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Heterogeneous frictional properties of natural carbonate-bearing normal faults

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In the active area of the Apennines (Italy), most of the strongest earthquakes, $6 < M < 7$, occur on normal faults nucleating within sedimentary rocks composed of carbonates. Exhumed (< 3 km) carbonate-bearing faults of the area show a fault zone structure consisting of continuous and striated principal slip surfaces separating hangingwall and footwall blocks made of: 1) fractured and cemented cataclasites, 2) fractured and cemented cataclasites vs. foliated and phyllosilicate-rich fault rocks, and 3) fractured and cemented cataclasites vs. phyllosilicate-rich fault gouge. In order to take into account the complexity of the fault zone structure we have collected natural slip surfaces, intact foliated fault samples, and powdered fault gouge. We performed friction experiments on: 1) slip surfaces vs. slip surfaces (SS/SS), 2) slip surfaces vs. foliated samples (SS/FS), and 3) slip surfaces vs. powders (SS/P). Friction, velocity dependence of sliding friction, and slide-hold-slide tests have been performed in a biaxial testing apparatus at room temperature, normal stresses of 2 to 30 MPa, and sliding velocities of 1 – 300 micron/s. SS/SS experiments show fiction in the range 0.6-0.7, a velocity weakening behaviour with increasing sliding velocity, and significant healing with holding time (0.1 in friction in 1000 seconds). We did not reach a steady state condition with displacement because of stress drops and re-strengthening associated with reactivation of riedel shear planes and/or smoothness of the slip surface. In SS/FS experiments, friction is low (about 0.4), the behaviour is velocity strengthening, and friction increases 0.02 in 1000 seconds of holding. SS/P experiments show friction in the range 0.6-0.7, both velocity weakening and strengthening behaviour not correlated with increasing sliding velocity, and an increase in friction in the range of 0.02-0.04 in 1000 seconds.
Our data suggest that in order to understand the complex seismic behaviour of the area represented by mainshocks and aftershock sequences, foreshocks, clusters of microseismicity, fault creep and slow earthquakes, we must take into account the complex fault zone structure observed in the field and the heterogeneous frictional properties documented in the lab.