Chronology of Daisen Plinian Tepharas Based on Correlation to the Lake Biwa Borehole Tephra Samples Using LA-ICP-MS Mineral Analysis

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Chronology of Daisen Plinian Tephras Based on Correlation to the Lake Biwa Borehole Tephra Samples Using LA-ICP-MS Mineral Analysis

Ichiro Saji
Graduate School of Natural Science and Technology, Kanazawa University, Kanazawa City, Ishikawa, 920-1192, JAPAN
Jun-ichi Kimura
Department of Geoscience, Shimane University, Matue City, Shimane, 690-8504, JAPAN
Syusaku Yoshikawa
Department of Geoscience, Osaka City University, Osaka, 558-8585, JAPAN

Abstract- Eighteen proximal tephras from Daisen volcano and tephras in a Lake Biwa drillcore are correlated on the basis of their mineral assemblages and EPMA and LA-ICPMS analyses of hornblende phenocrysts. The results of this correlation show intermittent plinian eruptions have occurred at Daisen since the middle Pleistocene, at an average interval of about 100 kys.

I. Introduction

Tephras consisting mainly of plinian pumice falls were erupted from Mt. Daisen during the Middle and Late Pleistocene. At least 35 tephras have been recognized. These have fission track and carbon-14 ages between 350 ka and 17 ka. However, despite much effort, the ages of each tephra are not precisely known, due to their relative youth. Takashima-Oki project drilling was performed in Lake Biwa, which is located some 230 km east of Daisen volcano (Fig.1). The drill cores obtained consist of continuously-deposited fine-grained clayey sediments containing a number of interbedded tephra layers. Detailed chronology of the drill cores has been established using orbitally-tuned ages based on climatic indicators, such as pollen fossils. The age range of the core examined here spans the interval between 350 ka and the present day. In this core, 29 tephra layers, which potentially originated from Daisen volcano have been identified based on mineral assemblages and glass chemistry. If proximal Daisen tephras can be correlated with those in Lake Biwa section, eruption ages can then be determined precisely. Unfortunately, glass shards in proximal Daisen tephras are altered, and are not suitable for analysis. To characterize the tephras petrographically and geochemically, we conducted mineral assemblage analysis, EPMA (electron probe micro-analyzer) major element analysis of phenocrystic minerals, and LA-ICP-MS (laser-ablation inductively coupled plasma mass spectrometry) trace element analysis of hornblende phenocrysts in tephras from both Daisen and the Lake Biwa cores. We here present the results of our correlation, and give an overview of the ages and frequency of volcanic eruptions at Daisen over the last 350 kyrs.

II. Locality and samples

A. Proximal Daisen tephra

Tephra samples were collected from six sections on the eastern and western flanks of Daisen volcano. Columnar sections of the sample sites are shown in Fig.2. Daisen tephras consists mainly of plinian pumice falls and volcanic ash falls. Biotite, hornblende, pyroxenes, Fe-Ti oxides and plagioclase occur as phenocrysts in the tephras. At least 19 plinian tephras are observed in the middle to late Pleistocene aeolian deposits. These tephras have fission track and carbon-14 ages ranging between 350 ka and 17 ka (Kimura et al., 1999). Samples for analysis were taken from plinian pumice beds.

