Underground mine mining systems and technological parameters of mine development

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***Abstract**: It is very important to provide mines with accessed, prepared and ready for extraction mineral reserves per production blocks at the stage of underground mine planning and design. Preparedness standards depend on geological and geotechnical conditions of mining, flow processes and intensity of first mining per levels. Sustainability of a mine is conditioned by the accepted systems of mine planning and design, production control and and product quality evaluation. Sound standards of prepared and ready for extraction reserves promotes efficiency of underground mine planning and improvement of technical and economic performance. Improved sustainability of operating mines ensures mine project productivity, uniformity of mining and quality of end product. The presented preparedness standards used in planning mining expansion per underground mines in the Republic are reflective of technological progress and take into account geological conditions of specific deposits. Adherence to these standards when substantiating the number of production blocks in underground mining enables accomplishment of planned production. Some gap in the presented standards of mineral preparedness for extraction means that these values should refined per specific mines.*

***Key words:** planning, mineral reserves preparedness, standard, mine-technical system, production block, mining plan, mineral mining*

Introduction

Once an ore body has been probed and outlined and sufficient information has been collected to warrant further analysis, the important process of selecting the most appropriate method or methods of mining can begin. At this stage, the selection is preliminary, serving only as the basis for a project layout and feasibility study. Later it may be found necessary to revise details, but the basic principles for ore extraction should remain a part of the final layout. With respect to the basic principles employed, relatively few mining methods are used today. Because of the uniqueness of each ore deposit, variations on each of these methods are nearly limitless. It is impossible to include even the major variations in

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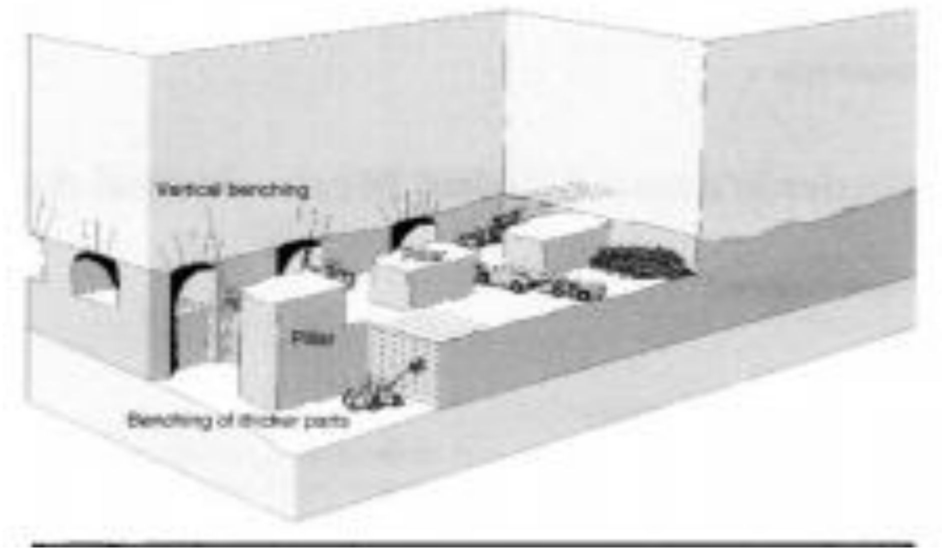

