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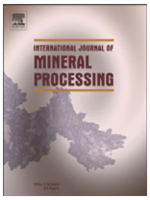

Niobium oxide mineral flotation: A review of relevant literature and the current state of industrial operations

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ABSTRACT

At present, nearly 99% of the world's niobium concentrate is produced by the Catalão and Araxá mines in Brazil and the Niobec mine (St. Honoré) in Canada. In total, Araxá produces approximately 150,000 tonnes of niobium per annum (tpa), while Niobec and Catalão produce 5300 tpa and 4500 tpa, respectively. Niobium recovery at all three operations is near or above 60%, with final concentrates grading 55–65% Nb_2O_5. The geographic diversification of niobium supply depends on the development of operable beneficiation flowsheets for the upgrading of known niobium deposits worldwide. The beneficiation of niobium oxide ores is predominantly carried out by froth flotation, which generally involves niobium mineral flotation at acid pH using a cationic amine collector. In the case of the Niobec and Catalão mines, there is a reverse gangue mineral flotation step prior to niobium flotation. The main issues associated with currently employed flowsheets are loss of niobium to the gangue mineral concentrate and the slime fraction. Further, there are a number of gaps in understanding with regard to the mechanisms by which amine collectors and auxiliary reagents interact with one another and with niobium minerals. To date, several alternate flotation reagents such as hydroxamates, sulfosuccinates, phosphorous compounds, and hydroxyquinolines have been examined with the aim of improving niobium recovery and concentrate grade in the flotation process. Notably, alkyl hydroxamates were identified in the 1960s as a potential collector for direct niobium mineral flotation eliminating the need to first deslime the ore. Subsequent testwork performed on Niobec ore using this collector has corroborated its effectiveness without desliming. However, due to increased reagent addition requirements when using hydroxamate collectors, the cost benefit of this reagent scheme compared to amine collectors is unclear. Overall, greater understanding of mechanisms at play in currently employed reagent systems is required to effectively improve plant operating conditions and maximize recovery at the industrial scale. Future testwork should also be conducted on real ores using reagents that have been identified as selective collectors at the single mineral flotation level.

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1. Introduction

The element now known as niobium was originally named columbium for its place of discovery in the basin of the Columbia River in 1801. It was not until the 1950s that niobium became an exploration target for geologists, after which discoveries were made in carbonatite plugs in Brazil, Canada, Europe and Africa (Perrault and Manker, 1981). A map outlining the location of past, current and undeveloped niobium deposits can be found in Fig. 1.

In pure form, niobium is a steel grey metal with a melting point of 2468 °C, and a density of 8.57 g/cm^3. Over 80% of the niobium produced worldwide is used as an alloying element in iron and steel. The remainder finds application as a component in super alloys used in the nuclear industry, and as unalloyed niobium chemicals and compounds (Gupta and Suri, 1994).

Prior to 1962, world production of niobium was attributed almost entirely to Nigeria (Perrault and Manker, 1981). At present, niobium mineral concentrates are still produced as by-products of mining operations worldwide, but the majority of the world's niobium concentrate is produced by two mines in Brazil; Catalão and Araxá, and the St. Honoré mine (or Niobec) in Canada (U.S. Geological Survey, 2013).

While there are only three mines significantly contributing to global niobium supply, an additional number of untapped niobium deposits exist worldwide in Africa, Brazil and Canada (de Oliveira Cordeiro et al., 2011).

Due to the limited nature of the niobium industry and the evident interest of niobium producing companies in maintaining control of the niobium market, there is little information available regarding niobium mineral beneficiation processes, particularly flotation flowsheets and reagent specifications, at these three existing operations. Information that is available is either outdated or omits necessary details for the reproduction of testwork results. Existing patent literature outlines potential processes and reagent schemes for industrial application without delving into fundamental aspects.

It is the aim of this review to provide insight into fundamental aspects of niobium oxide minerals flotation. It is hoped that this knowledge and understanding will aid in and expedite the development of efficient, operable beneficiation flowsheets.

