Combined trace element, isotopic and geochronological investigation of accessory minerals within magmatic rocks – implications for mantle sources and melt differentiation processes

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Recent advances in laser ablation-(multicollector)-inductively coupled plasma mass spectrometry (LA-(MC)-ICP-MS) have provided the capability of obtaining combined trace element, isotopic (Hf, Sr, Nd, Pb) and U-Pb geochronological data from single, constituent accessory mineral phases (e.g., apatite, monazite, niocalite, perovskite, zircon) within igneous rocks. This combined information can provide valuable insights into the nature of their source region, and crystallization history of melts. Most notably, recent generations of MC-ICP-MS instruments have introduced novel cup configuration arrays consisting of multiple ion counting systems; the latter permit for the accurate and relatively precise determination of in-situ Pb isotope ratios of low abundance (<1 ppm) Pb-bearing phases (e.g., calcite) that are critical for mantle source characterization, and accurate correction of the common Pb component for U-Pb dating purposes.

Examples of a combined multi-analytical approach will be given by presenting results obtained from a detailed chemical, isotopic and U-Pb investigation of the world renowned Cretaceous Oka carbonatite complex (Canada). In-situ U-Pb results obtained to date on apatite, perovskite and niocalite indicate that magmatic activity at Oka was a prolonged and two-stage event, which lasted ~12 Ma (between ~127 and ~115 million years ago); of interest, ages spanning the entire range were recorded by different mineral phases within the same thin sections. Chemical and Nd, Sr and Pb isotopic data obtained on apatite, perovskite and calcite indicate a complex, open-system behavior involving more than one parental melt derived from mixed lithosphere-asthenosphere (plume) mantle sources. The combined data clearly indicate that the carbonatites and associated alkali silica-undersaturated rocks (e.g., ijolites, alnoites) represent small volume melts derived from heterogeneous mantle. The presence of accessory minerals yielding variable U-Pb ages indicates that scavenging of earlier-formed crystals by later-formed small volume melts occurred, and that these represent cognate crystals. The data from Oka indicate that carbonatite magmatism associated with a single alkaline complex should not be envisaged as a single magmatic event involving solely one parental liquid.