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The Holocene drowned reef of Les Saintes plateau as witness of a long-term tectonic subsidence along the Lesser Antilles volcanic arc in Guadeloupe

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ABSTRACT

Resulting from the interplay between tectonics and eustatism, reef terraces are powerful markers of vertical movements at a scale of 1000 to 100,000 years. In the Lesser Antilles, they grow around every island of the archipelago and record both local and subduction-related tectonics. The recent acquisition and interpretation of very high-resolution bathymetry of Les Saintes submarine plateau, French West Indies, together with seismic reflection profiles, are a unique opportunity to study one of these submarine structures, at metric to kilometric scales, addressing the questions of its nature, age and growth environment, but also of the control of active tectonics on its formation. The 20 km wide Les Saintes reef plateau lies at about 45 mbsl. It is crosscut by NW–SE striking, north-dipping normal faults that belong to Les Saintes fault system and graben, which produced a Mw 6.3 earthquake in 2004. The plateau is composed of four 20 m thick reef units, piled up in "layer cake" morphology down to 110 mbsl. The upper unit has a fresh morphology and presents typical reef features, like barrier and lagoon, spurs and grooves, pinnacles, etc. From its morphology we propose that it grew during the Holocene last transgression. Below, the three other units likely formed during Pleistocene sea level highstands and were eroded during the low stands, as evidenced in seismic reflection profiles. This scenario would imply that Les Saintes plateau formed in a context of subsidence with a rate we evaluate to be of the order of tenths of mm/yr. Probably linked to local tectonics, we believe that this deformation is also related to plate-scale subduction processes, similarly to deformations occurring on the other islands of the Guadeloupe archipelago.

1. Introduction

Nowadays, submarine reef formations are investigated worldwide thanks to bathymetry, imagery, dredging and coring, 3.5 kHz and seismic reflection profiles (e.g. Cabioch et al., 2003; Beaman et al., 2008; Webster et al., 2009). Onshore or submarine terraces are described and studied to retrieve paleo-sea level, to measure coral growth response to environmental changes, and to understand their geomorphology with respect to Quaternary sea level variations. As terraces geometry is sensitive to vertical deformation, different authors also studied them to retrieve vertical motion of the coasts over different time scales and in various tectonic regimes (in subduction context, e.g. Taylor et al., 1980; Taylor and Mann, 1991; Hantoro et al., 1994; Pandolfi et al., 1994; in extensional context: e.g. Armijo et al., 1996; Feuillet et al., 2004; Flamand, 2006).

Extensive submarine carbonate platforms surround the islands of the Lesser Antilles arc (Macintyre, 1972; Bouysse and Martin, 1980), which results from the subduction of the North and South American plates (NAM–SAM) under the Caribbean plate (Fig. 1). At regional scale, they may record active deformation related to subduction processes. At more local scale, they are crosscut by active normal and oblique faults that accommodate the oblique convergence of the plates (Feuillet et al., 2001, 2002, 2010). These reefs are powerful marker of tectonic deformation at all scales and may be used to constrain faulting kinematics.

We focused our study on a large submarine plateau around Les Saintes islands in the Guadeloupe archipelago. Numerous high resolution geophysical data were acquired following a Mw 6.3 earthquake that occurred just south of the plateau on November 21, 2004, along a 20 km long submarine normal fault (Roseau fault, Bazin et al., 2010; Feuillet et al., 2011a).

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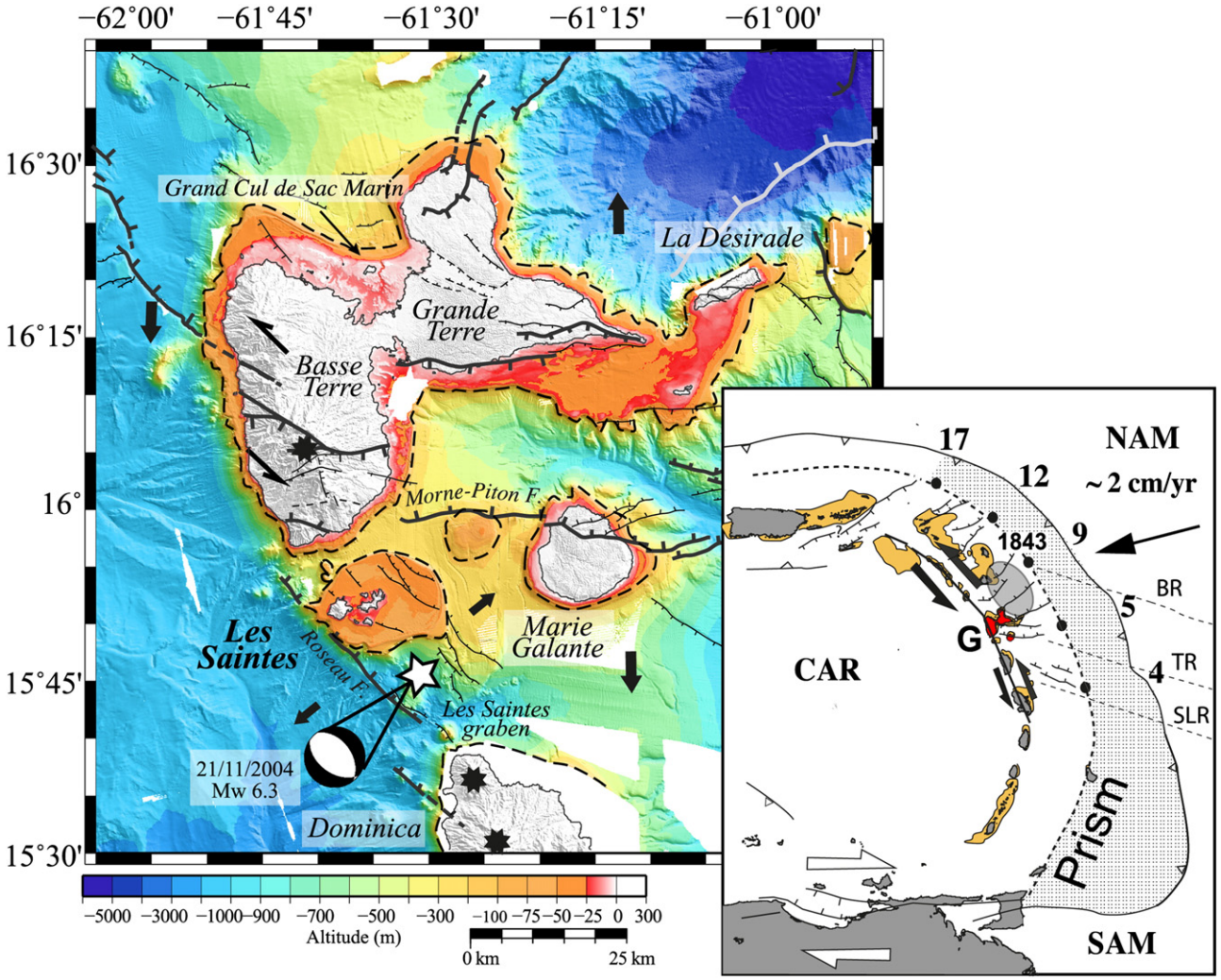

