

Ivan I. Golovaty¹, Sergei A. Chizhik², Andrey B. Petrovskiy¹, Viktor Ya. Prushak³

¹JSC “Belaruskali”, Soligorsk, Minsk Region, Belarus

²Presidium of the National Academy of Sciences of the Republic of Belarus, Minsk, Belarus

³Soligorsk Institute of Resources Saving Problems with Pilot Production, Soligorsk, Minsk Region, Belarus

DEVELOPMENT OF TECHNOLOGY FOR ADDITIONAL EXTRACTION OF POTASH ORE RESERVES FROM PREVIOUSLY MINED OUT PANELS AT THE DEPTHS EXCEEDING 600 METRES OF THE STAROBIN POTASH SALT DEPOSIT

Abstract. Studied the possibility to extend the life of the Production Unit no. 3 mine of JSC “Belaruskali” through the additional extraction of sylvinitic ore reserves left in the previously mined panels of the mine field of the 3rd potash level. It was determined, that during the period from 1971 to 1980 a considerable part of the southern direction of the mine field on the area of more than 5,3 million m² was mined by the roadways on the layers 2, 2–3, 3 without the mining of the 4th sylvinitic layer. The volume of the leftover reserves of minerals in the mined panels makes more than 22 million tons. There is direct access to these panels from the main southern gates. As a study result of geological structure of the mined panels it was determined that under the influence of rock pressure the undermined sylvinitic layer no. 4 took the form of a wave-shaped seam with the capacity of about 1 meter which rests on compressed inter-chamber pillars and on compressed rocks of layers 2, 2–3, 3 of destroyed inter-roadway pillars, which fills the space of the roadways. Such geological structure of the seam enables to extract minerals using the technology of selective layer mining by successive top and bottom faces. As a study result of the stability of the mine workings performed along the roadways and inter-chamber pillars under conditions of different roof positioning, it was determined that during the preparation of the faces the most advantageous locations for development workings are the areas previously mined by the room and pillar mining system. In this case, the highest stability of mine workings located in the stopes of the room and pillar mining system will be provided by their roofing location with cut of 0.15 m of the 4th sylvinitic layer. When this occurs, their predicted life without repair, even without the use of special protection methods, would be between 3.5 and 8 years. Based on the results of the study, a conclusion was made on the technical possibility and economic feasibility of additional extraction of sylvinitic ore reserves left in the western panels of the southern direction of the mine field of the 3rd potash level of the Production Unit no. 3 mine, finished over 40 years ago by the room and pillar mining system using selective layer mining technology by the longwall faces. With minimal capital, organizational and technical expenditures, the extraction of these reserves will allow the company to produce additionally 5.5 million tons of potash fertilizers.

Keywords: mine, seam, stopes, potash ore, geological structure

For citation: Golovaty I. I., Chizhik S. A., Petrovskiy A. B., Prushak V. Ya. Development of technology for additional extraction of potash ore reserves from previously mined out panels at the depths exceeding 600 metres of the Starobin potash salt deposit. *Vestsi Natsyyanal'nai akademii navuk Belarusi. Seryya fizika-technichnykh navuk = Proceedings of the National Academy of Sciences of Belarus. Physical-technical series*, 2022, vol. 67, no. 2, pp. 182–190. <https://doi.org/10.29235/1561-8358-2022-67-2-182-190>

И. И. Головатый¹, С. А. Чижик², А. Б. Петровский¹, В. Я. Прушак³

¹ОАО «Беларуськалий», Солигорск, Минская область, Республика Беларусь

²Президиум Национальной академии наук Беларуси, Минск, Республика Беларусь

³Солигорский Институт проблем ресурсосбережения с Опытным производством, Солигорск, Минская область, Республика Беларусь

РАЗРАБОТКА ТЕХНОЛОГИИ ДОИЗВЛЕЧЕНИЯ ЗАПАСОВ КАЛИЙНОЙ РУДЫ ИЗ РАНЕЕ ОТРАБОТАННЫХ ПАНЕЛЕЙ НА ГЛУБИНАХ СВЫШЕ 600 МЕТРОВ СТАРОБИНСКОГО МЕСТОРОЖДЕНИЯ КАЛИЙНЫХ СОЛЕЙ

Аннотация. Изучена возможность продления срока службы рудника Третьего рудоуправления ОАО «Беларуськалий» за счет доизвлечения запасов сильвинитовой руды, оставленных на глубинах свыше 600 м в отработанных ранее панелях шахтного поля Третьего калийного горизонта Старобинского месторождения калийных солей. Установлено, что в период с 1971 по 1980 г. значительная часть южного направления шахтного поля на площади более 5,3 млн м² была отработана очистными ходами по слоям 2, 2–3, 3 без выемки 4-го сильвинитового слоя. Объем оставленных запасов полезного ископаемого в отработанных панелях составляет более 22 млн т. При этом имеется прямой

