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Innovative Technologies For Mining And Processing Minerals In The Southern Regions Of Uzbekistan

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Abstract. The southern regions of Uzbekistan, including the Kashkadarya and Surkhandarya regions, as well as the adjacent mountain ranges, have significant potential for the development of mineral deposits. Effective development of these rich resources requires the introduction of advanced innovative technologies at all stages of the mining process - from the stage of development (extraction) to mineral processing. This paper examines modern approaches and technological solutions aimed at increasing productivity, reducing the environmental burden and improving the economic efficiency of mining enterprises in the region, which will significantly improve the use of available natural resources and minimize negative impacts on the environment.

Keywords: mountainous regions, minerals, natural-geographic factors, environmental safety, mining and geological conditions.

Аннотация. Южные регионы Узбекистана, включая Кашкадарьинскую и Сурхандарьинскую области, а также прилегающие горные массивы, обладают значительным потенциалом для разработки месторождений полезных ископаемых. Эффективное освоение этих богатых ресурсов требует внедрения передовых инновационных технологий на всех этапах горнодобывающего процесса - от стадии выработки (добычи) до переработки минералов. В рамках данной работы рассматриваются современные подходы и технологические решения, направленные на повышение производительности, снижение экологической нагрузки и улучшение экономической эффективности горнодобывающих предприятий региона, что позволит значительно улучшить использование имеющихся природных ресурсов и минимизировать негативные последствия для окружающей среды.

Ключевые слова: горные районы, полезные ископаемые, природно-географические факторы, экологическая безопасность, горно-геологические условия.

Introduction. Uzbekistan occupies one of the leading places in Central Asia in terms of the diversity and volume of mineral reserves. Particularly significant deposits are concentrated in the southern regions of the country, where there are extensive resources of lead, zinc, copper, gold, antimony and rare earth elements. However, many of these deposits are still being developed using outdated technologies that do not allow for the most efficient use of the available resource potential.

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Fig. -1 Uzbekistan is a country rich in deposits

In this regard, there is a need to introduce innovative methods that will not only improve the efficiency of extraction and processing, but also contribute to the sustainable environmental and socio-economic development of the region.

Relevance of the topic. Modern challenges related to environmental protection, energy efficiency and resource conservation put forward new requirements for the mining industry. In the context of global climate change and the growing need for sustainable management of natural resources, the transition to innovative and environmentally friendly methods of extraction and processing is becoming especially important. The development of high technologies, including digitalization and automation of processes, as well as the introduction of waste-free and low-cost technologies, are key factors that ensure not only increased production efficiency, but also a reduced impact on the environment. These changes are becoming the basis for the sustainable development of the mining industry in the 21st century, contributing to the conservation of resources for future generations and ensuring economic stability in the mining regions.

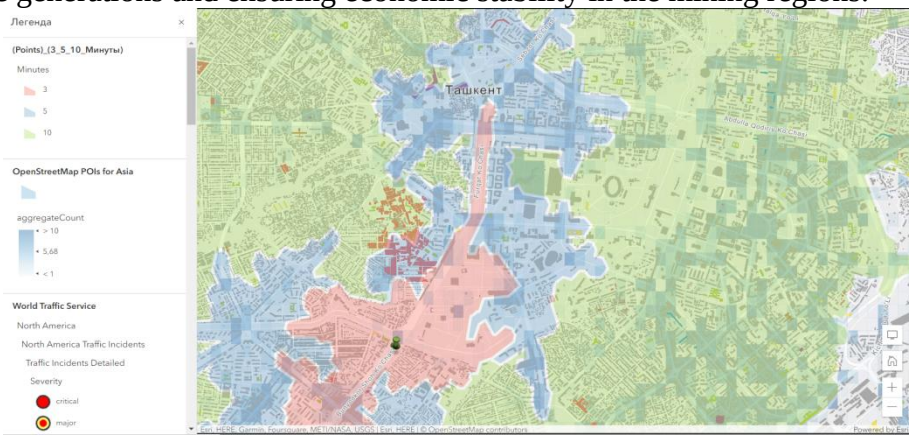

Fig. 2 Available geodata for Uzbekistan: vector maps, satellite images, land use maps, digital terrain models and other layers that can be used for GIS analysis

Main areas of innovation:

1. Geographic information systems (GIS) Using GIS technologies to build 3D models of deposits, assess the profitability of development, monitor the condition of quarries and mines.

