Early Pliocene circum-Antarctic warming events between 3.5 and 3.7 Ma recorded in sediments from ODP Sites 1165 (Prydz Bay) and 1095 and 1096 (Antarctic Peninsula)

C. Escutia,[1] M. A. Bárcena,[2] R. Lucchi,[3] O. Romero,[1] and A. M. Ballegeer[2]

[1]Instituto Andaluz de Ciencias de la Tierra, CSIC-Universidad de Granada, Fuentenueva s/n, 18002-Granada, Spain (cescutia@ugr.es; oromero@ugr.es)
[2]Universidad de Salamanca, Departamento de Geología, 37008 Salamanca, Spain (mbarcena@usal.es, amballegeer@usal.es)
[3]GRC Geociències Marines, Departament d'Estratigrafia, P. i Geociències Marines, Universitat de Barcelona, Facultat de Geologia C/ Martí i Franquès, s/n, 08028-Barcelona, Spain (rglucchi@ub.edu)

Summary Preliminary results from diatom sedimentological and biostratigraphic analyses conducted in cores recovered from the continental rise during Ocean Drilling Program (ODP) Legs 178 (Antarctic Peninsula) and 188 (Prydz Bay) show evidence for warming intervals between 3.6 and 3.8 Ma. Our preliminary results confirm the warming event previously reported from Prydz Bay at 3.7 Ma and show evidence for the same event in the Antarctic Peninsula, which implies the event was of continent-wide significance. Results from ongoing analyses of opal, clay mineralogy and elemental analysis, will likely give us a further insight into the nature of this warming events.

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Introduction

The stability of Antarctic Ice Sheets during the Late Miocene and the Pliocene has been the subject of almost a continuous debate for more than two decades (e.g., Hardwood and Webb, 1998; Stroeven et al., 1998). One key question is the warming-cooling climatic phases of the Pliocene, that is, if relatively short warm intervals can cause a loss in ice sheet volume once a stable ice sheet is thought to be in place (i.e., since the Middle-Late Miocene). The marine oxygen isotope record suggests warming in the earliest Pliocene, culminating at about 3 Ma during the mid-Pliocene Climate Optimum (e.g., Kennett and Hodell, 1995; Zachos et al., 2001). Marine sediments exposed on land show evidence for a dynamic ice sheet during the Late Miocene-Early Pliocene as well as for Early Pliocene warming. The marine record from drilling in Prydz Bay, the Ross Sea and the Antarctic Peninsula, also shows evidence for repeated advances and retreats of the Antarctic Ice Sheet during the Late Miocene and Early Pliocene. For example, the silicoflagellate assemblages at Site 1165 in Prydz Bay pinpoint three intervals within the Pliocene (3.7 Ma, 4.3-4.4 Ma, and 4.6-4.8 Ma) when sea surface temperatures in the Southern Ocean were roughly 5ºC warmer than today (Whitehead and Bohaty, 2003). In the Antarctic Peninsula a strong decrease in sea-ice coverage starting at 5.3 Ma and maintained during the early Pliocene is indicated by opal deposition (Grutzner et al., 2005; Hillebran and Ehrmann, 2005).

Here we present preliminary results on sedimentological and biostratigraphic analyses conducted in cores collected from the continental rise during Ocean Drilling Program (ODP) Leg 188 (Site 1165) in Prydz Bay, and ODP Leg 178 (Sites 1095 and 1096) in the Antarctic Peninsula. Our preliminary results confirm the 3.7Ma warming even in Prydz Bay (Whitehead and Bohaty, 2003) and show evidence for the same event in the Antarctic Peninsula, which implies the event was of continent-wide significance. Results from ongoing analyses of opal, clay mineralogy and elemental analyses, will likely give us a further insight into the nature of this warming events.

Circum-Antarctic warming event: Preliminary results

Sedimentological evidence

Sedimentological evidence for reduced ice conditions in cores from Sites 1165, 1095 and 1096 is drawn at this time from preliminary observation on the distribution of Ice Rafted Debris (IRD), qualitative smear-slide analyses, and grain size analyses.

