Comprehensive Utilization of Multicomponent Mineral Resources of the Arctic: Challenges and Solutions

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Abstract. The variety of mineral resources, complex multicomponent composition of many of them, various technological methods for comprehensive processing at different production stages, as well as the instability of competitive market environment, cause the multivariate functioning and development of the system of mineral resources use. The main scientific problems of evaluating the economic feasibility of extracting valuable components in the combined processing of multicomponent ores and the responsibility of subsoil users for the full use of Arctic resources are considered. The special relevance of rational use of mineral resources taking into account specific Arctic conditions, including increased production costs, is noted. Scientifically based principles, tasks and methodological approaches to determining the economic efficiency of integrated multi-productive use of mineral resources are proposed. For successful large-scale realization of the benefits of integrated development and use of mineral resources, the need for further scientific research, as well as the formation of a special State program to solve the problem of integrated use of the Arctic subsoil, is shown.

1. Introduction

Comprehensive processing of extracted mineral resources is the most cardinal and efficient direction of resource saving and greening of subsoil use. When studying the Khibiny apatite-nepheline ores, Academician A.E. Fersman in 1929 first drew attention to the “possibility of using some side components of apatite - fluorine, strontium and rare earths” [1], as well as nepheline and titanium-containing minerals. In 1932, at a conference of the USSR State Planning Commission on allocation of the country's productive forces A.E. Fersman first formulated the concept and introduced the notion and terminology of integrated use of mineral raw materials into scientific and industrial circulation.

In the early period of exploration of the Khibiny deposits until 1972, issues related to technological and economic evaluation of apatite-nepheline ores, as well as multicomponent ores in general as complex mineral raw materials were not considered, geological exploration did not set the task of studying them in regard to the whole range of useful components, therefore, reserves of associated components were not approved and were not taken into account by the state balance.

Thus, the forty-year period from 1932 to 1972 can be described as the initial research period of the study of comprehensive utilization of mineral raw materials. The study of these problems was carried out by scientists on an initiative basis. These fundamental works were not covered by state scientific and technical plans.
Nevertheless, at a number of mining enterprises significant progress was achieved in the development and practical implementation of the technology of combined processing of multicomponent mineral raw materials to produce collective concentrates and intermediate products with their subsequent chemical and metallurgical processing to produce finished products. Enterprises expanded the range of recoverable valuable components.

The greatest achievements in this direction were obtained at non-ferrous metallurgy enterprises, especially in the lead-zinc sub-industry, in which up to 17 valuable products were extracted from sulfide polymetallic ores. An important incentive was that the recoverable non-ferrous metals corresponded to the main industry profile and the responsible for them Ministry of Non-Ferrous Metallurgy. Other ministries in charge of mining enterprises with a complex composition of mineral raw materials were interested in producing only components that correspond to the industry profile.

Only in 1972 in the Decree of the Supreme Council of the USSR “On Measures to Further Improve Nature Conservation and the Rational Use of Natural Resources”, and “Legislation of the USSR and Union Republics on Subsoil” proclaimed that the best integrated use of natural resources is the most important state objective. Thus, 1972 can be considered the beginning of the development of comprehensive utilization of multicomponent raw materials in the USSR as an indispensable element of the state scientific, technical and industrial policies.

The purposeful calculation of the quantity of associated components in the contours of industrial reserves of multicomponent ores, and the registration with the State Accounting became mandatory after the approval in 1974 by the State Reserves Committee of the USSR of “The temporary requirements for calculating reserves of associated minerals and components in ores and other types of mineral raw materials”. [2]

2. Principles and objectives of developing comprehensive utilization of minerals

In 1974, the development of the integrated use of multicomponent ores became an integral part of state policy and responsibility for exploration and subsoil use.

Since the economic feasibility of extracting valuable components was determined on the basis of domestic planned prices that did not correspond to world prices, as a rule, taking into account, the entire technologically feasible amount of extraction of each of the valuable components that did not coincide with the current and future demand for them, neither of the domestic, nor the global economy. The traditional methodology for assessing the economic efficiency of extracting each of the valuable components was used, which did not reflect and did not take into account the specific features of complex multi-product industries. In [3], the fallacy of this technique was proved, underestimating significantly the value of industrial reserves of multicomponent mineral raw materials and each of the valuable components in them, as well as the economic efficiency of developing deposits of multicomponent ores.

Only since 2007, Russia began to carry out comprehensive utilization of minerals in the framework of the state policy of subsoil use. Although some elements of the methodology for assessing the efficiency of extraction of each of the associated valuable components in the combined processing of multicomponent mineral raw materials are still traditional, unchanged, not reflecting the specific features of complex multi-product industries, despite their proven fallacy [3].

According to the authors of the paper late 2000s should be considered the beginning of the third stage of development of comprehensive utilization of mineral raw materials in Russia. Until now, a characteristic feature and the main contradiction is, on the one hand, the completion of processing and the official approval of normative and methodological documentation for the study and evaluation of the economic efficiency of comprehensive utilization of mineral resources using market principles and, on the other hand, in cash was formed on the principles of the Soviet planned economy.

