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Magmatic processes for somma-lavas from Usu Volcano

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Usu volcano formed mainly by eruption of basaltic and andesitic magmas (somma lavas) at 10-20 ka, followed by intermittent eruptions of felsic magmas after A.D. 1663. Magmatic processes for the historical felsic magmas have been intensively examined by e.g. Tomiya and Takahashi (1995) and Matsumoto and Nakagawa (2010), while studies on the somma lavas have been limited. Ohba (1964) and Fujimaki (1986) suggested that the geochemical variation of the somma lavas can be explained principally by fractional crystallization. However, the number of samples which they examined were limited, and the processes were not well constrained by high-quality geochemical data.

In this study, we have performed a petrological and geochemical analysis on samples from the somma lavas to understand magmatic processes. Whole-rock major element compositions were determined for ~90 samples, and trace element and Pb isotopic data were also obtained for 40 samples, as well as lower crustal xenoliths from Ichinomegata volcano. Whole-rock SiO_2 content of the lavas ranges 49.6-54.9 wt.%, and they are divided into basaltic samples (SiO_2<52.0 wt.%) and andesitic samples (SiO_2>52.4 wt.%). The andesitic samples can further be subdivided into high-P_2O_5 (0.13-0.19 wt.%) type and low-P_2O_5 (0.08-0.13 wt.%) type. The phenocryst assemblage of the basalt is olivine + cpx + opx + pl, and that of the andesite is cpx + opx + pl. The phenocryst content is variable, ranging from ~10 to ~35%. P2O5 contents of the somma lavas correlate negatively with $^{206}Pb/^{204}Pb$ ratios, and the ratio decreases from 18.63 to 18.53 with increasing P2O5 content. The lower crustal xenoliths are significantly lower in $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios than those of the somma lavas.

We have performed a principal component analysis (PCA) for the whole-rock major element data of the lavas to understand what processes were involved in the evolution of the somma lavas. The analysis shows that some elements including SiO_2 and P_2O_5 are important in PC1, while two elements, Al_2O_3 and CaO, play a dominant role in PC2. The contribution of PC1 and PC2 is 58% and 24%, respectively, and these two components sum up to >80% of the total contribution. We found that PC1 shows a good correlation with Pb isotopic ratios and La/Yb ratios, and PC2 correlates positively with the modal abundance of plagioclase phenocryst. These results suggest that PC1 reflects a mixing process between a less radiogenic component and a more radiogenic component, whereas PC2 reflects separation and/or accumulation processes of plagioclase phenocrysts.

The high-PC1 end-member component is likely to be a less differentiated basaltic magma because of the low P_2O_5 feature of the component. On the other hand, the low-PC1 end-member component has a differentiated feature (i.e. high P_2O_5), but it has less radiogenic Pb isotopic composition than the somma lavas. Therefore, it is plausible that the low-PC1 component would be partial melt of the lower crust. This scenario is supported by the observation that the lead isotopic data of the lower crustal xenoliths plot mostly on the linear extension of the trend formed by the lava data in a $^{207}Pb/^{204}Pb$-$^{206}Pb/^{204}Pb$ and a $^{208}Pb/^{204}Pb$-$^{206}Pb/^{204}Pb$ compositional space. For these considerations, we conclude that the somma magma evolved through mixing of a less differentiated basalt magma and partial melt of the lower crust, followed by differentiation and re-distribution of plagioclase phenocrysts in a crustal magma reservoir.

Keywords: Usu Volcano, Somma lava, Magma process, Lower Crust