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Not sexy, but still dateable: Unravelling the P-T-t-d evolution of low-grade Permian metasediments using xenotime geochronology (Austroalpine Unit, Eastern Alps)

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The Austroalpine Unit is a nappe stack formed by the accretion of Adria-derived material during the Late Jurassic to mid-Late Cretaceous. Its geological history is primarily recorded in upper crustal, non-metamorphic rocks and lower crustal, metamorphic rocks ranging from upper greenschist to eclogite facies. However, data from the ubiquitous mid-crustal, low-grade metamorphic units are either absent or difficult to interpret, complicating the connection between shallow and deep orogenic levels. We present new pressure-temperature-time-deformation data for the Permian Präbichl Formation, sampled in the Tirolic-Noric Nappe System (TNNS) below the overlying Juvavic Nappe System (JNS) at two localities. The formation consists of lower greenschist facies clastic sediments, corresponding to the Permian cover of the pre-Variscan basement.

The metamorphic assemblage contains chloritoid + muscovite ± pyrophyllite + hematite + rutile + quartz. Phase equilibrium calculations and Raman spectroscopy on carbonaceous material indicate peak P-T conditions of ~350°C and 0.4-0.5 GPa. In both samples, xenotime crystals (10 to 30 µm) exhibit systematic chemical zoning with heterogeneous cores and MREE-rich rim. We targeted each chemical domain by in-situ LA-ICP-MS U-Pb dating. The concordant U-Pb dates from the cores range between 632 Ma and 250 Ma, likely reflecting inherited grains. Younger dates were obtained from the xenotime rims. In the eastern sample (Noric Nappe), a concordant cluster yields a weighted mean age of 133.6 ± 2.8 Ma (MSWD: 1.7, n: 14). Host-inclusion relationships between chloritoid and xenotime suggest simultaneous growth of the xenotime rim and chloritoid porphyroblasts, linking the U-Pb age to the formation of the main metamorphic assemblage. An additional set of discordant analyses provides an anchored discordia age of 91.5 ± 3.6 Ma (MSWD: 1.2, n: 7). In the western sample (Staufen-Höllengebirge Nappe), a set of concordant and discordant analyses yield an anchored age of 90.1 ± 1.4 Ma (MSWD: 1.8, n: 16). Xenotime and chloritoid are not in direct contact but their relationship is constrained by microstructures. This sample is characterized by pervasive crenulation cleavage that postdates chloritoid growth. The distribution and morphology of xenotime suggest that post-peak dissolution-precipitation related to crenulation cleavage formation facilitated xenotime rim growth.

These results have two significant implications. Firstly, the 133.6 ± 2.8 Ma date coincides with the age of the latest syn-orogenic sediments overthrusted by the Juvavic Dachstein Nappe. It is therefore, interpreted as the age of peak metamorphism following the cessation of JNS thrusting over the TNNS. The peak pressure of 0.4-0.5 GPa at this time corresponds to an overburden of ~17 km. This may imply the existence of a missing unit, given the present-day thickness of the JNS is 5-10 km. Secondly, the 90-92 Ma dates correspond to the onset of post-orogenic sedimentation in the Gosau basins overlying both the TNNS and JNS and the exhumation of the Austroalpine eclogites, indicating a major shift in orogenic dynamics at that time.

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