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Pb–Nd isotopic constraints on sedimentary input into the Lesser Antilles arc system

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ABSTRACT

The Lesser Antilles arc is a particularly interesting island arc because it is presently very active, it is located perpendicular to the South American continent and its chemical and isotopic compositions display a strong north–south gradient. While the presence in the south of a thick pile of sedimentary material coming from the old South American continent has long been suspected to explain the geochemical gradient, previous studies failed to demonstrate unambiguously a direct link between the arc lava compositions and the subducted sediment compositions.

Here, we present new Nd, Sm, Th, U and Pb concentrations and Nd–Pb isotopic data for over 60 sediments from three sites located in the fore arc region of the Lesser Antilles arc. New data for DSDP Site 543 drill core located east of Dominica Island complement the data published by White et al. [White, W.M., Dupré, B. and Vidal, P., 1985. Isotope and trace element geochemistry of sediments from the Barbados Ridge–Demerara Plain region, Atlantic Ocean. Geochimica et Cosmochimica Acta, 49: 1875–1886.] and confirm their relatively uniform isotopic compositions (i.e., $^{206}Pb/^{204}Pb$ between 19.13 and 19.53). In contrast, data obtained on DSDP Site 144 located further south, on the edge of the South American Rise and on sediments from Barbados Island are much more variable ($^{206}Pb/^{204}Pb$ ranges from 18.81 to 27.69). The very radiogenic Pb isotopic compositions are found in a 60 m thick black shale unit, which has no age equivalent in the Site 543 drill core. We interpret the peculiar composition of the southern sediments as being due to two factors, (a) the proximity of the South American craton, which contributes coarse grain old detrital material that does not travel far from the continental shelf, and (b) the presence of older sediments including the thick black shale unit formed during Oceanic Anoxic events 2 and 3.

The north–south isotopic change known along the Lesser Antilles arc can be explained by the observed geographical changes in the composition of the subducted sediments. About 1% contamination of the mantle wedge by Site 543 sediments explains the composition of the northern islands while up to 10% sediments like those of Site 144 is required in the source of the southern island lavas. The presence of black shales in the subducted pile provides a satisfactory explanation for the very low Δ8/4 values that characterize the Lesser Antilles arc.

1. Introduction

Magma in subduction zones results from melting of the mantle wedge, modified by material transferred from the subducted slab in hydrous fluids and/or partial melts. Thus, subducted oceanic crust and sediments are believed to influence the chemical composition of island arcs. Constraining the chemical composition of the input flux (i.e., subducted components) can therefore help understanding the role or such material in arc magma genesis.

Lavas in the Lesser Antilles arc (Fig. 1) exhibit a large range of Sr–Nd–Pb isotopic compositions which include the most radiogenic Pb isotopic compositions known for intra-oceanic arcs. They are also characterized by a pronounced chemical zoning from north to south along the arc (Hawkesworth and Powell, 1980; White and Dupré, 1986; Davidson, 1987; Turner et al., 1996), with the highest Pb isotope ratios and lowest Nd isotope ratios being found in the southern islands (Fig. 1). Such characteristics have been attributed to variable input in the magmas of crustal material located either in the arc crust or in the subducted sedimentary pile (i.e., Davidson, 1987; White and Dupré, 1986; Davidson and Harmon, 1989; Thirlwall et al., 1996; Turner et al., 1996).

Previous geochemical studies of subducting sediments along the Lesser Antilles arc focused on one site drilled during DSDP Leg 78A, and on surface sediments from a large area in front of the Lesser Antilles trench (White et al., 1985). These authors suggested that the isotopic compositions of both surface and drilled sediments were strongly influenced by detrital input from the South American continent, in particular, the Guyana Precambrian shield via the Orinoco River (White et al., 1985). They also highlighted an increase in Pb isotope ratios in the surface sediments southward, toward the

