Trace element analysis in zircon by ion microprobe (SHRIMP-RG): technique and applications

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The Sensitive High Resolution Ion Microprobe-Reverse Geometry (SHRIMP-RG) is ideally suited to the *in-situ* analysis of trace elements in zircon. The SHRIMP-RG couples the excellent spatial and depth resolution characteristic of conventional SIMS with high transmission and good peak shape even at extreme mass resolution (M/ΔM = ~12000 at 10% peak height), unique to the reverse geometry design. Although other large magnetic sector mass spectrometers can readily resolve the REE peaks from the REE oxides (M/ΔM = ~7000-9000) and $^{48}Ti^{+}$ from $^{96}Zr^{2+}$ (M/ΔM = 7760), only the SHRIMP-RG is capable of effectively resolving $^{45}Sc^{+}$ from $^{90}Zr^{2+}$ (M/ΔM = 12660) while still maintaining reproducible, flat-topped peaks. The addition of precise Sc measurement to analytical routines including Y and the REE thus provides a more complete picture of trivalent lanthanoid (Sc+Y+REE) incorporation in zircon than was previously feasible with other microbeam techniques. Preliminary results demonstrate that evidence for diverse lanthanoid substitution mechanisms can be recognized even within individual grains, reflecting fundamental differences in conditions or process during zircon growth.

In addition to Sc, Y and the REE, measurements for P, Ca, Ti, Fe, Hf, Th and U are also part of the comprehensive trace element set determined in zircon. Because the instrument set-up for trace elements is essentially the same as that for zircon U-Pb geochronology (only the magnet's mass range differs), it is possible to perform U-Pb age dating and trace element analyses in sequential analytical sessions without difficulty. Indeed, limited high mass trace elements (Er, Yb and Hf along with Th and U) are already included in the routine U-Pb age-dating analysis set-up and provide a triage to determine which samples may be of greatest interest for a more detailed trace element study.

Ongoing studies at the SHRIMP-RG facility on such diverse topics as magma differentiation and evolution, high pressure metamorphism, and metasomatism have already included critical components of trace element analysis in zircon. Ultimately, coupling zircon REE patterns and elemental ratios (e.g. Zr/Hf, Th/U) with geochronology and emerging techniques in petrology such as Ti-in-zircon geothermometry allows the SHRIMP-RG to offer new insights into many igneous and metamorphic processes.