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Long-term coupling along the subduction plate interface: insights from exhumed rocks and models

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Fragments of subducted oceanic lithosphere returned along the plate interface convey crucial information regarding the thermal and rheological conditions of convergent plate boundaries. Combining evidence from exhumed rocks worldwide and the results of recently published thermo-mechanical models, we herein investigate how long-term mechanical coupling takes place along deep portions of the plate interface (40-80 km depth), for which there is no counterflow (unlike in accretionary prisms) and no other known mechanisms to return eclogites than interplate friction or buoyancy.

Geological evidence indicates that, unlike subduction, exhumation is highly discontinuous. Besides, eclogites worldwide are found in essentially two types of tectonic setting, either as large scale (>km) slices with coherent PT estimates (W. Alps) or as isolated fragments (frequently m-hm) in a serpentinite- or sedimentary-rich matrix showing contrasting equilibration depths (with hints of punctuated exhumation and even reburial in some localities; Franciscan, Cuba, Sistan). This latter type tends to show warmer equilibration paths (although minor lawsonite-eclogite blocks can be found), whereas the larger tectonic slices from the former type remain systematically cold. Serpentinites are crucial for both in permitting decoupling and acting as a buoy, and fluid budget is important too in enhancing floatability and allowing large slices to survive. Numerical models implementing free migration of fluids in the subduction zone also show that the plate interface is strongly localized in the absence of fluids: mechanical decoupling efficiently occurs along the sediment veneer and/or at the top of the highly hydrothermalized crust. Whenever fluids are released in greater amounts (depending on initial fluid content and/or thermal structure), deformation becomes much more distributed and affects both the mantle wedge and the top of the downgoing lithosphere (hydrated crust and mantle top), thereby increasing mechanical coupling between the two plates.

Based on natural data and numerical modelling we thus propose that rheological contrast chiefly controls mechanical decoupling (and early exhumation). On a steady-state basis the subduction interface is apparently efficiently decoupled. In this context, we hypothesize that the liberation of fluid through pulses (or a somewhat increased amount of fluids) is required to locally modify mechanical coupling and induce the slicing of large pieces of oceanic material along the subduction interface (type 1). By contrast, an extreme hydration of the subduction interface and mantle wedge will result in the formation of serpentinite melanges and extensive material mixing (e.g., cold plumes, mafic pods and localized melting; type 2). This latter situation may be promoted by young/fast/wet subduction, such as subduction initiation and/or subduction of young lithosphere or subduction of a particularly hydrated lithosphere section (e.g., at the ridge and/or prior to entering the trench). By contrast cold, slow subduction (type 1) will result in irregular hydration and localized coupling able to detach large slices.