Hydrogeologic detection and finite-element modeling of a slow-slip event in the Costa Rica prism toe

Award: 02-42034 (May 2003) , 02-41998 (April 2003)

A. LaBonté[1,2], K. Brown[1], Y. Fialko[1]

[1]Scripps Institution of Oceanography; [2]Pacific Geoscience Centre, Geological Survey of Canada

In the absence of offshore geodetic measurements to resolve deformation in the shallow subduction zone up-dip of the seismogenic section, hydrogeologic observations (e.g. measurements of pore pressure and fluid flow) can provide an important means for characterizing and quantifying offshore deformation. Pore pressure gradients resulting from seismic and aseismic deformation can drive fluids in and out of the seafloor. We perform a quantitative investigation of the deformation events that Brown et al. [2005] speculate caused the three simultaneous flow events and associated seismic noise recorded at the sea bed near the toe of the Costa Rica prism in 2000 (Figure a). We demonstrate using a finite-element model (Abaqus) that the observed hydrogeologic anomalies likely result from propagating slow slip at the subduction interface between the frontal prism and downgoing plate. There are two sources of volumetric strain that drive fluid flux at the seafloor in response to fault slip at depth: 1) zones of compression and dilation in the vicinity of the tips of a slipping patch, and 2) zones of extension and compression due to flexure of the seafloor. The superposition of these two effects results in distinctive temporal patterns of fluid flow through the seafloor. Assuming a constant propagation rate and an elliptical profile for the distribution of slip along the decollement, we infer essential characteristics of fault geometry and slip history from a single time series of flow rate during the presumed slow-slip event. We use the model predictions to infer the location, extent, rate, and duration of the slow-slip event that was presumably responsible for anomalous seafloor flow rates recorded on the Costa Rica prism toe. The best-fit model (Figure b) suggests that the slow-slip event initiated within the toe at depth of less than 4 km, and propagated bi-laterally at an average rate of 0.5 kilometers per day. This interpretation implies that stress in the shallow subduction zone is relieved episodically. Furthermore, the Costa Rica data suggest that episodic slow-slip events may initiate in the prism toe without being triggered by a seismic event further down-dip.

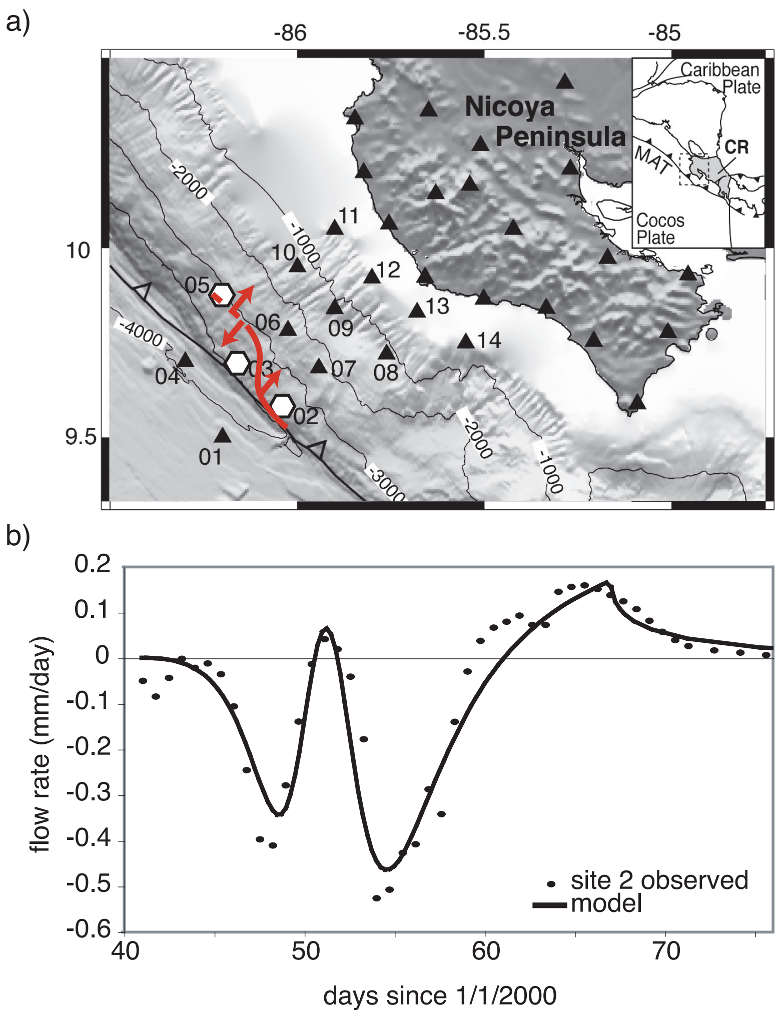

Figure: a) Location of the 14 flow meters in the Costa Rica subduction zone during the 2000 CRSEIZE [modified from Brown et al. 2005]. Red line represents proposed initiation of rupture and arrows show bidirectional rupture propagation direction. Coordinates in degrees. b) Best-fit down-dip propagating slow-slip prediction for Site 2 February time series (background flow rate removed). Optimal parameters used to scale best-fit model are: rupture length = 12.2 km, depth of rupture below observation = 1.70 km, rupture propagation velocity = 0.47 km/day, and slip = 4.8 m.

A. LaBonte, K. Brown, and Y. Fialko; Hydrologic detection and finite-element modeling of a slow-slip event in the Costa Rica prism toe, JGR, 2008 in review.

Brown, K.M., M.D. Tryon, H.R. DeShon, L.M. Dorman, and S.Y. Schwartz (2005), Correlated transient fluid pulsing and seismic tremor in the Costa Rica subduction zone, Earth and Planetary Science Letters, 238, 189-203.