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IMPROVING MINING TECHNOLOGY FOR MINERAL DEPOSITS IN COMPLEX GEOLOGICAL CONDITIONS

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Abstract. This study focuses on improving mining technology for mineral deposits developed under complex geological conditions. The research examines the influence of geological and geomechanical factors, including ore body geometry, rock mass strength, depth of mining, and rock stability, on the selection of effective mining methods. A comprehensive approach incorporating geological assessment, geomechanical analysis, comparative evaluation, and technical-economic optimization is proposed. Particular attention is given to increasing mineral recovery, reducing ore losses and dilution, improving operational safety, and lowering production costs. The proposed approach supports the selection of appropriate mining technologies according to the specific characteristics of deposits. The findings provide a methodological basis for improving mining efficiency and promoting the sustainable development of mineral resources. Further validation using field data and practical mining operations is recommended.

Keywords: complex geological conditions, mining technology, geomechanical assessment, mineral recovery, ore losses, mining optimization.

INTRODUCTION

The growing demand for mineral resources has made the efficient development of existing mineral deposits, the improvement of extraction processes, and the development of advanced mining technologies important scientific and practical priorities. The development of deposits located under complex geological conditions presents particular challenges due to variations in geological structure, the physical and mechanical properties of rock masses, tectonic disturbances, fractures, the geometry of ore bodies, and changes in geological conditions with depth. Under such circumstances, the application of conventional mining methods may lead to increased mineral losses, ore dilution, higher production costs, and difficulties in maintaining the stability of mine workings.

The effective organization of mining operations under complex geological conditions requires a comprehensive assessment of geological and geomechanical characteristics, the determination of rock strength parameters, and the selection of mining methods appropriate to the specific conditions of a deposit. The shape and thickness of the ore body, its dip angle, the distribution of valuable components, the physical and mechanical properties of surrounding rocks, and the influence of rock pressure are among the principal factors determining the choice of mining technology. Therefore, the development of effective technological solutions should be based not only on geological information but also on geophysical investigation results, engineering-geological observations, and numerical modeling techniques.

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In recent years, increasing attention has been paid to the application of digital modeling, automated control systems, artificial intelligence, and multi-criteria decision-making methods in the mining industry. These approaches provide opportunities to account for geological variability, assess the stability of mine workings, compare alternative mining methods, and improve the technical and economic performance of mining operations. The study by Tasoglu et al. (2026) emphasizes the importance of considering rock mechanics, occupational safety, multi-criteria decision-making, and economic analysis when selecting underground mining methods. Their research highlights the need for an integrated approach to technological decision-making in complex mining environments.

In this context, improving mining technology for mineral deposits under complex geological conditions requires a detailed analysis of geological factors, an assessment of the capabilities and limitations of existing mining methods, and the optimization of technical and economic performance indicators. The aim of this study is to investigate the influence of complex geological conditions on mineral extraction, identify the principal criteria for selecting appropriate technological solutions, and provide a scientific basis for improved approaches that ensure efficient, safe, and economically viable mineral extraction.

RESEARCH METHODOLOGY

The study employs a comprehensive methodological approach to improving mining technology under complex geological conditions. The methodology is based on the analysis of geological and geomechanical characteristics, comparative evaluation of mining methods, and assessment of technical and economic performance indicators.

The main research methods include:

- Geological analysis: assessment of ore body geometry, dip angle, thickness, and surrounding rock properties.
- Geomechanical assessment: evaluation of rock strength, fracture distribution, and mine stability.
- Comparative analysis: comparison of alternative mining methods according to geological and technological conditions.
- Technical and economic evaluation: assessment of production costs, mineral losses, ore dilution, and operational efficiency.
- Optimization: identification of suitable mining parameters to improve extraction efficiency and operational safety.

Table 1. Key Indicators for Improving Mining Technology under Complex Geological Conditions

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Assessment area	Key indicators	Purpose
Geological conditions	Ore-body thickness; dip angle; geometry; tectonic disturbances; fracture distribution	Characterize the deposit and identify geological constraints.
Geomechanical conditions	Rock strength; rock-mass stability; in-situ stress; surrounding-rock properties	Evaluate excavation stability and support requirements.
Mining technology	Mining method; extraction sequence; equipment suitability; operating parameters	Select a mining method suited to the deposit conditions.
Technical performance	Mineral recovery; ore loss; dilution; productivity	Compare the operational effectiveness of alternative methods.
Economic performance	Capital and operating costs; unit extraction cost; equipment utilization	Assess economic feasibility and cost efficiency.
Safety and environmental aspects	Ground-failure risk; worker exposure; waste generation; energy use	Reduce operational risks and support more sustainable mining.

