Infrared absorption band in deformed qtz crystals analyzed by combining different microstructural methods

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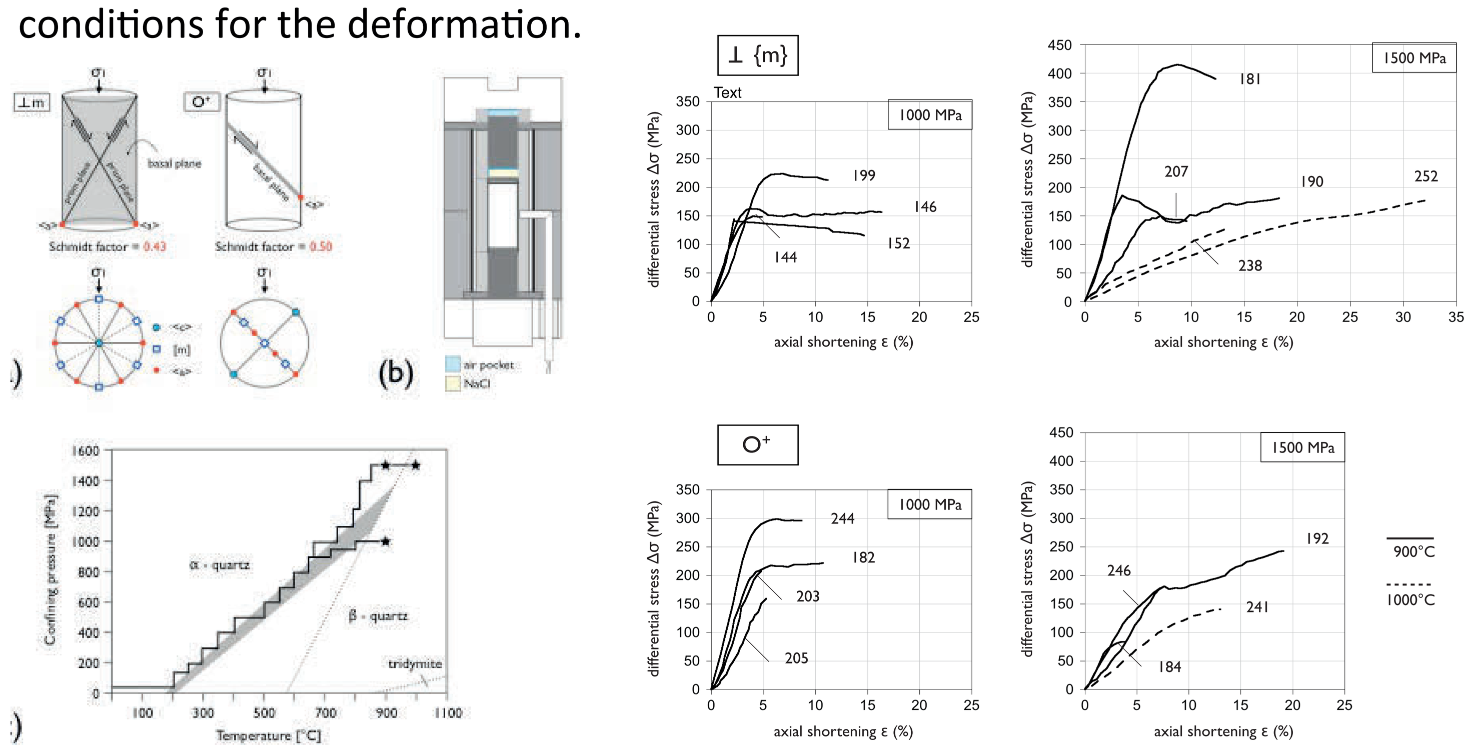
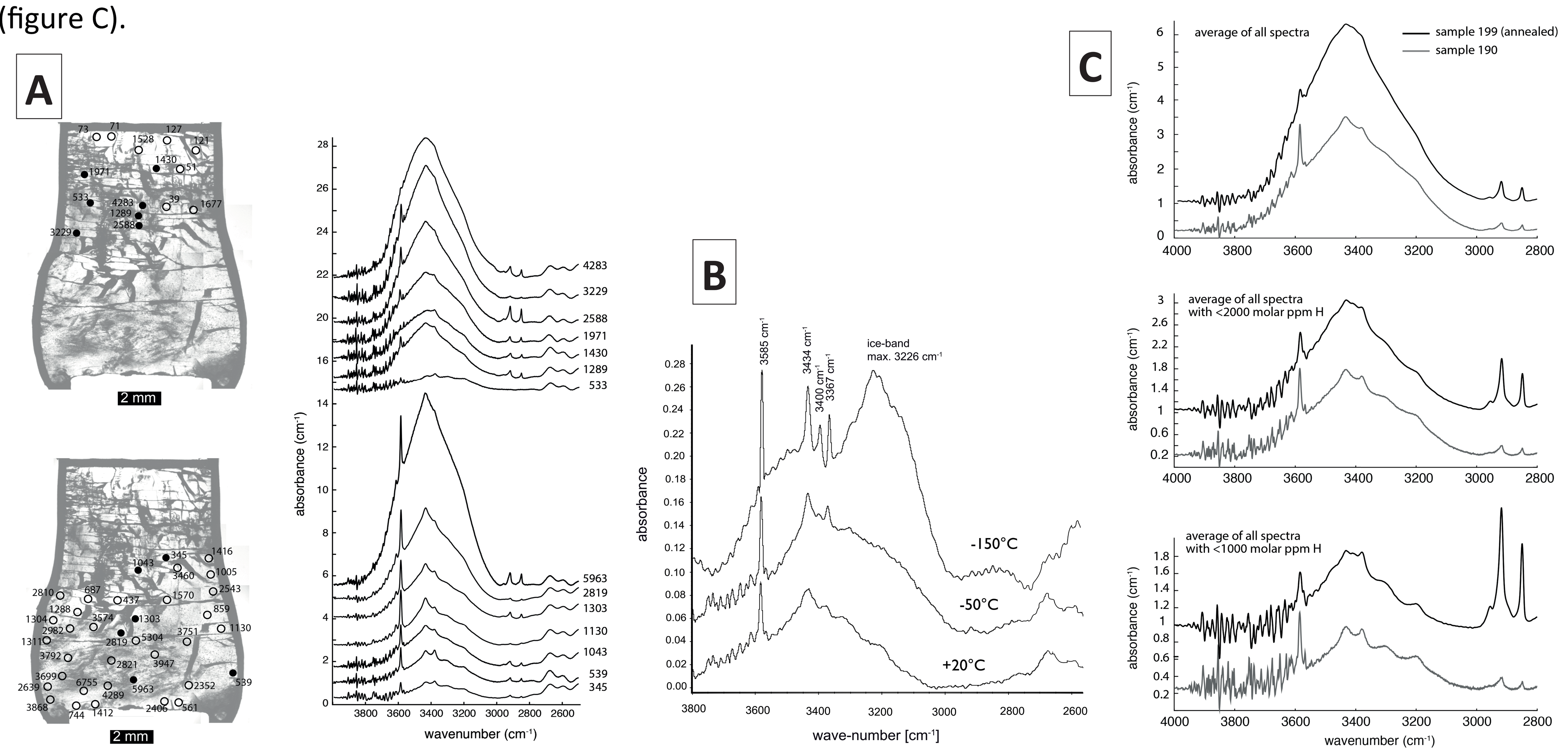
Experiments, starting material, mechanical data

