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STATUS AND DIRECTIONS OF IMPROVEMENT OF DEVELOPMENT SYSTEMS OF COAL SEAMS ON PERSPECTIVE KUZBASS COAL MINES

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The article presents the results of the analysis of the Russian coal mines experience in using the variant of the long-pillar development system with the abandonment of coal pillars in the mined out areas of longwall faces. In the Kuzbass mines, this option accounts for 90-95 % of the total volume of coal mined by the underground method. It is pointed out that it is necessary to take into account the negative influence of the pillars left in the worked out space on the geomechanical conditions of conducting mining operations in the overworked (underworked) seams.

A significant negative effect of the pillars is shown in combination with selective extraction of the adjacent layers on reduction of the balance reserves. The measures allowing to increase the efficiency of the use of long pillar mining systems for the development of adjacent series of seams are considered.

***Key words*:** development system, long pillars, coal pillars, adjacent seams, negative influence of pillars, non-pillar mining method

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Introduction. During the last 15-20 years, in the Russian coal mines, when developing low-grade sloping coal seams with a thickness of 1.4-6.0 m, the most widely used system has been the development of long-pillar system with the preparation of extraction pillars with double workings, one of which is extracted after a longwall face, and the second one is reused when developing the adjacent pillar [6, 10]. During implementation of this system in a worked out area of longwall faces between adjacent sections, they leave the coal pillars that are not destroyed by rock pressure (Fig.1).

Currently, the promising Russian mines using this type of development system mine almost all working areas with the most high-quality reserves. In the mines of the Kuznetsk basin this type of development accounts for more than 93 % of the total volume of coal mined by underground method [8, 9].

Sharp, from 30 to 93 %, increase of production volumes at the Russian coal mines with the use of this development system after the transition of the coal industry to market relations due to the

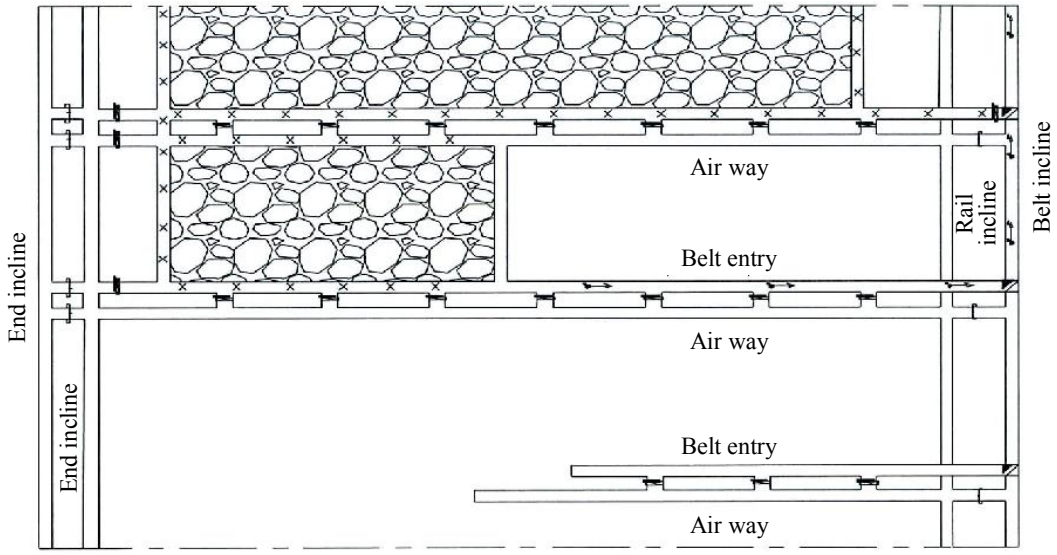


Fig.1. The principal layout of development system with long pillars with leaving pillars in worked out area used in promising mines in Kuzbass

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fact that, despite its shortcomings (Fig.2), this system is most suited to the corporate interests of subsoil users during the seam excavation in favorable mining-geological and mining-technical conditions, using high-performance long wall mechanized set of equipment.

Research results. The economic attractiveness of this development system is mostly driven by the possibility of the use of roof bolting as the primary support of the development workings sections, as well as by creating conditions for the fullest use of the potential of modern high-efficiency longwall mining set of equipment and achieving high average daily load on longwall face.

