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The History of Russian Caucasus Ore Deposit Development

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Abstract: The historical information about the operation of the Russian Caucasus ore fields and the condition of non-ferrous and rare metal ores is given. The options of the applied development systems with the open developed space are described. The scientific developments are characterized which make the contribution to the development of mining in the extracting countries of the world. The analysis of positive and negative development factors is performed and the survival trend of the mountain enterprises in new economic conditions is offered.

Key words: Field, North Caucasus, the extraction of ores, metals, history, mining, economy

INTRODUCTION

The North Caucasus deposits played an important role in the economy of Russia of the Soviet Union of the CIS countries, delivering valuable strategic raw materials. Their history is of interest for the determination of natural resources fates in the new economic and social structure.

The North Caucasus region has the deposits of tungsten and molybdenum ores: Tyrnyauz in Kabardino-Balkaria and Ktiteberdinskoye in Karachay-Cherkessia. In North Ossetia-Alania the deposits of molybdenum, arsenic, copper, tin, gold and mercury are explored. Dagestan has copper ore reserves at Hudesskoe and Kizil-Dere deposits and mercury reserves. The extraction of gold and bismuth is the promising trend in Kabardino-Balkaria. The iron ores of high quality are extracted from the head waters of the Malki river (Golik, 2016).

The history of deposit development is the major contribution to the development of mining. In the 40’s of the last century, these deposits were among the first ones which used the flexible separating overlapping structures by Prof. Ostroushko (Golik *et al*., 2015a). In 1976, the project of ore leaching was developed within the entire field (Golik *et al*., 2016). The technology of the field development under the river and similar technological innovations were implemented.

MATERIALS AND METHDODS

The Republic of North Ossetia-Alania: The production of non-ferrous metals on the territory of Ossetia achieved a significant peak in the X-YIII centuries BC. Alans extracted nonferrous metals more intensively, having moved to the mountainous areas in the 23rd century (Golik *et al*., 2014a).

The first studies of Sadonsky deposit were performed in 1842 and the industrial operation strated in 1843. The industrial ore base was created by 1860. Since, 1894 the products were given by Holstinsky, Ardonsky, Stur-Izdinsky and Kurtatinsky mines. By 1913 Sadonsky mine became a major mining company. In 1927 Ossetia is the only producer of Russian zinc and its share in the production of lead makes 63%.

In 1945 the development of Zgidsky vein deposit started and in 1953 the development of Holstinsky and Buronsky field started. In 1960, they started to develop Arhonsky deposit in 1967 they began to develop Left Bank deposit in 1969 they commenced to develop Kakadur-Hanikomsky field. Fasnalskoe deposit is developed periodically.

Sadonsky lead-zinc plant, established in 1922, develops the group of fields (Sadonsky, Oktyabrsky, Zgidsky, Buronsky, Holstinsky, Kudat-Hampaladagsky, Kakadur-Hanikomsky, Arhonsky and Left Bank) by the

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development systems with the stoping of ore, sublevel drifts, the layer and sublevel caving. The extraction of ore made 94%, the dilution reached 40%. Mizurskaya concentrator used the selective flotation and cyanide free technology.

The horizontal layers with laying by broken rocks and the rocks from the ore sorting were the prevailing development system of Sadonsky deposit. Since 1956, the development system with the use of ore was applied: the chamber stocks were processed during the first stage, interstorey and interblock pillars were processed during the second stage. In 1958, the development of previously lost reserves and "the metal-bearing" dry filling by collapse options started (Golik *et al*., 2015b).

The options of horizontal layers with the filling of voids by timber started to prevail with the increase of development depth and the mountain pressure increase. Since 1967, the system of layered destruction was mastered. At the option with flexible beams the length of an overlap reached 40 m and its width made 1.5 m. The productivity during overlap mounting was 1.3-1.8 m^2/person×cm. The collapse step made 1.7-2.0 m. The productivity of a face man reached 3 m^3/person×cm.

