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Rheology of the plate interface - the rock record

S. Wassmann and B. Stöckhert
Ruhr University, Bochum, Germany, (Sara.Wassmann@rub.de)

Models of subduction zones generally assume deformation to be localized into a comparatively narrow interplate shear zone. The cool crust of the subducted lithosphere, from which heat is additionally withdrawn by endothermic dehydration reactions, implies a cool geotherm for this region of interplate deformation. For localization of viscous flow in a region of low temperatures, specific material properties, environmental conditions, and mechanisms of deformation are prerequisite. As details on material behaviour cannot be predicted from models based on geophysical observations, the record of high pressure – low temperature (HP-LT) metamorphic rocks, probably being exhumed in a subduction channel, represents the only source of information on activated deformation mechanisms and typical stresses along the plate interface at depth.

The record of blueschist facies metabasalts from the Franciscan Complex (California), of eclogite facies serpentinites from the Western Alps (Italy), and of eclogite facies micaschist from the Eastern Alps (Austria) invariably indicates that crystal plastic deformation of all minerals is subordinate. Instead, viscous flow at HP-LT metamorphic conditions is primarily by dissolution precipitation creep (DPC). Interphase boundaries act as preferred sites of dissolution. Prominent local sinks include strain shadows, dilatant fractures, and veins. Incongruent DPC is coupled with mineral reactions. DPC still predominates during the earlier stages of exhumation.

Taking such observations to be representative for subducted material deformed at low temperatures along the plate interface between about 30 and 80 km depth, and exhumed without significant overprint within a weak subduction channel, the following is concluded: (1) Crystal plastic deformation and dislocation creep play no major role in long term viscous flow. (2) The absence of crystal plastic deformation all along the burial and exhumation path poses an upper bound to long term stress at the plate interface. (3) Long term deformation is essentially by dissolution precipitation creep at very low stress. (4) An aqueous fluid phase is present throughout. (5) Low stress implies little shear heating, hence supports a cool geotherm. (6) Inhomogeneous deformation to very high finite strain, controlled by contrasting rock properties, can lead to block-in-matrix structures and formation of a tectonic mélange, which may be a characteristic result of interplate deformation in the field of DPC. (7) Combined with the high strain rates expected for localized deformation between the plates, a very low viscosity of material in the interplate shear zone at depths between about 30 and 80 km is predicted.