Quaternary Science Reviews 98 (2014) 135–143

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

^{10}Be dating of the Narsarsuaq moraine in southernmost Greenland: evidence for a late-Holocene ice advance exceeding the Little Ice Age maximum

K. Winsor [a,*], A.E. Carlson [a,b], D.H. Rood [c,d]

[a] Department of Geoscience, University of Wisconsin-Madison, WI, Madison 53706, USA
[b] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331, USA
[c] Scottish Universities Environmental Research Centre (SUERC), University of Glasgow, East Kilbride G75 0QF, UK
[d] Earth Research Institute, University of California-Santa Barbara, Santa Barbara, CA 93106, USA

ARTICLE INFO

Article history:
Received 18 January 2014
Received in revised form
25 April 2014
Accepted 28 April 2014
Available online 26 June 2014

Keywords:
Cosmogenic surface exposure dating
Greenland ice sheet
Glacial geology

ABSTRACT

In southernmost Greenland near Narsarsuaq, the terminal Narsarsuaq moraine was deposited well outside of a historical Little Ice Age (LIA) moraine adjacent to the modern ice margin. Using ^{10}Be surface exposure dating, we determine Narsarsuaq moraine abandonment at 1.51 ± 0.11 ka. A second set of ^{10}Be ages from a more ice-proximal position shows that ice has been within or at its historical (i.e., LIA) extent since 1.34 ± 0.15 ka. Notably, Narsarsuaq moraine abandonment was coincident with climate amelioration in southern Greenland. Southern Greenland warming at ~1.5 ka was also concurrent with the end of the Roman Warm Period as climate along the northern North Atlantic sector of Europe cooled into the Dark Ages. The warming of southern Greenland and retreat of ice from the Narsarsuaq moraine is consistent with studies suggesting possible anti-phase centennial-scale climate variability between northwestern Europe and southern Greenland. Other southernmost Greenland ice-margin records do not preclude a pre-LIA ice-margin maximum, potentially concurrent with a Narsarsuaq advance prior to ~1.51 ka, but also lack sufficient ice-margin control to confirm such a correlation. We conclude that there is a clear need to further determine whether a late-Holocene pre-LIA maximum was a local phenomenon or a regional southern Greenland ice maximum, and if this advance and retreat reflects a regional fluctuation in climate.

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1. Introduction

Over the Holocene, boreal climate generally cooled in response to declining high northern latitude summer insolation, culminating in the Little Ice Age (LIA) of the last several centuries (Kaufman et al., 2009; Marcott et al., 2013). In Greenland, valley glaciers and the Greenland ice sheet advanced across the Neoglacial interval (the last 4 ka), with their maximum extents generally occurring during the LIA (Weidick, 1963; Kelly, 1980; Weidick et al., 2004, 2012; Kelly et al., 2008; Kelly and Lowell, 2009; Alley et al., 2010; Briner et al., 2011; Funder et al., 2011; Levy et al., 2012, 2014; Lowell et al., 2013). The timing and extent of these late-Holocene glacier maxima are often used as baselines for assessing the cause of present and future ice volume changes on the island (Oerlemans, 2005; Jansen et al., 2007). It is therefore societally relevant to determine the timings of Greenland ice margin maximum late-Holocene extents and to constrain the geographic variability of these maxima (Seidenkrantz et al., 2008).

Ice margin records from across Greenland suggest that general global cooling resulted in glacial maxima at different times during the late Holocene. Jakobshavn Isbræ, which is the largest single source of modern ice loss in Greenland, advanced throughout the LIA, surpassing older late Holocene extents (Weidick and Bennike, 2007; Briner et al., 2011). However, just to the south of Jakobshavn, ^{14}C dating of land-terminating ice margins indicates a late-Holocene maximum post-dating the LIA in the last century (Kelley et al., 2012). Ice-marginal records from east Greenland also show a nuanced response to late-Holocene climate change, with one valley glacier reaching its maximum extent early in the LIA (Kelly et al., 2008), while two ice caps neared their late-Holocene maximum prior to the LIA (Levy et al., 2014; Lowell et al., 2013). In southwest and southeast Greenland, ice-marginal records are

* Corresponding author. Tel.: +1 401 451 4037.
E-mail addresses: winsor@wisc.edu, kelsey.winsor@gmail.com (K. Winsor).

http://dx.doi.org/10.1016/j.quascirev.2014.04.026
0277-3791/Published by Elsevier Ltd.

