Magma degassing of Satsuma-Iwojima volcano: Constraints from melt inclusions, petrology and volcanic gases.

Genji SAITO

Geological Survey of Japan, AIST, Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan.

E-mail: saito-g@aist.go.jp

In their trip to the surface of the Earth, magmatic gases usually stay at “magma chamber” hotels. Satsuma-Iwojima volcano, Japan, is one of the best fields to study volatile evolution with mafic-felsic magma interaction in the magma chamber and current degassing process because of its contemporaneous bimodal activity of basalt and rhyolite in a small area and its intense and long-term passive degassing activity. The maximum temperature of the volcanic gases discharged from the summit crater of Iwodake has been almost constant for the past 10 years at about 900°C (Shinohara et al., 2002). Sulfur dioxide flux measured by COSPEC is almost constant with an average of 550 t/d since 1975 (Kazahaya et al., 2002). Most of the volatile components in the volcanic gases are believed to be of magmatic origin (e.g., Shinohara et al., 1993). Intense fumarolic activity at the summit crater has probably continued for more than 800 years (Kamada, 1964).

Petrological studies on basalts, rhyolites and mafic inclusions in the rhyolites from post-caldera eruptions suggest there is a stratified magma chamber beneath the volcano, which consists of a lower basaltic layer, upper rhyolitic layer and an episodically-present, thin middle-andesitic layer. Chemical analyses of 30 melt inclusions in plagioclase and pyroxene phenocrysts from the basaltic and rhyolitic eruptions showed large variations in volatile concentrations (H_2O, CO_2, S and Cl) of the melts (Fig. 1). (1) Water concentration of rhyolitic melts decreases with time; 3-4.6 wt.% at the time of latest caldera-forming eruption (ca. 7300 y.B.P.) of Takeshima pyroclastic flow deposit, 3 wt.% for small pyroclastic flow (ca. 500 y. B.P.) of Iwodake, and 0.7-1.4 wt.% for Showa-Iwojima rhyolitic lava eruption in 1934. (2) Rhyolitic melts of the Takeshima and Iwodake eruptions contained CO_2 of less than 40 ppm, while the Showa-Iwojima melt has higher CO_2 concentration of up to 140 ppm. (3) Water and CO_2 concentrations of basaltic to andesitic melt of Inamuradake, a post-caldera basaltic scoria cone (ca. 3000 y.B.P.), are 1.2-2.8 wt.% and ≤290 ppm, respectively. This suggests the following volatile evolution processes in the magma chamber: a) a gas-saturated condition due to pressure variation in the rhyolitic magma chamber just before the caldera-forming

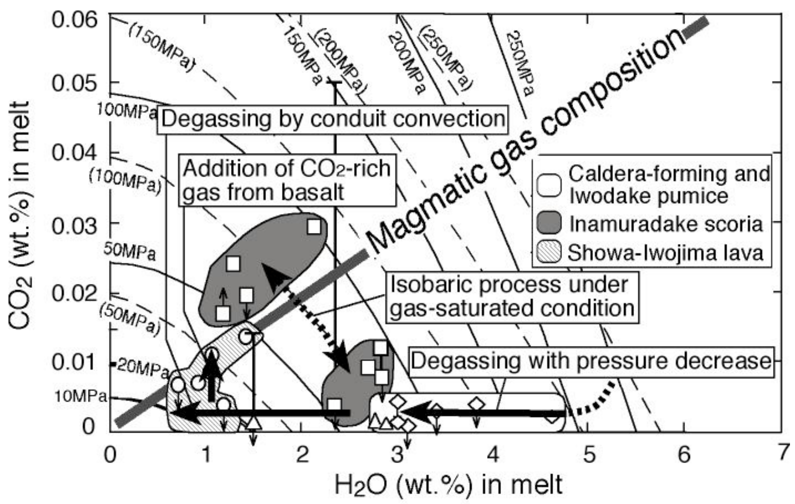

Fig. 1. Water nand CO_2 concentrations of melt inclusions of Satsuma-Iwojima volcano.

eruption; b) low pressure degassing of the rhyolitic magma chamber by magma convection in the conduit during the active degassing period in the post-caldera stage up to the present; and c) the addition of CO_2-rich volatile from the underlying basaltic magma in the stratified magma chamber to the upper gas-undersaturated (degassed) rhyolitic magma (Fig. 2).

