New Marine Sediment Core Data Support Holocene Stability of the Larsen B Ice Shelf

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Summary Multi-proxy data (sedimentologic, geochemical and micropaleontologic) from 10 kasten cores collected from within the Larsen B embayment during two research cruises, LMG0502 and NBP0603, support earlier data indicating that the March 2002 collapse of the Larsen B Ice Shelf was a unique event and that the ice shelf had been present since its formation at the end of the last glacial period. Chronologies for these cores have been developed through a combination of radiocarbon and ^{210}Pb analyses. In general, the sediment core data illustrate the transition from grounded ice to a sub-ice shelf setting, followed by the open marine environment present today. More details regarding processes associated with ice shelf collapse are recorded as well, including rapid deposition in sites proximal to the fast-moving glaciers that have responded to ice shelf collapse.

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Introduction

A major question concerning the March 2002 collapse of the Larsen B Ice Shelf was whether or not the collapse was a unique event consequent to the warming climate of the 21st century, as opposed to an episodic event repeated through the Holocene, such as observed with other Antarctic Peninsula ice shelves, as the George VI and Muller Ice Shelves (Clapperton and Sugden, 1982; Domack et al., 1995; Hjort et al., 2001; Bentley et al., 2005). This question was addressed initially by analyses of marine sediment cores that were collected just prior to the 2002 Larsen B Ice Shelf breakout. This initial suite of cores was collected at sites located in front of the ice shelf edge but which had been situated in a sub-ice shelf setting until 1995 (Figure 1, cruise NBP0107 kasten cores). The multi-proxy data set from these cores showed the unprecedented nature of the Larsen B collapse (Domack et al., 2005). New data, from ten marine sediment cores collected from within the region of the Larsen B embayment exposed by the post 2002 breakout (Figure 1) confirm these earlier findings, conclusively demonstrating that the Larsen B Ice Shelf was present through the entire Holocene until its collapse in 2002. Prior to ice shelf formation, grounded ice extended out onto the continental shelf. These data highlight the rapid response of the Larsen B Ice Shelf to recent environmental changes impacting the region (Hodgson et al., 2006; Scambos et al., 2003).

Discussion

Kasten cores were recovered from the Larsen B embayment during two recent research cruises, LMG05-02, conducted from February 11 – March 11, 2005, and NBP0603, conducted from April 11 – May 6, 2006. A fundamental rationale supporting this investigation was that modern surface sediments in the Larsen B embayment would reflect the newly open water conditions in the overlying water column; comparison of surface sediment characteristics to those exhibited downcore would permit the identification of periods of open water if they had occurred previously during the Holocene. These core sites all were located in a sub-ice shelf setting until March 2002; in fact, the calving of iceberg A-54 from the remnant Larsen B Ice Shelf in SCAR Inlet just two months prior to cruise NBP0603 permitted collection of kasten core NBP0603 KC3. Another kasten core NBP0603 KC8, was situated in a new fjord, formed by the retreat of the Crane Glacier following Larsen B Ice Shelf collapse. Collectively, the 10 kasten cores are ideally located to record the Holocene history of the Larsen B region, and to assess whether or not the embayment had been ice shelf free at any time over the past 10,000 years prior to the open water experienced today.

A suite of sedimentologic, geochemical, and micropaleontologic analyses have been performed on these cores. These include analysis of bulk density, grain size, carbon content, carbon/nitrogen ratios, magnetic susceptibility, and diatom and foraminiferal assemblage composition and concentration. Chronologies for the cores are being developed through a combination of radiocarbon and ^{210}Pb analyses. Radiocarbon analyses have been completed on 17 acid insoluble organic matter (AIOM) samples and 9 calcite samples from the two sets of cores. These data are entirely consistent with previously published data for the Larsen region (Domack et al., 2005). In general, ages increase systematically downcore and document the Holocene time frame for the cores. Old surface ages are measured for the AIOM dates, a consequence of the presence of reworked organic material. The pairing of AIOM data with dates on biogenic calcite has been used to establish an AIOM correction for this area (Domack et al., 2005). Comparison to a chronology independently developed for a Larsen A kasten core, using geomagnetic paleointensity (Brachfeld et al, 2003) supports the AIOM correction.

