Sediment records of ice-sheet instability at ODP Site 697 (Jane Basin), NW Weddell Sea, South Orkney Microcontinent

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Introduction

The instability of the East and West Antarctic Ice Sheets, WAIS/ EAIS, threatens global coastal populations as a 0.8 m sea-level rise would result in massive rebuilding and relocation efforts for inundated areas (Hallegatte et al., 2013; Hauer et al., 2016). The study and mitigation of WAIS/ EAIS destabilization is further necessitated by increased anthropogenic activity which has accelerated rates of sea-level rise approximately 0.08 mm annually since 1993; melt from glaciers and ice-sheets account for 61 ± 19% of this change alone (Gardner et al., 2013; Albrecht and Levermann, 2014; Nerem et al., 2018). Environmental models suggest that anthropogenic change will cause environmental conditions to mimic those of the Pliocene (5.33 to 2.58 mya) a slightly warmer epoch (~2-3 ℃) with similar CO_2 concentrations (around 400 ppm) and global mean sea-level approximately 6 m higher than those of present (Pagani et al., 2009; Fig. 1). The Jane Basin, a small back-arc basin southeast of the South Orkney Islands, is capable of capturing geologic material from around Antarctica as it is centrally located beyond the tip of the Antarctic Peninsula (Diekmann and Kuhn, 1998; Fig. 2). Here we examine marine sediment records from the Ocean Drilling Program (ODP) Site 697 (Jane Basin) including: grain size analyses, ice-rafted detritus (IRD) provenance, biogenic silica (bSi), XRF elemental counts, and ^{40}Ar-^{39}Ar dating which constrain Antarctic ice-sheet instability and prevailing environmental conditions during the early Pliocene. Results are compared to Kaufman (2016) who finds mean IRD accumulation in Cores 13-17X was 57.45 g/cm^2/kyr; such results align with estimates from shipboard reports (Fig 3.).

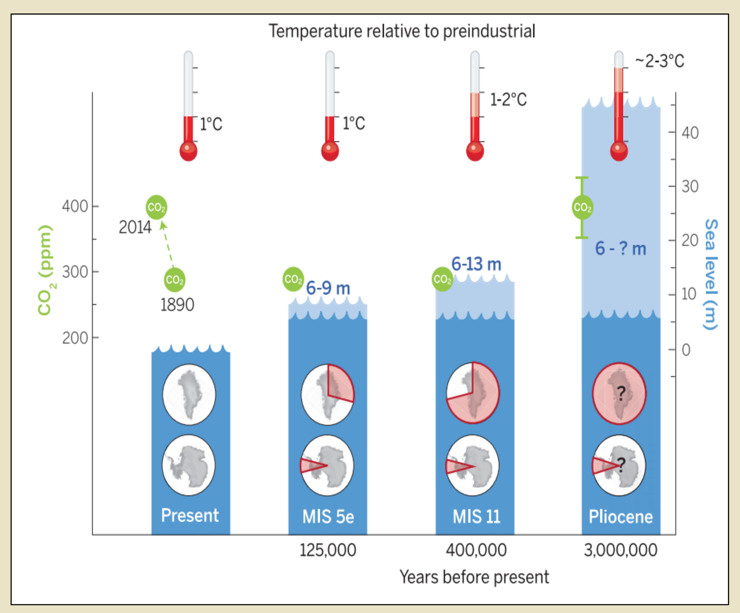


Figure 1. Pliocene atmospheric conditions. Although present day temperatures and CO_2 concentrations resemble those of the Pliocene sea-levels were different (Dutton et al., 2015).

