2005 GCSSEPM Foundation Ed Picou Fellowship Grant for Graduate Studies in the Earth Sciences Recipient

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Response of Eocene calcareous nannofossil to the transition from a greenhouse to an icehouse world: Evidence from Blake Nose, North Atlantic

Introduction:

The Eocene has been identified as the time when the Earth's climate shifted from the greenhouse of the early Eocene to the major expansion of ice sheets in the earliest Oligocene (Lear *et al.*, 2000; Zachos *et al.*, 2001). The early stages of the Cenozoic cooling trend began with a step-like climatic deterioration ultimately leading to the Quaternary ice age (Wade *et al.*, 2001). The Eocene, therefore, provides an opportunity to study a transitional climatic, oceanic, and biotic system. The variable nature of the climate has inspired scientific and public interest in climatic fluctuations and the desire to understand what the consequences of other possible transitional events will be on Earth's biota, and especially on humans.

Although the climatic shifts during Eocene time are understood in general terms, the mid-Eocene is inadequately documented in terms of its variability, timing of cooling and effect on oceanographic and biologic structure. This is because high-resolution, low-latitude Paleogene records are scarce, and complete records either lack the necessary stratigraphic resolution, or their microfossils are not sufficiently well preserved to record the rapid paleoceanographic changes that are associated with the transition period from a non-glacial to a glacial climate. This study focuses on the paleoceanography of the upper middle Eocene where complete and well preserved stratigraphic setting does occur.

Geologic Background of Blake Nose and previous work:

The Blake Nose is a salient on the eastern margin of the Blake Plateau located due east of the Florida-Georgia border. It is a gentle ramp that reaches a maximum depth of about 2700m at the Blake escarpment (Norris *et al.*, 1998,

Fig. 1). Drilling of the Blake Nose on DSDP Leg 44 (Benson *et al.*, 1978) and ODP Leg 171B (Norris *et al.*, 1998) indicates that little deposition of sediments has occurred since the end of the Eocene, as evidenced by the soupy, uncompacted nature of upper Eocene sediments underlying a thin veneer of manganese-phosphorite nodules.

Leg 171B recovered carbonate and siliceous-rich Paleocene-Eocene sediments with very good preservation of calcareous and siliceous microfossils (Norris et al., 1998). Biostratigraphy has been published by Mita (2001) on the lower to upper Eocene calcareous nannofossils of Sites 1051 and 1052 and by Sanfilippo and Blome (2001) on the Paleocene-Eocene radiolaria of Site 1051. Ogg and Bardot (2001) produced a magnetostratigraphy of all sites and intervals recovered during Leg 171B and Pälike *et al.* (2001) constructed a revised meters composite depth scale (RMCD) of the middle to upper Eocene using spectral analysis and astronomical tuning.

Wade and Kroon (2002) published a high resolution (3 kyr) $\delta^{18}O$ record of planktonic foraminifera from 37.3 to 39.6 Ma, within the interval calibrated by Pälike *et al.* (2001), which revealed large amplitude (10°C) sea surface temperature (SST) fluctuations with orbital cyclicities. They hypothesized that this temperature variation may be a regional event driven by displacements of the Gulf Stream. This and other data from the Blake Nose (Pinet *et al.*, 1981) may contribute to our understanding of the paleoceanographic circulations within the Gulf of Mexico/western North Atlantic.

The objective of the proposed research is to determine whether calcareous nannofossil assemblages in the North Atlantic Ocean reflect short-term (3Ka), large-scale (10°C), changes in temperature during the late middle Eocene. It is known that benthic and planktonic marine biota respond to climatic fluctuations, thus, they can provide insight into the exact nature of the oceanic changes and community ecological dynamics in a rapidly changing system. Studies of the response of microplankton have focused on longer-term (10^5-10^7 years) changes in the climate. Abreu and Anderson (1998) identified a number of isotopic events through the Eocene and their interpretations indicate that there is finer scale (10^3-10^5 years) pattern within the overall climatic cooling trend of the middle to late Eocene. Short-term paleoenvironmental fluctuations may have occurred during what was considered a relatively warm, stable period in Earth's history but not much is known about how calcareous nannofossils reflect these finer scale climatic changes.

The working ***hypothesis*** is that calcareous nannofossil assemblages reflect short-term, large-scale (10°C) changes in temperature during the transitional climate of the late middle Eocene. Wade and Kroon (2002) performed a high resolution (~3 kyr) $\delta^{18}O$ study of middle Eocene, mixed-layer dwelling planktonic foraminifera from Blake Nose and their results showed pronounced (>1 ‰)

variability (Fig. 2) which they attributed to large shifts in temperature of about 10°C.

