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Structural Control on Seismicity and Slip Behavior: Insights from 3D Tomography of the 2016 Mw 7.8 Pedernales Ecuador Earthquake Sequence

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The Ecuador subduction zone adjacent to and north of the Carnegie Ridge is the sight of multiple megathrust ruptures, Mw 8.8 in 1906, 1942 Mw 7.8, 1958 Mw 7.7, 1979 Mw 8.2, and most recently the 2016 Mw 7.8 Pedernales earthquake. Subducting seamounts and ridges on the Nazca Plate as it enters the trench, and accreted oceanic terranes and Cenozoic sedimentary basins in the forearc, provide an opportunity to document the influence of seafloor roughness and inherited structure on slip behavior and megathrust rupture. A dense temporary seismic network deployed in the wake of the mainshock augmented coastal stations of permanent national seismic and GPS networks. A range of slip behavior accommodates post-seismic deformation including fast earthquakes, aseismic slip, and earthquake swarms. Joint inversion for earthquake location and 3D velocity structure of aftershocks from the Pedernales earthquake reveal pronounced focusing of seismicity in space and time. Bands of seismicity observed in the post-Pedernales sequence resolve into tightly focused clusters when relocated in a 3D velocity model. Seismicity within these focused clusters host larger magnitude aftershocks as well as higher rates of seismicity best characterized as earthquake swarms lasting from several days to a week and in some cases several weeks. An abrupt eastward termination in seismicity corresponds to a steeply dipping high velocity body that extends to approximately 12-15 km depth. At the surface, this body outcrops as the Piñón formation, accreted Cretaceous oceanic basalts along the Jama-Quininde faults. Offshore clusters of seismicity flank individual subducted seamount of the Atacames seamount chain and topography along the Carnegie Ridge. Deformation adjacent to subducted seamounts triggers seismicity in both the subducting and overlying plate. These regions are characterized by higher velocities and lower Vp/Vs ratios than surrounding crust. The Pedernales mainshock triggered both moderate to strong earthquakes and earthquake swarms in the upper plate north of the mainshock rupture close to the epicenter of the 1906 Mw 8.8 earthquake and in the segment of the subduction zone that ruptured in 1958 in a Mw 7.7 earthquake. There is a clear but complicated relationship between seismic and aseismic moment release over multiple seismic cycles. While earthquake swarms and earthquakes with similar waveforms are commonly associated with aseismic slip, in detail the relationship between aseismic and seismic slip is not uniform indicating multiple processes are likely involved. Models of plate coupling and the consistency of earthquake clustering and slip behavior through both interseismic and seismic cycles reveal a segmented subduction zone primarily controlled by subducted seafloor topography, accreted terranes, and inherited structure. Observing the full spectrum of slip behavior and the relationship between different slip behaviors requires high-quality permanent observations from GPS and seismic networks combined with dense temporary deployments both on land and offshore.