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***Research Article***

# DEVELOPMENT SYSTEMS USED IN THE TRANSITION ZONE

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**ABSTRACT**
The paper considers examples of mines developing onboard reserves. To reduce the cost of excavation with onboard mineral reserves, it is possible to conduct mining operations from the open pit. At the same time, the choice of options for development systems is influenced by mining conditions, mining technology, distribution of ore bodies around the open pit in plan and height.

***Keywords**: sub-pit reserves, mining systems, ore storage, chamber mining system, guard pillar, barrier pillar, mining system classification, ore breaking, floor, sublevel, horizon, combined, intensive mining*

## INTRODUCTION

When developing near-mine reserves, as a rule, they are not limited to the use of any one class or group of development systems, but several modifications are used depending on changes in mining conditions, the stage of development of the deposit and the nature of the transition to underground mining. So, for example, at the Kiruna mine Sweden, which develops a steeply dipping iron ore deposit with a thickness of 50-200 m, a length of more than 4 km and a depth of up to 2 km, initially, when developing reserves immediately adjacent to the bottom of the quarry, a system was used with ore storage under protection barrier rear sight. However, this system did not allow for selective mining of five grades of ore. Therefore, as the opencast mining moved from north to south, then they switched to a system of sublevel caving with a sublevel height of 7.5-9.0 m. Currently, due to the use of powerful self-propelled drilling and loading equipment, the sublevel height was increased to 22-27 m. At the same time, at the experimental mine "Luossavaara", the parameters of the chamber mining system are being worked out with the extraction of ore in high blocks, which allows concentrating mining operations and effectively using larger and more efficient equipment, increasing labor productivity by almost 2 times (Kaplunov DR, Rylnikov MV, Blume EA and Krasavin, 2003).
At the Kidd Creek mine Canada, which develops a steeply dipping deposit of copper-zinc ores, represented by two deposits with a total length of 670 m, a maximum thickness of 183 m and a depth of over 900 m, the reserves adjacent to the guard pillar of the open pit were mined by a chamber-pillar system with a break from sublevel drifts, leaving longitudinal and transverse pillars to support the guard pillar. The maximum parameters of the chambers are 18x46x91 m, the width of the pillar is 46 m. After the completion of the work in the quarry, the guard pillar was worked out when the chambers were filled with a filling mixture of overburden and cement. Separate sections are worked out by a system of horizontal layers with a backfill.
At a depth of 732-793 m, an ore pillar with a thickness of 61 m was left, dividing the deposit into two mine fields in height. Below the pillar, the mine field is mined by a unique solid pointless system with a solidifying backfill with ore excavation by vertical cuts, measuring 15x15 m in plan, in the direction from the hanging side to the lying side and from the center to the flanks. The backfill mixture consists of crushed waste rock and cement. The mine's productivity reached 5 million tons per year. The Prince Lyell mine Australia mines a steeply dipping copper deposit with an average thickness of 61 m with ore reserves of about 400 million tons. In the initial period, when completing the near-mine reserves, a system with sublevel ore mining was used with the formation of open chambers, then they switched to a system of sublevel caving with end-face ore discharge. The distance between the sublevel roadways is 13.7 m in height and 10.7 m horizontally. The distance between the transport horizons is 70 m. The use of chamber

systems at the first stage made it possible, due to the high quality of the ore, to achieve the maximum return on costs (Kaplunov and Yukov, 2007).

It should be noted that at a number of enterprises, in order to prevent non-production costs from insufficiently reasonably selected development systems or their parameters when switching to underground development, they carry out preliminary approbation by organizing experimental works on underground mining of individual sections of deposits developed by open pits Koffiefontein, Eagle Mountain, Novo-Bakal mine, Vysokogorsk mine, Kara-gaysk quarry of the "Magnezit" combine, or development of new versions of systems at a special experimental mine Kiruna.

As follows from the analysis performed, the decisive influence on the formation of technological schemes for the underground mining of reserves located outside the design boundaries of open pit mining is exerted by their localization relative to the limiting contours of open pits and the nature of the transition to underground mining in space (Aristov II, Seleznev AV, Koltsov VN and Snitka NP, 2007).

The simultaneous implementation of open-pit and underground mining methods during the transition period, on the one hand, complicates the conduct of mining operations and requires the solution of technical tasks specific for joint development, dictates the conditions for the use of underground mining systems, blasting, ventilation and drainage, and on the other, creates the prerequisites for a significant increase in the efficiency of the development of the deposit by reducing the length of underground opening workings, the use of quarry transport communications and the use of quarry vehicles for the delivery of ore, underground mining, placement of ore preparation complexes in the mined-out space, the use of overburden rocks, as a dry backfill or as part of a backfill mixture of hardening backfill, the use of open pit drilling equipment for drilling out reserves adjacent directly to the bottom or sides of the open pit (Mislibaev and Giyazov, 2008).