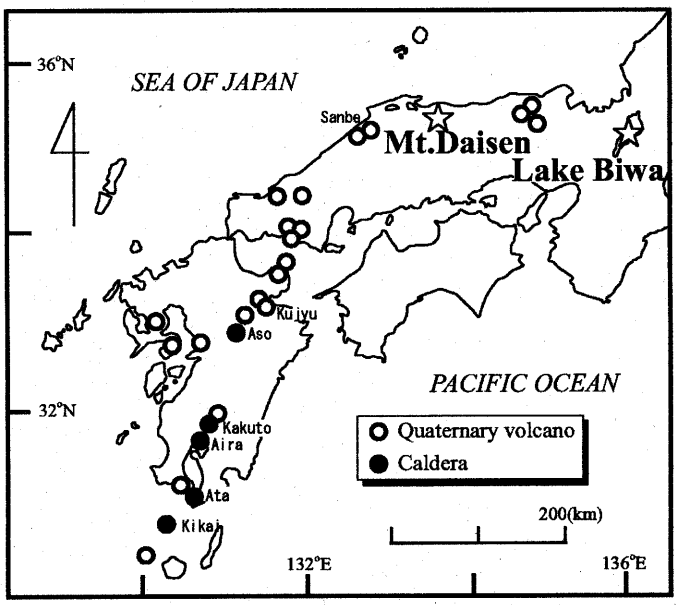

Fig. 1 Locality map of the study area and distribution of Quaternary volcanoes and calderas in Southwest Japan

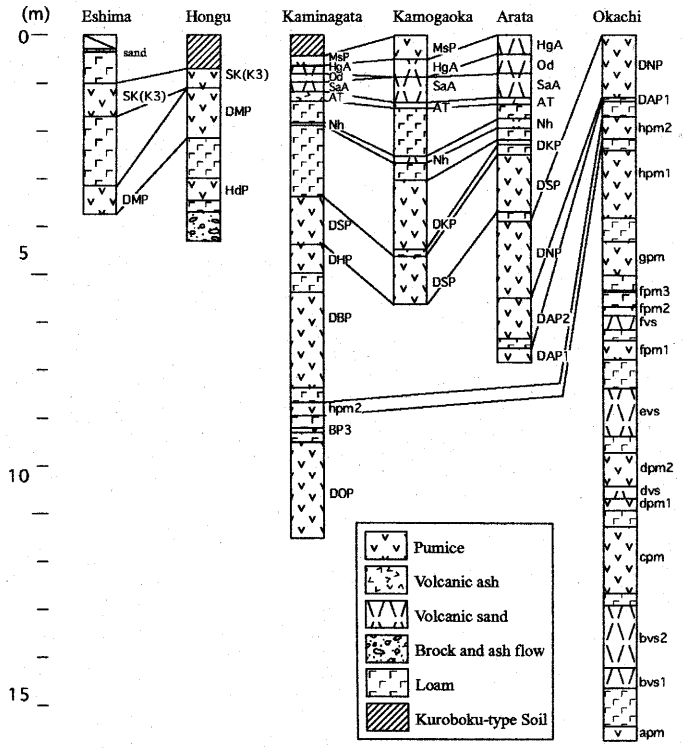

Fig. 2 Columnar sections of the proximal Daisen tephras.

B. Lake Biwa borehole

The Takashima-Oki drilling in Lake Biwa was carried out in 1986. The cores obtained were continuous sections of fine clay sediment containing numerous interbedded tephra layers. Petrographic features of the tephras in the core samples were described by Yoshikawa et al. (1991 and 1993, Fig.3). As no Quaternary volcanoes occur near Lake Biwa, all the tephras are though to be of wide spread origin, being derived from volcanoes more than 200km distant from Lake Biwa. Based on mineral assemblages and glass chemistry (Nagahashi, 2000), 29 of the tephra layers in the Biwa core potentially originated from Daisen.

III. Analytical procedures and results

Refractive indices of glass shards and phenocrystic minerals and EPMA major element analysis of volcanic glass shards have proved to be useful methods for tephra correlation. Unfortunately, glass shards in proximal Daisen tephras cannot be analysed, due to pervasive weathering. To improve reliability of possible correlations, we conducted EPMA analysis and LA-ICP-MS analysis of hornblende phenocrysts contained in tephras from the Daisen and the Lake Biwa sections. The EPMA results are discouraging, as no significant differences exist in the major element compositions of hornblende phenocrysts between tephras. However, this at least shows that the

