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

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INTRODUCTION AND GEOLOGICAL SETTING

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[1] (Tuscan Nappe).

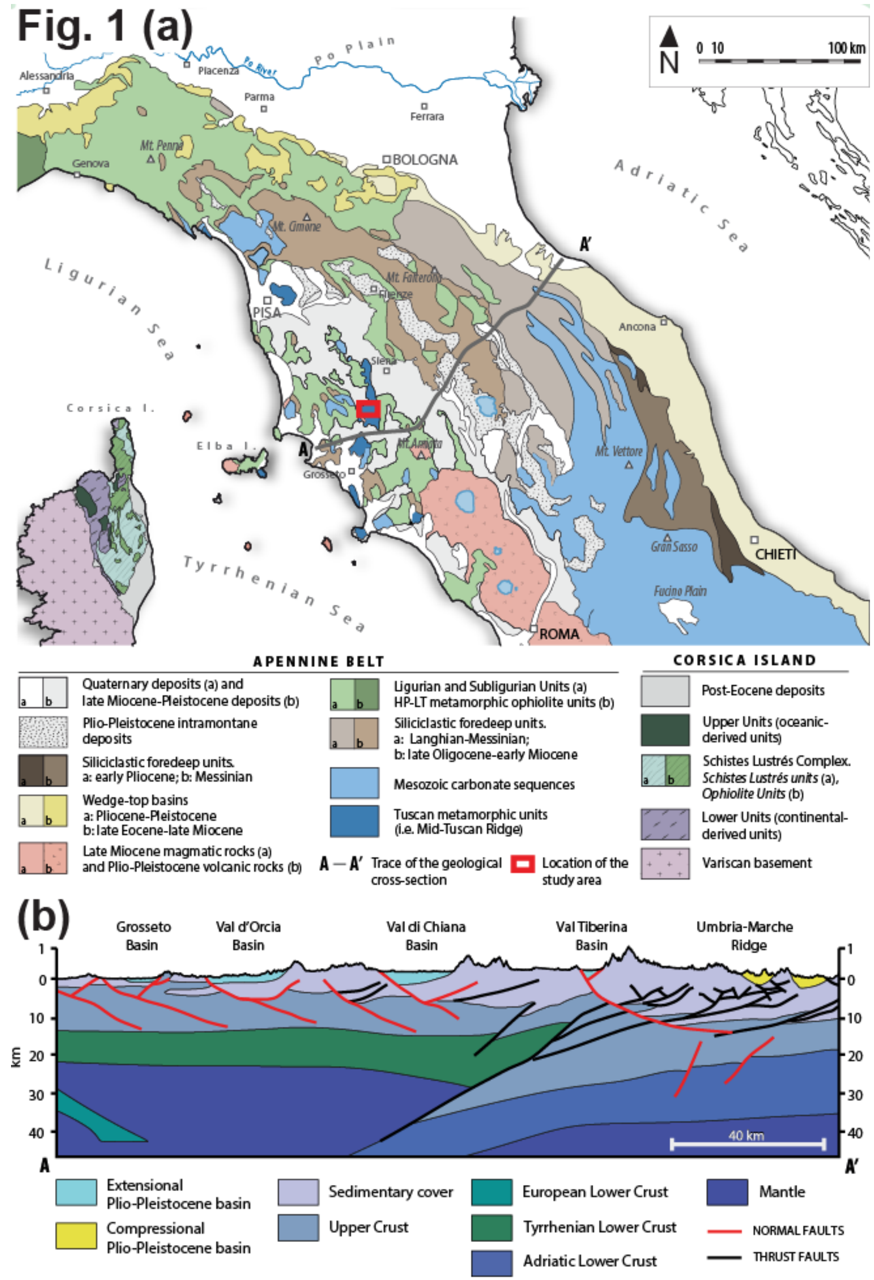

Fig. 1. (a) Geological sketch map of the Northern Apennines and location of the study area.
(b) Geological cross-section based on the seismic reflection line CROP03 (modified after[2]).

RESULTS: FIELD-MICROSTRUCTURAL AND PETROGRAPHIC DATA

The studied area displays a mesoscopic (~20x5 m) compressional duplex that deforms Palaeozoic-Triassic quartz-rich metasandstones, metaconglomerates and minor metapelites within a top-to-the-NE shear zone[3] (Figs. 2a and 3a). Severe strain partitioning occurred between metapelite-, corresponding to 10-50 cm thick high-strain zones (Fig. 2b), and metasandstone levels, which form relatively strain-free metric horses.

