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Geochemical environment of the Coniacian–Santonian western tropical Atlantic at Demerara Rise

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ABSTRACT

Organic carbon-rich shales deposited during the Coniacian–Santonian Oceanic Anoxic Event 3 were drilled during ODP Leg 207 at Demerara Rise. We present integrated high-resolution geochemical records of core intervals from ODP Sites 1259 and 1261 both from nannofossil biozone CC14. Our results reveal systematic variations in marine and detrital sediment contribution, depositional processes, and bottom water redox conditions during black shale formation at two locations on Demerara Rise in different paleo-water depths. A combination of redox proxies (Fe/S, P/Al, C/P, redox-sensitive/sulfide-forming trace metals Mn, Cd, Mo, Ni, V, Zn) and other analytical approaches (bulk sediment composition, P speciation, electron microscopy, X-ray diffraction) evidence anoxic to sulfidic bottom water and sediment conditions throughout the deposition of black shale. These extreme redox conditions persisted and were periodically punctuated by short-termed periods with less reducing bottom waters irrespective of paleo-water depth. Sediment supply at both sites was generally dominated by marine material (carbonate, organic matter, opal) although relationships of detrital proxies as well as glauconitic horizons support some influence of turbidites, winnowing bottom currents and/or variable detritus sources, along with less reducing bottom water at the proposed shallower location (ODP Site 1259). At Site 1261, located at greater paleo-depth, redox fluctuations were more regular, and steady hemipelagic sedimentation sustained the development of mostly undisturbed lamination in the sedimentary record. Strong similarities of the studied deposits exist with the stratigraphic older Cenomanian–Turonian OAE2 black shale sections at Demerara Rise, suggesting that the primary mechanisms controlling continental supply and ocean redox state were time-invariant and kept the western equatorial Atlantic margin widely anoxic over millions of years.

1. Introduction

Since Schlanger and Jenkyns (1976) introduced the original concept of Oceanic Anoxic Events (OAEs), much progress has been made in the understanding of the widespread deposition of organic matter (OM)-rich sediments in the Cretaceous Proto-Atlantic and adjacent seas. During ODP Leg 207, up to 90 m thick Cretaceous black shale deposits, including OAE2 and OAE3 were recovered from Demerara Rise (Erbacher et al., 2004; Mosher et al., 2007). Cenomanian–Turonian OAE2 black shales from ODP Leg 207 have been subject of intensive research (e.g. Erbacher et al., 2005; Friedrich et al., 2006; Hardas and Mutterlose, 2006; Musavu-Moussavou and Danelian, 2006; Forster et al., 2007a; Junium and Arthur, 2007; Nederbragt et al., 2007) whereas far less is known about the development of the later Coniacian–Santonian OAE3 in this critical area of the tropical North Atlantic (Friedrich and Erbacher, 2006; Beckmann et al., in press; März et al., in press). Given that OAE3 sediments from the adjacent tropical African margin (Deep Ivory Basin, ODP Leg 159) revealed spectacular evidence of astronomically forced sedimentary and redox cycles directly associated with African climate variability (Wagner, 2002; Wagner et al., 2004; Beckmann et al., 2005a,b; Flögel and Wagner, 2006) and the opening of the Equatorial Atlantic (Wagner and Pletsch, 1999; Pletsch et al., 2001) there is scope for more detailed investigation of this stratigraphic interval at Demerara Rise. First geochemical studies revealed that Demerara Rise black shales contain thermally immature marine OM (Meyers et al., 2006; Forster et al., 2007b). Its slow degradation still produces methane, which is anaerobically oxidized at the top of the Cretaceous black shale succession via sulfate reduction, resulting in sulfate depletion and long-lasting barite remobilization within the

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black shale succession (Erbacher et al., 2004; Arndt et al., 2006). High degrees of pyritization, but also sulfurized OM (Böttcher et al., 2006), enrichments of Mo, V, Zn, and Mn depletion (Hetzel et al., 2006) indicate overall oxygen-depleted, periodically even sulfidic bottom waters. Enrichments of P as well as high amounts of Ba (despite diagenetic redistribution) support enhanced nutrient supply and high productivity during black shale deposition (Arndt et al., 2006; Hetzel et al., 2006). We recently explored a broad variety of redox proxies in OAE3 black shales at ODP Site 1261. The records are consistent and show cyclic and rapid redox fluctuations from sulfidic to anoxic, non-sulfidic conditions in bottom waters (März et al., in press) obviously triggered astronomically by short eccentricity cycles (Flögel et al., in press).

In this study we add evidence to the findings of the Cretaceous low latitude Atlantic by applying a wide analytical spectrum in high temporal resolution to ODP Sites 1259 and 1261 from Demerara Rise. The main goal is to trace changes in deep ocean redox state, sediment sources and depositional processes along a bathymetric transect across the S-American continental margin. To achieve these goals we selected nannofossil biozone CC14 intervals from both sites and applied major and trace element geochemistry, P speciation, X-ray diffraction, and scanning electron microscopy. For completeness, some of the results presented by März et al. (in press) are shown here, however, we emphasize that this study takes the discussion forward by comparing synchronous stratigraphic intervals from two different paleo-water depths, and by adding new geochemical information on sediment sources and depositional processes. To place the results from OAE3 into wider perspective we compare them with new geochemical data from OAE2 at Demerara Rise (Brumsack, 2006; Junium and Arthur, 2007; Hetzel et al., 2009).

