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DISTRIBUTION OF TUNGSTEN MINERALS IN THE INGICHKA ORE AND DEVELOPMENT OF A BENEFICIATION FLOWSHEET

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Abstract. The efficient utilization of tungsten-bearing mineral resources requires a detailed understanding of mineralogical characteristics and the development of effective beneficiation technologies. This study investigates the mineralogical occurrence of rare metals in the Ingichka deposit and evaluates the potential for tungsten recovery using a combination of gravity and magnetic separation methods. Mineralogical analyses revealed that tungsten occurs predominantly as hubnerite, while scheelite is present only in minor quantities. The degree of mineral liberation increased significantly after grinding, reaching 80–90% in fine particle-size fractions. Radiometric investigations showed that the ore is characterized by low contrast, making radiometric separation ineffective for preliminary concentration. Gravity concentration studies demonstrated that tungsten is mainly concentrated in high-density fractions, with the highest enrichment observed in the −0.1+0.044 mm size class. Subsequent magnetic separation improved concentrate quality and reduced tungsten losses. The results confirmed that the combined application of gravity and high-intensity magnetic separation provides an effective approach for tungsten recovery from the Ingichka ore. The proposed beneficiation strategy contributes to improving tungsten extraction efficiency and supports the rational utilization of mineral resources.

Keywords: Ingichka deposit, tungsten, hubnerite, mineralogical analysis, gravity concentration, magnetic separation, beneficiation technology.

Introduction

The sustainable supply of critical and strategic metals has become an important challenge for the global mining industry. Among these metals, tungsten occupies a special position due to its extensive use in metallurgy, aerospace engineering, electronics, defense technologies, and the production of wear-resistant materials. The increasing demand for tungsten and associated rare metals has stimulated interest in the detailed investigation of tungsten-bearing deposits and the development of efficient extraction technologies.

The efficiency of tungsten recovery is largely determined by the mineralogical characteristics of the ore, including the occurrence forms of valuable minerals, their textural relationships, grain size, and association with gangue minerals. Numerous studies have demonstrated that the mineralogical composition of an ore significantly influences the selection of beneficiation methods and the overall recovery of valuable components. Therefore, detailed mineralogical investigations are essential for optimizing technological processes and improving resource utilization.

The Ingichka deposit is one of the most important tungsten-bearing deposits in Uzbekistan and contains a variety of tungsten and rare-metal minerals. Previous geological studies have identified the presence of scheelite, wolframite-group minerals, and associated rare-metal mineralization. However, information regarding the occurrence forms, distribution characteristics, and technological behavior of these minerals remains limited. Understanding these features is necessary for improving beneficiation efficiency and reducing metal losses during processing.

The present study focuses on the investigation of the mineralogical occurrence of rare metals within the Ingichka deposit and the assessment of their influence on tungsten extraction. Particular attention is given to the identification of tungsten-bearing mineral phases, their distribution within different particle-size fractions, and the development of an effective beneficiation strategy. The obtained results provide a scientific basis for enhancing tungsten recovery and ensuring the rational utilization of mineral resources from the Ingichka deposit.

Materials and Methods

The study was conducted using tungsten-bearing ore samples collected from the Ingichka deposit, one of the major tungsten occurrences in Uzbekistan. Representative samples were selected from different ore zones to ensure reliable characterization of tungsten and associated rare-metal mineralization. The collected material was subjected to crushing, grinding, and particle-size classification prior to mineralogical and technological investigations.

Granulometric analysis was performed to determine the distribution of material among different size fractions and to identify the particle-size ranges containing the highest concentration of tungsten-bearing minerals. Mineralogical studies were carried out to establish the composition, occurrence forms, and textural relationships of valuable minerals. Particular attention was paid to scheelite and wolframite-group minerals, their grain size, degree of liberation, and association with gangue minerals. The distribution of tungsten within different size classes was also evaluated to determine the most favorable conditions for beneficiation.

Technological investigations included gravity and magnetic separation methods commonly used in tungsten beneficiation. The obtained products were analyzed to determine tungsten content, concentrate grade, recovery, and metal distribution. The efficiency of the beneficiation process was assessed using standard technological indicators, including concentrate yield (%), WO_3 content (%), tungsten recovery (%), and distribution coefficient (%). Statistical processing of the experimental data was performed to establish relationships between mineralogical characteristics and beneficiation performance, providing a basis for the development of an efficient tungsten extraction technology for the Ingichka deposit.

