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Microstructures and Argon age dating

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Microstructures can be dated using 40Ar/39Ar geochronology, but certain conditions apply. In particular the nature of the physical processes that took place during development of need be identified, and the pattern of gas release (and/or retention) during their evolution in nature, and subsequently in the mass spectrometer, during the measurement process.

Most researchers cite temperature as the sole variable of importance. There is a belief that there is a single “closure temperature” or a “closure interval” above which the mineral is incapable of retaining radiogenic argon. This is a false conception. Closure is practically relevant only in circumstances that see a rock cooled relatively rapidly from temperatures that were high enough to prevent significant accumulation of radiogenic argon, to temperatures below which there is insignificant loss of radiogenic argon through the remainder of the geological history. These conditions accurately apply only to a limited subset - for example to rocks that cool rapidly from a melt and thereafter remain at or close to the Earth’s surface, without subsequent ingress of fluids that would cause alteration and modification of microstructure. Some minerals in metamorphic rocks might display such “cooling ages” but in principle these data are difficult to interpret since they depend on the rate of cooling, the pressures that applied, and the subsequent geological history.

Whereas the science of “cooling ages” is relatively well understood, the science of the Argon Partial Retention Zone is in its infancy. In the Argon PRZ it is evident that ages should (and do) show a strong correlation with microstructure. The difficulty is that, since diffusion of Argon is simultaneously multi-path and multi-scale, it is difficult to directly interrogate the distinct reservoirs that store gas populations and thus the age information that can be recorded as to the multiple events during the history of an individual microstructure. Laser methods invariably record mixing ages, since the spot sizes are large. Carefully designed furnace step-heating experiments on the other hand seem well capable of sequentially extracting ages from different microstructural reservoirs, and this can be tested by comparing samples with different proportions of these microstructures.

Here we examine the role of microstructure in Argon ‘age dating’ by comparing and contrasting observed measurements with theoretical predictions developed on the basis of modelling and simulation of the effects of multi-path and multi-scale diffusion. We analyse these results in the context of microstructures observed in white micas and K-feldspar, at both the scale of the optical microscope as well as utilising electron microscopy. Examples from three different tectonic settings will be provided to illustrate the effect of the different variables that apply: a) the extensional South Cyclades Shear Zone, Greece; b) granitoids exhumed from ultra-high-pressures in the Dora Maira, Italy; and c) leucogranites shed from the Ladakh Batholith into the Indus Formation, NW India.