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How does overriding plate control convergence zone dynamics?

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In convergence zones, oceanic or continental subduction/collision can form mountain belts presenting contrasted unit sizes, morphologies and metamorphisms sequences (e.g., Andes vs., Alps). Hence, some convergent zones evolving in a similar geodynamic framework (e.g., continent-continent convergence) exhibit very different deformation styles, with either very localized deformation (e.g., in the Alps) or deformation distributed over thousands of kilometers (e.g., in the Himalayas/Tibetan Plateau). On the other hand, other convergent zones share similar structures despite their different tectonic settings (e.g., Tibetan and Altiplano/Puma plateaus). Many studies already exist on the important role played by the subducting plate and the mantle flow on the convergence zone dynamics and the variability of the structures observed within the overriding plate. However, the influence of the overriding plate itself on the subduction system, and especially, the importance of its rheology, remains poorly understood.

In this study, we therefore present 3D thermo-mechanical numerical models of oceanic subduction followed by continental subduction/collision, where the rheological properties of the overriding plate are varied. For this, we systematically modified the crustal thickness of the overriding lithosphere (from 20 to 40 km) and the temperature at the Moho (between 300 and 800°C). These ranges of values correspond to thermal thicknesses for the overriding lithosphere ranging from 80 km to 265 km.

While all models share a common global evolution (i.e. slab sinking, slab interacting with the 660-km discontinuity and slab detachment after continental subduction and subduction cessation), our study highlights striking differences arising from the variation in overriding plate strength, both in terms of geometry and timing:
- The overriding plate rheology controls the subduction mode during oceanic subduction. With a thin, weak overriding plate (i.e. lithospheric thermal thickness < 150 km) the slab rolls back, while with a thick, strong overriding plate (i.e. lithospheric thermal thickness > 150 km) the slab folds forward.
- Mantle flow is impacted by the overriding plate rheology. With a strong overriding plate, the mantle flow is less vigorous and more localized around the slab.
- The location and the amount of strain within the overriding plate after continental subduction initiation vary between the two end-members. The weak model shows a diffuse deformation in the whole overriding plate while in the strong model the deformation is localized close to the trench.
- The trench has a higher curvature (convex toward the overriding plate) in models with strong overriding lithosphere.
- The slab break-off following continental subduction occurs earlier in the models involving a weak overriding plate than in the models with a "strong" overriding plate. The difference can be as much as 25 Ma within the range of tested parameters.

Our results evidence the first-order role played by the rheology of the overriding plate on the convergence zone dynamics. Studies focusing on the subduction dynamics should therefore no longer neglect it.