Microstructural shear bands in mylonites dated using muscovite sub-spectra from high-definition ultra-high-vacuum (UHV) argon diffusion experiments with phengitic white mica

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With excellent outcrop, the eclogite-blueschist belt exposed in the Cycladic archipelago in the Aegean Sea, Greece, offers a spectacular natural laboratory in which to decipher the structural geology of a highly extended orogenic belt and to ascertain the history of the different fabrics and microstructures that can be observed. Using phengitic white mica we demonstrate a robust correlation of age with microstructure, once again dispelling the myth that \(^{40}\text{Ar}/^{39}\text{Ar}\) geochronology using this mineral, produces cooling ages alone.

Further, we show that high-definition ultra-high-vacuum (UHV) \(^{39}\text{Ar}\) diffusion experiments using phengitic white mica routinely allow the extraction of muscovite sub-spectra in the first 10-30\% of \(^{39}\text{Ar}\) gas release during \(^{40}\text{Ar}/^{39}\text{Ar}\) geochronology. The muscovite sub-spectrum is distinct and separate to the main spectrum which is dominated by mixing of gas released from phengite as well as muscovite. The muscovite sub-spectra allow consistent estimates of the timing of the formation of microstructural shear bands in various mylonites, as well as allowing quantitative estimates of temperature variation with time during the cooling history of the eclogite-blueschist belt. Our new data reveals hitherto unsuspected variation in the timing of exhumation of individual slices of the eclogite-blueschist belt, caused by Eocene and Miocene detachment-related shear zones.

This study thus illustrates a new method for the quantitative determination of the timing of movement in mylonites and/or in strongly stretched metamorphic tectonites. Shear bands formed in such structures are rarely coarsely crystalline enough to allow mineral grains that can be individually dated using laser spot analysis. Where phengitic white mica is involved, interlaying is usually so fine as to preclude the application of laser methods. In any case, laser methods do not have the capability of extracting exact and detailed age-temperature spectra, and can never achieve the definition of the multitudinous steps of the age spectrum evident from our high-definition UHV diffusion experiments.

Previous work in the Cycladic eclogite-blueschist belt has incorrectly assumed that the diffusion parameters for phengitic white mica were the same as for muscovite. Arrhenius data suggest this is not the case, and that phengitic white mica is considerably more retentive of argon than
muscovite. Previous workers have also erred in dismissing microstructural variation in age as an artefact, supposedly as the result of the incorporation of excess argon. This has led to inconsistencies in interpretation, because phengite is able to retain argon at temperatures that exceed those estimated using metamorphic mineral parageneses. In consequence, we discover a robust correlation between microstructure and age, even down to the detail present in complex tectonic sequence diagrams produced during fabric and microstructural analysis of individual thin-sections.

A critical factor is that the recognition of muscovite sub-spectra requires Arrhenius data in order to recognise the steps dominated by release of $^{39}$Ar from muscovite. In turn this requires precise measurement of temperature during each heating step. To apply percentage-release formula for the estimation of diffusivity, there must be a sharp rise to the temperature in question, then that temperature must be maintained at a constant value, then dropped sharply to relatively low values.