

Dating mineral growth by $^{40}\text{Ar}/^{39}\text{Ar}$ age determination of fluid inclusions using stepwise crushing *in-vacuo*

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

At VU Amsterdam, a new *in-vacuo* crushing apparatus has been designed to extract fluid inclusions from minerals for $^{40}\text{Ar}/^{39}\text{Ar}$ analysis. Separates are crushed inside a crusher tube connected to a purification line and a quadrupole mass spectrometer. *In-vacuo* crushing is achieved by lifting and dropping a steel pestle using an externally controlled magnetic field. Stepwise crushing is achieved by increasing the amount of crushing strokes on a separate for each analysis, progressively sampling smaller inclusions while 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 and epidote from different samples from the HP metamorphic Cycladic Blueschist Unit in Greece were stepwise crushed to obtain fluid inclusion ages. Initial steps for all experiments yield significant components of excess argon, interpreted to originate from grain boundary fluids and SFI's. During subsequent crushing steps, age results stabilize to a plateau age, or isochron age when excess argon is present, which is interpreted to reflect the age of smaller PFI's. 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), possibly indicating two distinct phases of garnet growth for different subunits of the CBU.

The stepwise crushing and heating approach shows to be effective in dating primary fluid inclusions in natural mineral systems. As many metamorphic processes occur under influence or in the presence of fluids, the method should greatly expand our possibilities to date crustal processes.