Stable isotopic and foraminiferal evidence of Larsen-B Ice Shelf stability throughout the Holocene

S. Ishman,[1] M. Prentice,[2] S. McCallum,[3] E. Domack,[4] A. Leventer,[5] and V. Willmott[4]

[1]Department of Geology and Center for Ecology, Southern Illinois University Carbondale, Carbondale, IL 62901, USA (sishman@siu.edu)
[2]Indiana Geological Survey, Bloomington, IN 47405, USA (mlprenti@indiana.edu)
[3]Equitable Production, 225 North Shore Drive, Pittsburgh, PA, 15212, USA (SMcCallum@eqt.com)
[4]Department of Geosciences, Hamilton College, Clinton, NY 13323, USA (edomack@hamilton.edu and vwillmot@hamilton.edu)
[5]Geology Department, Colgate University, Hamilton, NY 13346, USA (aleventer@mail.colgate.edu)

Summary Kasten cores collected during the NBP01-07, LMG05-02 and NBP06-03 cruises to the Larsen-B Ice Shelf region, eastern Antarctic Peninsula contain sediments recording its Holocene history. Benthic foraminiferal transfer function analyses of the kasten core samples indicate persistent ice shelf conditions throughout the Holocene. Planktonic and benthic foraminiferal $\delta^{18}O$ stable isotopic analyses also indicate persistent ice shelf conditions with gradual melting resulting in freshening of the regional oceanography, independent of global Holocene isotopic shifts.

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Introduction

Antarctic ice shelves were noted by Mercer (1978) as climatic bellwethers when he suggested that their collapse is the first indication of significant global climate change. Recent trends in Larsen Ice Shelf disintegration (Skvarca et al., 1999) culminating in the rapid collapse of the Larsen-B Ice Shelf has precipitated great interest in understanding the dynamics of such events and their occurrences throughout the Holocene. Multiple cruises to the northwestern Weddell Sea have resulted in the collection of sediment cores from the region formerly covered by the Larsen-B Ice Shelf (LIS-B). Herein we report the initial results of foraminiferal and stable isotopic analyses of these cores to produce a record of ice shelf conditions in this region throughout the Holocene.

Background

Ice shelf breakup along the Antarctic Peninsula (AP) was first recognized on its western margin. Doake and Vaughn (1991) documented the retreat of the Wordie Ice Shelf, and subsequently Vaughn and Doake (1996) attributed the southern progression of ice shelf break-up to the southward migration of the -5ºC mean annual summer isotherm, which they suggested as the limit for ice shelf sustainability. Ice shelf disintegration on the western AP margin is further enhanced by incursions of warm Upper Circumpolar Deep Water onto the continental margin resulting in sub-ice shelf melting as observed beneath the George VI Ice Shelf (Potter and Paren, 1985).

The eastern margin of the AP, until recently, was dominated by ice shelf conditions with the Prince Gustav Ice Shelf occurring as far north as ~64ºS latitude. Historical observations of ice shelves in the northeastern AP margin show their retreat over the past 150 years, increasing during the 1980's and culminating in 1995 with the break-up of the Prince Gustav and Larsen-A (LIS-A) ice shelves (Rott et al., 1996; Cooper, 1997; Skvarca et al., 1999). The LIS-B collapse in 2002 (Scambos et al., 2003) marked the most recent, and perhaps the most dramatic ice shelf break-up.

These changes remain poorly understood but have been shown to impact terrestrial and marine ecosystems (Smith et al., 1999), and have implications for ice volume (Rignot et al., 2004; Scambos et al., 2003) and, consequently, sea-level (Vaughn et al., 2003). Sediment core records from Prince Gustav and LIS-A (Domack et al., 2001; Pudsey and Evans, 2001) indicate persistent ice shelf conditions in the early to mid-Holocene punctuated by a mid to late Holocene ice shelf retreat with a re-advance in the late Holocene and subsequent historical break-up. In contrast, sediment core records from LIS-B indicate the absence of a mid-Holocene retreat with its recent collapse unprecedented throughout the Holocene (Domack et al., 2007; Domack et al., 2005). This paper will present preliminary stable isotopic and foraminiferal data from sediment cores collected from the recently exposed region of LIS-B (from LMG05-02 and NBP06-03) and compare them with results from cores collected from previously exposed regions (NBP01-07).

