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Direct 40Ar/39Ar age determination of fluid inclusions using in-vacuo¬ stepwise crushing - Example of garnet from the Cycladic Blueschist Unit on Syros

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Metamorphic minerals and veins commonly trap attending hydrous fluids in fluid inclusions, which yield a wealth of information on the history of the hosting metamorphic system. When these fluids are sufficiently saline, the KCl in the inclusions can be used as a K/Ar geochronologic system, potentially dating inclusion incorporation. Whilst primary fluid inclusions (PFIs) can date fluid incorporation during mineral or vein growth, secondary fluid inclusion trails (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 40Ar/39Ar 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. As the gas can be analyzed between different crushing steps, the setup permits stepwise crushing experiments. Additionally, crushed powder can be heated by inserting the crusher tube in an externally controlled furnace.

Dating by 40Ar/39Ar stepwise crushing has the added advantage that, during neutron irradiation to produce 39Ar from 39K, 38Ar and 37Ar are also produced from 38Cl and 40Ca, respectively. Simultaneous analysis of these argon isotopes permits constraining the chemistry of the argon source sampled during the experiment. This allows a distinction between different fluid or crystal lattice sources.

Garnet from three samples of the HP metamorphic Cycladic Blueschist Unit on Syros, Greece was stepwise crushed to obtain fluid inclusion ages. Initial steps for all three experiments yield significant components of excess argon, which are interpreted to originate from grain boundary fluids and secondary fluid inclusions trails. During subsequent steps, age results stabilize to a plateau age. One garnet from North Syros yields an unusually old ∼80 Ma plateau age. However, isochrons indicate the presence of excess argon in the PFIs and isochron ages overlap with other isotopic constraints on the age of garnet growth during eclogite metamorphism (55-50 Ma) in the underlying metabasite. Garnet from two samples from the center of Syros yields younger ages overlapping with greenschist overprinting (25-30 Ma). Further studies will indicate whether these younger ages reflect a young garnet growth age or a young fluid flow event affecting older garnet crystals.

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