

EGU21-6627

<https://doi.org/10.5194/egusphere-egu21-6627>

EGU General Assembly 2021

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## Weak at what scale? Insights from a late interseismic interplate fault

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The central section of the Alpine Fault accommodates a majority (~75%) of the total relative Pacific-Australian plate boundary motion on a single structure. For strain localization to occur to such an extent, the Alpine Fault must accommodate deformation at spatially and temporally averaged work rates that are lower than those required by hanging wall and footwall structures. Exhumation of a complete fault rock sequence (mylonites-cataclasites-gouges) from ~35 km depth in <5 million years provides us with an unparalleled opportunity to identify the weakening mechanisms underpinning the fault's remarkable efficiency. We summarize the results of experimental, geochemical, geophysical, seismological, and geological research facilitated by the Deep Fault Drilling Project (DFDP).

Three main factors promote crustal-scale weakness on Alpine Fault: (1) high heat flow associated with rapid exhumation results in a shallow frictional-viscous transition at 8-10 km depth. In turn, temperature-sensitive creep (initially crystal-plasticity with an increasing contribution from grain size sensitive mechanisms during exhumation) can accommodate deformation at strain rates on the order of, and episodically higher than,  $10^{-12}\text{s}^{-1}$  across a broad portion of the fault zone (from ~8 to 35 km depth). (2) Above the frictional-viscous transition, cataclastic processes associated with quasiperiodic large-magnitude earthquakes have permanently reduced the elastic moduli of damage zone rocks; and (3) cataclastic processes, combined with fluid-rock interactions, have formed low-permeability principal slip zone gouges and cataclasites. The near-ubiquitous presence of juxtaposed, low-permeability fault core gouges and cataclasites promotes dynamic (coseismic) weakening mechanisms such as thermal pressurization.

Clay mineral alteration reactions are commonly thought to result in fault zone weakening through a reduction in the static coefficient of friction, but fluid-rock interactions on the central Alpine Fault largely result in the precipitation of frictionally strong minerals such as calcite and, locally, K-feldspar. Although relatively narrow in down-dip extent, the brittle seismogenic zone of the central Alpine Fault is not misoriented with respect to the maximum principal stress when a full 3D stress

analysis is performed. Moreover, the fault comprises frictionally strong gouges and cataclasites that can sustain high differential stresses. Combined, these factors have important implications for estimating dynamic stress drops and the extent to which future earthquake ruptures may propagate beneath the brittle-ductile transition, thereby increasing moment magnitude.