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Petrochronology of UHT garnet-free granulites: Linking zircon geochemistry to metamorphic reactions

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Granulite-facies metamorphism and migmatization play an important role in the redistribution of elements within the lower continental crust in space and time. Therefore, retrieving petrochronological information may provide valuable insights into crustal reworking and underlying processes throughout the evolution of the Earth. The strongly heterogeneous nature of migmatites and the high temperatures, often overprinting prograde mineral assemblages and producing protracted zircon geochronological records, render pressure-temperature-time reconstructions a challenging task.

In this study, we link bulk rock, and in situ geochronological, trace elements and Lu-Hf data from zircon and rock-forming silicates from an ultra-high temperature stromatic metatexite from the Guaxupé nappe (Brazil), in order to trace the re-distribution of trace elements and the formation of zircon during pro- and retrograde metamorphism. The studied granodioritic migmatite consists of alternating bands of tonalitic leucosome (mafic phases <10 vol%) and melanosome composed of orthopyroxene, clinopyroxene, and retrograde amphibole and biotite overgrown the former. U-Pb zircon analyses reveal a protracted geochronological record for zircon cores and rims, interpreted as result of U-Pb disturbed systems and prolonged zircon growth in a long-lived metamorphic event (680–580 Ma). Peak temperatures are recorded by orthopyroxene-clinopyroxene at T=1000 °C, followed by a retrograde stage at T$\sim$900 °C recorded by orthopyroxene-clinopyroxene rims, and a late hydration stage with crystallization of amphibole (T$\sim$740 °C) and biotite (T$\sim$740–660 °C).

Metamorphic zircon varies in REE abundances and patterns, with Eu anomalies ranging from strongly negative to slightly positive. Amphibole is 2–4 times more enriched in REEs than clinopyroxene, however both phases present similar wing-shaped REE patterns enriched in LREEs and with negative slopes for HREEs. Amphibole thereby displays increasing negative Eu anomalies and HREE enrichments from cores to rims. Clinopyroxene exhibits inverse patterns, with cores being more enriched in HREEs than rims, and less pronounced negative Eu anomalies. Orthopyroxene has the lowest REE abundances with highly variable LREE compositions and positive-sloped HREE patterns.

Metamorphic stages can be correlated as follows: i) during peak conditions (T=1000–900 °C) at around 650 Ma, protolith zircon recrystallized producing metamorphic rims; ii) during the first retrogression stage (900–800 °C) pyroxenes re-equilibrated accompanied by crystallization of high-HREE zircon rims due to zircon dissolution and HREE release from clinopyroxene; iii) late regression around T$\sim$740 °C, indicated by amphibole and biotite crystallization, with external fluid/melt input (supported by variable 176Hf/177Hf(t)). Retrograde amphibole is increasingly enriched in HREEs from core to rim, derived from clinopyroxene and orthopyroxene breakdown and fluid-controlled zircon dissolution. Negative Eu anomalies increase in zircon and amphibole as feldspar crystallizes from melt around 630–600 Ma. Locally, compositional domains may be responsible for some variation within the metamorphic U-Pb dates for each stage. The results reveal that combining geochemical and chronological information in orthopyroxene-clinopyroxene-amphibole-bearing migmatites could be used to geochemically assign zircon growth to specific metamorphic reactions and external fluid/melt inputs.