Fluid-Rock Interaction in the Alpine Fault Zone, New Zealand

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The Alpine Fault of the South Island, New Zealand marks the active transpressional boundary between the Australian and Pacific plates. It is late in its seismic cycle and capable of producing earthquakes of M_w ~8, providing a rare opportunity to document processes in a continental-scale fault zone that ruptures in major seismic events. Rapid uplift of ~10 mm/yr on the Alpine Fault has raised geothermal gradients (>60 °C/km) and topography, driving fluid flow. Alpine Fault Zone (AFZ) cataclasites are chemically altered from successive episodes of fluid-rock interaction, which influences fault strength, permeability evolution, and therefore the fault's mechanical behaviour.

We identify fluid sources, the degree of fluid-rock interaction, and flow paths in and around the AFZ. Secondary mineral δD compositions (δD_{H2O} = -45 to -87 ‰) require that meteoric waters are dominant. In support of this, modern day, meteoric-derived warm spring waters are saturated in secondary minerals observed in the AFZ and calculated vein-forming fluid trace element compositions are similar to spring waters. Fluids that formed vein minerals at greater crustal depths have more extensively exchanged trace elements and oxygen with host rocks. $^{87}Sr/^{86}Sr$ of hangingwall veins formed down to seismogenic depths show no evidence for interaction with highly radiogenic footwall rocks. Hydrothermal alteration has lowered permeability in the AFZ, creating a barrier to fluid flow that may promote thermal pressurisation and fault weakening during rupture. These findings indicate that the circulation of modern day meteoric waters plays an important role in the evolution of the AFZ by redistributing mass and consequently changing the material properties of the plate boundary.