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Experimental Evidence for Polybaric Intracrustal Differentiation of Primitive Arc Basalt beneath St. Vincent, Lesser Antilles

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We present experimental phase equilibria for a primitive, high-Mg basalt from St. Vincent, Lesser Antilles. Experimental details were presented in Melekhova et al (Nature Geosci, 2013); the objective here is to compare experimental phase compositions to those of erupted lavas and cumulates from St. Vincent.

Starting material with 4.5 wt% H_2O is multiply-saturated with a lherzolite assemblage at 1.3 GPa and 1180 ˚C, consistent with mantle wedge derivation. Experimental glasses from our study, in addition to those of Pichavant et al (GCA, 2002) and Pichavant & Macdonald (CMP 2007) on a similar high-Mg basalt, encompass a compositional range from high-magnesian basalt to dacite, with a systematic dependence on H_2O content, temperature and pressure. We are able to match the glasses from individual experiments to different lava types, so as to constrain the differentiation depths at which these magmas could be generated from a high-Mg parent, as follows:

Composition	wt% H_2O	P (GPa)	T (˚C)
High-Mg basalt	3.9-4.8	1.45-1.75	1180-1200
Low-Mg basalt	2.3-4.5	1.0-1.3	1065-1150
High alumina basalt	3.0-4.5	0.4	1050-1080
Basaltic andesite	0.6-4.5	0.7-1.0	1050-1130
Andesite	0.6	1.0	1060-1080

The fact that St. Vincent andesites (and some basaltic andesites) appear to derive from a low-H_2O (0.6 wt%) parent suggest that they are products of partial melting of older, high-Mg gabbroic rocks, as 0.6 wt% H_2O is approximately the amount that can be stored in amphibole-bearing gabbros. The higher H_2O contents of parents for the other lava compositions is consistent with derivation by crystallization of basalts with H_2O contents that accord with those of olivine-hosted melt inclusions from St. Vincent (Bouvier et al, J Petrol, 2008). The generation of evolved melts both by basalt crystallization and gabbro melting is consistent with the hot zone concept of Annen et al (J Petrol, 2006) wherein repeated intrusion of mantle-derived basalt simultaneously crystallize by cooling and melt country rocks composed of ancestral, solidified basalt. Isotopic data for St. Vincent (Heath et al, J Petrol, 1998) rule out any involvement of much older sialic crust.

Although our experimental glasses provide a very good match to erupted lavas, the compositions of residual minerals do not match those of cumulate xenoliths (Tollan et al, CMP, 2012), which are abundant on St. Vincent. Therefore cumulates are not entrained fragments of the source region, but shallow accumulations of crystals generated by cooling of magmas on their journey through the crust. Thus melt compositions are a consequence of high pressure, H_2O-understaurated phase relations, whereas cumulates are a consequence of low pressure, typically H_2O-saturated, phase relations. We integrate these findings into a simple polybaric model of magma differentiation on St. Vincent involving a single, high-Mg, mantle-derived parental basalt.