2. Automation and remote control. Implementation of autonomous drilling rigs, robotic loading and transportation systems, remote control of mining equipment.

3. Energy-efficient and environmentally friendly processing methods. Application of bio-hydrometallurgy, new generation flotation methods, processing of sludge and waste with the extraction of valuable components.

4. Digitalization of processes. Using sensors, IoT, Big Data and artificial intelligence to optimize production processes and predict man-made risks.

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5. Innovative methods of underground mining. In the southern regions, where mining conditions are difficult, underground mining technologies using new generation drilling and blasting and room and pillar systems are relevant.

Examples of innovation implementation in the southern regions of Uzbekistan

1. Kashkadarya region:

Kashkadarya has a number of promising antimony deposits (Tehutan, Shorsu), as well as occurrences of mercury, lead and other rare elements. The following are being actively implemented here:

- Selective underground mining methods using low-intensity drilling and blasting technologies.

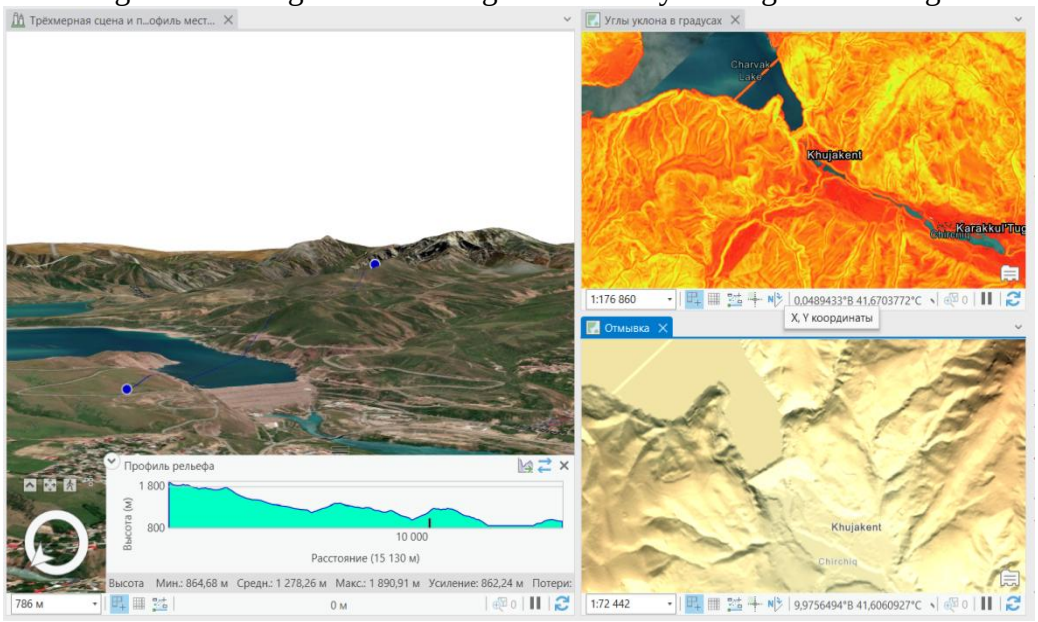

Fig -3 Digital terrain model with higher accuracy

Antimony deposits: Tehutan and Shorsu:

- Using the processing of man-made tailings using new generation flotation and refining plants to extract gold and antimony.

- Remote monitoring stations for mine atmosphere based on the Internet of Things.

The Tehutan and Shorsu deposits, located in the mountainous part of the Kashkadarya region, are of the hydrothermal type and are characterized by complex geological conditions. The main ore mineral is stibnite (Sb_2S_3), containing up to 45–70% antimony.

- The Tehutan deposit is distinguished by a high concentration of the useful component and significant reserves suitable for underground mining. In recent years, geological exploration has been carried out here using 3D modeling and scanning electron microscopy to clarify the morphology of the ore bodies. - Shorsu, in turn, is promising for integrated development, since along with antimony, traces of gold and mercury were found. The possibility of using biotechnology to leach antimony from difficult-to-enrich ores is currently being studied. Both sites are considered as potential sites for the introduction of mobile enrichment plants, which will significantly reduce logistics costs and minimize the impact on the environment.

