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Some environmental aspects of mineral resources extraction from uranium albitites deposits in Ukraine

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This study analyzes the potential for the rational utilization of uranium deposits of the albitite formation within the Inhul Megablock of the Ukrainian Shield, taking into account the complex nature of the mineralization. Valuable components have accumulated not only in the commercial-grade ores but also in the remaining mineral mass destined for waste dumps, which pose an environmental threat due to natural weathering. The rational utilization of these albitite-hosted uranium and associated element deposits—including through the application of bioleaching to waste rock—could enhance their economic viability while reducing the harmful impact on the environment.

Keywords: uranium-bearing albitites, bacterial leaching, uranium, associated elements, off-balance ores

Introduction. Almost all known deposits of the albitite formation within the Inhul Megablock of the Ukrainian Shield (US) have traditionally been viewed exclusively as uranium deposits. However, in addition to uranium, these deposits contain elevated – and in some cases, commercially viable – concentrations of other metals. At the same time, both globally and in Ukraine, the feasibility of the integrated extraction of mineral resources – including from mining waste At the same time, both globally and in Ukraine, the feasibility of the integrated extraction of mineral resources – including from mining waste – is being investigated as a means to improve operational cost-efficiency and reduce environmental contamination is being investigated as a means to improve operational cost-efficiency and reduce environmental contamination (Fomin et all., 2020).

Currently, the majority of global mineral resource extraction – including uranium, thorium, and rare-earth elements (REEs) – relies on primary resources; however, interest in utilizing secondary resources is steadily growing, particularly in light of environmental protection standards and the need to conserve reserves. Although some deposit waste piles have been studied in considerable detail for these purposes, plans for their exploitation were generally abandoned quickly, primarily due to economic factors (Patel et all., 2023).

The aim of the study is to investigate the potential for the rational use and increase in raw material resources, as well as the reduction of environmental impacts from harmful waste associated with uranium deposits of the albitite formation within the Inhul Megablock of the Ukrainian Shield. The research is conducted within the framework of the National Academy of Sciences of Ukraine project titled "Scientific principles for addressing geo-environmental issues regarding the integrated development of the mineral resource for Ukraine's nuclear energy sector under current conditions."

Objects of the study. Typical examples of commercially significant uranium-bearing albitites of the Ukrainian Shield were investigated, specifically the Severynivske, Michurinske, Yuriivske, Pivnichno-Konoplianske, Vatutinske, and Novokostiantynivske deposits.

According to our research, in addition to uranium, five other elements associated with uranium mineralization – Th, V, Be, as well as Zn and Pb – approach commercial-grade concentrations in these deposits (Fomin et all., 2020). Therefore, we examine in greater detail their distribution within the ores, host rocks, and minerals of uranium deposits belonging to the albitite formation, with the aim of assessing the potential for their rational utilization and considering them as commercial ores. It is also important to note that these elements are quite mobile under hypergene conditions; consequently, their long-term storage in waste piles poses a risk of environmental contamination.

An overview of ways to enhance the profitability of albitite deposits. Increasing the profitability of these deposits involves a combination of advanced mining methods, pre-concentration, and – most importantly – the co-extraction of associated elements. To achieve

significant recovery of U, Th, and associated elements from secondary sources, chemical and biological leaching methods are employed, followed by solvent extraction or alkaline fusion (Verkhovtsev et all., 2023).

As it is well known, ore is an economic concept. Therefore, the development of methods for the economically viable extraction of uranium and associated elements is of undoubted practical interest.

Microbial leaching (or bioleaching) is an attractive alternative to traditional physical and chemical ore beneficiation methods due to reduced energy consumption and transport costs, as well as a less detrimental environmental impact. The application of bioleaching dates back to the 16th century – in sulfide copper deposits in Hungary and Germany – predating a full understanding of the process's nature.

Bioleaching technology is particularly relevant for Ukrainian uranium ores, given the medium to low uranium content in the rock. Specifically, reducing extraction costs (including the cost of chemical reagents) – particularly when processing waste rock piles – can effectively reclassify such material as ore. Bacterial leaching can be applied to ores containing iron sulfides or reduced forms of sulfur. Therefore, adding sulfur to the ore – including sub-marginal grades – can facilitate bioleaching by increasing the sulfuric acid concentration in the system, thereby enhancing metal recovery.

Sulfide sulfur is almost absent in the ore-grade rocks. Consequently, during the exploitation of albitite deposits, sulfur primarily accumulates in industrial waste. Since the ores themselves lack significant quantities of sulfides, bioleaching cannot be applied to them without the addition of sulfur. However, barren and low-grade albitites exhibit sulfur levels two to three times higher than the crustal average (Clarke value). Furthermore, the pyrite within these rocks contains elevated levels of certain metals; specifically, Co and Pb concentrations reach levels of economic interest, while Zn and U levels approach that threshold. Therefore, these rocks appear promising for the bioleaching of the aforementioned metals. It is also necessary to investigate the feasibility of adding barren and low-grade albitites to the ore-grade rocks – thereby increasing the sulfide content – and to assess the prospects of applying bioleaching to such a mixture.

Associated elements in uranium-bearing albitites.

As previously noted, five elements associated with uranium mineralization – Th, V, Be, Zn, and Pb – reach concentrations approaching commercial grade. With the exception of Be, these elements are distributed relatively evenly between ore-bearing and barren rocks; consequently, they tend to accumulate in waste piles. Under supergene conditions, these elements exhibit varying behaviors but are generally mobile, posing a potential environmental hazard.

Conclusion

Currently, the bulk of global uranium and associated element production is derived from primary resources; however, increasing attention is being paid to the use of secondary resources, particularly from the perspectives of environmental protection and the rational use of reserves. An advantage of secondary resources is that the primary costs are incurred during the initial extraction of the raw materials, meaning only the additional costs of processing need to be considered.

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