REVIEW

of the doctoral dissertation
by **Gylym Kairatovich Sapinov**
entitled "**A Study on the Real-Time Spatial Localization of Seismic Events in Underground Mines**",
submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy (PhD)
in the educational program 8D07202 – Mining Engineering

No.	Criteria	Compliance with the criteria (please select one option)	Justification of the official reviewer's position
1.	The dissertation topic (as of the date of its approval) corresponds to the directions of scientific development and/or state programs	1.1 Compliance with priority areas of scientific development or state programs: 1) The dissertation was carried out within the framework of a project funded by the state budget; 2) The dissertation was carried out within the framework of another state program (specify the name of the program); **3) The dissertation corresponds to a priority area of scientific development approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (specify the area).**	The topic of the dissertation research conducted by G.K. Sapinov corresponds to the priority areas "Rational use of natural resources, including water resources, geology, processing, new materials and technologies, safe products and structures" and "Ecology, environment, and sustainable natural resource management." The work is aimed at addressing the challenges of enhancing safety and efficiency in mineral resource extraction under complex geomechanical conditions, which is fully aligned with the national agenda for the sustainable development of the mining industry.
2.	Scientific significance	The work makes a substantial **contribution** to science, and its significance is well articulated	The dissertation by G.K. Sapinov represents a significant and comprehensive scientific study aimed at improving the accuracy of seismic source localization in underground mining environments. The research addresses an important and underexplored aspect — the impact of changing rock mass properties on wavefield parameters. The integration of

			laboratory experiments, dynamic numerical modeling, and machine learning algorithms enables the development of an innovative approach to constructing adaptive velocity models used in seismic monitoring systems. Thus, the dissertation makes a valuable contribution to advancing the scientific foundations of rock mass monitoring and rockburst hazard mitigation, as well as to the digitalization of geomechanical observation systems.
3.	Principle of independence	Level of independence: **1) High;** 2) Medium; 3) Low; 4) No independence.	The personal contribution of the PhD candidate lies in formulating the aim and objectives of the research, developing and adapting laboratory methodologies, as well as constructing numerical models. The author carried out substantial experimental work on the preparation and testing of a large number of samples with varying parameters of voids and fillers, which allowed obtaining unique data on the impact of rock mass degradation on seismic wave velocity. The obtained results are substantiated both scientifically and practically, and they are presented in the form of publications in international peer-reviewed journals and conference abstracts. The author's level of independence is assessed as high.
4.	Justification of the dissertation's relevance	4.1 Justification of the relevance of the dissertation: **1) Justified;** 2) Partially justified; 3) Not justified.	The relevance of the dissertation research is unquestionable. Under the conditions of active development of deep underground mines, the problem of accurate localization of seismic event sources acquires key importance for ensuring mining safety and preventing rockbursts. Existing forecasting methods are limited to the use of static velocity models, which do not reflect the constantly changing geomechanical conditions. The development of an adaptive approach based on laboratory data, numerical modeling, and machine learning meets the current challenges of the mining industry and is in line with global trends in the digitalization of monitoring systems in mining.

4.2 The content of the dissertation reflects the topic of the dissertation: **1) Reflects;** 2) Partially reflects; 3) Does not reflect.	The content of the dissertation fully corresponds to the declared topic and covers all aspects related to the localization of seismic events under underground mining conditions. The work consistently presents theoretical foundations, experimental research, numerical modeling, and the application of machine learning methods. All chapters are logically connected and directed toward achieving the set goals. The results obtained are directly related to solving the key scientific task — developing an approach for real-time prediction of seismic wave velocities to enhance the accuracy of microseismic monitoring.
4.3 The aim and objectives correspond to the topic of the dissertation: **1) Correspond;** 2) Partially correspond; 3) Do not correspond.	The aim and objectives formulated in the dissertation fully correspond to the topic of the scientific study.They are aimed at solving the urgent problem — improving the accuracy of seismic event localization in underground conditions by accounting for changes in the velocity characteristics of the rock mass in real time. The objectives logically follow from the stated aim and cover laboratory studies, numerical modeling, and the application of artificial intelligence. Their implementation is traced in the corresponding chapters of the dissertation and supported by concrete results.
4.4 All sections and propositions of the dissertation are logically interconnected: **1) Fully interconnected;** 2) Partially interconnected; 3) Not interconnected.	The dissertation demonstrates internal unity: all its sections are logically interconnected. The stages of scientific research are revealed sequentially — from theoretical justification of the problem to practical implementation of the methods and analysis of results. Theoretical provisions are organically supported by experimental and modeling data, and the application of machine learning methods serves as a logical continuation of the obtained results. Such a structure gives the work integrity and a clear focus on achieving the stated aim.

