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How and when does argon redistribute during a metamorphic cycle?

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Linking metamorphic 'age' to metamorphic 'stage' is critical for accurately determining the rates and timescales of tectonic processes. 40Ar/39Ar ages of high temperature metamorphic minerals are commonly interpreted under the assumption that 40Ar produced by the decay of 40K is efficiently removed via thermally-driven diffusion at temperatures greater than the mineral 'closure temperature'. An increasing amount of age-dispersed total fusion and laser-ablation in-situ data suggests, however, that an open grain boundary system may be the exception rather than the norm during a metamorphic cycle. The Western Gneiss Region, Norway, exposes felsic gneisses that record the burial and exhumation of Baltican continental crust beneath Laurentia at ca 420-390 Ma. These gneisses record different stages of the breakdown and neo-crystallisation of K-bearing minerals; their 40Ar/39Ar ages allow the effect of processes such as diffusion, deformation, crystallization and partial melting on Ar mobility to be assessed. White mica, stable at peak metamorphic conditions of >2.6 GPa and 700°C yields total fusion and laser spot 40Ar/39Ar ages that are mostly older than and overlap the previously reported ∼405-400 Ma 'peak metamorphic' U-Pb zircon age. Biotite and plagioclase that replace the white mica in symplectitic coronas, yield total fusion and laser spot 40Ar/39Ar ages that are overall younger than the white mica ages but that overlap previously reported U-Pb titanite ages interpreted as constraining the timing of the amphibolite-facies overprint at 1 GPa and 700°C. The new 40Ar/39Ar ages therefore cannot be reconciled with a simple diffusive-loss history in an open system. Instead, recrystallization, partial melting and fluid infiltration (but significantly, not deformation) appear to have played a more major role in both removing but also adding Ar from and to the local system. Overall, the data show that even when rocks experience T>700°C for several Ma, Ar may not readily diffuse out of mica. Instead, the data suggest that changes in age populations in samples that record different metamorphic and microstructural stages yield information about Ar production, storage, (re)cycling and removal during a metamorphic cycle. Each sample needs careful investigation in order to robustly link 40Ar/39Ar age to metamorphic stage and thus provide useful constraints on the rates and timescales of tectonic processes.