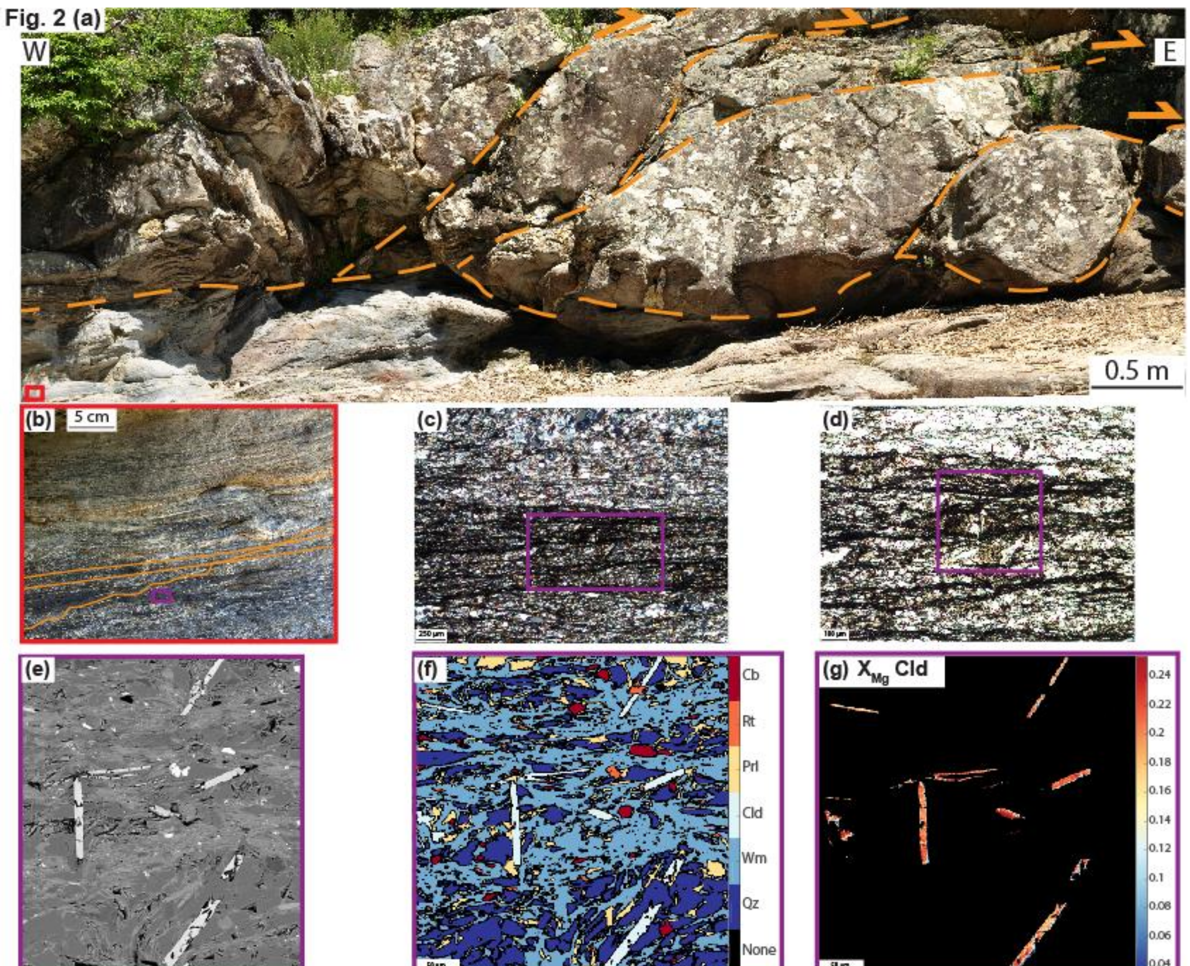

Fig. 2. (a) Duplex outcropping along the Farma River. Note the differential erosion of the harder metasandstones and the weaker metapelites. (b) Details of the metapelitic high-strain shear zone. (c, d) Thin-section photos of the metapelite. The dark bands are composed of graphite and K-white mica, the bright of quartz. (c): crossed-polarized light; (d): plane-polarized light. (e) BSE image displaying chloritoid parallel and at high angle compared to the foliation. (f, g) X-ray maps elaborated with XMapTools showing the mineral phases and X_{Mg} content of Chloritoid, respectively.