In the Antarctic Peninsula, we analyzed the sedimentary record from two locations, Site 1096 located on the proximal continental rise near the crest of a sediment drift, and Site 1095 located in the distal continental rise. Core 23X from Hole 1096C exhibits a marked change in color from dark-grey below to olive-gray mud above 405.65 mbsf (Core 23X-1, 15 cm) (Fig. 1). Below the color change there is a 10 cm-interval with large IRD pebbles (i.e., 3.5cm maximum diameter). Preliminary observations using smear slides indicate the sedimentary section below the IRD (i.e., Core 23X-2) is characterized by terrigenous sediments with few to common, but highly fragmented, diatoms. Up-section, at about 405.60 mbsf, diatoms are common and well preserved. Grain size analyses show that data falls into two well-separated groups of grain-size distribution located above and below the large IRD interval (Fig. 1). Sediments below the IRD interval contain higher percentage of clay with respect to the sediments located above the IRD event, whereas the IRD

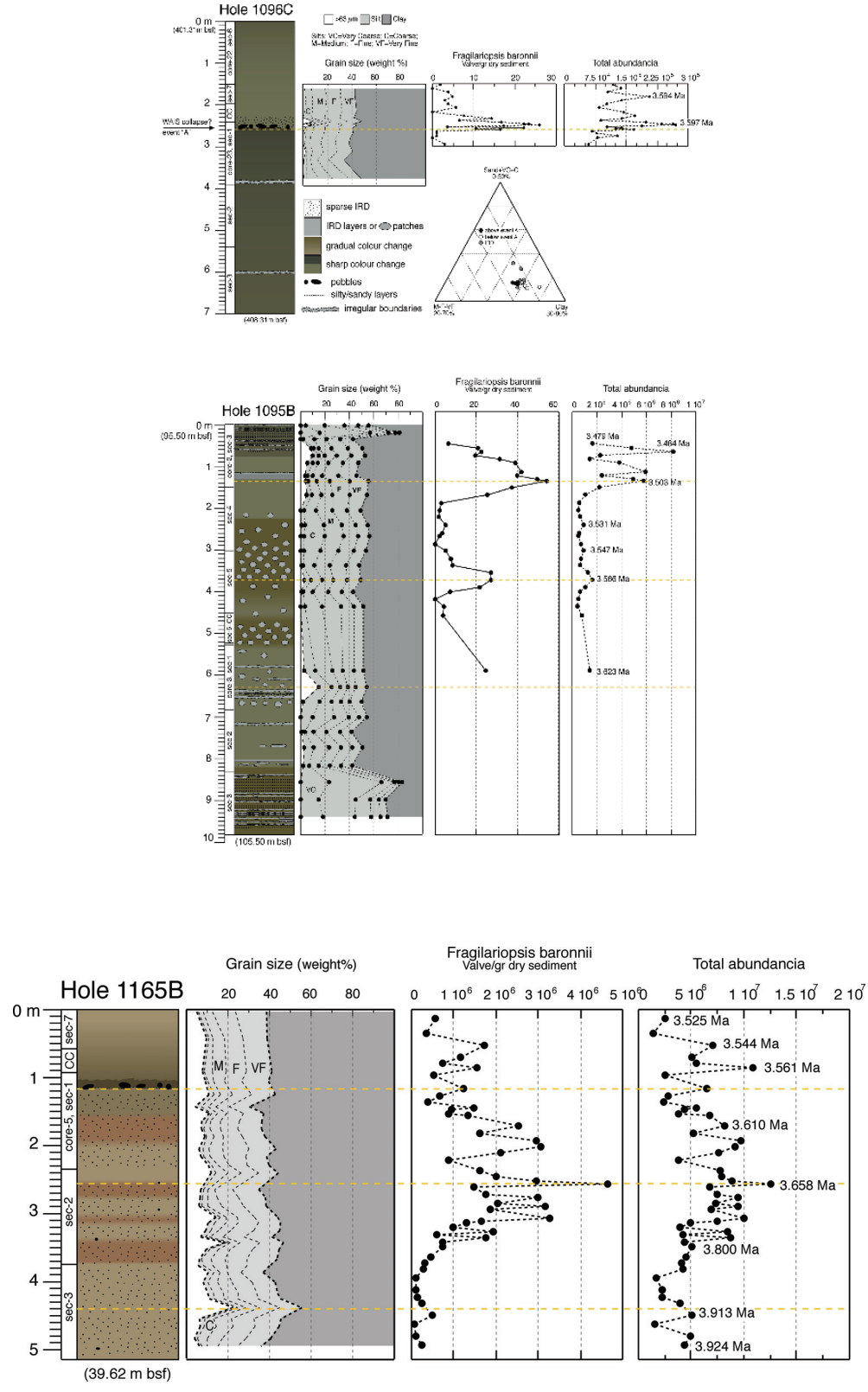

Figure 1. Results from grain size and diatom abundance analyses in cores from the Antarctic Peninsula (Sites 1095 and 1096) and Prydz Bay (1165).

interval can be differentiated by a higher percentage of sand and very coarse-coarse silt (4-5 phi). The sedimentary record from Site 1095 does not show the changes registered at Site 1096. Grain size analyses do not show distinctive grain size distribution and there is only a slight indication on apparent IRD granules-rich intervals between 97.54-99.26 mbsf, and 102-103.54 mbsf.

