Improving our understanding of the marine biotic response to anthropogenic CO_2 emissions

ESF-PAGES Workshop, Barcelona, Spain, 26-28 September 2007

Thorsten Kiefer[1], S. Barker[2], D. Schmidt[3] and P. Ziveri[4]

[1]PAGES International Project Office, Bern, Switzerland; kiefer@pages.unibe.ch
[2]School of Earth and Ocean Sciences, Cardiff University, UK; [3]Department of Earth Sciences, University of Bristol, UK; [4]Institute of Environmental Science and Technology, Autonomous University of Barcelona, Spain

During recent years, ocean acidification (OA) has rushed onto the global change agenda as a global-scale consequence of rising atmospheric CO_2 levels. Biotic responses to changing ocean carbonate chemistry are expected to impact ecosystems, feedback on global climate, and eventually affect socioeconomies. However, our knowledge about the nature of biotic responses to OA is still too limited to quantify their impacts (see also report on IGBP-SCOR Fast Track Initiative workshop in Lamont, 2006; *PAGES News*, 14:3, 29-30). Therefore, the European Science Foundation (ESF) EuroCLIMATE program, with co-sponsoring from PAGES, organized the Barcelona workshop to bring together a diverse range of experts to review knowledge of the likely effects of OA on planktonic calcifying organisms and marine biogeochemistry. Five sessions addressed 1) Biocalcification mechanisms, 2) Genetics and physiology, 3) Ecology and biogeography, 4) Lessons from the fossil record, and 5) OA in the Mediterranean.

Here, we focus on the fossil record and what can be learned from it about responses and effects of marine biota and ecological systems. More comprehensive reports are published in The Eggs (Ziveri et al., 2007) and Eos (Ziveri et al., 2008). Case studies, ranging from the onset of the Cenozoic era to the recent past, featured a range of perturbations of the carbon system:

Daniela Schmidt (University of Bristol) presented data from the Cretaceous/Paleogene (K-Pg) Boundary (~65 Myr ago), and suggested that the major environmental and climatic changes included abrupt OA (Fig. 1). A drop in average foraminiferal test size and a shift of the carbonate production from coccolithophore- to foraminifera-domination demonstrate profound changes in plankton composition. A decrease in carbonate accumulation at this time is related to a reduction in calcification rather than increased dissolution at the sea floor. Recovery of the carbonate production took several million years.

The Paleocene-Eocene Thermal Maximum (PETM), a rapid OA event ~55 Myr ago, was the subject of presentations by Jim Zachos (University of Santa Cruz) in a public lecture and by Heather Stoll (University of Oviedo). Stoll showed new evidence from the Southern Ocean (a region particularly sensitive to the effects of OA) of distinct shifts in plankton assemblage at the PETM, with an increase in the presence of species generally more suited to warmer conditions and less susceptible to dissolution (Fig. 2). Furthermore, coccolith Sr/Ca data provide some evidence that coccolithophore production may have peaked during the PETM in the Southern Ocean.

Significant deepening of the calcite lysocline and carbonate compensation depth during the Eocene-Oligocene (E-O) boundary (~34 Myr) reveals a whole ocean 'reverse' acidification event associated with the first major growth of ice sheets on Antarctica. Based on tests with a biogeochemical ocean box model, Toby Tyrell (University of Southampton) discussed sea-level fall due to the ice sheet growth and a consequent shift of carbonate deposition from shallow shelf reef areas to the deep sea as the favored explanation of these changes in carbonate chemistry.

