheme for determining the barrier pillar width to fall formation (*a*), along strike formation (*b*)
Δ, γ – complete shift angles

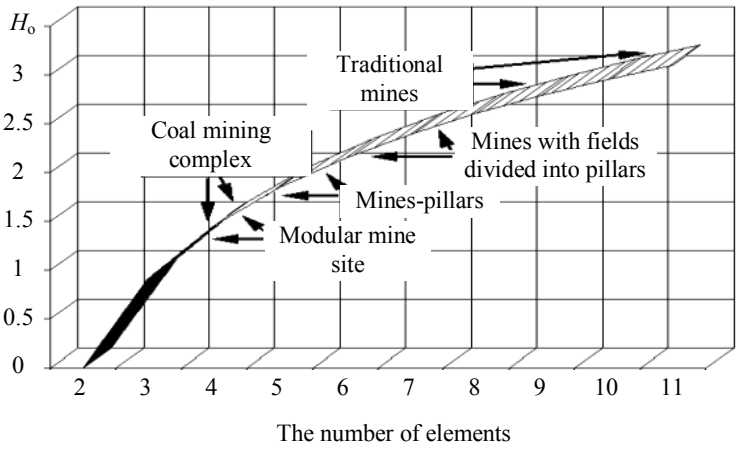


Fig.2. Summary quantitative assessment of entropy H_o depending on the number of elements of the mining and technological structure of coal mines [13]

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modular mine site is provided. In the example, from the point of view of economic efficiency and environmental safety, the central and flanking inclined shafts of the mine were laid from open-pit sites.

The boundaries mine fields along strike correspond to licensed materials and pass close to flank and central parts of the mine field; according to fall, boundary mine field is conveyor drift excavation column. This decision of formation cutting allows to ensure a constant outflow of available groundwater falling into workings and to push them into the worked out space, which favorably affect the technology of the mining site formation and does not violate it. Before starting work on the main mine field (main stage), construction and coal mining of the modular mine site on the Polysaevsky II formation begins from the flank industrial site (initial stage). It was planned to stop open-pit mining operations in the area of construction of the flank industrial site, leaving the pillar between the side of the cut and the flank slopes and also conducting from the flank and main industrial sites the two slopes for coal (ventilation and conveyor) with a pillar between them.

According to the project for stripping formation and carrying out the most labor-consuming part of the main and flank slopes along the overburden, the available open-pits earthmoving equipment is used, that will speed up the stripping to the stable rocks and enable to begin the excavation slope roadheaders.

The main conveyor slope has tilt angles from 19 to 23°. In this site, the roller supports of the belt conveyor are installed with a smaller interval between them, and the side rollers are installed more steeply than usual.

The first face preparation is provided for by ventilation, conveyor drifts and mounting box. Along with this, the main conveyor and track drifts are carried out (they are preserved for the entire life of the mine).

Based on the mining and geological conditions of the Polysaevsky II formation, the long pillar system along strike with a stoping mechanized complex is adopted. Mining out of the pit pillars of a mine field is performed in the direction from the flank slopes to the main ones. The order of mining out columns is accepted descending. The extraction pillar development of mine field is carried out in the direction from the flank slopes to the main ones. The order of extraction pillar development is accepted descending.

Based on the foregoing, in 2003 the company Kuzbassrazrezugol and the Mokhovsky open-pit started the construction of the modular mine site. At the moment, this site has been transformed into Baykaimskaya Mine LLC, which is mining longwall in Polysaevsky II formation of grade D. Mine balance reserves are estimated at 68 million 699 thousand tons. The average annual production is 2.5 million tons.

Technical and economic indicators of the conducting volume of the maintained development workings per 1000 tons of coal production from several projects at the time of mines construction relative to the modular mine site in Kuzbass [2]:

Name of mines	The length of maintain workings	
	Total, thousand m	Per 1000 t of coal production, m
Fizkulturnik	40.8	39.1
Sibirskoye colliery group	31.8	56.4
Pervomaiskaya	92.7	76.0
Berezovskaya	98.8	91.4
named by Kirov	98	30,8
Egozovskaya	27,5	32.3
Komcomolets	81.5	75.2
Yuzhnaya	78	29.7
Polysaevskaya	69.5	43.5
Octyabrskaya	68.7	30.5
Krasnoyarskaya	24.7	25.4
Novaya	19	105.5
Kolmogorovskaya	22	52.1
The average among mines	57.9	52.9
Baikaimskaya modular mine site	17.7	8.9
Mine site on average for the mines, %	31	17

Thus, the length of maintained mine workings is 3.3 times less (31 %) compared with other mines, and 5.9 times (17 %) per 1000 tons of mined coal.

Conclusions

The use of innovative scientific provisions [15] and also the world experience of the combined development system, will make it possible to achieve a whole chain of positive results in terms of technology [1]:

- synthesize underground and open-pit mining as a modular mining and technological structure "open-pit – modular mine site" for mutual coordination in time and structural elements;
- establish a balance of technological links of open-pit and underground mining operations for a more reasonable cost and, as a result, a higher coefficient of environmental cleanliness;
- create conditions for sequential production of coal mining processes by modular mine sites for maximum productivity of mining operations in open-pit;
- unite most production infrastructure – power lines, substations, roads, transport, etc.;
- extend life of existing mining enterprises;
- reduce area of degraded lands and accelerate their rehabilitation.

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