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The Structure and Mechanics of Large Strike-Slip Faults from Field Observations

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Elucidation of the internal structure of fault zones is paramount for understanding their mechanical, seismological and hydraulic properties. In order to observe representative brittle fault zone structures, the fault must be passively exhumed from seismogenic depths and the exposure must be in arid or semi-arid environments where the fragile fault rocks are not subject to extensive weathering. Observations of two such faults are used to constrain the likely mechanical properties. One fault is the Carboneras fault in southeastern Spain, where the predominant country rocks are phyllosilicate-rich lithologies, and the other is part of the Atacama fault system in northern Chile, where faults run through crystalline rocks of acidic to intermediate composition.

The Carboneras fault is a 40 km offset fault exhumed from approximately 4 km depth, and displays multiple strands of clay-bearing fault gouge, of 2-10 m width, that contain variably fractured lenses of protolithic mica schists. The strain is evenly distributed across the gouge layers, in accordance with the measured laboratory mechanical behaviour which shows predominantly strain hardening characteristics. The overall width of the fault zone is several hundred metres wide. Additionally, there are blocks of dolomitic material that are contained within the fault zones that show extremely localized deformation in the form of faults several centimetres wide. These are typically arranged at an angle of $\sim$20 degrees to the overall fault plane. These differing types of fault rock products allow for the possibility of ‘mixed mode’ seismicity, with fault creep occurring along the strands of velocity strengthening clay-rich gouge, punctuated by small seismic events that nucleate on the velocity weakening localized faults within the dolomite blocks.

The Caleta Coloso fault in northern Chile has an offset of approximately 5 km and exhumed from 5 to 10 km depth. The fault core is represented by a 200 – 300 m wide zone of hydrothermally-altered protocataclasite and ultracataclasite. This is surrounded by a zone of micro- and macro-fractures on the order of 150 m thick. The fault core shows a heterogeneous distribution of strain, with alternate layers of ultracataclasite and lower strain material. The strain-weakening behaviour of crystalline rocks might be expected to produce highly localized zones of deformation, and the wide core zone must be a result of additional process such as precipitation strengthening, or geometric irregularities along the fault plane.