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Hydrothermal alteration of monazite-(Ce) and chevkinite-(Ce) from the Sin Quyen Fe-Cu-LREE-Au deposit, northwestern Vietnam

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Abstract

The Sin Quyen deposit in northwestern Vietnam is composed of Fe-Cu-LREE-Au ore bodies hosted in Proterozoic metapelite. There are massive and banded replacement ores with variable amounts of monazite-(Ce) and chevkinite-(Ce) crystals, which have undergone fluid-induced alteration. Monazite-(Ce) and chevkinite-(Ce) were deposited from high-temperature fluids in the early ore-forming stage, but became thermodynamically unstable, and thus were altered to other phases in later ore-forming stages. The alteration of monazite-(Ce) formed a three-layered corona texture, which commonly has relict monazite-(Ce) in the core, newly formed fluorapatite in the mantle, and newly formed allanite-(Ce) in the rim. In some cases, the original monazite-(Ce) was completely consumed, forming a core of polygonal fluorapatite crystals rimmed by allanite-(Ce) crystals. The formation of allanite-(Ce) and fluorapatite at the expense of monazite-(Ce) indicates that the later-stage fluids had high Ca/Na ratios and relatively low temperatures. Chevkinite-(Ce) was variably replaced by an assemblage of allanite-(Ce) + aeschynite-(Ce) ± bastnäsite-(Ce) ± columbite-(Fe) ± ilmenite. The replacement of chevkinite-(Ce) by mainly allanite-(Ce) and aeschynite-(Ce) required low-temperature, Ca-, LREE-, and Nb-rich metasomatic fluids, probably with relatively low f_{O_2}.

Mass-balance calculations were made to investigate the hydrothermal element mobility. It is assumed that Th was immobile during the alteration process of monazite-(Ce). Light (and middle) REE from La to Tb, U, As, and Ge were variably lost relative to Th, while heavy REE from Dy to Lu, HFSE (e.g., Nb, Ta, Zr, and Hf) and Sr were variably gained relative to Th. Regarding the alteration of chevkinite-(Ce), some major elements in chevkinite-(Ce), such as Ti, La, and Ce, were obviously removed from the system during alteration, whereas Ca, Al, Nb, U, and HREE were needed to be variably supplied by the metasomatic fluids. Concerning the hydrothermal mobility of trace elements, previous studies demonstrated that REE and HFSE can be commonly reserved in the system during alteration, consistent with the traditionally assumed immobile nature of these elements. In contrast, this study shows that REE and HFSE can be mobilized on at least the hundreds of micrometers scale. This may be related to the high flux and strong chemical reactivity of the metasomatic fluids.

Keywords: Monazite, chevkinite, alteration, element mobility, Sin Quyen