Archean to Middle Proterozoic evolution of the Sandvik ultramafic body, Norway: Evidence from Sm-Nd and Lu-Hf isotope analyses

THOMAS J. LAPEN, L. GORDON MEDARIS JR., CLARK M. JOHNSON AND BRIAN L. BEARD

Department of Geology and Geophysics, University of Wisconsin-Madison, 1215 W. Dayton St., Madison, WI 53704, USA (lapen@geology.wisc.edu)

Combined Sm-Nd and Lu-Hf age and isotope data indicate that Mg- and Cr-rich ultramafic rocks at Sandvik, Western Gneiss Region (WGR), Norway, originated from depleted Archean lithospheric mantle that was chemically and physically modified in Middle Proterozoic time. The Sandvik outcrop consists of garnet peridotite and thin garnet±olivine pyroxenite layers. These contain two principal mineral assemblages: an earlier porphyroclastic assemblage of grt+opx+cpx±ol (1200-1000°C, 50 kbar) and a later kelyphitic assemblage of grt+spl+am±opx±ol (700-750°C; 12-18 kbar). A CHUR Hf model age indicates a period of melt extraction at ca. 3.3 Ga for garnet peridotite, reflecting extremely high Lu/Hf ratios and very radiogenic present-day $^{176}Hf/^{177}Hf$ (εHf = +2165). Lu-Hf garnet-cpx-whole rock ages of two olivine-bearing samples from the outcrop are ca. 1255 Ma, whereas two olivine-free garnet pyroxenites yield Lu-Hf ages of ca. 1185 Ma. All Sm-Nd garnet-cpx-whole rock ages of these samples are significantly younger (ca. 1150 Ma for garnet peridotite and ca.1120 Ma for garnet pyroxenite). The isotope systematics indicates that the Lu-Hf ages represent cooling from an earlier period of formation/recrystallization for garnet peridotite whereas they may reflect formation ages of the garnet pyroxenite. The Sm-Nd ages and isotope systematics of the garnet peridotite samples are consistent with an episode of LREE metasomatism, perhaps facilitated by a fluid of carbonatitic composition that strongly decoupled Sm-Nd and Lu-Hf in some lithologies. The Sm-Nd ages of the garnet pyroxenite may represent either LREE metasomatism or cooling, and, like the peridotites, Lu-Hf ages are older than Sm-Nd ages. The age data, as well as the inferred Nd isotope composition of the fluid that affected the olivine-bearing samples, suggests that these rocks were not in contact during the LREE metasomatic event. Moreover, the pyroxenite layers cannot have been emplaced as magmas into the host peridotite. The pyroxenite layers are interpreted to be tectonically juxtaposed with the host olivine-bearing samples sometime after 1150 Ma but before development of kelyphite.

HIMU lithospheric mantle beneath Northwest Africa

N. WITTIG[1], S. DUGGEN[1], J.A. BAKER[2], A. KLUEGEL[3] AND K. HOERNLE[4]

[1]Geological Institute-DLC, Copenhagen University, Oester Voldgade 10, 1350 Copenhagen, DK (nw@geol.ku.dk, sduggen@geol.ku.dk);
[2]School of Earth Sciences, Victoria University of Wellington, P.O. Box 600, Wellington, NZ (joel.baker@vuw.ac.nz);
[3]Department of Geosciences, University Bremen, Postfach 330 440, GER (akluegel@uni-bremen.de);
[4]IFM-GEOMAR, Wischhof Straße 1-3, 24148 Kiel, GER (khoernle@ifm-geomar.de)

High-precision Nd-Pb (double-spike) isotope (MC-ICP-MS) and trace element data (LA-ICP-MS) for clinopyroxene from spinel-facies xenoliths (n=12) from the Middle Atlas region (Morocco) have been determined. Clinopyroxene is dominantly LREE-enriched with steep MREE-HREE chondrite-normalised patterns and shows similarity to the hosting basanites. Clinopyroxene has $[La/Ce]_N<1$ and $[Sm/Nd]_N<0.55$ due to secondary La depletion unreported in the hosting basanites. Few clinopyroxenes lack secondary La depletion and have $[La/Ce]_N = 3$ and $[Sm/Nd]_N\sim1$.

Primitive-mantle-normalised multi-element diagrams of clinopyroxenes reveal marked depletion at Nb-Ta and Zr-Hf for clinopyroxene unlike associated basanites that only have distinct Zr-Hf troughs. Zr/Hf ratios vary between Zr/Hf = 30-61 whereas Nb/Ta ratios are generally sub-chondritic ranging between 3.6 and 14.5.

Clinopyroxene has HIMU-like Pb isotope signatures with $^{206}Pb/^{204}Pb$ = 19.70-20.25 and negative Δ7/4 (–0.35 to –3.99). U, Th and Pb concentrations range between 0.07-0.65, 0.47-2.45 and 0.164-0.374 ppm, respectively, with extreme μ, ω and k of up to 80, 573 and 11. Nd isotopes confirm the HIMU signature of the Moroccan SCLM with ε_{Nd} = +3.1 to +4.8 for the LREE-enriched clinopyroxenes. Clinopyroxene with $[Sm/Nd]_N\sim1$ have slightly higher ε_{Nd} = +6.9.

Radiogenic Pb isotope ratios, low ε_{Nd}, LREE enrichment in clinopyroxenes and the overall resemblances with associated basanites in addition to the strong U-Th-Pb enrichment suggest recent metasomatism of the sub-continental lithosphere probably during passage of the Quaternary basanitic melts in the Middle Atlas. This resulted in a relatively homogeneous lithospheric mantle with HIMU characteristics. The distinct HFSE depletion and the overall enrichment of incompatible elements in clinopyroxenes requires strong affinity of the most recent metasomatic agent with carbonatite (-silicate) melts overprinting the Moroccan sub-continental lithospheric mantle (SCLM).