For >150 years of operation the reserves were worked out on the area of about 1 km in depth and 2,000 m along. Lump galena was mined prior to the development of zinc production technology in Russia and zinc blende was used to fill voids. The total content of metals in a fill reached 12%. In 1930-1950, the mineral material acted as a fill with the metal content of about 2-3%. The amount of accumulated fill with the industrial content of polymetals is estimated at 1 million tons.

The industrial development of Zgidsky field started in 1945. The annual production capacity reached 200 thousand tons of ore or 10-12 thous. tons of metal. In the areas with the sustained capacity the development system with stoping and the laying of chambers by rocks was used, produced by pits on the surface.

The development systems with stoping ensured the productivity of a miner at 5 m^3/man×cm. At the extraction of powerful orebodies the chamber reserves were broken with small drill holes and the pillars were processed with the wells the diameters of which made 76-105 mm. Arhonsky deposit was processed with stoping at the vein power of >0.6 m. In the system with the release of ore on the loading crosscuts with the machine loading, the productivity reached 10 m^3/man×cm. The operating losses at the mine amounted to more than 140 thous. tons of ore, 6,000 tons of zinc and 2,300 tonnes of lead.

The system with a separate extraction and filling was used for Holstinsky field development: the block was divided into "ore" and "rock" halves. Initially the ore was broken in a "rock" half block. Then we were developing a raise and were breaking the ore in the "ore" half block. Along with the breaking of ore in the "ore" half block we were breaking the rocks in the "ore" half block. Kakadurskoe deposit with the reserves of 335 thous. tons of ore contained 2.07% of zinc and 1.26% of lead. At the system of sublevel drifts with the mass breaking of ore on a mined area the ledges were located 2-3 m ahead of overlying substages. After the excavation of chamber reserves it was crushed with pillars. The quality of ores was lower than we expected so, we were performing the selective mining of the deposit richest areas, leaving the poor ores in the depths. These reserves are available for operation at the use of new geotechnologies (Golik *et al*., 2014b).

The prospects of Sadon output recovery are associated with the involvement of reserves into operation on the flanks and in the depths of Sadon and Zgid, the upper horizons of Holst and Zgid and on new deposits: Nogkau, East Dzhimidon, Bozang, Orakh-Com. During the long-term operation due to the selective mining of rich areas the reserves were depleted with the transfer into the category of non-active ones which make up about 50% of Sadonskaya group reserves.

Karachay-cherkess republic: The Urup Mining Metallurgical Plant was commissioned in 1968 on the basis of Urup and Vlasichihinsky fields. The deposits are largely mined by the quarry (Golik and Razorenov, 2014). Development systems: with the collapse of overlying rocks with the filling of a mined space and chamber-and-pillar. The extraction of ore makes 85%, the dilution makes 25%.

The system of mining by horizontal layers with the hydraulic filling is used in the extraction of marginal under river reserves. The material for filling is mined by pits. The filling transport is the hydraulic one. The system of development by sublevel drifts is used outside of the marginal pillars of the Urup river on the flanks of the deposit within the areas with the slope angle of 50° and the capacity of 2-4 m. The chamber ore is mined by the blasting of 3-4 rows of holes with the diameters of 46-60 mm. The excavation block dimensions: length- 40-50 m; height-50-60 m. The height of the bottom and the distance between the exhaust box holes makes 6m. The ceiling and interchamber pillars are broken after the excavation of chamber reserves during the second stage. The bottom is broken by sublevel or mass destruction with a ceiling and an interchamber pillar (Golik *et al*., 2015c). The technical and economic indicators: the losses make 6-15%; the dilution makes 15-24%; a miner productivity makes 4.0-6.5 m^3/cm.

At the chamber-pillar development system with the regular pillars the reserves are mined with the leaving of 3×3 m pillars at the distance of 6-12 m from each other. At the mining system with an explosive delivery of ore a block is divided into 2-3 chambers. Sewage treatment works are performed top-down by sections. In order to keep the rising mining 4 m wide interblock pillars are remained. This variant provides the reduction of losses by 2-3 times, the reduction of production costs by 1.5 times and the productivity increase up to 45 t/shift. Kabardino-Balkar Republic. The industrial operation of Tyrnyauz deposit was launched in 1940. Until 1968 the reserves were mined by the underground method and then the combined method of mining was used (Golik *et al*., 2015d).