Calcareous nannofossil assemblages are known to display geographic changes in vertical community structure and diversity patterns related to SST and thermocline/nutricline depth (Honjo and Okada, 1974). The Eocene temperature variations reported by Wade and Kroon (2002) are, therefore, expected to be reflected in nannofossil assemblages. The ***expected result*** is that the distribution of known cool and warm temperature-loving species will match variations in the $\delta^{18}O$ isotope curve. For example, warm water species (*e.g.*, *Discoaster*) are expected to increase in abundance during warmer intervals represented by negative excursions of the $\delta^{18}O$ curve. An important implication of this result is that short-term, large-scale changes during a transitional climate will affect plankton communities which will in turn affect other marine organisms that depend on them and productivity levels in the ocean.

An ***alternative result*** could be that the distribution of temperature-specific species does not match the $\delta^{18}O$ curve. This could mean that the $\delta^{18}O$ curve is representative of other environmental factors such as ice volume change and salinity or that the calcareous nannofossils do not respond to short-term, large-scale changes in temperature during a warm transitional climate. Such a result will imply that in a transitional climate, factors other than temperature could be affecting the $\delta^{18}O$ and calcareous nannofossil variations.

Materials and Methods:

Wade and Kroon (2002) generated a stable oxygen isotope record with a mean sampling resolution of ~ 3 kyr for a 2.3 myr (ca. 39.6–37.3 Ma) interval spanning the latest middle Eocene from 77 to 133m composite depth (mcd) at Site 1052 (Fig. 2). Each sample averages a 2-cm-depth interval and represents a period of ~600 yr. To meet the stated objective, 133 samples, from the same site and intervals as those analyzed by Wade and Kroon (2002), will be analyzed using a random settling technique to determine the nannofossil accumulation rates. The samples will span 400 kyr (37.85-37.45Ma) and this will enable a direct comparison between the calcareous nannofossil assemblages and the stable isotope data generated by Wade and Kroon (2002). The random settling method to be used will be a modification of that described by Geisen *et al.* (1999). In addition, the introduction of an aliquot of microspheres to the settling chambers will yield an independent estimate of nannofossil accumulation rates to comparewith the random settling technique and for confirmation of results. The calcareous microfossils and microspheres will be counted using a light microscope. Counts of at least 300 specimens per sample will be made and multivariate statistical analyses will be used to discern patterns that represent paleoenvironmental information.

Summary:

Current scientific and public interest in climatic fluctuations is driven by the desire to understand what the consequences of transitional climatic settings will be on Earth's biota, and especially on humans. The upper middle Eocene provides an opportunity to study a transitional climatic, oceanic, and biotic system. Calcareous nannofossils are one of the major primary producers in the ocean and understanding how they respond to both large-scale and small-scale variations in a transitional climate is of great importance to us. It is important to paleoceanographers, for example, to know how these plankton in the ocean respond to varying scales of climatic and oceanographic variations which may help predict what to expect if a similar transitional climatic condition should occurred. For geochemists, knowing how calcareous nannofossils respond to different magnitudes of fluctuations recorded in the stable isotope curve will be of interest because it will provide another means of confirming their paleoclimatic interpretations.

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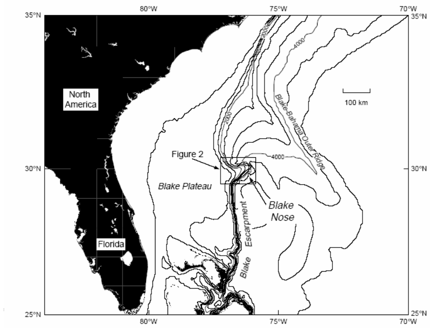

Figure 1

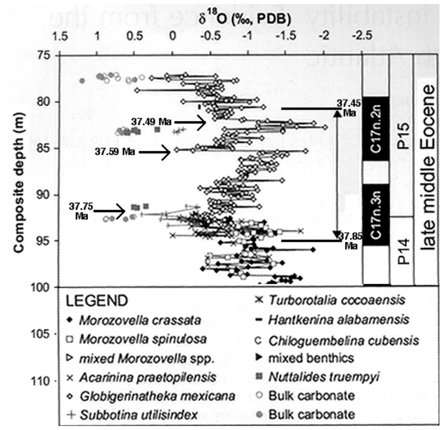

Figure 2

Figure 1 shows the location of Blake Nose, ODP Leg 171B, modified after Norris et al., 1998.

Figure 2 shows the $\delta^{18}O$ curve from Site 1052, modified from Wade and Kroon (2002). Vertical bar with arrows delineates proposed study interval from 37.45 to 37.85Ma.