Quaternary Science Reviews 128 (2015) 117–126

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

Early deglacial onset of southwestern Greenland ice-sheet retreat on the continental shelf

Kelsey Winsor [a,*], Anders E. Carlson [a,b], Bethany M. Welke [a], Brendan Reilly [b]

[a] *Department of Geoscience, University of Wisconsin, Madison, WI 53706, USA*
[b] *College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331, USA*

ARTICLE INFO

Article history:
Received 28 April 2015
Received in revised form
16 September 2015
Accepted 1 October 2015

Keywords:
Greenland
Sea level
Deglaciation
Retreat forcings
Sedimentation rate
Davis Strait

ABSTRACT

The Greenland ice sheet (GrIS) advanced onto the continental shelf during the last glacial period. While deglacial records for when the GrIS withdrew onto the modern coastline are relatively abundant, the timing of early GrIS retreat on the shelf is poorly constrained. Here we use planktic foraminiferal $\delta^{18}O$, sediment grain size, sedimentation rates, and ^{14}C ages in southeastern Davis Strait core HU87033-008 to develop an early deglaciation chronology of the southwestern GrIS while on the continental shelf. Sedimentation rates, and especially silt and clay fractions, are high between ~20.5 and ~17.1 ka, suggesting that the southwestern GrIS margin was near or at the shelf break, where it released subglacially derived sediment-laden meltwater. A peak in sedimentation rates of ~110 cm ka^{-1} between ~19.3 ka and ~18.6 ka, combined with an initial decrease in planktic $\delta^{18}O$ of ~0.5 per mil, suggests an early deglacial pull back of the GrIS margin from the shelf break with a concurrent increase in surface ocean meltwater discharge. A subsequent planktic $\delta^{18}O$ decrease of ~1.0 per mil combined with a drop in silt and clay sedimentation rates at 18–17 ka likely record further GrIS retreat inland from the shelf break. Terrestrial ^{10}Be surface exposure ages indicate that the GrIS margin remained on the continental shelf until ~11 ka, yet the cause of this subsequent ice-margin stability on the inner shelf is not known. Our new records provide the first evidence that the southwestern GrIS margin may have begun to deglaciate at the same time as other Northern Hemisphere ice sheets. As Labrador Sea water temperatures likely remained near glacial values until ~15 ka, we suggest that initial southwestern GrIS retreat was in response to rising global sea level from retreat of other ice sheets and/or the initial deglacial rise in boreal summer insolation.

1. Introduction

Constraints on retreat of the Greenland ice sheet (GrIS) once its margins retracted to the modern ice-free land suggest that much of the terrestrial GrIS deglaciation occurred in the early Holocene (see Funder et al. (2011) for a review). The record of earlier deglaciation, when the ice margin rested on the Greenland continental shelf, is more limited due to lack of subaerial exposure. Where the shelf is narrow, as in southern Greenland, the last glacial maximum (LGM, 26–19 ka; Clark et al., 2009) GrIS is generally thought to have extended to the shelf break (e.g., Sommerhoff, 1981; Kelly, 1985; Bennike et al., 2002; Jennings et al., 2006; Simpson et al., 2009; Funder et al., 2011). In regions with a wider shelf, interpretations vary as to the GrIS presence on the shelf break, outer shelf, or inner shelf (e.g., Kelly, 1985; Ó Cofaigh et al., 2004; Weidick et al., 2004; Evans et al., 2007; Roberts et al., 2009; Funder et al., 2011; Ó Cofaigh et al., 2013a, 2013b; Simon et al., 2013).

Because the GrIS extended onto the shelf during the LGM, the initial timing of GrIS retreat is difficult to constrain with terrestrial records (Funder et al., 2011). The terrestrial records that exist suggest a significant lag in GrIS retreat behind rising boreal summer insolation, rising atmospheric greenhouse gas concentrations, and other Northern Hemisphere ice sheets (Clark et al., 2009, 2012). Such a lag could suggest a limited sensitivity of GrIS margins to deglacial climate warming and sea-level rise (Clark et al., 2009). However, ^{10}Be surface exposure ages from western Greenland at ~67°N suggest initial GrIS thinning by 19–18 ka (Rinterknecht et al., 2009; Roberts et al., 2009; Winsor et al., 2015). Continental rise

* Corresponding author. Present address: Department of Environmental, Earth and Atmospheric Sciences, University of Massachusetts–Lowell, Lowell, MA 01854, USA.
E-mail addresses: kelsey.winsor@gmail.com (K. Winsor), acarlson@coas.oregonstate.edu (A.E. Carlson).

http://dx.doi.org/10.1016/j.quascirev.2015.10.008
0277-3791/

sediment records from eastern and southern Greenland show ice retreat commencing by 19–17 ka and ~19 ka, respectively (Nam et al., 1995; Andrews et al., 1997; Carlson et al., 2008). In contrast, western Greenland ice streams at ~70°N may have remained at or near the shelf break until 15–14 ka (Ó Cofaigh et al., 2013a; 2013b; Simon et al., 2013), although recent sedimentological data suggest a possible earlier retreat at ~16.7 ka (Jennings et al., 2014). Elsewhere on Greenland, our understanding of initial GrIS margin retreat on the continental shelf is even more restricted. Differences in the timing of retreat around Greenland may be partially a result of spatially variable ice-stream dynamics, though more study would be required to test this.

Here, we analyze grain size and sedimentation rates in southeastern Davis Strait sediment core HU87033-008 (Fig. 1A) to constrain the timing of southwestern GrIS presence on the outer shelf. We couple this sediment data with oxygen isotope analyses from the sub-polar to polar planktic foraminifera species *Neogloboquadrina pachyderma* (sinistral) to identify potential near-surface meltwater discharge.

