Forearc deformation across time scales - a tale of fluids, locking and transients

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Abstract

On the long term, forearc systems are known to be controlled by either accretion/underplating or by subduction erosion. Vertical surface motion is coupled to convergence rate - typically with an uplift rate of the coastal area ranging from 0 to +50% of convergence rate in accretive systems, and -20 to +30% in erosive systems. Vertical kinematics, however, are not necessarily linked to horizontal strain mode, i.e. upper plate shortening or extension, in a simple way. This range of kinematic behaviors is well expressed along the Chilean plate margin.

Towards the short end of the time scale, deformation exhibits a close correlation with the frictional properties and geodetic locking at the plate interface. Corroborating analogue experiments of strain accumulation, forearc deformation and uplift focus above the downdip and updip end of seismic coupling and slip and are each related to a particular stage of the seismic cycle, but with opposite trends for both domains. Similarly, barriers separating locked domains along strike appear to accumulate most upper plate faulting interseismically. Hence, locking patterns are reflected in topography over time. From the long-term memory contained in the forearc topography the relief of the Chilean forearc seems to reflect long term stability of the observed heterogeneity of locking at the plate interface. In addition, deformation accumulation on these faults is strongly controlled by both, the seismic cycle at the plate interface and overall seismicity. At the seismic cycle time scale, INSAR imaging clearly reveals faults to become activated around the mainshock, interestingly showing contrasting slip polarities before and after the main shock. Moreover, most slip accumulation is found to be very small slip increments, dynamically triggered by near field as well as far field earthquakes following a simple magnitude-distance scaling law.

Finally, the nature of locking at the plate interface controlling the above kinematic behavior appears to be strongly controlled by the degree of fluid overpressuring at the plate interface suggesting that the hydraulic system at the interface takes a key role for the forearc response. The rock record of a former seismogenic subduction thrust in the European Alps corroborates this dominant role of high pore fluid pressures with very low effective stresses. In addition, competing fabric styles varying from solution-precipitation creep to brittle fracture, involving also the formation of pseudotachylites, clearly indicate repeated transient changes in shear strain rate in the subduction channel rocks over more than 10 orders of magnitude.

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