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A new scenario for the last magmatic eruption of La Soufrière of Guadeloupe (Lesser Antilles) in 1530 A.D. Evidence from stratigraphy radiocarbon dating and magmatic evolution of erupted products

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ABSTRACT

La Soufrière of Guadeloupe is a dangerous volcano characterized over the last decade by moderate seismic and fumarolic unrest. In the last 15,000 years it has experienced phreatic and magmatic eruptions and unusually numerous flank collapse events sometimes associated with a magmatic eruption. We propose a new age of 1530 A.D. and a new eruptive scenario for the last magmatic eruption on the basis of a novel statistical analysis of radiocarbon age dates, and new field and geochemical data. This eruption is the only magmatic eruption likely to have occurred in Guadeloupe during the last 1400 years. The eruption mainly involved an andesitic magma which, in the first phase of the eruption, partially mixed with a slightly more differentiated magma stored in a small and shallow magma chamber. Ascent of magma to the surface generated a partial collapse of the hydrothermally altered edifice that increased the magma discharge and led to a sub-plinian phase with scoria fallout and column-collapse pyroclastic flows followed by near-vent pyroclastic scoria fountains. The eruption ended with growth of a lava dome. Our revised interpretation of the last magmatic eruption of La Soufrière constitutes the most likely key to a future magmatic eruption scenario for this volcano which displays strong evidence of unrest since 1992.

1. Introduction

As numerous volcanoes in the Lesser Antilles arc, the Grande Découverte–La Soufrière composite volcano in Guadeloupe (thereafter named La Soufrière volcano) has a well developed hydrothermal system (Zlotnicki et al., 1992; Bigot et al., 1994; Brombach et al., 2000; Villemant et al., 2005; Bernard et al., 2006). The volcanic activity of the last centuries at La Soufrière of Guadeloupe presents numerous similarities with the activity of Soufrière Hills volcano, on Montserrat, up to 1995, date of the onset of the on-going magmatic eruption (Sparks and Young, 2002). Before 1995, the hydrothermal system of Soufrière Hills was very active, with several fumarolic fields developed inside and outside the horseshoe-shaped crater (English's Crater). Several intense seismic crises have been recorded in 1897, 1933–1937 and 1966–1967 with no eruptive outcome. The last magmatic event before 1995 was a dome-forming eruption dated at 320±50 years B.P. (Smith et al., 2007).

At La Soufrière of Guadeloupe, an old lava dome is installed in the summit area and the hydrothermal system is also very active. The active fumarolic field is now restricted to the summit part of the lava dome but numerous hot springs are located in an area of ~20 km^2 around the lava dome. In historical times 6 phreatic eruptions (1690, 1797–98, 1812, 1836–37, 1956 and 1976–77 A.D.) have taken place from fractures and vents on La Soufrière lava dome (Barabé and Jolivet 1958; Feuillard et al., 1983; Boudon et al., 1988; Komorowski et al., 2005). The most violent phreatic eruption in 1976–1977 generated an important seismic crisis, 26 phreatic explosions, and forced the evacuation of about 73,000 persons for up to 6 months (Feuillard et al., 1983; Boudon et al., 1988; Komorowski et al., 2005). Although it did not evolve into a dome-forming eruption like at Soufrière Hills (Montserrat) geophysical and geochemical evidence supports its interpretation as a still-born or failed magmatic eruption (Feuillard et al., 1983; Villemant et al., 2005) linked to the probable intrusion of a small volume of viscous andesitic magma that stopped within a few kilometers of the surface triggering pressurization of the hydrothermal system, phreatic explosions, and continuing episodic chlorine degassing into the hydrothermal system (Villemant et al., 2005).

La Soufrière of Guadeloupe is a well-monitored active volcano located just 5 km North of the town of Saint Claude (population 10,000). In the last decade the Guadeloupe Volcanological and Seismological Observatory (OVSG-IPGP) has recorded a systematic and progressive increase in shallow depth low-energy seismicity, a slow rise of temperatures of some acid-sulfate thermal springs (Villemant et al., 2005)

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closest to the lava dome, and, most noticeably, a significant increase in summit fumarolic activity associated with HCl-rich and H_2S acid gas emanations (OVSG-IPGP, 1999–2008; Komorowski et al., 2005).

In this paper, the last magmatic eruption of La Soufrière, thereafter named the Soufriere eruption, is re-investigated on the basis of new field and analytical data and a re-analysis of radiocarbon dates. A younger age for this eruption and a new interpretation of the chronology and eruptive scenario are proposed. We discuss also the magmatic evolution and the role of interaction between acidic and more basic magmas at the origin of the eruption. The onset of unrest at La Soufrière, which began in 1992 and has systematically increased albeit at of low intensity levels, warrants a regular update and the undertaking of new studies of the eruptive past. This is of particular relevance because the Soufrière eruption is the most likely magmatic scenario in case of a hypothetical future eruption of this volcano. Hazards associated with such an eruption render La Soufrière one of the most dangerous volcanoes of the Lesser Antilles.

