Marine Micropaleontology 140 (2018) 56–68

Contents lists available at ScienceDirect

Marine Micropaleontology

journal homepage: www.elsevier.com/locate/marmicro

Research paper

Iceberg Alley, East Antarctic Margin: Continuously laminated diatomaceous sediments from the late Holocene

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ARTICLE INFO

Keywords:
Diatoms
Southern Ocean
Holocene
Laminated sediments
East Antarctica

ABSTRACT

A 24-meter jumbo piston core (NBP0101 JPC41) collected from an inner shelf basin in Iceberg Alley reveals an approximately 2000-year history of unusually high primary productivity. Iceberg Alley, an ~85 km long and 10–20 km wide cross-shelf trough on the Mac.Robertson Shelf, East Antarctica, reaches depths of 850 m and is bounded on either side by shallow banks that are lined with grounded icebergs. The sediments are laminated on a mm- to cm-scale throughout and are highly biosiliceous. Microscopic examination of smear slides, quantitative diatom slides, and sediment thin sections reveals that the sediments are visually dominated by the diatom *Corethron pennatum*, a large and lightly silicified species notable for its long and narrow shape; the valves, girdle bands and spines are all exceptionally well-preserved, suggesting rapid sedimentation. Other common species include sea ice-related *Fragilariopsis*, such as *F. curta* and *F. cylindrus*, with lesser contribution from other large diatoms, including *Rhizosolenia* spp. and *Chaetoceros* Ehrenberg subg. *Chaetoceros*. *Chaetoceros* Ehrenberg subg. *Hyalochaete* Gran resting spores, typically associated with large early-season blooms and common in many laminated sedimentary sections around the Antarctic margin, are surprisingly rare. Laminae with any significant terrigenous component are also very rare. Individual laminations appear to represent blooms, and in some cases sub-seasonal events are likely preserved. We suggest that this productive system is associated with the continuous presence of low-salinity meltwater derived from a combination of sea ice melt and grounded icebergs, which may be a source for a steady supply of micronutrients such as iron to the surface mixed layer.

1. Introduction

Diatoms in Antarctic sediments are powerful tools for paleoclimate reconstruction. The wide diversity of diatom species sensitive to changing oceanographic parameters such as water temperature, salinity, sea ice presence, and nutrient content allow for reconstruction of environmental and climatic conditions (Armand and Leventer, 2010). High rates of sediment accumulation in continental shelf troughs and basins, and in drift deposits may yield laminated records with annual or even seasonal resolution (Harris et al., 1999; Domack et al., 2001; Costa et al., 2007; Expedition 318 Scientists, 2011). Due to the excellent diatom preservation at many of these sites, diatom data have been instrumental in providing accurate reconstructions of local and regional climatic events, with the strength of interpretations dependent on a robust understanding of how the laminations formed. For example, studies of paired laminations in deglacial sediments from the western Antarctic Peninsula (Domack et al., 2005; Maddison et al., 2006; Leventer et al., 2002), Prydz Bay (Leventer et al., 2006), and the Mac.Robertson Shelf, East Antarctica (Stickley et al., 2005; Leventer et al., 2006) document the alternation of biosiliceous laminae, interpreted to have formed during periods of high productivity in spring and summer, followed by later season deposition of laminae containing greater terrigenous material and a more diverse diatom assemblage. These couplets record the short-lived formation of calving bay re-entrants as ice retreated across the continental shelf at the end of the last glacial maximum.

Laminations observed in Holocene sediments at these sites, and others on the Antarctic shelf, also appear to record sub-seasonal to seasonal signals (Denis et al., 2006; Maddison et al., 2006; Crosta et al., 2007; Crosta et al., 2008; Denis et al., 2009; Maddison et al., 2012). However, their interpretation can be complicated by the insignificant abundance of terrigenous material, leaving changes in diatom assemblages as the sole signal of seasonal to inter-annual climatic and oceanographic change. In 2001, a jumbo piston core (NBP0101 JPC41) was

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https://doi.org/10.1016/j.marmicro.2017.12.002
Received 22 June 2017; Received in revised form 7 November 2017; Accepted 29 December 2017
Available online 03 January 2018
0377-8398/