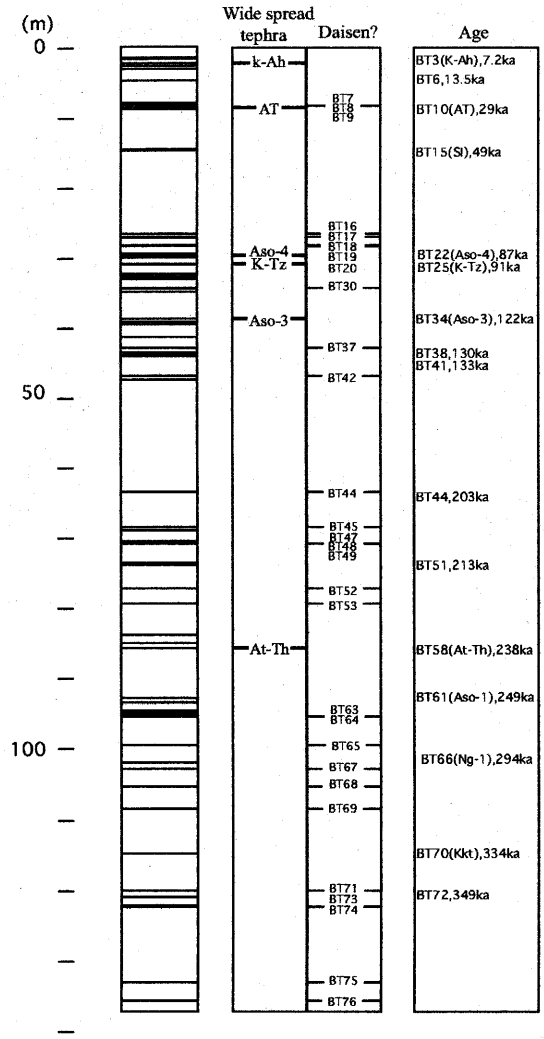

Fig. 3 Lake Biwa drillcore section. Left: stratigraphic positions of tephra layers, Middle: widespread tephras contained in both Daisen and Lake Biwa sections and tephras potentially originated from Daisen, Right: ages of tephras.

tephras examined are very much alike, and that the Daisen and Biwa tephras share common characteristics. This conclusion is consistent with that from EPMA analyses of Lake Biwa glass shards (Nagahashi et al., 2000). To further characterize the hornblendes, trace element and rare earth element (REE) concentrations were determined using a laser ablation inductively coupled plasma mass spectrometer (LA-ICP-MS) at Shimane University. Analytical procedures followed Kimura et al. (2000). Figure 4a shows the range of REE compositions of hornblendes from Daisen tephras, along with three typical REE patterns. Hornblendes with higher REE contents always have negative Eu anomalies, and the higher the REE contents, the more pronounced the anomalies become. In contrast, REE-poor hornblendes do not have Eu anomalies. Results for the Lake Biwa samples lie well within the range of the Daisen samples, and their REE patterns have similar characteristics. These similarities in

