

## Planktic foraminiferal paleoecology along the Paleocene/Eocene transition at Site 401 (Bay of Biscay, North Atlantic)

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### Introduction

A major benthic foraminiferal turnover occurred in the latest Paleocene characterized by decreased diversity in bathyal and abyssal species (Schnitker, 1979; Tjalsma and Lohman, 1983; Miller *et al.*, 1987; Thomas, 1990a; Ortiz, 1994). Pak and Miller (1992) reported that the benthic foraminiferal mass extinction event (BFMEE) occurred near the P/E boundary defined by the LAD of *M. velascoensis*. Moreover, this extinction event they claimed to be isochronous and recognizable worldwide and therefore proposed the benthic foraminiferal extinction event as the marker for the P/E boundary. In order to have a more general scenario the influx of the water warming has to be studied in planktic foraminifera as well. In lower latitude locations, such as Caravaca in southern Spain, a planktic foraminiferal turnover is also recorded coinciding with the benthic foraminiferal extinction event (Molina *et al.*, 1994; Canudo *et al.*, 1995) whereas in northern Spain at the Zumaya section, the planktic foraminiferal extinction event is much less severe (Canudo and Molina, 1992a; Canudo *et al.*, 1995). In the Antarctic Ocean the planktic foraminiferal turnover consists of an invasion of tropical and subtropical species (i.e., acarininids and morozovellids) which displaced the endemic cooler water fauna (i.e., subbotinids; Kennett and Stott, 1990; Lu and Keller, 1993) during the global warming. However, no net loss in taxic diversity was recorded (Lu and Keller,

1993). In this study we examined the planktic foraminiferal assemblage across the P/E transition at DSDP Site 401 in the Bay of Biscay, Northeast Atlantic, in order to check similarities and differences with other cooler environment sections and to compare it with the basin related Pyrenean sections at lower latitude.

DSDP Site 401 is located in the western border of the Biscay abyssal plain, at 47° 25.65'N and 08° 48.62'W, at a depth of -2495 m. A total number of 49 samples were analyzed for this study. Samples were disaggregated in water and a weak detergent with H<sub>2</sub>O<sub>2</sub> added to remove organic matter. Each sample was cleaned with ultrasonic agitation during 10 to 15 second intervals and washed through a 63 micron screen. Both planktic and benthic foraminifera are well preserved and the original calcite shells are slightly recrystallized. Population counts for planktic foraminifera are based on representative random splits (using an Otto microsplitter) of 300 to 400 specimens from the 106µm size fraction. The remaining sample was searched for rare species. The 63 to 106 µm size fraction was also scanned, but was found to be impractical for quantitative studies due to the large number of juveniles.

In this study we have followed the biostratigraphic zonation of Berggren and Miller (1988) and that of Canudo and Molina (1992b). We recognized all biozones and subzones from P6a to P8, as shown in Figure 1. Planktic foraminiferal researchers used to place the P/E



boundary at the LAD of *Morozovella velascoensis*, which was supposed to be coincident with the FAD of *Pseudohastigerina wilcoxensis* (Bolli, 1957; Toumarkine and Luterbacher, 1985; Berggren and Miller, 1988). But there are problems with this criterion. For example, *M. velascoensis* is a common species in tropical waters but not in colder environments, whereas the FAD of *P. wilcoxensis* appears to be diachronous (Molina et al., 1992; Canudo et al., 1995), and not coinciding with the FAD of *M. velascoensis* (King, 1990; Pardo et al., 1994). Currently, the placement of the P/E boundary is made at the level where a major extinction of benthic foraminifera occurs, plus a negative excursion in the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  isotope values measured in the shells of foraminifera (Thomas, 1990; Kennett and Stott, 1991; Pak and Miller, 1992; Lu and Keller, 1993; Molina, 1994; Canudo et al., 1995).

## Paleoecology

During the Paleocene-Eocene transition climate reached the warmest temperatures of the Cenozoic. A major change in oceanic deep water circulation patterns related to global warming, along with a temporary absence of cold Antarctic water formation and the production of warm saline deep waters in the Tethys region, is generally considered as possible causes for the isotope shift and the benthic foraminiferal mass extinction (Kennett and Stott, 1991; Pak and Miller, 1992).

