Near-surface earthquake rupturing in high-porosity sandstone documented by a combined meso-microstructural, mineralogical, and experimental approach (Crotone forearc Basin, Italy)

Mattia Pizzati(1), Stefano Aretusini(2), Elena Spagnuolo(2), Luca Aldega(3), Anita Torabi(4), Fabrizio Storti(1) and Fabrizio Balsamo(1)

(1)-University of Parma, Department of Chemistry, Life Sciences and Environmental Sustainability, 43124, Parma, Italy.
(2)-Istituto Nazionale di Geofisica e Vulcanologia, Sezione 1, 00143, Rome, Italy.
(3)-Sapienza University of Rome, Department of Earth Sciences, 00185, Rome, Italy.
(4)-University of Oslo, Department of Geosciences, Postbox 1047, Blindern 0316, Oslo, Norway.

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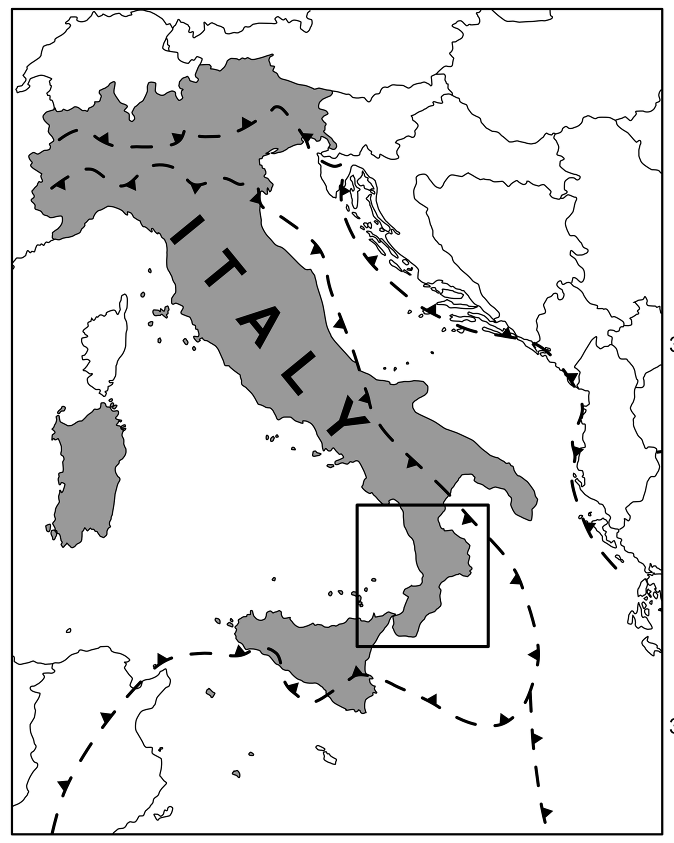
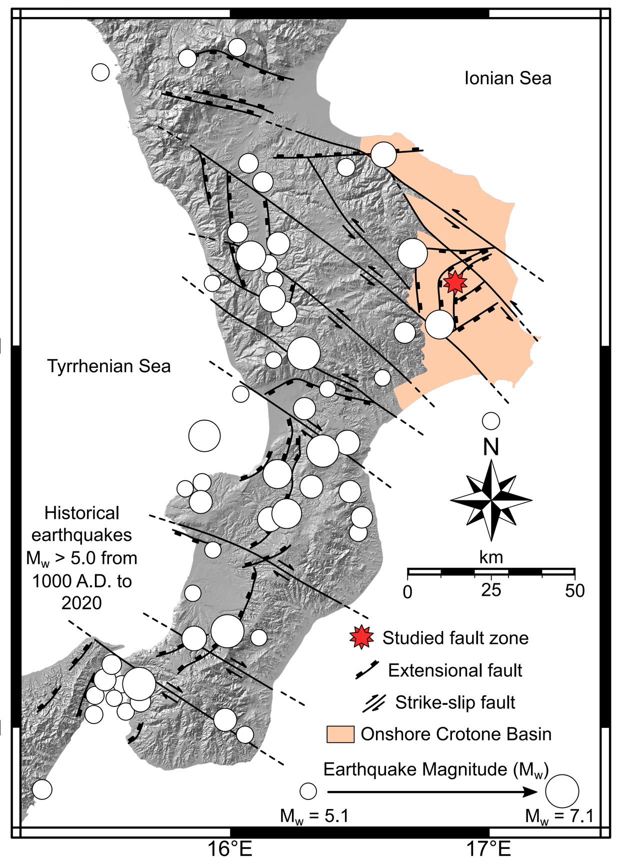
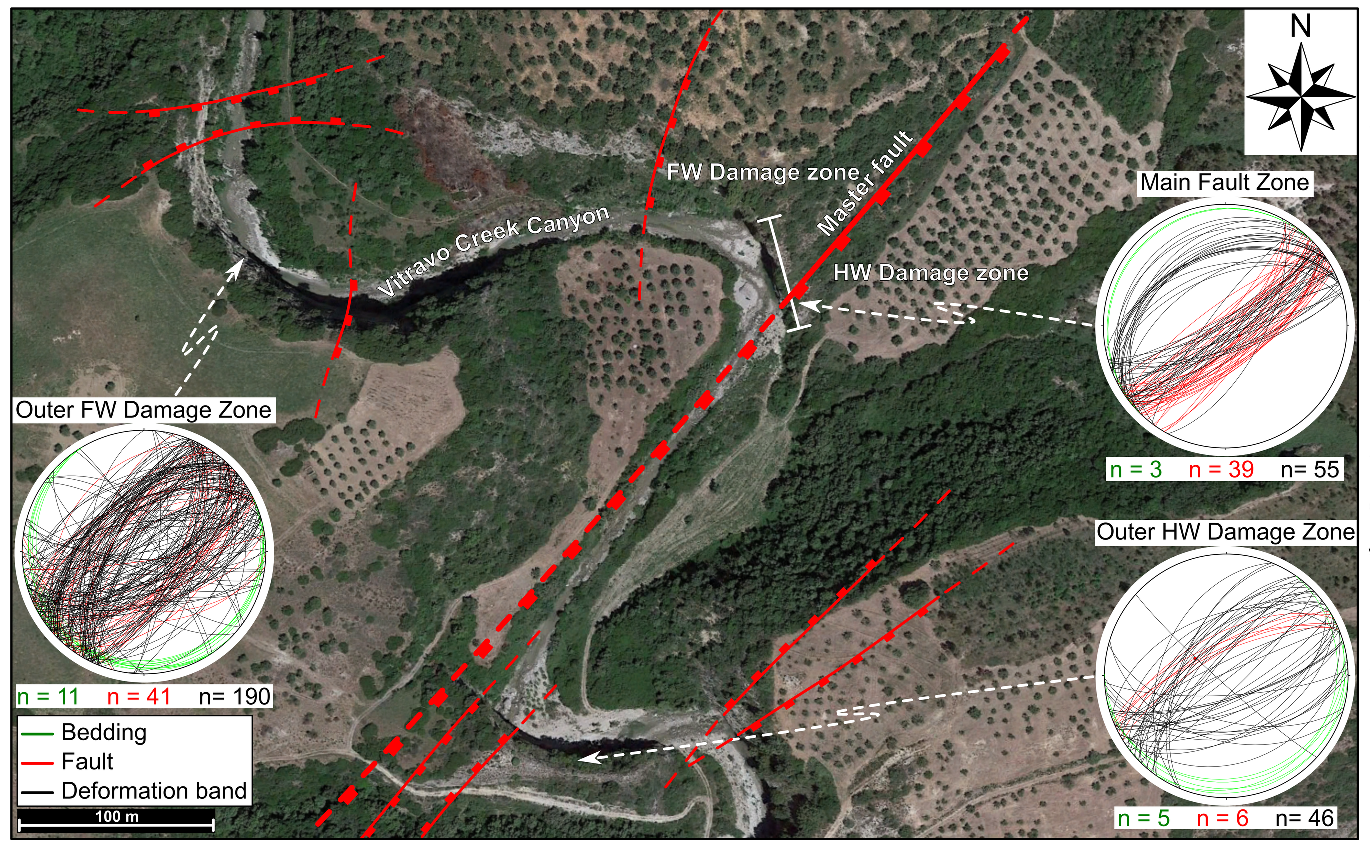
mattia.pizzati@unipr.it







