Magma evolution during the Aso-3 caldera-forming eruption cycle deduced from the chemistry of plagioclase phenocrysts

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Title

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Introduction

Caldera-forming eruptions are the most destructive type of volcanic activity and exert a great influence on the Earth’ s surface. Therefore, the underlying magmatic mechanism leading to caldera-forming eruptions is of fundamental importance in volcanology. The Aso volcano is the largest (18×25 km in diameter) caldera in the southwestern Japan Island Arc and formed through four large eruption cycles. In this study, we have investigated the evolution of magmas that erupted during the second youngest cycle among the four cycles, the Aso-3 cycle at 123 ka. It ejected >150 km^3 of pyroclasts that are divided into the following four units in stratigraphic ascending order: 3W, a plinian pumice fall deposit; 3A, a pumice flow deposit containing dominantly aphyric pumice and glassy ash; 3B, a scoria flow deposit characterized by abundant aphyric scoria; and 3C, a scoria flow deposit consisting mainly of porphyritic scoria and glassy ash matrix.

On the basis of major and trace element compositions and Sr-Nd-Pb isotope ratios of whole rocks as well as phenocrysts, Kaneko et al. (2015) argued that the pre-eruptive magma chamber was chemically stratified from a mafic lower part to a felsic upper part. The previous study further estimated water contents in the melts using the hygrometer based on plagioclase-melt partitioning of anorthite-albite components (Lange et al., 2009), but the estimates have large uncertainty. Here we determined hydrogen contents of plagioclase phenocrysts. By combining the hydrogen contents with major and trace element compositions of the plagioclase phenocrysts, this study aims to better understand pre-eruptive magma evolution and water behavior of the Aso-3 cycle.

Methods

Plagioclase as well as pyroxene and oxide mineral phenocrysts were separated from pumices of 3W, an obsidian clast of 3A, a welded clast of 3B, and a pumice clast of 3C. Major and trace elements in phenocrysts were quantified by electron probe microanalyzer (EPMA) and laser ablation-inductively

coupled plasma-mass spectrometry (LA-ICP-MS), respectively. In LA-ICP-MS analysis, Ca contents measured by EPMA were used for internal standard normalization. OH contents in plagioclase phenocrysts were determined by secondary ion mass spectrometry (SIMS).

Results

Anorthite contents (#An) of plagioclase phenocrysts are variable even in individual units, but show the systematic increase in ascending order, consistent with the results of Kaneko et al. (2015). REE patterns of plagioclase and pyroxene show positive and negative Eu anomalies, respectively. Plagioclase Ce content degreases as #An increases (Figure 1). On the other hand, OH contents in plagioclase phenocrysts are significantly higher in 3W (˜250 ppm) as compared to the others (<50 ppm) (Figure 2).

Discussion

OH contents in a plagioclase phenocryst of 3W are significantly higher than those of 3A-C, nevertheless Ce contents of plagioclase are not significantly different between 3W and 3A. Considering that the partition coefficients of Ce between anhydrous major minerals and melt are similar to those of OH, this finding suggests that H_2O was lost from the melt through gas exsolution or fractional crystallization of hydrous minerals. Alternatively, given the fast diffusion of hydrogen relative to Ce in plagioclase, it may be attributed to secondary loss of hydrogen from plagioclase phenocrysts of 3A-C during welding processes. From the observation of thin sections of 3W and 3A, however, microlite was rarely observed, suggesting that the secondary thermal effects would be restricted for both 3W and 3A. Furthermore, little hydrous phenocrysts have been observed from ejecta of the Aso-3 cycle. Therefore, the results of this study suggest that gas exsolution and degassing occurred between the eruptions of 3W and 3A.

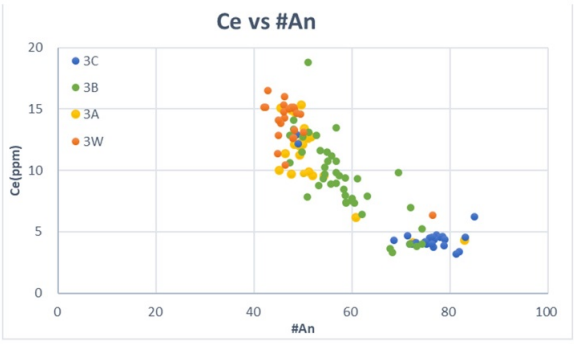

Figure 1 Ce vs anorthite contents for plagioclase phenocrysts

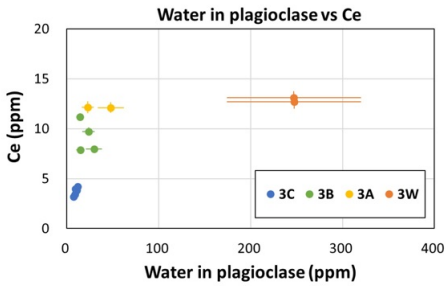

Figure 2 Water vs Ce contents for plagioclase phenocrysts (The water contents were calculated from hydrogen concentrations in the phenocrysts)

