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Lithological controls on the frictional behavior of a seismically active, upper crustal carbonate fault

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The Gubbio normal fault (1984, Mw = 5.6) is an active segment of the Umbria Fault System in the northern Apennines of Italy. It has accumulated >2 km of displacement since the Lower Miocene. We have studied a well-exposed section through the footwall of the fault, where rocks have been exhumed from 2.5-3 km. The protolith comprises two thinly-bedded (beds ~2-20 cm thick) limestone members of the mid-Cretaceous Scaglia Rossa formation. The first is a pale yellow, micritic limestone with interbedded clay layers 5-100 mm thick. The second is a red, marly limestone also with thin (2-10 mm) partings of clay between beds.

The majority of displacement is concentrated within a fault core ~15 m wide, which can be split into four structural domains (D1-D4), delimited by four major faults (F1-F4). In D1-D3, derived from the micritic limestone, rocks are heavily brecciated and slip is confined mainly to principal slip surfaces. Microstructural analysis reveals shear localization zones (Y-shears), <25 μm thick, composed of ultrafine, foliated, phyllosilicate-rich (up to 80%) gouge. Secondary electron microscope analysis of the natural slip surface shows that it is composed of tightly packed, tiny particles of calcite, which average 10-20 nm in size.

In D4, derived from the marly limestone, deformation style is markedly different. Shearing is distributed throughout via an S-C fabric, defined by synthetic shear planes and anastomosing, pressure-solution seams; brittle deformation is rare. The solution seams have spacings ranging from μm-cm scale and can be up to 100 μm wide. They are composed of ~50% phyllosilicates and 40% calcite, with the remaining 10% comprising quartz and diagenetic apatite. The seams are foliated internally and other microstructures include kinks/folds of the phyllosilicate foliation and pressure shadows around clasts, all of which have a sense of movement consistent with that of the fault zone.

The brittle and localised deformation features in D1-D3 are similar to those observed during laboratory experiments on materials displaying velocity-weakening behaviour. Earthquake nucleation could be favoured along the observed slip surfaces in D1-D3. In contrast, structures in D4 are comparable to those obtained during experiments where rocks have behaved in a velocity-strengthening (aseismic) manner, deforming predominantly by pressure-solution creep and foliation-parallel sliding. Thus the behaviour of the Gubbio fault during the seismic cycle is likely to be complex, with a lithologically-controlled interplay between brittle/localised (nucleation/propagation) and ductile/distributed (interseismic/post-seismic) deformation.

Using the low to high velocity rotary shear apparatus at Durham University, we will perform a set of experiments to examine the effect of phyllosilicate content on the frictional behaviour of samples collected from the Gubbio fault zone. Subsequently, it will be possible to assess the role of creeping deformation within the fault zone and its implications for tectonic loading and earthquake nucleation, and afterslip deformation.