		4.5 The new solutions (principles, methods) proposed by the author are substantiated and evaluated in comparison with known solutions: **1) Critical analysis is present;** 2) Partial analysis 3) The analysis consists of quotations from other authors rather than original opinions.	The PhD candidate, based on their own experimental and modeling data, as well as modern scientific publications, presents a reasoned analysis of the applied solutions. Each section of the dissertation consistently compares the proposed approach with existing methods for localizing seismic events. The necessity of transitioning from static models to adaptive approaches is substantiated, and the advantages of using machine learning over traditional calculation algorithms are demonstrated.Thus, the dissertation provides a full-fledged critical analysis of known solutions and a convincing justification of the novelty of the proposed methodology.
5.	Principle of Scientific Novelty	5.1 Scientific results and propositions **1) New;** 2) Partially new (25–75% are new); 3) Not new (less than 25% are new).	The author, based on the analysis of modern scientific literature, results of laboratory experiments, and numerical modeling, has obtained new scientific results aimed at solving the problem of accurate localization of seismic event sources under underground mining conditions. For the first time, a method is proposed for real-time prediction of seismic wave velocities taking into account rock mass degradation and the presence of voids. The possibility of integrating machine learning methods into microseismic monitoring algorithms is also substantiated. The obtained propositions are scientifically novel and represent a contribution to the development of digital safety technologies in the mining industry.
		5.2 Are the conclusions of the dissertation new? **1) New;** 2) Partially new (25–75% are new); 3) Not new (less than 25% are new).	The dissertation contains fundamentally new conclusions obtained as a result of a comprehensive approach, including laboratory modeling of mining conditions, dynamic modeling in FLAC3D, and the use of modern machine learning algorithms. These conclusions concern the influence of rock mass degradation on seismic wave propagation parameters and the justification for the need for an adaptive approach in monitoring systems. The novelty and scientific significance of the conclusions are confirmed by publications in journals indexed

			in international databases.
		5.3 Are the technical, technological, economic, or managerial solutions new and substantiated? **1) New;** 2) Partially new (25–75% are new); 3) Not new (less than 25% are new).	The technical and technological solutions developed in the dissertation are new and substantiated. For the first time, a method for adaptive selection of a velocity model for microseismic monitoring systems is proposed, based on laboratory data, numerical modeling, and machine learning-based forecasting. The presented approach accounts for dynamic changes in rock mass properties, thereby improving the accuracy of determining seismic event coordinates. The novelty and applicability of the solutions are confirmed by publications, presentations at international scientific conferences, and high interest from industry practitioners.
6.	Validity of the Main Conclusions	All the main conclusions are / are not based on scientifically significant evidence or are sufficiently well substantiated (for qualitative research and disciplines in the arts and humanities).	The main conclusions of the dissertation are based on reliable scientific data obtained through laboratory studies, numerical modeling, and analysis using machine learning methods. The methodological foundation of the study has been thoroughly developed, and the results obtained are consistently substantiated and analyzed. The credibility of the conclusions is confirmed by publications in ranked scientific journals and participation in international conferences.
7.	Key Provisions Submitted for Defense	The following questions must be answered for each provision individually: 7.1 7.1 Is the provision proven? **1) Proven;** 2) Rather proven; 3) Rather not proven; 4) Not proven. 7.2 Is the provision trivial? **1) Yes;**	Three provisions were submitted for defense. Responses regarding Provision 1: 7.1 **Proven** 7.2 Not trivial 7.3 New 7.4 Broad applicability 7.5 Yes Responses regarding Provision 2: 7.1 **Proven** 7.2 Not trivial 7.3 New

		2) No. 7.3 Is the provision new? **1) Yes;** 2) No. 7.4 Level of applicability: 1) Narrow; 2) Medium; **3) Broad.** 7.5 Is the provision proven in a publication? **1) Yes;** 2) No.	7.4 Broad applicability 7.5 Yes Responses regarding Provision 3: 7.1 **Proven** 7.2 Not trivial 7.3 New 7.4 Medium applicability 7.5 Yes
8.	Principle of Reliability Is the chosen methodology substantiated or sufficiently described?	8.1 Reliability of sources and information provided **1) Yes;** 2) No.	The choice of methodology in the dissertation is substantiated and clearly aligned with the aims and objectives of the research. The author applied a comprehensive approach, including laboratory modeling, dynamic numerical modeling using FLAC3D, and machine learning algorithms. Each stage of the methodology is described in detail and logically integrated into the structure of the study. This approach ensures the reproducibility of results and demonstrates a high level of methodological rigor.
		8.2 Were the results obtained using modern scientific research methods and data processing and interpretation techniques using computer technologies? **1) Yes;** 2) No.	All theoretical provisions, models, and identified relationships in the dissertation are confirmed by the results of experimental studies. The author conducted a series of laboratory tests simulating changes in the rock mass during underground mining, which empirically confirmed the influence of rock mass structure and types of backfill imitation on seismic wave propagation velocity. These data were additionally verified by numerical modeling, reinforcing the scientific validity of the conclusions.

