Dating deformation: multichronometric examples from the Western Alps, Naxos, and the Garhwal Himalaya

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In the eclogite facies shear zone of Bottarello, Monte Rosa, Western Alps [1], fault recrystallization around 600 °C gives concordant Lu-Hf (garnet) and 39Ar-40Ar (white mica, WM) 47 Ma ages whereas <100 m from the fault the unsheared rock at the same T preserves Mesozoic inheritance. The Ar retentivity of WM is not accurately predicted by hydrothermal laboratory experiments, because the latter are plagued by massive dissolution artefacts [2]. Independent field observations confirm that WM only starts losing Ar in dry rocks above 600 °C [3-8], but when retrograde reactions occur, WM can recrystallize and be totally reset below 230 °C [9]. The Bottarello fault obliterated all relict WM from the protolith; the neoformed WM records its own formation age.

The island of Naxos (Cyclades, Greece) is the classic example of multiple, coexisting WM generations [10]: relict pre-eclogitic basement WM, and eclogitic phengite retrograded to muscovite. Electron microprobe element maps demonstrate intergrowths at a scale <5 µm, which makes laser microprobe dating useless. Bulk mica dissolution for Rb-Sr gives Eocene ages [11], which agree with bulk K-Ar ages. This is paradoxical, as Ar diffusivity is c. 4 orders of magnitude higher than that of Sr [12]; the only explanation is that both chronometric systems record formation ages around 500-600 °C. The WM generations can be unravelled by their Ca/Cl/K signatures; coarse and fine sieve fractions are never isomineralic. Ages of pure mica generations are obtained by extrapolating Ca/Cl/K-vs-age trends.

The in-sequence thrusts of the Garhwal Himalaya add one complication: thrusting was long-lived. Microstructures combined with chemical microanalysis distinguish three monazite generations (dated by U-Pb) and three WM generations: relics in microlithons, foliation-defining mica, and static coronas. As in the previous examples, intergrowths are <<10 µm and only combining Ca/Cl/K systematics with the observed differences in structural breakdown temperatures can assign the different WM ages in the same sample to chemically distinct generations [13]. WM formation ages overlap with Mnz ages and date the onset of faulting, the kinematic peak, and the post-faulting corona formation.

There is no free lunch: dating deformation is extremely labor-intensive and requires, always, establishing the context between microtextural, microchemical, petrological and multichronometric analyses. Whenever one of these four is missing, the tectonic reconstruction is
invariably faulty [14].