Abstract

In this study, a protocol was developed for the measurement of trace elements in natural fluid inclusions trapped in minerals using laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS). This was combined with in situ measurements of trace element concentrations and Li isotope composition of minerals to address three petrological/ore-genetic problems: 1) nature of REE-mineralizing fluid in the Amba Dongar carbonatite complex in western India, 2) nature and the composition of Cu-mineralizing fluid in the Malanjkhand copper deposit, central India, 3) petrogenesis of granitic pegmatites of the Bihar Mica Belt (BMB) in eastern India.

The fluid inclusion analytical protocol involves external standardization with NIST reference glass. Higher laser fluence (8.5 J/cm^2) produces better sensitivity, lesser time-dependent elemental fractionation, lower detection limits, and better accuracy/precision and is recommended for ablation of natural fluid inclusions or liquids. The analytical protocol was tested by analyzing the composition of quartz-hosted fluid inclusions from the Malanjkhand copper deposit in central India. The fluid inclusions have high concentrations of K, Rb, and Cs and were sourced from highly differentiated granitic magmas.

The Amba Dongar carbonatite complex in western India hosts fluorite and REE-fluorcarbonate mineralization occurring as vug/vein fillings or as disseminated ores associated with calcite, dolomite, apatite, baryte, and quartz. Fluorite-hosted fluid inclusions furnish low salinities (0.4–2.2 wt.% NaCl equivalent) and homogenization temperatures (130°C–155°C). They have high concentrations of alkalis (Na, K), Si, Al, Mg, and Mn, and their chemistry resembles orthomagmatic fluid derived from evolved carbonatite melts. They also have elevated MREE and HREE concentrations relative to the LREE. The fluids were derived from residual brines post the LREE-mineralization stage, when the HREE still remained in solution, supporting experimental findings that alkali-carbonate-hydroxyl complexation helps to mobilize REE and fractionate LREE from MREE/HREE.

Quartz-hosted fluid inclusions in pegmatites from the BMB have 240–350°C homogenization temperatures, high Li, Na, and K concentrations, and low concentrations of Ca, Mg, suggestive of a granitic origin. Muscovite and biotite from the pegmatites display positive correlation between Rb, Cs, Li, Nb, and Ta, with continuously decreasing power-law-type trends of K/Rb, K/Cs, and K/Li which is best explained by the enrichment of Rb, Cs, and Li over K during fractional crystallization. The elevated δ^7Li of micas in the pegmatites is suggestive of derivation from extremely fractionated granitic magmas. Taken together, trace element and Li-isotopic modelling shows that the BMB pegmatites are variably evolved, having crystallized from evolved granitic melts (between 70% and >99% fractional crystallization), and are unlikely to have formed by direct crustal anatexis.

Keywords: *Fluid inclusion; Amba Dongar Carbonatite Complex; Bihar Mica Belt; Pegmatite; REE Mineralization; Fluorite; hydrothermal fluid*