

REVIEW

of the official opponent on the dissertation of
SHUKURLU ELNUR

on the topic «Scientific substantiation of the technology of explosive demand of gold-bearing quartzite», submitted for the degree of Doctor of Philosophy
in the field of knowledge 18 Production and Technologies
specialty 184 Mining

Relevance of the dissertation topic

The dissertation presents a new solution to a pressing scientific and applied problem, namely the scientific substantiation of an improved technology for the explosive fragmentation of gold-bearing quartzites based on an enhanced composition of foam stemming, using mathematical modelling and geographic information systems to optimise the directions of mining operations.

Gold mining in Azerbaijan is a comparatively young branch of industry, yet it is already marked by growing output, an expanding mineral resource base and the opening of new open pits in gold-bearing quartzite-containing rocks. Under such conditions modern geoinformation technologies acquire particular importance, since they make it possible to substantiate the direction of mining development, refine reserve estimates and optimise the volumes of rock mass extraction. At the same time, the large volumes of gold-bearing rock to be broken call for higher efficiency of drilling-and-blasting operations while maintaining the required particle-size distribution of the blasted rock, because fragmentation quality directly determines loading, haulage and subsequent crushing and, ultimately, overall production costs.

Considering the possible consequences of blasting in open pits, one of the principal technological tasks in the development of gold-bearing quartzites is to obtain the required fragmentation of the rock mass while keeping the adverse environmental impact to a minimum. Where blasting cannot be avoided, modern and scientifically substantiated organisational and technological measures are needed to achieve the required fragmentation quality and to reduce the environmental burden. In this dissertation the task is solved by selecting an effective stemming material and by mathematical modelling aimed at evaluating the ejection time of the stemming from the borehole charge. The research carried out and the scientific and practical results obtained are therefore undoubtedly relevant.

Validity, reliability and novelty of the scientific results

The principal propositions, conclusions and recommendations of the dissertation are well founded, as they rest on a comprehensive analysis of current achievements in the field and on a consistently completed set of research tasks:

- to study and analyse the mechanism of gold-bearing quartzite fragmentation;
- to investigate the influence of the stemming material on the formation of toxic post-blast gases and to perform numerical modelling of the effect of the stemming material on the retention of explosive energy and on the efficiency of rock fragmentation during open-pit blasting in gold-bearing quartzites;
- to improve the methodology for assessing the particle-size distribution of blasted rock mass over large volumes of rock;

– to establish the influence of the stemming material on the resulting particle-size distribution of the blasted rock mass and, by combining geodetic monitoring with GIS technologies, to develop a methodology for analysing a gold ore deposit and substantiating promising directions of mining operations.

The scientific novelty of the results obtained is as follows:

– a digital geospatial model of the Tulallar deposit has been created in the Surfer 3D software package which, on the basis of the geospatial analysis of ore bodies and mineral concentrations, makes it possible to select optimal directions for the development of mining operations;

– polynomial relationships describing the variation over time in the pressure of the detonation products of a borehole charge have been established for sand and for foam stemming;

– the influence of the stemming material on the distribution of harmful post-blast gases within the working zones of the open pit has been revealed and verified in practice;

– on the basis of numerical modelling, new quantitative and qualitative relationships have been obtained between the ejection time of stemming made of different materials, the character of the stress-strain state of the rock mass and the degree of gold-bearing quartzite fragmentation; these relationships are confirmed by field data and made it possible to reduce the yield of oversized material from 9% to 5%.

The practical value of the results consists in the development of a digital geospatial model of the Tulallar gold-bearing quartzite deposit, which made it possible to determine the optimal direction for the development of mining operations, and in the improvement of the methodology for assessing the particle-size distribution of blasted rock mass over large volumes of rock.

Thus, the scientific task set in the dissertation – the improvement of the technology of explosive fragmentation of gold-bearing quartzites through the selection of an effective stemming material in order to raise fragmentation quality – has been solved, and the candidate has fully mastered the methodology of scientific work.

Content of the dissertation, its completeness and compliance with the principles of academic integrity

In terms of its content, the dissertation of SHUKURLU ELNUR fully complies with the Higher Education Standard for specialty 184 Mining and with the research directions of the educational programme “Geoengineering”.

The dissertation is a completed piece of scientific work and demonstrates the personal contribution of the candidate to the research field defined by the topic «Scientific substantiation of the technology of explosive demand of gold-bearing quartzite».