1. Introduction:

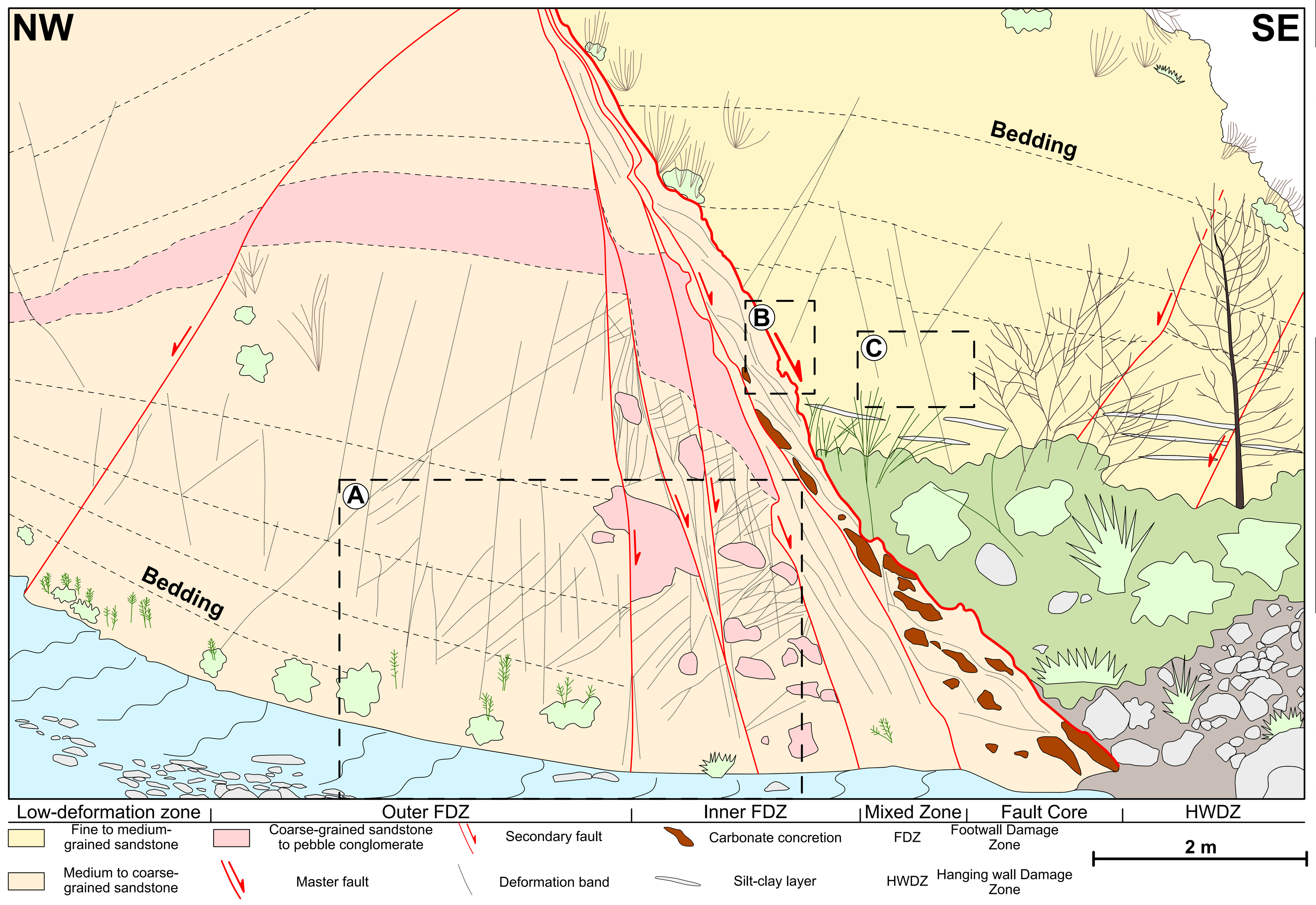
Coseismic deformation in high-porosity granular media represents a topic to be investigated as the mechanical behavior of sediments is typically associated with slip-hardening and velocity-strengthening processes, which hamper the nucleation and propagation of seismic slip. We hereafter provide evidence for coseismic deformation under shallow burial conditions (< 1 km depth).

