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Towards an integrated vision of tectonic underplating and associated deformation in subduction zones, insights from high-resolution numerical modeling

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Study of now-exhumed ancient subduction zones has evidenced km-scale tectonic units of marine sediments and oceanic crust that have been tectonically underplated (i.e. basally accreted) to the overriding plate at more than 20-km depth. However, the rare examples of such a huge mass transfer in active subduction zones (e.g. SW-Japan, New-Zealand, Chilean subduction) do not allow for constraining (i) the dynamics of deep duplex formation and (ii) the rheological parameters controlling their formation.
Using high-resolution visco-elasto-plastic thermo-mechanical models, we present with unprecedented details the dynamics of formation, preservation and destruction of underplated crustal nappes at 20-60-km depth in subductions zones. Initial conditions in our experiments are set to fit subduction systems of the circum-Pacific region and especially the Chilean active margin.
Our results show that basal accretion and erosion processes can coevally occur in the fore-arc region. Deep duplexes mainly consist in metasediments and metabasalts from the downgoing oceanic crust, with minor contribution of continental material removed from the base of overriding fore-arc crust. A significant deviatoric stress accumulation is commonly observed within the deep duplexes (> 200 MPa), despite the presence of relatively weak, fluid-saturated materials. Localized extensional deformation affects the inner fore-arc crust, associated with surface uplift above the duplex emplacement site. Coevally, the outer fore-arc subsides and sedimentary basins form as a response to basal erosion. Parametric investigation suggests that a weak oceanic lithosphere promotes frontal and basal accretion while a stronger slab leads for the formation of a typical erosional active margin. A mechanical link between the locus of deep duplexes formation (i.e. preferentially at Moho depth) and the rheological structure of the overriding crust is also evidenced.
These results reconcile (i) recent tectonics and long-term topographic variations observed above active subduction zones where tectonic underplating is suspected, with (ii) geological observations and paleo-stress estimations made on ancient deep accretionary duplexes.