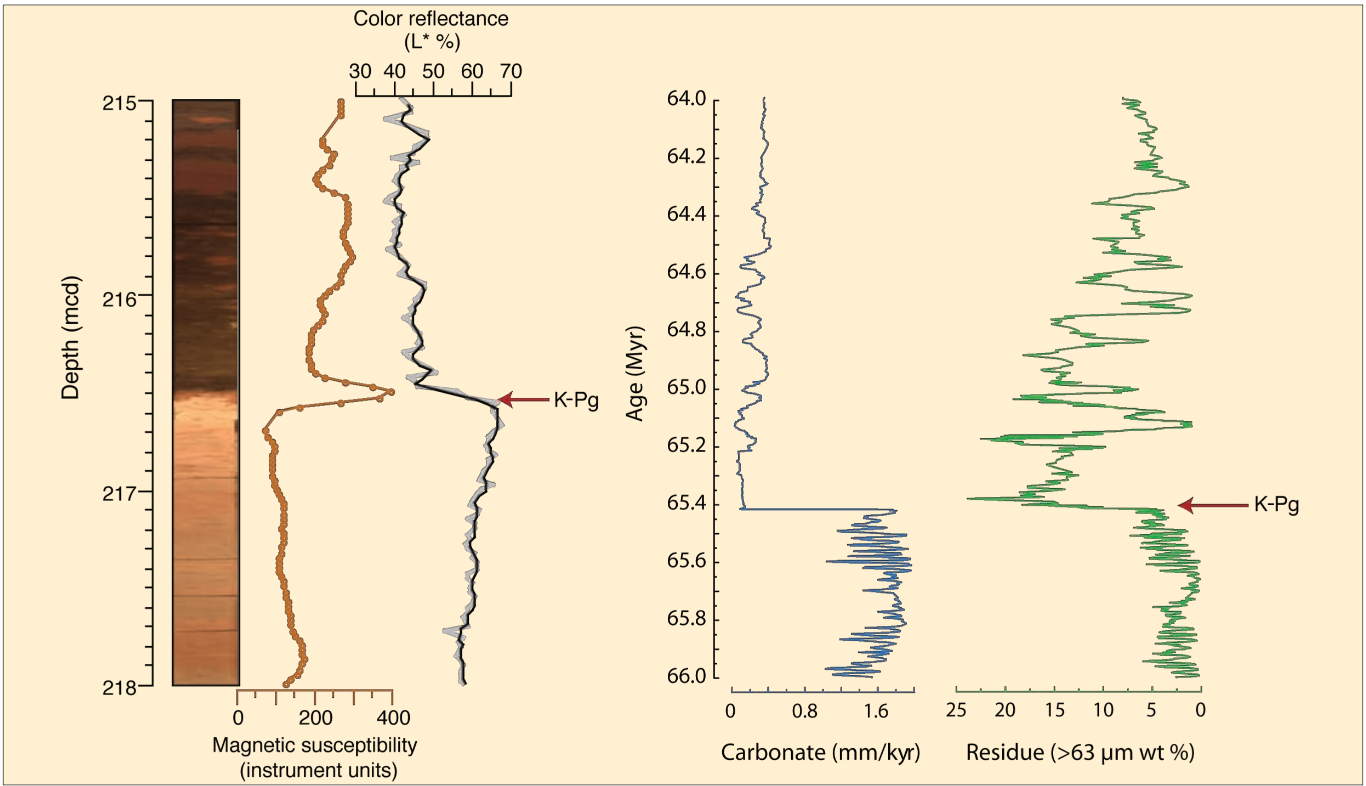

Figure 1: The Cretaceous/Paleogene (K-Pg) boundary at Walvis Ridge Ocean Drilling Paogram Site 1262. The boundary is characterized by a drop in carbonate accumulation and an increase in clay, iron oxide and volcanic ash accumulation, which produced distinctive increases in magnetic susceptibility and color reflectance (lightness L). A percentage increase of the coarse fraction relects the shift in dominant carbonate producers from coccolithophores to foraminifera. Figures after*

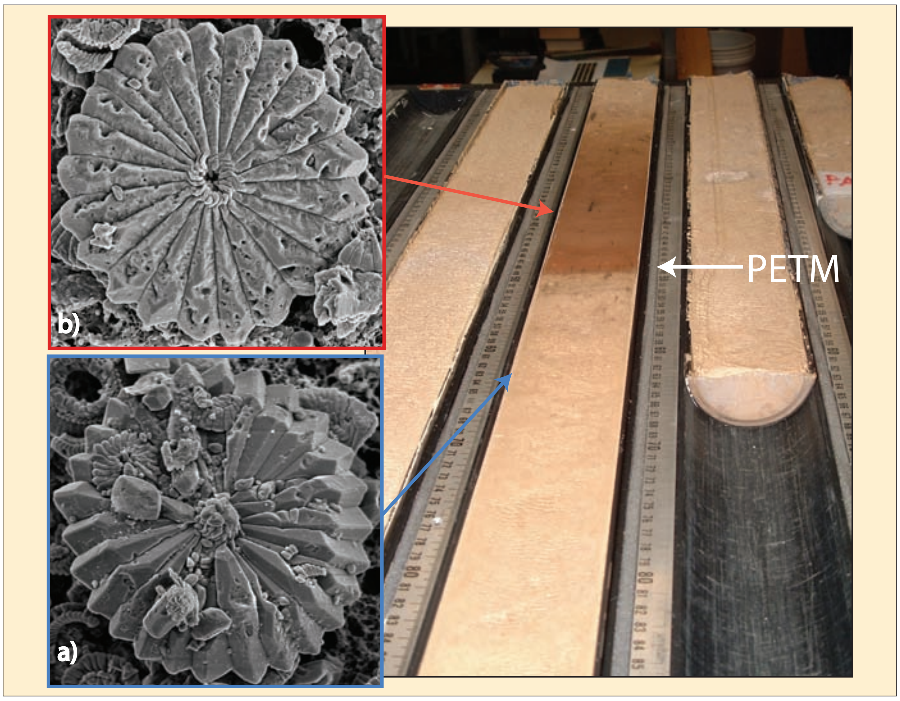

Figure 2: Core photo from Walvish Ridge (Ocean Drilling Program ODP Leg 208) with dark sediment representing the PETM, and calcareous nannofossils of Discoaster multiradiatus *(Site 1263). (**a**) a relatively well-preserved, pre-PETM specimen; (**b**) a corroded specimen from the acidification event during PETM. Scanning electron microscope (SEM) images from Mascha Dedert, Vrije Universiteit Amsterdam.*