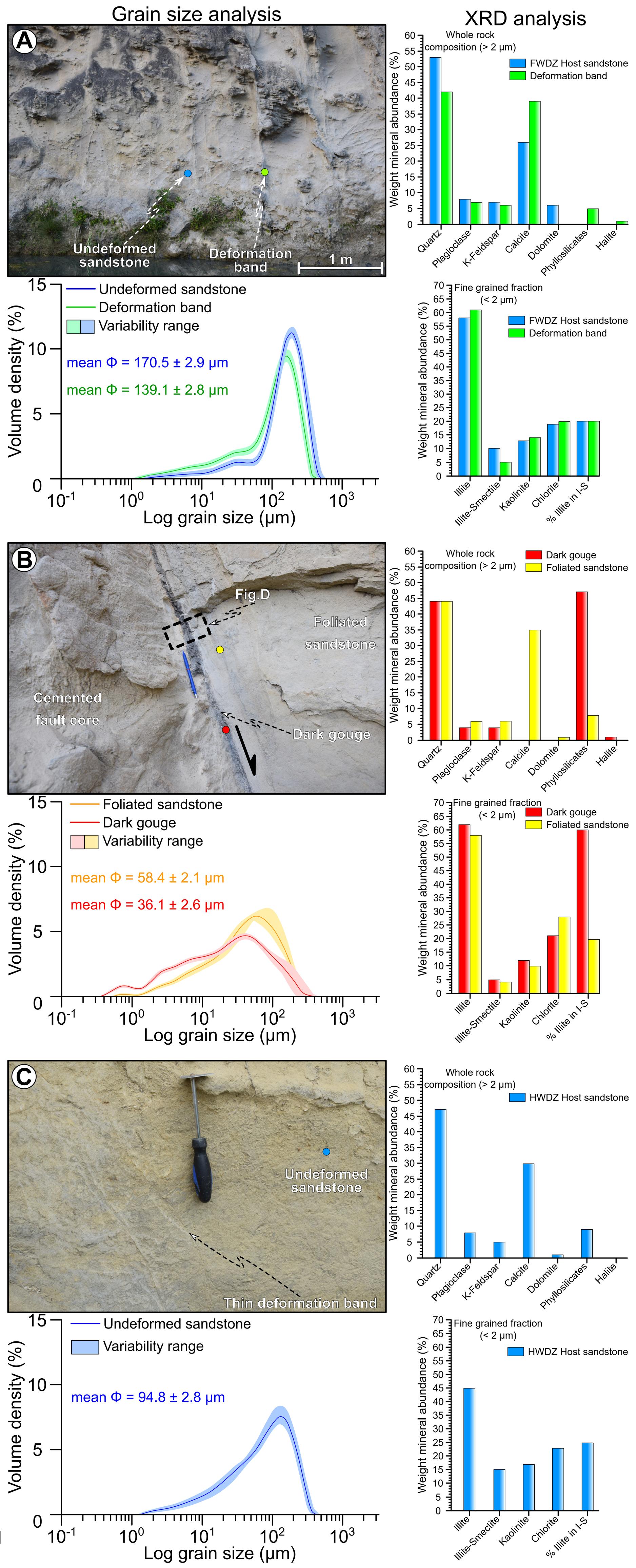
2. Geological setting:

The studied extensional fault zone is located along the Vitravo Creek, Crotone forearc Basin, South Italy and deforms Plio-Pleistocene high-porosity, shallow marine sandstones and conglomerates.

3. Fault zone structure:

The fault accommodated ~50 m of displacement and is composed of a core bounded by a 2-3 cm-thick dark gouge, a ~1 m-wide mixed zone, and footwall (8-9 m-wide) and hanging wall (5-6 m-wide) damage zones, with a wealth of deformation bands and subsidiary faults organized in conjugate sets resembling R-R[1] Riedel pattern.

