Hydrothermal Alteration-Induced Weakening in Experimental Fault Gouges

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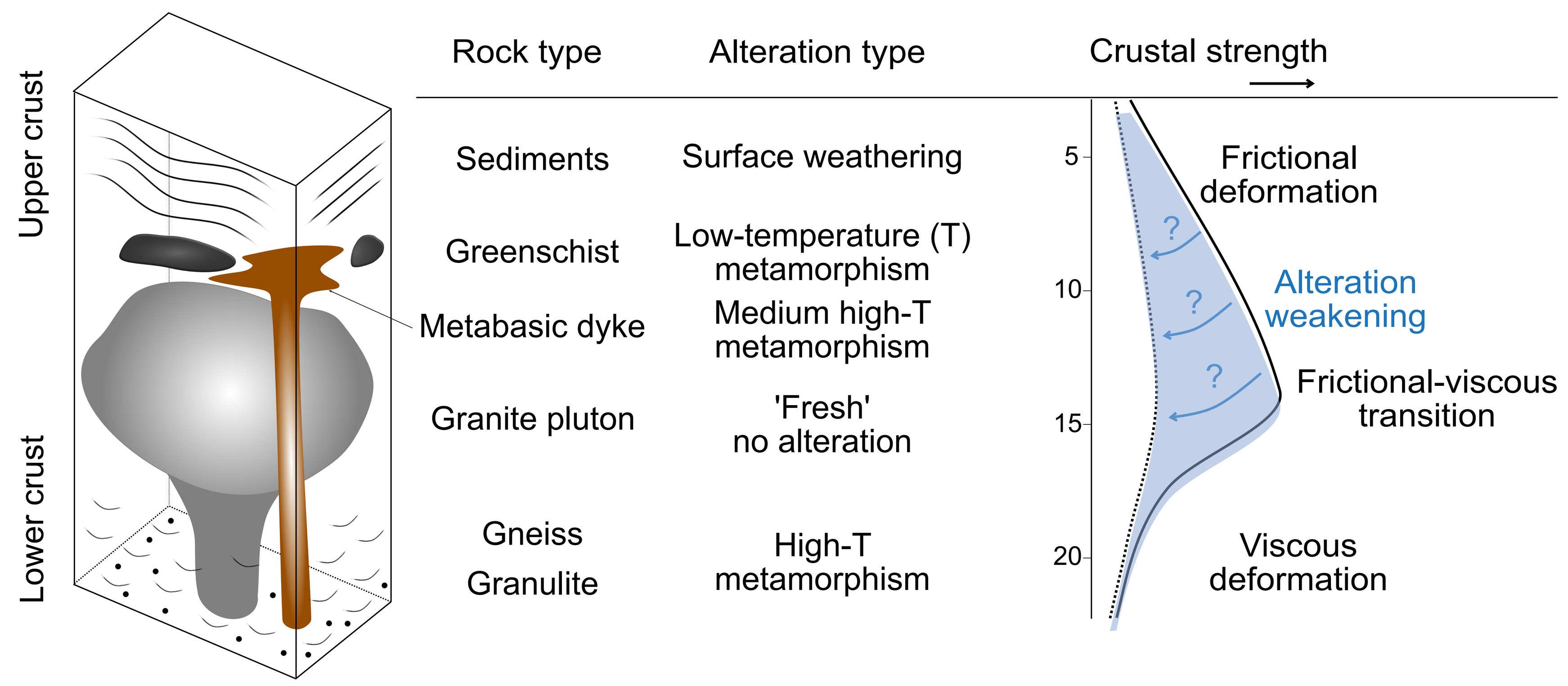
Background

How does hydrothermal alteration influence the strength of upper-middle continental crust?

