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Unravelling polymetamorphism in greenschist- and amphibolite-facies rocks using thermodynamic modeling and in situ U-Pb dating of REE-minerals (Austroalpine Unit, Eastern Alps, Austria)

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Precise thermobarometric and geochronologic data are crucial to correctly interpret the timing of metamorphism and identify complex polymetamorphic histories. We present new P-T-t-D data from samples collected in two Austroalpine nappes exposed in the Eastern Alps, Austria: the structurally upper greenschist-facies Schöckel Nappe ("Graz Paleozoic," Drauzug-Gurktal Nappe System) and the structurally lower amphibolite-facies Waxenegg Nappe (Koralpe-Wölz Nappe System). In the latter, polymetamorphism was previously inferred. However, the timing of metamorphism is poorly resolved and only limited geochronology exists in the Schöckel Nappe.

Detailed petrographic investigations of chloritoid-bearing phyllite and micaschist samples collected at two localities at the base and in a higher structural level of the Schöckel Nappe revealed complex phase relations of REE-minerals, involving multiple REE-epidote generations that may be associated with monazite, xenotime, apatite and zircon. In garnet-bearing micaschist of the Waxenegg Nappe, we observed large (up to 500 μm) monazite exhibiting distinct core-rim chemical zoning. From careful documentation of the microstructural phase relations, thermodynamic modeling, Raman spectroscopy of carbonaceous matter and in-situ LA-ICPMS U-(Th)-Pb dating of REE-epidote and monazite we show that rocks in all three localities were affected by LP metamorphism (0.3 – 0.4 GPa) during the Permian event (250 – 282 Ma) with peak temperatures decreasing from 560°C in the lower to 475°C in the upper nappe. During the Eo-Alpine event, overprinting at c. 90 Ma occurred under conditions of ~550°C and 1.0 – 1.1 GPa in the Waxenegg Nappe. At the base of the Schöckel Nappe, peak metamorphism at ~450 – 470°C and 0.4 – 0.7 GPa and cooling below 300°C likely took place before 110 Ma. Towards higher structural levels, only limited Eo-Alpine overprinting at low P-T conditions (<400°C, 0.3 – 0.5 GPa) is evident, thus the observed mineral assemblage reflects mostly Permian metamorphism.

Our results demonstrate that the main metamorphic signature in the Schöckel Nappe can be resolved as the Permian event and that the Eo-Alpine overprint is relatively lower grade than previously proposed. We observe a marked increase in Eo-Alpine peak conditions (~80 – 100°C, 0.3 – 0.5 GPa) across the nappe contact with higher grade rocks in the footwall compared to the hanging wall. The metamorphic pattern is consistent with the existence of a major normal fault between the Drauzug-Gurktal Nappe and Koralpe-Wölz Nappe systems in the easternmost part of the Austroalpine Unit, as already identified in its central and western parts. Finally, our study highlights that coupling modern thermobarometric analytical approaches with high spatial resolution geochronology on accessory minerals is critical to improve our understanding of the fundamentally important low-grade units of orogens.