доступ к этим панелям со стороны главных южных штреков. В результате изучения геологического строения отработанных панелей установлено, что под воздействием горного давления, подработанный 4-й сильвинитовый слой принял вид пласта волнообразного профиля, мощностью около 1 м, который покоится на сдавленных межкамерных целиках и на уплотненных породах слоев 2, 2–3, 3 разрушенных межходовых целиков, заполнивших пространство очистных ходов. Такое геологическое строение пласта делает возможным извлечение полезного ископаемого с применением технологии слоевой селективной выемки последовательно верхней и нижней лавами. В результате изучения устойчивости выработок, пройденных по очистным ходам и межкамерным целикам, в условиях разной привязки кровли установлено, что при подготовке очистных лав наиболее рациональными местами заложения подготовительных выработок являются участки ранее отработанные камерной системой, при этом наиболее высокую устойчивость выработок при расположении в очистных блоках камерной системы обеспечит привязка их кровли с прирезкой 0,15 м 4-го сильвинитового слоя. В этом случае их прогнозируемый безремонтный срок службы, даже без применения специальных способов охраны, составит от 3,5 до 8 лет. На основании результатов исследования сделан вывод о технической возможности и экономической целесообразности доизвлечения запасов сильвинитовой руды, оставленных в западных панелях южного направления шахтного поля Третьего калийного горизонта рудника Третьего рудоуправления, отработанных более 40 лет назад камерной системой разработки с использованием технологии слоевой селективной выемки пласта очистными лавами. При минимальных капитальных и организационно-технических затратах извлечение указанных запасов полезного ископаемого позволит предприятию выпустить дополнительно около 5,5 млн т калийных удобрений.

Ключевые слова: рудник, пласт, очистные камеры, калийная руда, геологическое строение

Для цитирования: Разработка технологии доизвлечения запасов калийной руды из ранее отработанных панелей на глубинах свыше 600 метров Старобинского месторождения калийных солей / И. И. Головатый [и др.] // Вест. Нац. акад. наук Беларусі. Сер. фіз.-тэхн. навук. – 2022. – Т. 67, №2. – С. 182–190. <https://doi.org/10.29235/1561-8358-2022-67-2-182-190>

Introduction. JSC “Belaruskali” is the world’s largest producer of potash fertilizers. Its main raw material base is the Starobin potash deposit. The development of the deposit is carried out by four Production Units, including the Production Unit no. 3 (PU 3), which mined out and processed 14.3 million tons of sylvinitic ore in 2020. Such intensive extraction of minerals from the subsurface is rapidly depleting mineral reserves. Currently, the mine mines out the second and third potash levels, which contain all the resources of the PU 3 mine field and previously they were classified as commercial reserves. The 2nd potash level is mined out for 90 %, while the 3rd level, which is the main one in terms of reserves and ore extraction volumes, is mined out for 75 %.

The urgent need to replenish and develop the mine’s resource base requires careful, resource-efficient approaches to mining the left reserves. One such promising approach, aimed at extending the mine life, is the additional extraction of potash reserves left in the 4th sylvinitic layer and the inter-chamber and inter-roadway pillars in the areas of the 3rd potash level previously mined out using the room and pillar mining system.

It is known that initially since 1971 the 3rd potash level at the PU 3 mine was mined out using a room and pillar mining system with a low mineral extraction rate. Only since the 1980s progressive longwall mining began to be used to ensure a more complete extraction of sylvinitic ore from the rock mass [1, 2]. As a result of the ten-year period of intensive application of the room and pillar mining system, a large section of the mine field has formed, containing significant amounts of minerals left in the 4th sylvinitic layer, inter-chamber and inter-roadway pillars. According to preliminary estimates, this amount significantly exceeds the annual output of the mine. However, the possibility of re-mining the stated area in order to mine additionally the left reserves has not been studied and appears to be a complex scientific and technical problem. Till now, many important geological and mining and technical aspects of this problem have not been investigated. Although there are a number of works devoted to the study of geological structure of the seam, describing the features of the distribution of rock pressure in the development and mining workings during the extraction of undermined and abandoned reserves in the 4th sylvinitic layer and between the pillars under conditions typical to the 3rd potash level of the PU 3 mine [3–8]. However, the following important aspects regarding the problem of abandoned mineral reserves mining in areas mined out by the room and pillar mining system at depths greater than 600 m have not been studied or have been insufficiently studied in these works: a condition and a degree of disturbance of the left reserves, a character of lowering the 4th sylvinitic layer above the roadways, a geological structure of rocks above the face roof; the content of KCl on the collapsed rocks in the inter-roadway pillars and roadways; possibility of extraction of the left reserves in relation to the sylvinitic layers 2, 2–3, 3, 4; a character of the workings deformation, caused by roadways and inter-chamber pillars, their stability in conditions of different roof location. Currently, there is only one known work [9], which addresses some aspects of the above problems in relation to other

geological and mining conditions of the Starobin deposit, different from the conditions of the PU 3 mine, characterized, first, by a significantly lower formation depth of mineral deposit. Therefore, the results of the abovementioned work could not be directly used to solve the problem of re-mining the mentioned sections of the 3rd potash level of the PU 3 mine, although we have used the methodology of this study. The task of the study was to solve the abovementioned issues, and the purpose of which was to assess the technical feasibility and economic viability of extracting the reserves left in the 4th sylvinite layer, inter-chamber and inter-roadway pillars at the sections of the 3rd potash level of the PU 3 mine, previously mined out using the room and pillar mining system, as well as to develop a technology for re-mining these sections.