The P/E warming trend seemed to produce a low extinction rate in planktic foraminifera if only the taxic diversity of the planktic foraminiferal assemblage is considered. This is mainly due to the shift in tropical-subtropical taxa to high latitudinal habitats, accompanied by the displacement of cooler water taxa (Kennett and Stott, 1991; Canudo and Molina, 1992; Lu and Keller, 1993, in press). Since there was no net loss in taxic diversity, an important turnover in the planktic foraminiferal assemblages (pre and post warming peak) has been observed in the Antarctic Ocean (Lu and Keller, 1993) and

equatorial Pacific Ocean (Lu and Keller, in press). The most abundant genus is *Subbotina*. The different taxa of this genus represent a total combined relative abundance of more than 45%. *Subbotina* is the genus with more specimens per sample in the whole interval, but the species richness of this genus is low, being no more than six different species of *Subbotina* per sample. *Morozovella* shows a gradual replacement of taxa in time and also major relative abundance fluctuations among the different species. This is a group that shows high taxonomic richness in the P/E transition. The highest species richness occurs around the BFMEE and extends up to the top of Zone P 6a. From the upper part of Zone P 6b a severe reduction of species richness is observed, yielding only two species (*M. aragonensis* and *M. caucasica*) at Zone P 8. *Muricoglobigerina* is very stable both in the relative percentage values and in the species richness during most of the section. In this group appear 4 species during the whole interval, and the whole genus (6 species) representatives seem to disappear in the upper part of Zone P 7. This could be possibly due to a displacement from their ecological niches by some acarininids new species that appear in the upper part of Zone P 7. *Acarinina* is also frequent in the whole interval examined with a remarkable species diversification in the upper part of the section, principally in Zone P 7. *Acarinina* becomes the leading genus in species richness in zones P 7 and P 8 after the P/E extinction event. Heterolids (*Chiloguembelina* and *Zeauvigerina* genera) show an increase both in species richness and specimens per sample in the upper part of the Paleocene and in the lowest Eocene, coinciding with the BFMEE. A number of 5 species appearances and 6 disappearances yielding the complete disappearance of this group at the upper part of Zone P 6b. Genera like *Planorotalites*, *Paragloborotalia*, *Globanomalina* or *Pseudohastigerina* show very stable relative abundance values in the whole interval, with minor variations in the proportions of the assemblages. *Pseudohastigerina wilcoxensis*



and *Paragloborotalia griffinae* are the only species that reach into Zone P8.

In general, the species richness of the samples is low with a mean of 17.84 species. This seems to be related to a cold environment which would limit severely the taxa able to survive in those extreme conditions. The same pattern can be observed at ODP Site 738C in the Indian Antarctic Ocean, with a richness average of 19 species per sample (Lu and Keller, 1993) or at the Knokke well (11E/138) in Belgium where the richness average is 9 species per sample (Pardo *et al.*, 1994).

The data set obtained during our study of the DSDP Site 401 seemed to confirm results obtained in other locations. Planktic foraminifera correspond to a typical middle-high latitude cold environment assemblage. This is confirmed by the high abundance of the genus *Subbotina*, which reach more than 60% in relative abundance. The presence of species of *Muricoglobigerina* and *Acarinina* with few chambers in the last whorl of the test (3, 3 1/2 and 4 chambers) confirm also a cold environment (Premoli Silva and Boersma, 1988). The low number of specimens in this interval of the typical warm water genus *Morozovella* confirm this observation. The presence of multi-chambered species of genera *Acarinina* and *Muricoglobigerina* indicate less severe water temperatures at Site 401 in the Bay of Biscay than in other high latitude locations, like the Belgian Basin (Pardo *et al.*, 1994) or the Antarctic (Lu and Keller, 1993).