Current degassing process of the magma chamber could be estimated by combining volatile concentrations of the melt inclusions with chemical composition and flux of the high temperature volcanic gas has been discharged from the summit crater of Iwodake. Volatile composition of the Showa-Iwojima rhyolitic melt agrees with that of the magmatic gas (Fig. 1), suggesting that source of the magmatic gas is a magma with similar composition with that of Showa-Iwojima magma, and that magma-gas separation occurs at a very shallow level. The mass rate of magma degassing is estimated at 8-13 m^3/s using volatile concentration (H_2O=1 wt.%, CO_2=100 ppm, S=110 ppm) of the Showa-Iwojima rhyolitic melt and the flux of the magmatic gas (H_2O=16000 t/d, CO_2=150 t/d, S=550 t/d; Kazahaya et al., 2002). Magma convection in a conduit, driven by the density difference between higher density degassed and lower density non-degassed magmas (Kazahaya et al., 1994; Stevenson and Blake, 1998), explains the high emission rate of magmatic volatiles released at shallow depth from the magma chamber. The degassed rhyolitic magma descends to the bottom of the rhyolitic magma chamber and is supplied with the CO_2-rich volatile components from the underlying basaltic magma, implying that the upper rhyolitic magma works as “transporters” of volatile components from the underlying basaltic magma to the surface. Assuming that similar degassing continued for 500 years, the total volcanic gas flux requires degassing of 50-80 km^3 of basaltic magma. This estimate suggests that mafic magma underlying felsic magma contribute excess degassing of the volcano not only during eruptions (e.g., 1991 Mount Pinatubo eruption), but also during passive degassing activity.

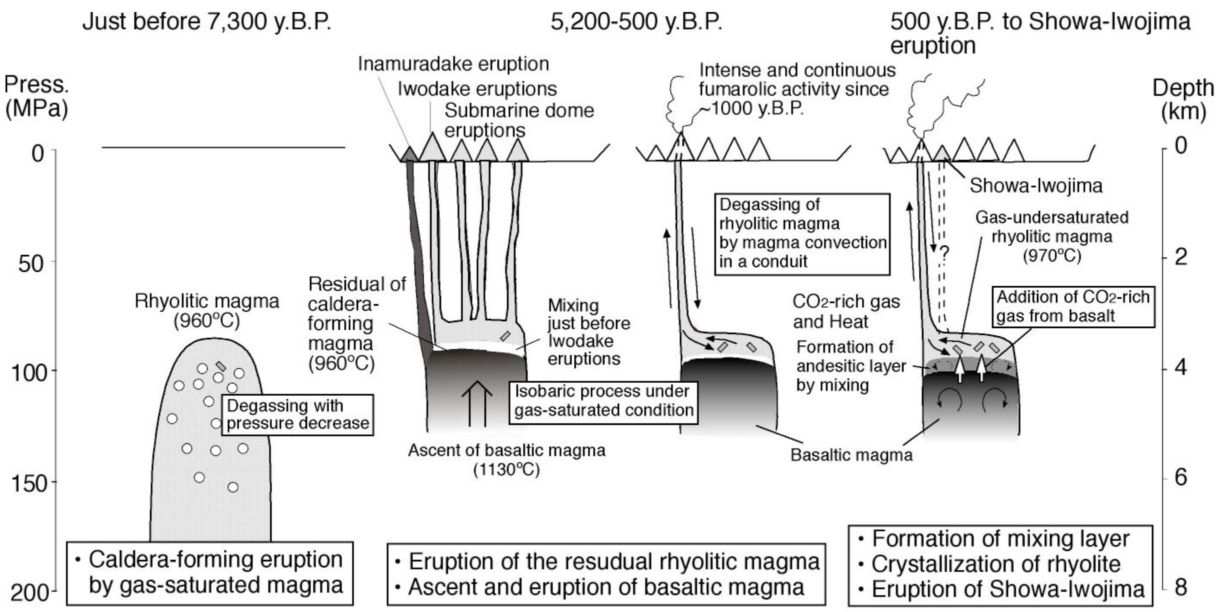

Fig. 2. Schematic illustration of volatile evolution and mafic-silicic magma interaction in the magma chamber of Satsuma-Iwojima volcano.