PICTURE 1.Classic room-and-pillar mining

this chapter; the goal of this chapter is to summarize briefly the characteristics of the major mining methods. Ore is an economic concept. It is defined as a concentration of minerals that can be exploited and turned into a saleable product to generate a financially acceptable profit under existing economic conditions. The definition of ore calls for afterthoughts. Ore does not properly exist until it has been labeled as such. To name a mineral prospect an ore body requires more information than needed to establish metal grades. Sufficient knowledge of the mineral deposit, mining technology, processing methods, and costs is needed for undertaking a feasibilitystudy and proving the prospect worthy of being developed into a mine. The expression "existing economic conditions" deserves an explanation. "Run-of-mine''ore is a mix of valuable minerals and worthless rock in which each ingredient is priced separately. Runof-mine ore is treated in the dressing plant and processed into different concentrates. Where the ore contains more than one metal of value, separate concentrates of, for example, copper, zinc, and lead are produced. The value of in situ ore can be calculated by applying market prices to metal content and deducting costs for treatment and transportation of concentrates and smelter fees. The balance must cover direct mining costs and leave a margin for the mine operator. Metal prices are set on international metal market exchanges in London and New York and fluctuate from day to day, depending on the supply-and-demand situation. An oversupply builds stocks of surplus metal, which is reflected in a drop in the market price. The profit margin for a mine decreases as the values of its products drop. As costs for processing, transport, smelting, and refining remain constant, the mine must adjust to a reduced income. The mine operating on a narrow margin must be prepared to survive periods of depressed metal prices. One tactic to deal with such a situation is to adjust the boundaries of the area being mined and draw these boundaries at a higher cut-offgrade. This will increasethe value of the run-of-mine product, and the mine will maintain its profit. Another way is to increase the efficiency of mine production. Modifymg the mining method and introducing new, more powerful machines are actions that should raise the efficiencyof work procedures. The mine must remain a profit generator, which is not a simple task in an environment of increasing labor costs and demands for better living. This chapter describes and explains methods for the underground mining of mineral deposits. The descriptions are generalized and focus on typical applications. Examples chosen illustrate types of mining practices as of 1999. However, every mineral deposit, with its geology, grade, shape, and volume, is unique. As methods are described here, please bear in mind that rock is variable, miners have ideas, and the world of mines will always display special features.

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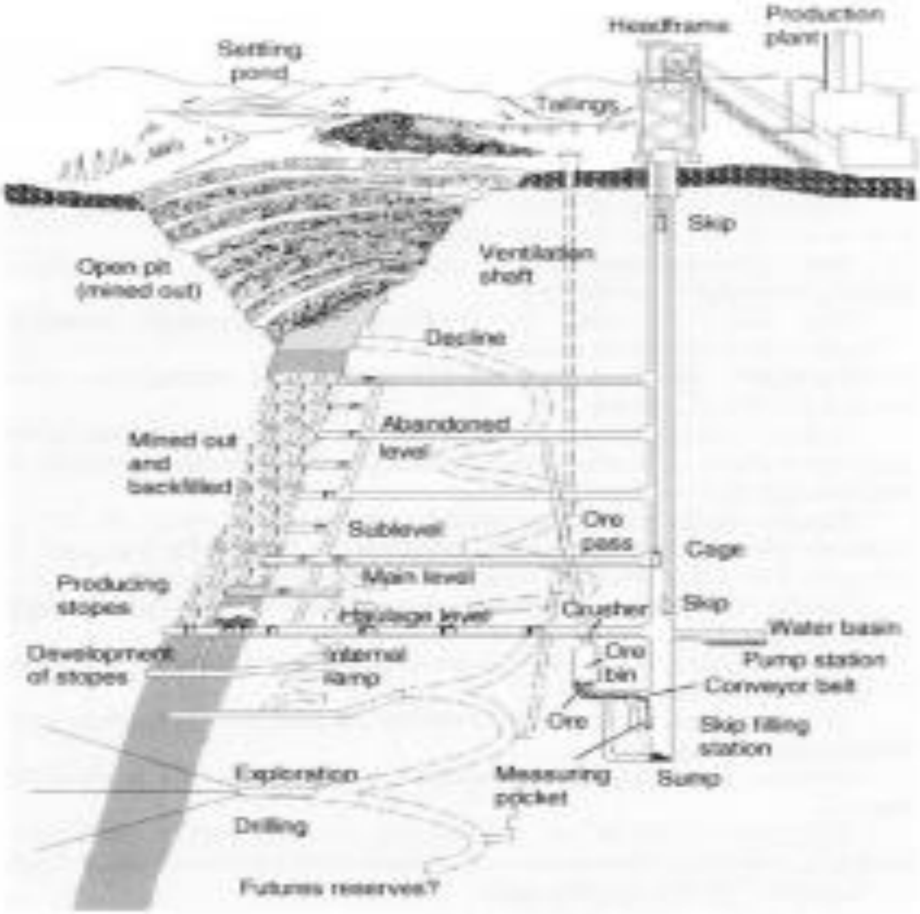

