Crustal differentiation

Elena Melekhova

Few erupted arc magmas are sufficiently primitive to be in equilibrium with mantle wedge peridotite, meaning a significant volume of arc crust must comprise plutonic cumulates formed during differentiation of primitive basalts. This cumulate material is typically not available for petrological study. A notable exception is the Lesser Antilles arc, which is renowned for the exceptional abundance and variety of cumulate xenoliths. Additionally, several Lesser Antilles islands erupt primitive basaltic magmas that are close to being in mantle equilibrium. The abundance of plutonic cumulate xenolith and presence of primitive basalts make the Lesser Antilles an ideal natural laboratory for understanding crust-building processes.

Here we evaluate the chemical consequences of basalt differentiation in the mid to lower crust and uppermost mantle (10 to 30 km) by means of experiments on a primitive basalt from St. Vincent. The results were combined with compositional and textural observation of plutonic cumulate xenoliths from the island. Our goal was to constrain the conditions under which basalt differentiation can generate the observed chemical diversity of erupted magmas at St. Vincent and the compositions of minerals in cumulate xenoliths.

Our experimental results show that it is possible to produce a wide compositional range of melts by differentiation at different depths and water contents from the same primitive source. The melts provide a close match to the full range of erupted lavas on the island. The cumulate assemblages, however, have a consistently lower pressure origin (6-10 km). They are formed by crystallisation of ascending melts generated in the deep crust. Phencocrysts in the lavas are distinct from those in cumulates, notably in the absence of amphibole. The phenocrysts demonstrably grew in response to crystallisation at very shallow depth, probably in sub-volcanic magma chambers. Thus St. Vincent shows clear evidence for polybaric crustal differentiation.