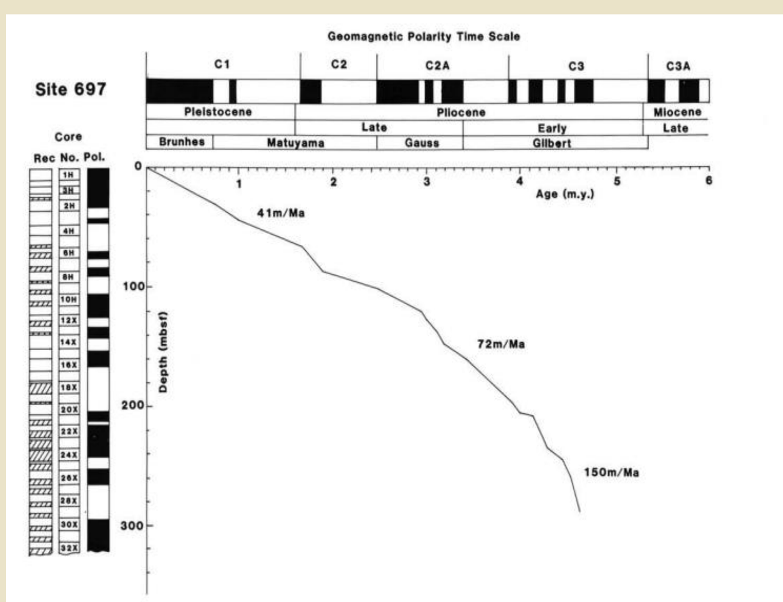


Figure 3. Geomagnetic polarity timescale of ODP Site 697. (Gee and Kent, 2007).