An examination of the similarity report obtained from the text-matching check leads to the conclusion that the dissertation of SHUKURLU ELNUR is the result of the candidate's own research and contains no elements of falsification, compilation, fabrication, plagiarism or unattributed borrowing. The ideas, results and texts of other authors are properly referenced to the relevant sources.

Language and style of presentation of the results

The dissertation is written in English, and the material is presented consistently and logically. The results are set out in an accessible form, clearly and comprehensibly, and the main propositions are properly argued. The text is written in a scientific and technical style, is technically correct and uses conventional mining terminology.

The dissertation consists of an introduction, four chapters, conclusions, a list of references and one appendix. The main body occupies 141 pages of printed text; the total length of the dissertation is 151 pages.

The introduction substantiates the relevance of the study, defines its aim and objectives, the scientific novelty and the practical value, states the personal contribution of the candidate to the published works, and describes the structure and scope of the dissertation.

Chapter 1 establishes the relevance of the study in the context of the strategic importance of gold deposit development for the mining industry of Azerbaijan. The author argues that gains in efficiency and environmental safety depend on modern tools for investigating and optimising extraction, and combines geodetic monitoring, which supplies high-accuracy spatial data for surface control and deposit parameterisation, with GIS processing, which allows such data to be integrated and interpreted, three-dimensional models to be built, reserves to be estimated and the consequences of mining to be forecast. On this basis a methodology for analysing a gold deposit and assessing the prospectivity of the mining direction is developed and tested on the Tulallar deposit (Azerbaijan) using Surfer and Google Earth.

Chapter 2 addresses stemming as one of the key elements of the borehole charge structure, which governs how fully the energy of the explosion is used. It is shown that reliable stemming retains the detonation products inside the borehole during the critical stage of gas expansion, thereby raising the initial pressure and prolonging the action of the explosion gases on the rock mass, which improves crack formation and fragmentation and reduces unproductive energy losses. Stemming is also shown to prevent premature gas escape, which would otherwise lead to incomplete detonation, more toxic post-blast gases, uncontrolled flyrock from the collar zone and a stronger air blast wave, so that it must be regarded as a factor of safety and environmental performance and not only of fragmentation efficiency. The chapter demonstrates that stemming performance depends on its mechanical properties, structure and geometry rather than on its length alone, and analyses the successive stages of its behaviour during blasting – shock compression, decompression, free movement and ejection – which together determine the sealing time of the borehole. Particular attention is paid to the environmental aspect: the choice of stemming material affects both the particle-size distribution of the blasted rock and the level of dust-and-gas emissions during mass blasting. Foam stemming, including compositions with a 5% chalk additive, is identified as a promising solution, since it combines longer pressure retention with a reduced spread of the dust-and-gas cloud and improved muckpile characteristics.

Chapter 3 presents a numerical model of explosive loading in a gold-bearing quartzite massif implemented in the ANSYS Explicit Dynamics software package. The modelling shows that the decisive factor of fragmentation efficiency is not the peak pressure but the retention time of the detonation products inside the borehole: for both

variants of stemming the maximum pressure is of similar magnitude, whereas the subsequent decay differs markedly, being much faster for sand stemming, which indicates earlier gas escape and the loss of part of the explosion energy. An important result of the chapter is the polynomial approximation of the pressure-time curves for the two types of stemming, which made it possible to move from a qualitative comparison to a quantitative assessment of the energy effect of the explosion and to determine the mean pressure, the mean force exerted by the detonation products on the stemming and the work performed along the ejection path. The calculations show that with foam stemming the mean force is approximately 41% higher than with sand stemming, that is, a considerably larger share of the explosion energy is directed towards fragmentation of the rock mass. The analysis of the stress state confirms this: whereas with sand stemming the effect is concentrated mainly along the borehole axis, foam stemming produces a wider and more uniform radial propagation of the affected zone and a larger effective area of stress distribution, which creates better conditions for uniform crack development.

Chapter 4 summarises the theoretical and applied aspects of controlling fragmentation quality in open-pit conditions. It is shown that fragmentation quality is determined by the combined influence of geological and structural factors – the physical and mechanical properties of the rocks, fracturing, blockiness and layering – together with bench geometry, drilling parameters, charge design, initiation schemes and unloading conditions; because of this multifactorial nature, purely theoretical prediction without account of the actual heterogeneity of the rock mass and without verification by industrial or field blasts is of limited value, which justifies combining calculation methods with systematic monitoring of actual blasting results. The requirements for fragmentation quality are shown to follow from the parameters of the mining, haulage and crushing-and-screening equipment, the main criteria being the yield of oversized fractions, the mean fragment size and the uniformity of the particle-size distribution. Field studies of foam stemming as an alternative to conventional sand stemming showed a clear improvement: the yield of oversized fractions fell to 5% against 9% with sand stemming, that is, by 4 percentage points, which confirms the higher technological efficiency of the proposed solution. To ensure the objectivity of the comparison, digital photo analysis of the particle-size distribution using specialised software was applied; unlike visual assessment or manual measurement, it yields quantitative fragmentation characteristics promptly, allows the sample to be extended by analysing multiple photographs, is suitable for field conditions without interrupting production, and provides a statistical basis for the further optimisation of drilling-and-blasting parameters.