Results and discussion. In accordance with the methodology adopted, the study was carried out along the following lines: study of the mine surveyor’s documents describing the location of the mine field areas, mined out by the room and pillar mining system; time and mining technologies used; visual and instrumental study of the rocks geological structure in the mined out area, characteristics of the rock pressure and course of deformation processes in the workings; calculation of mineral reserves in the areas available for re-mining; developing the ways for re-mining these areas, selecting the best methods for performing the development workings and assessing their stability.

Parameters of stopes driven by the room and pillar mining system in the 3rd potash level of the PU 3 mine were studied during the analysis of the survey documents taking into account the layers and the time for minerals mining. It was determined that in the period from 1971 to 1980 a part of the area of the mine field of the 3rd potash level, on the panels of the south direction from the 1st west to the 18th west panel (Figure 1, *a*), was mined out by room and pillar mining system on the layers 2, 2–3, 3. At the

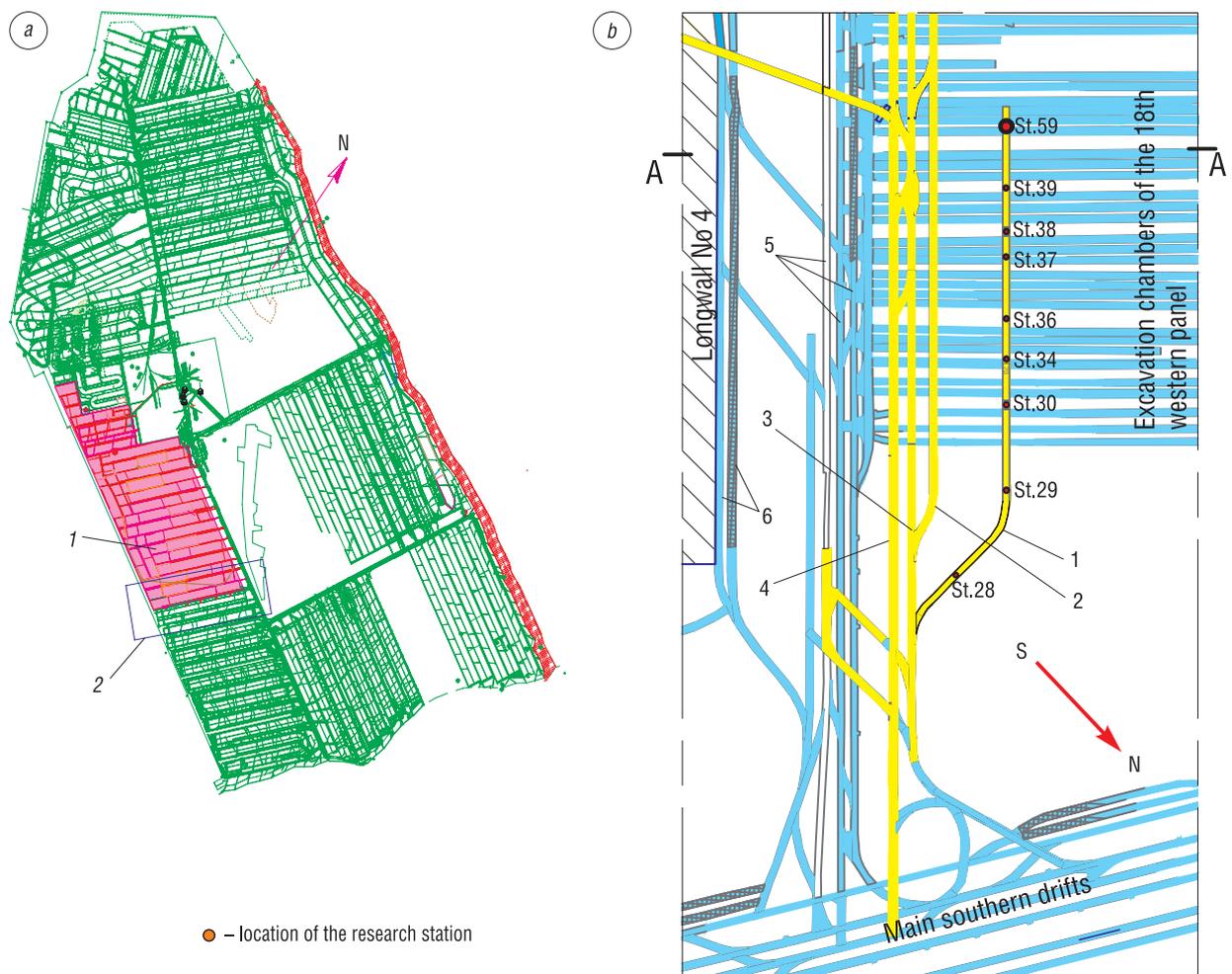


Figure 1. Mining plan of the 3rd potash horizon of mine: *a* – plan of the mine field (1 – blocks of the chamber development system, 2 – research area); *b* – layout of the research work (1 – research work, 2 – auxiliary drift no. 1 drift no. 11-5, 3 – lava transport drift no. 11-5, 4 – lava conveyor drift no. 11-5, 5 – drifts of the 18th western panel, 6 – lava drifts no. 4); St. 28–St. 59 – research stations

same time, significant amounts of minerals were left not only in the undermined 4th sylvinite layer, but also in inter-chamber and inter-roadway pillars where layers 2, 2–3, 3 were mined with recovery factor 0.38–0.45. Accordingly, should be investigated the possibility of preparing for mining followed by the extraction of the reserves left in all abovementioned layers of the western panels 1–18. It was assumed that the reserves of the 4th sylvinite layer, being prepared for mining, might have changed their spatial position over the past 40 years after undermining. Moreover, the main transport and air-feeding workings of the future face, its assembly gate on the pillar to be mined out should be carried out in the stope area of the room and pillar mining system.

