From lab to lode: Applications of experimental geochemistry to mineral exploration with reference to indium

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Mineral exploration is a venture that combines science and industrial innovation with the goal of providing raw materials for economic growth. Conceptual modeling of ore deposits may be concerned with grade and tonnage or where in space and time deposits were likely to form. Experimental geochemistry can provide constraints on the efficiency of the ore-forming process, as an increasing efficiency may enhance the tonnage of an ore deposit. The first step in applying experimentally-derived data to exploration involves the characterization of ore metal behavior prior to deposition, for which the determination of partition coefficients of ore metals between phases of interest is important. In this study, we will emphasize the data that bear on the magmatic-hydrothermal hypotheses for the formation of granite-related ores. The partition coefficients were determined by conducting experiments at 750-800°C and 100 MPa and measuring the concentrations of the ore metal in the crystalline phases, melt, and vapor. As the results of these equilibrium experiments are time- and scale-invariant, their use, in and of themselves, are not complicated by the spatial and temporal scales of ore formation. In this work, we have studied the magmatic-hydrothermal behavior of indium to exemplify how experimental geochemistry can be applied to exploration. We consider the efficiency of ore metal removal from magmas into ore-forming fluids given magma chamber dimensions, magmatic concentration of indium and water, and the depth at which volatile exsolution occurs. Consider, for example, a cubic kilometer of indium-bearing granodioritic magma emplaced at ~8 km depth with 0.05 ppm indium and 4 wt% water; crystallization of ~1/3 of the melt (with 9% biotite and 7% hornblende by mass in the crystallization products) results in saturation with respect to a magmatic volatile phase (MVP). The MVP is a potential proto-ore fluid that can provide ore metal transport. Prior to the release of the MVP, 57% of the indium, by mass, would be sequestered by the ferromagnesian phases, and the remaining 43% of indium is available for transportation, via the MVP, into the overlying rock, potentially forming an indium deposit. Upon volatile saturation, assuming all the indium partitions into the MVP, the indium concentration would be ~10 times that of the initial concentration of the melt. The proportion of mafic minerals in the crystallization products will control the efficiency of indium removal from the melt, the concentration of indium in the MVP, and indium ore formation.