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Mechanical coupling between megathrust and forearc crustal-scale faults: Insights from the Arauco Bay area, Chile (37°S)

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A wealth of geophysical and geological data shows crustal-scale reverse faults in the coastal forearc regions of many convergent margin i.e., Alaska, Cascadia, Nankai, Hikurangi, and south Chile. Crustal seismicity and seismic profiles suggest that the major faults are rooted in the megathrust and thus mechanical coupling should be expected. However, due to the short span of historical observations, the only direct evidence of megathrust-crustal fault coupling comes from the surface ruptures described by G. Plafker at Montague Island triggered by the 1964 Alaskan subduction earthquake. Strong ground motion and maximum coseismic uplift and therefore landslides and cracks are expected to be localized along these 'triggered' faults. Thus, mapping of these structures and furthermore understanding the time scales on which mechanical linkage between the rather periodic megathrust events and the mostly unknown crustal fault behavior is a first-order task for seismic hazards of coastal regions. We have Integrated various geological and geophysical data sets in the Arauco Bay area, Chile, constraining fault geometries near the surface and at depths, and which span various time scales of surface deformation ranging from months to million years. From the inspection of reflection profiles we conclude that here reverse faults resulted from inversion of Eocene-early Pliocene normal faults. Shortening accommodated by inverted, ca. 70° seaward-dipping reverse faults has been fairly steady at ca. 0.8 mm/a over the past 2.5 m.y. Secondary faults branch from the main, deep-reaching fault forming a ramp-flat-ramp structure. All faults here are blind, propagate anticlines, and are usually expressed at the surface by small bending-related normal faults. From

the inspection of syntectonic deposits in thrust-top basins we conclude that the main fault has been continuously active over 2.5 m.y., while in- and out-of-sequence migration of deformation occurred along shallow splay faults. However, because we lack detailed internal age control within the syntectonic sequence, we cannot precisely decipher the time scales over which splaying occurs but we estimate it to be on the order of 0.2-0.4 m.y. Leveling of dated deformed marine terraces on the forelimbs of two reverse-fault cored anticlines at Isla Santa María allowed us to quantify tilt and uplift rates for the past 50 k.y. of 0.032+-0.02 °/ka and 1.8+-0.4 m/ka, respectively. Unfortunately, mainly because of uncertainties in the sea-level curve (12 m), we cannot resolve shorter period variations within this data. On the other hand, the high-resolution topographic survey and dating of a sequence of emergent strandlines at this island indicates uplift at 2.3+-0.2 m/ka and tilting at 0.032+-0.02 °/ka, and permits to decipher millennial-scale variations. The wavelength and amplitude of the strandline sequence varies over periods of 1+-0.2 ka with maximum variance of 120 m and 75 cm, respectively. We relate this variations to phases of increased interseismic crustal fault activity. Crustal fault would uplift the island slowly, widening the beach berm continuously and therefore producing a higher wavelength within the sequence, while sudden coseismic uplift would be cause narrower berms with pronounced backswamp lows reflected in a shorter wavelengths. At Isla Santa María, coseismic uplift of 2.4 to 3.0 m was measured by Charles Darwin during the 1835 at an emerged abrasion platform. This surface is exposed today at similar elevations implying either no significant post-seismic recovery, which however is necessary to conceal long- and short-term uplift rates, or alternatively that transient crustal fault activity has been uplifting the island since. We favor the latter because of the wide present-day beach berm and the transient cluster of shallow crustal seismicity recorded during 3 month by the ISSA network, which illuminated a crustal reverse fault. Focal mechanisms agree with geometry and kinematics of this fault imaged in seismic profiles. Finite-element modeling requires the presence of a free-slipping blind reverse fault in order to fit the ca. 10 mm/a gradient in velocity derived from GPS data across this active fault. The principal shortening axis of infinitesimal strain derived from Delaunay triangulation of the GPS data is oriented WNW-ESE, nearly orthogonal to the crustal fault and oblique to shortening expected from plate locking. The abrasion platform that emerged during the 1835 event at Isla Santa María is steeply tilted eastward, with a wavelength of a few km. Tilt caused by the shallow-dipping megathrust ruptures has usually wavelength of ca. 100 km. In turn triggering of crustal faults below the island by the 1835 event is a plausible mechanism to conceal the steep tilt. This integrated study reveals complex mechanical coupling between the subduction zone megathrust and crustal-scale faults at various time scales, a process not well understood yet and that could play an important role in seismic hazards of coastal regions.