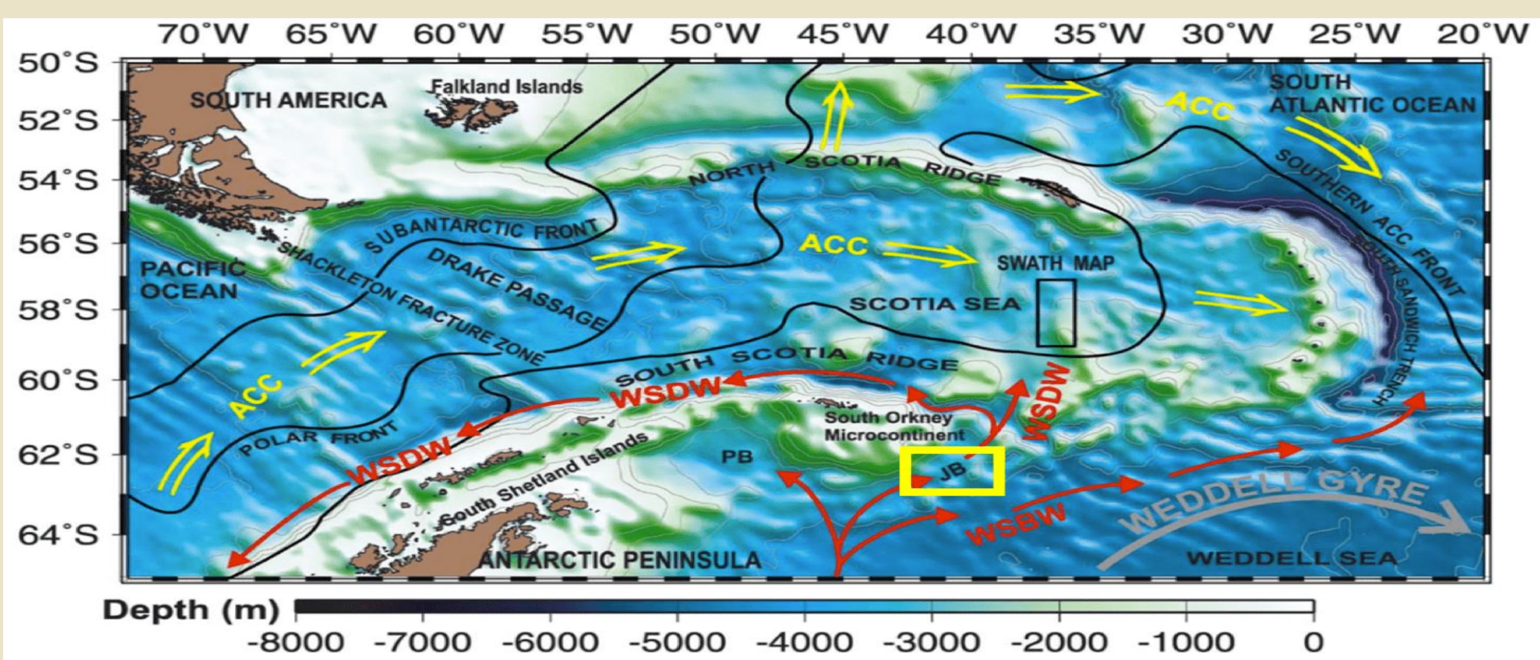
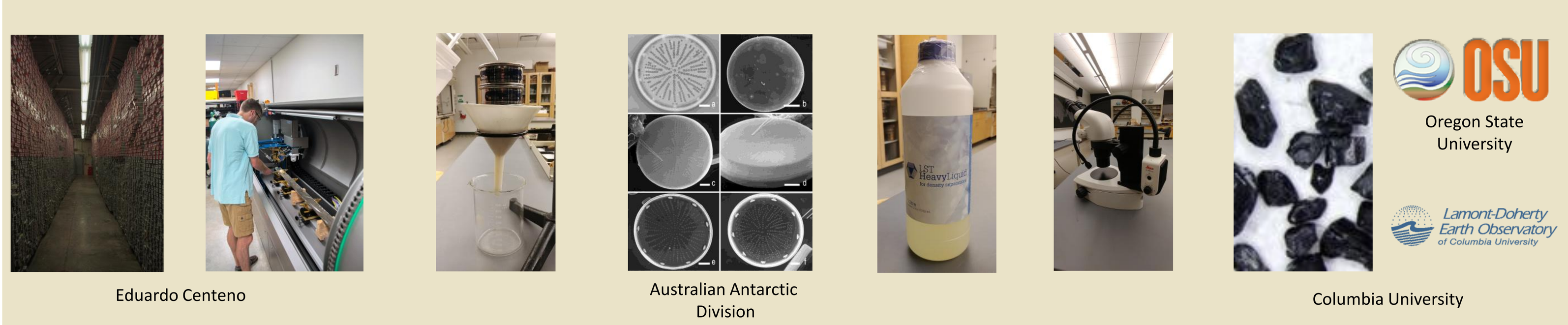
