Geophysical Research Abstracts
Vol. 19, EGU2017-1568-1, 2017
EGU General Assembly 2017

Linking zircon age to metamorphic stage using U-Pb/REE depth-profiling of zircon combined with Lu-Hf garnet geochronology

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The relatively novel approach of LASS-ICP-MS depth-profiling in zircon has enabled the analysis of sub-micrometer, isotopically/geochemically distinct zircon domains which are too thin to be analyzed by other in situ methods. The depth-profiling approach has proven to be particularly useful in targeting thin and discontinuous metamorphic zircon overgrowths, which are evidently capable of recording multiple short-duration tectonothermal events. Based on our knowledge of rare earth element (REE) partitioning between equilibrium zircon and garnet, it is possible to link LASS depth-profile data to specific metamorphic events, and discern the timing of garnet growth versus garnet breakdown.

Here we test the potential of this approach by applying LASS-ICP-MS depth profiling in zircon to samples from the Alpine Schist (New Zealand) that have been dated previously by Lu-Hf garnet geochronology. Our results show that thin (<8 μm) metamorphic zircon overgrowths are easily distinguished from igneous cores based on Th/U («1) and distinct enrichment/depletion in HREE. The latter is used to differentiate between zircon formed during garnet-stable conditions, and zircon formed in the presence of melt/fluid or during garnet breakdown. The corresponding U-Pb zircon ages are consistent with the timing of garnet growth and partial melting determined independently by Lu-Hf garnet geochronology (97 – 75 Ma), and U-Th/Pb monazite dates from anatectic pegmatites (80 – 51 Ma). The U-Pb data span the transition from garnet growth to garnet resorption and therefore can be used to corroborate bulk or 'mean' Lu-Hf garnet ages where garnet grew over protracted timescales. Additionally, comparison of zircon and garnet REE compositions provides estimates of D(REE) zircon/garnet for quartzofeldspathic compositions at greenschist – amphibolite conditions.

This study demonstrates the ability of depth-profiling to resolve multiple short-duration (re)crystallization events spanning a significant portion of metamorphic history, from prograde conditions to decompression and cooling. Both garnet and zircon (re)crystallization in the Alpine Schist are contemporaneous with the rifting of the Zealandia microcontinent from East Gondwana during 83 – 52 Ma. These results provide constraints on the P-T-t conditions recorded in the Alpine Schist during this period, with implications for the geodynamic processes involved in microcontinent formation.