Results and Discussion

Mineralogical investigations revealed that tungsten is the principal valuable component of the Ingichka technogenic material. The main tungsten-bearing mineral was identified as hubnerite, whereas scheelite was present only in minor quantities. Microscopic studies showed that in the initial material only 15–20% of hubnerite grains occur in a liberated state, while the remaining particles are associated with gangue minerals. After grinding to below 0.1 mm, the liberation degree increased to 80–90%, indicating favorable conditions for subsequent beneficiation processes.

The possibility of applying radiometric separation was evaluated through contrast analysis of WO_3 and sulfur-bearing components. The calculated contrast coefficients were 0.44 for WO_3 and 0.48 for sulfur, classifying the material as low-contrast ore. A strong positive correlation between WO_3 and sulfur content was established with a correlation coefficient of 0.827. Despite this relationship, the low contrast values indicate that radiometric separation is unlikely to provide efficient upgrading of the Ingichka material, especially in fine particle-size fractions.

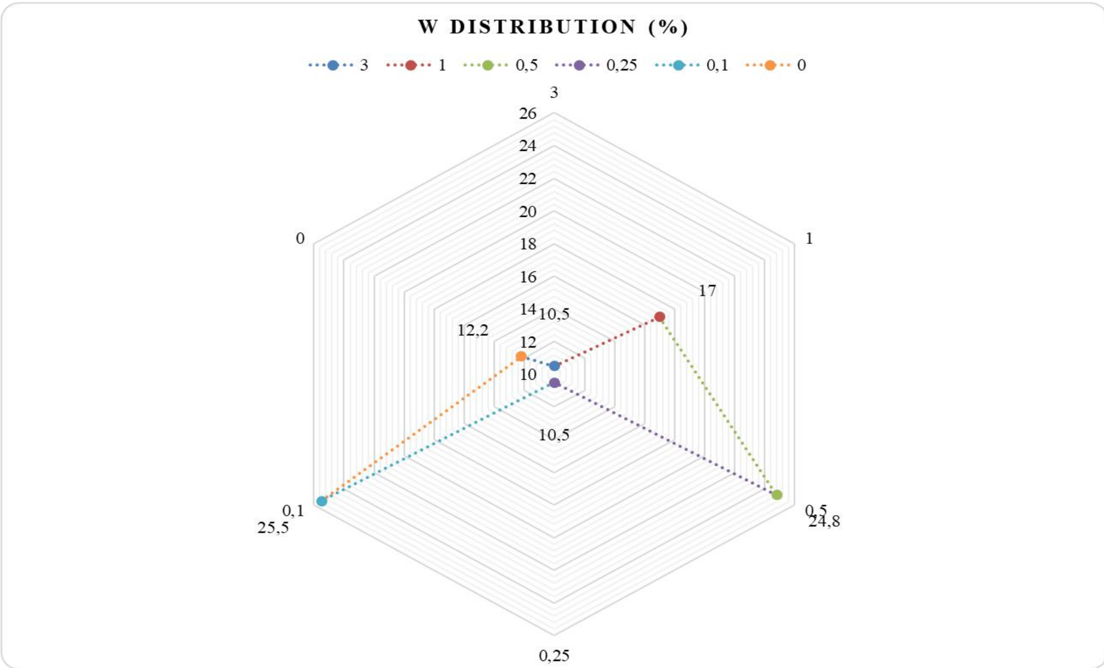

Figure 1. Relative distribution of tungsten in various size fractions of the investigated Ingichka ore sample.

Gravity concentration studies demonstrated a pronounced dependence of tungsten distribution on particle density and size. The heavy fraction (>3.6 g/cm³) contained the highest tungsten concentrations, with WO_3 content reaching 0.88% in the −0.1+0.044 mm size fraction. In contrast, the light fraction (<2.9 g/cm³), which constituted the majority of the material, contained only trace amounts of tungsten. These results confirm that tungsten minerals are predominantly concentrated in high-density fractions and can be effectively recovered by gravity methods.

