Evolution of melt-bearing shear zones during cooling in a shallow contact aureole: the Calamita Schists

Samuele Papeschi[1]*, Giovanni Musumeci[2,3], Omar Bartoli[4], Bernardo Cesare[4], Hans-Joachim Massonne[5,6], & Francesco Mazzarini[3]

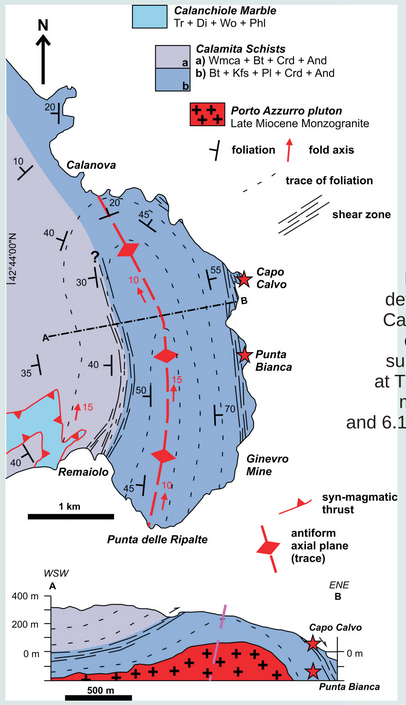
1. Kochi (X-Star), Japan Agency for Marine-earth Science and TECnology, Japan
2. Department of Earth Sciences, University of Pisa, Italy
3. Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy
4. Department of Earth Sciences, University of Padova, Italy
5. China University of Geosciences, Wuhan
6. Stuttgart University, Germany

* samuele.papeschi@jamstec.go.jp

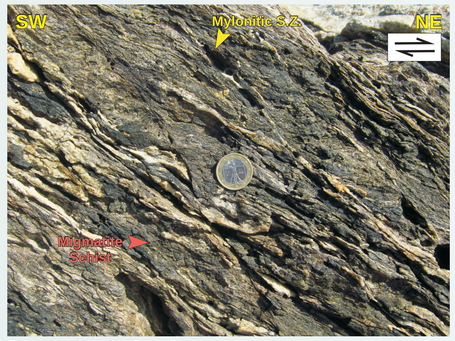
Introduction & Geologic Setting

Partial melting and emplacement of magma represent are efficient processes to reduce the strenght of crustal rocks, enhancing deformation (e.g. Rosenberg, 2001). Even low melt fractions cause significant strain weakening, allowing strain to distribute in the partially molten rock volume. On the other hand, melt crystallization has the opposite effect on shear zone rheology, de facto replacing 'weak' melt with 'strong' quartz and feldspar (e.g. Butler & Torvela, 2018). Consequently, a melt-bearing shear zone evolving to 'colder' conditions necessarily undergoes strain hardening (e.g. Zibra et al., 2018), thus promoting strain localization where strain softening mechanisms are active.

In this work, we document the switch from melt-present to subsolidus deformation in a cooling, syntectonic LP-HT complex: the Late Miocene Calamita Schists (Isle of Elba, Italy), representing a proxy for midcrustal conditions.The Porto Azzurro pluton (buried underneaththe Calamita) supplied heat for melting, which occurred in the presence of andalusite at T > 650 °C and P < 0.25 GPa. Geochronological data constrain LP/HT metamorphism in the Calamita between 6.7-6.8 Ma (Ar/Ar phlogopite) and 6.1 Ma (K/Ar fault gouge dating), implying that melt-present deformation must have occurred at near peak conditions as part of a 0.5 Ma cooling history. Cooling of the system strongly forced deformation to localize, assisted by ingress of fluids, reaction softening, and rheological heterogeneities.

