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Lithospheric scale rheological properties associated to the normal and flat slab domains along the Chilean Andes, insight from numerical models

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The Chilean Andes extend north-south for about 3000 km and show evidences of rheological control on their first order tectonic features. The Northern Chile Andes Altiplano and Puna domains are characterised by a normally dipping slab, large horizontal shortening, an erosional margin and high interplate friction properties. The Southern Andes display a normal dipping slab but little horizontal shortening, relatively low relief associated to an accretive and low friction margin. In between, the Central Chile flat slab area (∼33oS) is characterised by a flat slab extending for more than 300 km eastwards at 100 km depth, and lack of arc volcanism. Significant active seismicity occurs in the overriding crust, and coincides with the extent offshore of the Juan Fernandez ridge. While mechanical models have shown that continental shortening, thickening and trench motion, depend on interplate friction and continental strength, the causes for slab flattening in Central Chile remain debatable. Several studies have demonstrated the role of relative buoyancy of the subducting oceanic lithosphere. We argue here that its rheological strength is also of prime importance in its capacity to penetrate, or instead stretch and detach in response to mantle slab-pull. In fact, the Juan Fernandez Ridge displays a very moderate thickened crust and thus little buoyancy. However, sparse geophysical data indicate that the underlying mantle lithosphere may have been pervasively deformed and somehow hydrated, providing it with "weak" thermo-mechanical properties. In fact, the Juan Fernandez ridge is part of the broader Challenger Fracture zone which has formed when the triple junction between the Pacific, Nazca and Antarctic plates suddenly readjusted in the Oligocene, simultaneously with increasing plate convergence at the South American margin. Therefore, the subducting oceanic lithosphere may be effectively weak, in such a way that its response to slab-pull is to behave ductile, deviate and flatten below the more rigid continental indentor. Additional geophysical data are necessary to confirm this hypothesis.

The Central American flat slab area differs from the Central Chilean flat slab area in several ways, including its aseismic Benioff zone. However, both oceanic plates are relatively young and may have been mechanically weakened in a similar way during past reorganisation of plate motions, sufficiently to make them behave ductily when they enter subduction. Both trenches indicate ocean-wards retreat, consistent with plate convergence being rather accommodated by the oceanic plate than by continental shortening. These considerations show that the evolution of subduction zones is not only controlled by deep-seated mantle processes nor interplate friction, but also by the relative strength of both oceanic and continental plates.