

Molten carbonates, aqueous fluids and the mobilisation of niobium

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Niobium is a critical metal, today because of supply risk and tomorrow because niobium superconductivity will enable magnetic levitation trains to replace aeroplanes in long distance, within continent, travel. New deposits will need to be discovered and new ore deposit models will be required to aid in their discovery. A major impediment to the development of these models is our limited understanding of the behaviour of niobium in aqueous fluids and an almost complete lack of understanding of their behaviour in molten carbonates of the type that have produced the currently mined carbonatite-hosted deposits. Here, we summarise the available information on the complexation of niobium in aqueous fluids and its solubility in carbonate melts. We also present new models for its concentration and mobilisation. In carbonatite-hosted niobium deposits, which are currently responsible for 99% of global niobium production, there is a close spatial association of the mineralisation (mainly pyrochlore) with glimmerite (a phlogopite-rich rock). Noting this and the very high solubility (percentage level) of niobium in molten Ca-Mg carbonates, we propose that carbonatitic magmas react with their K-feldspar-rich wall-rocks (fenites) to form glimmerite, which consumes much of the magma, leaving behind a phoscoritic residue from which pyrochlore crystallises in amounts sufficient to form ore deposits. Results of our recent experiments, in which a hydrous Ca-Mg carbonate melt, doped with niobium and fluorine, replaced K-feldspar (containing traces of Na) with phlogopite and crystallised pyrochlore $\{(Ca,Na)_2Nb_2O_6(OH,F)\}$ adjacent to it, supports this hypothesis. In carbonatite-hosted niobium deposits developed in tropical to equatorial environments, weathering leads to supergene enrichment (due largely to the dissolution of carbonate minerals) that can double the niobium grade and make subeconomic deposits economic. Pyrochlore is the principal niobium mineral, although its composition differs considerably from that in the primary mineralisation, with the Ca and Na commonly being replaced by Ba, K and LREE. In some deposits, niobian rutile is important. We propose a model for this mineralisation involving leaching and hard soft acid base theory that successfully explains the chemistry of the pyrochlore, the occurrence of niobian rutile and the formation of exceptionally high-grade laterite-hosted niobium deposits above carbonatites.