Each chapter is followed by its own conclusions, and the general conclusions are presented at the end of the main body. The appendix contains the certificate of implementation. The chapters of the dissertation are logically interconnected.

The dissertation is formatted in accordance with the requirements of Order No. 40 of the Ministry of Education and Science of Ukraine of 12 January 2017 “On approval of the requirements for the formatting of a dissertation”.

Dissemination of the results of the dissertation

The scientific results of the dissertation are presented in 10 publications of the candidate, including 7 papers in journals included, as of the date of publication, in the list of professional scientific publications of Ukraine. The results were also presented at 3 scientific conferences.

The candidate's publications are of a sufficiently high scientific level, and no violations of the principles of academic integrity have been found. The main results of the study reflecting the personal contribution of the candidate are fully covered in the chapters of the dissertation. Thus, the scientific results described in the dissertation are fully reflected in the candidate's publications.

Shortcomings and comments on the dissertation

1. 1. In Section 1.2 the digital elevation model is built from elevations taken from Google Earth Pro and converted with the GPS Visualizer tool, whereas the work declares the use of high-accuracy geodetic monitoring. No accuracy assessment of these elevations and no comparison with the fourth-order geodetic network points listed in Table 1.1 are given. It would be appropriate to state the error of the terrain model and to justify that it is sufficient for the tasks addressed.

2. Kriging is selected for interpolation as the most scientifically substantiated method, yet the work presents neither the variogram model and its parameters (nugget, sill, range), nor an anisotropy assessment, nor cross-validation results or kriging variance. Moreover, the conclusions to Chapter 1 refer to the use of several interpolation methods, although no comparison of these methods appears in the text.

3. The isosurface of the economic ore body is constructed for a cut-off grade of 2.5 g/t, which is adopted without economic justification. The modelling results are not accompanied by quantitative figures — the volume and tonnage of ore, the average grade and the resource category within the identified south-western zone — so the conclusion that this direction of mining is the most promising remains largely qualitative.

4. Chapter 1 and Chapters 2–4 are only weakly connected methodologically: the results of the geospatial model are not used as input data for the design of drilling-and-blasting operations, in particular for zoning the drilling pattern or the charge parameters according to grade and fracturing. It would be appropriate to show how the digital model of the deposit influences the choice of drilling-and-blasting parameters.

5. The limiting size of oversized material is stated inconsistently: at the beginning of Chapter 4 it is no more than 60 cm, in Section 4.1 no more than 70 cm, while in Section 4.2 fractions larger than 60 mm are classified as oversized. In addition, it is stated that the average fragment size and the uniformity index of the distribution were recorded from the photo analysis, yet their numerical values do not appear in the text — only the percentage of oversized material is given.

The comments made above are not of a decisive nature; they do not diminish the overall scientific novelty and practical value of the results obtained and do not affect the positive assessment of the dissertation.

Conclusion on the dissertation

In my opinion, the dissertation of SHUKURLU ELNUR, candidate for the degree of Doctor of Philosophy, on the topic «Scientific substantiation of the technology of explosive demand of gold-bearing quartzite» has been carried out at a high scientific level, does not violate the principles of academic integrity and constitutes a completed piece of research, the body of theoretical and practical results of which solves a scientific task of substantial importance for the field of knowledge 18 Production and Technologies. In terms of its relevance, practical value and scientific novelty, the dissertation fully meets the requirements of the current legislation of Ukraine set out in paragraphs 6–9 of the “Procedure for awarding the degree of Doctor of Philosophy and for revoking the decision of a one-time specialised academic council of a higher education institution or research institution on awarding the degree of Doctor of Philosophy”, approved by Resolution No. 44 of the Cabinet of Ministers of Ukraine of 12 January 2022.

The candidate, SHUKURLU ELNUR, deserves to be awarded the degree of Doctor of Philosophy in the field of knowledge 18 Production and Technologies, specialty 184 Mining.

Official opponent:

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