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Hot when wet: the consequences of exothermic hydration on geochronology

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Retrogression and hydration commonly affect large portions of the crust, causing variable degrees of chloritization, sericitization and/or serpentinization depending on the protolith and the conditions of fluid ingression. Retrograde overprint involving hydration is a strongly exothermic process, and leads to a thermal perturbation around the pressure–temperature conditions of hydration, which in the case of chloritization of felsic rocks typically occurs at <500°C. These conditions of retrogression overlap with the closure temperatures of some isotopic systems commonly used for geochronology, for example $^{40}Ar/^{39}Ar$ in micas and feldspars. The exothermicity of hydration therefore disturbs the recorded apparent ages and cooling histories of reworked terranes. Using an average metapelite composition as case study, we estimate that hydration and retrogression of a high-grade amphibolite facies assemblage to a low-grade greenschist paragenesis involves approximately a twofold increase of the mineral-bound water content and releases about 50 $kJ.kg^{-1}$ latent heat. Using a simple 1-dimensional numerical model, we solve the heat equation for a steady-state continental geotherm that is advected towards the surface and track the cooling rates for markers that exhume from different depths. Assuming enthalpy production at 380°C to simulate exothermic hydration, the cooling rate is significantly reduced until the markers are exhumed to the temperature/depth of hydration and reaction. The calculated cooling paths feed into KADMOS (Moulas & Brandon, 2022), a set of MATLAB routines designed to calculate apparent $^{40}Ar/^{39}Ar$ ages as function of customized thermal histories. KADMOS solves the equation of ^{40}Ar production from ^{40}K decay and thermally-activated diffusive loss of ^{40}Ar for time (Fig. 1). Our results reveal that for intermediate exhumation rates, spherical muscovite grains with <100 μm in diameter are affected by a ~10% age error when latent heat is considered (Fig. 1b). Such muscovites in rocks exhuming with a velocity of, for example, 4 mm/year would record an apparent $^{40}Ar/^{39}Ar$ age of c. 10 Ma (Fig. 1a) and be affected by an absolute age error of ~1 Ma from thermal buffering by hydration, yielding an apparent age of 10 ± 1 Ma (Fig. 1b). Our calculations indicate that latent heat released from exothermic hydration may significantly disturb low-temperature isotopic systems, thereby complicating the cooling histories and obscuring the temporal constraints deduced from state-of-the-art geochronological systems.

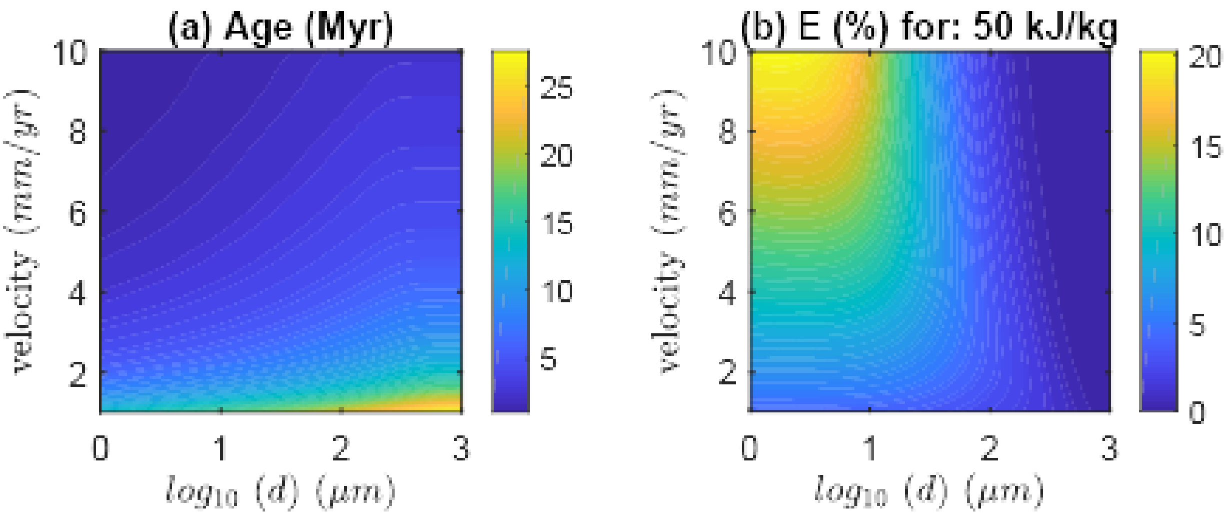

Figure 1 – Exhumation velocity vs. grainsize contoured for apparent $^{40}Ar/^{39}Ar$ age in muscovite (a) and relative error when latent heat is considered (b)

REFERENCES

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