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Precision and novel applications in Lu-Hf garnet chronology

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The geological interpretation of petrological processes depends on our ability to accurately and precisely place these in a tectonic time line. Accessory minerals are most commonly used in chronology. Nevertheless, interpreting age data in terms of petrological processes is typically non-trivial. Garnet Lu-Hf and Sm-Nd dating provide powerful alternatives. Garnet Lu-Hf chronology has gained particular interest since its first use in 1997; the method is now commonly used to date petrological processes in a variety of settings and rock systems at a precision of 1 %RSD or better. A survey of >80 samples analyzed in 3 labs during the past 10 years shows that extreme precision of 0.05 %RSD is now within grasp for specific rock types, such as eclogites.

Garnet Lu-Hf dates are quite often older than Sm-Nd dates. Different explanations have been proposed over the years to explain this phenomenon. In this study, we test the validity of these concepts by evaluating trace-element data and Lu-Hf dates for garnet from the same compilation of Lu-Hf data. The data do not reflect artificial skewing and dispersion as proposed for the Lu-Hf system by numerical models. The data instead highlight the control of Lu/Sm zoning and differential daughter-isotope loss on garnet chronometers. Garnet and zircon dates are typically dissimilar, even when REE signatures could suggest garnet-zircon equilibrium. This shows that zircon (re-)crystallization is largely fluid-driven and involves localized, rather than rock-wide REE equilibrium. The ability of garnet and zircon to record and retain complementary age information demonstrates the power of their combined use.

The constraints from this and previous research predict great potential for using Lu-Hf garnet chronology to accurately and precisely date petrological processes at mantle temperatures. To test this concept, we performed grain-size controlled Lu-Hf chronology to (Cr-)pyrope from asthenosphere-derived mantle fragments exposed in Western Norway. Previous garnet chronology using the Sm-Nd system yielded Mesoproterozoic and Silurian ages, representing cooling in the mantle and entrapment in the Caledonian Orogen, respectively. Our Lu-Hf dates are the first to confirm an Archean age for garnet in these rocks. This establishes these rare pyrope grains as timekeepers of 2.5 billion years melting, cooling and tectonic reworking within the mantle.