# Decrypting healed fault zones: How gouge production weakens the impact of fault roughness

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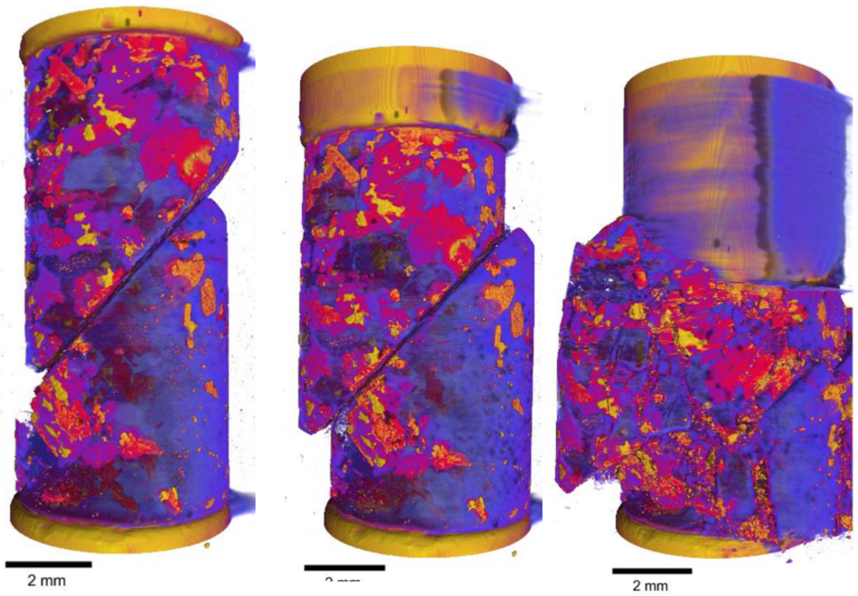
**Abstract**

Two key parameters control the localization of deformation and seismicity along and surrounding crustal faults: the strength and roughness of the preexisting fault surface. Using three-dimensional discrete element method simulations, we investigate how the anisotropy and amplitude of roughness control the mechanical behavior of healed faults within granite blocks during quasi-static triaxial compression. The results show that the localization of fracture development into a damage zone surrounding the initially weak fault zone coincides with the macroscopic failure of the rock. Rougher faults produce more gouge than smoother faults, providing an explanation for the weak influence of roughness on compressive strength. The particles within smoother fault zones slip with higher maximum fault-parallel velocities than rougher faults during the quasi-static loading, likely because the asperities do not impede slip as effectively in the smoother fault zone. The maximum fault-parallel velocity occurs after the peak stress, and falls to a steady state value by the end of the simulation, highlighting the non-constant evolution of slip despite the constant axial strain rate loading conditions. Smoother faults develop stronger correlations between the fault topography and fault slip magnitudes, likely because smoother faults experience higher velocities than rougher faults. Thus, fault surface asperities control slip by acting as speed bumps that hinder fault-plane parallel slip and promote fault-plane normal opening. These numerical models provide insights into the evolution of damage localization, fault roughness, gouge production, asperity abrasion, fault slip and stress concentrations along initially healed faults of varying roughness.

# Decrypting healed fault zones: How gouge production reduces the influence of fault roughness

How does healing influence the dynamics, stability, and strength of fault zones?
What is the influence of roughness on fault strength ***following healing***? (under review at GJI)

X-ray synchrotron experiments with pre-cut faults demonstrate the influence of roughness on fault stability for non-cohesive faults.