Figure 1 shows the evolution in time of certain genera which are supposed to live in restricted depths according to their isotopic signal: *Morozovella* and *Acarinina* are considered dwellers of surface waters (which show more positive  $\delta^{13}\text{C}$  values and more negative  $\delta^{18}\text{O}$  values), whereas *Subbotina*, *Chiloguembelina* and *Planorotalites* (more negative values on  $\delta^{13}\text{C}$  and more positive values on  $\delta^{18}\text{O}$ ) are considered to be deep dwellers (Lu and Keller, 1993; Canudo *et al.*, 1995). Isotopic analysis at DSDP Site 577 indicate that *Subbotina* and *Chiloguembelina*

species lived near or at thermocline depths, whereas *Planorotalites* taxa seemed to live at greater depths (Lu and Keller, in press).

Figure 1 shows an increase in the acarininids population near the BFME. The subbotinid group shows a high stability during the stratigraphic interval near the BFME. Starting at the base of P 6b Biozone, it can be observed the increase of the morozovellid population followed by the progressive substitution of the morozovellids by acarininids as main surface water dwellers. While this substitution took place, the number of subbotinid specimens began to diminish. This turnover event seems to show the invasion of the tropical and subtropical taxa, due to the warming trend, and the displacement of cooler water subbotinids. At the base of Zone P 7 a sudden recovery of the subbotinid group and a drastic decrease of the morozovellid group occurred. This final turnover in the planktic foraminiferal assemblage suggests the influx of cooler taxa (subbotinids and low chambered acarininids) at different depths after the warming trend, showing the displacement of tropical morozovellids with values of less than 10% of the assemblage.

A well developed population of chiloguembelinids is present near the BFME (Figure 1). In the Zumaya and Caravaca sections (Canudo and Molina, 1992a; Molina *et al.*, 1994; Canudo *et al.*, 1995) an anoxic event has been recorded in this interval. In higher latitudes this anoxic event could be reflected only by a decrease in the oxygen content of the water mass, possibly due to the mix of the salty and anoxic waters from the Tethys region with more oxygenated Atlantic waters. This low oxygen period would lead the increase of *Chiloguembelina* species adapted to this environmental low oxygen stress conditions (Premoli Silva and Boersma, 1988). The permanence of this group in the fossil record, after the P-E transition, may reveal a period of stability in the water mass. The later disappearance of the chiloguembelinids, as it is recorded at Site 401, may be related to the



