Geophysical Research Abstracts
Vol. 13, EGU2011-5506, 2011
EGU General Assembly 2011

Empirical Green's Functions Analysis of Volcanic Hybrid Earthquakes Simulated in the Laboratory

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Volcanic hybrid earthquakes often precede explosive volcanic eruptions by hours to days, and are therefore frequently used for short term eruption forecasting. In spite of their predictive capabilities, their high-frequency onsets which transition to a protracted, low-frequency ringing make inferring a source mechanism a perplexing task. Complex models involving some combination of elastic shear, fluid, fluid shear, and their interactions are commonly invoked to explain their mechanism. However, some field observations suggest that the highly attenuating, complex travel path in a volcanic edifice may be responsible for some portion of the low-frequency part of the waveform. Resolving the ambiguity in the role of fluids in hybrid generation is an important factor in understanding eruption dynamics, as it would better facilitate our ability to provide accurate forecasts of how explosive a given eruption may be.

Here we present a new analysis of experimental simulations of volcanic hybrid signals, in efforts to better understand their origin. We examine the waveforms of laboratory microseismic events generated during two rock deformation experiments performed on samples of Mt. Etna basalt to determine their source characteristics and establish evidence for a mode of failure. Events were recorded during deformation under (a), unsaturated (dry) conditions, and (b), samples saturated with water. We employ an empirical Green's function approach to isolate the acoustic emission source spectra from attenuation and travel path effects, and estimate the spectral corner frequency using a least-squares fit to a Brune spectral model. Spectral fits indicate that the acoustic emission events occurring under dry conditions follow the expected scaling of moment and corner frequency for standard brittle failure in an elastic medium with constant stress drop, namely $M_0 \propto f_c^{-3}$. Events occurring during the decompression phase of the saturated experiment have estimated corner frequencies not easily described by any simple scaling relationship. The observed moment-corner frequency scaling also suggests that event durations change in a predictable way with increasing moment for the events occurring under dry conditions. Conversely, events occurring under wet conditions do not show any distinctive relationship between duration and event size. The specific size dependence on duration exhibited by the events in the dry experiment must consequently rule out fluid flow as a source, as there is no plausible reason for the driving pressure for fluid flow to be dependent on duration in such a specific way. Similar scaling observations between AE events occurring during the dry experiment and volcanic hybrid earthquakes at Mount St. Helens volcano suggest that a brittle failure mechanism explains both laboratory and field results where $M_0 \propto f_c^{-3}$ scaling occurs. The consistency of laboratory and field observations suggest that the presence of brittle-failure scaling must exclude fluid flow as a source of the seismic signal for a particular group of events. Conversely, the absence of such scaling may suggest a fluid induced seismic signal.