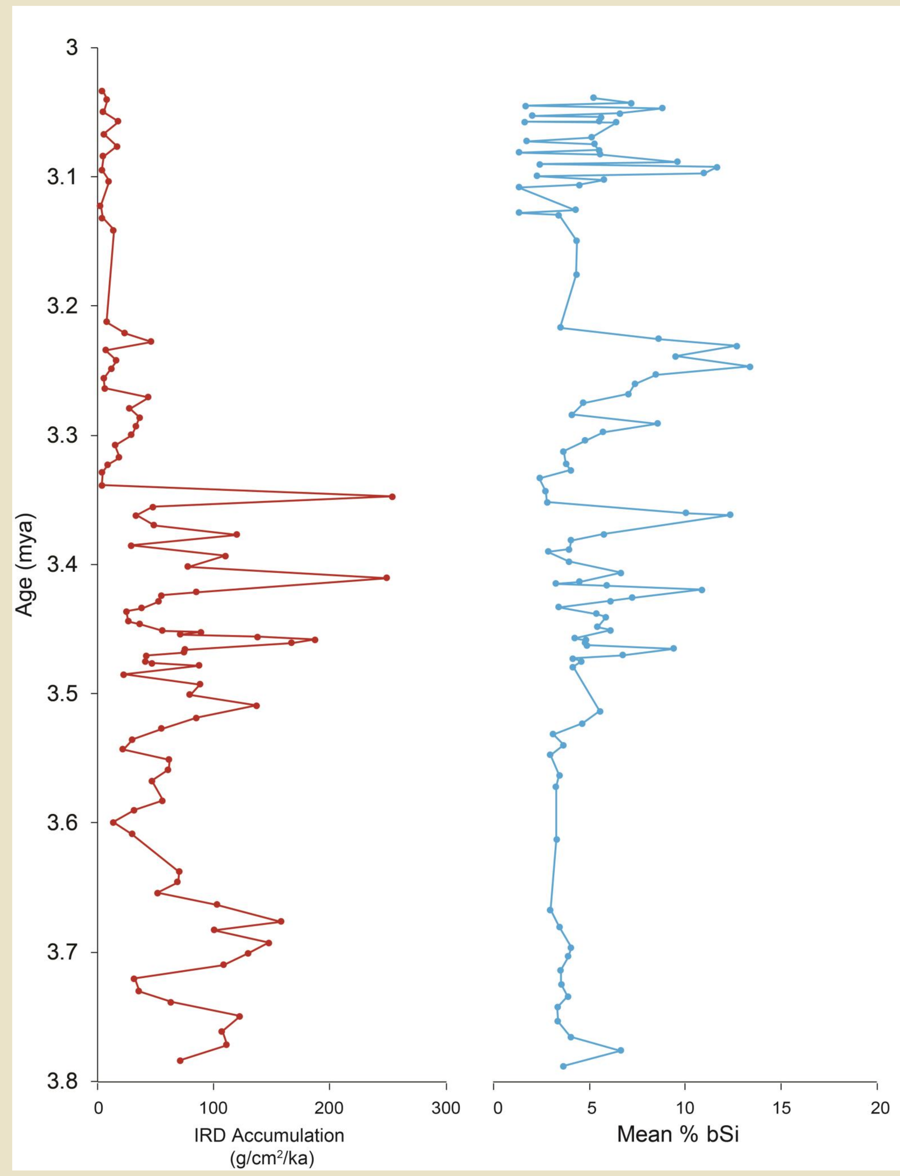


