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ABSTRACT

The analysis of the world experience in the development of potash deposits was conducted. It showed that the main problems in the development of potash mines are a high level of extraction losses and an increased risk of flooding of stopes due to the discontinuity of water-bearing strata. The implementation of the long-wall mining system with the stowing of the mined-out area allows comprehensively solving these problems. A computer model of the strains of the water-bearing strata during the development process using long-wall system with mechanized equipment systems was developed for the conditions of the Nivenskoe field. The models for the mining conditions: without the stowing; using the mechanical stowing with different filling ratios; and wall packing of the goaf, – were developed. It is revealed that the stowing of the goaf with the filling ratio of 50% and more decreases the height of the zone of water-conducting discontinuities. The efficiency of the wall packing of goaf in comparison with the complete stowing is substantiated. The dependence of the height of the zone of water-conducting discontinuities on the filling ratio of the goaf is determined. This dependence can be used for the initial assessment of the height of the zone of anthropogenic water-conducting discontinuities.

Keywords: filling mass, filling ratio, water-bearing strata, water-conducting discontinuities, potash-magnesium seams, computer modeling

1. INTRODUCTION

The development process of the potash-magnesium mines in Russia and the world is complicated by the high probability of the water and unsaturated brine leakages into the goaf areas. According to some experts, up to 50% of the potash and potash-magnesium mines in the world are destroyed because of emergency flooding [1-2]. The fundamentals for the development of the potash deposits differ from the fundamentals for the development of coal deposits, although the potash deposits may occur in the form of seams [3]. In particular, it is important to prevent the leakage of supra-salt water into the workings. This water leaks into the workings through the zone of water-conducting discontinuities (WCD), which occur in the water-bearing stratum (WBS) between the developing seams and aquifers as a result of the extraction of mineral resources.

In addition to the increased accident rate, the development of the potash-magnesium mines is described by a high level of extraction losses (about 60%) [4]. High level of extraction losses is associated with the necessity to leave the pillars of minerals in the ground. These pillars support overlying strata and, therefore, reduce the probability of occurrence of the zones of water-conducting discontinuities in them. Such development systems are called room-and-pillar systems or “short-wall systems”.

Contrary to these systems, there are “long-wall systems”. The main advantages of such systems in comparison to the sort-wall systems are low level of extraction losses and high output capacity. The main disadvantage is a significant anthropogenic impact on the overlying strata.

Nowadays, there is only one field of potash-magnesium salts, the Starobinskoe field in the Republic of Belarus, where the development is carried out using long-wall system with the roof caving [5]. The implementation of such method in this field is feasible due to its unique hydro-geological conditions. There is the quite thick water-bearing stratum (up to 300 m), which contains clay beds. These clay beds are deformed plastically without fracturing, and, moreover, they swell, when water penetrates them, which prevents the further leakage.

The main basis for the industrial applicability of one or another version of mining system, used for the development of the highly-soluble mineral resources, is the necessity to maintain the continuity of the water-bearing stratum between the developing seams (ore bodies) and aquifers [6-7]. According to the world’s experience in the development of such fields, the best way to maintain continuity of the water-bearing stratum in the long-term is to use the goaf stowing to control the roof. There are a number of fields (for instance, the Gremyachinskoie in the Volgograd region, the Nivenskoe in the Kaliningrad region) on the territory of the Russian Federation that are similar in their conditions to the Starobinskoe field. Therefore, it is safe to assume that the long-wall systems can be implemented there. Nowadays, these fields have not yet been developed. Subsequently, a highly topical problem is to justify the safe parameters of their future development.

A computer modeling of the development of the Nivenskoe field of potash-magnesium salts using the long-wall system was carried out in this article. The mining systems without the stowing and with the stowing of the goaf (as a safer way to maintain the continuity of the water-bearing stratum) were considered.

2. RESEARCH METHODS AND THE RESULTS

The Nivenskoe field is formed by a series of four horizontal closely spaced seams (ore bodies) of average thickness located at great depths [8].

