Geophysical Research Abstracts, Vol. 9, 01829, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-01829

Volcanic Hybrids that are Brittle Failure Events

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Volcanoes commonly generate a variety of low-frequency seismic signals prior to eruption. Hybrid earthquakes comprise a class of these signals that have a high-frequency onset followed by low frequency ringing. As distinctively volcanic phenomena, hybrids are sometimes used empirically to predict eruptions, but their physical origin is unclear and their diagnostic use is therefore limited. Existing source models typically involve a combination of brittle failure and a fluid process in order to explain both the high-frequency and long-period portion of their waveforms. Here we show that the near field seismograms of the hybrid earthquakes associated with the ongoing 2004 - 2006 Mount St. Helens eruption are relatively compact. Most, if not all of the prolonged low-frequency ringing develops with propagation and thus is not a source effect. We also use seismic source spectra to show that the hybrid earthquakes do scale as one would expect for stick-slip, brittle-failure. The combination of the scattering observation and the observed corner frequency/seismic moment relationship suggests that a resonating fluid cavity is not the major factor in determining the waveforms and thus the hybrids should not be used as direct indicators of subsurface magmatic fluids. The unusually low frequency of these volcanic earthquakes can result from low rupture velocities combined with strong path effects due to their shallow source. This new application of near-field instrumentation both allows hybrids to be used as a more precise tool for volcanic monitoring and provides the first seismological evidence for brittle failure as a major process in dome building.