Fig. 1. Tectonic context of the Guadeloupe archipelago. Active faulting around Guadeloupe modified from Feuillet et al. (2010). Topography from IGN and bathymetry from AGUADOMAR data. Dashed black lines indicate the shallow submarine carbonate platforms. Location (white star) and focal mechanism of the Mw 6.3 Les Saintes earthquake from Feuillet et al. (2011a). Black stars indicate active volcanic centers. Inset: Lesser Antilles geodynamic context modified after Feuillet et al. (2010). Vector of convergence between the North and South American plates (NAM–SAM) and the Caribbean plate (CAR) from DeMets et al. (2000). Guadeloupe archipelago in red. Submarine carbonate platforms in orange. Numbers and dots along the backstop (dashed line after Bowin, 1976) represent the trench-parallel component of shear that increases from 4 to 17 mm/yr between Martinique and Saba, after Feuillet et al. (2010) and Lòpez et al. (2006). Supposed rupture area of the 1843 earthquake after Feuillet et al. (2011b). BR: Barracuda Ridge, TR: Tiburon Rise, SLR: St Lucia Ridge. G: Guadeloupe.

Thanks to the new geophysical data, we have the opportunity to study one of the extensive submarine carbonate platforms of the Lesser Antilles arc, in unprecedented detail. We aim to characterize the control of carbonate platform development and reef growth by active regional tectonics, in this area where various subduction processes drive deformation. We describe the fine morphology of the plateau as well as its inner structure. Both result from the interplay between sea-level change and tectonics. We thus question its formation and propose a building chronology with regard to Holocene environmental, climatic and tectonic influences.

2. Data and methods

2.1. Cruise BATHYSAINTES and the data set

From 1 to 10 February 2010, cruise BATHYSAINTES (PIs: C. Deplus and N. Feuillet) surveyed Les Saintes archipelago seafloor, between Guadeloupe and Dominica, aboard the French N/O *Pourquoi Pas?* (Ifremer/French Navy) and SHOM's hydrographic launch *Pelican*. The main goal of the cruise was to acquire very high-resolution bathymetry on Les Saintes submarine plateau and in Les Saintes graben between Les Saintes and Dominica. In addition, the echo sounders provided metric-resolution backscatter images. At the same time, we acquired chirp subbottom profiles, gravity data and HR side-scan sonar imagery.

Three multibeam echo sounders were used during cruise BATHYSAINTES depending on the seafloor depth: the Reson Seabat 7111 echo sounder (100 kHz) of the N/O *Pourquoi Pas?* provided a bathymetric data set between 30 and 200 mbsl (meter below sea level; i.e. the plateau's depth) with a horizontal resolution of 1.25 m at a depth of 50 m. The Reson Seabat 7150 echo sounder (24 kHz) of the N/O *Pourquoi Pas?* provided bathymetric data of the seafloor deeper than 200 m with a horizontal resolution of 8.5 m at a depth of 1000 m (i.e. Les Saintes graben). The Kongsberg EM3002 echo sounder of the *Pelican* was used to acquire very shallow bathymetry (2–30 m deep) of the plateau between Les Saintes islands and provided a very high-resolution data set with a horizontal accuracy of 50 cm at a depth of 20 m.

Bathymetric data were processed using the CARAIBES software (Ifremer). We constructed a DEM of the whole plateau with 5 m horizontal resolution. Vertical accuracy is usually equivalent to 0.1 to 0.2% of the depth, namely 10 cm at 50 mbsl and 2 m at 1000 mbsl.