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Last millennium sedimentation in the Gulf of Cariaco (NE Venezuela): Evidence for morphological changes of gulf entrance and possible relations with large earthquakes

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ABSTRACT

The Cariaco Basin and the Gulf of Cariaco in Venezuela are two major basins along the seismogenic El Pilar right lateral fault, among which the Cariaco Basin is a pull-apart. Both basins are sites of anoxia and organic-rich deposits. To examine whether the sediments in the Gulf of Cariaco have recorded traces of historical or prehistorical earthquakes, we extracted and analyzed twelve 1 m-long gravity cores, sampling the last millennium sedimentation. We focused on analyzing the sediment sources with different techniques (particle size analysis, XRF, loss on ignition tests, magnetic properties, Rock-Eval pyrolysis, ^{14}C dating). The results confirm that major upwelling occurs at the western gulf entrance and makes deep water flowing from the Cariaco Basin into the Gulf of Cariaco. These flows carry an organic-rich suspended load. Furthermore, we found evidence of a particular, widespread fine-grained siliciclastic deposit (named SiCL3) within the gulf, whose age suggests that it likely formed during the large 1853 AD earthquake that stroke the Cumaná city. We suggest that the earthquake-induced large submarine landslides that modified the topography of the gulf's entrance, which in turn promoted upwelling and open marine water flows from the Cariaco Basin. The layer SiCL3 would be the sediment load remobilized during this chain of events.

Introduction

The relative displacement between the South America and the Caribbean plates is mainly accommodated along the right lateral strike slip San Sebastian-El Pilar fault system, at the northern boundary of Venezuela (Fig. 1; Audemard et al., 2000, 2005; DeMets et al., 2000; Pérez et al., 2001; Stéphan et al., 1990; Symithe et al., 2015; Weber et al., 2001). In the eastern part of the fault system, named El Pilar fault or EPF, the plate boundary fault is underlined by a 1400 m-deep, 160 km-long, 50 km-wide, pull-apart basin, the Cariaco Basin (also named Cariaco Trough) (Schubert, 1979, 1982). Further east, the Gulf of Cariaco is a smaller (65 km-long, 15 km-wide) and shallower (85 m-deep) basin, connected to the Cariaco Basin. The former developed directly upon and along the EPF, on the northern side. The EPF fault accommodates most of the relative plate motions through a combination

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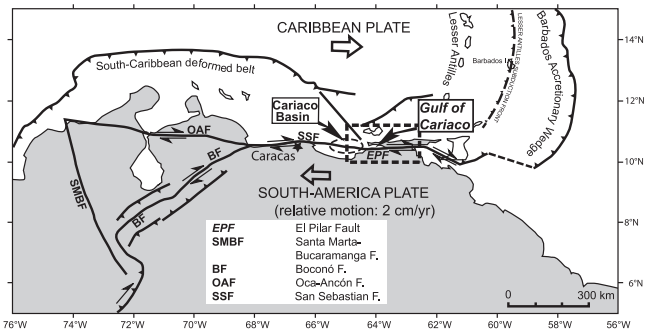

Fig. 1. Tectonic setting of the Gulf of Cariaco. Active faults from Audemard et al. (2000, 2005), DeMets et al. (2000), Pérez et al. (2001), Weber et al. (2001), Symithe et al. (2015).

of creep (~60%) and co-seismic offsets (~40%) (Audemard, 2007; Jouanne et al., 2011; Reinoza et al., 2015). The EPF fault has in particular produced large earthquakes (i.e. with estimated MSK intensities of IX/X; Audemard, 2007) over the last centuries; most have seriously affected the city of Cumaná (location in Fig. 2). In an attempt to estimate the seismogenic potential of the EPF fault, many studies have been conducted in the last decades, most were led by the Venezuelan Foundation for Seismological Investigations. Since the main section of the EPF fault (named "VE-13b" by Audemard, 2007) is offshore (Fig. 2), multiple high-resolution seismic reflection data have been acquired to analyze the fault and to search for information on its historical and prehistorical ruptures (Audemard et al., 2007; Van Daele et al., 2011). Subaqueous paleoseismology has also been conducted, using approaches previously developed along other seismogenic faults in Venezuela (Carrillo et al., 2008). These studies analyze the sedimentary content in short "gravity cores" (~1 m long) so as to search and identify sedimentary changes that might have resulted from large earthquake motions, as it was observed right after the most recent large earthquake in the area (M_w 6.9 Cariaco earthquake, Lorenzoni et al., 2012; Thunell et al., 1999).

