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The Role of Subducting Ridges in the Formation of Flat Slabs: Insights from the Peruvian Flat Slab

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Flattening of the subducting plate is often used to explain various geological features removed far from the subducting margins, including basement-cored uplifts, the cessation of arc volcanism, ignimbrite flare-ups, and the formation of high plateaus and ore deposits [Humphreys et al., 2003; Gutscher et al., 2000; Rosenbaum et al., 2005, Kay and Mpodozis, 2001]. Today, flat slab subduction is observed in central Chile and Peru, representing the modern analogues to the immense paleo-flat slab that subducted beneath the North American continent during the Laramide orogeny (80-55 Ma) [English et al., 2003]. However, how flat slabs form and what controls their inboard and along-strike extent is still poorly understood.

To better understand modern and paleo-flat slabs, we focus on the Peruvian flat slab, where the Nazca plate starts to bend at ∼90 km depth and travels horizontally for several hundred kilometers beneath the South American plate. Earlier studies propose a correlation between the flat slab and the subducting Nazca Ridge that has been migrating to the south over the past 11 ∼Ma [Hampel et al., 2004, Gutscher et al., 2003]. Combining 3D shear wave velocity structure and Rayleigh wave phase anisotropy between ∼10° and 18° S, we find that the flat slab has the greatest inboard extent along the track of the subducting Nazca Ridge. North of the ridge track, where the flat slab was initially formed, the flat slab starts to sag, tear and re-initiate steep slab subduction, allowing inflow of warm asthenosphere. Based on our new constraints on the geometry of the subducted plate, we find that the subduction of buoyant oceanic features with overthickened oceanic crust plays a vital role in the formation of flat slabs.

We further develop a model of temporal evolution of the Peruvian flab slab that forms as a result of the combined effects of the subducting ridge, trench retreat, and suction forces. Once the buoyant ridge subducts to ∼90 km depth, it will fail to sink, causing the flattening of the slab. Development of the flat slab is further accommodated by the northward motion of the overriding plate and suction between two plates. However, once the flat slab becomes too far away from the buoyant support, it will become unstable in spite of the presence of other factors. The position of the ridge, in particular its orientation with respect to the convergence direction, will dictate the along-strike extent of the flat slab. We find that the inboard extent of the flat slab correlates with the position of the ∼10 Ma old slab. We speculate that ∼10 Ma represents the period necessary for the slab to be sufficiently eclogitized and become negatively buoyant. Thus, the delayed eclogitization of the overthickened oceanic crust in combination with convergence rate controls the inboard extent of the flat slab. Our findings provide important constraints on the formation and size of flat slabs both past and present.