

The September 14, 2015 phreatomagmatic eruption of Nakadake first crater, Aso Volcano

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Nakadake Volcano, which is the only active central cone inside the Aso caldera, is one of the most active volcanoes in Japan. The active crater (first crater) of Nakadake is occupied by a hot, hyperacidic (pH = 0.43) crater lake during its calm periods (Miyabuchi and Terada, 2009; Ohsawa *et al.*, 2010). During active periods, volcanic activity of Nakadake first crater is characterized by continuous fallout of black sandy ash from a dark eruption plume (Ono *et al.*, 1995). In more active periods, strombolian eruptions have scattered red-hot scoriaceous clasts around the vent. Moreover, phreatic or phreatomagmatic eruptions occurred in September 1979 and April 1990, ejecting coarse lithic blocks and generating small low-temperature pyroclastic density currents around the crater (Ono *et al.*, 1982; Ikebe *et al.*, 2008).

Following the November 2014-May 2015 magmatic activity (Miyabuchi and Hara, 2019), an explosive eruption occurred at Nakadake first crater on September 14, 2015. The sequence and causes of the eruption were reconstructed from the distribution, textures, grain-size, component and chemical characteristics of the related deposits, and video record (Miyabuchi *et al.*, 2018). The eruptive deposits are divided into ballistics, pyroclastic density current and ash-fall deposits. A large number of ballistic clasts (mostly < 10 cm in diameter; maximum size 1.6 m) are scattered within about 500 m from the center of the crater. Almost half of the ballistics appear as fresh and unaltered basaltic andesite rocks interpreted to be derived from a fresh batch of magma, while the rest is weakly to highly altered clasts. A relatively thin ash derived from pyroclastic density currents covered an area of 2.3 km² with the SE-trending main axis and two minor axes to the NE and NW. The pyroclastic density current deposit (maximum thickness < 10 cm even at the crater rim) is wholly fine grained, containing no block-sized clasts. Based on the isopach map, the mass of the pyroclastic density current deposit was estimated at approximately 5.2×10^4 tons. The ash-fall deposit is finer grained and clearly distributed to about 8 km west of the source crater. The mass of the ash-fall deposit was calculated at about 2.7×10^4 tons. Adding the mass of the pyroclastic density current deposit, the total discharged mass of the September 14, 2015

eruption was 7.9×10^4 tons. The September 14 pyroclastic density current and ash-fall deposits consist of glass shards (ca. 30%), crystals (20-30%) and lithic (40-50%) grains. Most glass shards are unaltered poorly crystallized pale brown glasses which probably resulted from quenching of juvenile magma. This suggests that the September 14, 2015 event at the Nakadake first crater was a phreatomagmatic eruption although the eruption is one order of magnitude smaller in eruptive volume than the September 6, 1979 and April 20, 1990 eruptions. These events highlight the potential hazard from phreatic or phreatomagmatic eruptions at Nakadake first crater, and provide useful information that will assist in preventing or mitigating future disasters at other similar volcanoes worldwide.

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