The mined out panels 1–18 are located close to the active main south gates, but direct access for visual and instrumental investigation of the geological and mining conditions was not possible due to destruction of the panel entries. Taking into account the inaccessibility of these sections of the mine field for visual and instrumental studies, it was decided to fulfill a special research working (Figure 1, *b*) in the roadways and inter-chamber pillars of the 18th west panel in its north-east section adjacent to the face no. 4, that undermined the 4th sylvinite layer in the period from 1979 to 1981. Considering the fact, that while starting the researches described above, driving the development workings of the face no. 11-5, in the border zone of the 18th west panel, parallel to old gates of the above panel began, a research working, 240 m long, was made by the roadheading machine KRP-3 starting from the haulage road of the face no. 11-5.

As a result of visual inspection and instrumental measurements in the research working, it was found that the panel workings and the roadways of the 18th west panel, made 40 years ago, are collapsed and are in “compressed” condition, i.e. the previously mined out space is filled with rock debris. The soft pillars in the roadways were crushed and compressed by about 1 m. Accordingly, layers 3–4, 4, 4–5, 5 were lowered by the same value in this area; hard inter-chamber pillars with the width from 5.0 to 9.0 m were slightly compressed by 50–150 mm, in comparison with their capacity in the virgin rock. The results obtained are well in line with the results of the previous study of the geological structure of the deposit rocks in the southeastern border zone of the 18th west panel in its southeastern section [8].

The geological structure of the roof rocks was also investigated in the research working, with core sampling over 3.0 m high. Samples were taken from the bored core to assess the KCl content in the ore by chemical analysis. The boreholes chart for core samples collection and the geological structure of the roof rocks are shown in Figure 2.

Analysis and compilation of the obtained data on the geological structure of the deposit rocks of the 18th western panel enabled to calculate forecast values in relation to quantity and quality of the remaining ore reserves in other western panels of the south direction, mined out by the room and pillar mining system. According to the calculations, more than 22 million tons of sylvinite ore are concentrated in the area of 5.3 million m², including 13.4 million tons in the 4th sylvinite layer and 9 million tons in compressed and collapsed rocks of layers 2, 2–3, 3.

Analysis of the identified features of the seam geological structure allowed drawing the conclusions about its important features directly affecting the choice of mining technology of minerals left in the 18th western panel and, by analogy, in other western panels, mined out by the room and pillar mining system. It was found that the 4th underworked sylvinite layer took the form of a wave-shaped seam with the capacity of about 1 meter, with the wave height of 0.6–1.3 m at a wave pitch of about 17–20 m. The wave crests, located above the inter-chamber pillars, are parallel and directed along the strike of the roadways. Such geological structure of the 4th sylvinite layer enables to mine it with a top face using the SL-300-type shearers, with subsequent mining the layers 2, 2–3, and the 3rd layer – with a bottom face, i.e. the layer can be mined out by the widely used selective mining technology with longwall faces. This technology is described in “Instructions on application of development systems at the Starobin deposit” (Soligorsk, 2018).

In order to select the possibility and optimal locations for development workings of the future faces designed to mine the western panels of the south direction, the deformation character of the research workings contour was studied, including measuring the deformations of the workings contour according to the stations of the contour survey plugs; assessment of the workings stability and preliminary calculation of their maintenance-free period, depending on the chosen roof positioning; visual assessment of the workings contour condition after the mining.

