Crustal deformation accompanied with the eruption of Shinmoe-dake in early March 2018

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Shinmoe-dake is a part of Kirishima volcano group composed of 20 Quaternary volcanoes located in southern Kyushu, Japan, erupted on 19 January 2011. This eruption began with a phreatomagmatic event including atmospheric vibration and eventually developed to subplinian eruptions within a week. From GNSS data, position and volume change of the magma chamber were estimated to be about 5 km to the northwest of the top of Shinmoe-dake at a depth of 8-9 km and 1.3×10^7 m^3. Shinmoe-dake erupted on 11 October 2017 after an interval of six years, however, this eruption ended in a week. While the extension of baseline length between the sites across Mt. Kirishima has been detected by GNSS observation since July 2017, indicating the possibility of magma accumulation. Eventually, the extension of baseline length led to eruption on 1 March 2018. In this study, in order to clarify the mechanism of the volcanic eruption, we investigated the crustal deformation accompanied with a series of volcanic activities occurred in early March 2018 at Shinmoe-dake by using GNSS data, then estimated the position of the magma chamber.

For the study, GEONET F3 solutions obtained by GNSS observation sites located mainly in the Kyushu district from 1 January 2013 to 25 March 2018 were used. Firstly, common mode bias was removed from time series of GEONET F3 solutions according to the method of Wdowinski et al. (1997). Secondly, visco-elastic deformation due to the 2016 Kumamoto earthquake was corrected by using a code of Fukahata and Matsu’ura (2005, 2006). In this time, we used the co-seismic fault model of Geospatial Information Authority of Japan (GSI, 2016) and calculated the visco-elastic deformation, where the calculation was conducted on the condition that an elastic material with thickness of 25 km lies on a Maxwell visco-elastic half-space with viscosity of 2×10^{18} Pas. Thirdly, to estimate elastic deformation due to subduction of the Philippine Sea plate (PH), we reproduced the upper surface of the PH by 170 rectangular faults based on the result of Hirose et al. (2008) and estimated coupling ratio. The Green’s functions of rectangular faults were calculated by the formula of Okada (1985). Using horizontal and vertical velocities of GEONET 150 sites between 1 January 2013 and 31 March 2016, we conducted a back-slip inversion analysis with smoothing constraint of coupling ratio among the adjacent faults. Assuming the interplate coupling obtained by the analysis continues after July 2017, we corrected the effect of the plate subduction from original data. After completing three processes above mentioned, finally, the positions of the magma chambers were estimated in two periods: inflation phase (1 July 2017–28 February 2018) and deflation phase (14 February 2018–25 March 2018) by using the Mogi’s model. We selected 7 GEONET sites located around Shinmoe-dake and estimated the positions of Mogi sources (longitude, latitude, and depth) corresponding to the two phases by performing a grid search in the ranges of 130.6-131.1°every 0.001°for longitude, 31.7-32.1°every 0.001°for latitude, and 4-15 km every 0.1 km for depth. The volume change of the Mogi sources were assumed to be 1.6×10^7 m^3 in the inflation phase and -0.7×10^7 m^3 in the deflation phase, according to the results of Japan Meteorological Agency (JMA). The result showed that the positions of the magma sources were estimated not to be just under the top of Shinmoe-dake but to be about 6-7 km to the northwest of it at a depth of 7-12 km. Although our result is generally consistent with that of JMA, the depth of the magma sources in the inflation phase was estimated to be approximately 4 km deep part. For the next step, we investigate the effects of topography and heterogeneous structure on crustal deformation.

Keywords: Shinmoe-dake, GNSS data, visco-elastic deformation due to the 2016 Kumamoto earthquake, elastic deformation by subduction of the Philippine Sea plate, estimation of magma chambers