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Petrogenesis of late-Paleozoic high-Mg norites from North Xinjiang, China: Evidence for lower crust recycling in an intracontinental setting

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Here we report geochemical and Sr-Nd-Pb isotopic composition of 280 Ma noritic plutons in Eastern Tianshan, North Xinjiang, China. Since ubiquitous 300 Ma A-type high-epsilon Nd granites of North Xinjiang indicate an obviously crustal growth, the latish norite plutons along deep faults can provide compositional implications of the lithospheric mantle after the crustal growth. Eastern Tianshan norites show broad range in chemical compositions, with SiO₂ (48.7-54.5%), MgO (4.1-13.3%), and MgO/(MgO+Fe₂O₃) ratios (0.34-0.61). In primitive mantle normalized spidergrams, Eastern Tianshan norites show a strong crustal signature, i.e. enrichment of LILE, depletion of Nb and Ta, strongly positive Pb anomaly. Good correlations between Sr, Nd, and Pb isotopes suggest mixing genesis for Eastern Tianshan norites. High-SiO₂ norites have more radiogenic Sr, Pb isotopic composition, and lower radiogenic Nd isotopic composition than that of low-SiO₂ norites. High-SiO₂ norites show high Eu/Eu* ratios (>1.2) and obviously positive Sr and Ti anomaly in spidergrams, so we prefer source mixing to crust assimilation mode to interpret the mixing relationship. On the diagram of epsilon Sr vs. epsilon Nd, Eastern Tianshan norites deviate from normal mantle array and plot in the mixing line between depleted mantle component and 300 Ma A-type high-epsilon Nd granites of North Xinjiang. Meanwhile, the complementary feature in some trace elements, i.e. Sr, Eu, and Ti, suggests a genetic relationship between them. Therefore, we propose that juvenile lower crust, with complementary trace element feature and similar Sr-Nd-Pb isotopic composition with A-type granites, had sunk into mantle and contributed to Eastern Tianshan high-Mg norites.

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Mantle melting and metasomatism in European Lithosphere

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We have carried out a high-precision Pb (double-spike) and Lu-Hf isotope study of clinopyroxene from spinel-facies mantle xenoliths from the French Massif Central (FMC) and Pyrenean Iherzolite massifs (PM). Pb isotope analyses (n = 35) define a heterogeneous sub-continental lithospheric mantle (SCLM) with ²⁰⁶Pb/²⁰⁴Pb = 16.9-20.3. Most replicate digestions (n = 26) fail to reproduce within double-spike errors (±100 ppm) due to difficulties in reproducing leaching procedures prior to digestion, inclusions of accessory minerals, or heterogeneity within the clinopyroxene. Clinopyroxene from the PM have heterogeneous Pb isotopes (²⁰⁶Pb/²⁰⁴Pb = 16.9-19.5) and are generally LREE depleted ([La/Nd]_N < 0.55). In general, clinopyroxenes from the FMC with unradiogenic Pb (²⁰⁶Pb/²⁰⁴Pb < 18.6) are also LREE depleted, whereas radiogenic Pb samples (²⁰⁶Pb/²⁰⁴Pb > 18.6) are LREE enriched. LREE enrichment and radiogenic Pb in the FMC xenoliths reflects recent fluid-dominated metasomatism with radiogenic Pb and/or older increases in Th/Pb and U/Pb leading to development of radiogenic Pb. This metasomatism either occurred during Variscan subduction (400 Ma) or, more recently, related to FMC volcanism itself. Hf isotope ratios of clinopyroxene (n = 37) typically range between ε_{Hf} = -0.4 to +40.9. However, in the northern FMC, clinopyroxenes from Montboissier xenoliths have very high ε_{Hf} (+133 to +249) and ¹⁷⁶Lu/¹⁷⁷Hf (0.619-0.929; Hf < 0.036 ppm). Clinopyroxene from Puy de Halle, also in the northern FMC, has even more extreme ε_{Hf} (+468 to +1396). This Hf isotopic record of ancient melt depletion is accompanied by U-Th-Pb-LREE enrichment, unremarkable ¹⁴³Nd/¹⁴⁴Nd (ε_{Nd} = +2.1 to +18.1) and radiogenic Pb. However, radiogenic Nd (ε_{Nd} = +91.2) is preserved in one sample with ε_{Hf} = +220. The northern FMC clinopyroxenes have consistent Lu-Hf mantle depletion ages of 310-488 Ma (± 6 to 63 Ma; 2sd) recording melting during Variscan subduction beneath the FMC and subsequent incorporation of this material into European SCLM. Preservation of extreme ε_{Hf} highlights the robustness of Hf to fluid-dominated mantle metasomatism that overprinted Sr-Pb-(Nd) isotopes and incompatible trace element (U-Th-Pb-LREE) abundances, and also the high T_c of Hf in clinopyroxene. The Lu-Hf isotope system has great potential for directly dating and constraining the formation of depleted mantle as recorded in SCLM lithologies from different lithospheric terranes.