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40Ar/39Ar mica ages from marble mylonites: a cautionary tale

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40Ar/39Ar geochronology on white mica is a popular method to date deformation under moderate (brittle-ductile) temperatures. In particular, deformation events preserved in greenschist facies shear zones have been successfully dated with this method. A consequence of strain localization in many tectonic settings that bear calcitic marbles is the formation of marble mylonites and ultramylonites. Little is known, however, about the behaviour of the K/Ar systems and the influence of deformation on the ages in such rocks.

We studied an extremely localized shear zone (2 cm thick) in marble from Syros (Cyclades, Greece) and performed microstructural, chemical and isotopic analysis on samples from the host rock and the shear zone. The host rock is composed of coarse-grained (300 μm) calcite with only minor undulatory extinction and slightly curved grain boundaries. This initial large grain size is likely to have formed during the Eocene high-pressure – low-temperature event that is well documented in the Cyclades. In contrast, the marble within the shear zone shows evidence of strong intracrystalline deformation and recrystallization resulting in grain size reduction and the formation of an ultramylonite. Both microstructures and kinematics are consistent with the low grade evolution described on Syros. White mica (100's microns in size) are preferentially orientated parallel to the foliation. In both samples there is no clear evidence for crystal plastic deformation of the mica grains. Bigger grains behave brittle resulting in grain size reduction. A deformation mechanism map for calcite at 300 °C indicates that the host rock deformed at strain rates of around 10-12.5 s-1 whereas within the shear zone strain rates of up to 10-9.5 s-1 are attained.

We performed laser-heating 40Ar/39Ar analysis on white mica located in the host rock and the shear zone. The low-strain host rock yielded a ca. 40 Ma age, and the shear zone recorded a ca. 37 Ma age; both ages are statistically indistinguishable when errors are considered. These dates correspond to the regional Eocene high-pressure – low-temperature event and not the later low grade deformation event that is responsible for the formation of the studied shear zone. Although the marble within the shear zone was deformed at extremely fast strain rates, we observe no resetting in the isotopic system. Moreover, mineral chemistry demonstrates that (1) white mica is homogeneous and (2) there is no compositional difference between the host rock and the shear zone. This is in agreement with thermodynamical modelling, which indicates that the observed assemblage (calcite + dolomite + quartz + white mica) is stable without any composition change along the pressure-temperature path followed by the metamorphic rocks of Syros. Our case study emphasizes it is not the amount of strain the rock suffered but the degree of mica recrystallization that is important for resetting of the K/Ar system at low temperatures.