Long-term evolution of magma plumbing system in Aso volcano: petrological evolution of the silicic magmas

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Activities of Aso volcano are characterized by four large pyroclastic eruption cycles and many minor eruptions between them after 300 ka. To understand petrogenesis and evolution of the silicic magmas of Aso volcano, we investigated petrological features of magmas erupting between 150 ka and 90 ka, when three large eruptions (Aso-2, 3, and 4) occurred with interval of 20-30 ky.

Important petrological features of magmas are summarized as follows.

(1)In each large eruption cycle, the magmas erupted from a layered magma chamber with silicic magmas overlying denser mafic magmas. In the minor eruptions, silicic magmas were dominant. Petrological features of silicic magmas are similar in both the major and minor eruptions.

(2)On the silicic magmas, magmatic temperatures, water contents of the melt, redox state, and relative contents of K2O to SiO2 of the melts (relative K content) correlated throughout all the major and minor eruptions. A hotter silicic magma has higher water content, higher oxidized state, and higher relative K content. The magmatic temperature tends to decreases with time, keeping correlations with the other three values.

(3)In each large eruption cycle, the water content of the silicic magma is equal to or less than that of the mafic magma.

Feature (3) indicates that generation of the silicic magma cannot be explained only by fractional crystallization of the mafic magma. This fact and the formations of layered magma chambers imply that the silicic magmas were produced by melting processes of materials overlying the mafic magma. The materials may be (partially molten) surrounding crusts or solidifying magma in the chamber. Petrological features of the silicic magmas of the minor eruptions are similar to those of the large eruptions. This may indicate that all the silicic magmas were generated by the same processes (melting).

The physical model by Koyaguchi & Kaneko (2000) suggests that temperatures of magmas generated by melting are close to 'the effective fusion temperatures (EFT)'of the melted material. The EFT is the temperature at which behavior of a partially-molten material changes from solid to liquid macroscopically. The EFT is governed by melt fraction of the partially-molten material (assuming that the melt fraction at the EFT is 0.5 here) and hence the material composition.

Hereafter, we assume two aspects, one is that the silicic magmas are generated by melting processes and the other that the magmatic temperatures are equal to the EFTs of the melted materials, and discuss petrogenesis of the silicic magmas of Aso volcano.

The fact that a colder magma has larger water content in its melt is interpreted as a natural consequence. A partially-molten material at its EFT (0.5 melt fraction) has negligible small water content in its solid phases so that the bulk water content of the material is a half of the melt water content; the material with larger water content in its melt has larger bulk water content. Therefore, the material has lower EFT and generates a colder silicic magma. From observed results and phase relationships of rock materials, the original materials of the silicic magmas are tonalitic.

Next, relative K contents are discussed. When a tonalitic rock partially melts, both larger bulk water content and higher oxidized state cause relative K content of the partial melt to be smaller, because they increase magnetite to silicate minerals in the solid phases of the partially molten rock. Calculation results by MELTS using the observed waters content and redox states quantitatively explain the observed relative K contents of the silicic magmas.

As a result, when we assume the above two aspects, it is suggested that magmatic temperatures and relative K contents of the silicic melts of Aso-2 to 4 are governed by bulk water contents and redox states of the original materials of the silicic magmas, which tend to increase in bulk water content and degree of oxidization with time.