Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.18330

Dating the migration of high-pressure H_2-/CH_4-bearing fluids in subduction zones

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The production of deep H_2-/CH_4-bearing fluids in subduction zones has far-reaching implications on the habitability of a tectonically active planet. The existence of life's ingredients at depth is allegedly made possible by such a process (Vitale Brovarone et al. 2020, Nat. Comm.). High-pressure serpentinization may represent a major source of these reduced fluids at convergent margins. Microstructural and geochemical constraints are viable tools to distinguish between seafloor and HP serpentinization. However, these do not provide absolute time constraints, and their interpretation is not always unequivocal. Absolute geochronology allows us to pinpoint mineral reactions within the geodynamic evolution of a subduction zone. Although previous work has successfully dated serpentinization (e.g., Cooperdock and Stockli 2016, GEOLOGY), direct dating of the production of fluids has been a long-lived challenge. Nevertheless, the production of H_2-/CH_4-bearing fluids in subduction can also be dated indirectly: for example, by using geochronometers including, or associated with, by-products of fluid circulation (e.g., Piccoli et al. 2023, Chem.Geol.).

We applied LA-ICP-MS U–Pb geochronology of epidote and titanite in mafic rocks (Belvidere Mountain complex, Vermont, USA) and jadeitites (Guatemala). These lithologies are related to, or affected by, high-pressure serpentinization via the influx of fluids produced during such a process. Epidote and titanite in these rocks are associated with graphite and/or contain C-H-bearing fluid inclusions, as identified by Raman micro-spectroscopy. Epidote U–Pb ages (272 ± 161 Ma) indicate circulation of H_2-/CH_4-bearing fluids as products of serpentinization during subduction – rather than seafloor stages – in the Belvidere Mountain complex, in agreement with literature data (Boutier et al. 2021, Lithos). The U–Pb age (71.8 ± 4.1 Ma) of titanite in a Guatemalan jadeitite confirms the production and circulation of H_2-/CH_4-bearing fluids in the mantle wedge above subduction zones, which may have been channelized by jadeitites (see e.g., Angiboust et al. 2020, JMG).

Our work shows the great potential of the application of absolute geochronology to fleeting processes which leave little datable evidence, such as ancient fluid production.