The upper part of Tyrnyauz deposit at the elevations of 2800-3200 m was mined by "Vysotny" quarry. The system of mining is the transport one, the height of ledges makes 10-12 m. Mined ores were transported along the ore pass which was 900 m long. The mining in the quarry "Mukulansky" was conducted in several work areas with the repeated passing of ore along mine ore draw holes with the depth of 400-600 m.

The mine "Molybdenum" used the following development systems: storey-chamber and sublevel caving with the breaking on the "sandwiched" environment. Self-propelled diesel equipment, dump trucks and loaders were used on the passing of horizontal mining and during treatment works. The repeated passing of ore was carried out according to the system of deep ore passes with the depth of 200-600 m.

The technology had a high level of work mechanization, including the use of autonomous diesel drive. The cyclic-flow technology with the automated systems of process control was used. The use of intensive technologies for a deposit combined development was accompanied by array strains (Golik, 2016; Golik *et al*., 2016. The zone extension to the pit collapse marks led to the formation of sinkholes, landslides and collapses. The total number of sinkholes makes more than 120 with the diameter up to 40 m. The largest of landslides with the volume up to 4 million m^3 on an area of about 10 ha occurred between the marks 2725 and 2510 m in 1976. The volume of a shifted array was estimated as 15 million m^3.

The upper part of the North-West skarn was mined by the mining system with the mine charge breaking and a floor height up to 210 m. The lower part of the block was mined by deep wells. The ore in the upper part was broken by the charges at VV consumption of 1.8 kgt^{-1}. The mining of sublevel drifts with the breaking by deep wells began with a cut slit formation in the middle of the block by blasting of well colliding beams. After the breaking the chamber middle part from the bottom up the dilutions with the width of 25 m were taken out.

Within the system of the forced storey destruction with a one-step removal the ore body was divided into the panels with the height of 75 m with the width of 30-35 m and with the length up to 100 m. The ore was broken by horizontal layers with the height of 8-12 m. The first layer was broken on the compensation space formed by craters and the subsequent layers were broken on the space formed by the production of ore.

At the mining by the chambers with a dry filling the chamber width reached 50-60 m, the span of a hanging side rock exposure made 90 m, the width of interchamber pillars made 30m. The side walls were tilted up to 85°. The voids were covered with a dry filling supplied from the surface.

The system of mining with the filling by substandard ores and the subsequent removal by open works was carried out by the deposit division according to the fall on the floors with the height of 35 m, the chambers and the pillars. The ore was broken by the charges in boreholes with the diameter up to 76 mm and the depth up to 25 m and was released on loading drives. The breaking was carried out by a continuous front from flank to flank.

Stavropol region. Beshtaugorsky uranium deposit was mined by the following methods (Khasheva and Golik, 2015):

- With a reinforced expansion-type support and the filling in the ore bodies of low power
- Fastening with a rectangular lining and the filling in the ore bodies of average power
- Fastening with frames and a rock filling in thick ore bodies
- Preparation and board gates were fastened by a concrete-block support

Bykogorsky uranium deposit was mined by the systems of horizontal layers with the filling of the mined space by the rock from the drivages, off-balance ores and metal-containing rocks. Ore bodies with the favorable conditions for occurrence were mined by the systems with ore stoping taking into account the radon factor. The aeration of blocks was carried out by a downward stream using the drainage mining to filter the air through the ore.

The rock mass extracted from the block rock mass was dressed in the riddle drum with the holes of 50 mm in diameter. This allowed to extract up to 40% of ore with the industrial metal content from the off-balance ore. The field became a testing ground of metal production technology development using underground and heap leaching. This technology allowed to double the approved reserves of the metal to facilitate the working conditions and solve a number of environmental and economic problems.

