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Initial sub-aerial volcanic activity along the central Lesser Antilles inner arc: New K–Ar ages from Les Saintes volcanoes

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ABSTRACT

We present new groundmass K–Ar ages obtained using the Cassignol–Gillot technique, together with whole-rock major and trace elements, from Les Saintes islands (Terre-de-Haut and Terre-de-Bas). They are located along the northern Lesser Antilles inner arc, between Basse-Terre Island (western Guadeloupe) to the North and Dominica Island to the South. Ages reveal that the main volcanic phase in Terre-de-Haut occurred between 2.98 ± 0.04 and 2.00 ± 0.03 Ma, and show that the onset of sub-aerial volcanism in Terre-de-Haut is slightly older (~0.2 Myr) than that of northern Basse-Terre. Volcanism in Les Saintes resumed to the west, with the rapid construction of Terre-de-Bas Island at 0.888 ± 0.009 Ma. Major elements analyses show that most lavas from Les Saintes belong to a sub-alkaline medium-K magmatic series and are mainly andesites, with relatively rare basaltic andesites and dacites. Rare earth elements spectra reveal a strong enrichment in light elements, as observed for Dominica lavas, and significantly higher than observed for Basse-Terre lavas. Noticeably, Terre-de-Bas spectra display more enriched patterns relative to those from Terre-de-Haut lavas, suggesting a lower degree of partial melting or a stronger sedimentary component incorporated to the subducting slab. Overall, geochemical signatures of Les Saintes and Dominica magmas display common characteristics, which we interpret as reflecting strong petrogenetic affinities, while both are significantly different from that of Basse-Terre lavas. Finally, this study provides a precise timing of subaerial volcanism of Les Saintes Islands, which can be used to better constrain through time the development of the tectonic half-graben where these islands lie, which is part of the arc-parallel en-echelon faults system accommodating the oblique convergence of the North American plate from Montserrat to Dominica. In addition, these results reveal that the initiation of Terre-de-Haut volcanism is presently the oldest dated volcanism from the northern part of the Lesser Antilles active arc.

1. Introduction

The Lesser Antilles magmatism results from the subduction of the North and South American plates beneath the Caribbean plate at a relatively low velocity of about 2 cm/yr (e.g., Hawkesworth and Powell, 1980). Two main volcanic arcs, which merge southward of Martinique, were successively produced since Late-Oligocene, with a temporal westward displacement from the outer to the inner arc (e.g., Briden et al., 1979; Westercamp, 1979; Germa et al., 2011a). The inner arc is presently active, with about 20 active volcanoes and more than 34 historical eruptions. Within the Pliocene to Quaternary inner arc (e.g., Briden et al., 1979), Les Saintes Islands (Fig. 1) represent a key target to study the onset of the inner-arc sub-aerial volcanism because only a rather small volume of magma erupted, and hence was not covered by younger activity, and it displays a prolonged activity through the Pliocene to early Pleistocene (Jacques et al., 1984). It is located to the South of Basse-Terre, the western part of Guadeloupe Island where lies the active volcano of La Soufrière, and to the North of Dominica, with its northernmost active volcano of Morne aux Diables. Whole rock K–Ar ages obtained previously for Les Saintes (Jacques et al., 1984) have been used to establish the most recent geological map (Jacques and Maury, 1988), but they can be considered as poorly reliable. Recent studies focusing on Lesser Antilles lavas demonstrated that significant bias can affect whole-rock K–Ar ages, with overestimated ages in many cases (e.g., Samper et al., 2007, 2008; Germa et al., 2011b). Therefore, it appears important to obtain new accurate ages in Les Saintes in order to constraint the timing of the earliest inner arc activity. Moreover our new petrology and geochemistry data lead us to investigate the relationship between Les Saintes volcanism and that of the still active neighbor volcanic islands of Dominica and Basse-Terre.

