

The very-long-period seismic signals at Miyake-jima volcano during the caldera formation revisited: insights from GPS observations

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Miyake-jima island is an active stratovolcano that is located about 200 km south of Tokyo. Since the beginning of 20th century, eruptions had occurred four times in 1940, 1962, and 1983 and 2000. The 2000 eruption was totally different from the previous eruptions in that the gigantic caldera was formed. The 2000 eruption were characterized by the four stages: (1) Intrusion stage (26 June-8 July) when the magma from the reservoir beneath the summit of Miyake-jima towards the northwest, and submarine eruption occurred on 27 June about 1 km off the western coast; (2) Caldera forming stage (8 July – middle of August) when a collapsed caldera grew in the summit area; (3) Explosive stage (middle of August – September) when phreatic and phreatomagmatic eruptions with ash emission from the summit occurred; (4): Degassing stage (since September) when massive emission of SO₂ gas continued (more than 10⁷ ton/day) (Nakada et al., 2005).

During the caldera forming stage, very-long-period (VLP) seismic pulse waves with a duration of about 50-s, that were accompanied by the step-like inflation followed by gradual deflation, were repeatedly recorded. The time interval between the occurrence of the pulse waves/tilt changes were 0.5-2 days (Kikuchi et al., 2001). The pulses have been observed about 40 times during the period. Two different models have been proposed for the mechanism that generated the pulse waves based on the different dataset (broadband seismometer and ground tilts). The piston model is proposed based on the former dataset in which a vertical piston of solid materials in the conduit is intermittently sucked into the magma chamber located 3-5 km beneath the edifice (Kumagai et al., 2001); The magma sheet model is proposed based on the latter dataset in which a gigantic sill-like magma reservoir located at 6-8 km beneath the edifice opens intermittently (Fujita et al., 2002). There is no unified view on the source of the VLP pulse waves and its role in the development of the eruption sequence.

Here we used yet another dataset, i.e., the permanent displacements from the continuous GPS observation, to constrain the source geometry of the VLP pulse waves. We calculated the kinematic displacements of 15 GPS stations on Miyake-jima that were in operation at this stage (Fig. 1) w. r. t. 4 GPS stations on nearby islands using RTKLIB (Takasu, 2013) to obtain absolute displacements at the GPS stations on Miyake-jima at 30 sec interval. Then we stacked the coordinate time series at each station at the occurrence of each pulse to obtain mean displacements due to the VLP events. Then we constructed the model to explain the displacements using the least-square adjustment. We found that the combination of (1) a spherical source beneath the volcanic edifice at around 3.6 km, and (2) a vertical dike whose top locates at around 2.7 km reasonably explain the observed displacements (Fig. 1). The location of the spherical source is consistent with the source geometry requested from the piston model (Kumagai et al., 2001; Kobayashi et al., 2012), and may be interpreted as the andesite magma chamber inferred by petrological observations that have been existed since at least 15th century (e.g., Saito et al., 2010). The vertical dike is located in the

middle of the magma chamber and the dike that has opened at the onset of the 2000 eruption (Irwan et al, 2006). We interpreted that the VLP sources (a spherical source and the dike) is connected to the dikes that has opened at the onset of the 2000 eruption and thereafter (Irwan et al., 2006) and offered a pathway for the westward migration of the andesitic magma from the magma chamber (e.g., Kaneko et al., 2005), which resulted in the escape of the magma from the magma chamber and ultimately caused the formation of the gigantic caldera.

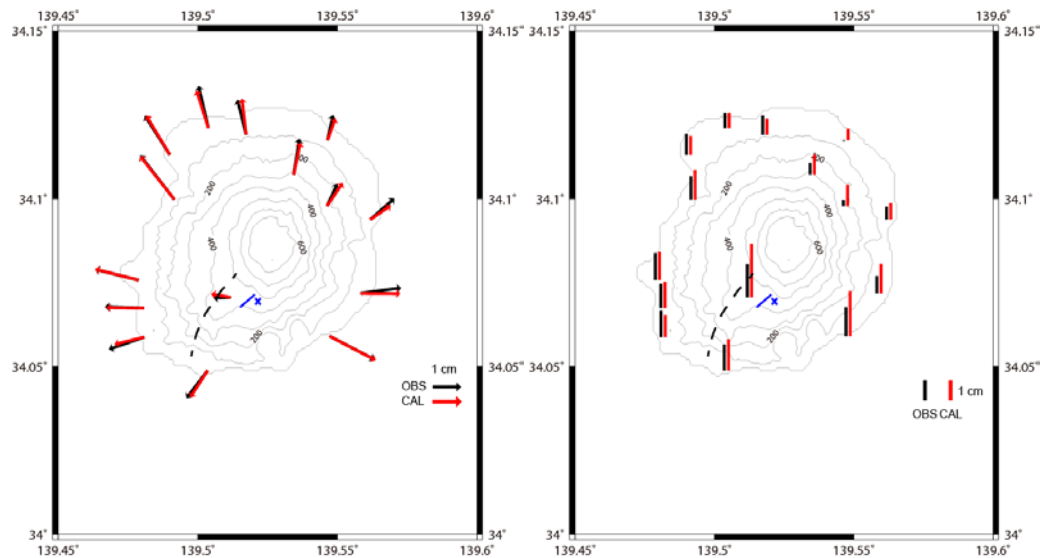


Fig. 1 The mean displacements caused by a VLP event, and the location of the estimated source model. Black and red arrows denote observed displacements at the GPS stations, and those expected from the model, respectively. The VLP source consists of the spherical source (blue cross) and vertical dike (blue line). The dashed black line represents the location of the fissure at the 1983 eruption.

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