The proposed methodology integrates geological, technological, safety, and economic criteria to support the selection of appropriate mining solutions for complex geological environments.

RESULTS

The assessment of mining technology under complex geological conditions was based on geological, geomechanical, technological, and economic indicators. The selected parameters included ore-body dip angle, rock-mass strength, mineral recovery, ore loss, ore dilution, productivity, and operating costs. These indicators provide a basis for comparing alternative mining methods and identifying suitable technological solutions.

Table 2. Illustrative Performance Indicators for Mining under Complex Geological Conditions

Indicator	Scenario A	Scenario B
Ore-body dip angle (°)	45	65
Rock-mass strength (MPa)	60	90
Mineral recovery (%)	85	92
Ore loss (%)	15	8
Ore dilution (%)	12	7
Productivity (t/day)	500	650
Operating cost (USD/t)	32	28

The illustrative comparison demonstrates how changes in mining conditions and technological parameters may influence operational performance. Scenario B shows a mineral recovery rate of 92%, compared with 85% in Scenario A, representing a difference of 7 percentage points. Ore loss decreases from 15% to 8%, while ore dilution declines from 12% to 7%. Productivity increases from 500 to 650 tonnes per day, equivalent to a 30% increase. Meanwhile, the operating cost decreases from 32 to 28 USD/t, corresponding to a reduction of 12.5%.

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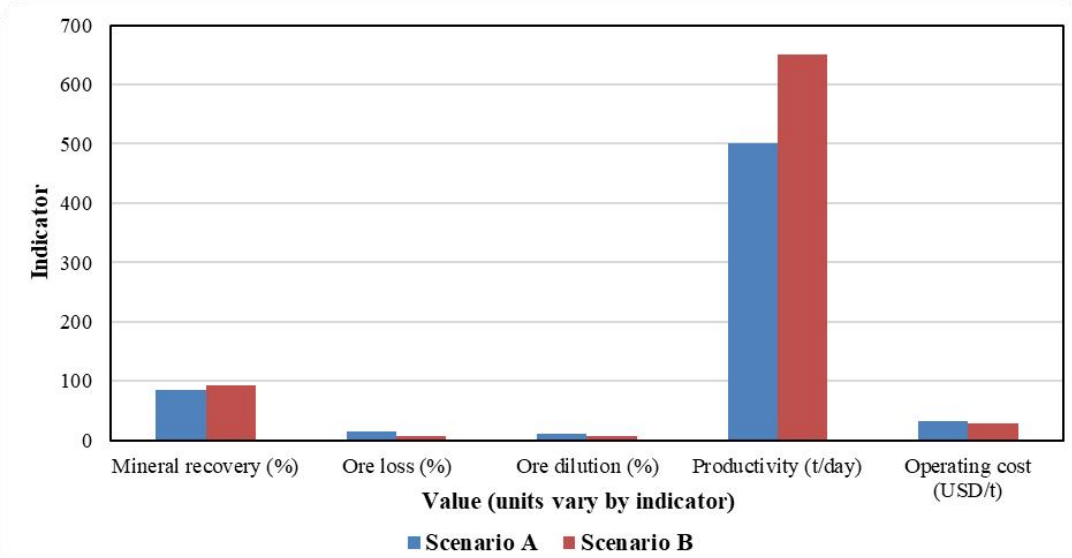


Figure 1. Comparison of Mining Performance Indicators under Scenarios A and B

These results illustrate the potential benefits of selecting mining technologies according to geological and geomechanical conditions. Nevertheless, the relationship between rock-mass strength, ore-body geometry, and operational performance must be evaluated using site-specific geological data, engineering calculations, and field measurements before conclusions can be generalized.

CONCLUSION

The study highlights the importance of improving mining technology for mineral deposits located under complex geological conditions. The analysis indicates that geological and geomechanical parameters, including ore-body geometry, dip angle, rock-mass strength, and fracture distribution, should be considered when selecting appropriate mining methods. An integrated assessment of these factors, together with mineral recovery, ore loss, dilution, productivity, and operating costs, provides a basis for selecting more efficient and safer technological solutions.

The comparative assessment framework demonstrates the potential benefits of adapting mining methods to specific geological conditions. Improvements in mineral recovery, reduction of ore losses and dilution, increased productivity, and lower operating costs may be achieved through appropriate technological selection and optimization. However, the numerical values presented in this study are illustrative and require verification using actual geological data and field measurements. Further research should focus on numerical modeling and practical validation to establish the effectiveness of the proposed approach and support its application in mining operations.

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