**ABSTRACT**

of the doctoral dissertation by
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on the topic: "Development of a technology for the rational mining of iron ore reserves in on-board massifs with ensuring their stability"
submitted for the degree of Doctor of Philosophy (PhD) in the educational program 8D07202 – "Mining Engineering"

**Topic relevance.** The further development of the open-pit mining industry in the Republic of Kazakhstan is accompanied by the exploitation of deeper deposit horizons and the formation of high-steepness slopes. This is evidenced by the experience of developing major deposits such as Kentobe, Bozshakol, Ushkatyn, Aktogay, and others where mining depths exceed 200 meters, and design extraction levels reach 300-500 meters or more. The open-pit development of such deposits involves an increased risk of slope stability failure due to rock fracturing, high degrees of water saturation within the massif, and the necessity for additional wall-shaping measures to ensure the stability of near-pit wall massifs based on geotechnical research.

One of the primary challenges in justifying the parameters for bench slopes and pit walls is the insufficient understanding of geomechanical processes and the incomplete representation of the massif's stress-strain state in existing computational models.

A key condition for addressing this problem is the development of the open pit geological-geomechanical model, integrated with a geomechanical monitoring system for the stability of bench slopes and pit walls. Such a system enables the prediction of geotechnical risks, optimization of mining operation parameters, and reduction of anthropogenic impact on the rock massif. Monitoring must be based on modern instrumental surveying and geodetic methods, including the establishment of observation stations network, the selection of tools and methodologies for high-precision measurements, mathematical processing of observation results, and the analysis and forecasting of near-pit wall massif stability.

Therefore, the geomechanical justification of rock stability parameters, combined with the improvement of extraction technologies for the boundary zone of open-pit mining and monitoring, represents a highly relevant scientific and practical task aimed at enhancing the efficiency of geomechanical support in deposit development.

**The objective of the dissertation research** is the scientific substantiation of rational iron ore reserve extraction in the near-pit wall massifs based on the improvement of drilling and blasting parameters using digital geological-geomechanical modeling of pit wall stability.

To achieve this objective, the following **tasks** have been defined:

- conduct an analytical review of scientific and technical literature focused on technological solutions for drilling and blasting operations and methods for ensuring pit wall stability using instrumental monitoring;

- develop a geological-geomechanical model based on data from the Kentobe iron ore deposit;

- perform theoretical studies on pit wall stability based on the developed block geological-geomechanical model of the deposit;

- substantiate the parameters for drilling and blasting operations, taking into account the physical and mechanical properties of the rocks and the seismic impact of explosions;

- implement modern laser-digital technologies for the monitoring and control of pit wall conditions.

**The idea of the work** is to optimize the technology of drilling and blasting operations taking into account the results of three-dimensional geological and geomechanical modeling and instrumental monitoring of the state of the rock mass.

**Object of research:** The pitwall rock mass of the Kentobe iron ore deposit, which is developed by open-pit mining under complex geomechanical conditions.

**Subject of research:** The technology for mining pitwall reserves utilizing a geological-geomechanical model that ensures rock mass stability and instrumental monitoring.

**Research methods.** A comprehensive research method was employed, which includes: analysis and scientific synthesis of previously published literature on the rational extraction of iron ore reserves in near-pit wall massifs while ensuring their stability; investigation of the mining, geological, hydrogeological, and geomechanical conditions influencing the formation and state of near-pit wall massifs; analytical studies of the stress-strain state and stability of near-pit wall massifs during iron ore extraction; substantiation of drilling and blasting parameters considering the physical and mechanical properties of the rock and the seismic impact of explosions; and the validation of the proposed technical and technological solutions under open-pit mining conditions.

