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Porosity evolution within the active Alpine Fault zone, New Zealand. Implications for fault zone rheology.

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Feedback between deformation mechanisms, fluid-rock interactions and porosity evolution in fault zone rocks has a crucial impact on their bulk rheology. Porosity formation within mid-crustal fault rocks (typically mylonites) can facilitate fluid flow, formation of mineral and geothermal resources, and can promote strain localization. On the contrary, porosity reduction in rocks from a brittle fault core (typically cataclasites) can cause elevated pore fluid pressures, and consequently influence the recurrence time of earthquakes.

We characterized the porosity distribution within the New Zealand's Alpine Fault zone in cataclasite samples recovered during the first phase of the Deep Fault Drilling Project and outcropping mylonitic rocks collected at Stoney Creek, New Zealand. Synchrotron X-ray microtomography-derived analyses of open pore spaces show total microscale porosity values in the range of 0.1-0.24% within the cataclasites and up to 0.44% in the mylonites. Synchrotron nanotomography datasets reveal additional 0.03 to 0.19% pore volumes within the mylonites. In all samples, pores are very small, not connected, with mainly non-spherical, elongated, flat shapes and show subtle bipolar orientation. Scanning and transmission electron microscopy reveal the samples' microstructural organization, where nanoscale pores ornament grain boundaries of the constituent minerals. Pores are mostly associated with (often newly formed) clay minerals in the cataclasite samples, suggesting the orientation of clays controls the shape and orientation of the associated pores. In the mylonitic samples, pores are sub-parallel to the foliation, and often associated with C'-type shear bands, indicating formation during creep cavitation.

Our observations imply that porosity within the Alpine Fault core was reduced due to pressure solution processes and the associated mineral precipitation. Simultaneously propagation of fluids triggered by cavity formation in the ductile regime is likely to cause further mineral precipitation in fluid filled pores within the fault zone. Such precipitation can affect the mechanical behavior of the Alpine Fault by decreasing the already critically low total porosity of the fault core, causing elevated pore fluid pressures, and/or introducing weak mineral phases, and thus lowering the overall fault frictional strength. We conclude that the current state of porosity in the Alpine Fault zone is likely to play a key role in the initiation of the next fault rupture.