In Prydz Bay, Core 5H section 1, from Site 1165 shows a sharp change in color at about 35.54 mbsf corresponding to an interval of large IRD pebbles (very dark and dark grayish brown). Below this interval grayish and reddish-brown sediments contain abundant and sparse IRD grains and pebbles suggesting progressive warming up climatic conditions. The qualitative smear slide analyses do not exhibit the marked changes in components observed in Site 1096 but they show that the change in color in the sediments also corresponds with a change from less biogenic productivity below the IRD interval to higher productivity above.

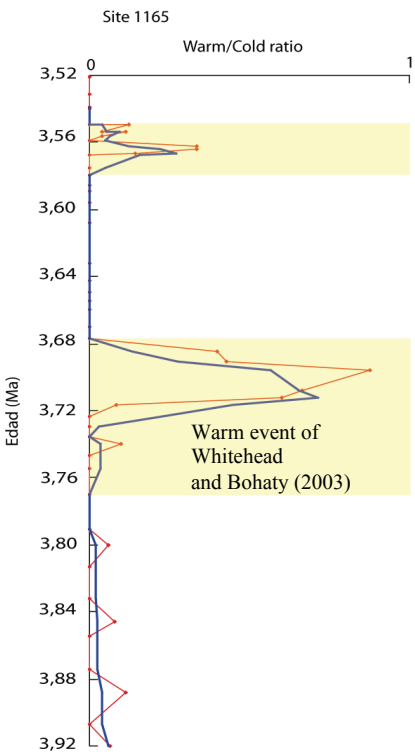

Figure 2. Warm-cold ratio from Silicoflagellate genera *Dyctyocha* and *Distephanus* from Site 1165.

Biostratigraphic analyses

Sediment samples from the three ODP Sites in Prydz Bay and the Antarctic Peninsula show one to two intervals of increased diatom assemblage abundance between 3.5 Ma and 3.7 Ma (Fig. 1). Diatom abundance in all the cores coincides with absolute abundance of *Fragilariopsis baronii,* the most abundant species in all the cores. Sediment samples from Site 1165 show relatively high diatom abundance in the interval between 3.5 Ma and 3.7 Ma (Fig. 1). The interval with more abundance of *Fragilariopsis baronii* coincides with abundance peaks in *Rouxia antarctica*, *Fragilariopsis interfrigidaria*, and *Thalassiosira oestrupii* among others. Diatoms are less abundant in the cores from Sites 1095 and 1096 (Fig. 1). Nevertheless, diatom abundance at Site 1095 exhibits one peak interval at about 3.5 Ma and two peak intervals at Site 1096 at about 3.6 Ma. Diatoms are almost absent at the base of the sampled interval in Site 1096.

The silicoflagellate genera *Dyctyocha* and *Distephanus* from Site 1165 have been used as warm and cold indicators, respectively. Two possible warm events can be differentiated (Fig. 2). The event at 3.7 Ma, was previously recognized in this same core by Whitehead and Bohaty (2003). In this study, we differentiate another possible event at 3.5 Ma. Silicoflagellates in the Antarctic Peninsula cores are few in number and belong mainly to the genera *Distephanus*.

Summary

Preliminary results from diatom sedimentological and biostratigraphic analyses conducted in cores recovered from the continental rise during Ocean Drilling Program (ODP) Legs 178 (Antarctic Peninsula) and 188 (Prydz Bay) show evidence for warming intervals between 3.6 and 3.8 Ma. Our preliminary results confirm the warming event previously reported from Prydz Bay at 3.7 Ma and show evidence for the same event in the Antarctic Peninsula, which implies the event was of continent-wide significance. Results from ongoing analyses of opal, clay mineralogy and elemental analysis, will likely give us a further insight into the nature of this warming event.

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