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Structure and eruption processes of magma plumbing system of pyroclastic eruption of Aira caldera

Michiko Bando[1]; # Mitsuhiro Nakagawa[1]

[1] Natural History Sci., Hokkaido Univ.

Aira-caldera was formed by a typical caldera-forming eruption which started with plinian eruption (Osumi and Tarumizu units), followed by pyroclastic flow eruption (Tsumaya and Ito units). Tsukui and Aramaki (1990) revealed that eruptive magma was nearly homogeneous high-silica rhyolite. Arakawa et al. (1990) suggested that another mafic magma mixed with the rhyolitic magma. Thus, it has been widely believed that the caldera-forming eruption was derived from a single, homogeneous ryolitic magma chamber, in which mafic magma injected. However, there existed time interval between plinian and pyroclastic flow eruptions. In addition, major vent had shifted after the plinian eruption. These have not been explained by the proposed model. In this study, we carried out petrological reinvestigation of caldera-forming eruptive materials of the Aira caldera.

Juveneile materials are composed of two types, pumice and banded pumice. Pumice is contained in all units, whereas banded pumice is contained in major units (Osumi and Ito) of plinian and pyroclastic flow eruptions. The pumice (SiO_2=73.4-76.4 wt%) makes linear trends in all Harker diagrams. It contains plagioclase, orthopyroxene and Fe-Ti oxides phenocrysts. Plagioclase phenocrysts show two peaks of An=32-60 and 70-90. On the other hand, orthopyroxene phenocrysts show wide variation ranging Mg#=42-69. Those phenocrysts with high An and Mg# show normal zonation, whereas those with low An and Mg# reverse zonation. These suggest that the pumice could be formed by magma mixing. However, chemical compositions of rims of phenocrystic minerals are nearly homogeneous. In addition, orthopyroxene phenocrysts do not show bi-modal compositional distribution. Thus, there existed enough time interval after magma mixing event to make a zoned magma chamber. Comparing chemical compositions of the pumice between Osumi and Ito units, possible compositional difference can be recognized. Firstly, pumice of Ito unit is slightly enriched in K_2O. Secondly, La/Yb ratios are different between the both. Thus, it could be concluded that eruptions of Osumi and Ito had been derived from different rhyolitic zoned magma chambers.

Banded pumice ranges SiO_2=73.5-75.5 wt%, and shows different trends in SiO_2-TiO_2, MgO, FeO, MnO and Na_2O diagrams from those of the pumice. In addition, matrix glass chemistry and Sr isotope ratios can be also distinct between the pumice and banded paumice. Although assemblage and compositional distribution of silicate phenocrystic minerals are identical between the both, small amount of Fe-Ti oxides phenocrysts showing higher equilibrium temperature can be found in the banded pumice. In addition, rims of silicate phenocrysts of the banded pumice are more mafic than those of the pumice. Thus, the banded pumice must be related to another mafic magma with higher temperature, which is not recognized in the pumice. Considering similar content and assemblage of phenocryst between pumice and banded pumice, it seems that the banded pumice was formed by injection of aphyric mafic magma into the rhyolitic magma. Comparing the banded pumice between Osumi and Ito, there exist several characteristic features. Although the Osumi one contains xenocrysts derived from granitic rocks, the Ito one has sedimentary xenoliths and xenocrysts. These indicate that two distinct mafic magmas injected successively through different dykes just before plinian and pyroclastic flow eruptions. This is consistent with different matrix glass chemistry between the both banded pumices. These banded pumice was quench products of mixing processes, indicating that these eruptions were triggered by injections of distinct mafic magmas. Our petrological interpretation for caldera-forming eruptions of Aira caldera is consistent with geological constraints, the time interval and shift of vent areas.