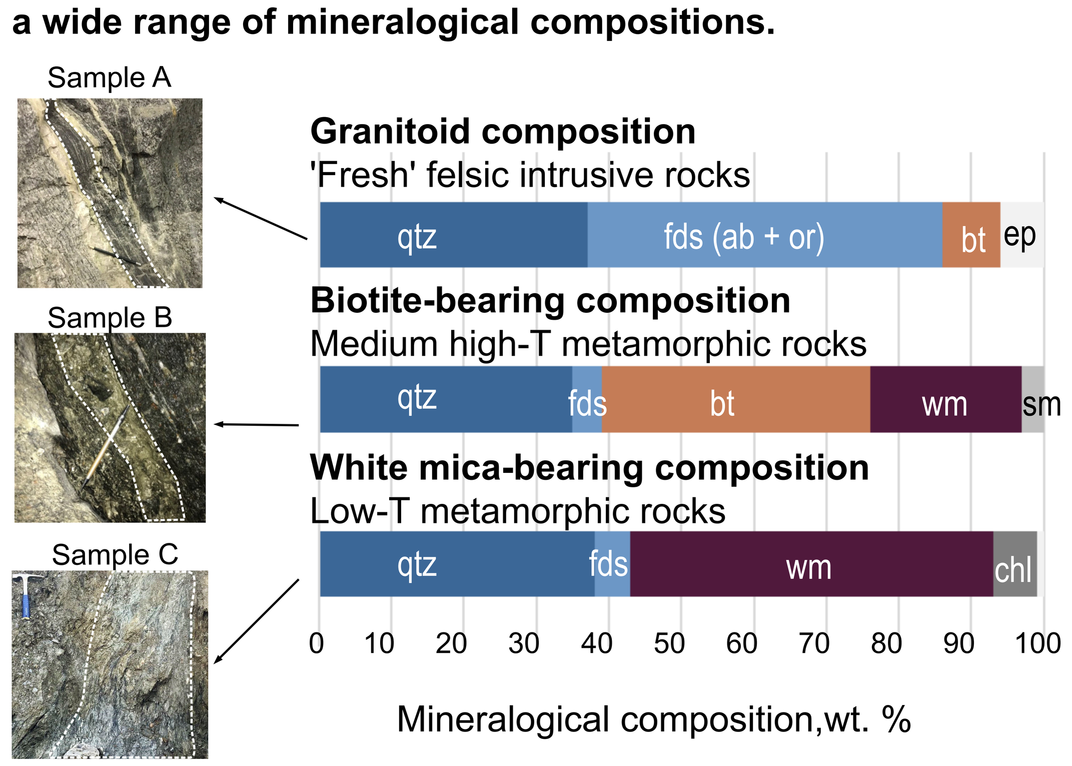


In the granitoid crust, phyllosilicate-rich fault gouges are prevalent in mature fault zones undergoing hydrothermal alteration and often exhibit lower frictional strength compared to framework minerals (e.g., qtz, fds) under deformation at room temperature. However, the mechanical behavior and deformation mechanisms of altered gouges under hydrothermal conditions are not fully understood so far.

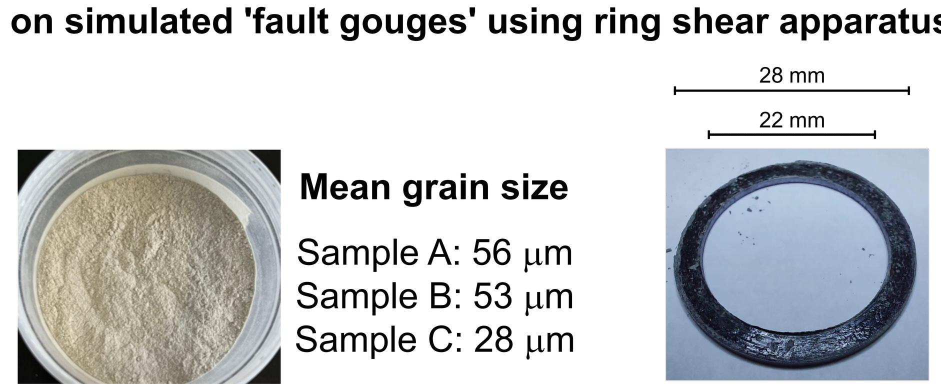
To investigate these effects, we conducted a series of experiments on three types of fault "gouge" material using a ring shear deformation apparatus. We used gouge mixtures obtained from (i) crushed granitoid ultramylonite, (ii) biotite- and (iii) white mica-bearing gouges to represent gouge materials with (i) no alteration, (ii) medium high-temperature and (iii) low-temperature alteration, respectively. The shear stresses measured from low velocity experiments were used to represent the rock strength.

METHODS

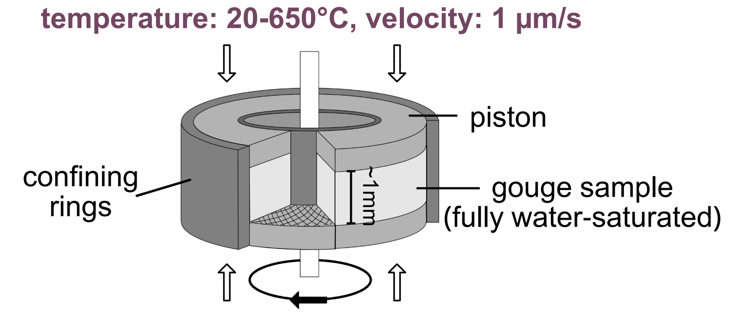
- **We selectively collected three natural fault rocks to cover a wide range of mineralogical compositions.**