The present paper focuses on this question, and explores the possible sedimentary signature of large historical earthquakes in the Gulf of Cariaco and in the eastern part of the Cariaco Basin. The eastern region of the Cariaco basin is interesting because it marks the entrance to the Gulf of Cariaco, and it is the site of a steep, 400 m-high, ~north–south-trending escarpment at the western edge of the Manzanares River delta (MRd in Fig. 2). The MRd delta is where the Cumaná city has developed. This delta is crosscut by the EPF fault. Therefore, we might expect that large historical and prehistorical earthquakes on the EPF fault in the area of Cumaná have disturbed the nearby eastern part of the Cariaco Basin, with possible consequences on the sedimentation within the Gulf of Cariaco.

To examine these hypotheses, we analyze the sedimentary content of 12 cores extracted in the Gulf of Cariaco. We focus on determining the sediment sources (based on mineralogy and geochemistry) and their distribution pattern. Previous results have suggested that upwelling at the basin–gulf junction significantly controlled the sediment sources (Gade, 1961; Okuda, 1981, 1982; Okuda et al., 1974, 1978). In turn, part of the upwelling might have been enhanced by historical large

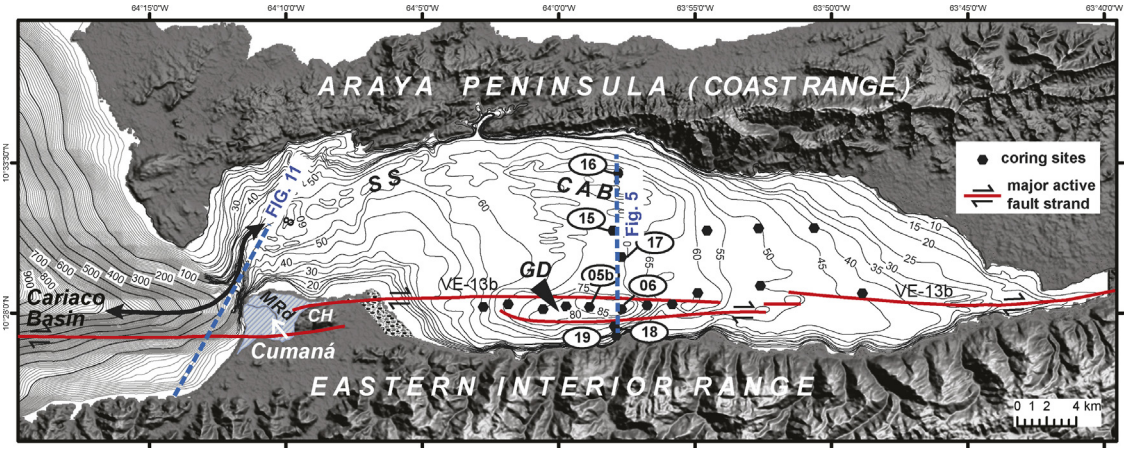

Fig. 2. (Color online). Geomorphic setting of the Gulf of Cariaco and of its connection with the Cariaco Basin. SS: Salazar Sill; CAB: Cerro Abajo Basin; GD: Guaracayal Deep; MRd: Manzanares River delta; CH: Caiguïre Hills. Bathymetry simplified from Caraballo (1982a). Shaded-relief map from Garrity et al. (2004).

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