2. Material and methods

The ODP Leg 207 Sites 1259 and 1261 were drilled on Demerara Rise, in water depths of 2354 m and 1899 m on the northern and northwestern slope, respectively (Fig. 1; Erbacher et al., 2004). For this high-resolution study, we chose core intervals from Sites 1259 (499.60–500.61 meters composite depth, mcd, 101 cm) and 1261 (570.20–571.40 mcd, 120 cm) and sampled them in continuous 1 cm resolution. For comparison we selected intervals from the same stratigraphic nannofossil biozone CC14 (Coniacian–Santonian), using the nannofossil stratigraphy published by Erbacher et al. (2004) that was recently refined by Flögel et al. (in press) for Site 1261 and by Bornemann et al. (2008) for Site 1259. Sedimentation rates were ~5.4 mm/ka at Site 1261 (Flögel et al., in press), and ~2–3 mm/ka at Site 1259 (Bornemann et al., 2008). Thus, both sampled intervals are

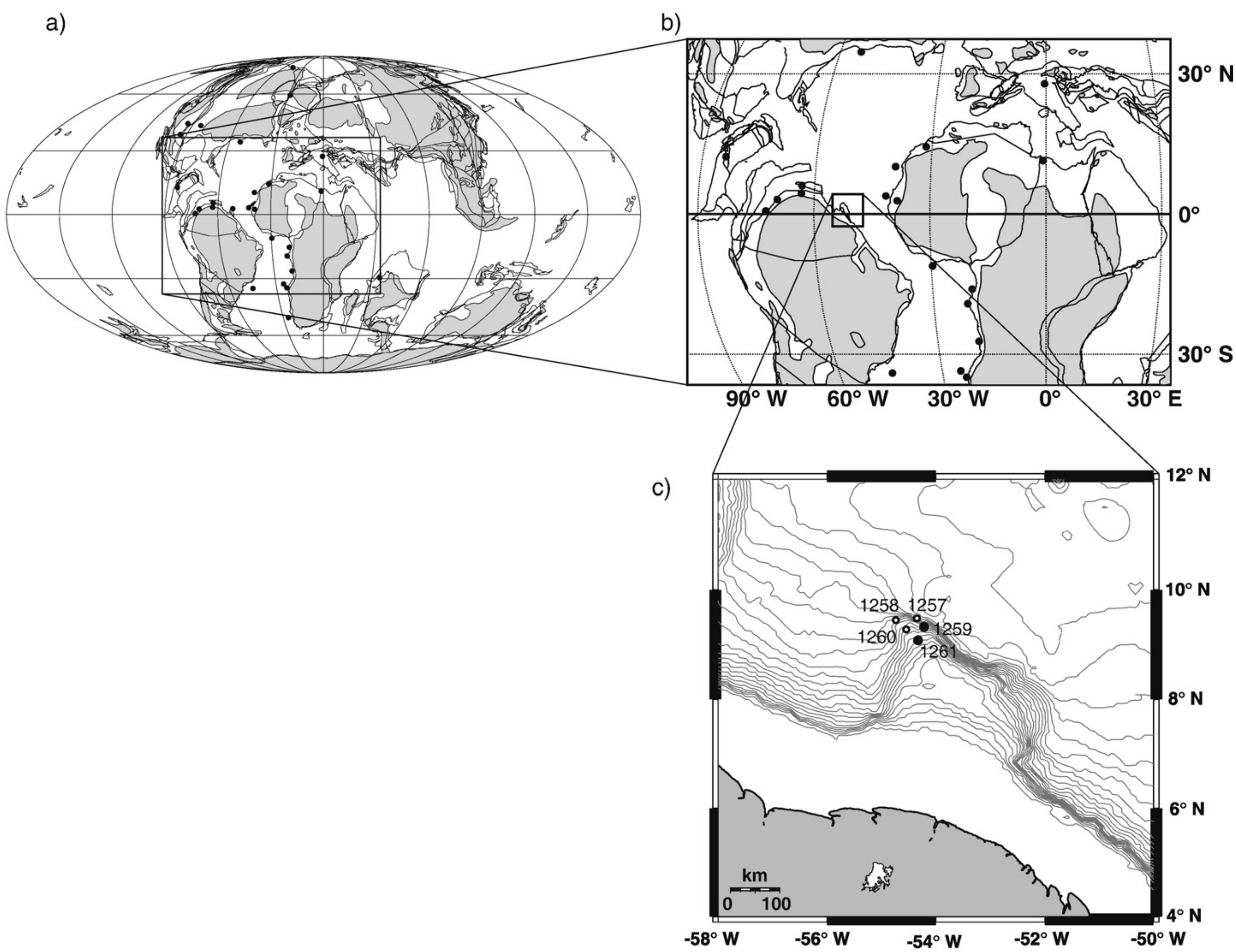

Fig. 1. a) Global plate-tectonic reconstruction for 80 Ma BP (after Hay et al., 1999; Wagner et al., 2004). Grey areas represent regions above sea level, white areas represent oceans, black lines depict plate boundaries. Black dots indicate locations of reported Late Cretaceous organic matter-rich deposits (Wagner et al., 2004 and references therein). b) Close-up of the equatorial Proto-Atlantic, with Demerara Rise marked by the black rectangle. c) Present-day bathymetry of Demerara Rise, with drill sites 1257–1261.