We used milky single crystals in O+ and normal to (m) orientation. Attaining P and T (900 and 1000°C; 1.0 and 1.5 GPa) was done by following the isochore in order to preserve as many fluid inclusions as possible. The flow stress of samples varies because of different distribution of fluid inclusions, but the values indicate fully plastic conditions for the deformation.



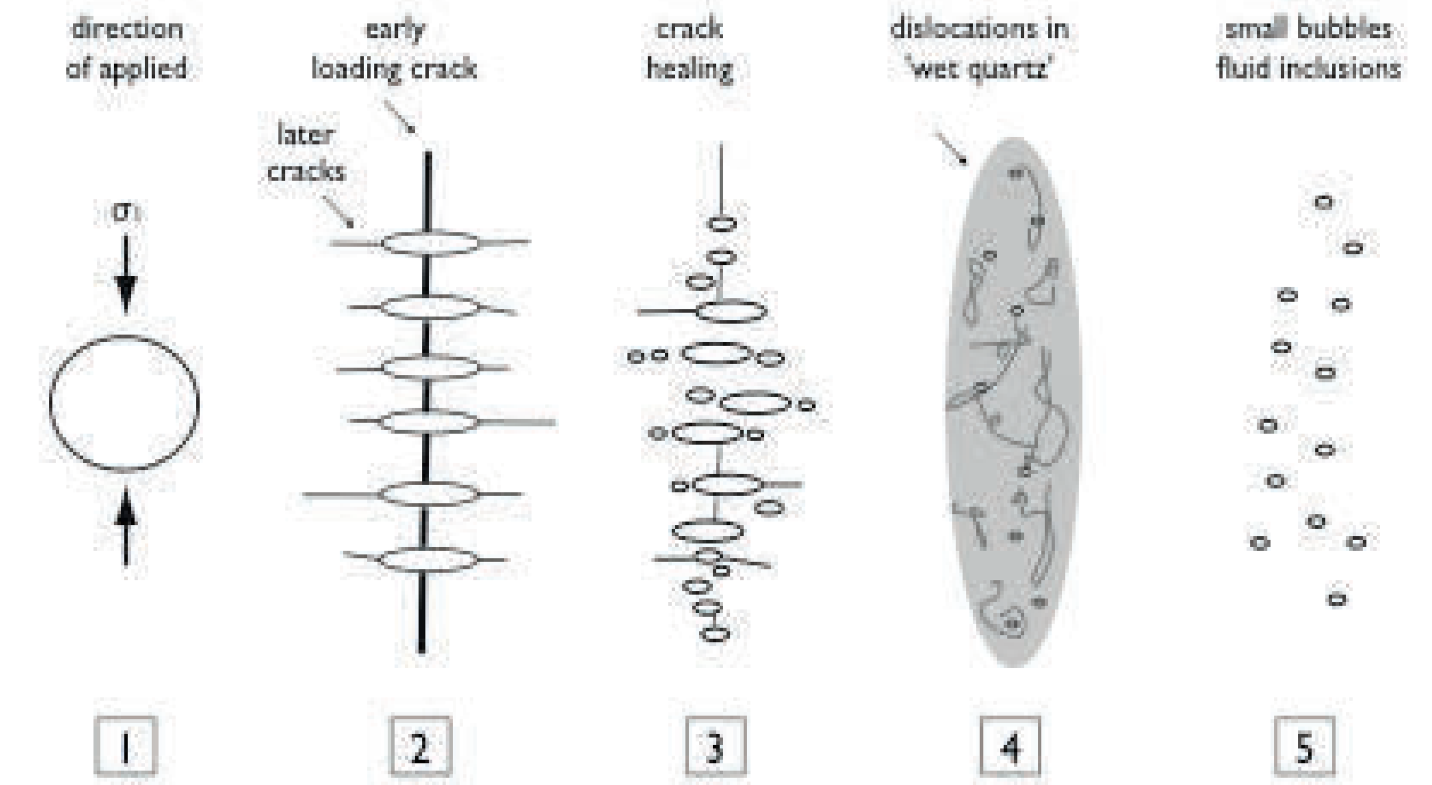
FTIR measurements on qtz crystals

IR spectra of undeformed and deformed regions of samples are different, as can be seen in figure A. Deformed regions (upper part of the crystal) have a more pointed H_2O band and a pronounced absorption band at 3585cm^{-1}. The pointed H_2O band is caused by a triplet of structurally bound OH bands, as seen in low temperature measurements (figure B). The pointed nature of the H_2O band and the 3585cm^{-1} absorption band are reduced or disappear after annealing (figure C).