The most common in practice options for combining technological elements of open-pit and underground mining methods are shown in Table. 1.

Table 1.

**The most common options for combining technological elements of open and underground miming**

| The main types of combinations of technological elements | The most common combinations in the practice of foreign mines |
|---|---|
| Placement of overburden and dressing wastes in the mined-out area of open-pit and underground works | 1.1. Storage of rocks in the caving zone of underground works<br>1.2. Placement of overburden (enrichment waste in underground chambers) or use as part of backfill material<br>1.3. Preliminary storage of overburden on the surface of areas intended for underground mining, for subsequent transfer to the worked-out area |
| Sharing rocks | 2.1.Carrying out of the open pit mine workings for the delivery of ore mined by the underground method<br>2.2. Carrying out auxiliary mine workings from the quarry for winding, delivery of equipment or filling materials |
| Use of open-pit mining and transport equipment at the stage of longwall excavation | 3.1. Application of quarry drilling equipment<br>3.2. Application of quarry transport equipment |

So, the most preferable when moving from open pit mining to underground mining is the primary development of near-pit reserves, i.e. reserves located in the immediate vicinity of the design contours of

the quarries, which makes it possible, with the minimum required capital investments, to largely compensate for the decrease in the production capacity of mining enterprises during the transition period.
As the analysis of foreign experience in the development of near-pit reserves in the design of prospective mining schemes has shown, their formation can be based on three types of combinations of technological elements of open-pit and underground mining: placement of overburden and enrichment wastes in the worked-out space and caving funnels; joint use of mine workings; the use of powerful quarry drilling and transport equipment in underground operations (Merkulov MV, Djuraev RU, Leontyeva OB, Makarova GY and Tarasova YB, 2020).
Thus, based on the analysis of technological schemes for underground mining of reserves located beyond the design boundaries of open pit mining, underground development can be considered for Muruntau from the lower horizons opened by the exploration mine "M" (Fig. 1). In the interval between the underground development horizon and the current bottom of the open pit, a powerful pillar with a thickness of at least 200 m is left, which will ensure the mutual isolation of open and underground mining operations. To ensure reliable stability of the pit walls with further deepening, it is necessary to use an underground mining system with backfilling of the worked-out area (Djuraev RU, Merkulov MV, Kosyanov VA, Limitovsky AM, 2020).
The general scheme for the development of various sections of the open-cut reserves of the open pit is shown in Fig. 2.

