Controls on the critical metals concentration during the magmatic-hydrothermal evolution of alkaline granite

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Critical metals, such as Rare earth elements (REE) and high field strength elements (HFSE, including Zr, Nb, Hf, Ta, Th, U) have been considered to be immobile in aqueous media and thus a reliable indicator of the evolution of geological systems. However, there is growing evidence from both experimental and natural systems that REE and HFSE can be highly mobile during magmatic-hydrothermal evolution, particularly in alkali- and F-rich granitic systems. This mobility can result in percent level concentrations of metals sufficient to form an economic resource, particularly in alkaline-peralkaline intrusions or complexes.

Based on the investigation on ore-bearing Baerzhe and ore-barren Nianzishan peralkaline granites in NE China, pervasive hydrothermal replacement processes can be recognized as the main controls on the metals redistribution and concentration. For example, partially replacement of K-feldspar phenocrysts by albite, induced by the Na-rich hydrothermal fluids, can be usually observed in the subsolvus granites from both mineralized and barren granite. Meanwhile, multiple stages of replacement of arfvedsonite by aegirine in late- to post-magmatic stage could be happened in relatively high and low temperature. These two types of replacement processes can be identified as fennitization or Na-metasomatism, which might be critical to the metals concentration in the residual melts of some alkaline-carbonatite complexes. Besides, low temperature silicification/hematization is characterized by the replacement of phosphate and/or oxide minerals by silicate, and the occurrence of hydrothermal quartz and/or hematite veins. For example, hingganite-(Y) is a late hydrothermal mineral in the subsolvus granite, with the participation of SiO_2 and H_2O in the replacement processes of REE bearing minerals, such as monazite and polycrase.

Geochemical investigation on these hydrothermal replacement processes reveal that large scale of critical metals can be effective transferred and redistributed. It is significant to constrain the metal behaviors and mineralization processes of economic deposit. However, the sequence and physical-chemical conditions of these hydrothermal reactions are still not very clear right now. So far, there is an urgent need for a well-recognized replacement sequence on both mineralogy and geochemistry, for the future exploration of critical metals in alkaline and peralkaline rocks.