RESULTS: FIELD-MICROSTRUCTURAL AND PETROGRAPHIC DATA

Early quartz vein generations are highly transposed (sheath folds, Fig. 3b) within the metapelitic high-strain shear zones. Veins are composed of iso-oriented quartz, Mg-carpholite needles and K-white mica marking the stretching lineation indicating high-pressure conditions (Fig. 3c-g). The mylonitic foliation in the metapelites is defined by quartz, chloritoid, pyrophyllite and K-white mica forming a stretching lineation coherent with that of the veins (Fig. 2c-g).

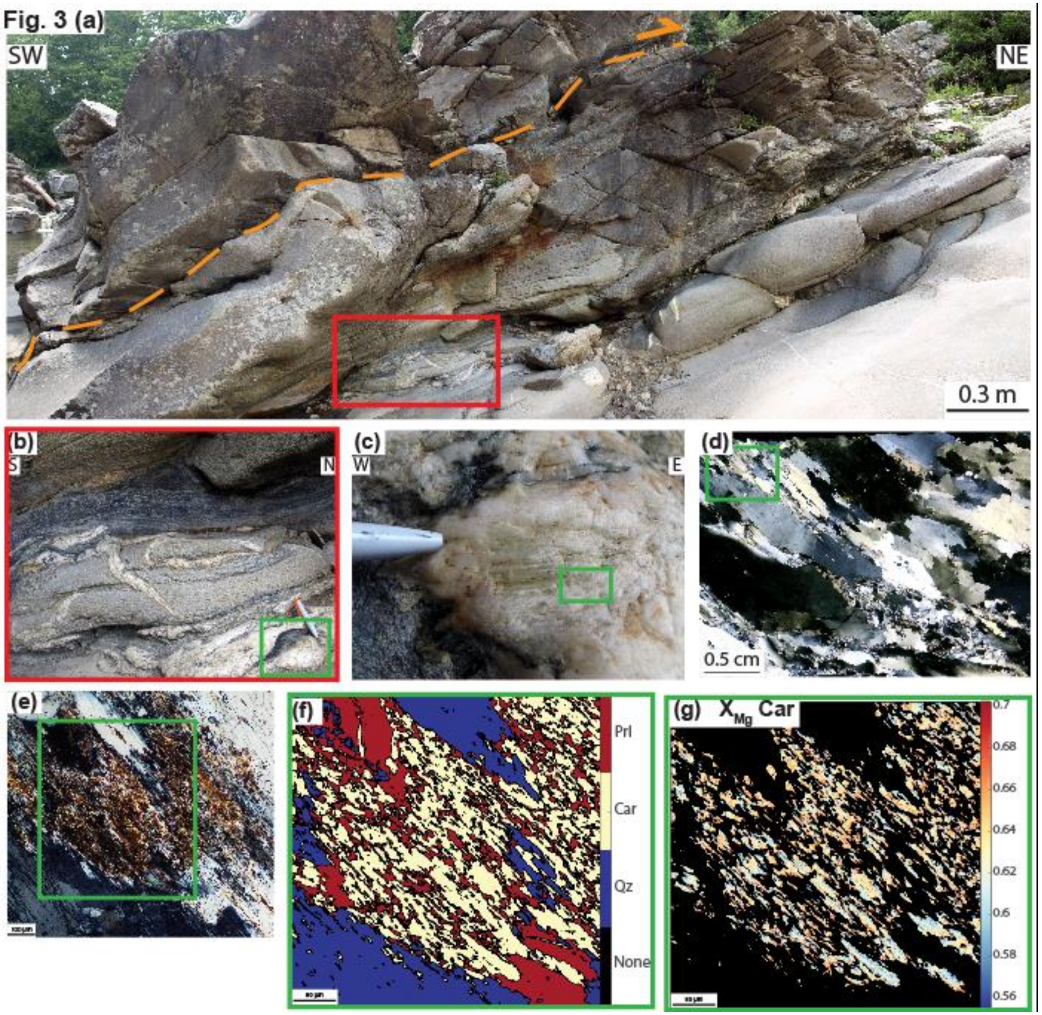

Fig. 3. (a) Outcrop located upstream of Fig. 2(a).
(b) Detail of the quartz veins and sheath folds.
(c) Quartz and carpholite marking the stretching lineation in the vein.
(d, e) Thin-section scan with iso-oriented quartz crystals, some centimetres in size with undulose extinction and subgrains, and acicular carpholite. Crossed-polarized light.
(f, g) X-ray maps showing the mineral phases and X_{Mg} content of carpholite, respectively.

RESULTS: THERMODYNAMIC MODELING

Thermodynamic modeling results suggest >0.8 GPa and 350-400 °C for the formation of both the high-pressure veins and the mylonitic foliation (Fig. 4a-b).

