American Mineralogist, Volume 107, pages 1116–1132, 2022

Timescales and rates of intrusive and metamorphic processes determined from zircon and garnet in migmatitic granulite, Fiordland, New Zealand

Harold Stowell[1,*], Joshua Schwartz[2,†], Elizabeth Bollen[1], Andy Tulloch[3], Jahandar Ramezani[4], and Keith Klepeis[5]

[1]Geological Sciences, University of Alabama, Tuscaloosa, Alabama 35487-0338, U.S.A.
[2]Geological Sciences, California State University Northridge, Northridge, California 91330, U.S.A.
[3]GNS Science 764 Cumberland Street, Dunedin 9016, Private Bag 1930, Dunedin 9054, New Zealand
[4]Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, U.S.A.
[5]Department of Geology, University of Vermont, 180 Colchester Avenue, Burlington, Vermont 05405, U.S.A.

Abstract

Zircon U-Pb, and garnet Sm-Nd and Lu-Hf dates provide important constraints on local and orogenic scale processes in lower-crustal rocks. However, in high-temperature metamorphic rocks these isotopic systems typically yield significant ranges reflecting both igneous and metamorphic processes. Therefore, linking dates to specific aspects of rock history can be problematic. In Fiordland, New Zealand, granulite-facies orthogneiss is cut by leucosomes that are bordered by garnet clinopyroxene reaction zones (garnet reaction zones). In both host orthogneiss and garnet reaction zones, zircon are typically anhedral with U-Pb dates ranging from 118.30 ± 0.13 to 115.70 ± 0.18 Ma (CA-ID-TIMS) and 121.4 ± 2.0 to 109.8 ± 1.8 Ma (SHRIMP-RG). Zircon dates in host and garnet reaction zone do not define distinct populations. In addition, the dates cannot be readily grouped based on external morphology or internal CL zoning. Zircon trace-element concentrations indicate two distinct crystallization trends, clearly seen in Th and U. Garnet occurs in selvages to the leucosome veins and in the adjacent garnet reaction zones. In selvages and host orthogneiss, garnet is generally 0.5 to 1 cm diameter and euhedral and is 0.1 to 0.5 cm diameter and subhedral in garnet reaction zones. Garnet Sm-Nd and Lu-Hf dates range from ca. 115 to 101 Ma (including uncertainties) and correlate with grain size. We interpret the CA-ID-TIMS zircon dates to record the age of magma emplacement and the SHRIMP-RG dates to record a range from igneous crystallization to metamorphic dissolution and reprecipitation and/or local Pb loss. Zircon compositional trends within the garnet reaction zone and host are compatible with locally isolated melt and/or separate intrusive magma batches for the two samples described here. Dates for the largest, ~1 cm, garnet of ~113 Ma record growth during metamorphism, while the smaller grains with younger dates reflect high-temperature intracrystalline diffusion and isotopic closure during cooling. The comprehensive geochronological data set for a single location in the Malaspina Pluton illustrates a complex and protracted geologic history common in granulite facies rocks, estimates lower crustal cooling rates of ~20 °C/m.y., and underlines the importance of multiple chronometers and careful textural characterization for assigning meaningful ages to lower-crustal rocks. Numerous data sets from single locations, like the one described here, are needed to evaluate the spatial extent and variation of cooling rates for Fiordland and other lower crustal exposures.

Keywords: Zircon U-Pb, garnet Sm-Nd, migmatite, lower crust, rates of intrusion, duration of metamorphism