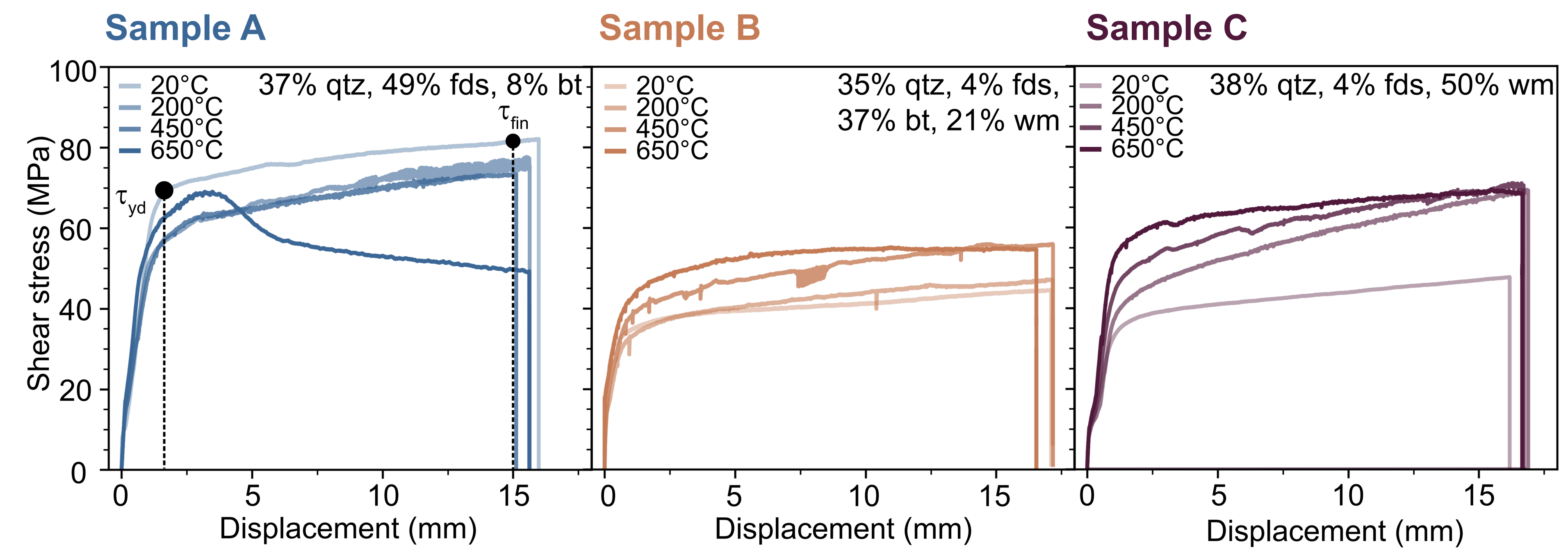
- **We conducted constant-velocity sliding experiments on simulated 'fault gouges' using ring shear apparatus.**



