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Bulk inclusion micro-zircon U-Pb geochronology: a new tool to date low-grade metamorphism

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Dating low-grade metamorphism is challenging since such rocks commonly lack suitable target minerals for acquiring pressure-temperature-time-deformation (P-T-t-d) data. In greenschist facies rocks, the presence of metamorphic micro-zircon is well documented, however, thus far no geochronological data could be derived from these minerals owed to the small grain-size. To overcome this problem, we present a new laser-ablation based method termed 'bulk inclusion dating' that utilizes a distinct micro-zircon population enclosed in porphyroblasts.

The new method is applied to a chloritoid-bearing schist sampled the upper structural level of the Austroalpine Unit (Eastern Alps, Austria, Europe) that contains mm-scale chloritoid porphyroblasts in a foliated matrix consisting of chlorite, muscovite and quartz. Accessory minerals include ilmenite, hematite, rutile, zoned epidote with REE-rich cores, euhedral apatite and zircon. Thermodynamic modeling predicts the stability of the equilibrium assemblage in a P-T field between 450–490°C and 0.5–0.7 GPa, which agrees with peak temperature constraints around 490°C derived from Raman spectroscopy of carbonaceous material. The zonation of inclusions within chloritoid and its chemical zoning confirms porphyroblast growth at these conditions. Detailed petrographic investigations using high-resolution imaging reveals numerous minute (0.1–3 µm), euhedral micro-zircon crystals included in chloritoid porphyroblasts and in the matrix. In situ laser-ablation ICPMS bulk inclusion dating of zircon in the chloritoid rim using a laser spot diameter of 120 µm yields a U-Pb age of 116.7 ± 9.1 Ma (MSWD: 1.5, n: 79). Systematic imaging of the targeted chloritoid domain clarifies the abundance and size of different U-Pb bearing inclusions. Combined with trace element data, we can unambiguously link the U-Pb age to micro-zircon inclusions and demonstrate that the influence of other U-Pb bearing inclusions or the host chloritoid is insignificant. Using crystal size distribution analysis of different micro-zircon populations in the chloritoid core, its rim and the matrix, we interpret zircon precipitation and progressive coarsening coeval with chloritoid growth during prograde metamorphism and thus link the age to the late prograde part of the P-T evolution. The method introduced here allows integration between metamorphic conditions and age constraints and opens up new potential applications in the investigation of low-grade metamorphic rocks.