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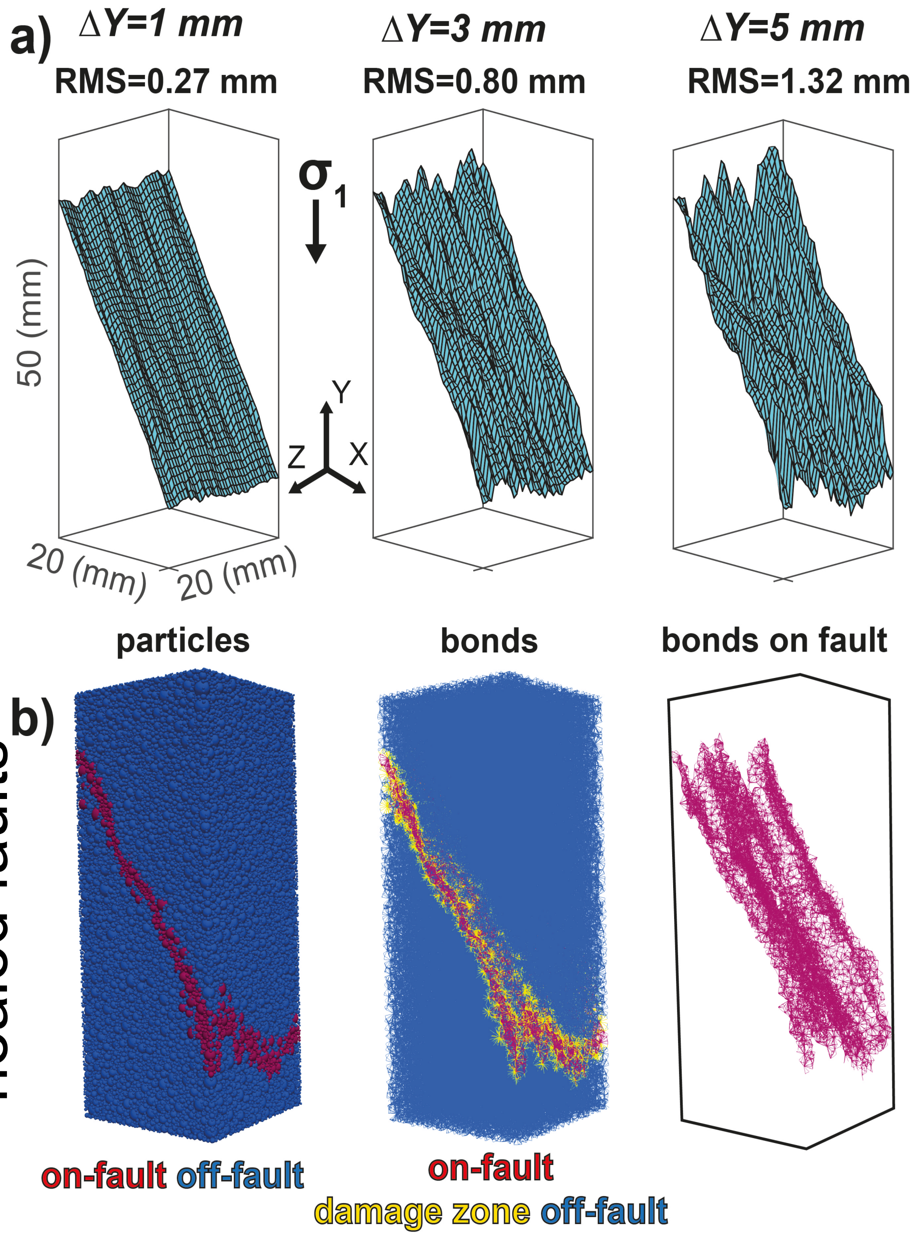
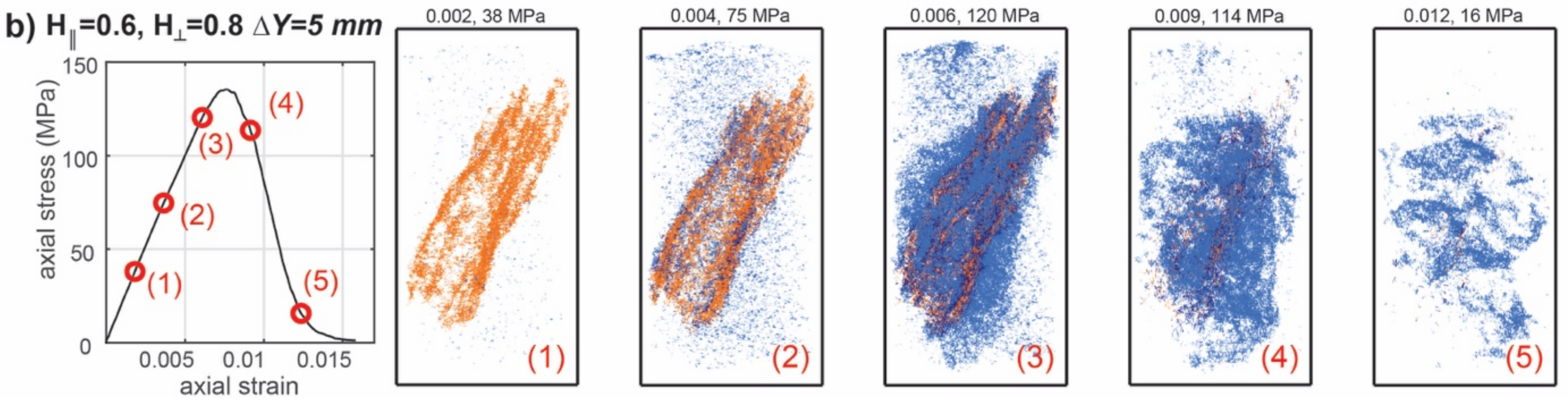
DEM model of healed faults

