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Fractures versus flow: How variations in carbonate composition control the rheology of altered subducting rocks

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Carbon recycling in subduction zones involves metamorphism and fluid-rock interactions that are responsible for dissolution or destabilization of carbon-bearing minerals. Such large-scale devolatilization of carbonates should impose profound alterations in the rheology of subducted lithologies, but this is an aspect that has received relatively scant attention so far.

This work focuses on the mechanical behaviour of carbonates in subducted carbonated serpentinites that constitute a substantial fraction of carbon input into subduction zones. These investigations have been conducted on carbonated serpentinites from the Negru Shear Zone in Corsica (France). Petrographic and fluid inclusion analyses indicate that these rocks recorded partial carbonate reduction by infiltrating H_2-rich fluids, as indicated by the conversion of carbonate to graphite and CH_4(Peng et al., 2021; Vitale Brovarone et al., 2017). The first generation of carbonate occurs as mm-sized equigranular, subhedral dolomite, with sutured grain boundaries (hereafter referred to as Carb1) along which graphite is distributed as discontinuous seams. Carb1 is fractured and brecciated, with limited evidence for crystal plasticity. A second generation of carbonate (calcite; Carb2), is observed in sheared carbonate + serpentinite domains, wherein the proportion of graphite is substantially higher. Carb2 grains are anhedral, elongate and form S-C structures within localized (~200 microns thick) shear zones.

Electron Backscatter Diffraction (EBSD) analyses on the different carbonate domains provide greater insights into the deformation of Carb1&2. The microstructures within the dolomite-rich domains are dominated by twinning, with a strong crystallographic preferred orientation manifested by an M-index of 0.61. Dolomite grains display limited low angle boundaries and dislocations, which imply minimal strain accommodation by crystal plasticity and recrystallization during deformation. The occurrence of extensive twinning in dolomite coupled with antigorite being the dominant serpentine mineral, constrains the brecciation of dolomite grains to temperatures higher than 380 °C during the high-pressure evolution of Alpine Corsica. On the other hand, calcite grains within the shear zones have a weaker preferred orientation (M-index of

0.086), abundant low angle boundaries and dislocations, and lesser twin boundaries compared to the dolomite grains. Our observations are relevant for an improved understanding of the deformation of carbonated lithologies in faults associated with subduction zones. If these lithologies are dominated by dolomite, brecciation, likely associated with seismicity, may be the dominant mechanism of deformation, as crystal plastic mechanisms within dolomite are non-operative at the temperatures (<400°C) and pressures (~1GPa) prevalent till at least intermediate depths within subduction zones. On the other hand, if calcite is the dominant carbonate mineral undergoing subduction, crystal plasticity may be the dominant mechanism that accommodates strain. The presence of graphite in association with both dolomite and calcite rules out the possibility of it having influenced these rheological variations. Our results provide novel insights into the role of chemistry in controlling the rheology of carbonated lithologies undergoing subduction, with implications on our understanding of the localization of seismicity in subduction settings.