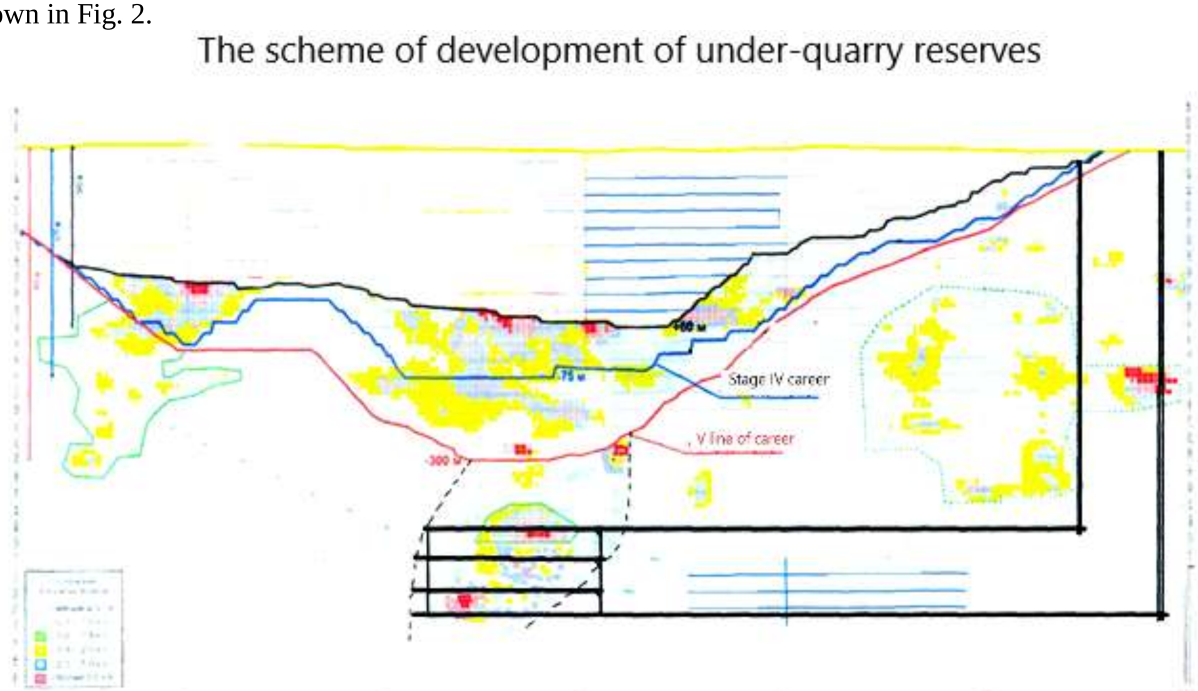


**Figure 1: Scheme of underground mining of the under-quarry section of the deposit**

The substantiation of the possibility of maintaining the production volumes of ore as the open pit deepens due to the parallel involvement of the near and under-pit reserves of the deposit in the development is shown in Fig. 3. As one of the possible options, the scheme of ore delivery from an open-pit and an underground mine in one flow along an inclined conveyor shaft is considered. According to some estimates, the use of underground workings for transporting ore from the quarry will reduce the length of transportation by 2-2.5 times. In this case, the ore from the open pit goes through the ore pass to the crushing plant, then it is fed to the surface along the conveyor shaft.


**Figure 2: Scheme of the combined development of the deposit when combining open-pit and underground mining operations at the Muruntau deposit**

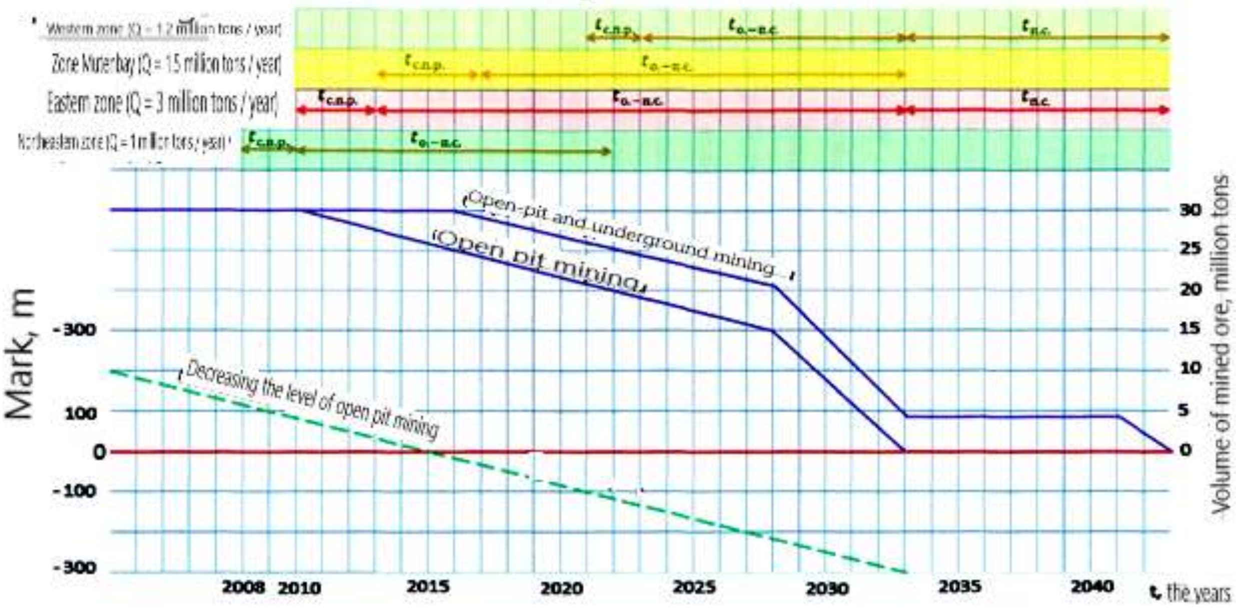


**Figure 3: Schematic diagram of the involvement of the open-cut reserves in the development of underground and combined methods**

## CONCLUSION

Today, the extraction of near-field reserves of minerals is one of the most important issues in the areas of activity of the mining industry. The selection and substantiation of options for the development of ore bodies discovered during exploration, ensuring safe and efficient development of the deposit, as well as economically feasible with the greatest completeness of extraction, is an urgent task at the present time.

When designing a technology for extracting near-bottom reserves, the greatest difficulties arise due to a decrease in the stability of the slopes of the sides and benches of the open pit. Therefore, for the development of device stocks, optimal options for the development system are needed, which should provide:

- safety of mining ore reserves;
- safety of the pit walls in a stable state;
- minimum indicators of losses and dilution of ore.

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