magmatic processes for producing the variations of alkali basalts: an example from St. Helena Island

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St. Helena is a volcanic island situated on 39 m.y. old lithosphere, approximately 750 km east of the Mid-Atlantic Ridge. The subaerially exposed portion of the island is dominated by a pile of basaltic lava flows erupted from two main centers (younger NE volcano and older SW volcano), associated with subordinate pyroclastics and trachytic to phonolitic intrusions. The K-Ar ages of 7-14 Ma have been reported for the volcanics comprising the NE and SW volcanoes (Baker et al., 1967; Abdel-Monem and Gast, 1967).

Rock samples collected from all stratigraphical units found above sea level form mildly alkalic suite ranging from ankaramite through trachyandesite to phonolite. These rocks show continuous compositional trends, but the change in slope is observed at ca. 5 wt% MgO. Basaltic rocks with more than 5 wt% MgO are mainly classified into ankaramite and olivine basalt. Ankaramite (8-16 wt% MgO) is characterized by abundance (50-10 vol.%) of coarse (15-3mm in longest dimension) olivine and clinopyroxene phenocrysts. Kink banded olivines, which have identical composition to kink band-free olivine phenocrysts, comprises 4-57% of the total olivine phenocryst population. In contrast, olivine basalt (5-8 wt% MgO) is the most abundant rock type in the subaerial portion of St. Helena Island. They have olivine microphenocryst and subordinate clinopyroxene and plagioclase microphenocrysts. Unlike ankaramite, mafic phenocrysts are less abundant (less than ca. 10 vol.%) and small (mainly about 0.5 mm in size).

Petrological features of these alkali basalts are summarized as follows: 1) Bulk MgO concentration shows a good correlation with amount of olivine and clinopyroxene phenocrysts. 2) Compositional trend from ankaramite to olivine basalt can be explained by addition of olivine and clinopyroxene into a magma and/or subtraction from it. 3) The maximum forsterite content in olivine core in ankaramites is almost constant at Fo85-87 irrespective of the variation in bulk FeO/MgO from 0.6 to 1.3. The most Mg#-rich olivine (Fo87) can be precipitated from a melt with FeO/MgO of 0.9, assuming a Kd of 0.3+/-0.03 (Roeder and Emsile, 1970). 4) Groundmass compositions of ankaramites have transitional chemical compositions between ankaramites and olivine basalts. This is further supported by compositions of olivine phenocrysts in ankaramites; the minimum forsterite contents (Fo74-80) in phenocryst core from individual ankaramite samples can be in equilibrium with a melt with FeO/MgO=1.5-2.1, which is comparable to the composition of olivine basalts.

These features indicate that alkali basalts from ankaramites to olivine basalts would be basically produced by crystallization of a parental magma with FeO/MgO=0.9 and subsequent magma extraction from the partially crystallized magma chamber. The difference in the proportion of melt to crystal in the extracted magmas controlled the variations from ankaramite to mafic olivine basalts. Kink-banded olivines and fractured coarse phenocrysts commonly found in ankaramites are likely to represent the crystals disrupted from a deformed rigid crust and/or crystal-mush zone present within the magma chamber.