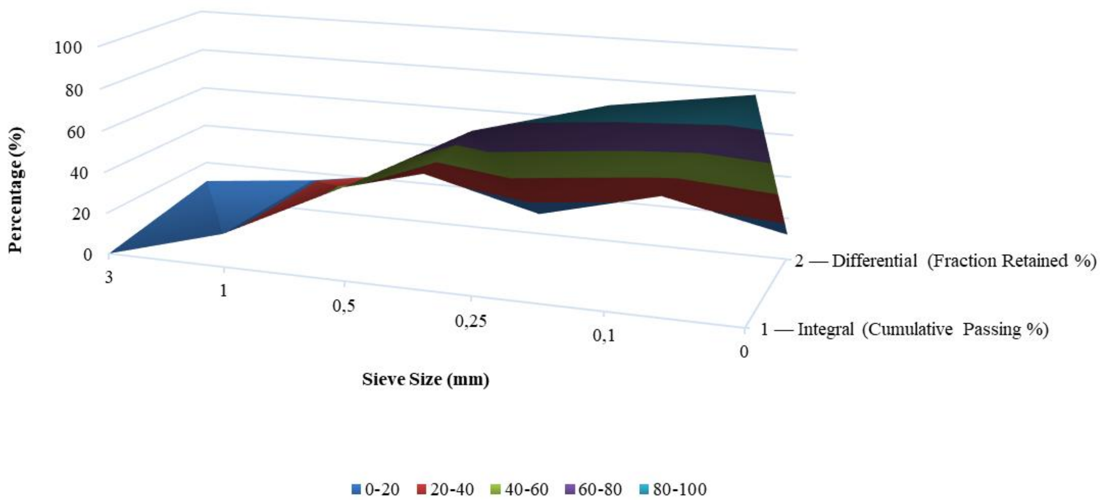

Figure 2. Granulometric distribution of the investigated ore sample, including cumulative passing and differential fraction-retained percentages across particle-size classes.

The analysis of generalized gravity washability curves further confirmed the suitability of gravity beneficiation. Among all investigated size classes, the −0.1+0.044 mm fraction exhibited the highest upgrading potential, producing a concentrate containing 1.017% WO_3 while maintaining minimal tungsten losses. The obtained results indicate that fine grinding followed by gravity concentration provides the most favorable conditions for tungsten recovery from the investigated material.

Electromagnetic fractionation of gravity concentrates showed that the non-magnetic fraction accounted for approximately 76.6% of the heavy product, whereas weakly magnetic and electromagnetic fractions represented a smaller proportion. Nevertheless, tungsten enrichment was concentrated mainly in the weakly magnetic products, reflecting the magnetic properties of hubnerite. The highest tungsten grade was recorded in the weakly magnetic concentrate, where WO_3 content reached approximately 40% with a recovery of 70.3%. Additional grinding and reprocessing of the non-magnetic product resulted in a secondary concentrate containing 24% WO_3 and recovering an additional 25.2% of tungsten.

The obtained results demonstrate that gravity concentration combined with high-intensity magnetic separation represents the most effective approach for processing the Ingichka technogenic material. The proposed beneficiation route ensures efficient recovery of tungsten-bearing minerals, minimizes metal losses, and improves concentrate quality. These findings provide a scientific basis for the industrial utilization of the Ingichka technogenic resources and contribute to the sustainable recovery of tungsten from mining wastes.

Conclusion

The conducted mineralogical and technological investigations demonstrated that tungsten is the principal valuable component of the Ingichka ore, occurring predominantly in the form of hubnerite, while scheelite is present only in minor quantities. The study revealed that the degree of mineral liberation increases significantly with decreasing particle size, reaching 80–90% in the −0.1 mm fraction. Analysis of ore contrast characteristics showed that the investigated material belongs to the low-contrast category, indicating that radiometric separation is not an effective method for tungsten recovery from the Ingichka deposit.

The results of gravity and magnetic beneficiation confirmed that tungsten minerals are mainly concentrated in high-density and weakly magnetic fractions. The highest tungsten enrichment was achieved in the −0.1+0.044 mm size fraction, where the recovery and concentrate quality were significantly improved. The combined application of gravity concentration and high-intensity magnetic separation proved to be the most efficient beneficiation approach, ensuring enhanced tungsten recovery and reduced metal losses. The obtained results provide a scientific and technological basis for the development of an effective processing scheme for the Ingichka deposit and contribute to the rational utilization of tungsten-bearing mineral resources.

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