Figure 2. Location of the Jane Basin. Site 697 (boxed in yellow) is situated near the Weddell Gyre, Antarctic Circumpolar Current (ACC) and is capable of capturing IRD from multiple locations (Maldonado et al., 2003).

Methodology

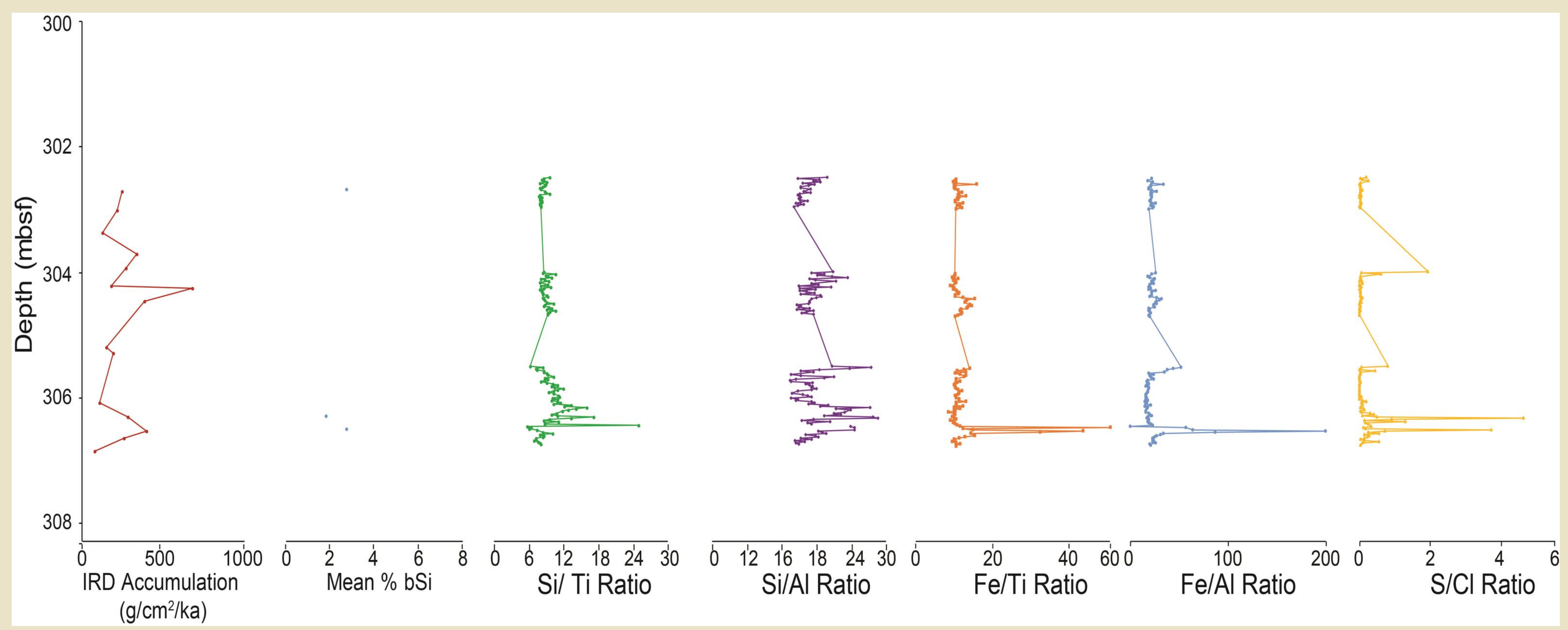


Results



IRD Accumulation & bSi weight percent from 697B-13X-17X. Pulses of IRD accumulation, from Coats Land and the Filchner Ice Shelf, in conjunction with ocean productivity occurred from 3.3-3.6 mya and were followed by periods of low accumulation from 3-3.3 mya (Kaufman, 2016).

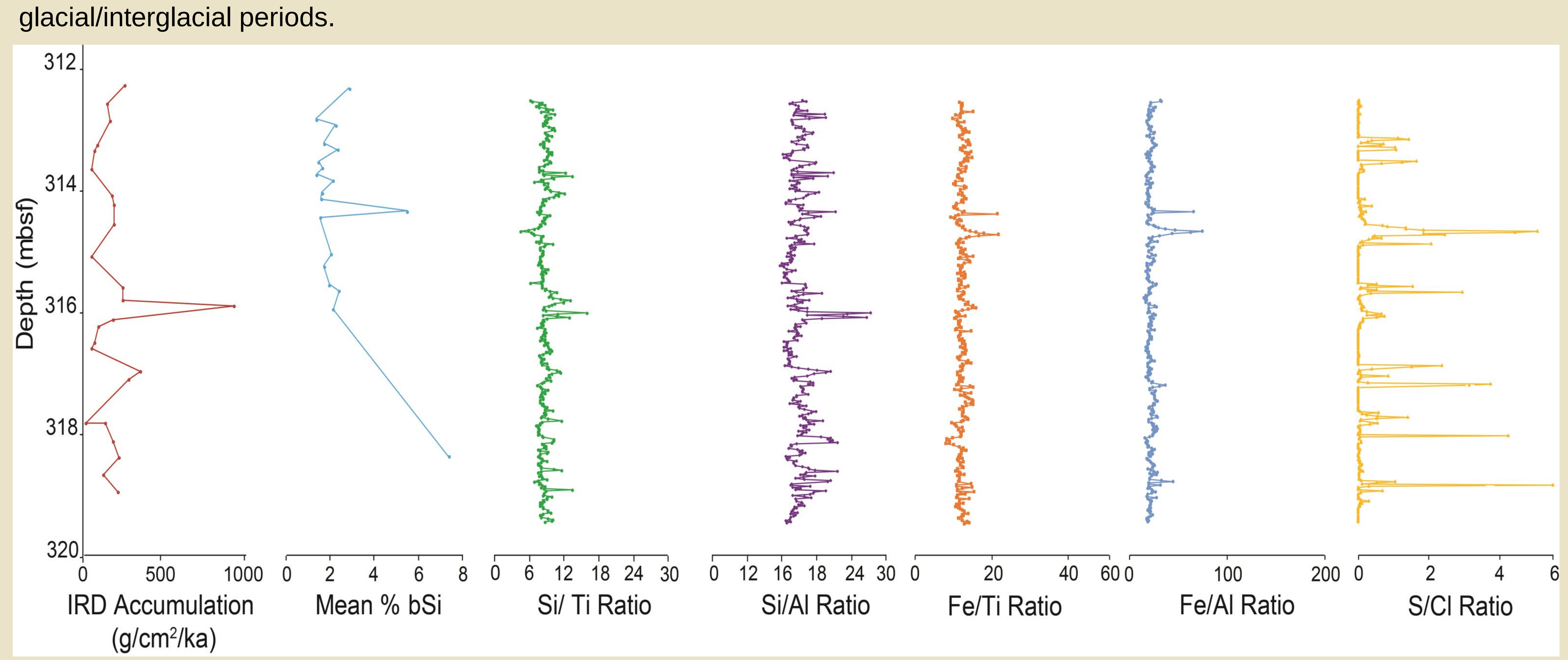
Photo showing variability in core section 32X-4-90-98. Core images such as this one taken from approximately 317.66 to 317.72 mbsf, display a range of colors and particle sizes as found throughout the hole. The light, silt-rich laminae are indicative of contourite deposits which form as a result of contour currents which are turbid and caused by bottom water interaction.