This contradiction is inherent in almost all modern mining enterprises exploiting deposits of multicomponent ores, most of them are forced to annually develop feasibility studies to write off the listed reserves of those “associated” components from the state’s balance sheet, the extraction of which was considered expedient and cost-efficient in the planned economy, but not cost-efficient
extracted under the modern market realities for a variety of reasons. The recovery of such valuable components is fundamentally possible and actually carried out only at the final chemical and metallurgical processes. However, the responsibility for the level and completeness of comprehensive utilization of all valuable components of the industrial reserves of multicomponent ores of exploited deposits is traditionally assigned to the subsoil user, which is, in most cases, a mining and processing enterprise.

Recently, at various levels of research and management, issues of increasing the material liability of subsoil users for comprehensive utilization of industrial reserves of exploited deposits in accordance with licensing agreements have been increasingly discussed. The practical implementation of this measure in subsoil use in the presence of the contradictions noted above can put many mining and processing enterprises exploiting deposits of multicomponent ores in a difficult financial situation with the prospect of revoking the license.

In this situation, the urgency of the problem is the complete systematic interdisciplinary technical and economic revaluation of previously approved reserves of all major and associated useful components on a unified methodological basis, taking into account the totality of all factors, including the technological capability to extract them, the long-term needs of science-intensive sectors of the national economy, the situations at the domestic and global markets, etc. [3]

Moreover, periodic revaluation and re-approval of mineral reserves should be carried out on a regular basis. In this case, when recounting the industrial reserves of multicomponent ores of explored deposits, there is the possibility of a targeted priority increase in the resources of the scarcest valuable components at the global market by reducing the industrial reserves of less significant components when re-contouring ore deposits in accordance with the method described in [4, 5].

The Society of Russian Subsoil Use Experts, established on March 16, 2007, is currently developing the Russian Code of public reporting on the results of geological exploration, resources and reserves of solid minerals, taking the Australian JORC Code as the analogue [6]. The Code developed by the Society of Russian Subsoil Use Experts, as well as the JORC Code, involves an annual review of mineral resources and mineral reserves.

3. Methodology
The variety of mineral resources, complex multicomponent composition of many of them, various technological methods for comprehensive processing at different production stages, as well as the instability of competitive market environment, cause the multivariate functioning and development of the system of mineral resources use and require development of a special methodology.

Substantiation of rational options and parameters of subsoil use, including indicators characterizing the level and efficiency of comprehensive development and utilization of the totality of subsoil resources, is a difficult task.

In developing the methodology, it is necessary to provide for the need and the possibility of determining differentiated individual cost estimates of each of the used types of resources and their valuable components separately, the possible approaches to which are presented in [3]. On their basis, it becomes possible to carry out various kinds of technical and economic calculations and justified comparison of options and parameters of subsoil use, including determining an economically rational list of mineral resources to be used industrially under the specific socio-economic conditions, determining optimal parameters and the most economically efficient option for an integrated ecologically balanced and resource-saving subsoil use.

The theory and practice of quantitative assessment of the parameters of the level and efficiency of comprehensive development and utilization of subsoil resources should replenish the resources and capabilities of geoinformatics, providing an interdisciplinary approach to assessing processes and objects of the geological environment in conjunction with the processes of development of nature and society [6-9].

International authors, unlike the Russian ones, practically do not encounter the concept and terminology of comprehensive utilization of multicomponent mineral raw materials, and the problems
of combined multi-commodity use of multicomponent raw materials are considered only in terms of the distribution of total costs between manufactured products [10-12]. In practice, geostatistical methods in the form of co-kriging using correlations of component contents are applied to calculate the reserves of multicomponent ore deposits [13-16].

Moreover, in domestic and international practice, the definition of the range of useful components and their minimum content included in the calculation of industrial reserves for a particular block or field as a whole is, in most cases, decided subjectively, largely depending on the competence and preferences of the contractor, since the economic feasibility of extracting the so-called associated components according to the traditional method is not detected.

4. Conclusion
1. The high importance of rational subsoil use for economic growth, improving the efficiency and greening of the Russian economy necessitates state support, stimulation and regulation of comprehensive development and utilization of subsoil resources. First of all, on the basis of improving the economic mechanism of paid nature management, a reasonable level of payments for environmental pollution, taking nature rent, taxing the business in the mineral resource sector, etc.

2. The principles and objectives that reflect the specific features of integrated multi-product production of Arctic enterprises of mineral raw materials specialization are proposed.

3. Scientifically-based approaches are proposed for determining differentiated individual cost estimates of each of the used types of resources and their valuable components separately for determining the economic efficiency of integrated multi-product use of mineral resources of the Arctic.

4. For successful large-scale implementation of the benefits of comprehensive development and utilization of mineral resources, it is advisable to work out on a fundamental basis the State program for assessing, studying, developing and maintaining the country's mineral resources base and other subsoil resources for 30-50 years.

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