The combination of these factors makes it possible to implement such progressive principle as «mine-longwall face» («mine-seam») in the favorable mining-geological and mining-technical conditions as the basis for forming the topology of mines. Mines, technological schemes of which are developed in accordance with this principle, are characterized by a high level of spatial concentration of mining operations and minimal production costs. Examples of such mines in the Kuznetsk basin are the following: «Taldinskaya – Zapadnaya 1», «Taldinskaya – Zapadnaya 2», «Kotinskaya», «Imeni V.D.Yalevsky», «Imeni A.D.Ruban», «Komsomolets», «Imeni 7 Noyabrya», and «Polysaevskaya».

When assessing the prospects for the use and the direction of improvement in the conditions of the Kuzbass mines, the development of long pillars with the abandonment of coal pillars in the mined out areas (see Fig.1), it is necessary to take into account the following trends in the change of

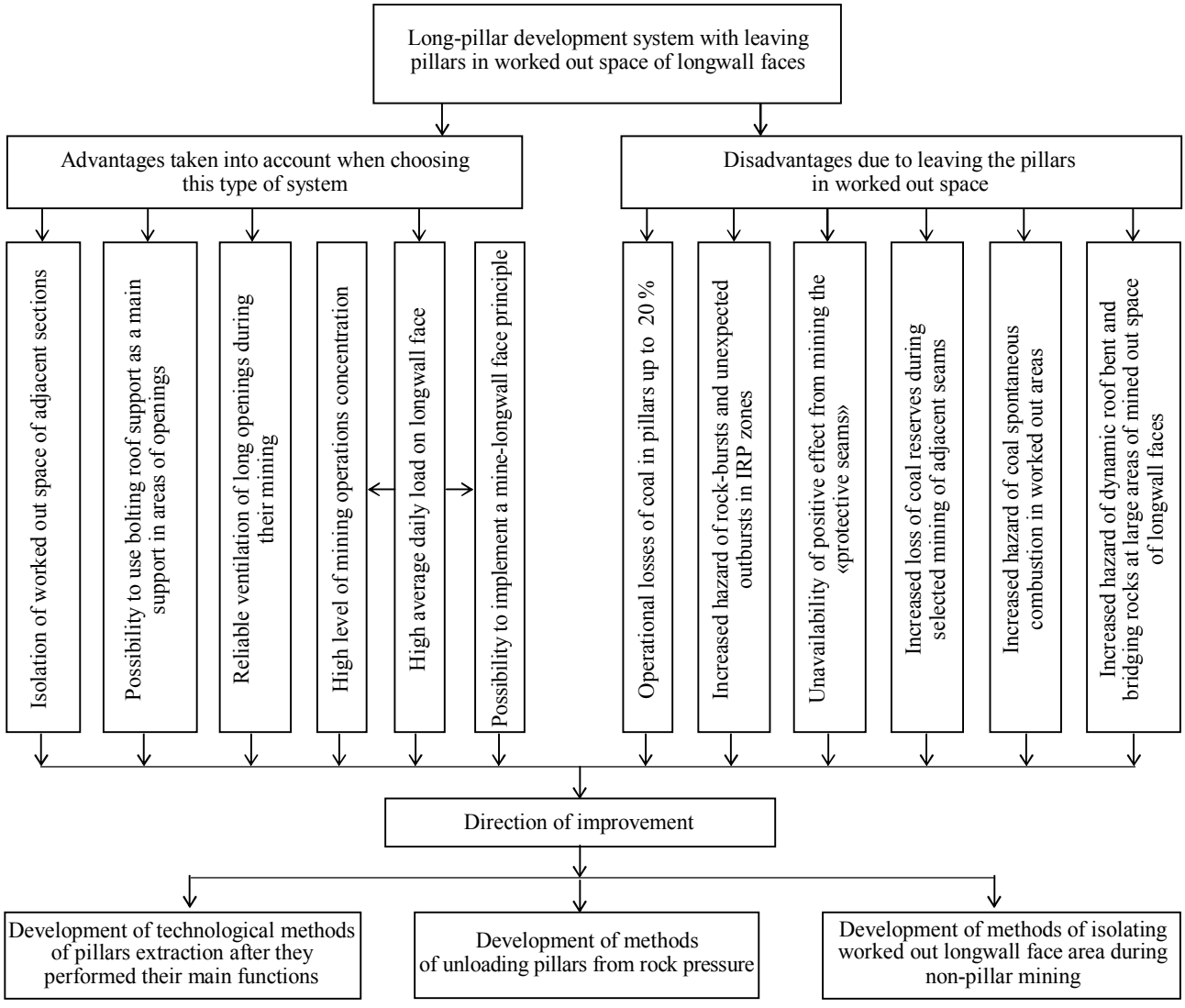


Fig.2. Assessment of long-pillar development system with preparation of pillars by double workings and leaving pillars in mined-out areas