All XRF proxies for anoxic conditions (Fe/Ti, Fe/Al, and S/Cl ratios) which are necessary for pyrite formation are found peaking at the same depths downhole for Core 31X and Core 32X; pyrite is found at these depths.

Peaks from IRD (red) and bSi accumulation (light blue) tend to be synchronous and exhibit similar trends in warming.

The bSi curve (solid light blue) is plotted downcore with proxies for bSi production (Si/Ti, and Si/Al); notice that although samples were not taken down the entire hole peaks match and can be used to infer other periods of productivity as they relate to glacial/interglacial periods.



Discussion

- Depth to age correlation has been made difficult as the last paleomagnetic reversal occurs in Core 30X (295.7 mbsf); Cores 31X & 32X record approximately 108 kyrs (5.13 Ma to 5.03 Ma) assuming LSR of 150 m/my (Pudsey, 1990; Gee and Kent, 2007).
- Abundance of Si and contourite deposits suggest that the site is located at depth, cool, and turbid.
- Data suggest that the Pliocene is characterized by a series of warming/cooling cycles which began in the Zanclean and culminated in the mid-Pliocene.
- IRD and bSi peaks suggest that the recorded period may have been warmer than the mid-Pliocene warming period which had average IRD accumulation rates of 216.1 g/cm^2/kyr (Kaufman, 2016).
  - Differences in accumulation rates may occur the result of a change in provenance or increased ice-rafting at the site.
- Additional data from Cores 18X-30X would be beneficial in discerning prevalence of glacially dominated periods, but such cores are highly disturbed.
- Si/Al and Si/Ti XRF spectral count ratios suggest Si is biogenically sourced, likely from diatom frustules (Agnihotri et al., 2008; Dickson et al., 2010).
- Peaks in Fe/Ti, Fe/Al, and S/Cl ratios suggest the presence of anoxic conditions or formation of bottom water at ODP Site 697.
  - Possibly the result of increased eutrophication.

Future work

Hornblende age dates (^{40}Ar/^{39}Ar) and results from the analysis of fine grains (<63 µm) will be used to determine IRD provenance and understand conditions related to bottom water formation during the Pliocene; results will be compared to those of Kaufman (2016) to determine if source regions have changed during this earlier interval.

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