Petrology of mafic inclusions in the 1991-1995 dacite of Unzen volcano

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The 1991-1995 dacite of Unzen volcano contains mafic inclusions. They are usually ovoidal and 1-50 cm in diameter, constituting ca. 0.2-1 volume % of the host dacite. Nakada and Motomura (1997) showed that the bulk rock SiO$_2$ contents of the mafic inclusions range from 50 to 60 wt%, and suggested that these mafic inclusions are derived from the marginal boundary layer of the magma chamber of Unzen volcano. In the present study, the author carried out petrographic work on the mafic inclusions, and concluded that the mafic inclusions represents quenched liquid drops of high-temperature mafic magmas in low-temperature felsic magma based on the following observations. (1) Chilled margin in the mafic inclusion is rarely found. Among 50 mafic inclusions, only one sample showed fine-grained chilled margin against the host dacite. (2) Ubiquitous occurrence of skeletal plagioclase and hornblende in the mafic inclusions, Generally, the mafic inclusions show diktytaxitic texture, consisting of elongated microlites of plagioclase and hornblende in vesicular glass. Even tabular plagioclase show skeletal distribution of Ca-rich framework with Na-rich plagioclase filling the hollow of the framework. (3) Plagioclase microlites in the mafic inclusions tend to have higher Ca/(Ca+Na) ratio (up to 0.91) compared with the phenocryst plagioclase in the dacite (up to 0.75). (4) Pyroxenes in the mafic inclusions show high equilibration temperatures of ca. 1075 °C. One mafic inclusion contained pigeonite, augite, and orthopyroxene, giving equilibration temperature of 1075 °C, whereas only orthopyroxene appears in some of the mafic inclusions.

A magma mixing model of Holtz et al.(2005) indicate high-temperature end member magma has SiO$_2$ content of 60-64 wt% with temperature of 1050 °C, which is slightly high in SiO$_2$ compared with the range of mafic inclusions. This discrepancy may be reconciled when we take the rheological behaviour of mafic magma during mafic-felsic magma interaction into consideration. Sparks and Marshall(1986) and Blake and Koyaguchi (1991) pointed out that mafic inclusion may form only if the temperature difference of two magmas is large, and the mass ratio of mafic to felsic magma is small, in which conditions the mafic magma would be congealed to form mafic inclusions. In other conditions the mafic magma remains fluidal and hybridization of the two magma proceeds, which actually took place to form the hybridized dacite of the 1991-1995 dacite of Unzen volcano.

We found marked variations of mineral chemistry of hornblende and plagioclase in the
Figure 1. composition of plagioclase in mafic inclusions.

The mafic inclusions in Unzen dacite, which may reflect variations of the generation conditions of mafic inclusions. We classified the mafic inclusions into type-I, type-II, and type-III by mineral chemistry of hornblende and plagioclase; i.e., type-I consists of microlites of high-Mg plagioclase and low-Cl hornblende, and type-III includes low-Mg plagioclase and high-Cl hornblende as microlites, and type-II has intermediate chemistry of microlites. Mineral chemistry of type-I is almost the same as those of the groundmass of host dacite, whereas that of type-III mafic inclusions corresponds to those of phenocryst of the host dacite. Type-I mafic inclusions tend to show finer-grained in the matrix, (55-62 wt.%) compared with type-III mafic inclusions (SiO₂=52-57 wt.%), but overall bulk rock compositions is similar to the basalt-andesite-dacite suite of Quaternary monogenetic volcanoes around Unzen volcano. One mafic inclusion is rich in hornblende and departs from the general compositional trend of the suite. Two possible models of the origin of the variable types of mafic inclusions are examined. One model proposes several stages of intrusions of mafic inclusions mafic magma, causing the compositional variation of minerals due to different degrees of diffusion relaxation; i.e., older intrusion produced mafic inclusions, which were subsequently annealed in the dacitic chamber to the low-temperature mineral chemistry corresponding to the phenocrysts. Another model supposes that the mafic inclusions are the product of crystal segregation where different degrees of magma/fluid mixing caused the variation of the mineral chemistry; i.e., replenishment of silicic magma chamber by mafic magma may generated type-I mafic inclusions, whereas segregation of minerals in the wall or floor of the chamber repeatedly affected by fluid input/outgassing produced type-III mafic inclusions. Type-II mafic inclusions may record both magma mixing and fluid input processes during replenishment of the silicic magma chamber.

Figure 2 composition of hornblende in mafic inclusion have slightly higher bulk rock SiO₂ contents