

Pre-eruptive process of the 1991-1995 eruption at Unzen volcano, Japan : constraints from amphibole phenocrysts

*Kurumi Iwahashi¹, Hidemi Ishibashi², Natsumi Hokanishi¹, ATSUSHI YASUDA¹

1. Earthquake Research Institute, University of Tokyo, 2. Shizuoka University

1. Introduction

Unzen volcano is one of the typical arc volcanoes located in NW Kyushu, Japan. The latest eruption of the volcano occurred at 1991-95. This eruption is characterized by continuous growth of dacitic lava domes and pyroclastic flows caused by collapse of the lava domes. During the eruption, two vulcanian eruptions were recognized. Previous studies proposed that magma mixing between nearly aphyric, mafic and crystal-rich, silicic end-members occurred in the magma chamber at the depth of ~10km (e.g., Sato et al., 1999).

The 1991-95 dacites contain amphibole phenocrysts. Recent studies demonstrated that igneous amphiboles are powerful tools to constrain pre-eruptive magmatic conditions (e.g., Ridolfi and Renzulli, 2012; Putirka, 2016). For example, empirical equations relating temperature and SiO₂ content of co-existing melt with amphibole composition were proposed by Putirka (2016). By using these equations, we can constrain physicochemical conditions of melts in which individual phenocryst crystallized. Therefore, analyses of amphiboles may offer useful information for understanding pre-eruptive magmatic processes of the Unzen 1991-1995 eruption.

In this study, we aimed to reevaluate pre-eruptive processes of 1991-1995 eruption in terms of amphibole mineralogy. First, we analyzed amphibole phenocrysts in the 1991-95 dacites. In addition, we analyzed amphiboles, plagioclases, and interstitial glasses in crystal clots. Then, we estimate temperatures and SiO₂ contents of melts in equilibrium with amphiboles.

2. Methods

We used 6 dacitic samples erupted at different times during the 1991-95 eruption. All of these samples contain amphibole phenocrysts, and two of these samples contain crystal clots composed of amphiboles, plagioclases, Fe-Ti oxides and interstitial glass. The major element compositions of amphibole phenocrysts and constituent minerals and glasses in crystal clots were measured by using EPMA at ERI, University of Tokyo. In addition, temperature and SiO₂ content conditions of melts coexisted with amphiboles were estimated from amphibole compositions by using the empirical equations of Putirka (2016).

3. Results

Amphibole phenocrysts are classified into magnesiohornblende and tchermakite based on their compositions. There is an apparent compositional gap between these two clusters. All amphiboles in

crystal clots are magnesiohornblende. Crystallization temperatures are estimated to be $\sim 750\text{-}800^\circ\text{C}$ and $\sim 870\text{-}950^\circ\text{C}$ for magnesiohornblendes and tchermakites, respectively. Amphiboles in crystal clots reveal temperatures of $\sim 750\text{-}800^\circ\text{C}$. Estimated SiO_2 contents of melts coexisted with amphiboles ($\text{SiO}_2^{\text{melt}}$) are $\sim 66\text{-}73\text{wt.}\%$ and $\sim 60\text{-}65\text{wt.}\%$ for magnesiohornblendes and tchermakites, respectively. For amphiboles in crystal clots, $\text{SiO}_2^{\text{melt}}$ is estimated to be $\sim 71\text{-}72\text{wt.}\%$. On the other hand, SiO_2 contents of interstitial melts are $\sim 68\text{-}72\text{wt.}\%$, which is consistent with $\text{SiO}_2^{\text{melt}}$ estimated from amphiboles in crystal clots.

4. Discussion

Previous studies proposed that the 1991-95 magma was formed by magma mixing between crystal-rich, silicic and nearly aphyric, mafic endmembers ($T \sim 1050^\circ\text{C}$, $\text{SiO}_2 \sim 50\text{wt.}\%$, Holtz et al., 2005, Browne et al., 2006). Temperatures estimated from magnesiohornblende phenocrysts and also amphiboles in crystal clots are consistent with the proposed temperature of the silicic endmember magma (Holtz et al., 2005). In addition, $\text{SiO}_2^{\text{melt}}$ estimated from these amphiboles are consistent with compositions of interstitial melts in crystal clots. Moreover, H_2O saturation depth estimated for the interstitial melt compositions are consistent with that of C-magma chamber in which the silicic endmember magma was thought to be stored. These results suggest that interstitial melts in crystal clots represent the silicic endmember melt.

Temperatures estimated from tchermakite phenocrysts are apparently lower than that of the mafic endmember magma proposed in previous studies. In addition, temperature gap is found between tchermakites and magnesiohornblendes. These results suggest that an unrecognized magma with $T \sim 920^\circ\text{C}$ and $\text{SiO}_2^{\text{melt}} \sim 63\text{wt.}\%$ contributed as the 3rd endmember to form the 1991-95 magma. We estimated the mixing ratio of the three end-members based on the estimated $T\text{-SiO}_2^{\text{melt}}$ conditions, to be $\sim 11\text{wt.}\%$, $\sim 54\text{wt.}\%$ and $\sim 35\text{wt.}\%$ for the mafic, the 3rd and the silicic endmembers, respectively. Our results suggest that the 1991-95 magma was formed by three-component mixing, in which contribution of the newly-recognized 3rd endmember magma is largest and that of the mafic endmember magma, which has been thought to be a major component, is relatively minor.

Keywords: Unzen volcano, magma, amphibole, pre-eruptive process, magma mixing