Deep-Ocean Ostracode Faunal Response to Rapid Global Warming During the Paleocene-Eocene Thermal Maximum at ODP Site 689 (Maud Rise, South Atlantic Ocean)

Elizabeth A. Landau and Stephen A. Schellenberg, Department of Geological Sciences, San Diego State University, San Diego, CA

BACKGROUND AND INTRODUCTION

The Paleocene-Eocene Thermal Maximum (PETM) marks a transient interval of rapid global warming ~55 Ma and is widely regarded as one of the best ancient analogs for current and future anthropogenic warming. The PETM is attributed to a large release of isotopically light carbon to the ocean-atmosphere system based on a pronounced carbon isotope excursion (CIE) of -2-3 ‰ and major global warming. Hypotheses for the carbon source in the late Paleocene include oxidation of sedimentary organic matter by intrusive volcanism and destabilization of methane clathrates in ocean sediments.

The PETM record at ODP Site 690 (Figure 1, ~2 km paleodepth) on Maud Rise has been extensively studied, but the adjacent and shallower ODP Site 689 (Figure 1, ~1.2 km paleodepth) has received significantly less attention. We investigated the Site 689 ostracode faunal response to the PETM and examined this record within a cm-scale bulk carbonate $\delta^{13}C$ chemostratigraphy.

Numerous studies have revealed a major global benthic foraminiferal response to the PETM (e.g. Thomas, 2003). In contrast, deep-ocean ostracode records have only been published for Site 689, though only three of their faunal samples are located within the PETM (Steineck and Thomas, 1996). Establishing a high-resolution ostracode faunal record at Site 689 is a key step towards understanding deep-ocean metazoan response to this extreme warming event.

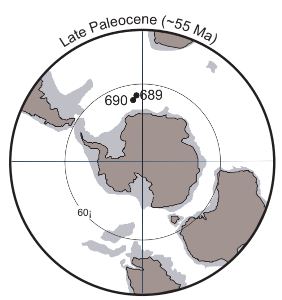


Figure 1. Paleogeography of ODP Sites 689 and 690 on Maud Rise in the Southern Atlantic during the Late Paleocene. Site 690 paleodepth is ~2 km and Site 689 paleodepth is ~1.2 km.

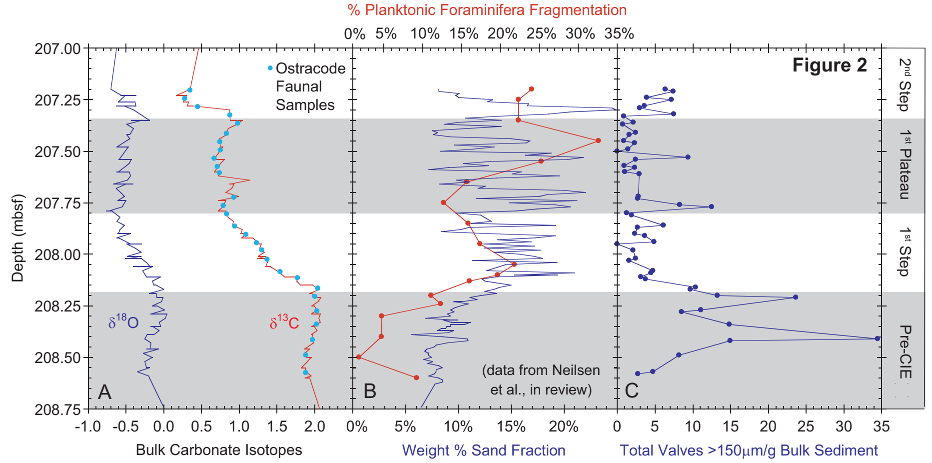
The oceans and atmosphere warmed ~4-8° C during the PETM, and the lysocline and carbonate compensation depth shoaled signficantly due to ocean acidification. The region of deep-water production for intermediate depths is also hypothesized to have transiently switched from high latitudes to the subtropics.

ISOTOPES AND STRATIGRAPHY

Bulk carbonate $\delta^{13}C$ is relatively constant before the event (Pre-CIE), drops ~1 ‰ during a 1st CIE step, transiently stabilizes within a 1st plateau, and appears to drop another ~0.5 ‰ during a 2nd CIE step before record truncation by a coring gap (Figure 2A). The bulk carbonate isotope record serves as a temperature proxy, showing rapid and dramatic warming of the oceans during this interval.

