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Geochemistry and petrogenesis of late Pleistocene to Recent volcanism in Southern Dominica, Lesser Antilles

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Abstract

Dominica is the most productive volcanic island in the Lesser Antilles arc and contains the largest number of potentially active volcanoes, but is not well studied petrologically. Quaternary volcanic activity on Dominica has been dominated by intermediate to felsic magmas, erupted as large-volume ignimbrites (Roseau, Grand Savanne, Grand Bay) and dome complexes. One of the largest concentrations of these deposits, and one of the currently most active areas in terms of shallow seismicity and hotspring activity, is the Plat Pays Volcanic Complex (PPVC) at the southern tip of the island. The PPVC is made up of medium-K calc-alkaline silicic andesites and rarer dacites. The major and trace element compositions define regular variation trends that can be explained by fractionation of observed phenocryst phases (plagioclase, clinopyroxene, orthopyroxene, Fe–Ti oxides). The contemporary Morne Anglais center erupted a wider range of magmas, extending from silicic andesites (identical in composition to the PPVC) to basalt. The new geochemical and Sr–Nd–Pb isotope data presented here cover all main units of the PPVC and Morne Anglais, and give a reconnaisance view of three other important Quaternary volcanic centers on Dominica that are associated with large-volume ignimbrite eruptions: Diablotins, Wotten Waven/Micotrin and Trios Pitons. Geochemical modelling of variation trends from the PPVC and Anglais centers indicates these are consistent with derivation from a basaltic parent magma like that of Morne Anglais. With a few exceptions at the mafic end of the spectrum, Sr, Nd and Pb isotope ratios remain constant with fractionation from 52 to 64 wt.% SiO_2. The εNd values range from +2 and +4, and $^{87}Sr/^{86}Sr$ between 0.7041 and 0.7047. The range of values for $^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ are 39.2–39.4, 15.71–15.75, and 19.4–19.5, respectively. Exceptions to this are basalt scoria clasts from Anglais and an andesite dike cutting PPVC domes. These samples have higher εNd and less radiogenic Pb isotope ratios. This, together with other geochemical anomalies observed in the Anglais scoria samples and field evidence for magma mixing from their sample locations, indicates a more open-system behavior of the Anglais system, perhaps involving magma recharge.

Application to the PPVC and Morne Anglais samples of magnetite–ilmenite, hornblende–plagioclase and two-pyroxene geothermometry yielded temperature estimates in the range of 800 to 890 °C for silicic andesite and dacite, and 970–1100 °C

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for basaltic andesites from Morne Anglais. Pressure estimates from magnetite–ilmenite–orthopyroxene equilibria are 200–300 MPa, similar to an estimate of 200 MPa derived from dissolved Cl and H_2O contents in melt inclusions, and consistent with the 5–6 km depth of volcanic seismicity observed in the PPVC area between 1998 and 2000. The similarity of chemical and isotopic compositions, regular differentiation trends and *P–T* conditions for the different units of the PPVC suggest that recurrent eruptions in the last 40 ka have tapped a common, rather homogeneous magma source. Variations are due to local differences in the degree of differentiation before eruption. The long eruptive history at the PPVC, including episodic dome growth over the last 40 ka, may indicate rejuvination of the system by mafic magma recharge and this is supported by the proximity to the contemporaneous mafic Anglais center which itself shows some evidence of basaltic magma recharge. Despite this, we find no convincing petrographic or geochemical evidence in its eruptive products for mafic recharge into the PPVC magma system.

Keywords: Lesser Antilles; Dominica; Plat Pays; Morne Anglais; magma recharge; isotopes; arc volcanism

1. Introduction

The island of Dominica has the unenviable distinction of hosting the highest concentration of potentially active volcanoes (9) in the Lesser Antilles arc (LAA) and one of highest worldwide, making it extremely susceptible to volcanic risk (Fig. 1). Dominica is not only the most volcanically productive of the Lesser Antilles islands over the last 100,000 years (Wadge, 1984), it was also the setting of the largest known explosive eruptions in the Lesser Antilles. Between ~40 and 20 ka, silicic andesite to dacitic pyroclastic eruptions in Dominica led to the emplacement of the Roseau Tuff (Carey and Sigurdsson, 1980), the Grand Savanne ignimbrite (Sparks et al., 1980a,b) and Grand Bay ignimbrite (Lindsay et al., 2003). This felsic ignimbrite activity is not typical for the Lesser Antilles arc and the only comparable deposits are the more or less contemporaneous Belfond and Choiseul deposits on St. Lucia (Wright et al., 1984; Wohletz et al., 1986). Despite the importance of volcanism on Dominica, both for its local hazard impact and in the regional context of Lesser Antilles arc magmatism, the rugged topography and dense forest cover have meant that the volcanoes on Dominica are among the least-studied in the Lesser Antilles. Geochemical data from Dominica have figured in several overview studies of the Lesser Antilles arc (see Macdonald et al., 2000 and references therein) but there has been no comprehensive geochemical study to date of any of the volcanic centers. This paper presents a geochemical and petrologic study of a large and recently active system of intermediate to felsic volcanism on Dominica, the Plat Pays Volcanic Complex (PPVC), as defined by Lindsay et al. (2003). The PPVC comprises Morne Plat Pays stratovolcano, the Grand Bay Ignimbrite and at least 12 volcanic domes in and around the Soufrière depression (Fig. 2). All units of the PPVC are silicic andesite to dacite in composition, and to better constrain the magma sources and evolution in southern Dominica, we also studied more mafic units (basalt to basaltic andesite) from the nearby and contemporaneous Morne Anglais center. In addition, we also performed a reconnaissance geochemical and radiogenic isotope survey of three other intermediate to felsic volcanic centers in central and northern Dominica (Trois Pitons, Micotrin, Diablotins). The focus of this paper will be on the compositional and magma–genetic relationships among the volcanic units within the PPVC, and we also discuss how the intermediate to felsic magmas on Dominica relate to the basaltic systems on that island and elsewhere in the Lesser Antilles arc.

The volcanic activity in the PPVC took place in the last approximately 40,000 years and both field and geochronologic evidence indicate a repeated history of eruption and episodic growth of several of the domes (Lindsay et al., 2003). Wills (1974) suggested that the Plat Pays stratovolcano and the Patates dome, youngest of the PPVC domes, shared the same crustal magma chamber and this idea was echoed by Wadge (1985), who interpreted a narrow positive gravity anomaly running from Morne Patates to Morne Plat Pays as a shallow intrusive body connecting the feeder systems of the two volcanoes. Recurrent swarms of