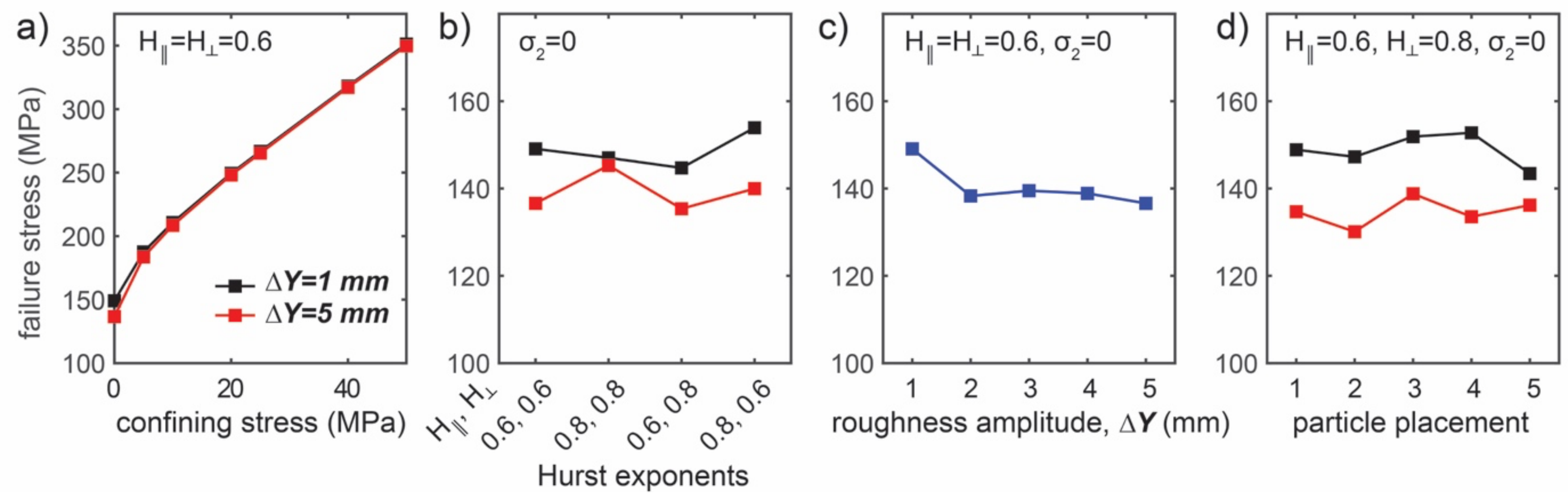


# Characteristic fracture development

Orange: on-fault fractures
Blue: off-fault fractures

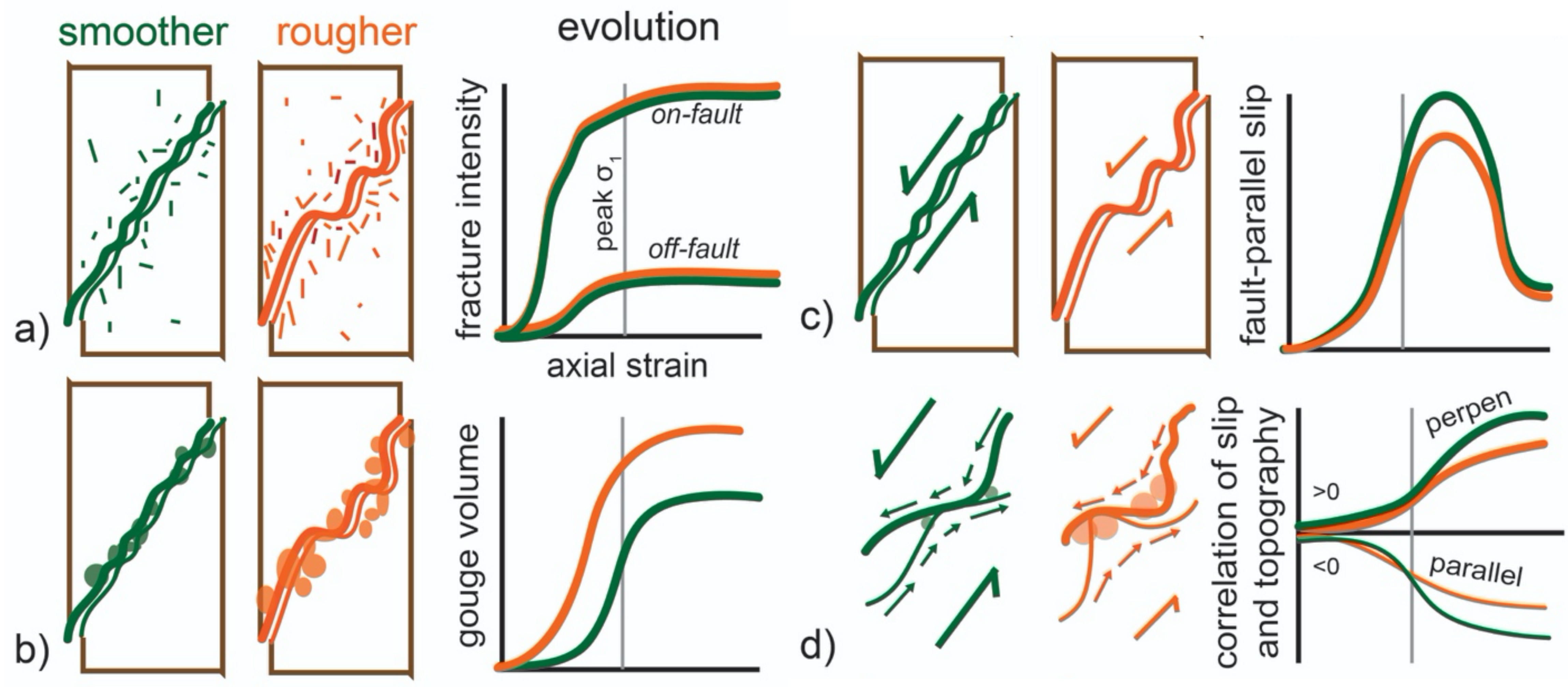



Below: Surprisingly, the tested combinations of Hurst exponents (b) and roughness amplitudes (c) ***do not produce changes*** in the macroscopic strength that are larger than those produced by random variations in particle packing (d).




***We attribute this result to the greater gouge production along the rougher fault.***

# Schematic Summary: Influence of smooth and rough fault surfaces on a) fracture network partitioning, b) gouge production, c) fault slip, d) asperity interaction

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