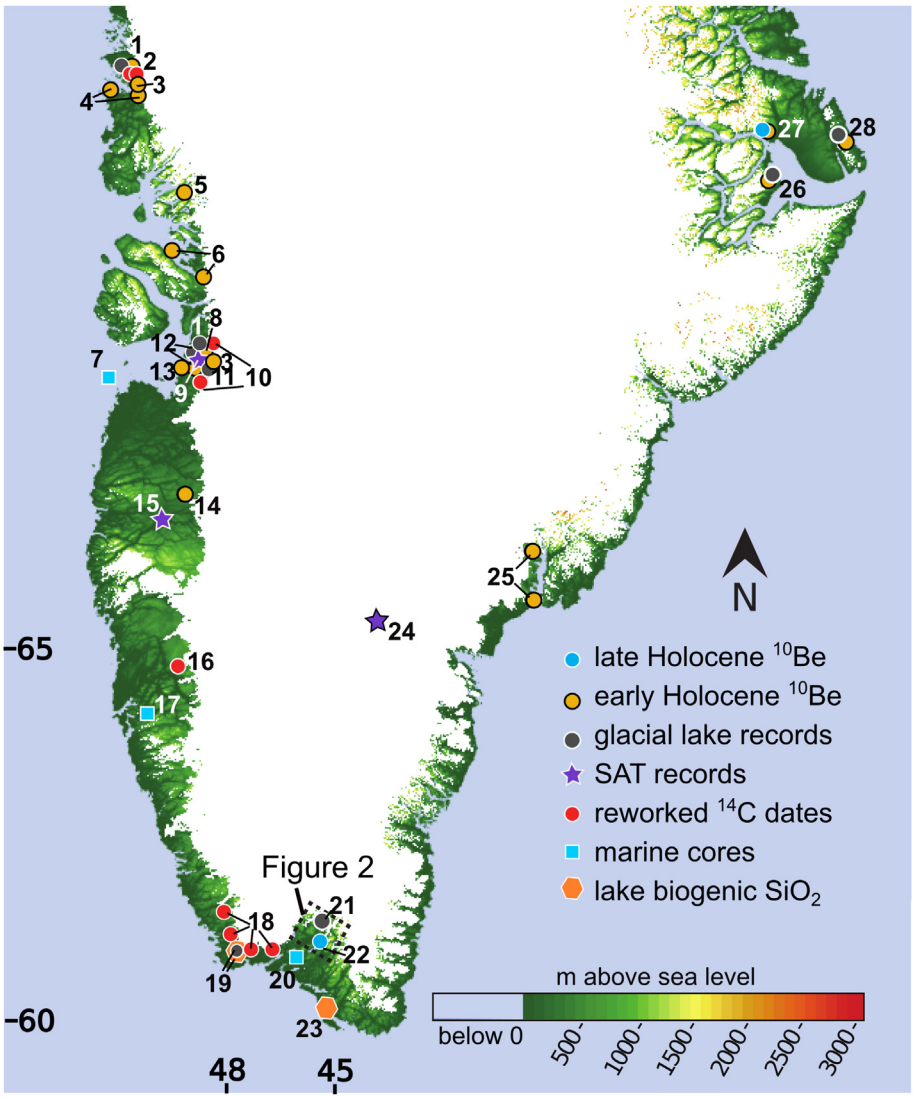

Fig. 1. Location of Holocene records from southern to central Greenland. Fig. 2 location is indicated by the dashed-line box. Also shown are early and late Holocene ^{10}Be dates, ice-marginal lake records, reworked ^{14}C dates in historical moraines, surface-air temperature (SAT) records, lake biogenic silica records, marine ice-rafted debris, and benthic faunal records. In counter-clockwise order around the island are represented sites from [1]Briner et al. (2011), [2]Briner et al. (2014), [3]Briner et al. (2013), [4]Corbett et al. (2013), [5]Lane et al. (2013), [6]Roberts et al. (2013), [7]Perner et al. (2011), [8]Corbett et al. (2011), [9]Axford et al. (2013), [10]Weidick et al. (1990), [11]Briner et al. (2010), [12]Kelley et al. (2012), [13]Young et al. (2011), [14]Levy et al. (2012), [15]D'Andrea et al. (2011), [16]Kelly (1980), [17]Seidenkrantz et al. (2007), [18]Weidick et al. (2004), [19]Kaplan et al. (2002), [20]Nørgaard-Pedersen and Mikkelsen (2009), [21]Larsen et al. (2011), [22]this study, [23]Andresen et al. (2004), [24]Dahl-Jensen et al. (1998), [25]Hughes et al. (2012), [26]Levy et al. (2014), [27]Kelly et al. (2008), and [28]Lowell et al. (2013).

more limited and do not provide a close constraint on late-Holocene Greenland ice sheet and valley glacier behavior (e.g., Roberts et al., 2008; Hughes et al., 2012; Weidick et al., 2012; Larsen et al., 2014).

In southernmost Greenland, the prominent Narsarsuaq moraine was deposited outside of the LIA/historical extent of the outlet glacier Kiagtût sermiat, and is indirectly inferred to be late Holocene in age, although an early or middle Holocene age is also plausible given available chronologic constraints (Weidick, 1963; Kelly, 1980; Dawson, 1983; Bennike and Sparrenbom, 2007). Existing records from other southern Greenland ice margins are somewhat contradictory, and are interpreted to show either ice-margin late-Holocene maxima during the LIA (Kaplan et al., 2002) or an earlier maximum (Larsen et al., 2011). Here, we use ^{10}Be surface exposure ages to directly date ice retreat from the Narsarsuaq moraine and to determine if this moraine represents a pre-LIA late-Holocene maximum ice-margin advance.

2. Kiagtût sermiat setting & methodology

Northeast of Narsarsuaq [61.15°N, 45.43°W] (Fig. 1), the Kiagtût sermiat outlet glacier flows to the southwest. The outlet glacier is sourced from the southern dome of the Greenland ice sheet as part of a larger outlet glacier that splits into Kiagtût sermiat and Qôrqup sermia glaciers (Fig. 2) (Weidick et al., 2004; Larsen et al., 2011). The modern glacier is land-terminating, with the head of Tunugliarfik fjord located ~8 km down valley to the southwest of the present ice margin. Kiagtût sermiat glacier is sometimes referred to as Kiattut sermiat of Kiatuut sermia (e.g., Weidick et al., 2004; Nelson et al., 2014).

The Narsarsuaq moraine of Kiagtût sermiat is clast-supported and consists of a prominent ridge extending from the valley mouth up onto the plateau (Fig. 2) (Weidick, 1963; Larsen et al., 2011). Several recessional moraines are up-valley of the terminal moraine, but these as well as the terminal moraine have been heavily reworked by human activity, particularly during and