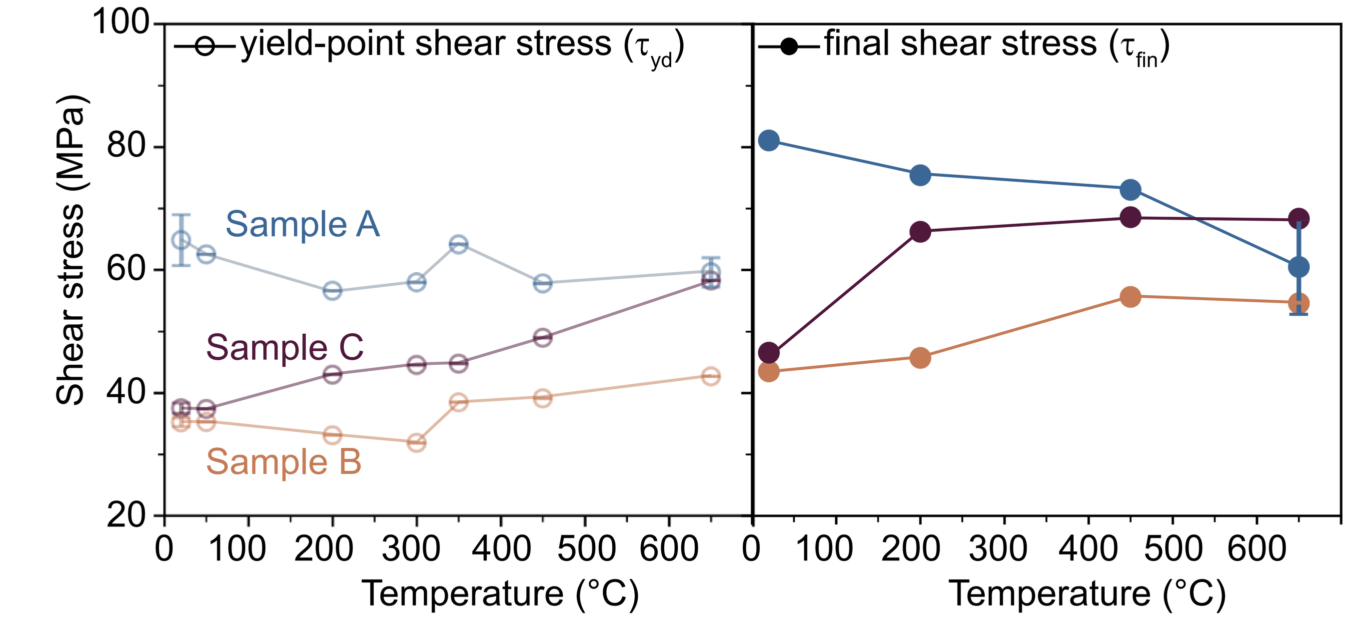
Normal stress:200 MPa, pore fluid pressure: 100 MPa, temperature: 20-650°C, velocity: 1 μm/s