Stephen Barker (Cardiff University) illustrated widespread deep ocean acidification and resulting dissolution of carbonate sediments during the Mid-Brunhes interval (~0.6-0.2 Myr ago). This global change in ocean carbonate chemistry may have been driven by an increase in pelagic carbonate production caused by the proliferation of the calcifying *Gephyrocapsa* coccolithophore. This example provides a case for: (1) how profound changes in biology can drive (or feedback on) OA, and (2) how changes in the calcifying planktonic ecosystem can influence the balance between the organic and inorganic carbon pumps and hence ocean-atmospheric CO_2 exchange and global climate.

Carles Pelejero (CMIMA-CSIC Barcelona) gave an example of an OA study from the historical past. A 300-year reconstruction of pH from boron isotopes in corals from Flinders Reef (NE Australia) shows a strong (~0.2 pH units) multi-decadal oscillation with ~50 yr cyclicity, rather than the monotonic decrease expected as a consequence of anthropogenic CO_2 release. While the oscillating pH may be a local phenomenon in the reef environment associated with the Interdecadal Pacific Oscillation, an interesting key finding was that the measured coral calcification rate did not apparently respond to the pH changes.

Andy Ridgwell (University of Bristol) stressed a general point arising from attempts to model the sediment response to changes in OA: Although it is relatively straightforward to predict the inorganic response of carbonate sediments to changes in ocean acidity, it is extremely important that we are able to constrain the associated changes in atmospheric CO_2 and possible biological calcification responses before we will be able to reduce the uncertainties in our models.

According to Richard Zeebe (University of Hawaii) none of the past OA scenarios will be able to depict the true extent of future acidification. The injection of carbon into the ocean–atmosphere system, even during the PETM, was most likely not as rapid and intense as the modern situation. A more gradual release of carbon would have been more efficiently buffered by deep sea carbonate dissolution, resulting in a reduced effect on surface ocean pH. A noteworthy implication of this is that any effect on marine biocalcification during past OA events, including the PETM, may represent the very minimum response that might be expected in the future.

Particular emphasis was given to considering the geographical distribution of any event in terms of response in the system. For example, the extent of carbonate dissolution during the PETM was not equal globally. Although none of the past OA analogs seem to be able to depict the true extent of future acidification, they all provide important constraints on the nature of the threat for the near and distant future. These constraints are also critical in order to assess planktonic species adaptation rates to such perturbations, putting our ability to understand the future on firmer ground.

References

Kroon, D., Zachos, J.C. and Leg 208 Scientific Party, 2007: Leg 208 synthesis: Cenozoic climate cycles and excursions, In: D., Kroon et al., (Eds), *Proceedings of the ODP, Scientific Results*, **208**: College Station, TX (Ocean Drilling Program), 1–55, doi:10.2973/odp.proc.sr.208.201.2007

Ziveri, P., et al., 2007: Atmospheric CO_2, ocean acidification, and ecological changes in planktonic calcifying organisms, *The Eggs*, **22** (21 December): http://the-eggs.org/articles.php?id=112

Ziveri, P., Young, J., Fabry, V., Bijma, J., Turk, D., Kiefer, T. and Eisenhauer, T., 2008: Understanding Marine Biotic Responses to Fossil Fuel Emissions, *Eos*, Transactions, American Geophysical Union, **89**: 127.

Oceanography and Climate Change: Past, present and future scenarios

Austral Summer Institute VIII, Dichato, Chile, 7-14 January 2008

Sergio Contreras Quintana (Workshop Participant)

Department of Biogeochemistry, Max Planck Institute for Marine Microbiology, Bremen, Germany; scontrer@mpi-bremen.de

The Austral Summer Institute VIII on "Oceanography and Climate Change: Past, present and future scenarios" was held in Dichato, Chile, from 7 – 14th January 2008. Twenty students were selected from 92 applicants to participate in the workshop, which also involved the participation of word-class lecturers.

The first week focused on two key topics:

1) El Niño Southern Oscillation, theory, observations and predictions was lectured by Dr. Axel Timmerman, from the University of Hawaii. Lectures were complemented with computer-based exercises and homework, including ocean and atmosphere data analyses and simple model runs for ENSO predictions.
2) The role of the thermohaline circulation on the Earth's climate was lectured by Dr. Andrey Ganopolsky from the Potsdam Institute for Climate Impact Research. This included a discussion of climate consequences in modern times