Methods

Kasten cores were collected from the LIS-B and LIS-A regions during cruises NBP01-07, LMG05-02 and NBP06-03 (Figure 1). Chronology for the cores is based upon a combination of radiocarbon, ^{210}Pb, and geomagnetic paleointensity analyses (Domack et al., 2007; Domack et al., 2005; Brachfeld et al., 2003). Upon their collection 10 cc sediment samples were taken at 5 cm intervals (NBP01-07) and 2 cm intervals (LMG05-02 and NBP06-03) for foraminiferal analyses. These samples were also used for stable isotopic analyses. The samples were sieved using de-ionized water and dried at <50ºC. The 63µm and greater size fraction was picked for benthic and planktonic foraminifera. A total of 300 specimens of benthic foraminifera from each sample were picked when possible. When

300 specimens were not attainable, only those samples producing 100 specimens or more were used in the benthic foraminiferal statistical analyses. Planktonic foraminifera were picked when found but not included in the count data for statistical analyses. Benthic foraminiferal counts were transformed using log squared transformation and analyzed using transfer function analyses with the modern benthic foraminiferal data set from Szymcek (2005) as the modern analogs.

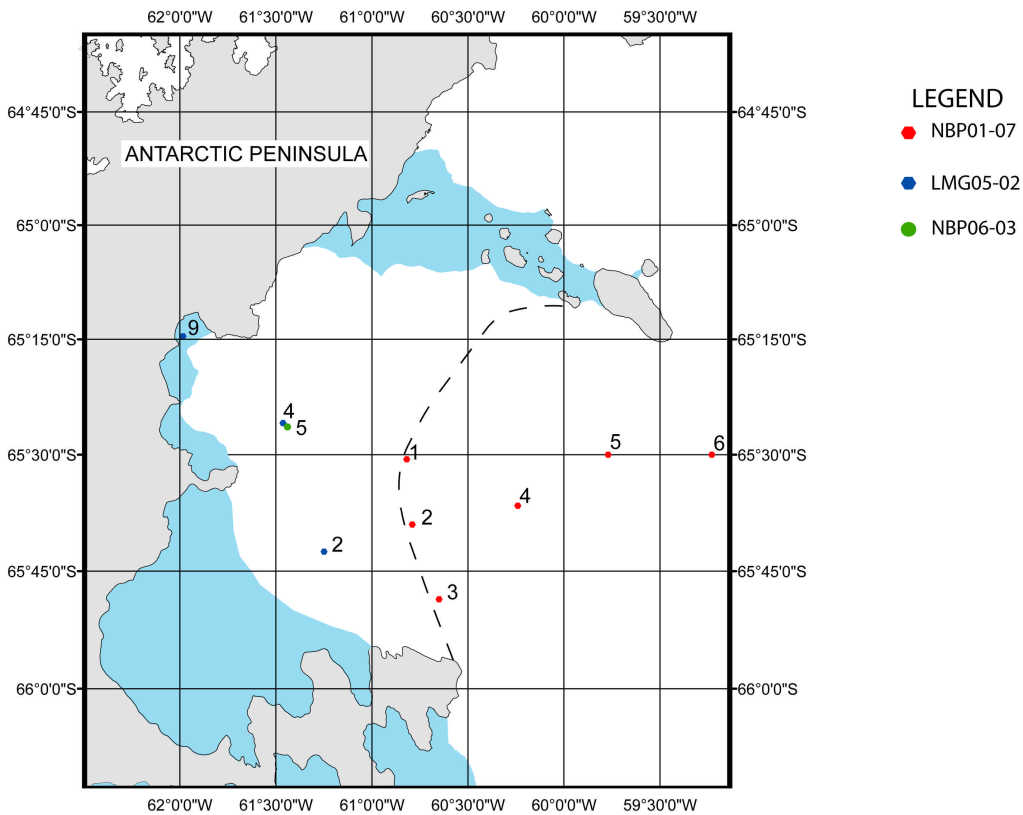

Figure 1. Map of the Larsen A and Larsen B embayments. Kasten core locations are designated by the colored dots. Present ice shelf is shown in blue. Dashed line is the approximate position of the LIS-B edge just prior to the March 2002 break out.

