

Dating mineral fluid inclusions: The $^{40}\text{Ar}/^{39}\text{Ar}$ crushing technique

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Metamorphic minerals and veins trap fluids in fluid inclusions. When sufficiently saline, dissolved KCl in the inclusions over time will produce radiogenic ^{40}Ar by radioactive decay, potentially allowing the dating of fluid incorporation by the K/Ar system. Whilst primary fluid inclusions (PFIs) can date fluid incorporation during mineral or vein growth, secondary fluid inclusions (SFIs) can provide age constraints on subsequent fluid flow events.

At VU Amsterdam, a new in-vacuo crushing apparatus has been designed to determine the $^{40}\text{Ar}/^{39}\text{Ar}$ age of fluid inclusions. Mineral separates are crushed inside a crusher tube connected to mass spectrometry. In-vacuo crushing is achieved by lifting and dropping a steel pestle on the separates using an externally controlled electromagnet. Stepwise crushing is achieved by increasing the number of crushing strokes for each analysis, progressively sampling smaller inclusions whilst reducing a sample's grain size. Finally, a stepwise heating experiment can be conducted on the crushed powder by inserting the crusher tube in an externally controlled tube furnace.

Garnet, glaucophane, clinopyroxene, epidote and actinolite from different samples from the high pressure (HP) metamorphic Cycladic Blueschist Unit in Greece were crushed stepwise to obtain fluid inclusion ages. The initial steps for all experiments yield excess argon, interpreted to originate from grain boundary fluids and SFIs. During subsequent crushing steps, age results stabilise to a plateau age, or, when excess argon is present, an isochron age, derived from PFIs interpreted to record mineral growth. Resulting ages for garnet from different rocks of the CBU overlap either with the age of garnet growth during eclogite metamorphism (55-50 Ma) or with the age of greenschist overprinting (25-30 Ma), thus indicating two distinct phases of garnet growth for different subunits of the CBU. Garnet Lu/Hf and Sm/Nd dating on the same samples will reveal whether the obtained ages reflect the age of garnet growth.

The stepwise crushing approach shows promise as an effective tool for dating primary fluid inclusions in minerals. Especially in HP metamorphic rocks, where phengite commonly is the only potassium bearing phase but often yields ambiguous results, the method greatly expands our possibilities to date metamorphic processes.