A computer model was developed in the FLAC 2D software package to estimate the height of the zone of the water-conducting discontinuities above the developing seams [8, 10].
Research of the Influence of the Goaf Stowing on the Height of the Water-Condutcing Discontinuities During the Development of the Potash-Magnesium Fields

The propagations of horizontal and vertical tensile strains are presented in the figures 1 and 2. The development of the micro-cracks in rocks occurs due to these deformations. These areas can be interpreted as areas of formation of water-conducting discontinuities. These discontinuities make up to a height of about ~ 226 m above the upper developing seam in the case of the implementation of the system without the stowing.

Figure 1 The area of the propagation of horizontal tensile strains after the development of all seams in the series without the stowing.

Figure 2 The area of the propagation of vertical tensile strains after the development of all seams in the series without the stowing.

Overall examination of the figures 1 and 2 shows that horizontal tensile strains develop in the edge of the mined-out space, which leads to the formation of vertical fractures, and vertical tensile strains occur directly above the mined-out space, which correspond with the formation of horizontal stratification there. In addition to this, the area of the vertical fracturing exceeds the zone of the stratification in height (226 m versus 124 m).
The vertical fracturing can reach the upper edge of the WBS under the unfavorable conditions (large thickness of the extracted seams, the presence of abnormalities in the WBS, low thickness of the WBS and etc.). And then it can lead to the leakage of water into the WBS from the aquifers. Fresh water will be able to spread to almost any point of the developing mine’s area after it reaches the stratification zone through the systems of the vertical fractures.

In this regard, the stowing plays a major role in reducing the height of the zone of the water-conducting discontinuities. The state of the WBS is presented in the figures 3 and 4. In this case the complete stowing of the goaf using bulk materials with the filling ratio of 75% was used. The maximum height of the zone of the water-conducting discontinuities decreases from 226 m to ~ 176 m, and the area of this zone decreases significantly as well.

**Figure 3** The area of the propagation of horizontal tensile strains after the development of all seams in the series using complete stowing of the goaf with bulk materials.

**Figure 4** The area of the propagation of vertical tensile strains after the development of all seams in the series using complete stowing of the goaf with bulk materials.
Cumulative findings on the height of the zone of water-conducting discontinuities above the roof of the upper developing seam at various parameters of the stowing are presented in the figure 5. The numbering of the seams corresponds to the sequence of their extraction in the descending order.

\[ H_{WCD} = 237 - 83.6k \]

**Figure 5** Height of the zone of water-conducting discontinuities above the edge of the pillar at different filling ratios.

**3. CONCLUSION**

The implementation of stowing of the goaf of long-wall workings affects the development of the zone of the water-conducting discontinuities in the following manner.

The implementation of the stowing using bulk materials with the filling ratio of 25% does not lead to a decrease in the final height of the WCD.

The implementation of the stowing using bulk materials with the filling ratio of 50% leads to a decrease in the final height of the WCD by ~ 9%.

The implementation of the stowing using bulk materials with the filling ratio of 75% leads to a decrease in the final height of the WCD by ~ 22%.

The implementation of the stowing using bulk materials with the filling ratio of 88% leads to a decrease in the final height of the WCD by ~ 32%.

The implementation of the wall packing of the goaf leads to a decrease in the final height of the WCD by ~ 17%. Therefore, the wall packing method is more effective than the complete stowing with the filling ratio of 50% in terms of the restraining influence on the development of the fracturing in the WBS.

The dependence of the height of the zone of the water-conducting discontinuities \( H_{WCD} \) on the filling ratio \( k \) was derived based on the conducted research:

\[ H_{WCD} = 237 - 83.6k \]
The obtained dependence can be used for the initial assessment of the height of the zone of the anthropogenic water-conducting discontinuities that occur above the mined-out area of the long-wall workings during the development of the seams of the Nivenskoe field of potash-magnesium salts in the Russian Federation.

REFERENCES


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