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Dynamic conductivity of mid-crustal shear zones.

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Magnetotelluric models around the inferred down-dip projection of New Zealand's dextral-reverse Alpine Fault Zone (AFZ) demonstrate it has anomalously high conductivity ($\rho \sim 10 - 100$ ohm-m) from 10-20 km depth and high conductivity ($\rho \sim 100 - 1000$ ohm-m) from 20-30 km depth (Wannamaker et al., 2002). Comparison of laboratory measurements of resistivities of samples of AFZ outcrops with wireline resistivities measured in situ to 820 m depth during the recent Deep Fault Drilling Project (DFDP-2; Sutherland et al., 2017) indicate an order of magnitude difference that is demonstrably not a result of surface conductivity, and cannot be resolved even by considering realistic fluid compositions (Doan et al., in prep).

In exhumed and borehole samples we have characterised the distributions and arrangements of the most conductive phases observed in these rocks – solid graphite, possibly amorphous carbon, and grain boundary pores that would have contained brines or other conductive fluids at depth (Billia et al., 2013; Sauer et al., 2017). These become progressively concentrated onto grain boundaries with increasing total creep shear strain (Kirilova et al., in press; cf. Craw Norris, 2003). However, even at high strains they are disseminated, rather than linked in conductive networks.

Lower strain (proto)-mylonites with a segregated microstructure of interlinked layers of quartz and strong CPOs likely deformed by grain size insensitive (GSI) creep in the deeper parts of the shear zone. With increasing shear strain, ultramylonites are generated, within which the constituent phases are more well-mixed/dispersed and CPOs are weaker (Toy et al., 2012; Sauer et al. 2017). There is also evidence that retrograde reactions occurred, albeit to a limited extent because fluids are not abundant during exhumation of comparatively anhydrous lower crust. For example, there is sporadic chlorite, and sharp albitization fronts extend a few hundred nanometres from phase boundaries. These observations are consistent with dominance of solution-accommodated grain size sensitive (GSS) creep in the ultramylonites.

These ultramylonites are interpreted to have accommodated the highest strains in the AFZ. They represent the shallowest expression of the creeping crust prior to the onset of brittle mechanisms during progressive localization of strain as the shear zone was exhumed. As such, they, are likely to have formed in the zone that has the highest conductivity in MT models. This high conductivity is best explained by dynamic interlinking of the disseminated conductive grain boundary phases and fluids by grain boundary sliding during GSS creep in the ultramylonites.

References: Craw, D., Norris, R.J. 1993, J. Met. Geol. 11, 371-378; Kluge, K.E., et al., Geophys. Res. Abs. 19, EGU2017-10139; Kirilova, M. et al., in press. DOI: 10.1144/SP453.13; Sauer, K. et al., Geophys. Res. Abs. 19, EGU2017-10485; Sutherland, R.S. et al., 2017, DOI: 10.1038/nature22355; Toy, V.G. et al., 2012., DOI: 10.1016/j.epsl.2012.04.037; Wannamaker, P. et al., 2002, DOI: 0.1029/2001JB000186.