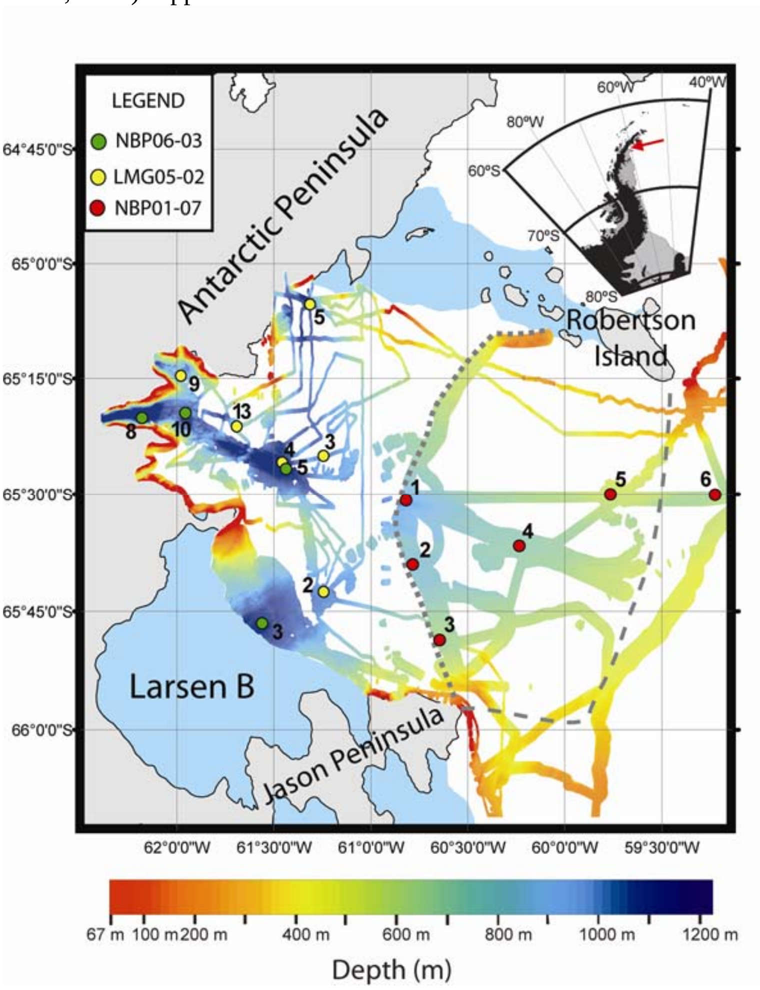

Figure 1. Map of the Larsen B embayment. Bathymetric data was collected on cruises NBP0107, LMG0502 and NBP0603. Kasten core locations are designated by colored dots. The dashed line represents the Larsen B Ice Shelf edge in 1995. The dotted line represents the position of the shelf edge just prior to the March 2002 collapse. The remaining Larsen B Ice Shelf is shown in blue.

Lithologically the cores show the same stratigraphic succession as observed in the NBP0107 cores, with the additional advantage of capturing the sedimentary sequence that resulted from both the 2002 ice shelf collapse and the subsequent open marine setting that now characterizes the Larsen embayment. The lowermost unit in the stratigraphic succession is homogenous diamicton, interpreted to have formed in a sub-glacial setting. As observed in the NBP0107 cores (Domack et al., 2005), the diamictons are characterized by relatively high sand content. Above the till is a stratified to cross-stratified gravelly sand to granulated mud that represents deposition in a proximal grounding line setting. This is overlain by silty muds interpreted to have been deposited in a sub-ice shelf environment. Increased biosiliceous content is observed in the upper few centimeters of most, but not all, of the cores, reflecting the modern open water setting and glacial marine deposition. Kasten core NBP0603 KC8, which is located in the newly formed fjord associated with the retreat of the Crane Glacier, has experienced very high sedimentation rates during and subsequent to ice shelf breakout. This 260 cm core is characterized by a relatively thick sequence of sand and mud; the presence of common and well-preserved diatom valves suggests the entire sequence was deposited in the open marine conditions that have been present only recently. Single-channel seismic data indicate that the kasten core recovered only a fraction of the thick sedimentary fill located in the > 1200 m deep trough.

Quantitative diatom analyses show a surface and/or near-surface peak in absolute diatom abundance in many of the cores (Figure 2). These data complement bottom photos and visual observations of core tops; all demonstrate the heterogeneous distribution of newly deposited phytodetritus at the sea floor, to be expected given the short time since ice shelf breakout. The diatoms are dominated by forms associated with sea ice, mostly specimens of the genus *Fragilariopsis*, including *F. vanheurckii*, *F. sublinearis* and *F. curta*, as well as *Chaetoceros* vegetative cells.

Preservation is excellent, with many very lightly silicified specimens often occurring in ribbon colonies, observations that point to the very recent and rapid deposition of the valves at the sea floor. In several of the cores, the highest diatom concentration occurs just beneath the sediment-water interface, suggesting that increased biological production in the spring, and settling of diatom valves to the sea floor, was followed by increased terrigenous input, perhaps in response to increased meltwater production through the summer. In general, below the surface/near surface peak in diatoms, diatom concentration decreases sharply and many of the specimens present are extinct forms, such as *Actinocyclus ingens, Denticulopsis simonsenii, Denticulopsis maccollumii*, and *Stephanopyxis* sp., suggesting a mid to late Miocene source for these reworked diatoms. Two exceptions to this are observed. The first is in cores LMG0502 KC5A; the large diatom peak at depth has the same assemblage composition as the surface peaks. The origin of this peak currently is being investigated. And in NBP0603 KC8, a modern diatom assemblage occurs throughout the core, though in low absolute abundance. In this case the entire core is assumed to have been deposited since ice breakout and low absolute abundances are the result of dilution by terrigenous input.