PICTURE 2.The underground mine-basic infrastructure

The method of dividing the mine by breaking it into pieces

The method of dividing the mine by breaking it into pieces is designed for flat-bedded deposits of limited thickness, such as copper shale, coal, salt and potash, limestone, and dolomite. This method is used to recover resources in open stopes. The method leaves pillars to support the hanging wall; to recover the maximum amount of ore, miners aim to leave the smallest possible pillars. The roof must remain intact, and rock bolts are often installed to reinforce rock strata. Rooms and pillars are normally arranged in regular patterns. Pillars can be designed with circular or square cross sections or shaped as elongated walls separating the rooms. Minerals contained in pillars are nonrecoverable and therefore are not included in the ore reserves of the mine. Differing geological conditions give rise to variations in room-and-pillar mining. Three typical variations are described in the following text. Classic room-and-pillar mining applies to flat deposits having moderate-to-thick beds and to inclined deposits with thicker beds. Mining the ore body creates large open stopes where trackless machines can travel on the flat floor. Ore bodies with large vertical heights are mined in horizontal slices starting at the top and benching down in steps. Post room-and-pillar mining (Picture 3) applies to inclined ore bodies with dip angles from 20" to 55". These mines have large vertical heights where the mined-out space is backfilled. The fill keeps the rock mass stable and serves as a work platform while the next ore slice is mined. Step room-and-pillar mining (Picture 1.4) is an adaptation of trackless mining to ore bodies where dip is too steep for rubbertired vehicles. A special "angle" orientation of haulage drifts and stopes related to dip creates work areas with level floors. This allows trackless equipment to be used in drilling and mucking. Mining advances downward along the step room angle. Classic Room-and-Pillar Mining. In classic room-andpillar mining, only a minimum of

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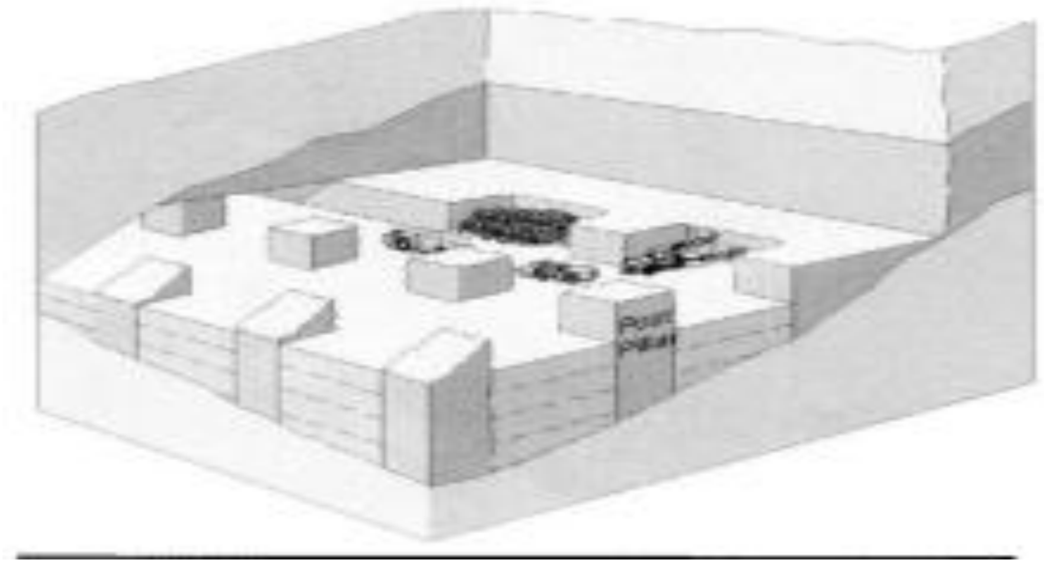
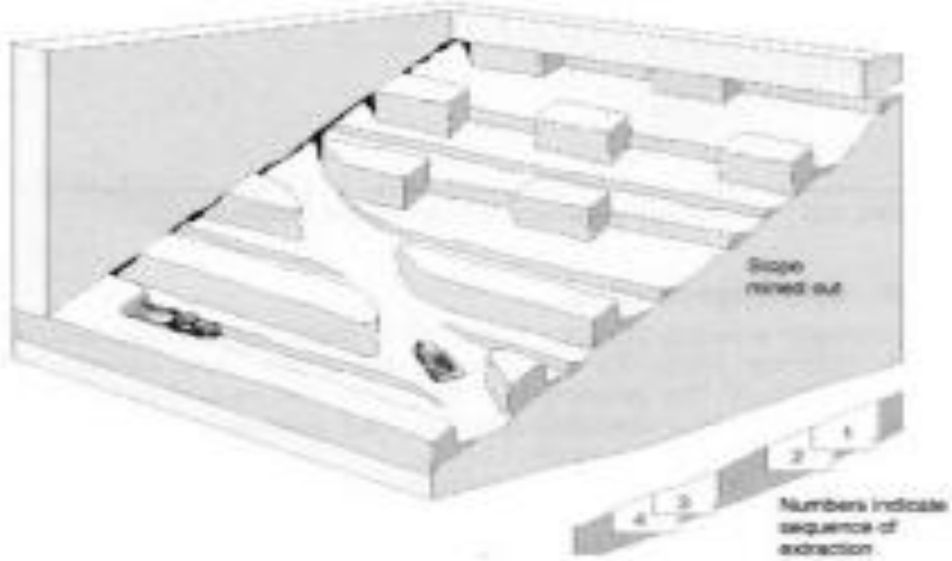
development work is required to prepare a flat-bedded deposit for mining. Roadways for ore transport and communication are established inside production stopes. Excavation of roadways can be combined with ore production, and mined-out stopes can serve as transport routes. Ore production involves the same drill-blast techniques as in normal drifting where drift dimensions equal the width and height of the stope. Where geological conditions are favorable, stopes can be large, and big drill jumbos can be used for mechanized drilling.



