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Abstract

Water-added experiments of simulated quartz-feldspar shear zone at brittle-ductile transitional condition

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Backgrounds & Motivation

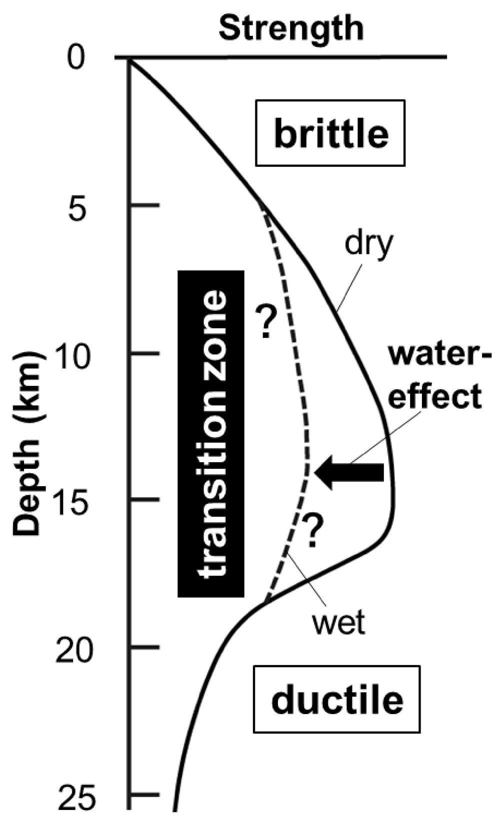


Fig. 1 Schematic of strength profile

Crustal strength is estimated to become the maximum at the brittle-ductile transition zone[1] (Fig. 1). Experiments have shown that rocks are weakened in the presence of water[2]. However, microphysical processes that reduce the strength of quartz-feldspar aggregates, that mainly composes the continental crust, remain unclear.

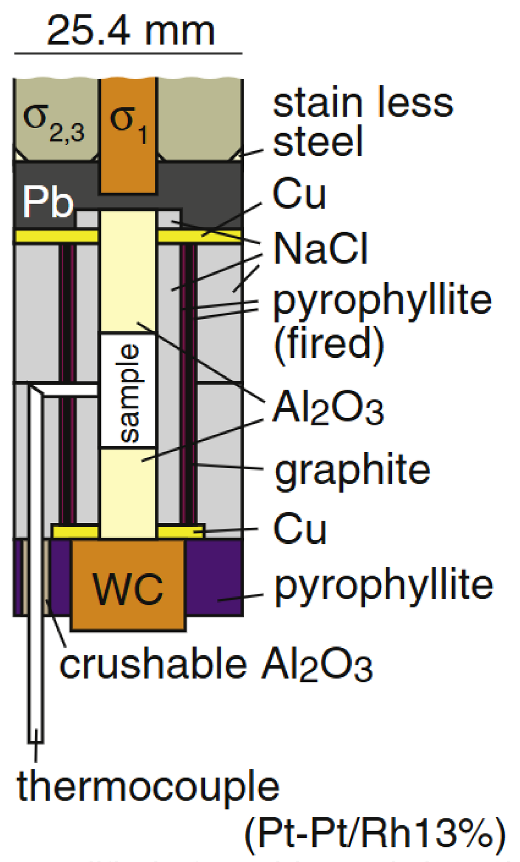
What deformation mechanisms reduce the crustal strength?

Methods

We performed shear deformation experiments using a Griggs-type solid salt assembly (Fig. 2). Samples are quartz-albite mixtures, consisting of quartz: albite = 1: 1.

Each experiment used ~0.1 g of the sample mixture, and a trace amount of purified water (either 0.2wt% or 0.4wt%) was added before sealing the sample jacket. Temperature and confining pressure are 720°C and ~750 MPa, respectively, so that the difference between the experiments becomes only the amount of water. The shear strain rate was changed between ~10^{-3} /s and ~10^{-4} /s.

