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Faulting of a turbidite sandstone-siltstone successions: the case study of the Macigno Formation, Tuscany, Italy

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Faults in siliciclastic rocks are characterized by a great variability of fault zone architecture and relative permeability properties. This is because siliciclastic rocks (i.e turbidites) are often represented by alternating beds of various thickness and grain size forming a succession of strata with contrasting mechanical properties. For example, the presence of sandstone and clay-rich layers is responsible for the simultaneous occurrence of brittle and ductile deformation, known as “clay smear structures”. Moreover, numerous studies have identified grain size as one of the main influencing factors for fault nucleation processes and fracture intensity in the damage zone.
In this work, we present the results of field and laboratory analyses performed on the Macigno Formation cropping out along the coast of western Tuscany. Here, the Macigno Formation is represented by Late Oligocene foredeep siliciclastic succession dominated by turbiditic sandstones with minor siltstones, mudstones, marls and shales. Thin section and 3D analyses, performed by X-ray Synchrotron tomography, allowed us to characterize the grain size and grain and cement composition of studied rocks. Grain size varies from channelized fine-grained sandstones to granule-conglomerates beds (0.006 mm to 4 mm) alternating with heterolithic levee strata of siltstones to fine-grained sandstones (0.0035-0.008 mm). The lithic components consist of metamorphic rocks by 70-80%, magmatic rocks by 15-20% and sedimentary rocks by 5-15%. The turbidite beds are normally well-cemented (by quartz and calcite) and heavily faulted and fractured.
Investigated faults show dip-, oblique- and and strike-slip motion and their displacement range from 10s of centimetres to 10s of metres. We documented how both the grain size and the mechanical properties of the alternating beds strongly control the fault zone architecture, in particular in terms of damage zone thickness and fracture frequency. The fault rock types (i.e. breccia vs. gauge) are strictly related to the amount of displacement as well as to the grain size and the cementation of the sandstone. Furthermore, the development of clay smear structures are enhanced by the presence of interbedded thin clay-rich layers.