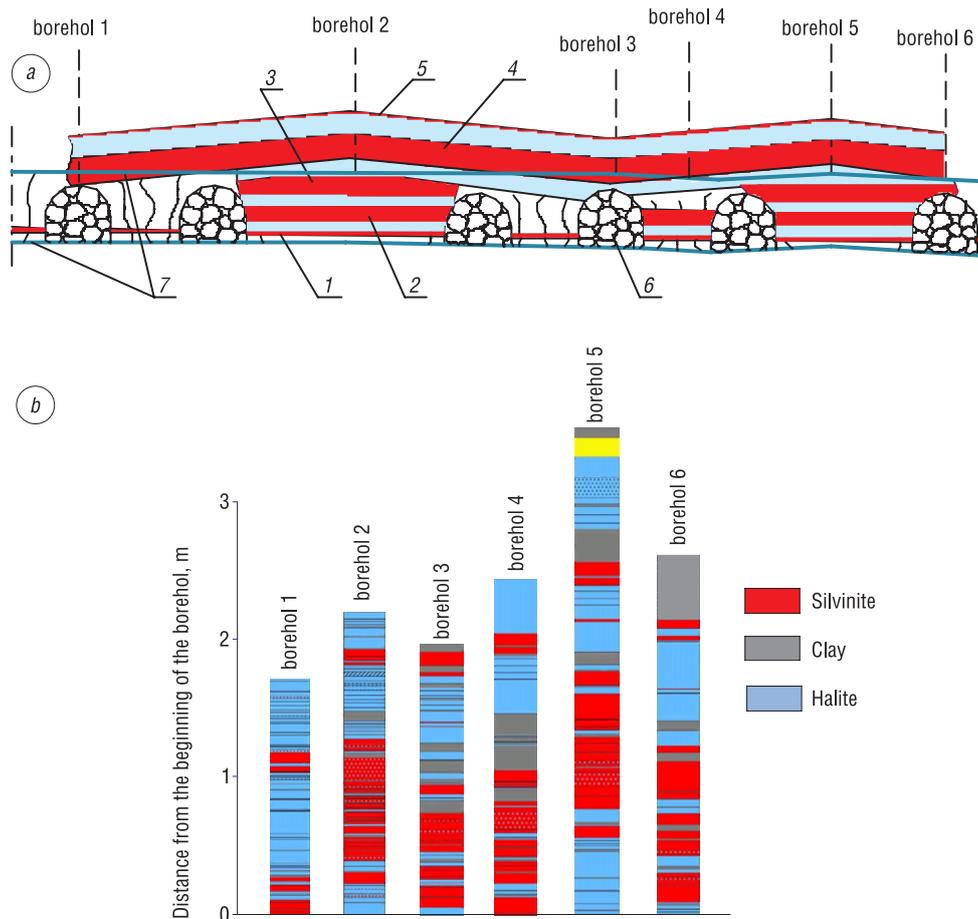


Figure 2. Study of geology aspects of the deposit rock from the research working: a – boreholes chart for core samples collection in the roof of the research working no. 5 (1 – 1st sylvinite layer, 2 – 2nd sylvinite layer, 3 – 3rd sylvinite layer, 4 – 4th sylvinite layer, 5 – 5th sylvinite layer, 6 – roadways of the 18th western panel, 7 – roof and ground profile of the research working no. 5); b – geological structure of roof rocks by boreholes

The research working was made in stages with several risings in order to study its stability in different roof locations. The working was conventionally divided into 4 sections, differing in their location and roof positioning:

section 1 is approximately 90.0 m long. The working was made in a protective pillar, with a protective band, left in the roof, in the 3rd sylvinite layer with the capacity of 0.25–0.30 m;

section 2 is approximately 60.0 m long. The working was made in the roadways and in the inter-chamber pillars; the roof positioning was done with 0.15 m cut of the 4th sylvinite layer;

section 3 is approximately 60.0 m long. The working was made in the roadways and in the inter-chamber pillars, with a protective band, left in the roof, in the 4th sylvinite layer with the capacity of 0.3 m;

section 4 is approximately 30.0 m long. The working was made by the 5th sylvinite layer.

The research working width was 3.0 m. There was no anchoring. As a protection measure in section 1, compensating slots were cut in the ground, roof and walls of the working.

Installation lay-out of the monitoring stations for the roof-ground convergence and the convergence of the workings walls is shown in Figure 1b. Previous investigations in the border zone of the 18th western panel in its northeastern part showed that the contour of the working is deformed more in the areas where it crosses the inter-chamber pillars, and the de-stressed zone is still kept in the roadways [8]. This is why it was decided to install monitoring stations in the most highly stressed zones of the working, i.e. where the linear parts of the workings intersect the inter-chamber pillars. The monitoring stations were installed following the roadheader with the lag not exceeding 30.0 m from the face.

During the whole monitoring period of 231–306 days, the convergence of the research working was 12–62 mm and the convergence of the walls was 7–48 mm. The minimum deformations values of the working contour were observed at the stations installed in the sections worked out by the room and pillar mining system and were on average 2 times less than at the section of the working made in the protective pillar (station no. 28). The lowest convergence rate was observed at the section 2 (stations no. 30, no. 34, no. 36) and it was 0.04–0.09 mm/day. The maximum rate of 0.12–0.20 mm/day was recorded at the section 1 (stations no. 28 and no. 29) in the protective pillar. At the sections 3 and 4 these rates were 0.13–0.15 mm/day and 0.09 mm/day respectively.

Figure 3 shows the visual condition of the research working and the nature of the deformation along the entire length of the working. After more than 300 days from start of instrumental as well as visual monitoring, the condition of the research working was satisfactory. The graphs in Figure 3, *e* show that the convergence values in all the study sections do not exceed the maximum permissible values.