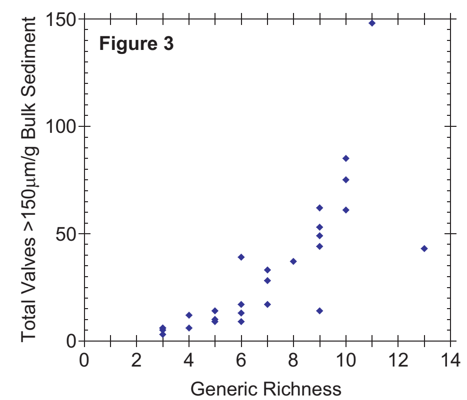
Percent planktonic foraminifera fragmentation increase during the PETM is probably due to increased corrosiveness of the water and some reworking of sediment (Figure 2B). The weight percent sand (>63 µm) increase is likely due to preferential dissolution of coccoliths given their high surface:volume ratio (Figure 2B). Both analyses show more variable values during the event.

Total ostracode valves per gram of bulk sediment decreases at the start of the event and remains low through the section (Figure 2C), likely due to increased dissolution and less favorable environmental conditions for many ostracode taxa.



METHODS

The >150 µm size-fraction of 26 two-cm thick quarter-round sediment samples were picked for all ostracode material. Sample locations are plotted as light blue circles on the $\delta^{13}C$ isotope curve (Figure 2A). Specimens were assigned to one of twenty genera, with genera typically represented by one distinctive morphotype (i. e., monospecific). Each valve was identified and counted as a right or left valve and an adult or juvenile based on shape, ornamentation, calcification, and size. If the valve was broken and genus could be determined but one of the other parameters could not, the valve was identified as a fragment. For the total valve counts, fragments 25-50% (denoted F1) of the entire valve are counted as 1/2 of a valve, and fragments <25% (F2) of a valve counted as 1/4 of a valve. Values presented are from the following equation, rounded up to the nearest whole number: Total valves = (whole valves + (1/2) F1 + (1/4) F2)



RESULTS

Figure 3: Generic richness (genera in each sample) plotted against total valves (valves in each sample) shows a positive correlation, suggesting that when more valves are preserved, more genera are represented.

Figure 4: Rank abundance plots show the genera present ranked by abundance versus their percentage of the assemblage. Graphs show a tendency towards convex-down pre-CIE curves, which increase in strength within the CIE, indicating more stressed communities within the PETM.

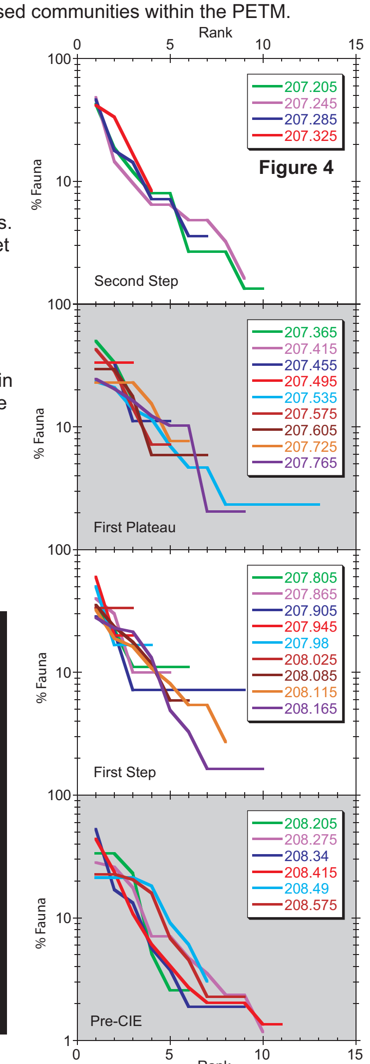
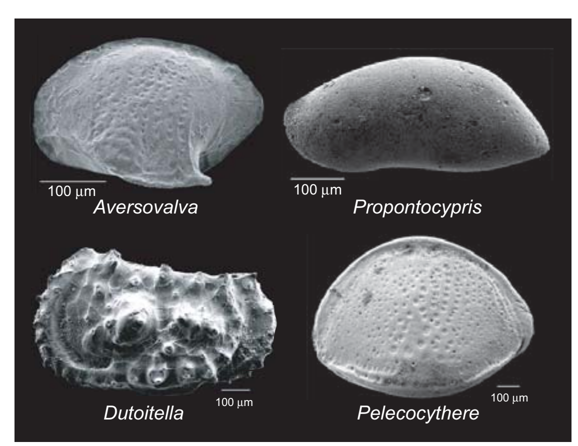