Stable isotope measurements of benthic and planktonic foraminifera were made on a Finnegan MAT 252 gas-mass spectrometer fitted with a Kiel III Carbonate Preparation System in the Benedum Stable Isotope Laboratory of Brown University following standard procedures. Data are reported in per mille relative to VPDB via the NBS-19 standard. Analytical precision of NBS-19 and BYM standards of 15-50 micrograms analyzed to bracket the data reported here is ± 0.08 ‰ for $\delta^{18}O$. All tests were measured with a micrometer and analyzed in monospecific groups of 2 to 10 tests using the minimum size range. Uncertainty for individual taxa based on replicate analyses is ± 0.1 ‰ for $\delta^{18}O$.

Discussion

Results of the transfer function analyses of benthic foraminiferal data from kasten cores NBP01-07 1-6 indicate little variability throughout the Holocene in the benthic foraminiferal assemblages, with changes beginning to occur in the mid to late Holocene (Figure 2). Samples from the ice edge proximal localities (NBP01-07 KC1-KC3) in LIS-B have calcareous benthic dominated assemblages consistent with ice edge environments for the Larsen Ice Shelf system. These remain consistent throughout with a slight shift associated with the change from *Nonionella iridea* dominated assemblages in the early to mid Holocene to *Alabaminella weddellensis* and *Globocassidulina subglobosa* dominated assemblages in the mid to late Holocene, as is present today. Holocene assemblages from kasten cores KC4 and KC5 are also characterized by calcareous benthic foraminifera dominated by *A. weddellensis* and *G. subglobosa*, indicating persistent ice shelf or ice shelf edge conditions at these sites throughout the Holocene. The outermost kasten core (KC6) assemblages are comprised of agglutinated foraminifera, dominated by the taxa *Cystammina argentea* and *Conotrochammina bullata*. These assemblages are characteristic of modern assemblages associated with saline shelf waters on the outer shelf of the eastern AP margin and the Weddell Sea.