PICTURE 3 Post room-and-pillar mining.



PICTURE 4 Steproom mining of inclined orebody.

Deposits with large vertical heights are mined in slices. Mining starts at the top below the hanging wall. At this stage, rock bolts are installed for roof control with the back at a convenient height. Sections below are recovered in one or more steps by benching. Standard crawler rigs are used for drilling vertical holes and for conventional bench blasting. Horizontal drilling and "flat" benching are more practical alternatives because the same drilljumbo can be used for both topheading and drilling flat bench holds. The blasted ore is loaded at the muckpile with diesel-driven front-end

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loaders. Different transport systems are used, depending on stope height and transport distance. Where the opening is high enough, the common dump truck provides economical transport from stopes to collection points. In thin ore bodies, specially built low mine trucks are available from manufacturers. Stopes with very little headroom can be cleaned by load-haul-dump (LHD) machines, and muck can be transferred onto trucks parked in special loadingbays for transport over longer distances. Mobile mechanized equipment is ideal in flat or slightly inclined ore bodies. In the room-and-pillar layout, several production areas can be established. Communications are straightforward and simple. These factors set the stage for the high utilization of both men and machines in an efficient ore recovery system.. Post room-and-pillar mining (or "post-pillar" mining) is a combination of room-andpillar and cut-and-fill stoping. With this method, ore is recovered in horizontal slices starting from the bottom and advancing upward. Pillars are left inside the stope to support the roof. Mined-out stopes are hydraulically backfilled with tailings, and the next slice is mined by machines working from the fill surface. Pillars continue through several layers of fill. Sandfill provides the possibility of modifymg the stope layout and adapting the post-pillar method to variations in rock conditions and ore boundaries. Both backfill and sandfill increase the support capability of the pillar, permitting a higher rate of ore recovery than does classic room-and-pillar mining. Post-pillar mining combines the advantages of cut-and-fill mining-that is, allowing work on flat, smooth floors-with the spacious stopes offered by room-and-pillar mining. Easy access to multiple production points favors the use of efficient mechanized equipment. Mining is a variation in which the footwall of an inclined ore body is adapted for efficient use of trackless equipment. Although applications cannot be fully generalized, step room-and-pillar mining applies to tabular deposits with thicknesses from 2 to 5 m and dips ranging from 15"to 30". The method features a layout in which stopes and haulageways cross the dip of the ore body in a polar coordinate system. By orienting stopes at certain angles across dip, stope floors assume an angle that is comfortably traveled by trackless vehicles. Transport routes cross in the opposite direction to establish roadway access to stopes and to transport blasted ore to the shaft. The main development of step room-and-pillar mining includes a network of parallel transport drifts traversing the ore body in predetermined directions. Drift floors are maintained with grades that allow the use of selected trucks. Stopes are excavated from transport drifts branching out at a predetermined step-room angle. The stope is advanced forward in a mode similar to drifting until breakthrough into the next parallel transport drive. The next step is to excavate a similar drift or side slash one step downdip and adjacent to the first drive. This procedure is repeated until the roof span becomes almost too wide to remain stable. Then an elongated strip parallel to the stopes is left as a pillar. The next stope is excavated the same way, and mining continues downward step by step. The numbers in Picture 1.4indicate the sequence of extraction.

