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Fluid content along the subduction plate interface: how it impacts the long- (and short-) term rheology and exhumation modes

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Over the last decade, many studies based on field, petrological and geophysical evidence have emphasized the link between mineral reactions, fluid release and seismogenesis, either along the whole plate interface (eg., Hacker et al., 2003) or at specific depths (e.g., ∼30 km: Audet et al., 2009; ∼70-80 km: Angiboust et al., 2012). Although they argue for a crucial influence of fluids on subduction processes, large uncertainties remain when assessing their impact on the rheology of the plate interface across space and time.

Kilometer-scale accreted terranes/units in both ancient and present-day subduction zones potentially allow to track changes in mechanical coupling along the plate interface. Despite some potential biases (exhumation is limited and episodic, lasting no more than a few My if any, from prefered depths — mainly 30-40 and 70-80 km, and there are so far only few examples precisely located with respect to the plate interface) their record of changes in fluid regime and strain localisation is extremely valuable.

One striking example of the role of fluids on plate interface rheology during nascent subduction is provided by metamorphic soles (i.e. ∼500 m thick tectonic slices welded to the base of ophiolites). We show that their accretion to the ophiolite indeed only happens across a transient, optimal time-T-P window (after < 1-2 My, at 1±0.2 GPa, 750-850°C) associated with fluid release and infiltration, leading to similar effective rheology on both sides (i.e. downgoing crust and mantle wedge). This maximizes interplate mechanical coupling, as deformation gets distributed over a large band encompassing the plate interface (i.e. a few km), and promotes detachment of the sole from the sinking slab.

We also show how tectonic slicing during mature subduction likely relates to short-term fluid release and repeated seismicity, based on the Monviso exposures (W. Alps, a relatively continuous, 15 km long fragment of oceanic lithosphere exhumed from ∼80 km depths), which preserve evidence of intraslab fluid flow and eclogitic, intermediate-depth seismicity of Mw ∼4.

We finally address how, in the long-term and at subduction scale, the overall fluid content and fluid regime may control the slicing, size and metastability of exhumed units. We propose that mechanical coupling varies through time, from weak to strong, as a function of the contrast of effective viscosity on either side of the interface: a young and wet subduction interface will promote the formation of knockers and sole accretion, whereas a fluid-present yet drier and colder one will lead to mainly metasedimentary underplated material and large-scale slivers of (metastable) oceanic lithosphere.

This interpretation is supported by bi-phase numerical models (allowing for fluid migration driven by concentrations in the rocks, non-lithostatic pressure gradients and deformation, mantle wedge hydration and mechanical weakening of the plate interface) showing that the detachment of large-scale oceanic tectonic slices is in particular promoted by fluid migration along the subduction interface.

[Hacker et al., Journal of Geophysical Research 2003; Audet et al., Nature, 2009; Angiboust et al., Geology 2012]