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Origin of two differentiation trends derived from a basaltic magma: Constraints from Aogashima Volcano

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Volcanic rocks occurring island arc are mostly porphyritic and usually contain abundant phenocrysts. It is, however, not clear whether whole-rock composition represents melt composition or not. It is, therefore, necessary to understand the origin of such phenocrysts and its relationship to the groundmass.

Two differentiation trends observed in volcanoes of the Izu arc are discussed particularly focusing on Aogashima Volcano. The first trend is peculiar to the Izu arc, which is L-shaped in the SiO_2-Al_2O_3 diagram (Aogashima-type), and the other shows a gentle decrease of Al_2O_3 with increasing SiO_2 content (Hachijo-jima Higashiyama type=HH-type) which is very common to world-wide volcanisms.

Basalts from Aogashima Volcano can be divided into three types based on petrography and whole-rock composition: highly plagioclase-phyric (HPP) basalt, aphyric basalt, and moderately plagioclase-phyric (MPP) basalt. HPP basalt contains 20-40 vol% plagioclase phenocrysts, and the Al_2O_3 content is more than 18wt%. The olivine phenocrysts usually have pigeonite rim. MPP basalt contains -20vol% plagioclase phenocrysts and the Al_2O_3 content ranges 17-19.5wt%. It has euhedral olivine phenocrysts and contains olivine in groundmass. Aphyric basalt contains a small amount of phenocryst less than 5vol%, and the Al_2O_3 content is about 15wt%.

The groundmass composition of HPP is nearly the same as that of the whole-rock aphyric basalt. The mode values of An content of plagioclase core and Fo content of olivine core show correlation with the FeO*/MgO contents of the groundmass. The FeO* and MgO contents of plagioclase phenocrysts have a correlation with the FeO*/MgO contents. These facts suggest an intimate genetic relation between phenocrysts and groundmass.

Liquidus phases in equilibrium with groundmass melt or whole-rock compositions was examined with the MELTS program (Ghiorso and Sack, 1995). The pressure (0.5-3kbar), water contents (0-4wt%), and fO_2 (QFM and NNO) were changed as parameters. The groundmass composition of HPP never gets in equilibrium with the averaged core plagioclase phenocrysts. On the contrary, melt with the whole-rock MPP can be in equilibrium with the average An contents of plagioclase phenocrysts at wide conditions. At 1kbar and with 1.5wt% water content, a melt of the whole-rock MPP can differentiate to the aphyric basalt by fractionating only plagioclase according to MELTS.

The Aogashima-type trend is shown to be derived from the least differentiated MPP basalt. Crystallization of plagioclase from enormous liquid of MPP found crystal mush near the roof of a magma chamber. When the interstitial liquid was isolated from the main body, it crystallized plagioclase to give rise to the aphyric basalt composition. If this mush and the interstitial liquid erupted together, it becomes highly plagioclase-phyric basalt. If the differentiated liquid was expelled from the mush and erupted, it became the aphyric basalt.

The other differentiation trend of the Izu arc (HH-type trend) can be explained by fractional crystallization at 1kbar and with 2.7wt% water content according to MELTS. The least differentiated composition of Aogashima Volcano belongs to MPP, and it is similar to that from the Izu arc and other volcanoes in the NE Japan arc. The composition of MPP basalt is within the range of HH-type. From these facts, the Aogashima-type trend is inferred to have derived from the HH-type. The coexistence of the two trends starting from a parental melt may be attributable to the difference in water content. Low water content is required to derive the Aogashima-type trend.