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Siliceous phytoplankton response to a Middle Eocene warming event recorded in the tropical Atlantic (Demerara Rise, ODP Site 1260A)

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ABSTRACT

The Middle Eocene diatom and silicoflagellate record of ODP Site 1260A (Demerara Rise) is studied quantitatively in order to throw light on the changes that siliceous phytoplankton communities experienced during a Middle Eocene warming event that occurred between 44.0 and 42.0 Ma. Both Pianka's overlap index, calculated per couple of successive samples, and cluster analysis, point to a number of significant turnover events highlighted by changes in the structure of floristic communities. The pre-warming flora, dominated by cosmopolitan species of the diatom genus *Triceratium*, is replaced during the warming interval by a new and more diverse assemblage, dominated by *Paralia sulcata* (an indicator of high productivity) and two endemic tropical species of the genus *Hemiaulus*. The critical warming interval is characterized by a steady increase in biogenic silica and a comparable increase in excess Ba, both reflecting an increase in productivity. In general, it appears that high productivity not only increased the flux of biogenic silica, but also sustained a higher diversity in the siliceous phytoplankton communities. The microflora preserved above the critical interval is once again of low diversity and dominated by various species of the diatom genus *Hemiaulus*. All assemblages in the studied material are characterized by the total absence of continental and benthic diatoms and the relative abundance of neritic forms, suggesting a transitional depositional environment between the neritic and the oceanic realms.

1. Introduction

Palaeogene siliceous phytoplankton have been fairly well studied from a taxonomic and biostratigraphic point of view (Mukhina, 1976; Fenner, 1978, 1984, 1985, 1991; Jousé, 1982; Perch-Nielsen et al., 1985; Fourtanier, 1991; Baldauf, 1992), but the floral response to environmental changes during the Palaeogene is less well reported. A noticeable exception is the Middle and Late Eocene increase in diatom provincialism (reported by Fenner 1985), which could be at the origin of some floristic renewal events (Baldauf, 1992; Barron, 1993).

Previously, one of the main difficulties for the study of the siliceous phytoplankton response to Palaeogene climate change was due to the paucity of continuous diatomaceous sedimentary sequences recovered from the oceanic realm. The presence of well-preserved diatom assemblages in an expanded Middle Eocene sequence recovered from Demerara Rise in the equatorial Atlantic (Danelian et al., 2007) offers the first opportunity to explore the response of the siliceous phytoplankton (mainly diatoms) in relation to a warming event recognised by Sexton et al. (2006) based on material from Demerara Rise (ODP Site 1260).

The Eocene is a period of climatic transition, characterized by a progressive drop in global temperatures, between the Early Eocene Climatic Optimum and the Antarctic glaciations at the Eocene/Oligocene transition. However, this progressive cooling trend was interrupted by several short-lived warming reversals, such as the Middle Eocene Climatic Optimum (MECO; Bohaty and Zachos, 2003), a *ca.* 500 Ka event that occurred at about 40.0 Ma (just above the base of magnetochron C18n.2n; Bohaty et al., 2009). The recent evaluation of the MECO's timing by Bohaty et al. (2009) suggests that the warming reversal, recognised by Sexton et al. (2006) between 44.0 and 42.0 Ma (based essentially on the magnetostratigraphic control provided by Suganuma and Ogg, 2006 and in combination with the biostratigraphic constraints published in Erbacher et al., 2004), represents an earlier warming event in the climate history of the Middle Eocene.

Based on a quantitative micropalaeontological analysis of the siliceous phytoplankton record from ODP Site 1260, this study aims to describe the changes that can be observed in the structure of the siliceous floristic assemblages recorded across the 44.0–42.0 Ma warming event. Understanding the environmental changes that may have been at the origin of the floral turnover is another question that is explored in this work using

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both biotic and geochemical proxies (i.e. barium). We also improve our understanding of the palaeoenvironmental conditions that prevailed during the Middle Eocene in the western part of the equatorial Atlantic.

2. Stratigraphic framework

Demerara Rise (ODP Leg 207) is a continental shelf off the coast of Surinam (Fig. 1). Site 1260A was drilled on the north-western slope of the shelf, at 2549 m depth. The locality is situated today at a latitude of 9°N, but during the Middle Eocene it was much closer to the equator (1°N, Suganuma and Ogg, 2006). The Middle Eocene record of Site 1260 is composed of a calcareous nannofossil chalk that is enriched in biogenic silica (Danelian et al., 2005) and it appears to be continuous between the magnetochrons C21r and C18r. The sequence is also very expanded, with an average sedimentation rate estimated as 20 m/My (Erbacher et al., 2004). The studied interval contains 19 cores (1260A-24R to 1260A-6R); according to Sexton et al. (2006), who based their isotopic study on benthic foraminifera of Site 1260, the critical warming interval is recorded between the lower part of core 15R and the bottom of core 10R.

