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Serpentinization as a tape-recorder of mantle exhumation: the example of the Alpine Tethys rifted margins

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Serpentinization is a major hydrothermal process that affects the lithospheric mantle, modifying its rheology and facilitating its exhumation at the seafloor. Serpentinization also plays a key role in mass-fluxes enhanced by multiple fluid-rock interactions that ultimately lead to the formation of hydrothermal mineralization and natural H_2 production. Although hydrothermal alteration of mantle peridotites has been extensively documented at (ultra)-slow spreading mid-ocean ridges (MOR) over the last two decades, it remains poorly understood at magma-poor rifted margins. However, at these settings, the mineralogy (and consequently the chemical composition) of subcontinental mantle peridotites differs from that at MOR, which may affect serpentinization pathways. Because serpentinite is the main rock composing the exhumed mantle at the Ocean-Continent Transition (OCT), its study is a prerequisite for understanding of how fluids percolate into the mantle and how serpentinization contributes to the final rifting and early seafloor spreading.

For this purpose, we investigated serpentinites from well-preserved remnants of an ancient Alpine Tethys OCT now exposed in the Swiss Alps. By coupling textural investigations, Raman spectroscopy and in-situ major and trace element analyses, five distinct generations of serpentine were identified: lizardite mesh and bastite (S1) → polyhedral serpentine veins (S2) → chrysotile/polygonal serpentine/lizardite banded veins (S3) → antigorite veins (S4) → chrysotile crack seals (S5). This serpentine paragenesis recorded different tectonic events and changes of serpentinization pressure and temperature that were caused by the progressive mantle unroofing from depth ~6 km to the seafloor.

Serpentinization near the continent (i.e., the proximal OCT domain) differs from toward the ocean (i.e., the distal OCT domain). At proximal domain, the exhumed mantle recorded the complete history of hydrothermal alteration, highlighting a continuous footwall exhumation process along a large detachment fault. In contrast, serpentinites at a more distal position lack most serpentine generations, attesting to a discontinuous mantle exhumation process along flip-flop detachment faults. These interpretations may account for serpentinization at MOR settings, where serpentinites are largely dominated by a mesh texture crosscut by crack-seals. However, where detachment faults remain active for at least hundreds of thousands of years (e.g., Kane Fracture Zone, Atlantis massif), a full serpentinization paragenesis is observed.