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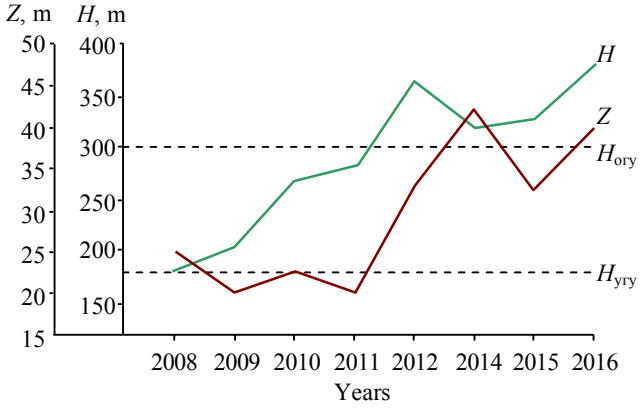


Fig.3. Changes of depth of mining H and width of pillars Z, left in worked-out areas at mine «Kotinskaya»
H_{yry} и H_{ory} – limit depths of mining, after reaching them the seams are considered as hazardous or liable to rock bursts

mining, geological and mining factors: a rapid increase in the depth of mining, annual increments of which reach up to 25-30 m (Fig.3); an increase in the process of moving of mining operations to deeper horizons of outburst and rock-bump hazards of coal seams; an increase in the degree of negative influence of the pillars left in the worked-out space on the reliability of the functioning of the stopes and openings of adjacent coal seams in zones of increased rock pressure (IRP); an increase in operational losses of coal in the pillars left in the worked-out space; an increase of share of the overdeveloped (underworked) coal seams during performance of production tasks of coal companies in terms of production volumes.

When evaluating the directions for improving the currently widely used development system (*see Fig.1*), *it is fundamentally important to take into account that the prospects of coal companies depend on the efficiency of mining of previously overworked or underworked adjacent seams.*

So, in the next 5-10 years, the economic indicators of underground coal mining in 10 of the 12 mines of OJSC SUEK that develop formations of strata according to the «mine-longwall face» scheme will depend on the timeliness and efficiency of solving issues related to safe mining of previously overworked and underworked seams in the zones of influence of the pillars left in the worked out space of adjacent layers. It should be noted that the contribution of the mines of the coal company OAO SUEK to the total volume of coal mined by underground method in the Russian Federation is about 30 %.

Specificity of planning and conducting mining operations on the adjacent layers is associated with the need to take into account the IRP zones formed under (above) the pillars left in the worked-out space of the previously mined seam. The distance between the pillars, equal to the length of the longwall face, is 150-350 m. The length of the pillars is equal to the length of the extraction columns (up to 4000 m and more). The width of the pillars (see Fig.1), determined from the condition of ensuring a technologically satisfactory state of the developing areas of sections, fixed by the anchor support, reaches 35-40 m (Fig.3). With such a network of pillars left in the developed space above the seam, the total area of IRP zones in the overworked seam can reach 25-30 % and more of the area of the mine field. With the abandonment of the pillars in the developed space, it is practically impossible to use advanced development of «protective» seams as a regional method to prevent rock bursts and sudden outburst. Moreover, the probability of these dangerous events when developing the overworked (underworked) layers in the IRP zones is significantly increased.

It should be noted that in most of the Kuzbass mines, the depth of mining works has reached depths of 150-180 m, when exceeding, the seams are classified as liable to rock bursts. At present, more than 80 % of production faces are mined in conditions dangerous for rock bursts [9].

The negative effect of the coal pillars left in the worked-out space is manifested not only in increasing the outburst and rock burst hazard in overworked (underworked) seams in the IRP zones, but also in reducing the reliability of the functioning of the stopes and openings of these strata [2, 7]. When a certain maximum depth of mining operations is reached, the value of which depends on the specific combination of geological and mining factors, a change in the role of factors determining the state of the openings and the efficiency of controlling the rock pressure in the longwall faces are observed in the zones of IRP [2].

The technologically satisfactory condition of the openings is mainly determined by the values of the roof rocks subsidence and the swelling of the soil rocks. With the increase of stressed state of the rock mass near the openings, the role of these factors changes from the point of view of their influence on the stability of the workings.

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In conditions characterized by values of coefficient $\eta_п < 0.4$ ($\eta_п = \sigma_{гм}/\sigma^{п}_{гм}$; σ_c – stress in rock mass; $\sigma^{п}_{c}$ – ultimate compressive strength of immediate bottom during axial compression), the main type of deformation, determining the stability of the openings, is the subsidence of roof rocks. At the same time, the amount of the lowering of roof rocks exceeds 85 % of the value of convergence of the roof rocks and the floor. In these conditions, the violation of the normal mode of exploitation of openings occurs mainly as a result of faults and fractures of the roof rocks.