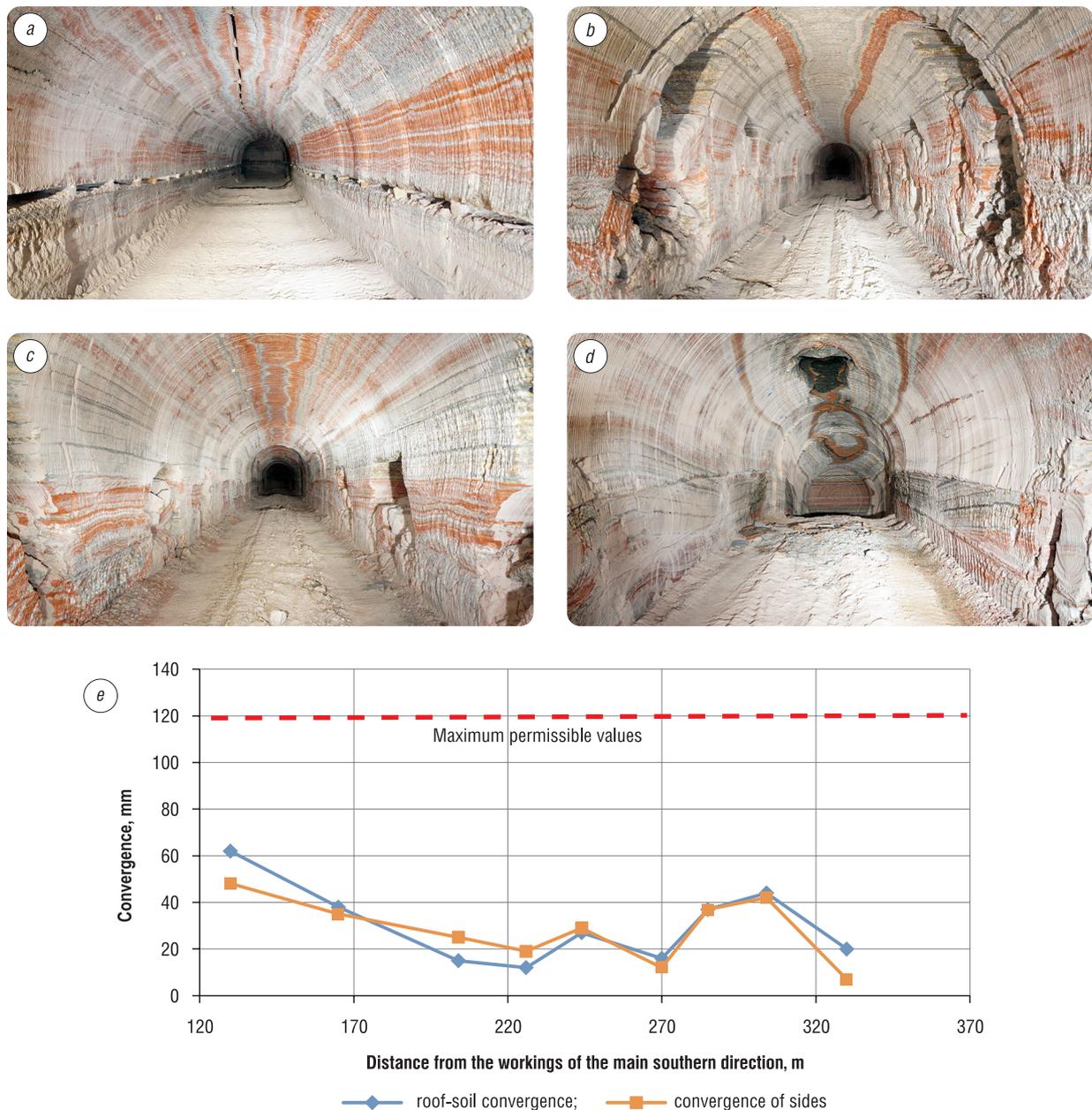


Figure 3. Nature of research working deformation along the entire length after 231–306 days of monitoring: *a* – 1st section visual condition 1, *b* – 2nd section visual condition, *c* – 3rd section visual condition, *d* – 4th section visual condition, *e* – contour deformation values

The summary table presents the value on the deformation of the research working and the remaining time of its maintenance-free condition. The forecast calculation of the remaining maintenance-free service life of the working was carried out according to the formula:

$$t = U_{\max.\text{perm.}}/V_{\text{st}},$$

where t – maintenance-free life of the working, day; $U_{\max.\text{perm.}}$ – maximum permissible values of the working contour deformation in mm according to the “Instruction on protection and support of mine workings in the Starobin deposit” (Soligorsk, 2018); V_{st} – average steady deformation rate of the working part, mm/day.

Summary of the deformation nature of the research working

Station number	Conditions/roof positioning	Monitoring time, days	Accumulated deformations of the contour U , mm		Maximum permissible values of the convergence, $U_{\max.\text{perm.}}$, mm	Steady convergence rate, mm/day	Remaining maintenance-free service life, t , days(years)
			Roof-ground convergence	Convergence of the walls			
28	Section no. 1 in the protective pillar / 0.25–0.30 m 3 rd sylvinite layer	306	62.0	48.0	120	0.20	530 (1.45)
29		306	38.0	35.0	120	0.12	928 (2.54)
30	Section no. 2 in the roadways / 0.15 m 4 th sylvinite layer	306	15.0	25.0	120	0.05	2433 (6.67)
34		299	12.0	19.0	120	0.04	2978 (8.16)
36		294	27.0	29.0	120	0.09	1280 (3.51)
37	Section no. 3 in the roadways / 0.3 m 4 th sylvinite layer	294	16.0	12.0	120	0.05	2189 (6.0)
38		294	37.0	37.0	120	0.13	917 (2.51)
39		294	44.0	42.0	120	0.15	758 (2.08)
59	Section no. 4 in the roadways / 5 th sylvinite layer	231	20.0	7.0	120	0.09	1366 (3.74)

According to calculations, the longest period of 3.5–8.2 years of maintenance-free working life is predicted for section no. 2, the shortest of 1.5–2.5 years – for section no. 1.

