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Seismic tomographic constraints on plate-tectonic reconstruction of Nazca subduction under South America since late Cretaceous (~80 Ma)

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Our understanding of the global plate tectonics is based mainly on seafloor spreading and hotspot data obtained from the present earth surface, which records the growth of present ocean basins. However, in convergent tectonic settings vast amounts of lithosphere has been lost to subduction, contributing to increasing uncertainty in plate reconstruction with age. However, subducted lithosphere imaged in seismic tomography provides important information. By analyzing subducted slabs we identify the loci of subduction and assess the size and shape of subducted slabs, giving better constrained global plate tectonic models.

The Andean margin of South America is a classic example of continuous subduction up to the present day, providing an opportunity to test the global plate prediction that ~24×10e6 km2 (4.7% of earth surface) lithosphere has been subducted since ~80 Ma. In this study, we used 10 different global seismic tomographies and Benioff zone seismicity under South America. To identify slabs, we first compared all data sets in horizontal slices and found the subducted Nazca slab is the most obvious structure between the surface and 750 km depth, well imaged between 10°N and 30°S. The bottom of the subducted Nazca slab reaches its greatest depth at 1400 km at 3°N (Carnegie Andes) and gradually shallows towards the south with 900 km minimum depth at 30°S (Pampean Andes).

To assess the undeformed length of subducted slab, we used a refined cross-sectional area unfolding method from Wu et al. (in prep.) in the MITP08 seismic tomography (Li et al., 2008). Having cut spherical-Earth tomographic profiles that parallel to the Nazca-South America convergence direction, we measured slab areas as a function of depth based on edges defined by steep velocity gradients, calculating the raw length of the slab by the area and dividing an assumed initial thickness of oceanic lithosphere of 100km. Slab areas were corrected for density based on the PREM Earth model (Dziewonski and Anderson, 1981). We found the unfolded length of the Nazca slab is 7000km at 5°N and gradually decreases to 4700 km at 30°S, with total area of ~24×10e6 km2.

Finally, we imported our unfolded Nazca slab into Gplates software to reconstruct its tectonic evolution, using the Seton et al. (2012) and Gibbons et al. (2015) global plate model. We find that our unfolded base of the Nazca slab fits tightly against South America at ~80 Ma if the pre-deformed South America margin of McQuarrie (2002) is used. This close fit implies a plate reorganization at the South American margin, marking the beginning of Nazca subduction at ~80 Ma. This observation is in agreement with a beginning of Andian magmatism ~80 Ma, following a 80-100 Ma hiatus in magmatism (Haschke et al., 2002). This result illustrates the importance of subducted-slab constraints in convergent plate-tectonic reconstruction. Our study also provides tracers for mantle flow yielding Nazca slab sinking rates between 1.2 cm/yr and 1.6 cm/yr, which are similar to other global results.