Post-eruptive thermoelastic deflation of intruded magma in Usu volcano, Japan, 1992–2017

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Abstract

Observations of post-eruptive deformation of an active volcano are important for inferring underground magma processes. Secular ground subsidence at Usu volcano (Japan) has been reported around the eruption vents following the four eruptions in 1910, 1943, 1977, and 2000. However, the mechanisms accounting for the subsidence have not been well understood due to the poor spatial and temporal resolution of previous observations. In this study, we systematically investigated the post-eruptive deformation at Usu volcano using Interferometric Synthetic Aperture Radar (InSAR) based on 111 JERS, ALOS-1, and ALOS-2 images acquired from five different tracks from 1992 to 2017. We also calculated quasi east-west and vertical ground displacements between 2006 and 2017 with the available of ascending and descending InSAR observations. Our results show three localized deformation regions from west to east of Usu volcano with their locations corresponding to the 2000, 1977, and 1943 eruption vents, respectively. All the deformation sites show patterns of east-west contraction and subsidence. The extent and rate of post-eruptive subsidence declined dramatically at the vent of the 2000 eruption site from 2006 to 2017, decreased gradually at the 1977 vent, and shows a steady pattern for the 1943 site during 1992–2017. We ascribed the observed post-eruptive subsidence to thermoelastic contraction of a sphere intruded at the time of the eruptions to constrain locations, depths, volumes of heat sources with the assumption of the spherical source shapes. Thermoelastic modeling reveals that the heat sources are embedded at shallow depths not deeper than 400 m below sea level with volumes of about 0.009, 0.132 and 0.005 cubic kilometers (km3) for the 2000, 1977 and 1943 eruption sites, respectively. Quantitative comparisons between the simulated and observed temporal evolution of ground displacements show a good agreement, justifying the inferred heat sources. The modeling also highlights the importance of underground water in assessing thermal diffusion process and the associated post-eruptive deformation.

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