Assimilation and fractional crystallization controlled by transport processes of crustal melt

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Mechanisms of fractional crystallization with simultaneous crustal assimilation are examined for the Kutsugata and Tanetomi lavas, an alkali basalt-dacite suite erupted sequentially from Rishiri Volcano, northern Japan. The major element variations within the suite can be explained by boundary layer fractionation; i.e. mixing of a magma in the main part of the magma body with a fractionated interstitial melt transported from the mushy boundary layer at the floor. Systematic variations in SiO2 correlate with variations in the Pb, Sr and Nd isotopic compositions of the lavas. The geochemical variations of the lavas are explained by a constant and relatively low ratio of assimilated mass to crystallized mass (r-value). In the magma chamber in which the Kutsugata and Tanetomi magmas evolved, a strong thermal gradient was present and it is suggested that the marginal part of the reservoir was completely solidified. The assimilant was transported as a crack flow from the partially fused floor crust to molten main magmas through fractures in the solidified margin, formed mainly by thermal stresses resulting from cooling of the solidified margin and heating of the crust. The crustal melt was then mixed with the fractionated interstitial melt in the mushy zone, and the mixed melt was further transported through compositional convection to the main magma, causing its geochemical evolution to be characteristic of AFC. The volume flux of the assimilant from the crust to the magma chamber is suggested to have decreased progressively with time (proportional to t-1/2), and was about 3 x 10-2 m/year at t = 10 years and 1 x 10-2 m/year at t = 100 years. It has been commonly considered that the heat balance between magmas and the surrounding crust controls the coupling of assimilation and fractional crystallization processes (i.e. absolute value of r). However, it is inferred from this study that the ratio of assimilated mass to crystallized mass can be controlled by the transport process of assimilant from the crust to magma chambers.