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Exposure-age record of Holocene ice sheet and ice shelf change in the northeast Antarctic Peninsula

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ABSTRACT

This paper describes glacial–geologic observations and cosmogenic-nuclide exposure ages from ice-free areas adjacent to the Sjögren, Boydell, and Drygalski Glaciers of the northeast Antarctic Peninsula. These provide a record of Holocene glacier and ice shelf change in this region. Early Holocene ice surface elevation near the present coastline was locally at least 500 m above present sea level, but our observations do not constrain the maximum thickness of Last Glacial Maximum (LGM) ice or the time at which it was attained. The boundary between frozen-based and wet-based ice reached a maximum elevation of 100–150 m above present sea level. The ice surface elevation decreased from 300–500 m elevation to near present sea level between 9 ka and ca 4 ka. Below 160 m elevation, we observed a bimodal distribution of apparent exposure ages in which a population of glacially transported clasts with mid-Holocene exposure ages coexists with another that has exposure ages of 100–600 years. We consider the most likely explanation for this to be i) complete deglaciation of currently ice-free areas, which presumably required the absence of ice shelves, at 3.5–4.5 ka, followed by ii) subsequent ice shelf formation and grounding line advance after ca 1.4 ka, and iii) complete re-exposure of the sites after ice shelf breakup and glacier surface lowering in recent decades. This explanation is consistent with marine sedimentary records indicating that ice shelves in the Prince Gustav Channel and Larsen A embayment were absent in the middle to late Holocene and were re-established within the last 2000 years.

1. Introduction

This paper describes glacial–geologic observations and cosmogenic nuclide exposure ages from terrestrial sites on the east side of the northern Antarctic Peninsula (Fig. 1). Glacier change in this region during the past several decades has been notable for the rapid and spectacular collapse of major ice shelves, mainly i) the ice shelves occupying the southern end of Prince Gustav Channel (PGC), Larsen Inlet, and the Larsen A embayment, in 1995; and ii) the majority of the Larsen B ice shelf in 2002 (for summaries, see Rott et al., 1996; Vaughan and Doake, 1996; Scambos et al., 2004; Cook and Vaughan, 2010). These ice shelf collapses resulted in extremely rapid (over a period of a few years) drawdown and grounding line retreat of glaciers feeding these ice shelves. Marine-geological evidence (Pudsey and Evans, 2001; Brachfeld et al., 2003; Domack et al., 2005) indicates that the PGC–Larsen A ice shelf system disappeared and reformed at least once during the Holocene, but the Larsen B ice shelf was present throughout the Holocene. This paper describes geologic and geochronologic evidence from ice-free sites on land adjacent to glaciers that fed the former PGC–Larsen A ice shelf system. This complements marine records of glacier and ice shelf changes by providing an independent chronology for these changes and by providing information about past changes in ice thickness as well as extent.

2. Review of LGM-to-Holocene ice sheet change, northeast Antarctic Peninsula

Recent reviews of glacier change in the northeast Antarctic Peninsula between the Last Glacial Maximum (LGM) and the present include Davies et al. (2012), Johnson et al. (2011), Heroy and Anderson (2007), Domack et al. (2005), and Evans et al. (2005); the brief summary in the remainder of this section is drawn from these references. We use the term "Last Glacial Maximum" loosely to

