Cyclic brittle-ductile behaviour recorded in exhuming high-pressure continental units of the Northern Apennines.

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Exhumation of subducted high-pressure units is favoured by relatively narrow, high-strain shear zones, where most metamorphic and deformational processes occur. Unfortunately, these are commonly overprinted and/or partly or fully obliterated along the exhumation path by younger fabrics or by metamorphic re-equilibration. Their identification and characterization are, therefore, of primary importance when aiming at reconstructing the deepest (and thus earliest) tectonometamorphic history of high-pressure crustal units.

The Northern Apennines (Italy) offer the opportunity to study a unique setting where continental units (Tuscan Metamorphic Units) were subducted to high-pressure conditions and then exhumed and juxtaposed against non-metamorphic units (Tuscan Nappe). We have studied a well exposed section in the Monticiano-Roccastrada Unit of the Mid Tuscan Ridge (MTR), where a mesoscopic (~20 m length and 5 m high) compressional duplex deforms the Palaeozoic-Triassic quartz-rich metasandstones, metaconglomerates and minor metapelites of the Monte Quoio - Montagnola Senese Unit with a top-to-the-NE sense of shear (Arenarie di Poggio al Carpino Formation; Casini et al., 2007).

Our approach is based on detailed fieldwork, microstructural and petrological investigations. Field observations reveal severe strain partitioning within the duplex between metapelite levels, corresponding to 10-50 cm thick high-strain zones, and metasandstone levels, which form relatively strain-free metric horses. Early generations of quartz veins are highly transposed (sheath folds occur) parallel to the metapelitic high-strain shear zones. Veins are composed of iso-oriented quartz, forming up to several centimetre long single-grain ribbons, Mg-carpholite (X\text{Mg}~0.65) needles and K-white mica marking the stretching lineation. Carpholite in the transposed veins invariably defines the stretching direction of shear zones. These high-P veins coexist with a later generation of less deformed, oblique quartz veins. The mylonitic foliation in the metapelites is defined by quartz, chloritoid, pyrophyllite and K-white mica forming a stretching lineation coherent with the one visible in the veins. Geometrical, cross-cutting and petrographic relations suggest that there has occurred cyclic deformation between brittle and viscous conditions, with the veins forming broadly syn-mylonitic shearing. Thermodynamic modeling results suggest >0.8 GPa and ~350°C for the formation of both the high-pressure veins and the mylonitic foliation.

Shear zones were subsequently folded about the NNW-SSE axis of the regional antiform
associated with the MTR. Later brittle overprinting is represented by quart-filled tension gashes and localized C’ planes, mostly within the more competent metasandstone levels, indicating top-to-the-SW reactivation. In summary, our results suggest a cyclic brittle-ductile behaviour occurring at high pressure conditions. This could potentially reflect the repeated alternation between aseismic creep (viscous) and coseismic slip (brittle) during the first stages of the exhumation history of this portion of the northern Apennines, from lower to middle crustal levels in a compressional top-to-the-NE setting. Dating of K-white mica is ongoing to constrain the geodynamic scenario of such shear zone.