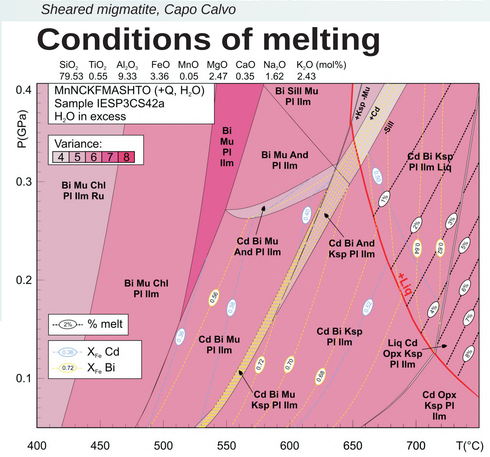


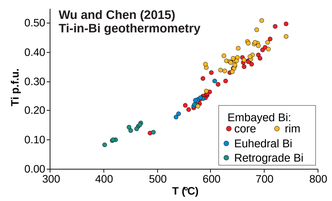




Sheared migmatite, Capo Calvo

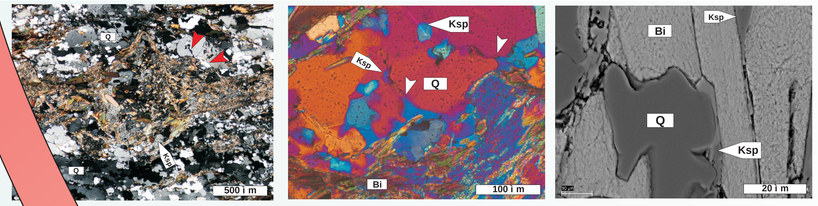
Conditions of melting

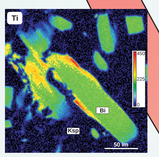




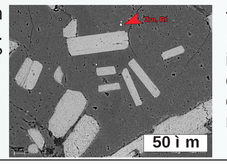
Peak: 0.1 - 0.25 GPa; 660-710 °C
Note: in the melt-present part, we fixed H2O at 0.5 % vol.
Calculated with THERMOCALC (Holland & Powell, 1998)

(1) HT deformation in the presence of melt





Euhedral biotite in melt pools. Peritectic phase?

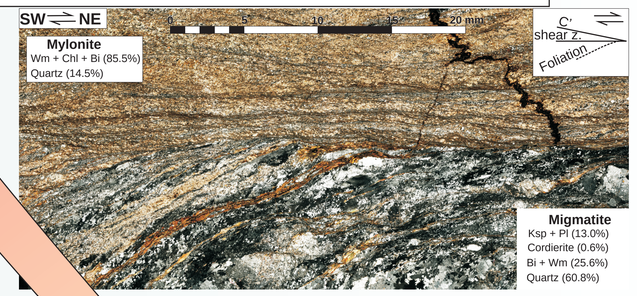


The biotite-rich foliation contains 'melt pools' of K-feldspar + plagioclase (oligoclase) + biotite. Melt is present in quartz and biotite in the forms of 'films' of K-feldspar between grains. Quartz is extensively deformed by GBM-recrystallization. No evidence of mylonitic deformation at this stage.

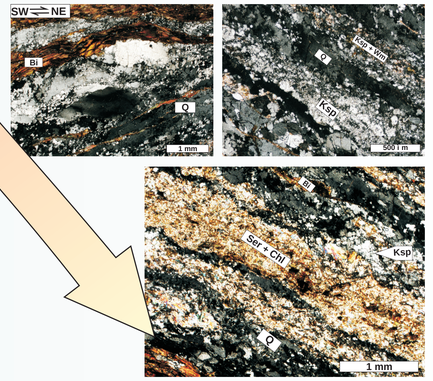
Embayed biotite grains in melt pools, preserving Ti-zoning interpreted as prograde metamorphic zoning.

Temperature decrease

(2) When melt is gone: Strain hardening



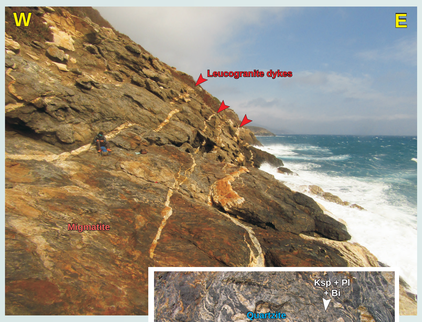
There is an evident strain, metamorphic and compositional gradient between the lozenges, preserving HT migmatite to sub-solidus structures, and mylonitic shear zones, consisting of greenschist-facies Wm+Chl+Bi.



