Lu-Hf geochronology of eclogites from Pfulwe, Zermatt-Saas ophiolite, western Alps, Switzerland

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Major-element zoning patterns in garnets from eclogite-facies metabasalts of the Zermatt-Saas ophiolite complex, western Alps, record large segments of the prograde P-T-t path to HP/UHP conditions. Ca, Fe, Mg, and Mn contents in garnet from core to rim are indicative of prograde growth zoning. Core to rim trace element analyses and 3-D imaging of garnet by laser-ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) and x-ray tomography indicates strong HREE (Er, Yb, Lu) zoning, where the highest concentrations occur in the garnet core. Lu zoning is typically characterized by a very sharp, narrow spike in concentration (50 to 170 ppm) in the garnet core flanked by concentration values of 10 to 20 ppm that decrease toward the rim. Zr, and by proxy Hf, concentrations are typically constant across garnet traverses.

Lu and Hf garnet zoning patterns have important implications for Lu-Hf geochronology because they indicate that the Lu/Hf ratios are highest in the garnet core, though we note that the very highest values are in a very small volume of the garnet (1-2%). Therefore, if bulk garnet separates are used for geochronology, the measured Lu-Hf ages are strongly skewed toward the early prograde growth because the majority of the Lu is within the first 30% (by volume) of grown garnet.

Five ages from samples collected along the trail to the Pfulwe pass and from the famous Pfulwe pillow locality (near Zermatt, Switzerland) range from 46.5 to 54.5 Ma, as determined by MC-ICP-MS. These Lu-Hf ages, which overlap within error, reflect early garnet growth during subduction and prograde metamorphism, not the peak P-T conditions. Sm-Nd ages obtained on the same samples are very imprecise or undeterminable due to the presence of LREE inclusions in garnet. The relative insensitivity of Lu/Hf ratios to common LREE rich inclusions in eclogitic garnet highlights one advantage of Lu-Hf geochronology over Sm-Nd.

Grenville-age metamorphism on the western margin of Laurentia, northern Idaho: Evidence from Lu-Hf garnet geochronology

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Lu-Hf geochronology of garnet-bearing amphibolite facies rocks in northern Idaho reveal a complex multistage metamorphic history. We determined Lu-Hf ages on amphibolite and pelitic schists from the Clearwater complex of northern Idaho and on a pelitic schist more proximal to the Cretaceous Idaho batholith. The core and rim of the garnet amphibolite have Lu-Hf ages of 1149±4 and 118±4 Ma, respectively. Very high Lu/Hf ratios in the garnet core ($^{176}Lu/^{177}Hf$ up to 17.83) result in extraordinary present day $^{176}Hf/^{177}Hf$ ratios as high as 0.688932 (ε_{Hf} = +13,656). Grenville ages of 1056±57 and 1006±5 Ma are recorded in the pelitic schists samples. In contrast, the pelitic schist near the Idaho batholith yields a well-defined age of 89.6±2.6 Ma.

The ~1.1 Ga metamorphic ages combined with polyphase penetrative structures observed in metamorphic tectonites and metasedimentary rocks north of the Idaho batholith strongly suggest that Grenville-age tectonism in the northwestern U.S. Cordillera was widespread and reflects a period of Proterozoic crustal thickening prior to or during the assembly of Rodinia. Thus Early and Middle Proterozoic basins of western Laurentia may record deposition and contraction in an intracontinental setting or may have developed during a history of both passive margin and convergent margin tectonism. The younger Lu-Hf ages are consistent with widely observed evidence for Cretaceous metamorphism in the region.

The presence of domains within a single garnet that record ages differing by over a billion years clearly supports a complex tectonic history for these rocks. This juxtaposition of ages demonstrates the potential of the Lu-Hf isotope system in garnets to see through younger metamorphic overprints and resolve an earlier metamorphic history. Taken together with regional structural analysis, this work illustrates the utility of the Lu-Hf system in dating complex, polymetamorphic histories associated with regional deformation.