Quaternary International 397 (2016) 39–51

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

# Large scale explosive eruptions of Akan volcano, eastern Hokkaido, Japan: A geological and petrological case study for establishing tephro-stratigraphy and -chronology around a caldera cluster

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A R T I C L E I N F O

*Article history:*
Available online 29 August 2015

*Keywords:*
Akan volcano
Caldera cluster
Tephrostratigraphy
Tephrochronology eruptive groups
Silicic magmas

A B S T R A C T

Akan volcano, in eastern Hokkaido in the southern Kurile arc, occupies a rectangular caldera (24 × 13 km) with a long (1.7–0.2 Ma) and complex history. This paper combines tephrostratigraphy, tephrochronology, and petrological and geochemical evidence to elucidate the eruptive history and evolution of the caldera. Pyroclastic deposits from Akan caldera are divided into at least 40 "eruptive units", separated by paleosols, that constitute 17 "eruptive groups" (Ak1 to Ak17, in descending stratigraphic order) that are petrologically distinct and separated by indicators of longer dormancy periods such as thick (>30 cm) paleosols and angular unconformities. The estimated volumes of most eruptive groups are less than 10 $km^3$ dense rock equivalent, and four groups (Ak2, Ak4, Ak7, and Ak13) are larger. Group Ak2, exceeding 50 $km^3$, is the largest. Pyroclastic deposits from Akan caldera are intercalated with pyroclastic deposits from the adjacent Kutcharo caldera and distal air-fall ash layers from central Hokkaido, suggesting that caldera-forming episodes overlapped in central and eastern Hokkaido. Radiometric ages from these exotic deposits range from 1.46 to 0.21 Ma, indicating that caldera-forming eruptions occurred at Akan volcano for more than 1 million years at an average magma discharge rate of approximately $10^{-1}$ $km^3$/kyr. Juvenile materials in Akan caldera pyroclastics consist of dominantly aphyric, two-pyroxene dacite to rhyolite. They are characterized by a wide range of $K_2O$ compositions (0.8–2.8 wt.%) within a narrow range of $SiO_2$ compositions (67–73 wt.%). Plots of $SiO_2$ vs. $K_2O$ suggest that each eruptive group is the product of a distinct, ephemeral magma system rather than a single long-lived magma system. These magma systems appear to have been generated and erupted successively beneath the caldera for more than 1 million years. Each magma system thus appears to represent a relatively short period of activity, and they were separated by relatively long dormancy periods before the next magma system. In particular, a long dormancy of 400 kyr preceded eruptive group Ak2, which consists of the most voluminous and compositionally varied silicic magmas.



## 1. Introduction

Tephra layers from large scale explosive eruptions are widely used as a correlation tool to establish local and regional stratigraphy. Tephro-stratigraphy, combined with the petrology, can contribute to construct the eruptive history including magmatic processes of the source volcanoes (e.g. Miyabuchi, 2009; Hasegawa et al., 2011a; Cole et al., 2014). In addition, tephra correlation between distal volcanic areas along an arc-trench system is important to understand the temporal and spatial evolution of caldera clusters and related regional tectonics (e.g. Gravley et al., 2007; Kutterolf et al., 2007).

Three Quaternary calderas—Akan, Kutcharo, and Mashu—form a cluster in eastern Hokkaido, Japan, at the southern end of the Kurile arc (Fig. 1-a). Akan caldera (1.7–0.2 Ma), the oldest, is characterized by a rectangular structure 24 km × 13 km in extent. Tephra layers around the volcano record the long, complex history of the caldera-forming eruptions, but their detailed stratigraphy and chronology have been unclear owing to the number and similarity of the pyroclastic rocks as well as the presence of similar products of adjacent calderas. Because the chronostratigraphy of

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http://dx.doi.org/10.1016/j.quaint.2015.07.058
1040-6182/

