Magma plumbing system at Zao volcano, NE Japan: time scales of magmatic processes revealed by chemical zoning in orthopyroxene phenocrysts

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[Introduction]

Understanding of magma plumbing system is fundamentally the most important issue for the volcanic disasters mitigation. The youngest activity of Zao volcano (NE Japan) repeated phreato-magmatic eruptions in "Okama crater" (ca. AD1200 to present) and precursory phenomena, such as volcanic tremors and earthquakes has been observed since 2013. Recent advance of volcanic petrology allows us to reveal the magma plumbing system more in detail. The detailed analysis of textures and chemical zoning of phenocrystic minerals can provide useful information of the magma pluming system. Moreover, using the elemental diffusion chronometry applied to compositionally zoned crystals, we can know the time scales of complex magma dynamics. Here, we present and discuss pre-eruptive processes of Okama crater eruption products (Okp) by using zoning profiles of orthopyroxene phenocrysts.

[Mineral compositions and end-member magmas]

Juvenile bomb samples are medium-K and calc-alkaline series basaltic andesite to andesite (56-57% SiO2), including plagioclase, orthopyroxene, clinopyroxene and magnetite as phenocryst. Plagioclase phenocrysts show wide range of compositions between $An_{60\text{-}92}$ and broad peaks were identified ($An_{65, 75, 88}$). Orthopyroxene compositions range between 56-76 Mg# with two peaks (66, 74 Mg#). Clinopyroxene compositions range between 63-77 Mg# with a single peak (68 Mg#). These various crystals are made by magma mixing between low-T end-member magma (L-magma) with low An and Mg#, and high-T end-member magma (H-magma) with high An and Mg#. Physicochemical conditions of end-member magmas were constrained by using the rhyolite-MELTS algorithm. The optimum conditions for each end-member magmas are as follows, H-magma: >76 Mg#, 52-53% SiO_2, >1040˚C, 200-250 MPa, 5.0% H_2O, and L-magma: 64-66 Mg#, 60% SiO_2, 950-970˚C, 200 MPa, 3.0% H_2O.

[Zoning profiles of orthopyroxene phenocrysts]

The opx phenocrysts can be divided low-(opx-A, 64-66 Mg#), high- (opx-B, >72 Mg#), and extremely low-(opx-A’, <63 Mg#) Mg types based on core composition. Based on compositional zoning of rim (inside from outermost rim), opx-A are subdivided into -A1 to -A4. A1 show no zoning, while A2 to A4 have Mg rich rims (>70 Mg#). In the Mg rich rim, Al is high, but Cr is low in A2, Al and Cr are high in A-3, and Al and Cr are low in A4. Type B is subdivided into B1, which has normal zoned rim, and B2, which shows skeletal texture. Core compositions of opx-A are equilibrium in L-magma, and reverse zoned rim compositions of opx-A3 and core compositions of opx-B1 and -B2 are in equilibrium with H-magma. Outermost rims (66-67 Mg#, almost high-Al content) are observed in many of the phenocrysts, which were formed in the mixed magma. The composition of the mixed magma is estimated to be similar to that of the groundmass.

[Mixing processes and the time scales]

Based on above zoning profiles of Mg#, Al, and Cr in orthopyroxene phenocrysts, low-T and modified high-T magmas mixing is recognized other than low- and high-T magmas mixing. The modified high-T magma (Mm magma) was formed by incorporation of the mixed magma into the high-T magma when the

latter injected into the former. We estimated the residence time of both cases of mixing by Fe-Mg diffusion modeling applied to the Mg# zoning of orthopyroxene phenocrysts. The estimated timescales are mostly a few decades for low- and high-T magma mixing and a few days to decades for low-T and the Mm magma mixing.

The pre-eruptive processes of the Okp are proceeded as follows. The injection of the high-T magma and mixed with the low-T magma (a few decades before the eruption), resulted in the formation of the mixed magma. The injection of the high-T magma into the mixed magma formed the Mm magma tentatively, that mixed with the L-magma (a few decades to a few days before the eruption).

Keywords: Plumbing system, Magma mixing, Residence time, Orthopyroxene, Rhyolite-MELTS, Zao volcano

