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Fluid circulation in the Troodos supra-subduction zone, Cyprus: preliminary insights from fluid inclusions, trace elements, and stable and radiogenic isotopes

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The Troodos supra-subduction zone ophiolite exposes a complete and well-preserved section through ca. 92 Ma old oceanic lithosphere and provides insights into a predominantly fracture-initiated fossil fluid circulation system. Most previous studies on secondary mineralization of the Troodos pillow lavas focused on mineralogy and stable isotope compositions but lack any structural information on vein mineral growth and further geochemical data. Here we present a multidisciplinary approach comprising fluid inclusion microthermometry, cathodoluminescence microscopy, and trace element, stable (O and C) and radiogenic (Sr) isotope geochemistry of calcite, quartz, and zeolite veins from the Upper and Lower Pillow Lavas. These veins have the potential to record the structural and geochemical post-magmatic evolution of the Troodos supra-subduction zone.

Microtextures from blocky and syntaxial veins indicate hydro- and extensional fracturing, respectively, while antitaxial veins are related to diffusion-crystallization processes. Oxygen and carbon isotopes of most calcite veins point to precipitation from seawater in an open system until late-stage precipitates associated with geochemical self-organization sealed fluid channels completely. Low 87Sr/86Sr ratio (0.70613) and elevated trace element contents (e.g., Li, Sc, Y, Pb) that infer a host rock-modified seawater signature represent a subordinate feature.

Based on aqueous fluid inclusion chemistry with seawater salinities, representative fluid isochores crossed with a minimum hydrostatic pressure of 250 bar yield mineral formation temperatures between 180 and 210 °C. This implies that veining of the Upper and Lower Pillow Lavas occurred shortly after host rock solidification. Matching of the 87Sr/86Sr ratio of an antitaxial calcite vein (0.70781) with the marine Sr isotope curve results in a precipitation age of 35 or 65±2 Ma and emplaces vein formation before Miocene uplift.

The widespread occurrence of decrepitated fluid inclusion textures independently of mineral and vein type in conjunction with steep fluid isochores suggests a Troodos-wide isobaric cooling event that initiated with the precipitation of late-stage calcite at 150 to 170 °C and ceased with the decrepitation of fluid inclusions. Blocky calcite veins from the Lower Pillow Lavas display an oxygen isotopic zonation (-10 to -22 ‰ PDB) that coincides with Mn-/decrepitation-rich growth patterns. This is interpreted as partial oxygen isotopic re-equilibration. Thus, fluid inclusion decrepitation caused crystal defects and generated microscale fluid paths. Cool seawater penetrated these paths, healed the crystal, and reset the oxygen isotope composition.