Conclusions

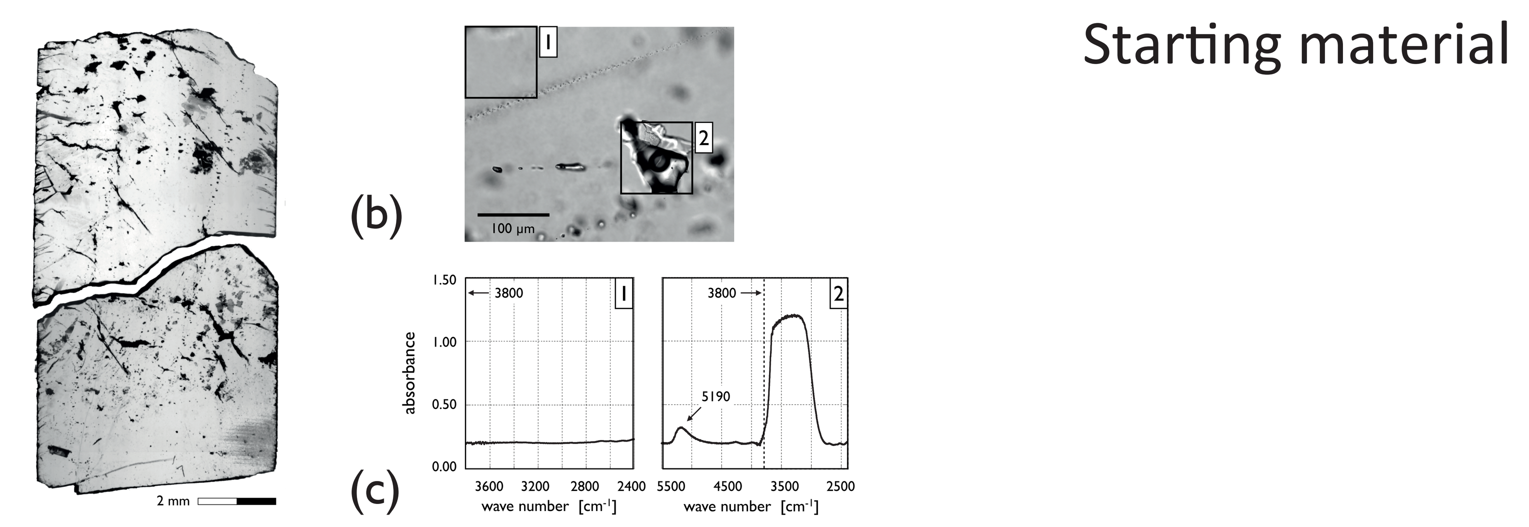
- Crystal plastic deformation of wet qtz single crystals at 900 and 1000°C takes place by dominantly glide with limited recovery (almost no recrystallization).
- Decrepitation of fluid inclusions and crack healing cause nucleation of glissile dislocations (2-4)
- Further size reduction of fluid inclusions to nm-scale during deformation causes further production and multiplication of dislocations (4).
- OH is structurally bound in dislocations and produces characteristic absorption bands at 3585cm^{-1} and a triplet around 3400cm^{-1}.
- Annealing reduces or obliterates these bands by precipitation of H_2O from dislocations (5).
- H_2O weakening in qtz takes place by dislocation generation at bubbles and healed cracks. It is a disequilibrium process and dependent on H_2O content.