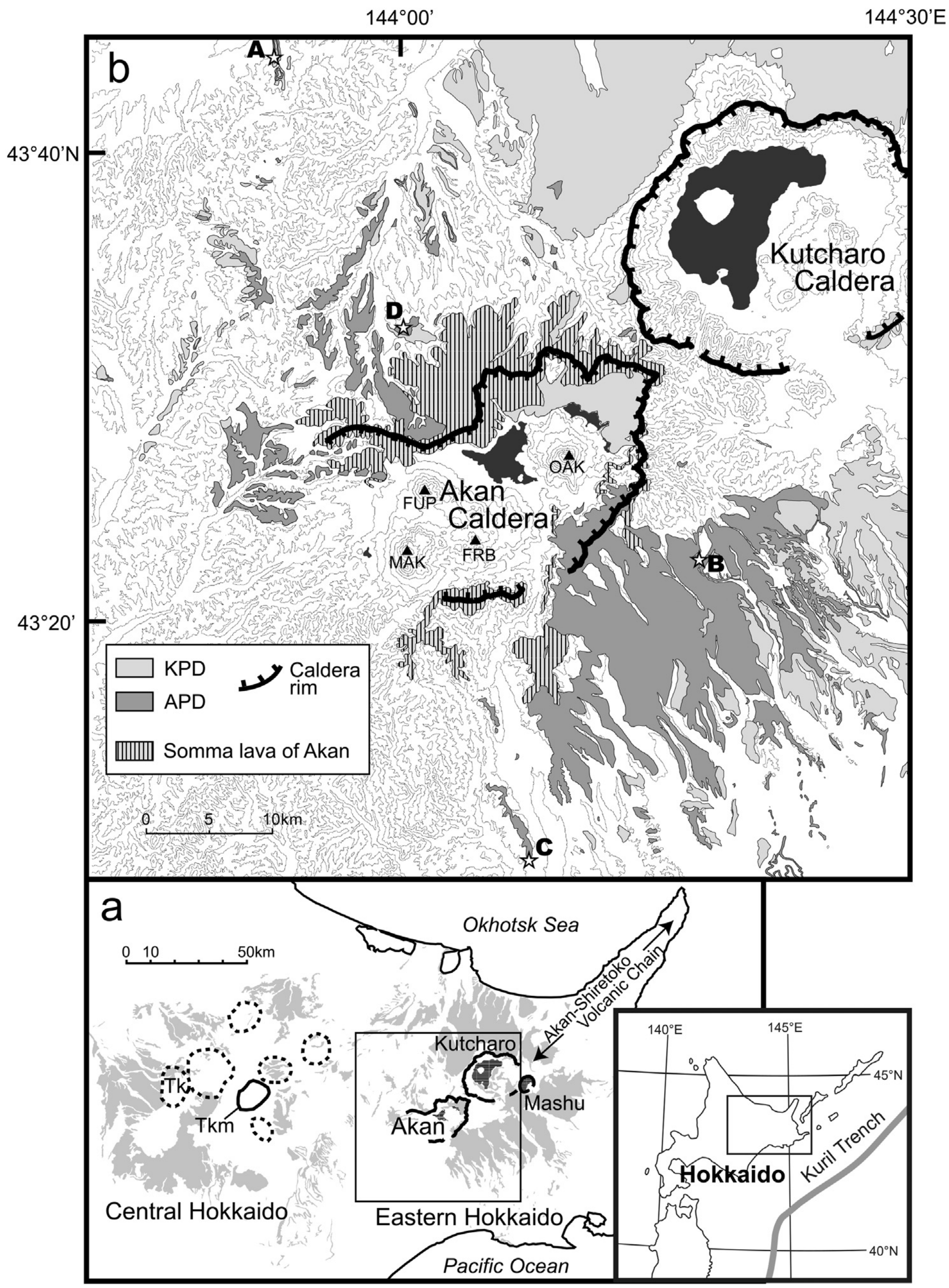


**Fig. 1.** (a) Location map showing calderas (solid and dashed lines) and Quaternary large-scale pyroclastic flow deposits (shaded areas) in central and eastern Hokkaido, Japan. Geological information is based on Geological Survey of Japan (2006) and Hasegawa and Nakagawa (2007). Dashed circles indicate inferred calderas based on gravity evidence by Yamamoto (2004). Tkm – Tokachimitsumata Caldera (Ishii et al., 2008). Tk – Tokachi caldera (Nakano et al., 2013). (b) Map of the study area showing Akan and Kutcharo caldera rims (revised from Hasegawa and Nakagawa, 2007) and pyroclastic deposits of Akan (APD) and Kutcharo calderas (KPD). Caldera lakes are shown in black. Stars indicate localities of Figs. 3 and 6. Triangles represent summits of post-caldera volcanoes: OAK – Mt. O-Akan, MAK – Mt. Me-Akan, FUP – Mt. Fuppushi, FRB – Mt. Furebetsu.

Akan caldera is essential for understanding the history of the caldera cluster, we have carried out geological and volcanological surveys of the tephra layers around Akan caldera. This paper reviews the results of previous studies (e.g. Hasegawa and Nakagawa, 2007; Hasegawa et al., 2008, 2011b, 2012) and the insights they give into the complex eruption history of Akan.

Our petrological data include phenocryst assemblages, glass chemistry, and whole-rock chemistry of juvenile materials in the pyroclastic deposits. These data support accurate correlations of tephra layers, enabling us to conduct tephrostratigraphic and tephrochronologic analyses with high resolution. We have classified the pyroclastic materials into a sequence of petrologically coherent tephra layers termed “eruptive groups”. The grouping of successive tephra layers is useful for researching caldera clusters, which often generate numerous and resemble pyroclastic deposits on the periphery for long periods. In addition, we have made new estimates of the magma discharge rate of Akan caldera on the basis of supplemental data on the volume and age of each tephra. By