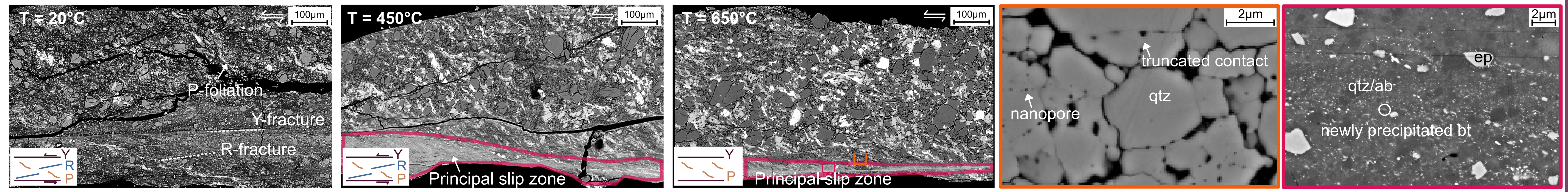
★ RESULTS AND DISCUSSION

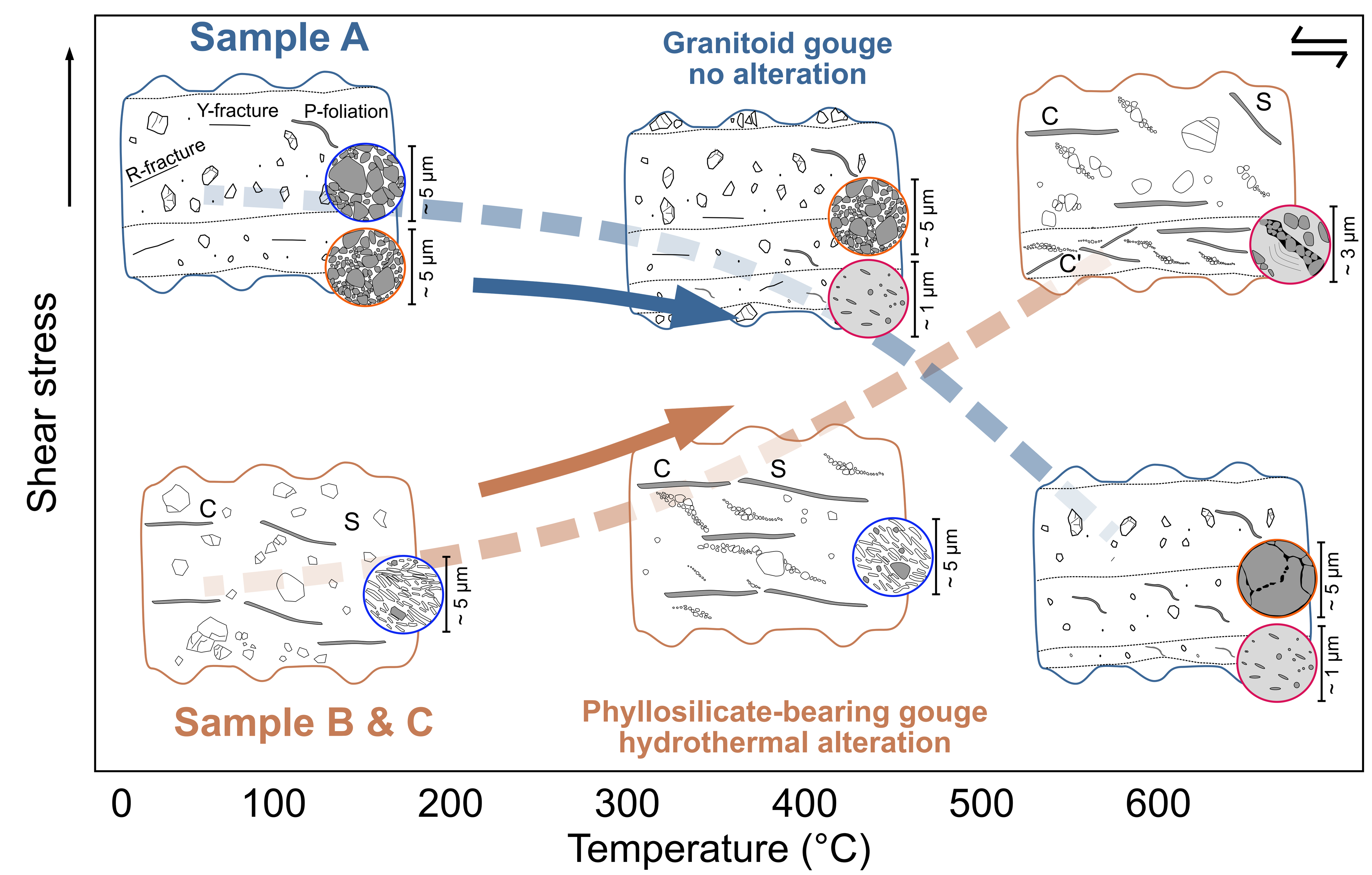


- **The granitoid gouges (sample A) showed a decrease in τ at T ≥ 450°C.**
- **Both mica-rich gouges (sample B & C) showed an increase in τ with T at all tested conditions.**



Sample A: granular load-bearing microstructure





Granitoid gouges

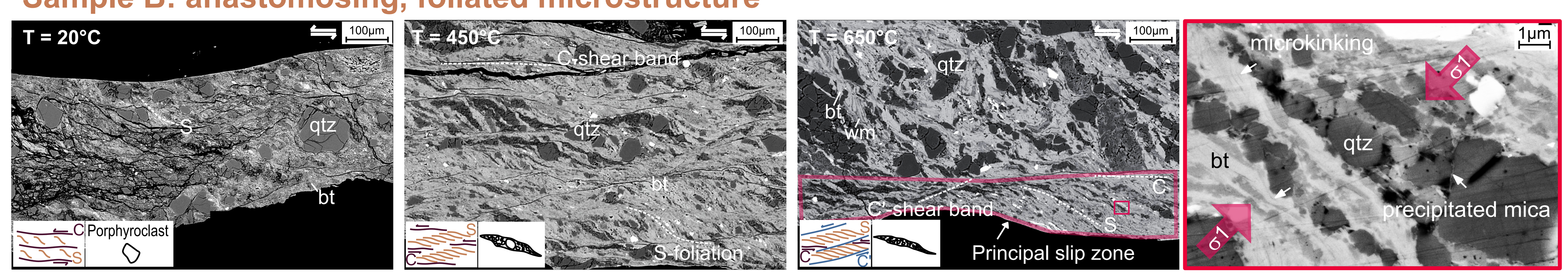
(Zhan et al., 2024 JGR pending revision)

1. Gouge strength decreases as temperature increases.
2. The strength weakening involves forming a dense, ultrafine-grained principal slip zone where dissolution-precipitation creep (DPC) operates.
3. DPC is a temperature-, rate- and grain size-sensitive process.

Phyllosilicate-bearing gouges

1. Gouge strength increases as temperature increases.
2. The strength hardening involves localization of deformation and development of SCC' fabric, where frictional processes are assisted by DPC and microkinking.
3. The grain sizes within principal slip zone are larger compared to the granitoid gouges, suggesting a less efficient DPC. This may attributed to less comminution caused by the rheological contrast between phyllosilicate and quartz.
4. Although phyllosilicates developed high interconnectivity at high temperatures, their foliations make only a limited contribution to deformation, primarily due to their orientation perpendicular to the principal stress σ1.

Sample B: anastomosing, foliated microstructure



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