In a companion paper, Komorowski et al. (2008-this issue) present a detailed reconstruction of the dispersal of fallout tephra of the Soufrière eruption and its implications for deterministic and probabilistic tephra fallout hazard assessment. Spence et al. (2008-this issue) discussed an integrated impact and vulnerability model for a future hypothetic sub-plinian eruption on this volcano similar to the Soufrière eruption.

2. Geological and volcanological setting

2.1. The Lesser Antilles arc

Guadeloupe archipelago (latitude 16° N, longitude 61°30 W) is located in the central part of the Lesser Antilles arc that results from the subduction of the Atlantic oceanic crust under the Caribbean plate. It is composed of several islands (Fig. 1). The eastern islands (Grande-Terre, Marie-Galante), with thick calcareous platforms covering the volcanic basement, belong to the external and older part of the arc. The western island (Basse-Terre) is part of the inner and recent arc associated with active volcanoes. It is composed of seven volcanic chains or volcanic complexes built in the last 3 Ma, with a temporal

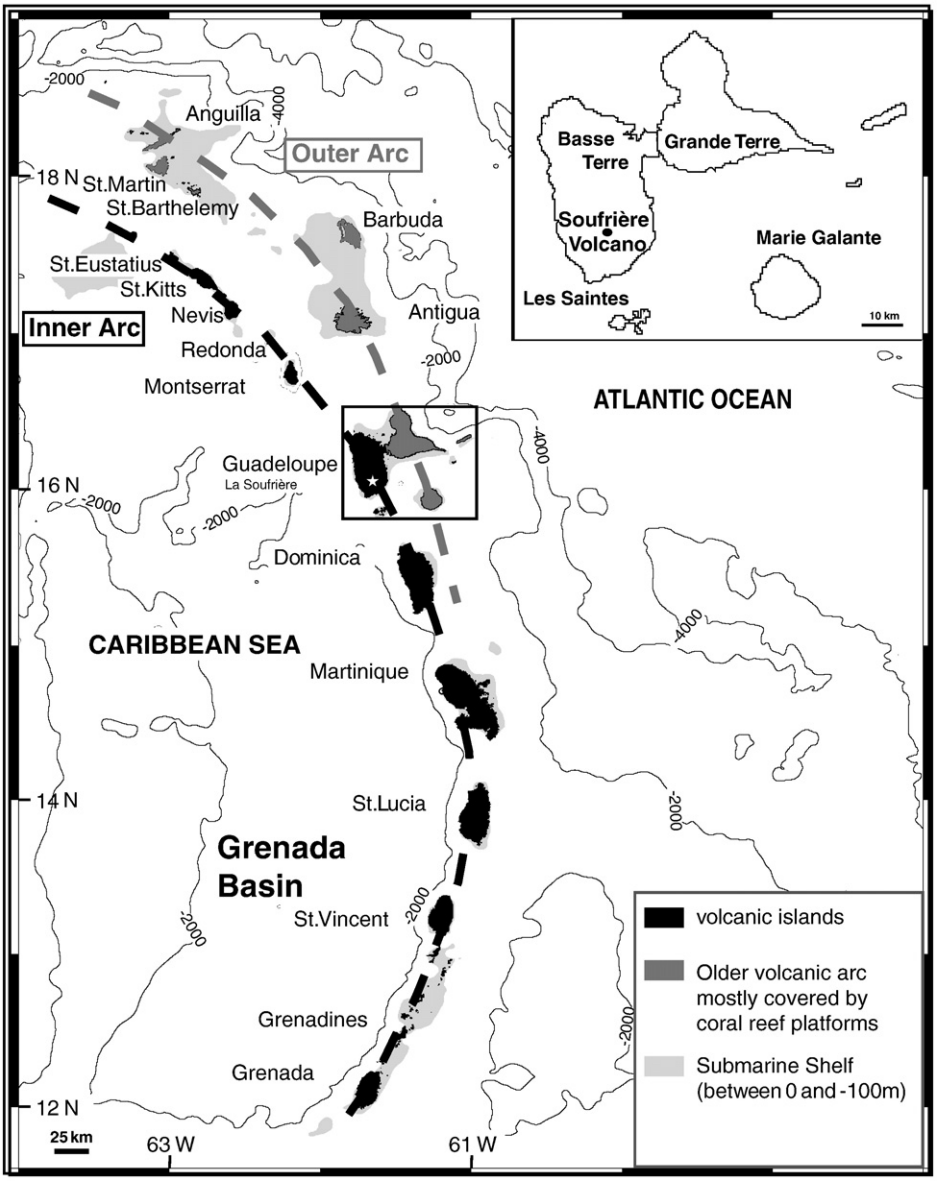

Fig. 1. The Lesser Antilles arc. Volcanic islands in black and subaerial coral reef platforms in dark grey. The 100 m depth submarine shelf is in light grey. The isobaths 2000 m and 4000 m are reported (predicted bathymetry from Smith and Sandwell, 1997). Inset: detailed map of the Guadeloupe archipelago.