3. Materials and methods

3.1. Siliceous phytoplankton

Following initial observations on smear slides of 62 samples, 58 levels were selected to be studied quantitatively based on strewn slide preparations (Table 1; Fig. 2). Samples were processed according to the preparation method described by Schrader and Gersonde (1978): 1 to 2 cm^3 of sediments were placed in a beaker with 0.2 L of water and 0.05 to 0.1 L of hydrogen peroxide (~10%), then heated for *ca.* 1 h; the solution was then cooled and left to settle overnight; 0.05 to 0.1 L of hydrochloric acid (~30%) was then added; when all carbonates were dissolved, the solution was left to settle overnight; the following day most of the water was removed very carefully, without disturbing the settled residue. The beaker was filled again with 0.2 L of fresh water and left to settle for over 1.5 h. Most of the water was again removed, leaving the solution in water of approximately 2 cm in height. This last process was repeated about ten times. After the solution was finally put in suspension, a drop of the solution was placed and strewn on a slide. When dry, the slide was mounted with Canada balsam under a coverslip. The relative abundance of the various siliceous phytoplankton species (diatoms, silicoflagellates and synuracean scales) was calculated based on 300 to 500 specimens counted in each strewn slide. Taxonomic concepts applied in this study follow those of Fenner (1978, 1985) and Sancetta (1982, 1987) for diatoms and Loeblich et al. (1968) for silicoflagellates, synuracean scales and ebridians.

In order to describe changes recorded in the siliceous phytoplankton assemblages, Pianka's Overlap Index (Pianka, 1973) was calculated using the relative abundance of the studied taxa for each couple of successive samples (Table 2). It allows description of the floral continuity between two samples. The value of this index approaches one if all species are present in both samples in increasingly similar proportions. If a low value is obtained for this index, this argues for a significant floral turnover. A Q-mode cluster analysis was conducted with the help of PAST software (Hammer et al., 2001) in order to characterize the changes in the assemblages: relative abundance of taxa were used, with the exception of rare taxa (representing less than 1% of counted specimens per strewn slide), that were not considered in this quantitative study. Forty-three taxa were included in the analysis. Diatom resting spores were treated as a single taxon. This was also the case for morphogenus *Liostephania*. The other taxa analysed concern forty-one species, thirty-eight of which are diatoms, two silicoflagellates and synuracean scales. They are all highlighted in Table 1. The correlation index used was Pearson's *r*. The relative abundance of each cluster was then examined throughout the sequence. At some intervals the siliceous phytoplankton are very rare and as a result were excluded from the analysis because no statistically significant data could be obtained. However, in order to

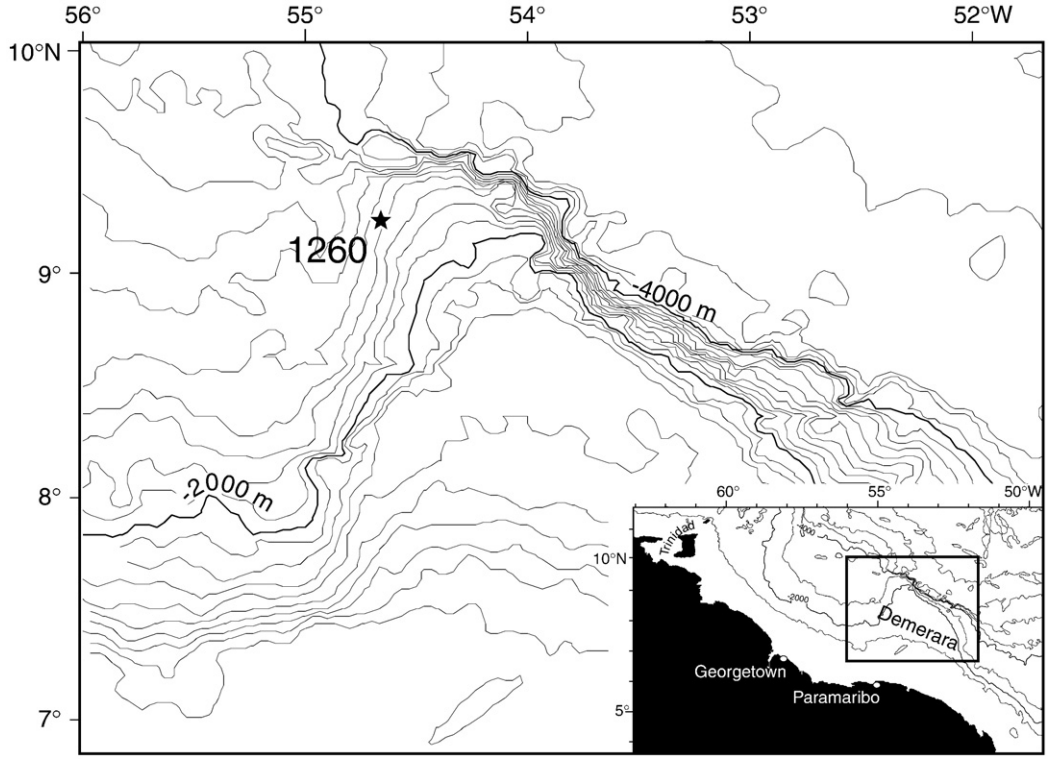

Fig. 1. Location of site 1260 drilled on Demerara Rise during ODP Leg 207. The box, bottom right, gives an overview of the bathymetric map of the western tropical Atlantic with Demerara Rise.