2. Geology and mineralogy

Pyrochlore, $(Na,Ca)_2Nb_2O_6(OH,F)$, is the predominant niobium-bearing mineral (Samsonov and Konstantinov, 1959). Pyrochlore is translucent to opaque and can be black to brown, chocolate brown, reddish brown, amber-orange, or red-orange with a vitreous to greasy lustre. It is brittle in tenacity, with a density ranging from 4.45 to 4.90,

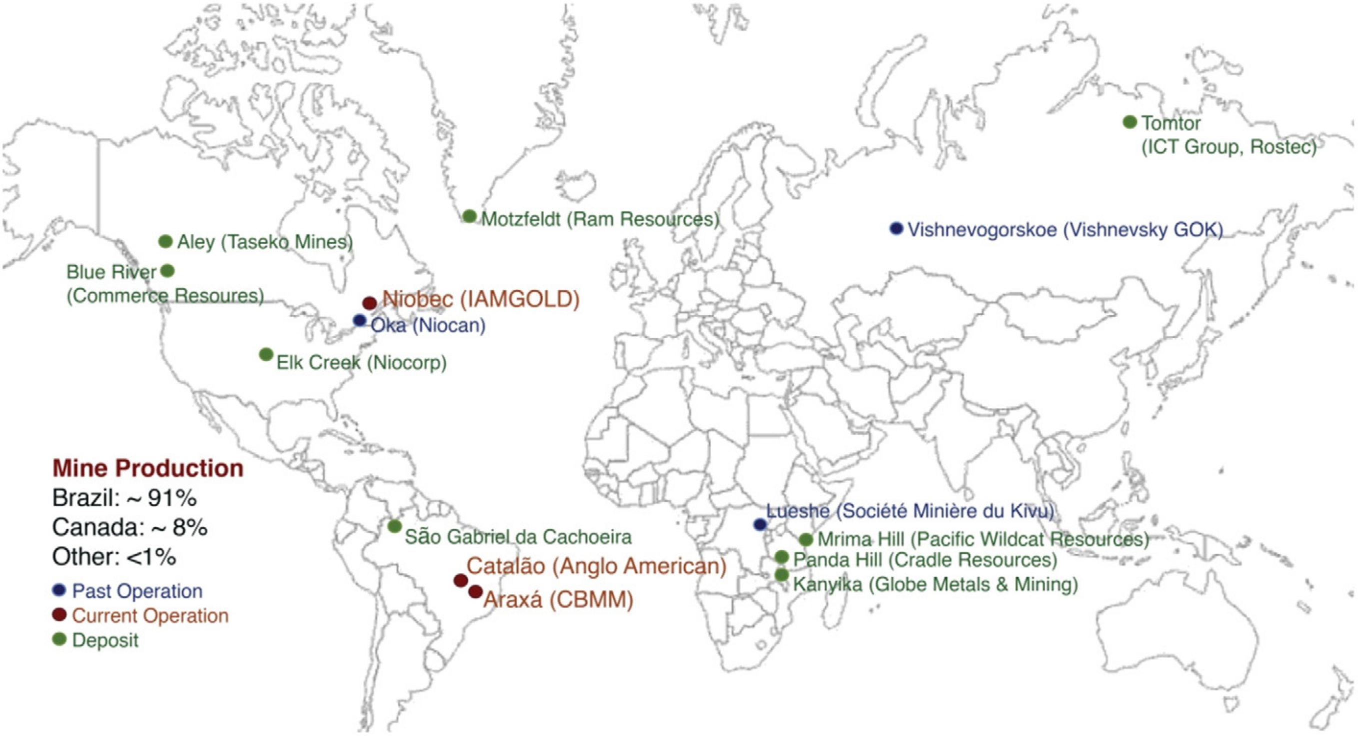

Fig. 1. Global production of niobium and selected pyrochlore deposits based on data from U.S. Geological Survey (2013) and Roskill Information Services Ltd. (2009).