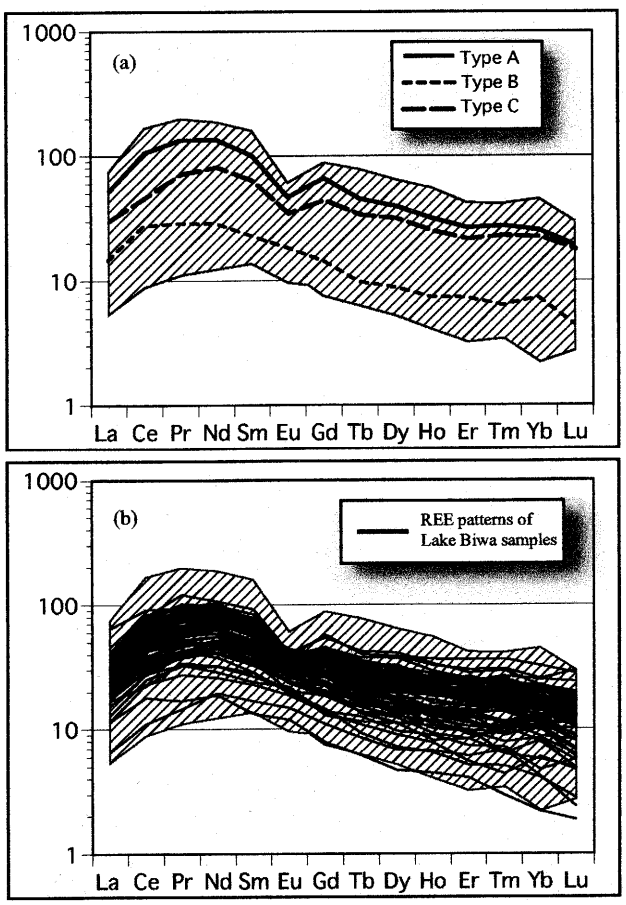

Fig. 4 REE patterns of hornblende phenocrysts contained in Daisen plinian tephras.

hornblende REE compositions and patterns from Daisen and Lake Biwa further support the correlation previously proposed by Nagahashi et al. (2000). During our work we found that one Lake Biwa tephra sample showed a completely flat REE pattern with a very strong negative Eu anomaly. This tephra is precluded as a potential correlative of the Daisen tephras, and is thought to have originated from volcanoes in Kyushu.

IV. Correlation of Lake Biwa tephras to Daisen volcano

Although the major element and REE compositions of Daisen hornblendes are similar between tephras, occurrence of cummingtonite phenocrysts and Ba contents of hornblende are useful parameters for further identification. Tephras in the middle of the Lake Biwa core contain cummingtonite phenocrysts, as do those in a similar position in the Daisen section (Fig.5). In both the Biwa and Daisen sections, hornblende phenocrysts in the tephras above the cummingtonite horizon have higher Ba contents (〉 50 ppm) than those within it. The uppermost tephras in the Daisen and Biwa sections also contain

TABLE 1 Table showing tephra correlation between Daisen and Lake Biwa sections with ages.(*Estimated by loam thickness)

Daisen	Lake-Biwa	Rank of possibility	Age(ka)
MsP	BT7	A	26.1
HgA	BT8	A	27.9
SaA	BT9	A	28.0
Nh			*59.0
DKP	BT16	A	79.6
DSP	BT17	C	80.2
DNP	BT18	B	80.9
DAP2	BT19	A	83.5
DAP1	BT20	C	83.8
DHP	BT30	C	99.5
DMP			99.5～122
DBP	BT42	C	*143.1
hpm2	BT42	C	*175.8
hpm1	BT44	A	203
BP3	BT45	C	208
HdP			208～209.9
DOP	BT47 ,BT48	A	209.9
gpm	BT49	A	210
fpm3			*215
fpm2			*220.1
fvs			*220.1
fpm1	BT53	A	223.8
evs			*281.7
dpm2	BT69	B	314.5
dvs			*314.5
dpm1			*314.5
cpm	BT73	B	352
bvs2			*371.2
bvs1			*371.2
apm			*412.3

cummingtonite. Based on this broad zonal correlation and further examination of the REE compositions, one-to-one correlation of the Daisen and Lake Biwa tephras is proposed as shown in Fig.5. Due to the strong similarities between tephras at different eruptions from Daisen, characterization and identification of individual tephras from geochemical data alone is still difficult. However, the almost one-to-one correlation of tephras between the two areas supports our conclusions.

TABLE 1 shows the results of our correlation. Using this correlation, tephra ages determined at Lake Biwa can then be used for volcanological investigations. We thus examined the frequency of explosive volcanism at Daisen over the past 350 ky. Explosive eruptions occurred at about 30 ka, and between 70-100 ka, 200-230 ka, 280-320 ka, and 350-370 ka. This suggests that although explosive volcanism occurred intermittently, activity was repeated at 100 ky intervals. This information is important for long-term prediction of eruptions at such volcanic centers.

