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Seismic Cycle Deformation along the Nicoya Peninsula Seismogenic Zone, Costa Rica: Morphotectonics and Seismic Strong Motion Array Project (SSMAP)

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The Nicoya Peninsula, Costa Rica forms a prominent forearc high along the southern Middle America convergent margin between the Cocos and Caribbean plates. This emergent coastal landmass overlies the seismogenic zone and occupies a seismic gap that last ruptured in 1950 with a M7.7 megathrust earthquake. The edges of both the Nicoya seismic gap and the peninsula's abrupt shorelines correspond with aftershock limits of the 1992 M7.2 Nicaragua tsunami earthquake to the north, and the 1990 M7.0 Cobano seamount rupture to the south. The coincidence of emergent topography and recent rupture zones suggests persistence of the Nicoya seismic source area through multiple earthquake cycles. The seismic strong motion array project (SSMAP) for the Nicoya Peninsula, in place since 2006, consists of 10 sites with Geotech A900/A800 accelerographs (three-component) and GPS timing. The main objectives of SSMAP are to: 1) record and locate strong subduction zone mainshocks, foreshocks, preshocks, and early aftershocks, and 2) record and locate moderate to strong upper plate earthquakes triggered by the mainshock. In addition, geomorphic field studies, conducted since 2001, provide constraints on rates and patterns of both short-term seismic cycle deformation and long-term net uplift of the Nicoya coastline.
Despite tectonic erosion of the upper plate, the Nicoya Peninsula has undergone progressive uplift and topographic growth throughout the late Cenozoic. Active coastal uplift is recorded by emergent strandlines, marine terraces, and incised valley-fill alluvium. Field mapping, topographic surveying, and isotopic dating of these landforms reveal uplift variations that coincide with three contrasting domains of subducting seafloor: 1) Northern Nicoya with slow uplift (0.1-0.2 m/ky) inboard of older EPR seafloor, 2) Central Nicoya with moderate uplift (0.2-0.5 m/ky) inboard of younger CNS-1 seafloor, and 3) Southern Nicoya with fast uplift (1.5-2.5 m/ky) inboard of CNS-2 seamounts. Variable uplift along the Nicoya margin may reflect along-strike differences in subducting-plate roughness, thermal structure, fluid flow, and seismogenic-zone locking.
Based on convergence rate (9 cm/yr) and historic seismicity, the recurrence interval for large Nicoya earthquakes is estimated at $\sim$50 years. The most recent event (1950) generated >1m of coseismic uplift along the central Nicoya coast. Since then, most of this has been recovered by gradual interseismic subsidence, reflecting strain accumulation toward the next earthquake. While elastic seismic-cycle strain produces high frequency shoreline fluctuations, long-term net uplift results in gradual coastal emergence and the growth of topographic relief. We suggest that net uplift of the Nicoya Peninsula is the product of irrecoverable upper plate shortening, coupled with tectonic erosion near the trench and underplating of eroded material beneath the peninsula. The persistence of the Nicoya Peninsula as a source of large earthquakes may be the result of feedback between subduction generated thickening of the upper plate and increased coupling along the plate interface due to isostatic loading. We are now collecting a database of coastal benchmarks and strong motion records for moderate earthquakes (M=4.0-5.1) to document the final stage of interseismic strain prior to the next megathrust rupture. Also, the relocation solutions define the geometry of the subducting Cocos plate.