Vein Mining

In vein mines (Pictures 5), the dimensionsof mineral deposits are highly variable. An ore body can be anything from a large, massive formation several square kilometers in surface area to a 0.5-m-wide quartz vein containing some 20 g/tonne of gold. Miners aim to recover the mineral's value, but prefer to leave waste rock in the hanging wall and the footwall intact. In the thicker deposits, a machine operates within the ore body walls without problems. When the mineralized zone narrows to a few meters, machinesmay be too wide to fit insidethe ore boundaries. To excavate rock only to permit the machine to fit produces waste, which dilutes the ore. The alternative is to use manual labor to recover high-grade ore. However, labor is costly, and manual mining techniques are inefficient.Also, it is difficult to find people who accept working with hand-held rock drills and using musclepower. Today, a selection of standard slim-sized machines is available, allowing mechanized mining in 2-m-wide drifts. These slimsized machines include the facejumbo for narrow drifts matched with a longhole rig of the same size. The small drifter jumbo and longhole rig complemented with an LHD with a 2-m3 bucket provides everything needed for the mechanized mining of a 2-mwide vein.

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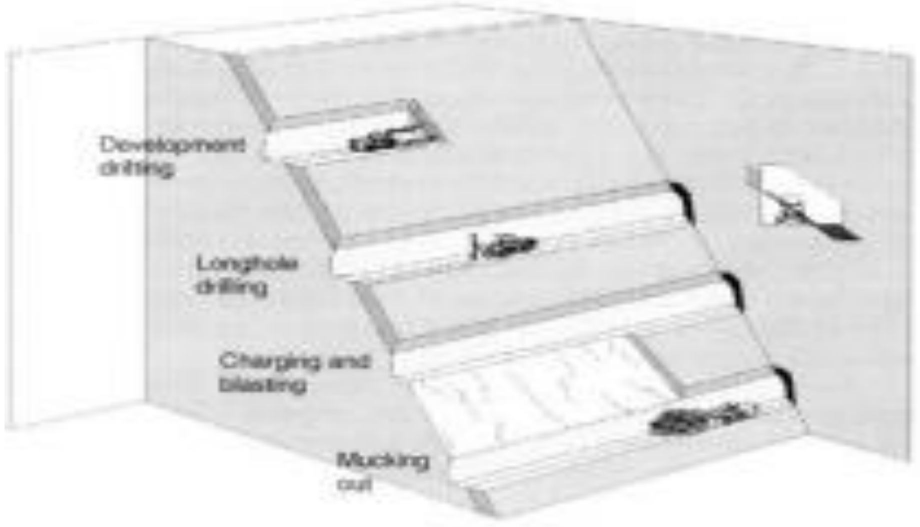

PICTURE 5. Mininga narrow vein with steep dip.

Sublevel Open Stoping

In sublevel open stoping (Pictures 1.9and l.lO), ore is recovered in open stopes normally backfilled after being mined. Stopes are often large, particularly in the vertical direction. The ore body is divided into separate stopes. Between stopes, ore sections are set aside for pillars to support the hanging wall. Pillars are normally shaped as vertical beams across the ore body. Horizontal sections of ore, known as crown pillars, are also left to support mine workings above the producing stopes. Enlarging stope dimensions influences mining efficiency. Miners therefore aim for the largest possible stopes. The stability of the rock mass is a limiting factor to be considered when selecting the sizes of stopes and pillars. Sublevel stoping is used for mining mineral deposits with following characteristics:

*Steepdip-the inclinationofthefootwallmust exceed the angle of repose, Stable rock in both the hanging wall and the footwall,

* Competentore andhostrock,

* Regularoreboundaries.

