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Geochemical constraints on magma genesis of silicic and mafic magmas in large pyroclastic eruption cycles at Aso volcano

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Activities of Aso volcano are characterized by four large pyroclastic eruption cycles (LPEC) and many minor eruptions between them after 300 ka. In order to understand magma genesis of Aso volcano, we investigated petrological and geochemical features of magmas of three large eruption cycles between 150 ka and 90 ka, when three LPECs (Aso-2, 3, and 4) occurred with time interval of 20-30 ky.

In each LPEC, the magmas erupted from a layered magma chamber with silicic magmas overlying denser mafic magmas. Important geochemical features of silicic and mafic magmas are summarized as follows.

(1) Whole-rock Ni content of a silicic magma is equal to or larger than that of a mafic magma in each large eruption cycle.

(2) Silicic and mafic magmas in each LPEC have identical Sr isotope ratios ($^{87}Sr/^{86}Sr$) in whole-rock and groundmass compositions.

(3) Magmas of the three LPECs have different Sr isotope ratios in whole-rock and groundmass compositions (representative Sr isotope ratios are 0.70411, 0.70408, and 0.70410 in Aso-2, 3, and 4, respectively).

(4) Sr isotope ratios of plagioclase phenocrysts except plagioclase phenocrysts with more than 80 in An content are identical to that of the magmas that contain them. The plagioclase phenocrysts with high An content in the mafic magmas of Aso-3 and 4 have lower Sr isotope ratios than the mafic magmas containing them (0.70400-0.70405).

The feature (3) that Sr isotope ratios of the magmas are different between the three LPECs indicates that the magmas of each LPEC were produced by distinct processes from magma generations of the other LPECs. The feature (2) that the Sr isotope ratios of the silicic and mafic magmas in each LPEC are identical and the feature (3) that the plagioclase phenocrysts basically have identical Sr isotope ratio to the magmas containing them strongly suggest that the silicic and mafic magmas of each LPEC are generated from a same source material. On the other hand, the feature (1) on Ni content indicates the silicic magma was not generated by fractionation of the mafic magma because Ni is compatible element with 3-6 in bulk distribution coefficient.

We focus on the petrogenesis of the silicic and mafic magmas that are generated from a same source material but do not have parent-daughter relationship on fractionation. We propose the following hypothesis explaining this petrogenesis qualitatively. The source material is a gabbro. The mafic magma was produced by fractional crystallization of segregated melt from the partially-molten gabbro with high degree of partial melting. The silicic magma was generated as segregated melt from the same gabbro with low degree of partial melting that was not fractionated after segregation. Partial melt generated from the source gabbro with high degree of melting has larger compatible element content than that with lower degree of melting at that time. When the high-degree partial melt segregates and fractionates, however, its compatible element content rapidly decreases with fractional crystallization. Therefore, the mafic magma can have lower compatible element content than the silicic magma.

Magma generation by partial melting of the gabbro probably occurred in a lower crust; hot magmas from mantle rose and heated up the lower crust. In this case, the difference of the degrees of partial melting between the mafic and silicic magmas can be understood as a natural consequence as follows. The mafic magma is produced near the hot mantle magma, whereas the silicic magma is generated from the gabbro far from the mantle magma that was heated up conductively. This model should be investigated quantitatively with physical processes of transportation of the magmas and some other petrological features in future work.