Exposing the Hidden Record of Crustal Growth using In Situ Isotopic Analyses of Minerals

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There is tremendous uncertainty about the nature and volume of continental crust produced during the first 2 billion years of Earth history, despite decades of research. Preserved Archean rocks make up only ca 10% of the presently exposed continental crust yet models for crustal growth predict that the original volume of Archean crust was either moderately or substantially greater. The missing Archean rocks have been hidden by: (1) burial in the middle and lower crust; (2) reworking in younger terranes particularly during the Proterozoic; and (3) recycling back in to the mantle. Traditional approaches using isotopic compositions of whole rocks have failed to constrain the nature and volume of the hidden Archean crust. This is because isotopic compositions of Archean whole rocks have been variably affected by metamorphism, deformation and secondary alteration, and pristine magmatic compositions are difficult to identify conclusively.

Recent analytical developments for in situ isotopic analyses of minerals by laser ablation–inductively coupled plasma mass spectrometry have provided new avenues for research on crustal growth. Minerals provide more attractive targets for isotopic analyses than whole rocks because they preserve pristine domains that can be recognized on the basis of imaging and chemical criteria. Techniques for combined U-Pb geochronology and Hf-isotope geochemistry of zircon and baddeleyite are now well established. Newer methods for common Pb-isotope geochemistry of feldspar and combined U-Th-Pb geochronology and Nd-isotope geochemistry of monazite, apatite and titanite will be increasingly applied to the problem of crustal growth in the coming decade. Detrital minerals in metasedimentary rocks can provide direct evidence for hidden source terranes whereas magmatic minerals in metaigneous rocks may give indirect evidence based on models of Hf, Nd, Pb isotope evolution in the crust and mantle. In examples from the Archean Narryer Gneiss Terrane of Western Australia and the Early Proterozoic Makkovik Province of Labrador, both detrital and magmatic minerals preserve evidence for hidden Archean crust.