Relative Slowness Estimates for Locations of Repeating Low-Frequency Earthquakes and Narrow-Band Tremor at Fuego Volcano, Guatemala

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Fuego volcano, Guatemala, is an open-vent basaltic stratovolcano characterized by nearly constant, but low-level eruptive activity since 1999. In January 2008, we deployed small antennas of six broadband seismic and five acoustic sensors 0.9 km north of the active vent to investigate the source of explosions and low-frequency seismicity. The seismic array had stations spaced 30 m apart and a total aperture of ~140 m. The infrasound sensors were deployed in a similar array, but with average station spacing of 50 m. There was no lava effusion during the deployment, but explosions were recorded approximately once per hour, with varied amounts of ash, and with durations from 20-150 s. In addition to the explosions, our seismic array recorded narrow band tremor with dominant frequencies of 1.6 and 1.9 Hz and discrete events that were not generally detected by the acoustic array. The dominant class of these events, which repeated approximately 10-15 times per hour, had an impulsive onset with first motion toward the vent, a short duration of <5 s, and dominant frequencies from 1-3 Hz. Their similarity suggests a nondestructive source process. While waveforms are similar from event to event when viewed on the same channel, the large variation in waveforms across the array yields a large uncertainty in slowness parameter estimates. We take advantage of the high degree of similarity between events to determine relative slowness estimates. After determining the best-fit slowness parameters for a master event, we measured the relative slowness parameters for 203 similar events. The results indicate a stationary source, although subtle variations in waveforms suggest that the source mechanism or source location varied slightly with time. The low-frequency events were located by computing slowness parameters from synthetic waveforms for a volume of sources beneath the summit region. The source is ~150 m directly beneath the active vent, but not associated with explosions. Full moment tensor source inversion is not possible due to the limited array geometries, but we use forward modeling of candidate source geometries to infer differences between the sources of the dominant seismic signals. The events are consistent with a near-vertical north-south oriented crack. Despite the stability of the source during our observation period in January 2008, these events did not occur during subsequent deployments in July 2008 and January 2009 during similar, albeit more energetic eruptive activity. Relative slowness estimates were also determined for the narrowband tremor, revealing a slightly shallower source than that of the discrete events.