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How do fluid-rock reactions influence the strength of the Alpine Fault, New Zealand?

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The transpressive Alpine Fault, New Zealand, has a ~300 year recurrence period of large events (Mw 7-8), the last being in 1717, indicating it is late in its seismic cycle [1]. Previous work has identified, rich in illite and chlorite (±smectite) that is a low permeability barrier to fluid flow [2]. In this study we investigate the role fluids play in modifying the chemical and physical properties of fault zones, which may prime them for repeated rupture.

Rapid uplift of ~10 mm/yr on the Alpine Fault has raised geothermal gradients (>60 °C/km) and topography, driving fluid flow in the hangingwall. This results in the fault's damage zone undergoing extensive fluid-rock interaction with circulating meteoric waters [3]. As the fault zone is exhumed, rock strength is controlled by the evolution of mechanically strong quartzofeldspathic mylonites to a weaker clay-rich cataclastic fault core, a process facilitated by these fluids. We quantify fluid-assisted mineralogical and chemical changes using whole rock major and trace element geochemistry. This shows that the observed decreasing permeability in proximity to the principal slip zone is accompanied by increased hydration and carbonation driven by fluid-rock interaction. We use stable oxygen and hydrogen isotopes of alteration phases to identify fluid-rock ratios and model temperatures of key fluid-mineral and mineral-mineral transformation reactions. Linking fluid-rock interaction to seismic cycle timing, whole rock $\delta^{18}O$ values were found to change during direct shear experiments lasting under an hour. Thus indicating fluid-rock oxygen isotope exchanges may be rapid during shearing and minerals formed during such events may record an isotopic signature of syn-deformation fluids. Our study aims to quantify the importance of specific fault strengthening (healing and sealing by strong minerals, e.g. calcite) and weakening (alteration of strong to weak minerals, e.g. clay alteration) processes in an active fault zone.

[1] Sutherland et al. (2007), *Geophys. Monogr Ser*. 175.
[2] Sutherland et al. (2012), *Geology 40 (12), 1143–1146.*
[3] Menzies et al. (2016), *EPSL* 445, 125-135.