2. Regional setting

2.1. Modern and paleo hydrography

The Labrador Sea is located south of the Davis Strait, between the northeastern coast of Canada and the southwestern coast of Greenland (Fig 1A). Hydrography of the Labrador Sea is of interest to this study in that it determines the source region for sediments. Major surface currents enter the area from the westward-flowing arm of the subpolar gyre, and are composed of both Arctic- and Atlantic-sourced waters. Arctic-sourced waters pass through the Fram and Denmark Straits in the East Greenland Current, skirting the Greenland shelf. From the south, the North Atlantic Current delivers relatively warm, saline waters to the Irminger Current, which flows northwest past Iceland and toward southern Greenland (Fig. 1A). Near Cape Farwell, Irminger Water and the East Greenland Current are directed into the West Greenland Current (Coachman and Aagaard, 1974; Cuny et al., 2005).

In the eastern Davis Strait, the West Greenland Current bifurcates into northward and westward components (Cuny et al., 2002). The westward-flowing segment of the West Greenland Current and the southward-flowing Baffin Island Current mix in the western Davis Strait, forming the surface component of the Labrador Current. The Labrador Current then travels south along the eastern Canadian shelf (Mudie et al., 1984). Thus, ice and runoff entering the Labrador Sea from terrestrial North America are brought southward, as opposed to eastward towards core site HU87033-008 along the southwestern Greenland margin (Fig. 1A).

Below these surface currents, the modern Deep Western Boundary Current passes nearby to, but at lower depth than, our core site (2424 m water depth), with its main high velocity core at approximately 2800–3400 m water depth (Fagel et al., 2001; Cuny et al., 2002). At our core site, Labrador Sea Water occupies the water column below the variable-depth surface mixed layer and above Northeast Atlantic Deep Water (Bilodeau et al., 1994). Although Labrador Sea Water possesses relatively low velocity (Dickson and Brown, 1994), it composes part of a recirculation loop of waters from the Labrador Sea, into the Irminger Sea, and back to the Labrador Basin. In the winter, wind-driven cooling and buoyancy loss of Labrador Sea surface waters permit deep overturning circulation in the Labrador Basin (Marshall and Schott, 1999) and formation of Labrador Sea Water. The water column is re-stratified by summertime, with buoyancy gain derived from influx of warm Irminger Water (Cuny et al., 2002). Combined with convection and deep-water formation in the Nordic Seas, Labrador Sea overturning is a primary driver of the strength of Atlantic meridional overturning circulation (e.g., Broecker, 1997; Hillaire-Marcel and Bilodeau, 2000).

At the LGM, deep-water circulation in the Labrador Sea persisted (Ledbetter and Balsam, 1985), although at lower velocities than during present, and with less recirculation outside of the Labrador Basin (Fagel et al., 1999). During the last deglaciation, Deep Western Boundary Current velocity increased, reaching a maximum by ~11 ka (Fagel et al., 1997, 1999). The presence of a circulating Deep Western Boundary Current suggests that the Labrador Current also continued transporting water and ice from North America southward away from our study site (Kirby, 1998). However, sediments from Hudson Strait discharged during Heinrich events were transported to the continental rise west of Greenland (Hillaire-Marcel et al., 1994; Fagel et al., 2001).

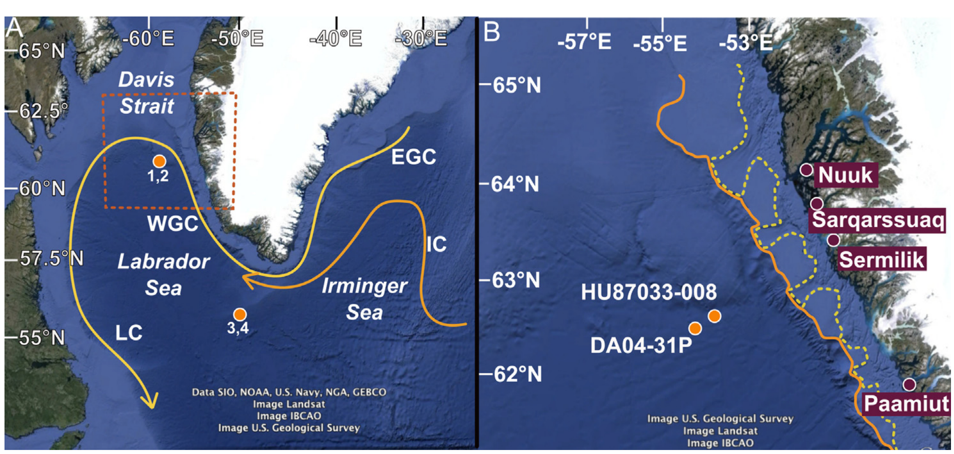

Fig. 1. A) North Atlantic surface water bodies, bathymetry (Smith and Sandwell, 1997), and core locations. Currents: LC = Labrador Current, EGC = East Greenland Current, WGC = West Greenland Current, IC = Irminger Current. Sediment cores: 1 = HU87033-008, 2 = DA04-31P, 3 = MD99-2227, 4 = HU90-013-013. Dotted outline shows location of B. B) Google Earth image of bathymetry and coastline near southwestern Greenland. A hypothesized general GrIS margin location along the shelf break is outlined in solid orange. A hypothesized mid-to inner-shelf general margin location with ice stream margins extending to the shelf break is outlined in dashed yellow. Also shown are sediment cores HU87033-008 and DA04-31P, and coastal towns of Paamiut and Nuuk discussed in Winsor et al. (2015), and the Sarqarssuaq and Sermilik fjords discussed in Larsen et al. (2014). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)