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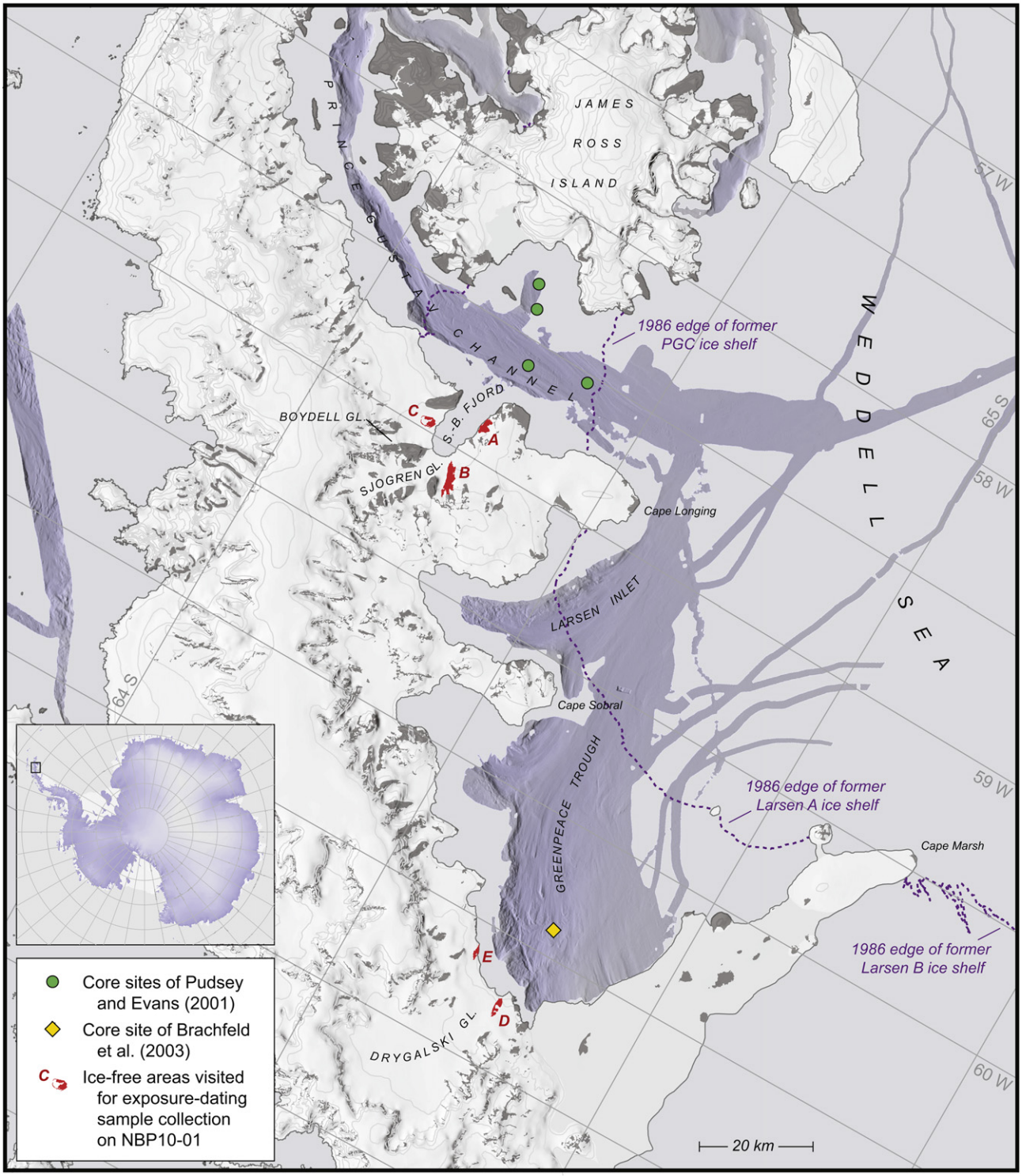

Fig. 1. East coast of the Antarctic Peninsula between Cape Marsh and James Ross Island. Inset map of Antarctica shows location. All vector data, including former ice shelf edges, are from the SCAR Antarctic Digital Database (https://www.add.scar.org). Shaded-relief topography of land areas is generated from the RAMP DEM (Liu et al., 2001). The blue shaded area shows shaded-relief bathymetry generated from selected multibeam swath data compiled by Johnson et al. (2011). The streamlining evident on the seafloor records past ice flow directions that presumably reflect the ice sheet configuration during the LGM and/or subsequent deglaciation. Red areas highlight ice-free areas where we collected exposure-dating samples surrounding the Sjögren–Boydell fjord (sites A–C) and near the grounding line of the Drygalski Glacier (sites D and E). We only show marine sediment cores that we specifically discuss in the text; many others have been collected from this region. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

refer to the period of the Last Glacial–Interglacial cycle during which the Antarctic ice sheets were near their maximum geographic extents, between approximately 25–15 ka (all ages in this paper are stated in calendar years before present). Multibeam bathymetric surveys of the seafloor to the northeast of the Peninsula show evidence that grounded ice extended nearly to the edge of the Weddell Sea continental shelf (past the eastern edge of Fig. 1) during the most recent glacial cycle, and this is generally agreed to