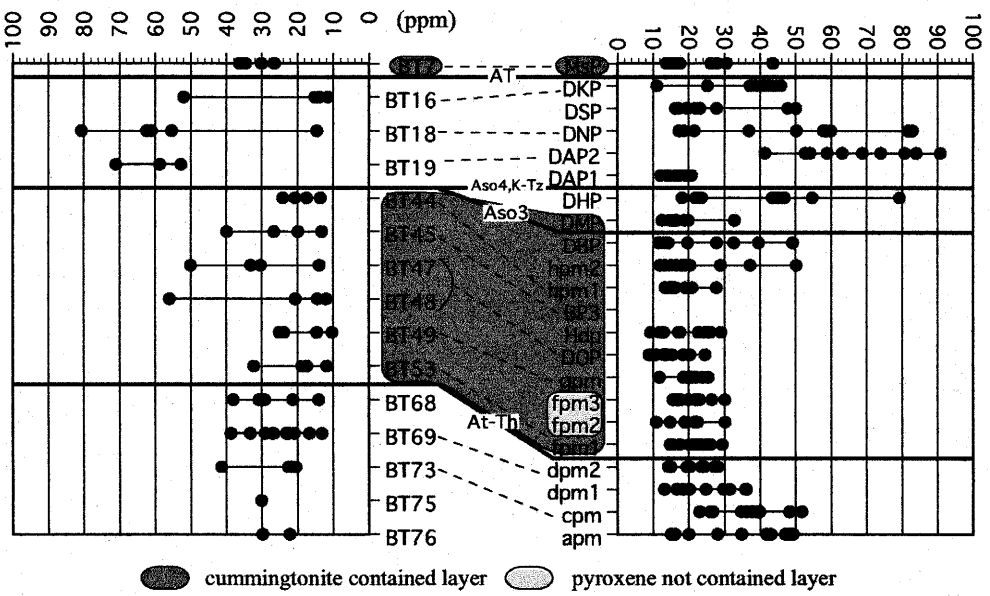

Fig. 5 Correlation of tephras between Daisen and Lake Biwa sections. The correlation is based on mineral assembrages and Ba cotents in hornblende phenocrysts.

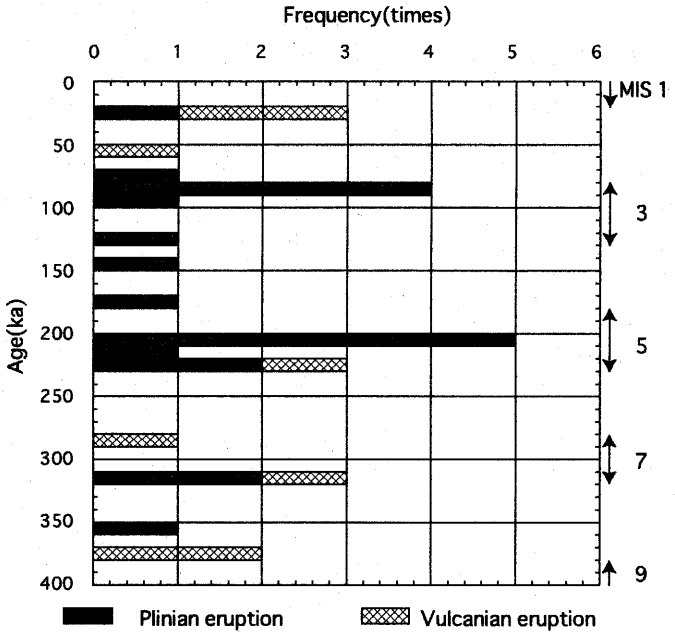

Fig. 6 Frequency of explosive volcanism

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