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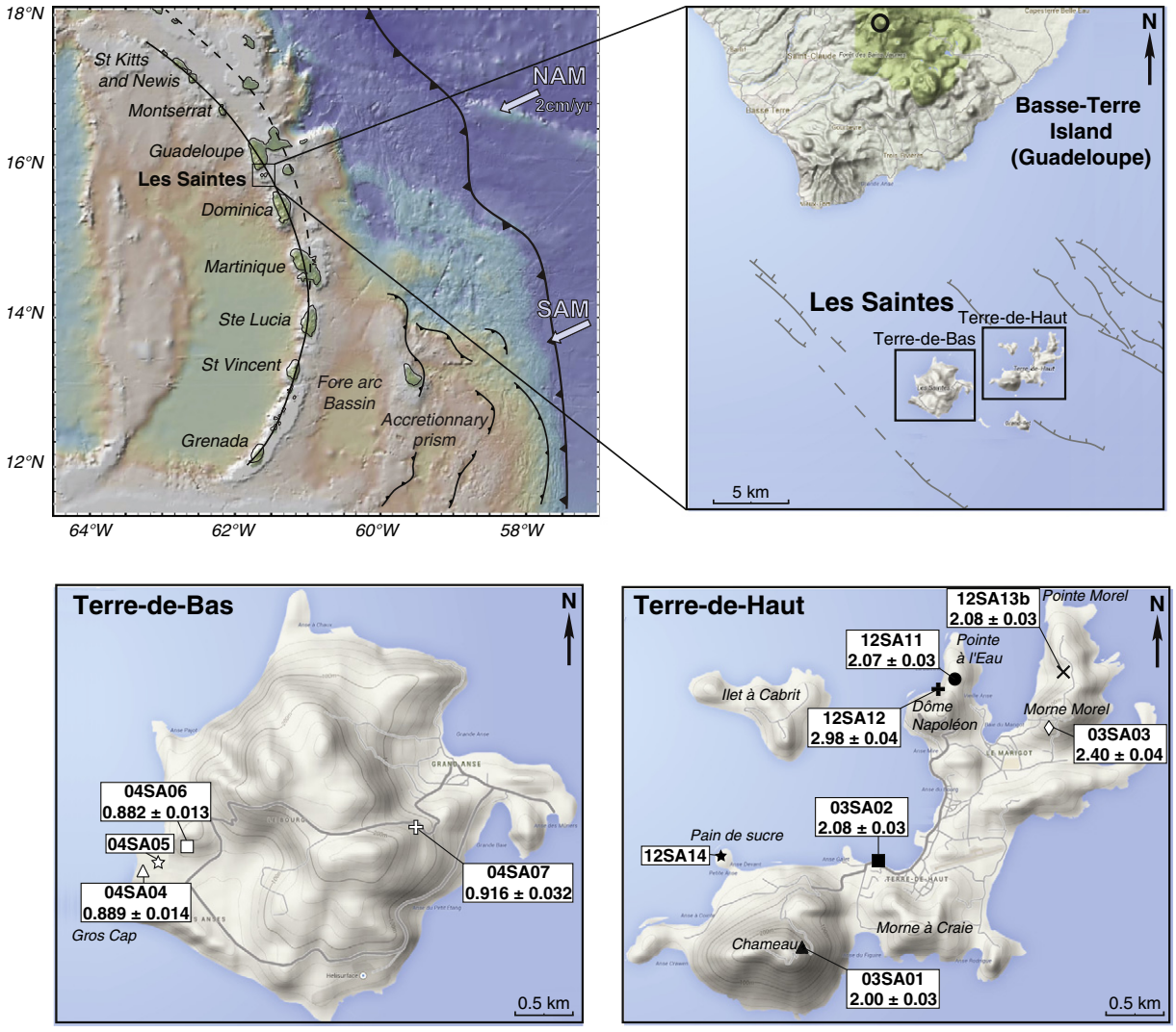

Fig. 1. Geodynamic setting of the Lesser Antilles arc. The white arrows show the subduction of the Atlantic plate under the Caribbean plate at a rate of 2 cm/yr (e.g., Macdonald et al., 2000). Bathymetry image is from GeoMapApp using bathymetry data of Smith and Sandwell (1997). The dashed and plain line shows the location of the outer older arc and the inner recent active arc, respectively. The right-side insert shows the location of Les Saintes Islands with respect to southern Basse-Terre (Guadeloupe Islands). The open circle shows the location of the active Soufrière volcano. Normal faults locations are from Feuillet et al. (2011). Left and right lower frames show the location of samples analyzed here from Terre-de-Bas and Terre-de-Haut, respectively. Ages from this study, when available, are given in Ma.

2. Geological background

Distribution of volcanism within the inner arc divides in a northern, a central and a southern arc segment, which differ by their magma production rates and their dominant composition of erupted magmas (e.g., Macdonald et al., 2000). Islands from the central arc segment, which includes Basse-Terre (Guadeloupe), Dominica and Martinique from North to South, are the most active islands and present the largest emitted volumes of the inner arc (Wadge, 1984). Magma compositions vary from tholeiitic (low-K) in the northern segment, through calc-alcaline (medium-K) in the central segment, to highly magnesian magmas approximating primary magma compositions in the southern segment (Brown et al., 1977). The dip of the Benioff zone varies from about 50° in the northern segment of the arc, to vertical in the southern segment (Wadge and Shepherd, 1984). Based on Sr, Nd, Pb isotopes signatures with continental crust similarities (e.g., White and Dupré, 1986; Carpentier et al., 2008), it has been proposed that sediments are involved in magma genesis with varying degree, depending on the island latitude. Such variation has been related to the northward decreasing terrigenous sediments thickness present onto the subducting slab, away from their source located within the Archean South-American craton (White et al., 1985), while conversely, pelagic sediment proportion increases northward. However, the origin of the sediment contamination remains debated, with either an assimilation process combined with fractional crystallization (e.g., Davidson and Harmon, 1989), or a deeper contamination of the source in the mantle wedge through sediment melting, with time varying proportion (e.g., Labanieh et al., 2010), or through enrichment in fluid-mobile elements (such as Ba, U, Sr, Pb).

The 9 km^2 Les Saintes Islands are located between Basse-Terre and Dominica, about 10 and 30 km away, respectively, within a 15 km wide tectonic basin striking N135°E parallel to the arc (Fig. 1). This active Les Saintes graben belongs to the en echelon left lateral transtensive fault system that runs along the arc (Bouysse and Westercamp, 1990; Feuillet et al., 2001, 2002; Bazin et al., 2010), and accommodates the oblique component of the subducting plate. This fault system was reactivated in 2004 during the Mw = 6.3 Les Saintes earthquake (Feuillet et al., 2011). Les Saintes archipelago consists of two main volcanic islands, Terre-de-Haut and Terre-de-Bas, which have a rather limited eruption rate compared to other islands from the central segment of the inner arc. Based on whole-rock K–Ar ages, Jacques et al. (1984) and Jacques and Maury (1988) documented five distinct construction phases and proposed that magmatic activity was continuous