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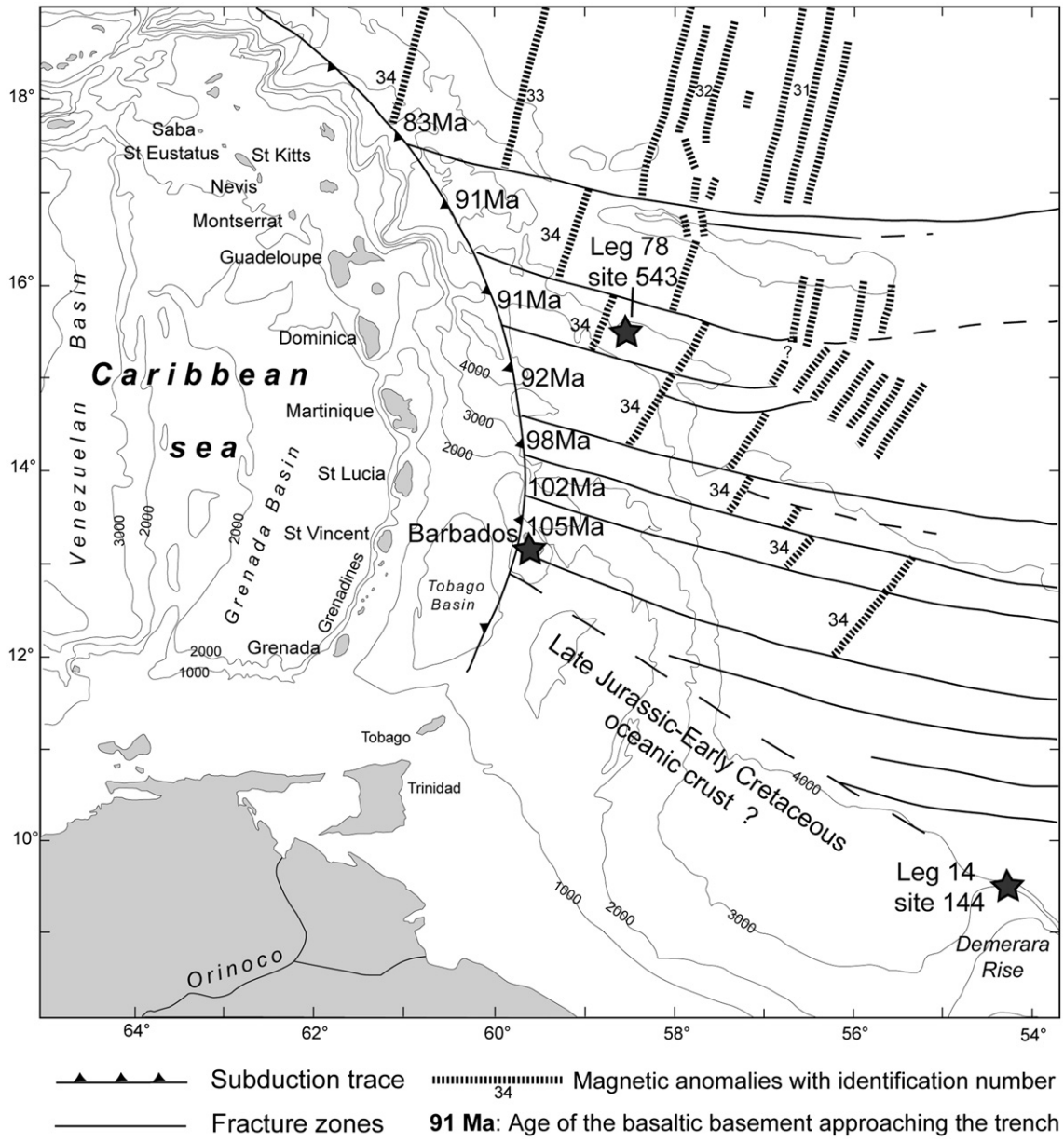

Fig. 1. Bathymetric map of the studied area showing the locations of the three sampled sites (DSDP 78A Site 543, DSDP 14 Site 144 and Barbados Island shown with stars). The major oceanic magnetic anomalies and fracture zones in the Atlantic crust are also shown (modified from Speed et al., 1984). The age of the subducting slab is indicated next to the trench and was calculated using a Cretaceous half-spreading rate of 2.2 cm/yr for the middle Atlantic ridge (Cogné and Humler, 2004) and the distance to the magnetic anomaly 34.

mouth of the Orinoco River, and attributed this gradient to an increasing input of radiogenic Pb derived from the shield.

However, when the isotopic compositions of Lesser Antilles lavas are compared with those of the soon-to-be subducted sediments of White et al. (1985), it appears clearly that some lavas from the southern islands have Pb isotope ratios that are more radiogenic than the sediments. While all studies agree that variable amounts (and/or compositions) of sediments are the cause of the observed geochemical variations, the manner in which the sedimentary signature was introduced into the lavas is still discussed: it could be "contamination" of the mantle wedge by subducted sediments as suggested by White and Dupré (1986), Vidal et al. (1991) and Turner et al. (1996), or it could be high-level contamination of the magmas by sediments intercalated within the arc crust as suggested by Thirlwall and Graham (1984), Davidson (1985, 1986, 1987), Davidson and Harmon (1989), Smith et al. (1996) and Thirlwall et al. (1996). White and Dupré (1986) suggested that sediments with more radiogenic Pb compositions might exist in deep horizons south of Site 543, as observed in surface sediments (White et al., 1985) and their involvement in the source of magmas below the southern islands would explain the Pb-radiogenic signature of southern islands. Such sediments, with the required Pb-radiogenic composition, have not yet been identified; neither on the subducting plate nor in the sedimentary components of the arc crust (Thirlwall et al., 1996).

The aim of this work is therefore to determine whether a north–south chemical variation exists within the sediment cover on the subducting oceanic crust. We report new Nd–Pb isotope analyses on sediments from three sites: (a) DSDP 78A Site 543, which is located in front of Dominica Island. These data complement the pioneering results of White et al. (1985) which concentrated in the 230–280 m depth range of the sedimentary pile (b) Sediments drilled on the Demerara Rise at Site 144 during DSDP Leg 14 (see Fig. 1) at a latitude of about 9.4 °N (c) Sediments from Barbados Island on the accretionary prism in front of St Vincent Island. The comparison between the three