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Accretion/underplating, detachment and exhumation: short/long-term rheology of the subduction plate interface

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The presence of km-scale accreted terranes/units in both ancient and present-day subduction zones attests to changes in strain localization along the plate interface, whereby these terranes/units get detached from the downgoing slab (or, in places, are eroded away from the tip of the upper plate) and either directly exhumed or accreted/underplated below the upper plate before final exhumation. The rock record (P-T-t data) indicates that, for a given subduction zone, exhumation is episodic: no more than a few My compared to the ∼100 My lifetime of typical subduction zones. Not much is known, however, regarding this process and important open questions remain: what exactly is episodic (i.e. detachment from the slab and/or exhumation?), for how long and where? How is mechanical coupling impacted by the initial structure of the incoming plates (structural/lithological heterogeneities, thermo-fluid regime, geodynamic boundary conditions, etc...)?

We herein present both new and literature structural and P-T-t data ranging from shallow (i.e. 15-20 km) to intermediate depths (∼100 km) along the subduction interface, that span a range from long-term to short-lived events of underplating and/or exhumation, and confront them with the recent wealth of geophysical data gathered on subduction zones. Structural and petrological data indicate that the slicing of km-scale units mostly occurs at specific depths where major mechanical changes occur along the plate interface: at 30-40 km (downdip of the seismogenic zone) and 70-80 km (where mechanical coupling between the two plates resumes and where eclogites get critically dense). This suggests that switches in mechanical coupling (i.e. in the rheology of the material) are key in controlling the ability to detach pieces from the slab (and that later exhumation is rather controlled by large-scale, lithospheric-scale boundary conditions). The study of rock remnants detached from the slab and underplated during subduction infancy (i.e. metamorphic soles) further illustrates how changing rheologies (crust v. mantle) and increased mechanical coupling affect the potential to retrieve rocks/units and emphasize the role of fluids (and of the mantle wedge). Fully-coupled thermo-mechanical models taking into account variable hydration conditions strengthen these conclusions. From these observations, we infer that long-term mechanical coupling probably varies throughout subduction lifetime, from strong to weak, as a function of the contrast of effective viscosity on either side of the subduction interface: a young and wet interface will promote strong viscous coupling, metamorphic sole accretion and the formation of high-temperature (eclogite) knockers, whereas a fluid-present yet drier and colder one will mainly promote underplating of metasedimentary material and, occasionally, large-scale slivers of oceanic lithosphere. We finally discuss the possible link between strain localization mechanisms leading to tectonic slicing and seismicity (regular or slow earthquakes), particularly in the light of the recent finding of eclogite breccias.