Process of small explosion at Stromboli volcano as inferred from analyses of broad-band seismic waveforms recorded at very-near-field stations

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Very-long-period (VLP) earthquakes are frequently observed several seconds before the onset of an explosion at Stromboli volcano (e.g., Ripepe et al., 2001). The VLP seismic waves are considered to be generated by a gas coalescence and gas slug ascent in the shallow part of the conduit. However, tilt analyses (Genco and Ripepe, 2010) revealed that each explosion is preceded by a slow inflation lasting ~ 200 s which may not be explained by a slug ascent in a vertical conduit (Kawaguchi and Nishimura, 2015). To understand dynamic processes of magma/gas motions from several tens to hundreds of seconds before each explosion, this study analyzes VLP seismic waves and a preceding phase appearing 10-20 seconds before the onset of explosions.

In the end of September 2016, the University of Florence deployed five broad-band seismometers at locations only 100-300 m away from the active craters of Stromboli volcano. These stations record large VLP signals that start about 5 seconds before the onset of explosions. We analyze 103 VLPs recorded for 5 days observation. We filter the seismic signals at 0.05-0.2 Hz. Carefully examining the waveforms, we find that 21 events accompany a small phase that are recognized 10-20 seconds before the onset of explosions. The amplitudes of this phase are not large, but about 2-3 times larger than the seismic noise. The particle motions of the preceding VLP phase and the large VLP phase show strong rectilinearity. The former points to the west of the craters and the latter to the region closer to the craters. To examine the spatio-temporal changes in VLP seismic source locations before and after explosions, the semblance analysis (Kawakatsu et al., 2000) is performed for different elapsed time sections of the VLP seismograms. The source location of the preceding phase is estimated to be at 170 m deep from the craters and about 200 m west of the eruptive crater. On the other hand, the source location of large VLP just before explosion moves 50-100 m eastward toward the craters, and that of large VLP during explosion goes back westward to the location where the preceding phase is excited.

We also apply the moment tensor inversion to the all waveforms of the VLPs. The estimated centroid is located at very close to the source locations of the preceding phase and the large phase during the explosion which are determined by the semblance analysis. On the other hand, the centroids for higher frequency bands at 0.2-0.5 Hz and 0.5-1.0 Hz are located beneath the craters. Since the seismic waves at the two frequency bands are recognized mainly at the onset time of explosion, these waves are excited by the eruption process.

Following these results and previous studies, we summarize the process of small summit explosion at Stromboli volcano for several tens of seconds as follows. About 10-20 seconds before the onset of an explosion, an initiation of magma/gas movement starts in a shallow magma chamber at west out of the craters, exciting small VLP seismic waves. About 5 seconds before the onset of the explosion, a pressure is built up in the top of magma chamber, generating large VLP and LP seismic waves. Then, an explosion occurs and seismic and acoustic waves are excited at the top of magma level, probably in the conduit. After the explosion, fluid flow and/or pressure migrate westward in the shallow magma chamber to compensate the disturbance caused by eruption, which are represented by a very large VLP (0.05-0.2 Hz)

phase.
The broad-band seismograms recorded very close to the active craters enable us to detect horizontal movements of fluid flow/pressure in the shallow chamber, which are quite important to understand the mechanism and repetitive behavior of summit explosion at Stromboli volcano.

Keywords: Very-long-period earthquakes, Preceding phase, Strombolian eruptions, Very-near-field observation

