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Seismic slip on clay nano-foliation

Stefano Aretusini (1), Oliver Plümper (2), Elena Spagnuolo (3), and Giulio Di Toro (1)

(1) University of Manchester, School of Earth and Environmental Sciences, Manchester, United Kingdom (stefano.aretusini@postgrad.manchester.ac.uk), (2) Utrecht University, Utrecht, The Netherlands, (3) Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy

Deformation processes active at seismic slip rates (ca. 1 m/s) on smectite-rich slipping zones are not well understood, although they likely control the mechanical behaviour of: i) subduction zone faults affected by tsunamigenic earthquakes and seismic surface rupturing, and ii) landslide decollements.
Here we present a set of rotary experiments performed on water-dampened 2 mm thick clay-rich (70% wt. smectite and 30% wt. opal) gouge layers sheared at slip rates V ranging from 0.01 to 1.5 m/s, for 3 m of displacement under 5 MPa normal stress. Microstructural analyses were conducted on pre- and post-sheared gouges using focused ion beam scanning electron and transmission electron microscopy. All sheared gouges were slip weakening in the first 0.1 m of displacement, with friction coefficient decreasing from 0.4-0.3 to 0.1-0.05. Then, with progressive slip, gouges evolved to slip-strengthening (final friction coefficient of 0.47-0.35) at V $\leq$0.1 m/s and slip-neutral (final friction of 0.05) at V=1.5 m/s. Despite the large difference in the imposed slip rate and frictional behaviour, the slipping zone always consisted of a nano-foliation defined by sub-micrometric smectite crystals wrapping opal grains. The microstructural differences were (1) the thickness of the slipping zone which decreased from 1.5 mm at V$\leq$0.1 m/s to 0.15 mm at V=1.5 m/s, and (2) the structure of the foliated fabric, which was S/C'-type at V$\leq$0.1 m/s and anastomosing-type at V=1.5 m/s. The presence of a similar nano-foliation in all the smectite-rich wet gouges suggests the activation of similar frictional processes, most likely grain boundary and interlayer frictional sliding aided by water films, operating from sub-seismic to seismic strain rates ($\sim$10-10000 1/s).
Water films on crystal boundaries and interlayers possibly control the micro- and nano-mechanics of smectite deformation, therefore influencing the bulk frictional behaviour during seismic slip.