In conditions characterized by values of coefficient $\eta_п > 0.6$, the main type of deformations determining the stability of the openings, is rock swelling of the floor, the amount of which in convergence of rock of roof and floor can reach up to 70 % and more.

During descending mining of adjacent seams the negative influence of pillars on technical-economic indicators of mine operation process significantly increases when reaching depths, characterized by values of coefficients $\eta_п$ и $\eta_к$, equal to 0.25-0.35.

The different nature of the manifestations of rock pressure at different sections along the length of the openings and slopes also suggests different requirements for the methods of controlling the roof in longwall faces and ways of protecting the workings, which significantly complicates the fulfillment of the requirements for ensuring the reliability of their functioning.

The adaptation of production to the new conditions of mining operations during transition to the extraction of overworked (underworked) adjacent layers, as a rule, occurs with significant economic losses, increased risks of non-fulfillment of production tasks, a decrease in the safety of mining operations, and an increase in the operating loss of coal. This is evidenced by the experience of development process in 1972-1994 of adjacent coal seams $К^{1в}_{5}$ and $К_6$ in mines «Gukovskaya» and «Krasniy partisan» (Eastern Donbass) [2].

The issues under consideration are no less relevant for the coal industries of Australia, the USA, China, Ukraine and other foreign countries, developed in the field of mining [11, 12].

The presence of coal pillars in the worked-out space at high rates of longwall face advance increases the likelihood of congestion in significant areas and dynamic hanging of rocks of the main roof (bridging rocks) with falling of large masses of methane from the developed space into the longwall face and working sections, and thus appearance of serious accidents with explosions of methane and dust. The tragic consequences of the major accidents in the last 10-15 years on the most promising mines of Kuzbass show that this factor, which influences the level of industrial safety in the coal industry, should be the subject of detailed study. In the opinion of the author of this article, the significant complication of mining conditions in the overworked (underworked) seams with the use of technologies with the abandonment of the pillars in the worked-out space in combination with selective extraction of the seams is one of the main reasons why in the operating mines of Kuzbass up to 64 % [1, 5] of coal reserves previously attributed to balance reserves are now recognized as not promising for development.

Despite significant shortcomings (*see Fig.2*), *the development system of long pillars with the abandonment of the pillars in the worked-out space is planned to be used practically in all the mines of Kuzbass when developing low-grade sloping seams with one layer at full capacity.* At the mines of JSC «SUEK-Kuzbass» with the development of seams with thickness from 1.4 to 6.0 m, only this version of the development system is considered [6].

Directions of technology improvement. Depending on the specific combination of geological and mining and technical factors that determine the conditions for conducting mining operations, as well as the stage of development of adjacent layers, a reduction in the negative influence of the pillars can be achieved:

• when developing the first stratum of the suite with the complete development of the pillar on the same line as the longwall face; partial development of the pillar with a decrease in its width to the limit values at which the effect of the pillar on the working out of the adjacent layers is excluded; the creation of bands of rocks and other non-combustible materials between extraction sites; unloading the pillar from increased rock pressure after the fulfillment of its basic functions; increasing the length of the longwall face;

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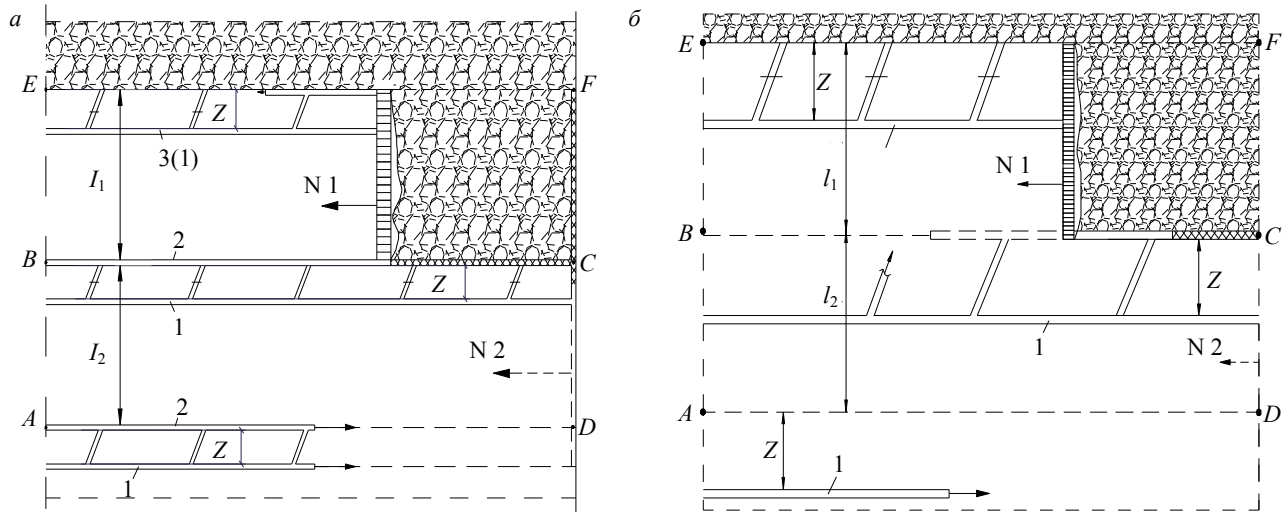