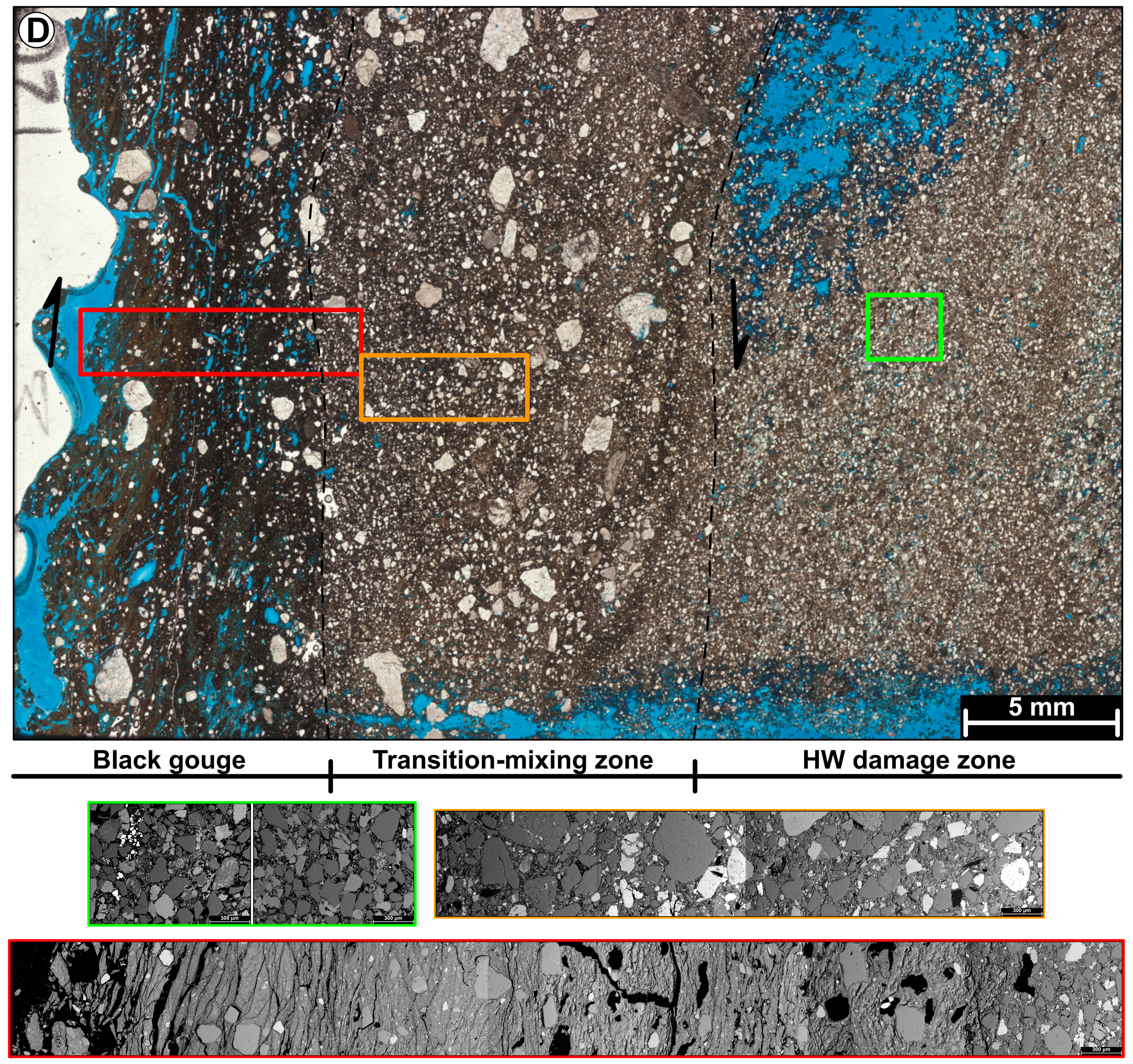




4. Microstructural features:

Deformation bands display moderate grain size reduction and fabric reorganization imparted by granular flow overprinted by cataclasis after porosity loss.

The dark gouge shows severe grain size reduction, accompained by tectonic mixing of different sedimentary layers. The gouge displays a gradient of grain size reduction with the footwall side being more comminuted than the hanging wall side.