After the experiments, the retrieved samples were observed using electron microscopes.



modified after Kido et al. (2016)

Fig. 2 Solid salt assembly

Results

Mechanical data show different behaviors between that the experiments (Fig. 3). The sample deformed with 0.2wt% water reaches a shear stress τ of 1040 MPa and remains at around a constant stress within the same velocity step. Meanwhile, the sample deformed with 0.4wt% water reaches τ of 790 MPa, followed by a significant weakening by ~200 MPa. The values of the peak shear stresses are smaller in the water-added experiments than in a room-dry experiment at the identical temperature and confining pressure conditions, since the peak shear stress was 1280 MPa in the room-dry experiment[3].

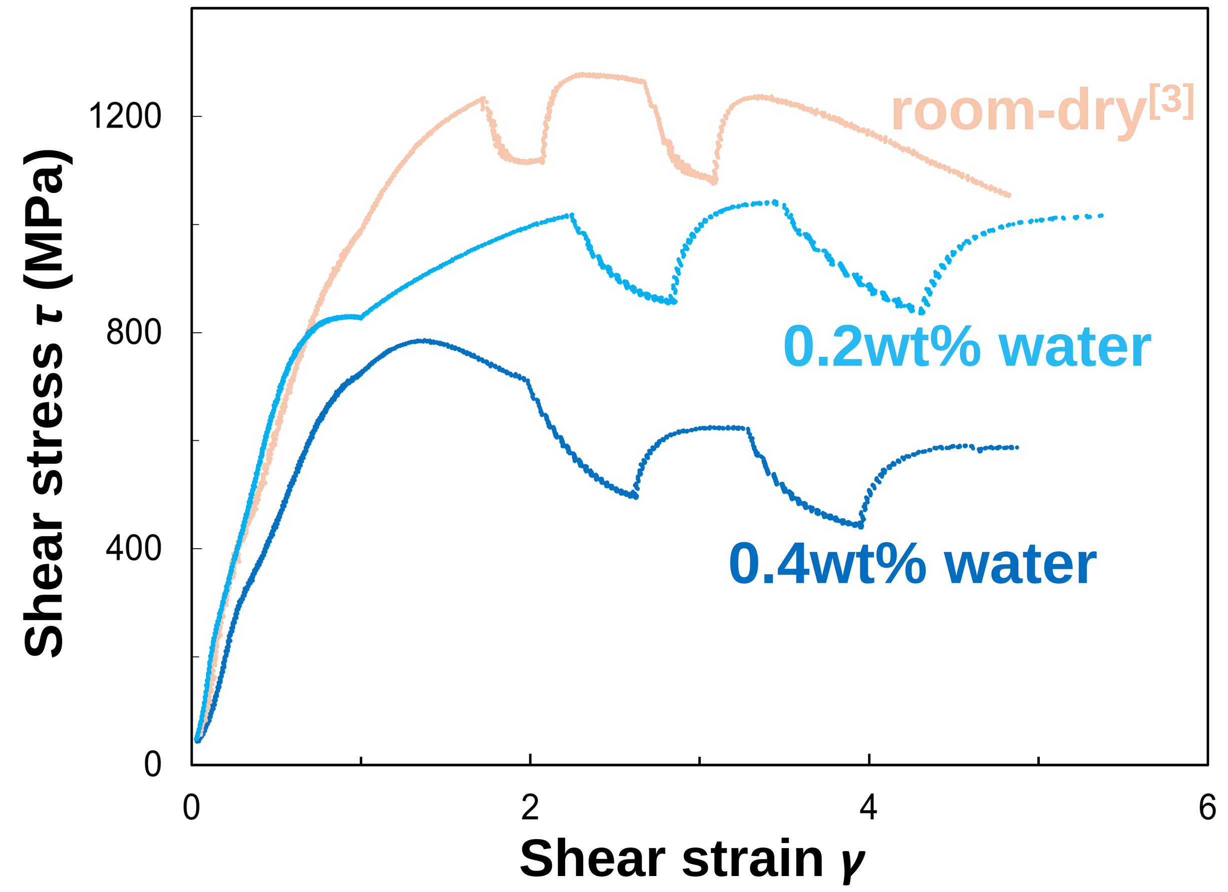


Fig. 3 Relationships between shear stress and shear strain during experiments

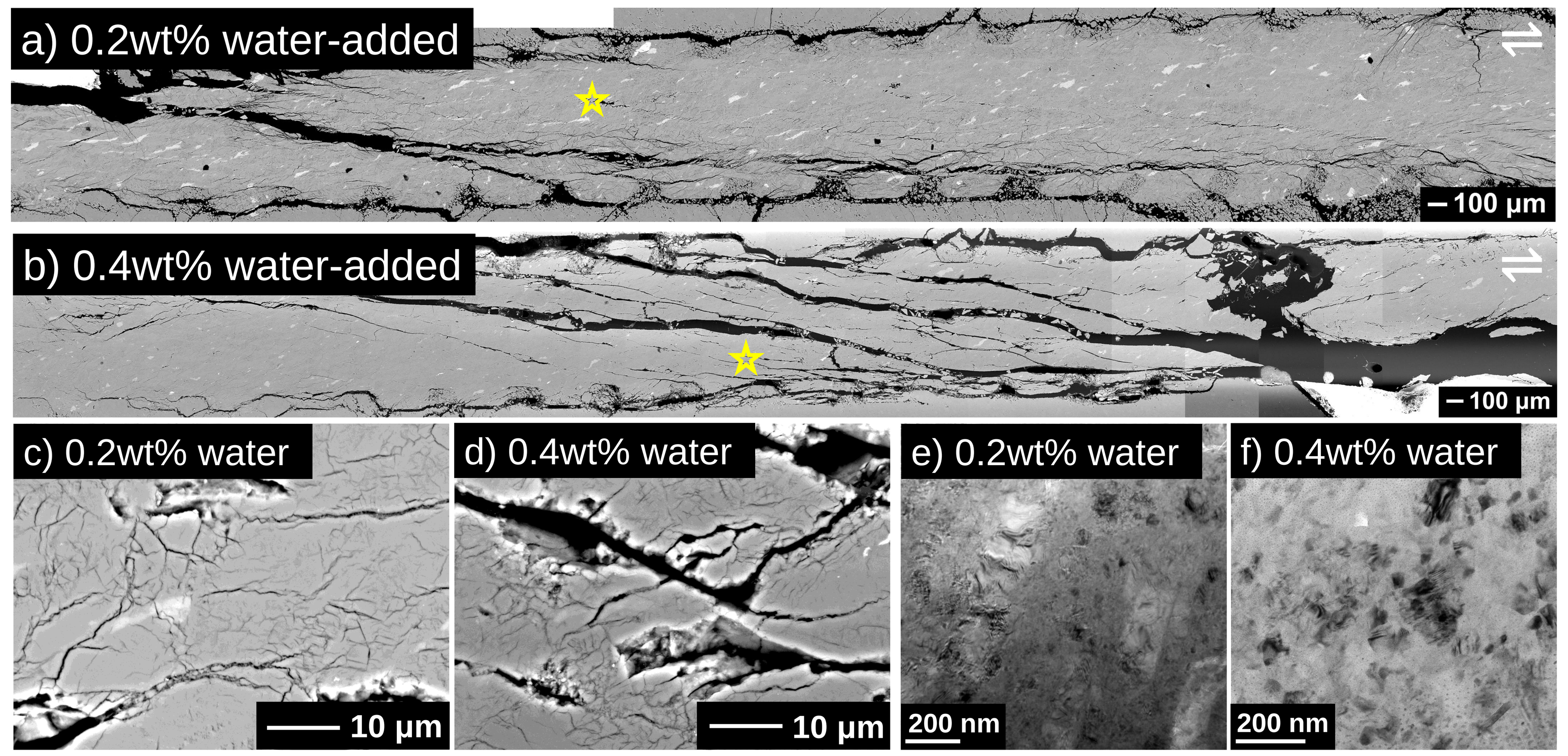


Fig. 4 Photomicrographs of the samples obtained with a scanning electron microscope (SEM, a-d) and a transmission electron microscope (TEM, e and f). Yellow stars denote the locations of c and d.