8.3 Are theoretical conclusions, models, identified relationships, and patterns proven and confirmed by experimental studies?	All theoretical provisions, models, and identified relationships presented in the dissertation are confirmed by carefully planned and consistently conducted experimental studies. The author implemented a unique laboratory setup that simulated various stages of rock mass degradation with variable parameters: voids, degree of fracturing, and different types of fillers. The obtained data allowed for quantitative assessment of the influence of these factors on seismic wave velocity. The theoretical models proposed based on these observations were then verified numerically using FLAC3D software, reproducing similar dependencies under controlled conditions. This combination of laboratory verification and numerical modeling provides a high level of scientific reliability for all conclusions made. Moreover, the comprehensive nature of the research allows one to conclude that the obtained dependencies are not random or site-specific, but applicable across a wide range of underground mining conditions.
1) Yes; 2) No.	
8.4 Are important statements confirmed / partially confirmed / not confirmed by references to up-to-date and credible scientific literature?	The most important propositions of the dissertation are substantiated by references to modern scientific literature, confirming the high level of informational depth and relevance of the study. The reference list includes authoritative sources from Scopus and Web of Science databases, as well as specialized publications in geomechanics, seismology, and mining engineering. The cited works reflect the latest advancements in microseismic monitoring and rockburst prediction methods, allowing the dissertation to be viewed as scientifically integrated into the global research context.
8.5 Are the used sources of literature sufficient / insufficient for a literature review?	The sources of literature used in the dissertation are sufficient for a comprehensive literature review. The author cites scientific publications, including articles from international peer-reviewed journals indexed in Web of Science and Scopus. The review includes both classical works in seismic monitoring and

			geomechanics and modern studies reflecting current scientific approaches and technological solutions.
9	Principle of Practical Value	9.1 Does the dissertation have theoretical significance? **1) Yes;** 2) No.	The dissertation has pronounced theoretical significance, as it forms a scientifically grounded approach to the localization of seismic events in dynamically changing underground environments. The developed concept of adaptive selection of seismic wave velocity models complements and advances wave propagation theory in heterogeneous media. The revealed dependencies between geomechanical parameters of the rock mass and seismic wave velocity contribute to the theoretical foundation of mining geomechanics and microseismic monitoring of rock masses.
		9.2 Does the dissertation have practical significance, and is there a high probability of applying the obtained results in practice? **1) Yes;** 2) No.	The dissertation has high practical potential. The obtained results can be directly implemented into seismic monitoring systems of underground mines to improve the accuracy of real-time seismic event localization. The developed methodology of adaptive calculation of seismic velocities allows for rapid response to changes in the rock mass, thereby enhancing mine safety and reducing the risk of emergency situations. The practical applicability is confirmed by interest in the results from industrial enterprises and the potential for integration into existing monitoring systems.
		9.3 Are the practical proposals new? **1) Completely new;** 2) Partially new (25–75% are new): 3) Not new (less than 25% are new).	The proposals formulated in the dissertation are entirely new. The author developed an original methodology for adaptively determining seismic wave velocities in underground conditions, which had not previously been used in a comprehensive combination with laboratory modeling, numerical analysis, and machine learning. These practical solutions are recommended for implementation in industrial technologies, confirming their originality and applied relevance.

10.	Quality of Writing and Formatting	Academic writing quality 1) **High;** 2) Medium: 3) Below average: 4) Low.	The academic writing quality of the dissertation is high. The text is grammatically correct, written in a scientific style, with logical structure and clear presentation of the material. All sections of the dissertation are interconnected and consistently reveal the research topic. The formatting of the work meets the established requirements for dissertations, and the reference list is thoroughly compiled and includes up-to-date sources.
11.	Remarks on the dissertation	no	
12	The scientific level of the doctoral candidate's articles on the research topic (In the case of a thesis defended in the form of a series of articles, the official reviewers are to comment on the scientific level of each article	The doctoral candidate's publications are fully consistent with the subject of the dissertation and directly reflect the scope and focus of the conducted research.	

	by the doctoral candidate on the research topic.)	
13	Decision of the Official Reviewer (in accordance with Clause 28 of the present Standard Regulations)	The dissertation of Gylym Kairatovich Sapinov titled "A study on the real-time spatial localization of seismic events in underground mines", completed under the educational program 8D07202 – Mining Engineering, is an original and independent scientific research project of current relevance. The work is based on a thorough methodological framework and includes theoretical, experimental, and computational components. The dissertation demonstrates scientific novelty, practical significance, and a high level of academic quality. In accordance with the requirements of the Committee for Quality Assurance in Education and Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan, I recommend awarding Gylym Kairatovich Sapinov the degree of Doctor of Philosophy (PhD) in the educational program 8D07202 – Mining Engineering.

Reviewer
PhD, Associate Professor
of the Department "Mining, Construction and Ecology"
NJSC "Sh. Ualikhanov Kokshetau University" **Kaumetova Dinara Suyundikovna**

Ш.Уәлиханов атындағы Көкшетау университетінің коммерциялық емес акционерлік қоғамы
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