**Scientific provisions submitted for defense of the dissertation:**

- when predicting critical parameters of rock water saturation, the safety factor of the pit walls directly depends on the dynamics of groundwater level changes;

- when determining the patterns and parameters of pre-split (wall-shaping) blasting at the final pit limit, the seismic impact coefficient depends on the ratio of the compressive and tensile strengths of the rock;

- scientifically substantiated concept of integrated slope stability management, based on the integration of geological-geomechanical modeling data, allows for the consolidation of drilling and blasting technology and instrumental monitoring into a unified geotechnical support system.

**Scientific novelty of the dissertation work:**

- blasting technology has been adapted based on the geological-geomechanical model of the deposit to ensure the formation of stable bench slopes;

- drilling and blasting parameters have been optimized to ensure the stability of near-pit wall massifs by establishing the dependence of the explosive mass in a borehole on the safety factor of the bench.

**The practical significance** of the work lies in the substantiation of slope and bench parameters, as well as drilling and blasting operations for the Kentobe open-pit mine. This is achieved through a geological-geomechanical model that accounts for the physical and mechanical properties of the rocks, structural and geological features of the massif, and the seismic impact of explosions. Furthermore, it involves the development of an instrumental monitoring technology for near-pit wall massifs using laser-digital methods.

The results of the dissertation research were obtained within the framework of economic contract work between Karaganda Technical University (NAO KarTU) and "Orken" LLP (Contract No. 4100056427 dated May 19, 2023) on the topic: "Observations of Pit Wall and Dump Displacement, Study of Rock Mass Properties with the Construction of a Geomechanical Model at the Kentobe Iron Ore Deposit." An act of implementation for the research results into the production process at the Kentobe mine (Orken-Kentobe branch of Orken LLP) has been signed.

The research findings have been integrated into lectures and practical classes for the discipline PKODEG 4222 "Non-traditional Geotechnologies for Mining and Mineral Extraction" under the 6B07202 "Mining Engineering" educational program.

**The validity and reliability of the scientific propositions** are confirmed by the rigorous application of theoretical and experimental research methods, the representativeness of the source data, and the convergence between calculated and actual results.

**The applicant's personal contribution** consists in developing the goals and objectives, selecting research methods, as well as formulating the scientific and technological principles for the rational mining of iron ore reserves in pitwall rock masses while ensuring their stability. The results of analytical studies, the processing of baseline mining-geological, geomechanical, and mine-surveying data, as well as the substantiation of mining and drilling and blasting (D&B) parameters, were obtained with his direct participation. Approbation of the developed technological solutions was carried out under the conditions of the Kentobe deposit, which is developed by open-pit mining. In the co-authored published articles, the author is credited with the research results, analysis, preparation, formatting, submission, and tracking of the materials.

**Approbation of the work.** The main results of the research were presented and discussed at the following scientific events: the International Forum of Mine Surveyors "Digital Technologies in Geodesy, Mine Surveying, and Geomechanics", Karaganda, 2019; the International Scientific and Practical Conference "Integration of Science, Education, and Production — the Basis for Implementing the Plan of the Nation" (Saginov Readings No. 13), Karaganda, 2021; and the multi-author monograph "Energy- and resource-saving technologies of developing the raw-material base of mining regions", Petroșani, Romania, 2021.

The research internship was completed at "Orken-Kentobe" LLP, and the scientific internship was conducted at the Islam Karimov Tashkent State Technical University at the Department of Mining and Geotechnology of Coal and Stratified Deposits (Tashkent).

**Publications.** The main findings of the dissertation research are reflected in 9 scientific works. These include 4 articles in peer-reviewed scientific journals within the scope of the dissertation topic, indexed in the Scopus (Elsevier) database with a CiteScore ranking in the Q3 quartile; 1 article in a journal indexed in the Russian Science Citation Index (RSCI) database; 1 certificate of state registration of rights to copyright objects issued by the National Institute of Intellectual Property; and 2 (two) articles in the proceedings of International and Republican scientific and practical conferences.

**Structure and scope of the work.** The dissertation consists of an introduction, 4 chapters, a conclusion, and a reference list. It comprises 154 pages of typescript, including 79 figures and 14 tables.Acknowledgements.

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