Microstructural observations reveal that the 0.4wt% water-added sample is more pervasively fractured than the 0.2wt% water-added sample. At a magnified view, the 0.2wt% and the 0.4wt% water-added samples show similar microstructures covered with microcracks. Both samples exhibit nanograins as small as ~50 nm.

References

[1] Kohlstedt et al., 1995JGR, [2] Tullis & Yund, 1980JSG, [3] Furukawa et al., 2023WRI-17, [4] Parks, 1984JGR

Discussion & Conclusion

Based on the microstructures, it is suggested that fracturing is promoted with increasing water. This would be explained by the reduction in the surface free energy in the presence of water[4].

The friction coefficient is calculated using $\mu = \tau/(\tau + P_C)$, where P_C is the average confining pressure (Fig. 5). The values of μ becomes smaller with increasing water from 0.2wt% to 0.4wt%, suggesting that the excess amount of water promotes sliding along fractures.

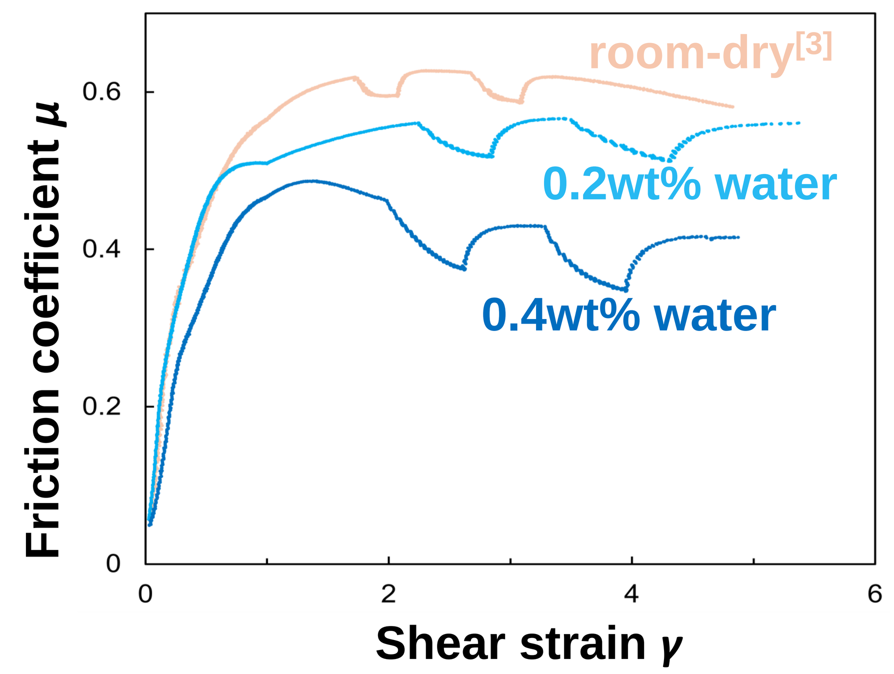


Fig. 5 Relationships between friction coefficient and shear strain during experiments

Combining mechanical and microstructural results, we conclude that water reduces the crustal strength both by fracturing and by grain boundary sliding of nanograins.

Summary

- ✓ Shear deformation experiments of quartz-albite mixtures
- ✓ Varying the amount of water (0.2wt% or 0.4wt%)
- ✓ 0.4wt% water-added sample shows strain-weakening
- ✓ Increasing water from 0.2wt% to 0.4wt% promotes fracturing, while nanograins are produced in both samples
- ✓ Water reduces the crustal strength by a mechanism where fracturing is accompanied with grain boundary sliding

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