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Constraining fluid-rock alteration and temperature history using multi-mineral argon spectra and conjoint T–t-Δ inversion

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Metamorphic rocks record the imprint of the tectonic processes that shaped the lithosphere and record the effects of their journey through time and space. The record can be interrogated by using a number of different geochronological techniques. The $^{40}Ar/^{39}Ar$ geochronology method is particular useful when it comes to extracting information from the major rock-forming minerals such as mica and feldspar, commonly filling the temporal gap between the ages obtained by U–Pb dating of accessory minerals and the application of low-temperature thermochronometers. Here we present a case study illustrating a novel and innovative way to investigate metamorphic processes across tectonic settings and geologic time, involving metamorphic petrology, geochronology, geochemistry, numerical modelling and tectonics.

The method involves quantitative modelling of $^{40}Ar/^{39}Ar$ age spectrum morphologies, constrained by conjointly using information from white mica, biotite and potassium feldspar from a single Proterozoic gneiss. Temperature-controlled step-heating diffusion experiments provide estimates of the relevant diffusion parameters using Multi-Domain Diffusion (MDD) models to invert Arrhenius data. Computer modelling and simulation then allows the production of admissible temperature-time paths for all three minerals used in this study, allowing the identification of previously unrecognised episodes of mineral growth and/or periods of cryptic metasomatism. In this way, $^{40}Ar/^{39}Ar$ geochronology enables estimates for the timing of a sequence of mineral growth events and the veriation of ambient temperature through time.

Two examples are provided from Palaeoproterozoic gneisses from northern Australia. Typically, the morphology of each age spectrum (for biotite, white mica, and potassium feldspar) required a minimal two-component microstructure to explain the mixing pattern. In each mineral, a MDD model is needed to explain the pattern of gas release during furnace step-heating. Estimates of the diffusion parameters using the Arrhenius data allow the inference that both phengite-poorer muscovite and phengite-richer muscovite existed in the white mica aliquot. Quantitative modelling of the age spectrum morphology allowed constraints to be placed on possible temperature-time-

growth (T-t-Δ) paths followed by the rock sample in the natural environment, spanning a duration of more than a billion years.