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Stratigraphy, grain-size and component characteristics of the 2011 Shinmoedake eruption deposits, Kirishima Volcano, Japan

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ABSTRACT

The 2011 eruption of Shinmoedake Volcano, part of Kirishima Volcanic Complex in southern Kyushu, southwestern Japan was characterized by a significant change in eruption style from subplinian eruptions to lava effusion in the summit crater, and subsequent vulcanian eruptions. The stratigraphy, distribution and textures of fallout tephra deposits reveal the character and sequence of the eruption. The tephra-fall deposits distributed southeast of the volcano are divided into five units based on the eruptive events. Unit 1 is a lithic-rich fine ash-fall deposited on 19 January 2011. Unit 2 is a very well to well sorted pumice-fall deposit from the evening of January 26 to early morning of January 27, and is the main product of the 2011 eruption. The unit-2 deposit was dispersed throughout an area extending more than 20 km SE of the source crater. Unit 3 comprises tephra-fall deposits related to the January 27 15 h 41 min explosion, and is subdivided into lower (3L) and upper (3U) parts. Unit 3L is a lithic-rich well-sorted coarse ash-fall, deposited during the initial stage of the January 27 15 h 41 min eruption, whereas the unit 3U is composed mainly of coarse-grained pumiceous lapilli. Unit 4 is a fine ash-fall deposited on January 28–29, and consists mostly of fresh lava fragments and crystal grains. Unit 5 is a product of the largest vulcanian eruption, on March 13. Unit-5 tephra is a lithic-rich medium to coarse ash-fall deposit. Furthermore, the 31 August 2011 ash-fall deposit extending 19 km southwest of the Shinmoedake crater is fine grained and contains abundant lava fragments. Temporal variations in grain size and components of the 2011 eruption deposits reveal the eruption sequence and the conditions of the crater, conduit and magma chamber.

1. Introduction

The Shinmoedake Volcano at Kirishima Volcanic Complex in southern Kyushu, southwestern Japan, began a series of eruptions on January 19, 2011. These were preceded by a 13-month-long inflation of the volcano by magma supply. The eruptions began with a small phreatomagmatic eruption, but shifted on January 26 to magmatic eruptions characterized by subplinian eruptions. Subsequently, lava appeared in the summit crater, and filled the crater completely by February 2. Multiple vulcanian explosions occurred in the lava-filled crater, and the number of eruptions declined after February 9. The largest vulcanian explosion happened on March 13, after which relatively small eruptions occurred intermittently until September 7, 2011. Although this series of eruptions caused no fatalities, the area surrounding Kirishima Volcano was greatly affected by the 2011 eruption, with evacuation of local inhabitants and damage to infrastructure and agriculture. A risk of further eruptions persists.

Vulcanian and subplinian eruptions occur frequently worldwide although they are smaller in volume and magnitude than plinian eruptions. Whereas tephra deposits of plinian, phreatoplinian and strombolian eruptions are moderately well-understood with respect to their dispersal, grain-size and textural characteristics (e.g., Cas and Wright, 1987), little work has been done on subplinian and vulcanian activity. Many vulcanian and subplinian tephra deposits, which are generally small in volume, do not form a conspicuous part of the tephra stratigraphy preserved around volcanoes because of their impermanent nature especially in pluvious regions. The lack of the small-volume deposits results in incomplete record of past eruptions. It is therefore very important to understand distribution and character of these tephra deposits for estimating the sequence of future eruptions at volcanoes where small eruptions frequently occur.

This paper presents an integrated tephra stratigraphy of the 2011 Shinmoedake eruption deposits at Kirishima Volcanic Complex. Based on the stratigraphy, distribution, textures, grain-size and details of components of the deposits, the likely sequence and style of the 2011 eruption at Shinmoedake Volcano are discussed.

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2. Geological setting

Kirishima Volcano is a Quaternary composite volcano located in southern Kyushu, southwestern Japan (Fig. 1). It spans about 30 km from east to west and 25 km from north to south, and includes a cluster of more than 25 small andesitic stratovolcanoes and two calderas (e.g., Imura, 1994; Imura and Kobayashi, 2001). The volcano has been active for the last 600 ka, and the composite is divided into two groups: Older Kirishima and Younger Kirishima Volcanoes (Imura and Kobayashi, 2001; Nagaoka et al., 2009; Nagaoka and Okuno, 2011).

The Older Kirishima Volcano (600–330 ka) is characterized by caldera-forming eruptions involving two large pyroclastic flows (Kobayashi–Kasamori and Kakuto pyroclastic flows; e.g., Machida and Arai, 2003), of volumes >50 km^3 dense rock equivalent (DRE). Apart from the large pyroclastic-flow deposits, the volcanic products of the older stage are now exposed only in the western foot of the Kirishima Volcano (Imura and Kobayashi, 2001).

There was a short (<10 ka) dormant period after the Kakuto pyroclastic-flow eruption. Activity of the Younger Kirishima Volcano began at 330 ka (Nagaoka and Okuno, 2011). The activity of plinian, vulcanian, strombolian and phreatomagmatic eruptions, which produced numerous fallout tephra layers, gave rise to more than 25 small stratovolcanoes and pyroclastic cones, including Kurinodake Volcano (200–100 ka), Ebinodake (100–50 ka), Onamiike (45 ka), Ohatayama (45–38 ka), Hinamoridake (38 ka), Futagoishi (38–30 ka), Iimoriyama (29–22 ka), Karakunidake (the highest peak of Kirishima Volcano; 22–15 ka), Koshikidake, Shinmoedake (10.4 ka-present), Takachihonomine (8.1–6.8 ka), Miike maar (4.6 ka) and Ohachi (8–18C) (Nagaoka and Okuno, 2011).