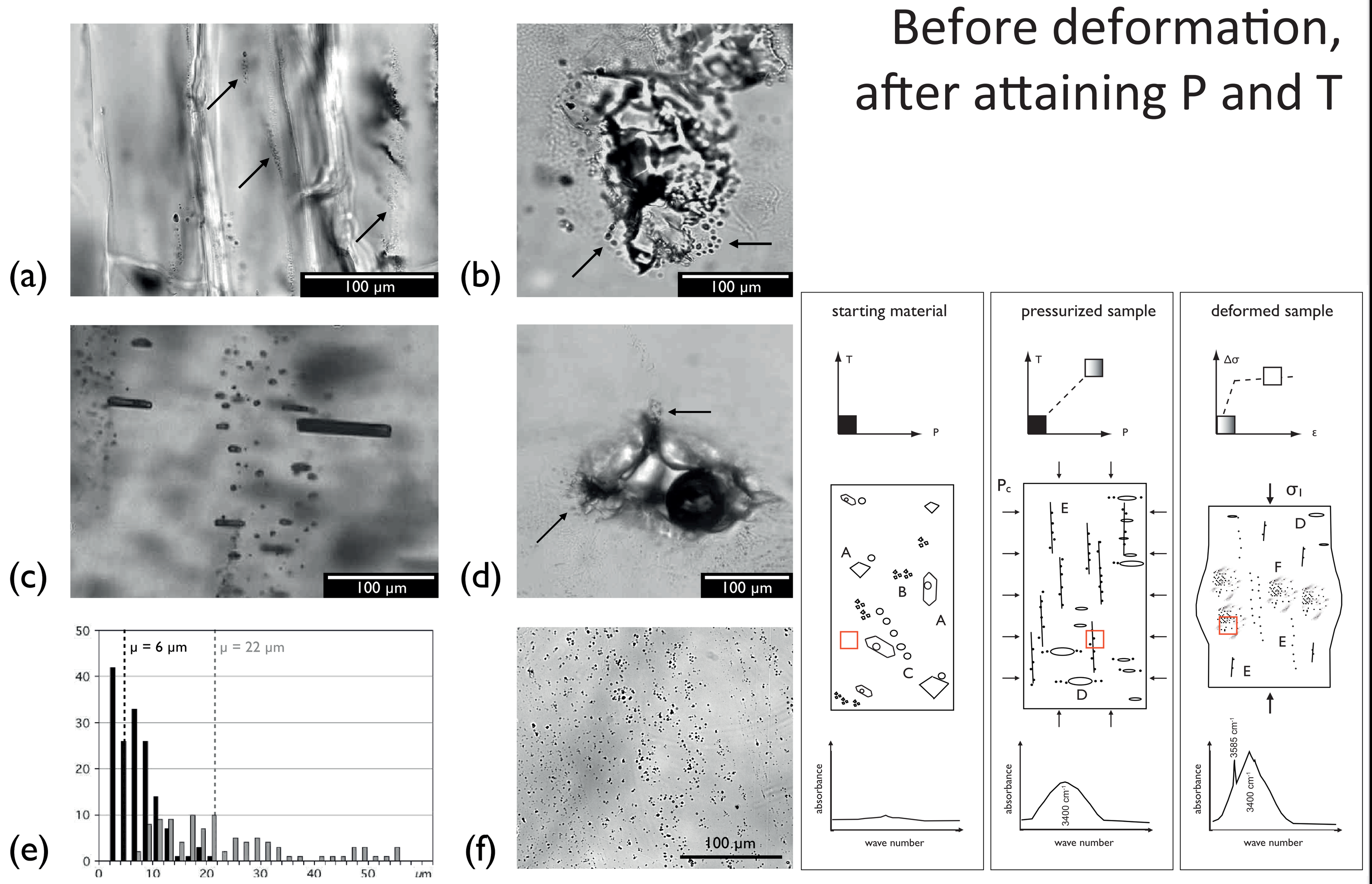
Size evolution of fluid inclusions

Original fluid inclusions are up to 100´s of µm in size (a). All the H_2O is stored in the fluid inclusions – the qtz crystals are dry (b, c). During attaining of the P and T conditions fluid inclusions decrepitate and produce plenty of much smaller neonate inclusions (arrows) and crack healing. During deformation, the size of inclusions is further reduced (f). A summary of the evolution of the fluid inclusions is given in the schematic drawing.