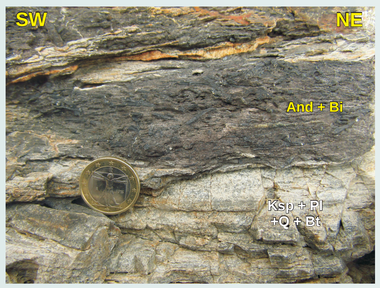
(3) Strain localization

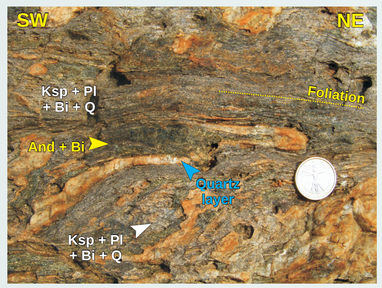
Recrystallization of quartz and feldspar in the presence of biotite is taken over by replacement of silicates by a fine-grained mixture of sericite and phyllosilicates. This indicates that the ingress of H2O-rich fluids now controls **reaction softening**, facilitating strain localization.

Melting of the Upper Crust

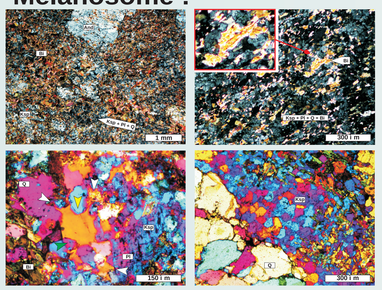


Stromatic migmatite, Punta Bianca

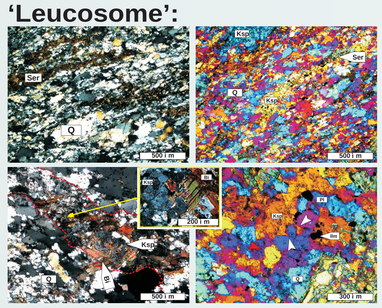




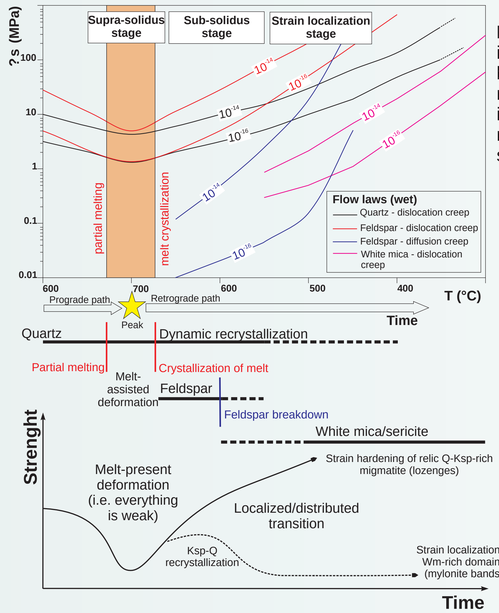
'Melanosome':



'Leucosome':



Migmatites have patch to stromatic structures, with 'melanosomes' of And + Bi ± Cd and 'leucosomes' of Ksp + Pl + Q + Bi. Quartzite layers are relics of the original layering of the Calamita. Deformation is generally distributed but leucosomes appear more foliated.



Flow laws: *quartz (Gleason & Tullis, 1995); Feldspar (Rybacki et al., 2006); muscovite (Mariani et al., 2006)*

Implications & Conclusions

We document a natural example of deformation from **melt-present HT conditions** to **LT mylonitic deformation** in quartz-feldspathic rocks.
In the presence of melt, deformation easily distribute throughout the rock volume and no easily identifiable shear zone develops.
Melt crystallization causes extreme strain hardening, forcing deformation to localize. Shear zone nucleate in weaker (metapelitic) lithotypes, where fluid infiltration and reaction softening produces phyllosilicate-rich ultramylonites. Relic quartz-feldspar lozenges become progressively stronger at decreasing temperature, preserving the HT fabric.
Just as importantly, we document for the first time evidence of partial melting and coeval regional deformation around Late Miocene intrusives in the Northern Tyrrhenian Sea, constraining peak P-T conditions to 0.1-0.25 GPa and 660-710 °C.

Papeschi et al. (2019). Lithos 350-351, 105230