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Weakening processes and character of slip along low-angle normal faults

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In extensional environments, Anderson-Byerlee frictional fault mechanics predicts no slip on normal faults dipping less than 30˚. This prediction is consistent with the dip-range of large normal-slip ruptures unambiguously identified from focal mechanisms, but is inconsistent with the increasing recognition of low-angle normal faults (LANF; dips <30˚). Good examples occur in the Northern Apennines of Italy, where seismic reflection profiles and two dense seismic networks have identified an active LANF characterised by microseismicity in an Andersonian stress field.

In order to investigate the deformation processes operating along the active LANF we have studied an exhumed analogue belonging to the same fault system. Field based and microstructural studies from the exhumed (from 3-6 km depths) Zuccale fault in the Isle of Elba, suggest an evolution from an initial brittle cataclasite to a narrow foliated fault core formed as the result of syntectonic fluid–rock interactions. Fluids reacted with the fine-grained cataclasite to produce fine-grained aggregates of weak, phyllosilicate-rich fault rocks leading to reaction softening. In addition, the fine grain sizes trigger the widespread onset of stress-induced dissolution and precipitation processes. The resulting fault rock textures are very similar to those formed during pressure-solution accommodated creep in experimental phyllosilicate-rich fault rock analogues. In the experimental work, the switch in rheology is associated with a decrease in friction from Byerlee's values to 0.2 or less. With a friction coefficient of

0.2, LANFs such as those observed in the Northern Apennines could move easily in a stress field with vertical S1. Furthermore, such weak faults would be incapable of generating big earthquakes because, at low sliding velocity, the pressure-solution accommodated deformation is a velocity strengthening process favouring aseismic slip.

The microseismic activity affecting the active LANF could be the result of local short lived attainment of fluid overpressure favoured by both the impermeable character of the foliated fault core and the large regional CO_2 degassing affecting the area. Fluid overpressures up to 80% of the lithostatic load have been recorded in the San Donato borehole located in the footwall of the microsesimically active LANF. A fossil example of these processes is represented by the complex syntectonic vein systems associated with the ZF where crack-seal textures in the hydrofractures testify to cyclic build ups in fluid overpressure during fault activity.