Source depth of Strombolian eruptions at Aso volcano in April 2015

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At the Nakadake 1st crater of Aso volcano, magmatic eruptions had started in November 2014 after 22 years dormancy. This eruption activity lasted until May 2015. It was a first time for us to observe the eruptions using a network of seismo-acoustic sensors deployed around the crater. We have stations equipped with a low-frequency microphone (ACM) and a short-period seismometer (KAF) on the crater rim. They are situated at 260 m SW and 230 m SWW from the active vent, respectively. On the NNW flank of the volcano (830 m distance), a broadband seismometer (UMAB) is installed. In this study, we analyze seismo-acoustic data acquired at these three stations in the 19:00-20:00 JST (GMT+9:00) on 24 April 2015 to estimate source depths of Strombolian eruptions.
At each Stromoblian eruption, characteristic seismo-acoustic signals were observed. They were typically started by a downward phase of low-frequency (<0.1 Hz) seismic velocity to the UMAB station. This wave corresponded to a long period tremor (LPT; Yamamoto et al., 1999, GRL). A couple of seconds later (1.7-5.4 s), higher frequency (5-10 Hz) seismic velocity arrived to the KAF station. Infrasound wave was detected at ACM about 1 s after the seismic arrival to KAF. The infrasound wave (peak frequency is ~0.5 Hz) was started by a compression phase, however in 0.1 s later a high-frequency content (>10 Hz) was added on it. We can recognize a strong positive correlation (R=0.92) between Root-Mean-Squared (RMS) amplitude of the seismic velocity at KAF and that of 10 Hz high-passed infrasound wave at ACM. The time delay between the arrivals of these two signals was 0.93-1.56 s (mean 1.2 s).
To estimate source depth of each Strombolian eruption, we assumed that a space in the conduit through which infrasound wave propagates was occupied with hot volcanic gases. On the basis of a composition (H_2O:SO_2:CO_2=90:4:4; Shinohara, Pers. Comm., 2016) and a temperature data (330-360 K at the vent), the sound velocity inside the conduit was estimated to be 410-430 m/s. We also considered that seismic signals observed at KAF are composed of the P wave (V_P=3.3 km/s; Tsutsui et al., 2003, BVSJ). It resulted in the source depth of each Strombolian eruption to be 70-380 m. This depth is consisted with a shallow region above an upper edge of the crack-like conduit (300 m; Yamamoto et al., 1999, GRL).
We intended that signals of LPT arrived to UMAB was 1.7-5.4 s earlier from the arrival time of high-frequency seismic wave to KAF. Because LPT is resulted from a resonant oscillation of the fluid-filled crack-like conduit beneath the active crater (Yamamoto et al., 1999, GRL), Strombolian seems to relate the source of LPT as well. According to a near-field effect, the phase velocity of the LPT has a value between those of the P and S waves (3.3 and 1.9 km/s; Sudo and Kong, 2001, BV). It indicates that ascending speed from the source location of the LPT, at the center of the crack-like conduit (1.6-1.8 km; Yamamoto et al., 1999, GRL), to the depth of Stromoblian eruption we could estimate (70-380 m) is 300-700 m/s. It is too fast to consider that the volcanic fluids (magma and gases) migrate upward with this velocity. At the present, we interpret it as a pressure wave; it is radiated from the LPT source at the same time of the LPT occurrence and propagates inside the crack-like conduit to the depth of Strombolian eruption. Estimated speed of the pressure wave (300-700 m/s) is accountable either when andesite molten magma (sound velocity is 2.3-2.5 km/s; Murase and McBirny, 1973, BGSA) includes bubbles at a few vol.% (Morrissey and Chouet, 2001, JVGR), or when H_2O vapor steam contains small amount of ash particles (< 10 vol.%). The time delay of 0.1 s between arrival times of the 0.5Hz and >10Hz infrasound waves at ACM may become a clue to understand detailed process of Strombolian eruption at the depth.

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