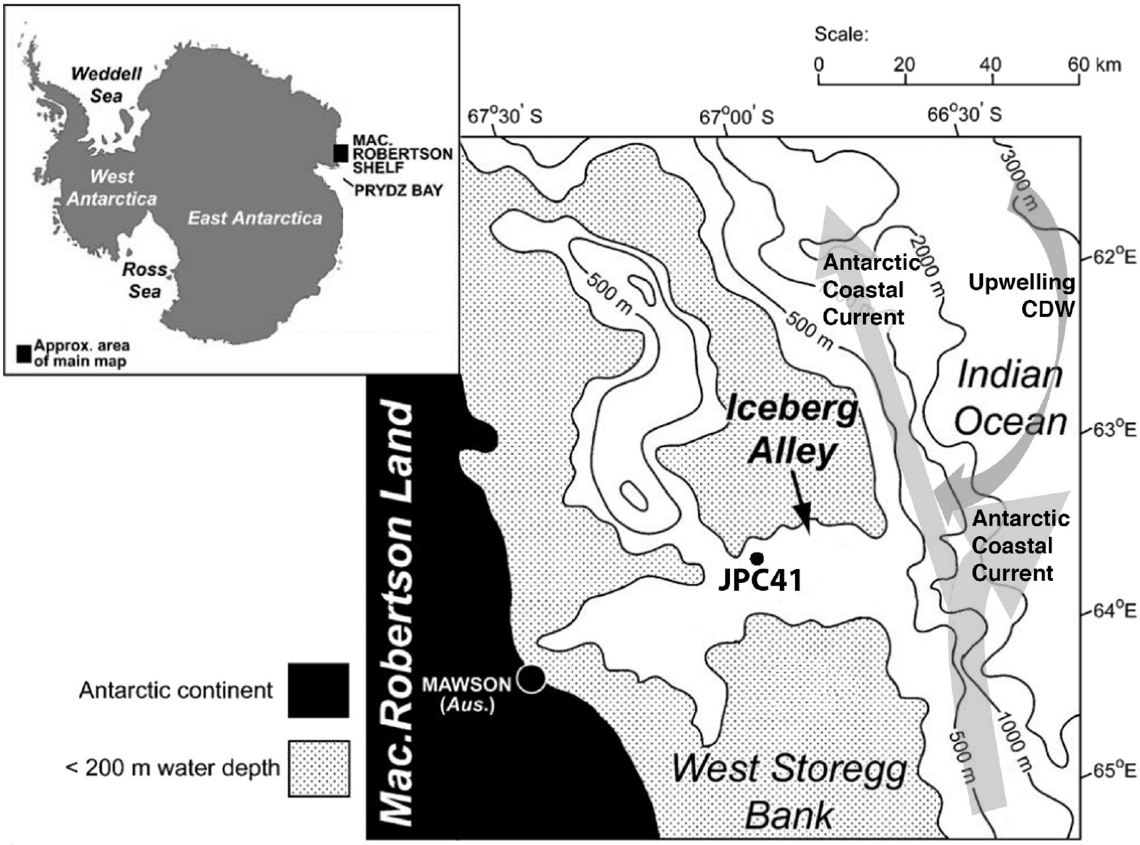

Fig. 1. Study location, including the site of Jumbo Piston Core 41 (JPC41). Major currents are also shown. (Adapted from Stickley et al., 2005.)

collected from inner Iceberg Alley on the Mac.Robertson Shelf, East Antarctica (Fig. 1); the core comprises millimeter- to centimeter-scale laminations along its entire 24-meter length (Fig. 2). Like other high-resolution Antarctic margin post-deglaciation laminated records (Leventer et al., 2002; Denis et al., 2006; Maddison et al., 2006; Gregory, 2012; Maddison et al., 2012), the core lacks a significant percentage of terrigenous material, and is composed predominantly of diatom ooze laminations that vary greatly in thickness, texture, and sharpness of upper and lower boundaries. The diatom assemblage is visually dominated through most of the core by whole and broken valves and spines of *Corethron pennatum*, valves and setae of *Chaetoceros* Ehrenberg subg. *Chaetoceros*, and sea-ice-associated *Fragilariopsis*, especially *Fragilariopsis curta*. Other episodically common genera include *Rhizosolenia*.

In this study, we evaluate the role of deep cross-shelf trough geometry, the presence of icebergs grounded along the shallow banks that rim Iceberg Alley, and melting sea ice, in facilitating high primary productivity and subsequently high sediment accumulation rates. Microscopic evaluation of the complex laminations in JPC41 indicates that high-resolution information from the late Holocene is preserved, but the record remains hard to interpret given difficulties in distinguishing an annually repeated pattern in the laminations and the likelihood that missing years occur. This study of inner Iceberg Alley sediments therefore provides the opportunity to learn about influences on diatom productivity at a high temporal resolution, and provides a framework for continued research.

2. Oceanographic setting

Iceberg Alley is located at approximately 67°S, 63°E on the Mac.Robertson Shelf, Mac.Robertson Land, just west of Prydz Bay and the Amery Ice Shelf (Fig. 1). The Mac.Robertson Shelf is moderately narrow and shallow (O'Brien et al., 1994; Harris and O'Brien, 1996). In most locations, metamorphic basement rock is covered by a relatively thin veneer of sediments reflecting low sedimentation rates and the influence of currents and glaciations (O'Brien et al., 1994; Harris and O'Brien, 1996; Sedwick et al., 2001). Shallow banks divide deep basins and troughs as is typical of the Antarctic continental shelf (Taylor and McMinn, 2001). The deepest point on the Mac.Robertson Shelf is found in Nielsen Basin, which reaches ~1300 m (Leventer et al., 2006). Storegg Bank separates Nielsen Basin from Iceberg Alley to the west (O'Brien et al., 1994).

Iceberg Alley was carved across the Mac.Robertson Shelf during Quaternary glaciations, leaving a U-shaped trough with steep sides and a flat floor typical of glacial fjords. Iceberg Alley is about ~85 km long, 10–20 km wide and ~475–575 m deep, although some areas reach depths of 850 m (Leventer et al., 2006). Iceberg Alley receives its name from icebergs grounded at depths of 50–300 m that line both shallow banks (O'Brien et al., 1994; Stickley et al., 2005; Leventer et al., 2006). The geometry of troughs like Iceberg Alley traps sediment. Consequently, the deeper reaches of Iceberg Alley exhibit very high sedimentation rates (Stickley et al., 2005; Leventer et al., 2006).

Waters along the Mac.Robertson Coast are influenced at shallow depths (< 200 m) by a westward-flowing Antarctic Coastal Current, with flow fastest along the outer shelf and slope, and slower on the inner shelf (O'Brien et al., 1994; Harris and O'Brien, 1998; O'Brien et al., 2014). Although some of this water mass continues along the shelf, much of the current is diverted offshore in the vicinity of Iceberg Alley (O'Brien et al., 1994; Taylor et al., 1997). Deeper waters north of this current are affected by Circumpolar Deep Water (CDW), which upwells onto the Mac.Robertson Shelf. This relatively warm water mass is modified and cools as it meets the waters of the westward-flowing Antarctic Coastal Current (Stickley et al., 2005). Although the shallow banks prevent the modified CDW from intruding across the whole shelf,