Starting material

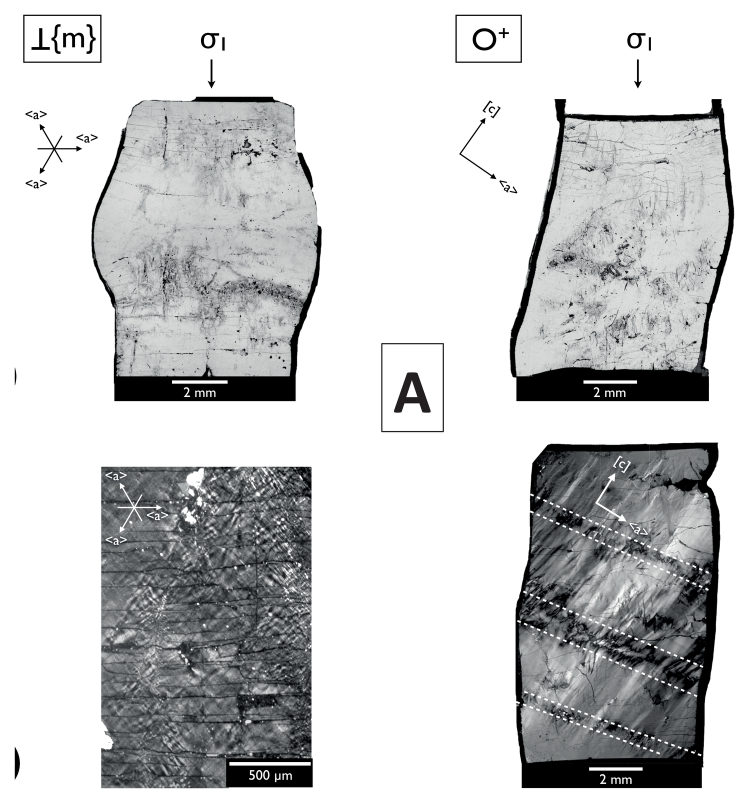


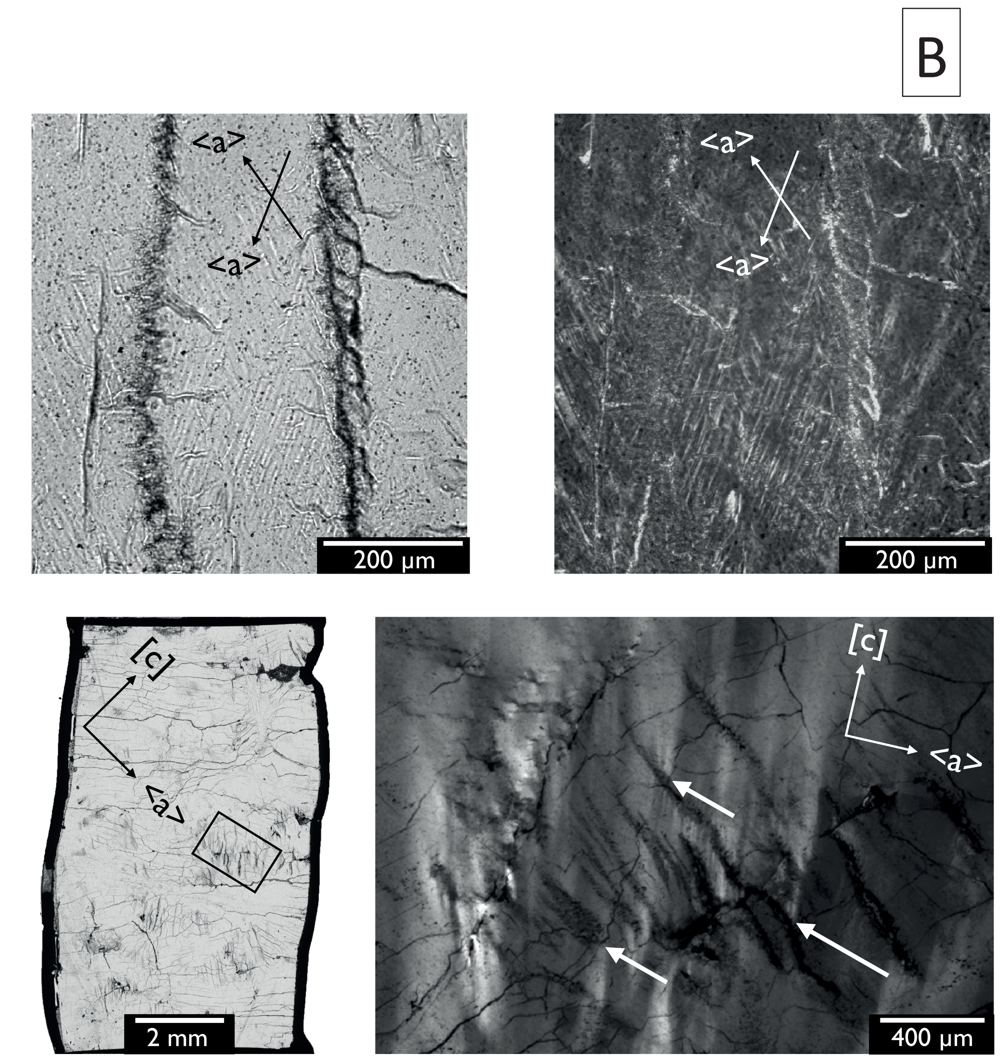
Before deformation, after attaining P and T



Deformation microstructures

A.) Systematically different microstructures depending on sample orientation indicate activation of different slip systems (basal <a> and prism <a>). Deformation lamellae short wavelength undulatory extinction (SWUE) bands are restricted to slip planes (B), and SWUE bands often terminate at healed cracks (arrows in B).