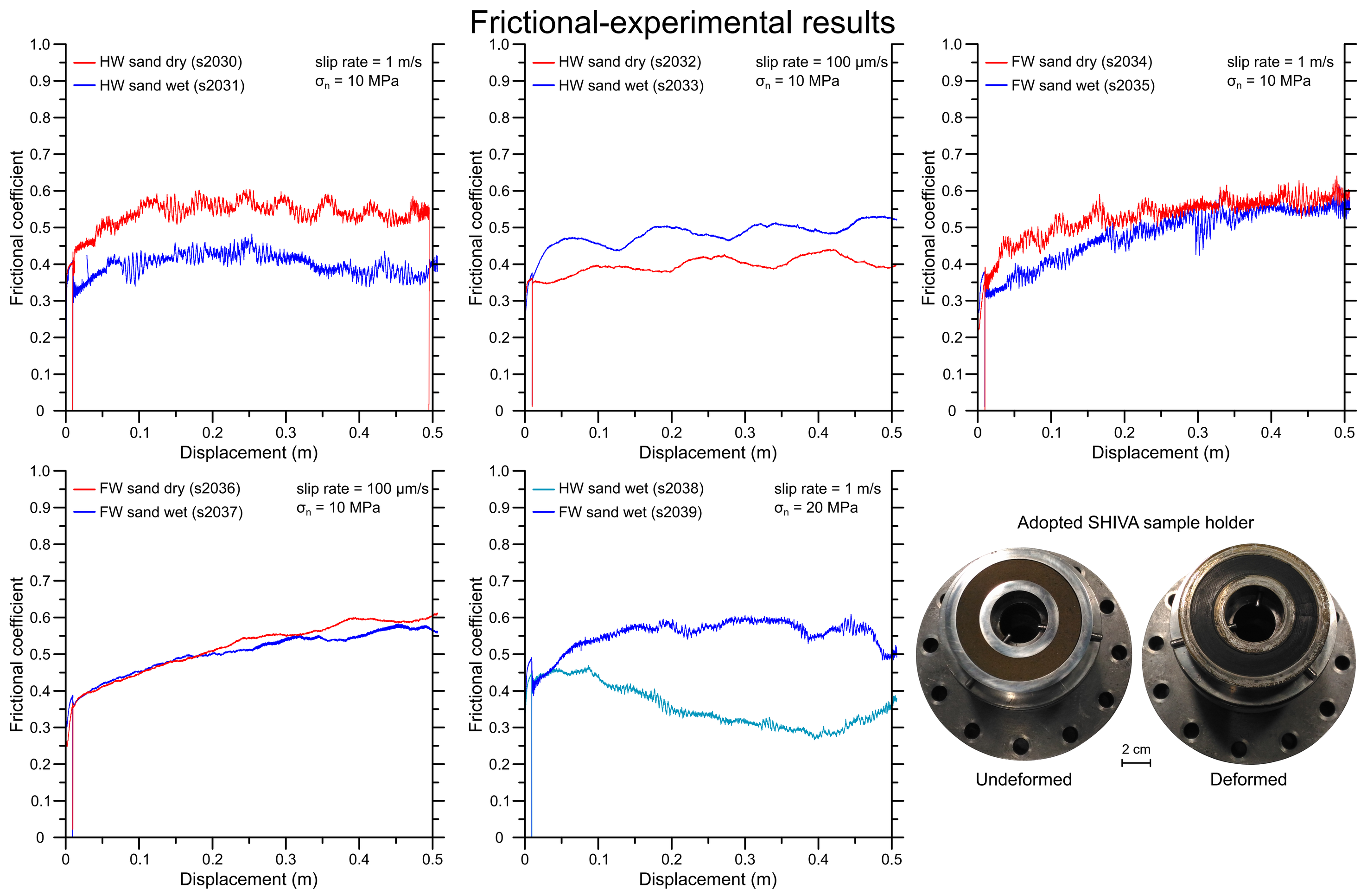


5. Mineralogical analysis:

Quartz, calcite, and feldspar-plagioclase dominate the undeformed host rock and deformation band samples, while dark gouge shows high amounts of phyllosilicates (illite and smectite). In short-ordered illite-smectite layers of dark gouges, the percentage of illite is 60%, while it is less than 25% in other deformation structures.

6. Mechanical properties:

The host footwall sandstone shows a slip-hardening behavior under both aseismic and coseismic slip rates with dry and fluid saturated conditions at normal stress of 10 and 20 MPa. Conversely, the hanging wall sandstone displays a slip-weakening behavior under coseismic slip rate and fluid saturated conditions at normal stress of 20 MPa.



7. Discussion and conclusions:

The mineralogical composition of dark gouge suggests deformation temperatures above 100 °C, exceeding the burial-related temperature for 0.5-1.0 km sediment overburden. This temperature anomaly is found only in the 2-3 cm-thick dark gouge, while the surrounding cemented fault core and host sandstone recorded shallow burial related temperature (< 50 °C). The severe cataclastic grain size reduction supports the hypothesis of fast slip rates, corroborated by the slip-weakening behavior characterizing the hanging wall sandstone under fluid saturated conditions. We interpret the local increase in temperature within the dark gouge as witness of flash heating related to strain localization during shallow, moderate magnitude (M_w 5.0-5.5) earthquakes.

Further readings:

Balsamo, F., Aldega, L., De Paola, N., Faoro, I., and Storti, F., 2014, The signature and mechanics of earthquake ruptures along shallow creeping faults in poorly lithified sediments: Geology, v. 42, p. 435–438, doi:10.1130/G35272.1.

Pizzati, M., Balsamo, F., and Storti, F., 2023, Fingerprints and energy budget of the earthquake cycle in shallow sediments: Journal of Structural Geology, v. 170, p. 104858, doi:10.1016/j.jsg.2023.104858.