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Role of subducted sediments in plate interface dynamics and forearc topography: Observations and modelling constraints for the Andes

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Forearc topography and inferred paleotopography are key constraints on the processes acting at plate interfaces along subduction margins. We used along-strike variations in modern topography, trench sediment thickness, and instrumental seismic data sets over >2000 km of the Chilean margin to test previously proposed feedbacks among subducted sediments, plate interface rheology, megathrust seismicity, and forearc elevation. Observed correlations are consistent with subducted sediments playing a prominent role in controlling plate interface rheology, which, in turn, controls the downdip distribution of megathrust seismicity and long-term forearc elevation.

This control suggests that the Andean subduction plate interface (19.5-39.5ºS) constitutes a subduction channel, able to accommodate long-term sediment flow in the downdip direction to depths greater than the updip end of the seismogenic zone. We explored numerically the role of subduction channel flow on forearc surface elevation. Results show that low (high) rates of trench sedimentation promote long-term interseismic coupled offshore forearc subsidence (uplift) and onshore forearc platform uplift (subsidence), due to long-term viscoelastic flow in a strengthened (weakened) finite-thickness subduction channel. Low trench sedimentation rates may also promote deeper megathrust seismic slip, enhancing short-wavelength coastal zone uplift.

The high elevation of the onshore forearc platform in northern Chile cannot be accounted for by previously proposed tectonic mechanisms such as coastal underplating and coseismic deformation, whose topographic effects are restricted to the coastal zone. This section of the Andean forearc is particularly suited to test the above-mentioned feedbacks, given that the extremely low denudation rates of this hyperarid region have allowed better reconstructions of the histories of paleo-elevations and paleoclimate compared to other sections of the forearc. These histories, together with modern data sets and numerical experiments, are consistent with the onset of hyperaridity in the coastal zone at 25–20 Ma triggering (1) trench sediment starvation, (2) a rise in shear stress at the top of the subduction channel, (2) long-term, long-wavelength offshore forearc subsidence and onshore forearc uplift, and (4) acceleration of short-wavelength coastal zone uplift.