Shinmoedake (1420.8 m asl), which is located near the center of Kirishima Volcano, is an andesitic stratovolcano. Its crater is approximately 800 m in diameter and 180 m in depth from the summit (Fig. 2). It began its activity with the Setao pumice fall (Inoue, 1988) at 10.4 cal ka (calibrated ^{14}C date of Imura and Koga, (1992)), and has continued to undergo intermittent small eruptive episodes. These include the Maeyama pumice fall (Inoue, 1988) of 5.6 cal ka BP, the Kyoho pumice fall of AD 1716–1717 and the Showa ash fall of AD 1959 (Imura and Kobayashi, 1991).

The 1716–1717 Kyoho eruption has been the largest eruptive event at Shinmoedake Volcano. During the eruption, pumice-fall deposits were dispersed over large areas east of the summit crater, and pyroclastic flows cascaded down slopes all around the volcano. Most of the present volcano edifice was believed to be formed by the Kyoho eruption. The Showa activity in February 1959 was a phreatic eruption forming a 500-m-long fissure on the western slope of the volcano. The phreatic eruption emitted ballistic blocks within 2 km of the crater, and the related ash-fall deposit was distributed over a wide area east of the volcano, and damaged forests and farmlands (Japan Meteorological Agency, 2005). From November 1991 to February 1992, fumaroles in the summit crater discharged small amounts of ash-fall deposits. Moreover, a phreatic eruption in August 2008 formed some explosion craters and fissures running E–W inside the summit crater and the western flank of the volcano (Geshi et al., 2010).

3. Summary of 2011 Shinmoedake eruption

There had been many small phreatic eruptions at Shinmoedake Volcano from August 2008, and inflation of the volcano was observed using the GPS network by the Geospatial Information Authority of Japan from December 2009. According to the Fukuoka District Meteorological Observatory and Kagoshima Local Meteorological Observatory (2012), the activity of the 2011 eruption at Shinmoedake was as follows.

A small phreatomagmatic eruption occurred on 19 January and produced a shock wave that was detected 12 km NE and an ash plume that

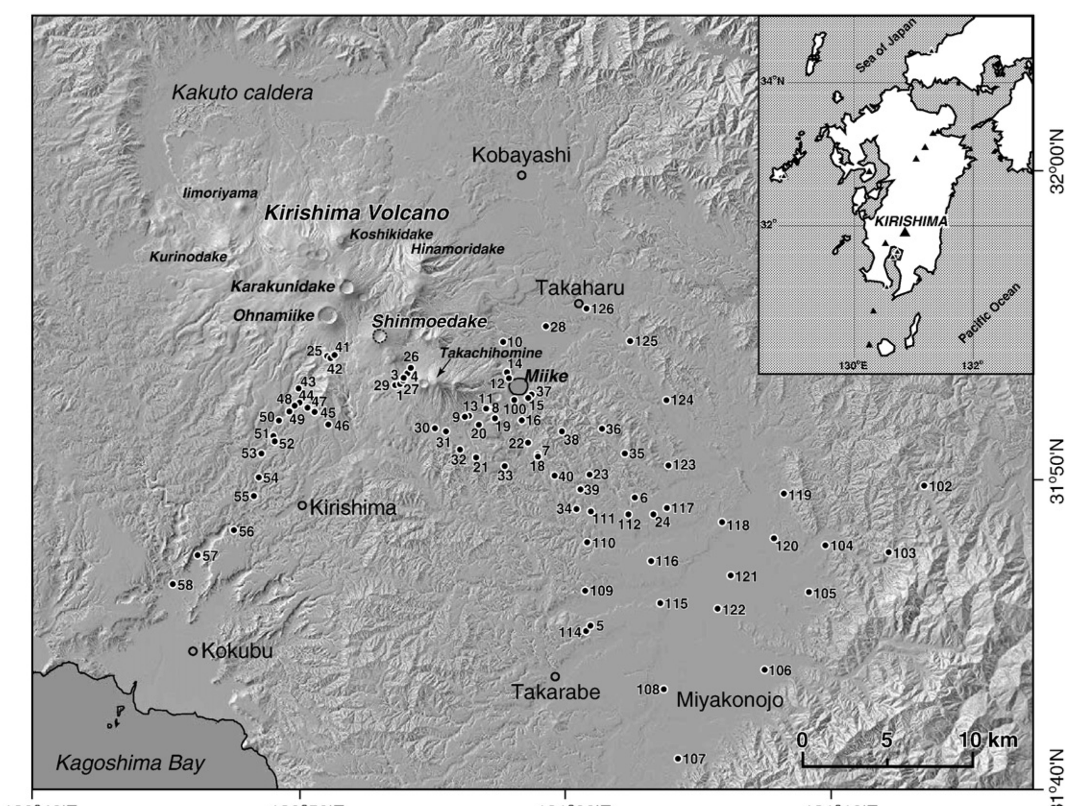

Fig. 1. Location of stratigraphic sections measured in and around Kirishima Volcano. The relief map was produced by Kashmir 3D using the 50-m-mesh DEM data published by the Geospatial Information Authority of Japan.