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Pre-Alpine Metamorphism in Alpine low-grade metamorphic units in the Eastern Alps

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Pre-Alpine basement units, originating from the northern Gondwana margin, have been incorporated into the Austroalpine Nappe System and were overprinted during Alpine nappe stacking. Some of these units were only slightly affected by Alpine metamorphism, offering valuable insights into their pre-Alpine history. The Kaintaleck Metamorphic Complex, part of the Eastern Greywacke Zone, along with the Silvretta-Seckau Nappe System, underwent only greenschist facies metamorphism during Eo-Alpine times and thus still preserve Variscan or even pre-Variscan information within their mineralogical assemblages. To enhance our understanding of the pre-Alpine metamorphic evolution of the Eastern Alps, different basement units are being investigated by geochronological, geochemical and geothermobarometric techniques to reconstruct their pre-Alpine tectonic and metamorphic evolution.

The Kaintaleck Metamorphic Complex consists of a mafic suite, including amphibolite, garnet-amphibolite, greenschist, and serpentinite, and a felsic suite, primarily composed of gneiss and mica-schist, some of which are garnet-bearing. Geochemical analyses of the metabasites indicate a tholeiitic basalt source with MORB affinity. U-Pb zircon dating of a garnet-bearing amphibolite suggests an Early Devonian age (414 ± 5.6 Ma) of protolith formation. Chemical U-Th-Pb dating of monazites reveals Late Devonian to Early Carboniferous ages (362 ± 6 Ma, 358 ± 15 Ma, 351 ± 4 Ma, 349 ± 3 Ma), which represent peak metamorphic conditions during the Variscan orogeny. The Kaintaleck Metamorphic Complex underwent a two-stage metamorphic history, characterized by a HT/LP metamorphic event of ~ 600-700°C and ~ 0.5-0.7 GPa, followed by a LT/HP metamorphic event of ~ 550°C and ~1.7-2.2 GPa, inferred from Zr-in-rutile thermometry and thermodynamic modeling. This development is related to the opening and closure of the short-lived Balkan-Carpathian Ocean and also suggests a correlation with other Devonian-aged ophiolitic relics in the North-Gemeric Klatov and Rakovec Complexes in the Western Carpathians (Neubauer et al., 2022; Putiš et al., 2009).

The Seckau Complex, part of the Silvretta-Seckau Nappe System, is characterized by various metagranitoids, such as the Late Cambrian to Early Ordovician Hochreichart Plutonic Suite and the Late Devonian to Early Carboniferous Hintertal Plutonic Suite. These large intrusions are hosted by the Glaneck Metamorphic Suite, which is predominantly composed of garnet-bearing paragneiss and mica-schist, but also includes amphibolite and tschermakite-bearing gneiss, which might be of magmatic origin. U-Pb zircon dating of the paragneisses indicates a detrital origin, with age clusters in the Neoarchean, Paleoproterozoic, and Ediacaran, ranging from 2.7 Ga to 559 Ma (Mandl et al., 2018). A migmatized paragneiss yielded an age of 505 Ma, suggesting that migmatization was likely triggered by the intrusion of the Hochreichart Plutonic Suite. Thus, the timing of pre-Alpine metamorphism can be constrained between 559 Ma and 505 Ma. Most samples exhibit two-phase garnet growth with a strong increase in grossular towards the rim, indicating an additional metamorphic event, possibly during the Variscan orogeny. Preliminary results from conventional geothermobarometry and thermodynamic modeling for paragneisses and metapelites suggest metamorphic conditions of ~ 550°C and ~ 0.4-0.5 GPa for incipient garnet growth and ~ 570-620°C and ~1.1-1.2 GPa for garnet-rim compositions. Garnet-bearing amphibolites show quite homogeneous garnet-compositions with only a subtle increase in spessartine towards the core, revealing peak metamorphic conditions of ~ 680-720°C and ~ 1.1-1.2 GPa. Whole-rock geochemical data of amphibolites suggest a tholeiitic differentiation trend deriving from basaltic to andesitic protoliths. Trace element compositions indicate MORB and Within-Plate-Lava affinities.

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