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Multistage magma mixing determined by phenocryst composition and zoning of the Sessho lava, Kusatsu-shirane Volcano

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We present a detailed study of the texture and chemical zoning of phenocrysts in the Sessho lava, andesite lava flow from Kusatsu-shirane volcano, Central Japan, in order to reconstruct cooling and crystallization processes of andesite magma. The Sessho lava is estimated to have been erupted 5 ka from the Moto-shirane cone (Yoshimoto et al., 2013) and exhibits andesitic composition with SiO2 content of 60˜63 wt. % (e.g., Ueki and Terada, 2012). We sampled 5 different samples to cover the whole area of the Sessho lava, and conducted textural and chemical analysis of the samples. Phenocryst assemblage of the Sessho lava is plagioclase, clinopyroxene, orthopyroxene, magnetite and rare olivine with glassy groundmass.

Disequilibrium olivine (Fo=˜80) with reaction rim suggests the mixing between basaltic and evolved magmas during evolution of the Sessho lava. Orthopyroxene-magnetite symplectite, which is estimated to be formed by olivine breakdown by oxidization (e.g., Goode, 1974), coexists with the olivine phenocryst.

Pyroxene thermometry (Lindsley, 1983) based on rim compositions of opx and cpx phenocrysts suggests the mixing between high temperature (1000 degree) and low temperature (700 degree) magmas. The rim compositions of higher temperature opx show higher Al content and rim compositions of the lower temperature opx and core compositions of opx show lower Al content, suggesting these pyroxenes have been derived from different magmas both in terms of composition and temperature. The high temperature pair and the low temperature pair coexist in some samples.

We observed four different types of plagioclase phenocrysts in a single rock sample, in terms of zoning profiles, internal textures and external shape. Type 1 plagioclase exhibits euhedral shape, clear and homogeneous core with An content of 55˜65. Type 2 plagioclase exhibits euhedral shape with oscillatory zoned core between An content of 50˜80. Type 3 plagioclase exhibits rounded shape, rough interface and dusty core with An content of 80˜90. Type 4 plagioclase exhibits clear core with An# of 55˜80 surrounded by dusty mantle zone with An# of 80˜90, and rough interface. All types of plagioclases have thin (˜50μm) rim with An content of 60˜80. This rim may represent a crystallization during upwards migration, because plagioclase microphenocryst in groundmass exhibits similar An content with the rim. Dusty core of type 3 and dusty mantle of type 4 show higher MgO and FeO contents than the clear and oscillatory parts and type 1 and type 2 plagioclases, suggesting the dusty core and mantle crystallized in higher FeO and MgO content magmas. Type 1 and type 2 plagioclases are larger (˜1.5mm) than the type 3 and 4 (˜1mm). Crystal size distribution analysis of plagioclase phenocryst suggests that type 1 and 2, and type 3 and 4 crystallized in different physical conditions. Clear plagioclase (type 1) may represent equilibrium crystallization process in relatively low temperature evolved magma, whereas dusty plagioclase (Type 3) may represent crystallization in relatively mafic and high temperature magma. Oscillatory zoning (Type 2) and dusty mantle (Type 4) may represent interaction between the high temperature and low temperature magmas.

Based on the above observations, we propose multi-stage magma mixing and crystallization processes during the evolution of andesite magma of the Kusatsu-shirane volcano; high temperature basaltic magma with olivine, and calcic plagioclase was recharged periodically in a crystallized lower temperature silicic magma chamber, and inhomogeneous mushy magma chamber was formed.

Keywords: lava flow, two pyroxene geothermometry, crystal size distribution, andesite, eruption, active volcano