As a study result of stability of workings made along the roadways and inter-chamber pillars, their stability in conditions of different roof positioning, it was concluded that the most advantageous places for the development workings are areas previously mined out by room and pillar mining system, completely destroyed and filled with consolidated rocks. Thus the highest stability of mine workings while locating in the roadways of room and pillar mining system will be ensured by their roof positioning with 0.15 m cut of the 4th sylvinite layer.

In this case the forecast period of their maintenance-free condition, even without the use of special protection methods, will be from 3.5 to 8 years.

Then, the studies performed enabled to determine that it is technically possible to extract additionally sylvinite ore reserves from the western panels of the southern direction of the 3rd potash level of PU 3 mine, which were mined out 40–50 years ago by the room and pillar mining system. Extraction of mineral reserves is possible and reasonable by means of faces using the selective layer mining. Preparation of longwall faces will require minimal capital expenditures, associated with development workings, mainly in the de-stressed zones, with minimum protective equipment, provided that there is an optimal roof positioning. Re-mining these areas is very convenient from an organizational and technical point of view, as they are compactly located, close to the skip shafts and adjoin directly to the existing main southern gates.

The economic feasibility of additional mineral resources extraction at the western panels is also evident. With minimal capital and organizational and technical costs, about 22 million tons of ore can be extracted, from which, with the existing beneficiation technology, about 5.5 million tons of potash fertilizers.

Conclusion. Studied the possibility of extending the life of the PU 3 mine through the extraction of off-balance reserves of sylvinite ore left in the mine field section of the 3rd potash level, which was mined more than 40 years ago by the room and pillar mining system. It was determined, that during the

period from 1971 to 1980 a considerable part of the mine field on the area of more than 5300 million m² was mined out by the roadways on the layers 2, 2–3, 3 without mining of the 4th sylvinite layer. The amount of the mineral resources left in the mined out panels exceeds 22 million tons, including 13.4 million tons of the 4th sylvinite layer and 9 million tons of the 2nd and 3rd sylvinite layers. However, these panels are close to the shaft yard and are directly accessible from the main southern gates.

As a result of studying the geological aspects of the mined panels, it was determined that under the influence of rock pressure, the undermined sylvinite layer no. 4 took the form of a wave-shaped seam with the capacity of about 1 meter which rests on compressed inter-chamber pillars and on compressed rocks of layers 2, 2–3, 3 of destroyed inter-roadway pillars, which fill the space of roadways. Such geological structure of the seam enables to extract minerals using the technology of selective layer mining by successive top and bottom faces.

Based on the study result of the stability of the mine workings made along the roadways and inter-chamber pillars, as well as their stability under conditions of different roof positioning, it was determined that the most advantageous locations for development workings are the areas previously mined out by the room and pillar mining system, fully destroyed and filled with the consolidated rocks. Thus, the highest stability of mine workings, when located in the roadways of the room and pillar mining system, will be ensured by their roof positioning with 0.15 m cut of the 4th sylvinite layer. In this case, the forecast period of their maintenance-free condition, even without the use of special protection methods, will be from 3.5 to 8 years.

As a study result the conclusion was made about the technical feasibility and economic viability of additional extraction of sylvinite ore reserves in the mine field of the 3rd potash level of the PU 3 mine, mined more than 40 years ago by the room and pillar mining system using the selective layer mining of the seam by longwall faces. With minimal capital, organizational and technical expenditures, the extraction of these reserves will allow the company to produce about 5.5 million tons of potash fertilizers.