RESULTS AND DISCUSSION

At the North-Caucasian deposits the developed space was left open or filled with haphazardly arranged mining operations waste in the vast majority of cases. the filling of overlying horizons was moved down during the development of the bottom levels. If the ore quality was

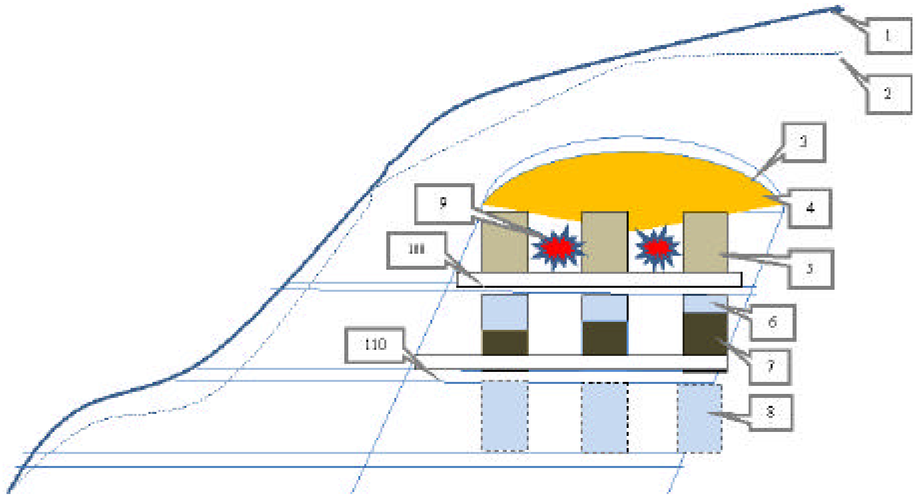

Fig. 1: The technology of deposit underground mining with a mined area and the breaking of pillars: 1: the earth surface; 2: the border of sediments; 3: the collapse area border; 4: the fallen rocks within the pressure arch; 5: an open chamber; 6: undamaged ore; 7: broken ore; 8: the prepared chamber; 9: the blasting of the pillar; 10: the overdrift pillar; 11: the drift

satisfactory during the mining of the primary chambers, the breaking of pillars reduced the quality of metals and made its production more expensive (Fig. 1).

The practice of the North Caucasus deposit mining helped to launch the modern innovative environmental and resource-saving technologies that will determine the global mining fates (Golik *et al*., 2016e-f, 2016).

The modern history of the North Caucasus mines did not show the implementation of mining technology qualitative changes: with the filling of voids by hardening mixtures and the underground leaching of metals from ores as well as the replacement of pyrometallurgy during the processing of multicomponent ores by hydrometallurgy.

The mining enterprises of the North Caucasus had not such an incentive, as competition. The extracted ores belonged to the strategic raw materials. The losses of extraction technologies were compensated by the grants which did not contribute to the development of resource-saving technologies with hardening mixtures for example, the dilution and the ore losses led to the fact that the extraction of metals became more expensive many-fold. In new economy terms, the financial health of ferrous metallurgy former champions is not provided without a state support. The deposits are characterized by the patterns of development: the anticipatory mining of rich deposit areas; the increase of ore production volume with the decrease of metal content; the change of conditions which determine a selective extraction and the leaving of pillars.

Due to the advanced mining of the areas with a high metal content the half of reserves became unsuitable for the traditional ways of underground mining but it remains available for the new technologies of metal production. The possibility of mining revival provides conversion of the mining and processing industries based on the combination of traditional and innovative technologies: the leaching of substandard ores, the hydrometallurgical processing of upgraded concentrates, the extraction of metals from mine refuses by mechanic-chemical methods; the extraction of metals from mine wastes, etc.

CONCLUSION

The long history of deposit development is a major contribution to the development of global mining. The technologies are developed on the mines fields. Those technologies were the advanced ones during that period. The survival of mining enterprises in the new economy terms requires the radical change of technologies with the provision of economic and environmental benefits..

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