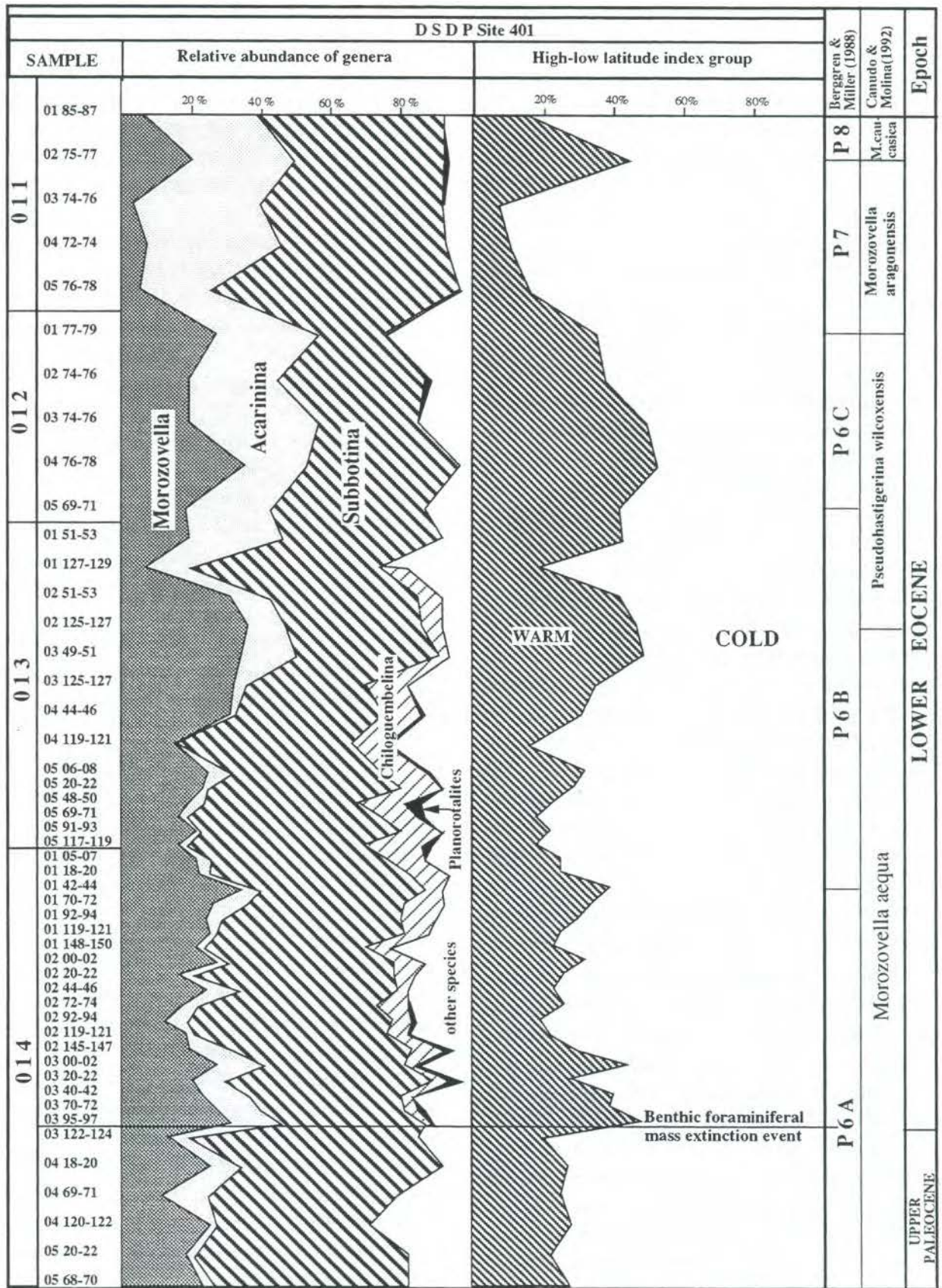


Figure 1. Relative abundance of different planktic foraminifera genera at Site 401.



increase of the oxygen content after the warming of the water mass.

The paleotemperatures inferred by the abundance of tropical-subtropical and cooler water taxa at the DSDP Site 401 indicate of colder temperatures in Zone P 6a, warmer temperatures in Zones P 6b and P 6c, and a return to cooler temperatures near the top of zones P 7 and P 8. In Figure 1 we have plotted taxa considered as warm water dwellers (i.e., species typical from low latitudes, such as the genera *Subbotina*, *Muricoglobigerina*, *Chiloguembelina*, etc.) versus those species considered cool water dwellers (or species typical from middle and high latitudes, such as genera *Morozovella* and *Acarinina*) to indicate climatic trends.

This figure suggests three important observations: 1) after a period of relative stability of temperature (shown by the stability in the percentage of low latitudinal versus medium-high latitudinal taxa) the first peak that shows the warming of the water mass coincides with the sample interval where the benthic foraminiferal mass extinction event was recorded by Pak and Miller (1992). 2) There is a warming trend reflected by the increase of the relative percent of specimens of taxa adapted to warm waters in zones P 6a and P 6b. 3) In zones P 7 and P 8 cooling is indicated by the increase in cold water species.

Some workers support the idea that main source of warm saline deep waters was the Tethys region (Kennett and Stott, 1991; Pak and Miller, 1992). If this was the case, this would explain why the planktic foraminiferal extinction event during the P/E transition was more abrupt in the Caravaca section, near the warm water source, than in the Zumaya section, to the north influenced by Atlantic cold and oxygenated waters (Canudo et al., 1995). At DSDP Site 401 the turnover of planktic foraminifera is even more gradual than in the Zumaya section. This may be explained by the distance of the section to the warm water Tethys Seaway and the influx of Atlantic water, that would reduce the effect of tethyan warm saline waters.

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