Table 1

Table displaying key data on deposits of the Kashkadarya region

Deposit/ Region	**Main minerals**	**Technologies and development methods**
Kashkadarya region	Antimony, mercury, lead, other rare elements	Selective methods of underground mining, processing of man-made tailings, IoT stations for monitoring
Tehutan	Antimony (Stibnite, Sb_2S_3)	Geological exploration with 3D modeling, scanning electron microscopy
Shorsu	Antimony, gold, mercury	Biotechnology for antimony leaching, mobile enrichment plants

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2. Surkhandarya region:

The region is characterized by complex tectonics, but rich deposits of polymetallic ores. At deposits such as Agrobulak and Boysun, the following are being implemented:

-Ground-penetrating radar technologies and 3D seismic exploration to study the underground structure.

-Mobile modular enrichment plants that allow ore to be processed directly at the deposit.

-Use of biotechnology for leaching copper from poor ores.

Table 2

Table including information on the technologies used for Surkhandarya region

Technology	Description of application
Georadar technologies and 3D seismic exploration	They are used for precise mapping of the underground structure of deposits and ore bodies.
Mobile modular processing plants	Processing of ore directly at the deposit, which reduces transportation costs and increases efficiency.
Biotechnology for copper leaching	Using biotechnology to extract copper from low-grade ores, improving the cost-effectiveness of mining.

Agrobulak and Boysun deposits.

The Agrobulak and Boysun deposits are important sources of polymetallic ores containing lead, zinc, copper and silver. Both sites are located in a complex tectonic zone characterized by intense folding and faults.

- The Agrobulak deposit is being developed using modular processing plants, which allows for efficient metal extraction with minimal capital investment. Geological exploration is carried out using 3D seismic exploration and ground penetrating radar, which ensures high accuracy in mapping ore bodies.

- Boysun has a high zinc and silver content. Flotation technologies using nanoreactants are used here, increasing metal extraction at the fine enrichment stage. The introduction of passive bioreactors for wastewater treatment after processing is also being considered.

Table 3

Table taking into account their characteristics and applied technologies for the Agrobulak and Boysun deposits:

Field	Main minerals	Geological features	Technologies and development methods
Agrobulak	Lead, zinc, copper, silver	Complex tectonics, folding and faulting	Modular enrichment plants, 3D seismic exploration, ground penetrating radar
Boysun	Zinc, silver	Complex tectonic zone, intense folding	Nanoreactor flotation technologies, passive bioreactors

In both cases, an important area of development is integration II for mining optimization, including production scenario modeling, collapse prediction, and water inflow monitoring.

Rare and trace elements in the border areas of Surkhandarya and Kashkadarya. In the mountainous and foothill areas of southern Uzbekistan, especially at the junction of the Surkhandarya and Kashkadarya regions, manifestations of rare and trace elements such as gallium (Ga), germanium (Ge), and scandium (Sc) are recorded. These elements are used in high-tech industries: microelectronics, solar energy, aviation, and the production of new-generation alloys.

- gallium is found in small quantities in bauxites and sphalerites associated with polymetallic deposits. Extraction is possible through the introduction of combined hydrometallurgical processes with selective sorption. - germanium is associated with carbonaceous shales and sulphide ores, and is promising for extraction during complex processing of copper-zinc concentrates.

- scandium is fixed in residual ores, as well as in clastic terrigenous formations. Ion exchange and nanofiltration methods are considered for its extraction.

The use of digital mapping and geochemical analysis with AI modeling allows localizing the most promising zones for further study and development.

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Fig. -4 Innovative technologies for mineral production

Table 4

Table for displaying information on rare and trace elements, their sources and extraction methods

Element	Geological origin	Extraction methods	Application
Gallium	Bauxites, sphalerites associated with polymetallic deposits	Combined hydrometallurgical processes with selective sorption	Microelectronics, solar energy, aviation, alloy production
Germanium	Carbonaceous shales, sulphide ores	Complex processing of copper-zinc concentrates	Electronic components, optics, solar panels
Scandium	Residual ores, clastic terrigenous formations	Ion exchange, nanofiltration	New generation alloys, aviation, metallurgy, energy

Conclusion. The use of innovative technologies in the mining industry of the southern regions of Uzbekistan demonstrates high potential for the comprehensive development of the industry. Modern solutions - from digitalization of processes and automation to the introduction of environmentally friendly processing methods - can significantly increase the efficiency of developing the region's mineral resource base. In addition, the use of high-tech approaches helps reduce the environmental burden and promotes sustainable socio-economic development of hard-to-reach mountainous areas. Of particular importance is the integration of digital platforms, geographic information systems and artificial intelligence methods into the mineral resource management strategy, which opens up new horizons for sustainable growth of the industry in the long term.

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