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The single grain fusion dating approach: Determining the factors that control white mica 40Ar/39Ar age formation during HP metamorphism of the Cycladic Blueschist Unit, Greece

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White mica 40Ar/39Ar dating is a proven powerful tool for constraining the timing and rate of metamorphism, deformation and exhumation. However, for high-pressure metamorphic rocks dating often results in wide age ranges, which are not in agreement with constraints from other isotopic systems, indicating that geological and chemical processes complicate straightforward 40Ar/39Ar dating.

Despite hosting one of the largest geochronological datasets in the world, the Cycladic Blueschist Unit in Greece is presently one of the focal areas in the discussion on the interpretation of metamorphic 40Ar/39Ar ages. Previous phengite multi grain step heating experiments commonly yielded undulating age spectra ranging between 20 – 60 Ma. While some studies attempt to assign geological significance to these ages, others argue the ages are geologically meaningless and the result of the interplay between partial diffusive resetting and continued crystallization.

By taking an alternative approach of multiple single grain fusion experiments, this study investigates age heterogeneity between samples of contrasting metamorphic facies, rheology and strain from the Cycladic islands of Syros and Sifnos. Comparing the size and shape of single grain fusion age distributions at the grain, rock, outcrop and island scale allows determination of the scale at which different age-forming processes operate.

Resulting ages show a previously unreported consistent variation between different outcrops, moving from the eclogite-blueschist facies (55-45 Ma) to greenschist overprinting (40-30 Ma). This indicates that outcrop scale homogeneous resetting is the dominant processes for age formation in the CBU. Single grain age variation at the sample and outcrop scale is only limited to $\sim$10 Ma, indicating a smaller but observable role for local age perturbing processes of incomplete resetting, continued (re)crystallization or infiltration of excess argon. Some of the partially overprinted samples show homogeneous single grain age populations, indicating at least a partial role for efficient resetting by thermally activated diffusion at the outcrop scale.

Traditional multi grain step heating experiments on the same samples yield flat plateaus for various single grain age distributions, indicating that age heterogeneities resolved by single grain fusion dating are mixed to a meaningless average in step heating experiments. In contrast, our approach leads to a better understanding of the processes responsible for age formation during high pressure metamorphism.