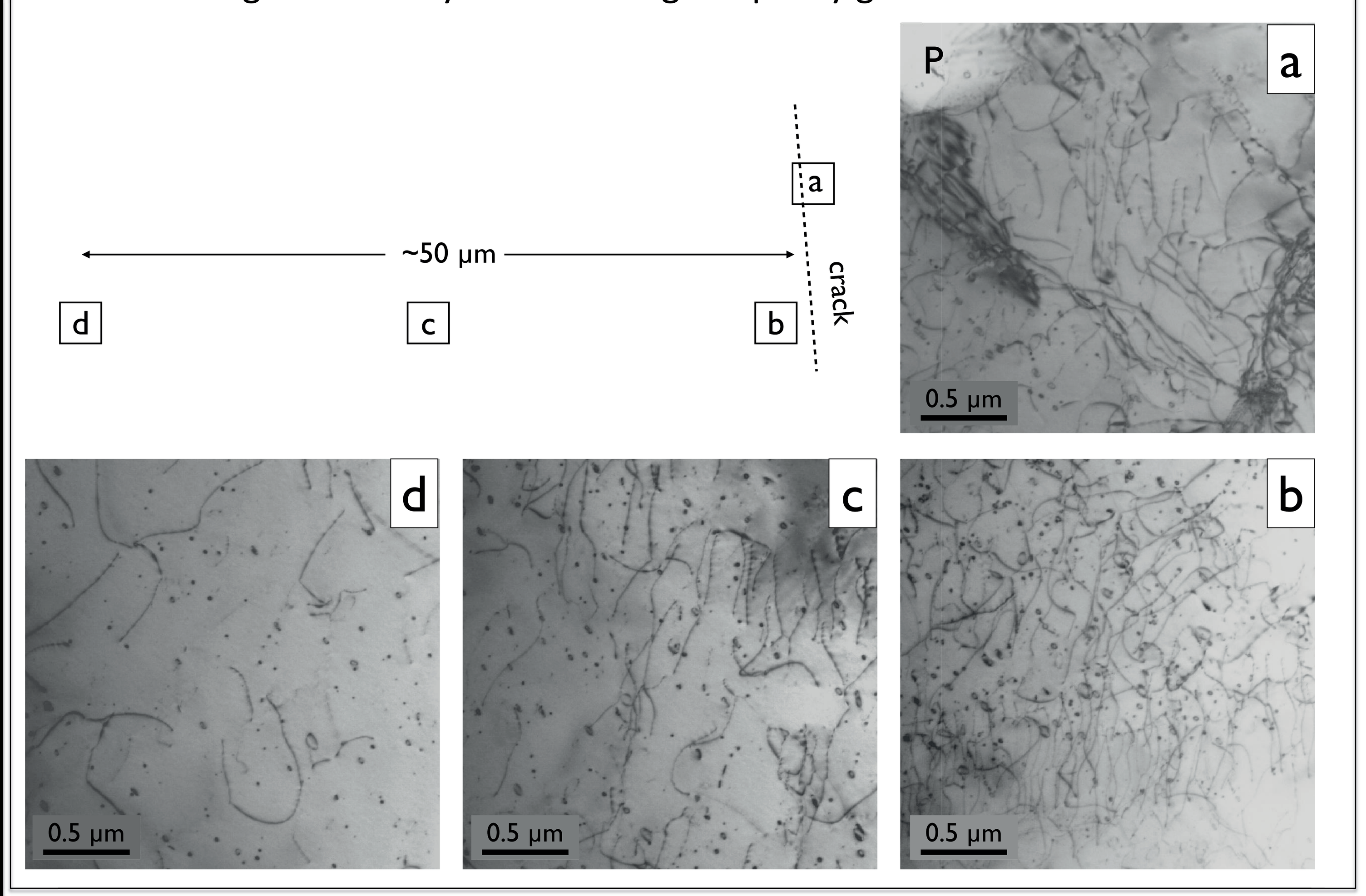




TEM observations

indicate that dislocations are generated by healed cracks and bubbles

A series of TEM images over a distance of ~50 µm shows that the dislocation density decreases away from a healed crack at a pore (P), indicating that dislocations generated by crack healing are partly glissile.



Deformation lamellae and bands of SWUE are marked by abrupt changes in dislocation density. Bubbles and pores associated with dislocation arrays demonstrate their origin as healed cracks. Very small bubbles are directly associated with dislocations