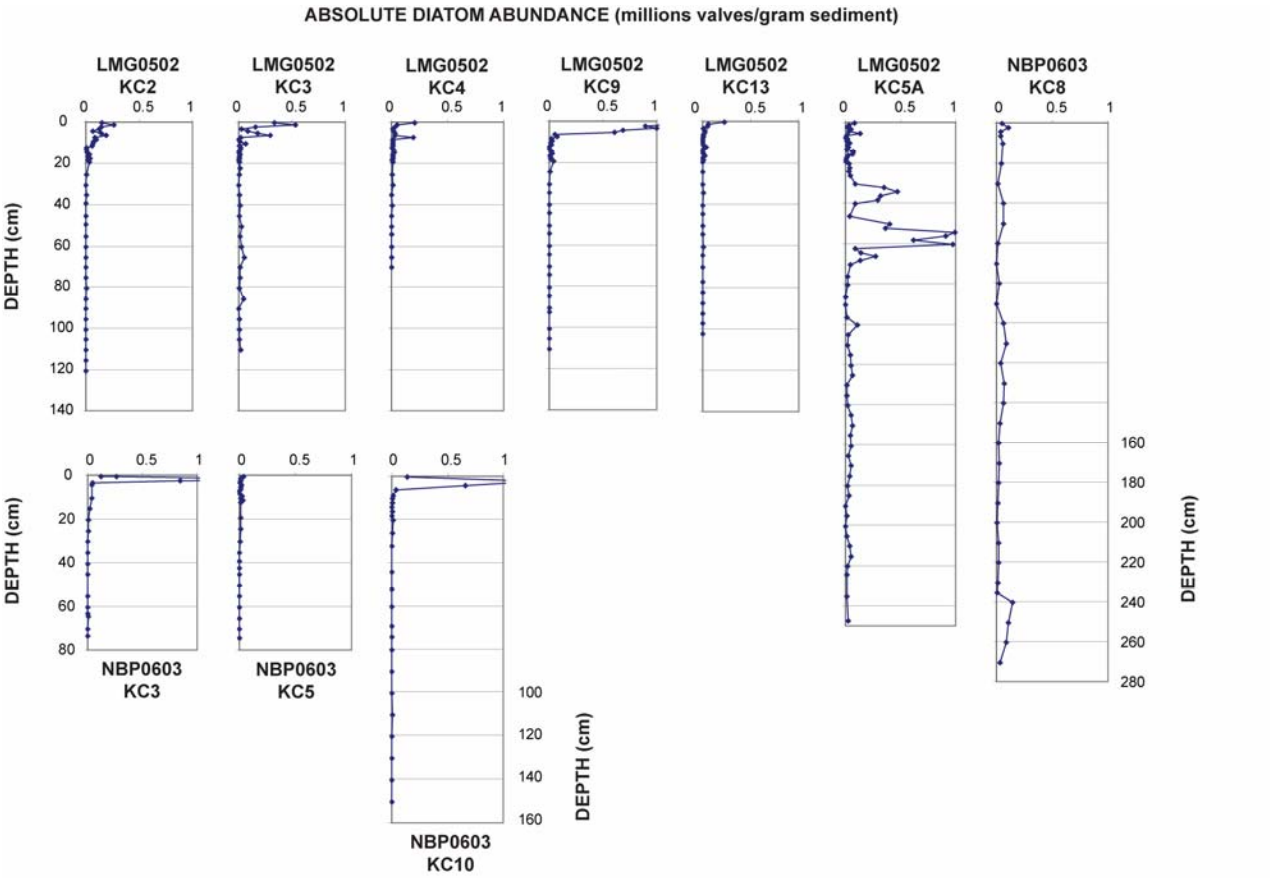

Figure 2. Absolute diatom abundance data (in millions of valves per gram sediment (mvpgs)) for kasten cores from the Larsen B embayment. See figure 1 for locations of cores, recovered during cruises LMG0502 and NBP0603. Note that in general, abundance is very low, but many of the cores exhibit a surface and/or near surface peak in diatom abundance. The maximum abundances are off scale in the graphs for LMG0502 KC9 (1.55 mvpgs at 0.5 cm), NBP0603 KC3 (2.45 mvpgs at 1.5 cm), and NBP0603 KC5 (1.29 mvpgs at 2.5 cm).

Summary

A multi-proxy data set, including sedimentologic, geochemical, and micropaleontologic analyses, has been developed for kasten cores collected from the Larsen B embayment during two research cruises, LMG0502 and NBP0603. Chronologies for the cores are constrained through a combination of radiocarbon and ^{210}Pb analyses. These records add to those previously published (Domack et al., 2005) and conclusively demonstrate that the Larsen B Ice Shelf was a persistent presence throughout the Holocene, until its most recent collapse in March 2002. This observation is significant, indicating that modern climate perturbations in the region have had a greater impact on the Larsen B Ice Shelf than natural variability of the Holocene.

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