Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)


SVC50-08 Room:315 Time:May 2 11:00-11:15

# A phreatic explosion model for Mayon volcano, Philippines, inferred from analyses of an explosion earthquake

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Mayon is one of the most active volcanoes in the Philippines with 49 known historical eruptions from 1616 to 2010. A phreatic explosion took place at Mayon on 7 May 2013 that killed five climbers. In this presentation, we show the results of the waveform inversion for the explosion earthquake and discuss a phreatic explosion model for Mayon.

During the explosion in 2013, a VLP event with a peak frequency of 0.4 Hz was recorded by three broadband seismometers which we had installed in 2011. We performed a frequency-domain waveform inversion in 0.1-0.6 Hz, which pointed to a combination of a subhorizontal tensile crack and a vertical single force at a shallow part beneath the summit crater. Contributions from the crack and force to the waveforms had amplitudes comparable to each other.

The source time functions obtained by the waveform inversion are bandpassed forms (filtered source time functions; FSTFs), which may be different from the source time functions without filters (deconvolved forms of the source time functions; DSTFs). Instead of performing numerically unstable deconvolution operations, we assumed simple step- and impulse-type functions with finite durations as candidates of the DSTFs. We applied the bandpass filter to these functions and compared with the FSTFs. The bandpassed waveforms of the impulse-type functions were similar to the FSTFs for both the crack and force, suggesting that the DSTFs can be approximated by the impulse-type functions. The estimated DSTF for the tensile crack showed an inflation followed by a deflation, whereas that for the single force showed a downward force around the time of the maximum opening of the crack.

The RMS seismic amplitudes, GPS baseline lengths over the volcano, ground surface temperatures around the summit, waveform correlations among the seismic stations, the sulfur dioxide emission, and rainfall did not show clear precursory signals.

Since the analyzed VLP event occurred during the phreatic explosion, the initial inflation in the DSTF for the crack may have been caused by boiling of underground water. This crack is subhorizontal and located at a shallow part, suggesting that the crack may be located on a boundary between permeable and impermeable layers where the water may have accumulated and finally boiled, generating the explosion. The downward force may represent the counter force of the explosion. The deflation of the crack in the latter half of the DSTF may have been caused by outgassing of water vapor during the explosion.

The estimated moment amplitude is explained by a volume change of 400 m $\times$ 400 m $\times$ 0.4 m. A topographic change comparable to this crack size was not observed during the explosion, suggesting that the explosion destroyed only a limited portion of the crack. This crack may repeat the explosion once the fragmented portion of the crack is sealed through the hydrothermal alteration. At Mayon, small ash explosions occurred in 2003, 2004, 2006, and 2009, with intervals of a few days to a few years (mostly longer than one month). These intervals are close to experimentally derived time scales of fracture sealing by the hydrothermal alteration; according to the experiments by Berger et al. (1994, Geochim. Cosmo. Acta), who used basalt samples with chemical compositions similar to magmatic eruption deposits at Mayon, a centimeter-order fracture is sealed in two months for 300 ℃ and 54 months for 150 ℃.

In this model, timings of the explosions are controlled by the sealing of the fracture. Therefore the explosions can occur even with a constant supply of heat and water. This may be the reason why no clear precursory signals were observed before the explosion in 2013. No VLP events other than that associated with the explosion in 2013 have been observed at Mayon since the beginning of the observation in 2011, which may be explained by the sealing of the fracture just prior to the explosion.

Keywords: Phreatic explosion, Waveform inversion, Source time function, Hydrothermal alteration