Sublevel drifts for longhole drilling are prepared inside the ore body between main levels. These are strategically located since these are the points from which the longhole rig drills the blast pattern. The drill pattern specifies where blastholes are to be collared and the depth and angle of each hole, all of which must be set with great precision to achieve a successful blast. Drawpoints are excavated below the stope bottom for safe mucking with LHDs, which may be combined with trucks or rail cars for longer transport. Different layouts for undercut drawpoints are used. The trough-shaped stope bottom is typically accessed through loading drifts at regular spacings. Developing the set of drifts and drawpoints underneath the stope is an extensive and costly procedure. A simpler layout is gaining in popularity as an alternative to the conventional drawpoint-and-muck-out system. Here, the loading level is integrated with the undercut. Mucking out is done directly on the stope bottom inside the open stope. The LHD works inside the open stope and, for safety reasons, is operated by radio control by an operator based inside the access drift. Sublevel stoping requires a regular shape of stopes and ore boundaries. Inside the drill pattern, everything qualifies as ore. In larger ore bodies, the area between the hanging wall and the footwall is divided into modules along strike and mined as primary and secondary stopes.

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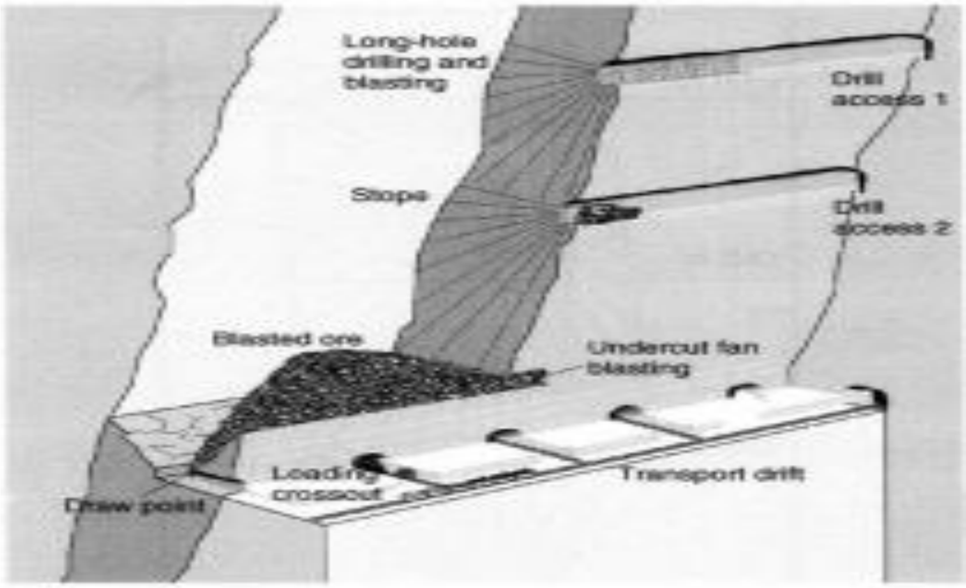

PICTURE 6 Sublevel open stoping

PICTURE 7. Longhole rig with slide posltioning, remote control, and tube carouse

Conclusions

Mining new technology the near future, the mining industry must overcome the problems of structural changes in raw material demand and raise the productivity up to the level of high-tech industries to maintain profits. This means the formation of a comprehensive and integral response to such challenges as the need for innovative modernization of mining equipment and an increase in its reliability, the widespread introduction of Industry 4.0 technologies in the activities of mining enterprises, the transition to “green mining” and the improvement of labor safety and avoidance of man-made accidents. The answer to these challenges is impossible without involving a wide range of

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the scientific community in the publication of research results and the exchange of views and ideas. To solve the problem, this Special Issue has combined the works of researchers from the world's leading centers of mining science on the development of mining machines and mechanical systems, surface and underground geotechnology, mineral processing, digital systems in mining, mine ventilation and labor protection, in geo-ecology. A special place among the articles in the Special Issue is given to the post-mining technologies research. We associate the further advancement of scientific thought in the field of innovative development of mining technologies, on the one hand, with deepening research in the areas of searching for answers to the key challenges facing the mining industry.

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