Magmatic processes of Plinian eruptions: a comparison between the 1667 eruption of Tarumai (Tarumae) and the 1663 eruption of Usu

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1. Introduction

Plinian eruptions cause serious damage to wide area and unexpectedly occur at volcanoes dormant for a long time. We should understand the mechanism to predict it. Plinian eruptions can eject high-viscosity magma with low-T and, in many cases, high crystal content. Several mechanisms have been proposed, such as injection of high-T magma (Sparks et al., 1977), remobilization of low-T magma by addition of volatile from high-T magma (Bachmann & Bergantz, 2006), and precursory eruption of low-viscosity hybrid magma between low-T and high-T magmas (Pallister et al., 1996; Takeuchi & Nakamura, 2001). In this study, we discuss this matter by comparison of the two eruptions in the title.

2. The two eruptions

The 1667 eruption of Tarumai and the 1663 eruption of Usu (hereafter we call them Ta-1667 and Us-1663, respectively) have common features: they are plinian eruptions of VEI 5, occurred in SW Hokkaido, Japan, in 17th century, emerged after thousands of years of dormancy, and are the largest ones (Soya et al, 1981, 2007; Soya & Sato, 1980). The two volcanoes also have common features: they are post-caldera cones, active since 10-20 ka, and characterized by pumice fall, pyroclastic flow and dome formation in historical time.

There are also differences. The rocks from Tarumai, including Ta-1667, are mainly andesite (Nakagawa et al., 2006), whereas those from Usu are basalt to basaltic andesite or dacite to rhyolite and Us-1663 is rhyolite (Oba et al., 1983). Phenocryst content of Ta-1667 reaches 20-40 %, whereas that of Us-1663 is only a few percent.

The process of Us-1663 eruption has been well studied (Tomiya & Takahashi, 1995; Matsumoto et al., 2005): (1) there were homogeneous low-T and high-T magmas; (2) they formed a stratified magma chamber; (3) a hybrid magma between the two was produced at the boundary layer; (4) the hybrid magma firstly erupted as a precursory eruption. The process of Ta-1667 eruption has not been well known, however.

3. Re-examination of the Ta-1667 deposit (Ta-b)

Ta-b has many sub-units (Soya, 1971; Furukawa, 1998). Hiraga & Nakagawa (2000) reported that the bulk rock was homogeneous (SiO_2 = 58-62 wt.%) from b8 (lower) to b1 (upper). Nakagawa et al. (2006) followed it and discussed phenocryst compositions. On the other hand, Takeuchi (2001) found that the lowermost part of b8 was more mafic (SiO_2 = 56-58 wt.%) and the precursory hybrid magma.

We analyzed phenocrysts in the precursory phase and other phases (e.g., b1) and obtained the following new findings. [Plagioclase (pl)] (1) There are four types in texture (calcic core, mantled, complex, sodic core); (2) their An contents are 96-90, 90-80, 80-65 and 60-50, respectively; (3) An content of the rim is similar to that of the core of type-complex; (4) their FeO content is low (type-1 of Nakagawa et al.) except for their rim (type-2); (5) calcic-core pl coexists with olivine (ol). [Magnetite (mt)] (1) Those in the precursory phase have high Mg/Mn and Al and show bimodal compositions (type-2 and -3); (2) those included in pyroxene phenocrysts of the precursory phase have the same compositions as other phases (type-1). As for opx and cpx, the results are same as Takeuchi (2001): homogeneous, except for reverse zoning at the rim in the precursory phase.

4. The eruption processes

The results indicate the following sequence: (1) a high-T magma injected into a low-T magma, forming a precursory hybrid magma; (2) the high-T magma contained ol + pl (calcic core; type-1) + high-Mg mt (type-3); (3) the low-T magma contained opx + cpx + pl (mantled, complex & sodic core; type-1) + mt (type-1); (4) the high-T magma was homogeneous and the low-T magma was homogeneous except for pl phenocrysts; (5) the heterogeneity of the pl phenocrysts were caused by former magma mixing.

The sequences of the two eruptions apparently resemble each other. This is interesting, considering the difference in their phenocryst contents.