References

1. Zubov V. P., Smychnik A. D., Kirienko V.M. Enhancement of the development system of the 3rd potash seam at the mines of PA “Belaruskali”. *Zapiski Gornogo instituta = Journal of Mining Institute*, 2006, vol. 168, no. 3, pp. 15–18 (in Russian).
2. Podlesnyi I. A., Getmanov V. N., Petrovskii B. I., Nosulya I.E. Technology of the layer mining while developing the 3rd potash level of the Starobin deposit. *Gornyi zhurnal = Mining Journal*, 2018, no. 8, pp. 59–64 (in Russian). <https://doi.org/10.17580/gzh.2018.08.08>
3. Polyakov A. L. Analysis of the geological structure of the roof of the 3rd potash layer at the Starobin potash deposit. *Gornaya mekhanika [Mining Mechanics]*, 2002, no. 2, pp. 30–36 (in Russian).
4. Puzanov D. A., Mozgoenko M. S., Gubanov V. A. Study results on the stability of mine openings when they are driven in the 4th sylvinite layer, undermined by the bottom face, PU 3 mine, JSC Belaruskali. *Gornaya mekhanika i mashinostroenie [Mining Mechanics and Mechanical Engineering]*, 2014, no. 1, pp. 26–34 (in Russian).
5. Gubanov V. A., Puzanov D. A., Mozgoenko M. S., Erokhin K. A., Podlesny I. A., Petrovsky A. B., Dolgikh A. S. Study of manifestations of rock pressure in development and stope workings during mining the underworked and left reserves in the 4th sylvinite layer and inter-stope pillar by the test face No. 11-3 of the level – 620 m, PU 3 mine, JSC Belaruskali. *Gornaya mekhanika i mashinostroenie [Mining Mechanics and Mechanical Engineering]*, 2017, no. 2, pp. 5–18 (in Russian).
6. Gubanov V. A., Puzanov D. A., Mozgoenko M. S., Erokhin K. A., Podlesny I. A., Petrovsky A. B., Dolgikh A. S. Justification of mining and maintenance methods of development workings of a test face on extraction of the 4th underworked sylvinite layer and of written-off reserves in the inter-stope pillars of the level – 620 m, PU 3 mine, JSC Belaruskali. *Gornaya mekhanika i mashinostroenie [Mining Mechanics and Mechanical Engineering]*, 2016, no. 4, pp. 5–17 (in Russian).
7. Polyakov A. L., Gubanov V. A., Puzanov D. A., Mozgoenko M. S. New deformation patterns of the single working contour in the “massif” and de-stressed zones. *Gornaya mekhanika i mashinostroenie [Mining Mechanics and Mechanical Engineering]*, 2015, no. 4, pp. 13–20 (in Russian).
8. Petrovsky A. B., Prushak V. Ya., Puzanov D. A. Features of the development of longwalls that extract the underworked sylvinite layer in the deep horizons of the Starobin potash salt deposit. *Doklady Natsional’noi akademii nauk Belarusi = Doklady of the National Academy of Sciences of Belarus*, 2020, vol. 64, no. 4, pp. 477–487 (in Russian). <https://doi.org/10.29235/1561-8323-2020-64-4-477-487>
9. Golovaty I. I., Petrovskii A. B., Prushak V. Ya. Substantiation of the possibility of developing reserves of the Third potash horizon of the Starobin deposit, previously worked out by the chamber system. *Vestsi Natsyyanal’nai akademii navuk Belarusi. Seryya fizika-technichnykh navuk = Proceedings of the National Academy of Sciences of Belarus. Physical-technical series*, 2019, vol. 64, no. 4, pp. 497–510 (in Russian). <https://doi.org/10.29235/1561-8358-2019-64-4-497-510>

Information about the authors

Ivan I. Golovaty – General Director, JSC “Belaruskali” (5, Korzh Str., 223710, Soligorsk, Minsk Region, Republic of Belarus). E-mail: belaruskali.office@kali.by

Sergei A. Chizhik – Academician of the National Academy of Sciences of Belarus, D. Sc. (Engineering), Professor, First Deputy Chairman of the Presidium of the National Academy of Sciences of Belarus (66, Nezavisimosti Ave., 220072, Minsk, Republic of Belarus); Chief Researcher, A. V. Luikov Heat and Mass Transfer Institute of National Academy of Sciences of Belarus (15, P. Brovka Str., 220072, Minsk, Republic of Belarus). E-mail: chizhik_sa@tut.by

Andrey B. Petrovskiy – Deputy Chief Engineer for Mining, JSC “Belaruskali” (5, Korzh Str., 223710, Soligorsk, Minsk Region, Republic of Belarus). E-mail: belaruskali.office@kali.by

Viktor Ya. Prushak – Academician of the National Academy of Sciences of Belarus, D. Sc. (Engineering), Professor, Technical Director, Soligorsk Institute of Resource Saving Problems with Pilot Production (69, Kozlov Str., 223710, Soligorsk, Minsk Region, Republic of Belarus). E-mail: ipr@sipr.by

Информация об авторах

Головатый Иван Иванович – генеральный директор, ОАО «Беларуськалий» (ул. Коржа 5, 223710, Солигорск, Минская область, Республика Беларусь). E-mail: belaruskali.office@kali.by

Чижик Сергей Антонович – академик Национальной академии наук Беларуси, доктор технических наук, профессор, первый заместитель Председателя Президиума Национальной академии наук Беларуси (пр. Независимости, 66, 220072, Минск, Республика Беларусь); главный научный сотрудник, Институт тепло- и массообмена имени А. В. Лыкова Национальной академии наук Беларуси (ул. П. Бровки, 15, 220072, Минск, Республика Беларусь). E-mail: chizhik_sa@tut.by

Петровский Андрей Борисович – заместитель главного инженера по горным работам, ОАО «Беларуськалий» (ул. Коржа, 5, 223710, Солигорск, Минская область, Республика Беларусь). E-mail: belaruskali.office@kali.by

Прушак Виктор Яковлевич – академик Национальной академии наук Беларуси, доктор технических наук, профессор, технический директор, Солигорский Институт проблем ресурсосбережения с Опытным производством (ул. Козлова, 69, 223710, Солигорск, Минская область, Республика Беларусь). E-mail: ipr@sipr.by