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The southern African Kaapvaal craton: Formation and modification of continental lithospheric mantle in Archaean subduction zones?

N.S.C. SIMON[1], G.R. DAVIES[1], D.G. PEARSON[2] AND R.W. CARLSON[3]

[1] FALW, VU Amsterdam, De Boelelaan 1085, 1081HV Amsterdam, The Netherlands (nina.simon@falw.vu.nl)
[2] Dep. of Geological Sciences, Durham University, South Rd, Durham DH1 3LE, UK (d.g.pearson@durham.ac.uk)
[3] DTM, Carnegie Inst. Washington, 5241 Broad Branch Road N.W., Washington, D.C. 20015, USA (carlson@dtm.ciw.edu)

The Kaapvaal craton is underlain by an at least 200 km thick lithospheric keel. The sub-cratonic lithospheric mantle (SCLM) is distinct from oceanic mantle in that it is more depleted in magmaphile elements (Fe, Al, Ca, HREE), but at the same time strongly enriched in incompatible trace elements like LILE and LREE. The Kaapvaal SCLM also has a distinctly higher Si/Mg ratio and therefore higher modal opx content (at a given Mg/Fe) than oceanic and most continental upper mantle.

We carried out a detailed petrological and geochemical study on low-temperature peridotite xenoliths for Kimberley and northern Lesotho in order to obtain information about the processes that led to the depletion and re-enrichment of the Kaapvaal SCLM. Samples have been characterized for Re-Os isotope systematics, major and trace element concentrations in whole rocks and minerals, and garnet and cpx Lu-Hf, Sm-Nd and Rb-Sr isotopes.

The combined results require a multistage history of the Kaapvaal mantle. They are most consistent with a model that involves ancient trace element enrichment of the garnets and opx by aqueous fluids, possibly derived from a subducting oceanic slab. This is consistent with the observed enrichment in Si (opx) and the Re-Os systematics. Infiltration of hydrous fluids would also increase the degree of mantle melting and could therefore explain the strong major and HREE depletion of the SCLM. The Nd-Hf isotope characteristics of the garnets require the trace element enrichment to be ancient. We therefore suggest that melting and metasomatism of the Kaapvaal SCLM took place in subduction zone settings, probably during amalgamation of smaller pre-existing terranes in the Late Archaean.

Trace element and Nd and Hf isotope disequilibrium between garnet and cpx is preserved in many samples and indicates that garnet and cpx are not co-genetic. Calculated equilibrium liquids and Hf-Nd isotopic compositions for cpx suggest that most diopside in the xenoliths studied crystallized from an infiltrating kimberlite-like melt, shortly prior to eruption.

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Lu-Hf systematics of kimberlite-hosted eclogite xenoliths from South Africa and Canada

S.S. SCHMIDBERGER, L.M. HEAMAN, A. SIMONETTI AND R.A. CREASER

Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, T6G 2E3, Canada (stefanie.schmidberger@ualberta.ca)

Eclogite xenoliths hosted by kimberlites provide invaluable information on the chemical composition of the lithosphere beneath Archean cratons. The timing of eclogite formation, whether during stabilization or post-Archean modification of the subcratonic mantle, is currently poorly constrained. This ongoing study presents Lu-Hf, and in-situ Pb and Sr isotopic ratios of clinopyroxene obtained by laser ablation MC-ICP-MS for eclogite xenoliths from the Kaapvaal craton, South Africa (Roberts Victor, Kimberley Pool, Jagersfontein) and a suite of rare zircon-bearing eclogites [1] from the Slave craton, Canada (Jericho kimberlite).

Epsilon Hf values for the South African eclogites show a large variation from -16 to +25 at the time of kimberlite emplacement (at ~90-120 Ma). The Roberts Victor kimberlite is characterized by an initial epsilon Hf value of -8.1. The Roberts Victor eclogites (n=6) define a Lu-Hf regression line corresponding to an errorchron age of 1.6±0.4 Ga. The initial Hf isotopic ratio of 0.28192 obtained from the regression is consistent with this age, since it intersects the temporal evolution line for a depleted mantle reservoir at 1.7 Ga.

In-situ $^{87}Sr/^{86}Sr$ ratios obtained on single clinopyroxene grains selected from four Roberts Victor eclogite samples vary between 0.7059 and 0.7068, and are interpreted to reflect source characteristics. In-situ $^{206}Pb/^{204}Pb$ (15.9-17.2) and $^{207}Pb/^{204}Pb$ (14.6-15.6) ratios for the clinopyroxenes are extremely variable and yield younger Pb-Pb model ages, possibly the result of metasomatic interaction with the host kimberlite. As noted in a previous study of a similar nature [2], the data obtained here support the more robust nature of the Lu-Hf chronometer in resisting chemical changes associated with metasomatic activity.

Epsilon Hf values for the Jericho eclogites are much lower ranging from -28 to -33 (at ~170Ma). They are characterized by very low $^{176}Lu/^{177}Hf$ ratios (0.001 to 0.006) and fairly consistent $^{176}Hf/^{177}Hf$ values, and yield Paleoproterozoic $Hf_{(depleted\ mantle)}$ model ages (2.0 to 1.7 Ga). This is consistent with their origin involving Paleoproterozoic subduction as suggested by U-Pb zircon dating [1].

References

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