Fig.4. Variants of development system with long-pillar without leaving coal pillars in worked out space
ABCD – prepared columns; *BEFC* – developed columns; 1, 2 and 3 – sectional openings

• when working out the 2nd and subsequent adjacent layers of the formation by developing the pillars left in the worked-out space; the use of combined schemes that provide for a rational combination of the descending and ascending orders of development the adjacent seams and the locations of mutual arrangement of the pillars; unloading of the pillars left earlier in the worked-out space, from increased rock pressure; rational planning of mining operations in seams, taking into account the degree of negative influence of the pillars on the state of the openings and the management of the roof in the longwall faces.

When designing technological schemes for development of adjacent series of strata as an alternative to the development system presented in Fig.1, it is advisable to consider non-pillar technologies, in the implementation of which almost all drawbacks (see Fig.2) associated with the abandonment of coal pillars in the worked out space are eliminated [3, 4]. The creation of such resource-saving technologies is one of the priority directions of the research of the scientific school «Development of Solid Mineral Deposits» of the Stain-Petersburg Mining University. As an example in Fig.4 are shown schematic diagrams of the variants of the development system of long pillars with the extraction of the pillars on one line with the slope.

The area of application of the variant in Fig.4 *a* is gas mines with a long length of pillars and equipping longwall faces with high-performance mechanized complexes. It is advisable to consider the variant in Fig.4 *b* for sections of mine fields with limited dimensions and low rates of movement of the working face.

In order to ensure the possibility of using non-pillar technologies in development of coal seams liable to spontaneous combustion, within the framework of the scientific school «Development of Solid Mineral Deposits», options are being developed for creating the yielding strips of rock and other non-combustible materials between adjacent mined sections with characteristics that exclude formation of IRP zones in the underworked (overworked) coal seams.

Main conclusions

1. When determining the directions for improving the technology for the development of flat coal seams with thickness of 1.5-6.0 m, it is of fundamental importance that in the short term the technical and economic indicators of underground coal mining in the mines of the Kuznetsk basin will depend significantly on the effectiveness of resolving issues related to development of adjacent layers, previously overworked or underworked using the development system long pillars with the abandonment of coal pillars in the worked-out space

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2. In assessing the economic feasibility and the permissibility of using a long-pillar development system with the abandonment of coal pillars in the worked-out space for the development of adjacent series of seams, it is necessary to take into account the additional operational losses of coal in the pillars (up to 20 %); costs associated with ensuring the safety of mining operations and the reliability of the functioning of the slopes and openings in the IRP zones, the total area of which is up to 25-30 % of the mine field area; reduction of balance coal reserves, associated with the worsening of mining and geological and mining-technical conditions of workings in overworked (underworked) adjacent seams; increased likelihood of hanging in large areas and dynamic sedimentation of rocks of the main roof (bridging rocks) with falling of large masses of methane from the developed space into the longwall face and working sections.

3. The priority areas of research in improving the long-pillar development system include the establishment of technology of erection between adjacent workings the air-isolating strips of noncombustible materials with parameters that provide technologically satisfactory condition of sectional openings having roof bolting support, insulation of developed areas of adjacent extraction sections, excluding formation of hazardous IRP zones in overworked (underworked) seams.

4. In current socio-economic conditions of the coal industry's operation, the problem of selecting coal mining technologies in promising Russian mines is beyond the scope of solving only technical issues. The present «conflict of interests» between the state and subsoil users demonstrates the relevance of issues related to the search for compromise solutions based on legislative acts and ensuring rational (from the state's perspective) development of nonrenewable natural resources and financial interest of companies in the use of resource-saving technologies

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