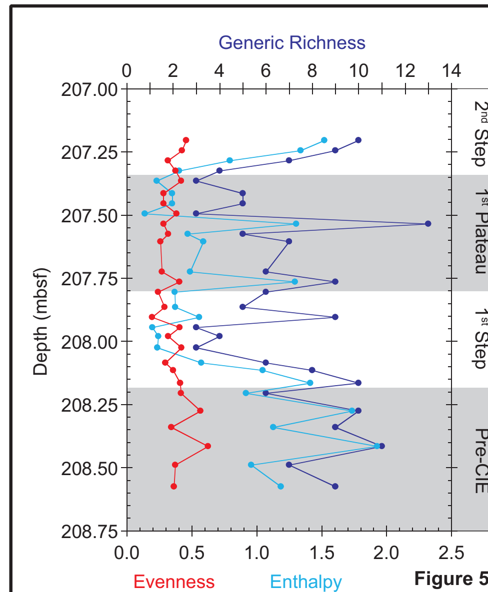
Figure 5: Enthalpy (a measure of the uncertainty of choosing any specific genus by randomly selecting a specimen from a sample) and generic richness are correlated. When more genera are present, taxa are more evenly distributed among communities. Evenness becomes slightly lower and less variable after the onset of the CIE.

Figure 6A: The total valve abundance and generic richness correlation indicates that the number of genera and individual valves decreased at the start of the PETM. $\delta^{13}C$ record is shown in gray for reference. The fluctuation of values through the rest of the event may be due to changing environmental conditions.

Figure 6B,C: *Krithe and Pelecocythere* decreases during 1st step and remains low for the rest of the section. *Propontocypris* and *Aversovalva* increases during the 1st step and remains high through the section.



SEM photos of ostracodes from Site 689

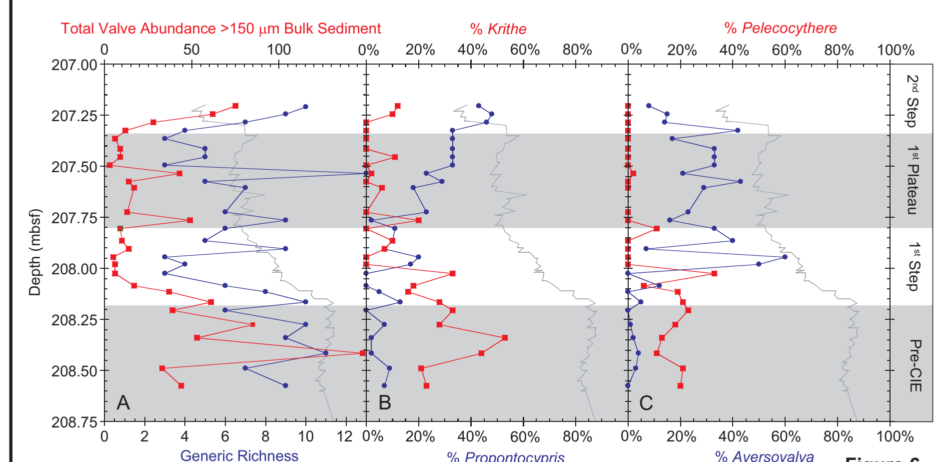


CONCLUSIONS

Propontocypris is thought to be an opportunist thriving in environments that exclude many other taxa, including localized food-rich environments such as hydrothermal vents (Maddocks and Steineck, 1987). Foraminifera with modern analogues living in similar environments also increased in abundance during the PETM in ODP site 690 (Thomas, 1996). The transient faunal change may reflect altered intermediate water conditions at the time.

Ostracode faunal response at Site 689 supports the hypothesis of enhanced delivery of organic matter during part of the PETM. Valve abundance decreases overall during the event, likely because the dominant genera were not well-suited for the new environmental conditions. These records show that metazoan faunal response is similar to the established protistan record.

During the PETM, when less genera are present, the number of individuals tend to be less evenly distributed among genera. This may indicate environmental stress, which is also supported by the rank abundance data. The number of genera and the number of valves decrease at the start of the event and fluctuate through the rest of the PETM, suggesting environmental instability.



ONGOING AND FUTURE WORK

Our data will be compared to foraminifera records from this site and Site 690 to provide insights on the PETM metazoan response compared to the established protistan record. The authors are currently conducting a high-resolution isotopic study of individual ostracodes from Site 689 through the PETM. This record will show any discrepancies between the metazoan and established bulk carbonate and individual foraminifera isotopic data.

An additional faunal study of ostracodes from ODP Site 738, located at nearly the same latitude but 90° East of Maud Rise, is planned and will also give information regarding the global metazoan reaction to this event. More research on sites such as this will allow a more global reconstruction of this rapid global warming event and its biotic repercussions.

ACKNOWLEDGEMENTS

This study would not be possible without the extraordinary efforts of the crew of the JOIDES Resolution. This research used samples and data from the Ocean Drilling Program (ODP), which is sponsored by the U.S. National Science Foundation (NSF) and participating countries under management of Joint Oceanographic Institutions (JOI), Inc. Funding for this research was provided by a NSF grant to Schellenberg and a Paleontological Society grant to Landau.