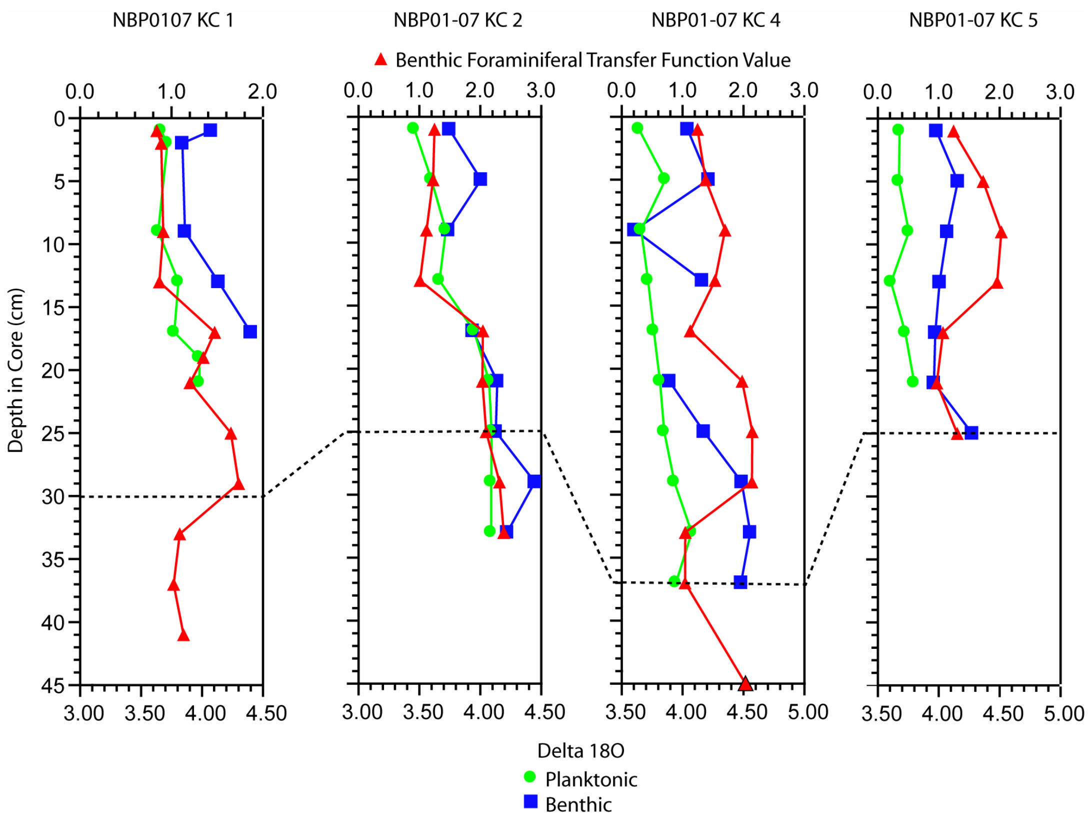

Figure 2. Plot of transfer function and stable isotopic results for the NBP01-07 kasten cores (KC1, KC2, KC4, and KC5). Transfer function values are associated with modern benthic foraminiferal assemblages: 1 with the Larsen-B Ice Edge, 2 with the Larsen-A Ice Edge, and 3 with the Larsen-A Trough. Stable isotopic values are shown with planktonic $\delta^{18}O$ values shown in green circles and benthic $\delta^{18}O$ values shown in blue squares. Dashed line shows approximate correlation between cores based on their lithostratigraphy (Domack et al., 2005).

Stable isotopic analyses of benthic (*Globocassidulina subglobosa*) and planktonic (*Neogloboquadrina pachyderma*) foraminifera (Figure 2) show changes consistent with a gradual change in ice shelf conditions throughout the Holocene. Kasten cores NBP01-07 KC1, KC2, and KC4 show gradual lightening of the planktonic and benthic $\delta^{18}O$ values with a maximum shift of ~0.7‰ occurring in KC2. The gradational decrease in $\delta^{18}O$ values is interpreted as representing gradual freshening of the water column as a result of thinning of the ice shelf throughout the Holocene. Also noted is the offset between the planktonic and benthic isotopic values, with the exception of KC2. We interpret this as representing water column stratification with again, the planktonic values being isotopically light as a result of salinity stratification. NBP01-07 KC5 was farthest removed from the ice shelf edge and does not show the gradual decrease in $\delta^{18}O$ values indicating that at that position on the shelf a temporal salinity gradient did not develop. This may also indicate that the $\delta^{18}O$ signal observed is primarily controlled by regional and local changes rather than the global ocean isotopic shift for the Holocene. In addition, the impact of significant volumes of meltwater in the western Weddell Sea on the production of Weddell Sea Shelf Water and its effects on the Weddell Gyre remain uncertain.

With the addition of cores collected from the LIS-B region most recently exposed (LMG05-02 KC2, KC4; KC9, and NBP06-03 KC5) we hope to increase our understanding of the processes resulting in the recent collapse of the LIS-B. Preliminary sedimentary and diatom data from the LMG05-02 and NBP06-03 support our earlier conclusion of Holocene ice shelf stability for the LIS-B (Domack et al., 2007).

Summary

Kasten cores collected during the NBP01-07, LMG05-02 and NBP06-03 cruises to the Larsen-B Ice Shelf region, eastern Antarctic Peninsula contain sediments recording its Holocene history. Benthic foraminiferal transfer function analyses of the kasten core samples indicate persistent ice shelf conditions throughout the Holocene. Planktonic and benthic foraminiferal $\delta^{18}O$ stable isotopic analyses also indicate persistent ice shelf conditions with gradual melting resulting in freshening of the regional oceanography, independent of global Holocene isotopic shifts.

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