I. Introduction

Volcanic tremor (persistent ground motion occurring over a time range from minutes to days) is typically associated with different types of material transport beneath a volcano, and tremor that presents with multiple peaks (overtones) at integer multiples, it is termed harmonic [Konstantinou and Schlindwein, 2003]. Harmonic tremor can provide insight into the source processes that created them, but interpretation is complicated by the complex volcanic environments.

Santiaguito (2500 m) is a dacitic dome complex located in the 1902 eruption crater of Santa Maria (5772 m). We recorded data at SG01 using a 3-component broadband (30 second) seismometer for ~44 days of data from 1 January - 7 April 2009 with data gaps due to intermittent power losses. The data set was supplemented by infrasound (30 second) seismometer for ~44 days of data from 1 January - 7 April 2009 with data gaps due to intermittent power losses. The data set was supplemented by infrasound recordings, time-lapse images, thermal images, and video recordings.

Fuego (3263 m) is a basaltic andesite composite volcano and marks the current active center of the Fuego-Acatenango volcanic complex. We gathered broadband seismic data at 19 stations around Fuego from 9 January - 30 January 2009 along with infrasound recordings, time-lapse images, thermal images, and video recordings.

II. Gliding Tremor

Short-time window Fourier transforms (SWFT) plots along an 8 second window and 50% overlap reveal tremor with spectral peaks at integer multiples.

<table>
<thead>
<tr>
<th>Volcano</th>
<th>Fuego</th>
<th>Santiaguito</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>0.5 Hz</td>
<td>0.3 Hz</td>
</tr>
<tr>
<td>Duration</td>
<td>&gt; 3000 s</td>
<td>&gt; 1248 s</td>
</tr>
</tbody>
</table>

Both volcanoes demonstrated spectral gliding of the harmonic frequencies. We quantify the gliding in the signals using the peak function developed by Gong, A. (2007) to pick local maxima and minima within the spectrograms. These short frequency fluctuations have direct implications for source interpretation.

<table>
<thead>
<tr>
<th>Volcano</th>
<th>Maximum Rate of Change</th>
<th>Maximum Total Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santiaguito</td>
<td>0.4 Hz/30 s</td>
<td>0.75 Hz</td>
</tr>
<tr>
<td>Fuego</td>
<td>0.1 Hz/sec</td>
<td>0.1 Hz/sec</td>
</tr>
</tbody>
</table>

Most proposed models (thermo-organ resonators [Busu et al., 2005], magma column wobbling [Lesage et al., 2001], cavity-organ pipes [Lesage et al., 2006]) are not capable of producing such dynamic frequency shifts over such short time without invoking geophysically improbable geometries or implausible situations. We rely on our extensive data from contemporaneously collected data to aid in our interpretation.

III. Tremor Source

The best fit model to our data and observations at each volcano is a repeating series of nonlinear excitation of fracture walls as gas flows through the system after Julian [1994]. Differences in how cracks form and heal themselves account for variability in activity.

At both Santiaguito and Fuego volcanoes, gliding harmonic tremor signals with highly variable particle motions point to sources which are unstable by themselves but formed by repetitious processes capable of producing similar although not identical conditions. Pressurized gases passing through a changing crack network and exciting nonlinear responses from the crack walls as proposed by Julian [1994] best explain these characteristics.

IV. Particle Motions

We see unexpected changes in the polarization of particle motions at both Santiaguito and Fuego volcanoes. We use the frequencies identified by the Fast Peak Value algorithm and create 2-pole band pass filters on either side of the chosen frequency. When the isolated frequencies are plotted, the particle motions are typically elliptical and not easily attributed to a single wave type. Many examples show 90° rotations in particle motions from one overtone to the next. The relative amplitude contributions and dominant directions also vary greatly within continuous events.

One possible explanation for these behaviors could be that the lower frequency signals are within the near-field for those wavelengths, while the higher frequencies are not. Signals between 0.3 and 2.0 Hz correspond to wavelengths of 10 km or 1.5 km at 7.5 km, our events are mostly at a 1.5 km distance. Lokmer and Bean [2010] highlight fine resolution frequency contribution changes as well as polarized particle motions as the near-field term decays. Exploring the details of when and how the near-field term affects the wave field at about one wavelength distance could shed more light on this phenomenon.

V. Conclusion

At both Santiaguito and Fuego volcanoes, gliding harmonic tremor signals with highly variable particle motions point to sources which are unstable by themselves but formed by repetitive processes capable of producing similar although not identical conditions. Pressurized gases passing through a changing crack network and exciting nonlinear responses from the crack walls as proposed by Julian [1994] best explain these characteristics.

At Santiaguito, crack networks are created by shear fracture after Holland et al. [2011], while at Fuego, cracks open through a secondary vent filled by cooled lava [Nadeau et al., 2011].

References


Lokmer, I., and C. J. Bean (2010), Properties of the near field term affects the wave field at about one wavelength distance could shed more light on this phenomenon.


Lyons, J. J., and G. P. Waite (2011), Dynamics of explosive volcanism at Fuego volcano imaged with very long period seismicit

Pressures are released, fractures heal with added heat. Gas escapes and excites fracture walls.

Infrasonic waves are released, fractures heal with added heat.