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Chile's seismogenic coupling zones – geophysical and neotectonic observations from the South American subduction zone prior to the Maule 2010 earthquake

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Accumulation of deformation at convergent plate margins is recently identified to be highly discontinuous and transient in nature: silent slip events, non-volcanic tremors, afterslip, fault coupling and complex response patterns of the upper plate during a single event as well as across several seismic cycles have all been observed in various settings and combinations. Segments of convergent plate margins with high recurrence rates and at different stages of the rupture cycle like the Chilean margin offer an exceptional opportunity to study these features and their interaction resolving behaviour during the seismic cycle and over repeated cycles. A past (TIPTEQ) and an active international initiative (IPOC; Integrated Plate Boundary Observatory Chile) address these goals with research groups from IPG Paris, Seismological Survey of Chile, Free University Berlin, Potsdam University, Hamburg University, IFM-GEOMAR Kiel, and GFZ Potsdam employing an integrated plate boundary observatory and associated projects.

We focus on the south Central Chilean convergent margin and the North Chilean margin as natural laboratories embracing the recent Maule 2010 megathrust event. Here, major recent seismic events have occurred (south Central Chile: 1960, Mw = 9.5; 2010, Mw = 8.8; North Chile: 1995, Mw = 8; 2001, Mw = 8.7; 2007, Mw: 7.8) or are expected in the very near future (Iquique, last ruptured 1877, Mw = 8.8) allowing observation at critical time windows of the seismic cycle. Seismic imaging and seismological data have allowed us to relocate major rupture hypocentres and to locate the geometry of the locked zone and the degree of locking in both areas. The reflection seismic data exhibit well defined changes of reflectivity and Vp/Vs ratio along the plate interface that can be correlated with different parts of the coupling zone as well as with changes during the seismic cycle. Observations suggest an important role of the hydraulic system, an inference that is strongly supported from recent findings along the exhumed, fossil seismogenic coupling zone of the European Alps. The data provide additional evidence that the degree of interseismic locking is closely mirrored by subsequent megathrust failure as evidenced by the slip and aftershock pattern of the Maule 2010 earthquake.

Neogene surface deformation in Chile has been complex exhibiting tectonically uplifting areas along the coast driven by interseismically active reverse faulting. In addition, we observe coseismically subsiding domains along other parts of the coast. Moreover, the coseismic and interseismic vertical displacement identified is not coincident with long-term vertical motion that probably is superseded by slow basal underplating or tectonic erosion occurring at the downdip parts of the seismogenic zone causing discontinuous uplift. Analogue and numerical modelling lend additional support to the kinematic patterns linking slip at the seismogenic coupling zone and upper plate response. Finally we note that the characteristic peninsulas along the South American margin constitute stable rupture boundaries/barriers and appear to have done so for a protracted time as evidenced by their long-term uplift history since at least the Late Pliocene that points to anomalous properties of the plate interface affecting the mode of strain accumulation and plate interface rupture.