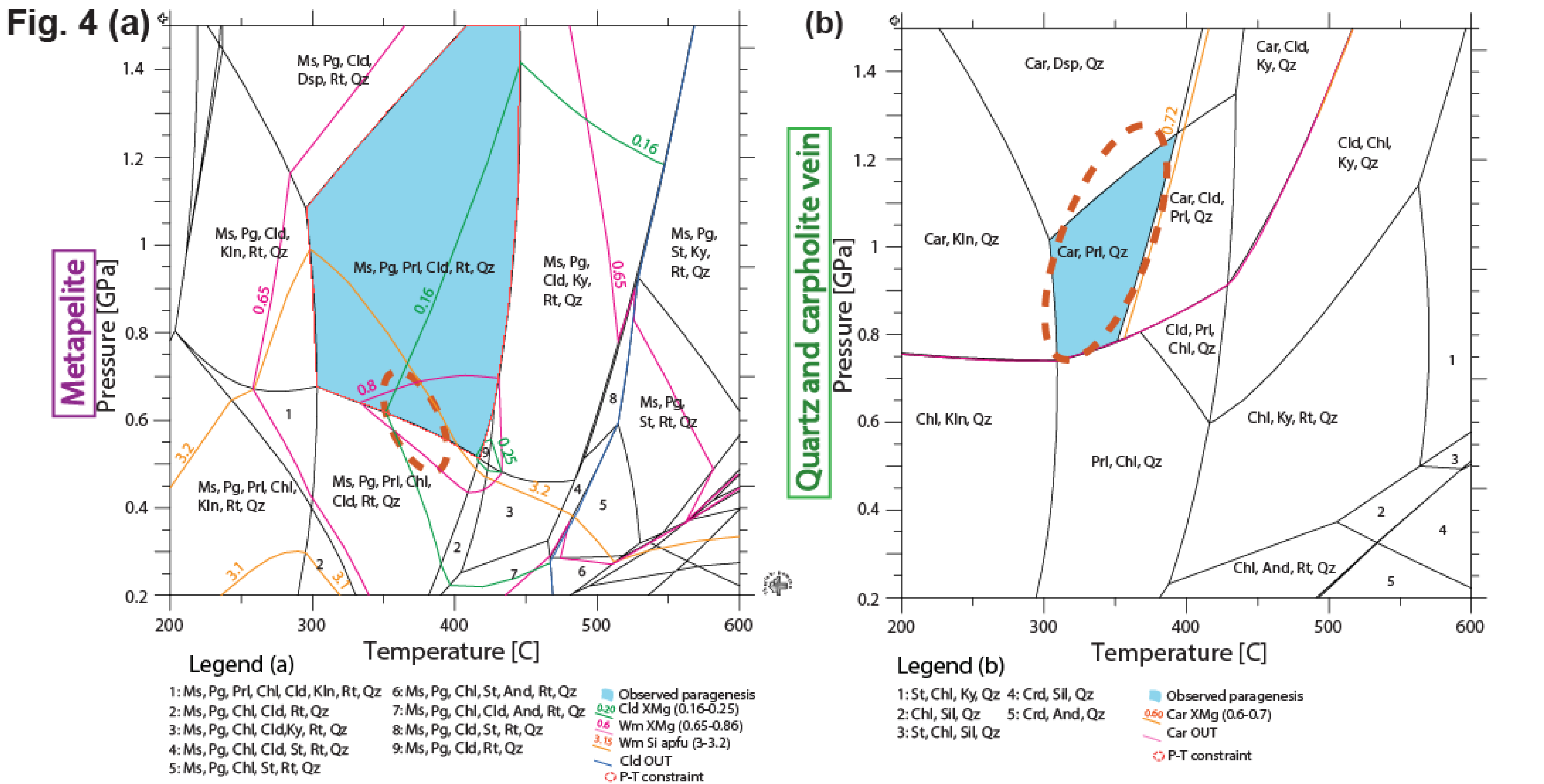

Fig. 4. (a, b) Equilibrium phase diagrams of the metapelite and the quartz and carpholite vein computed with Theriak–Domino software assuming a free H_2O fluid.

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DISCUSSION AND CONCLUSIONS

Geometrical, cross-cutting and petrographic relations and thermodynamic modelling suggest that there has occurred cyclic deformation between brittle and viscous conditions at P >0.8 GPa and T 350-400 °C, with the veins forming broadly during ductile shearing.

The results might 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.

EBSD analysis and K-white mica Ar-Ar dating are ongoing to constrain the deformation mechanisms and the geodynamic scenario of shear zone development.

References

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