

Fluctuations of the Greenland Ice Sheet during past warm climates

Laura B. Levy¹, Meredith A. Kelly¹, Ross A. Virginia²

¹Department of Earth Sciences, ²Environmental Studies Program, Dartmouth College, Hanover, NH 03755

I. Summary

The response of the Greenland Ice Sheet (GIS) to warming conditions in the Arctic is uncertain.¹ Recent changes in the GIS, such as thinning and increased velocity of outlet glaciers, have alarmed scientists and the public alike.^{2,3,4,5} A better understanding of GIS responses to warmer climates will help predict future change and guide adaptation policies for the Greenlandic people.

This study documents the response of the GIS to warmer climate (Fig. 1) during the Holocene epoch (11,600 yr BP to present) by tracking past positions of the ice sheet margin near Kangerlussuaq. Here, we present a chronology of GIS margin positions using surface exposure (¹⁰Be) dating of moraines (Fig. 3). Our data indicate these moraines were deposited 6,800±320 yr BP and that the GIS was smaller than present from 6,540±190 yr BP until the Little Ice Age (LIA) advance (~1850 AD⁶).

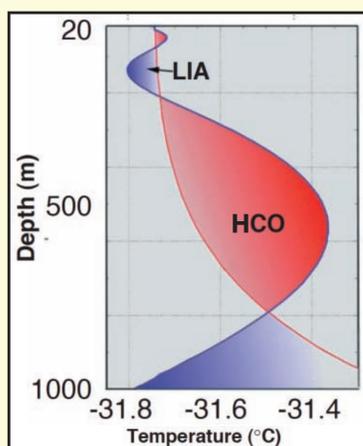


Figure 1. Past temperatures from borehole thermometry of the GIS.⁶ The blue line tracks the measured temperature profile while the red line shows the profile that constant present surface conditions would have created. The LIA was colder than present and the Holocene Climatic Optimum (HCO; 8,000-5,000 yr BP)⁶ was warmer than present.

II. Background

Kangerlussuaq, Greenland (67.0°N, -50.7°W) is located 25 km from the western margin of the GIS (Fig. 2). At the last glacial maximum, the GIS extended to the edge of the continental shelf⁷ and by 7,650 yr BP⁸ had retreated inland of Kangerlussuaq. Continued deglaciation at the margin of the GIS is marked by a sequence of regionally extensive moraines⁹, which provide a direct means to track Holocene fluctuations of the GIS. The age of the Ørkendalen moraines, however, is not well-constrained. Reported ages range from 6,800±300 yr BP⁸ to 400-2,000 yr BP¹⁰. We aim to date the Ørkendalen moraines using ¹⁰Be dating to reconstruct past GIS dynamics.



Figure 2. Landsat satellite image of field area. Ørkendalen and Kegen moraines mark the Holocene extents of the GIS. Moraines deposited during the LIA exist within 100 m of the modern ice margin and, in places, the LIA advance over ran the Ørkendalen moraines.

Greenland Ice Sheet
Lake/stream, glacially fed
Lake/stream, meteorically fed
Bedrock, soil, vegetation
Kegen moraine limit
Ørkendalen moraine limit
LIA moraine limit

III. Methods

In 2009, we conducted geomorphic mapping of the region and collected samples for ¹⁰Be dating. ¹⁰Be dating of boulders atop moraines is often used to develop chronologies of past glacier extents.^{11,12}

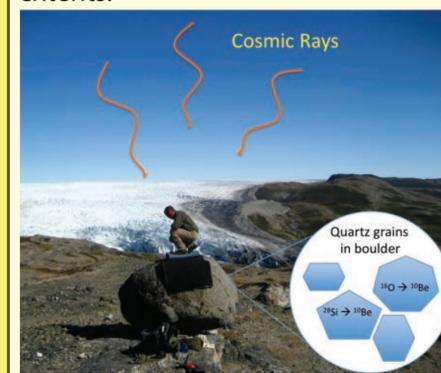
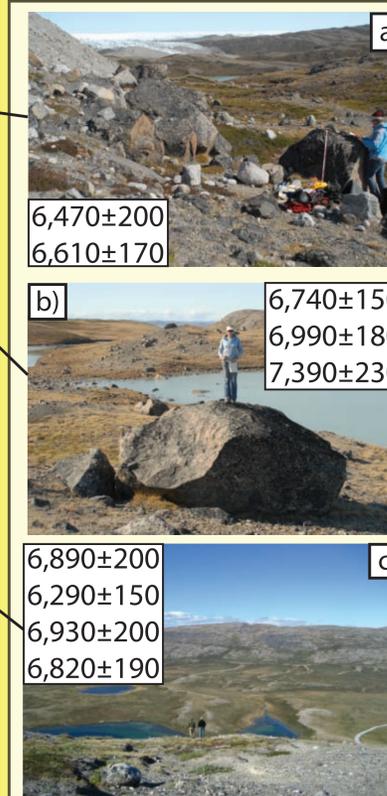


Figure 3. Boulders are transported at the base of a glacier and deposited within moraines. Once deposited, these boulders are exposed to cosmic rays from the atmosphere, which induce nuclear reactions and produce *in situ* ¹⁰Be in quartz minerals in the surface of the boulders. Based on the concentration of ¹⁰Be in a sample, and assuming a constant ¹⁰Be production rate, we can calculate the duration of time that the boulder was exposed to the atmosphere, and hence the timing of ice retreat.

VII. Acknowledgements

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IV. Results

Nine ¹⁰Be ages from the Ørkendalen moraines range from 6,290±150 yr BP to 7,390±230 yr BP, with a mean age of 6,800±320 yr BP (Fig. 4). The ages from the Ørkendalen moraines adjacent to the LIA moraines (Fig. 4a) have a mean age of 6,540±190 yr BP.

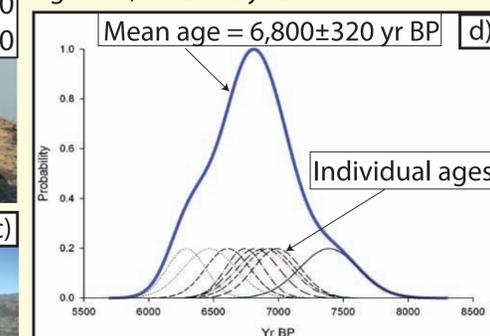


Figure 4. a-c) Sampling locations and ¹⁰Be ages of moraines (yr BP), d) Frequency distribution plot of ¹⁰Be ages.

V. Conclusions and Future Work

Based on our ¹⁰Be ages, the mean age of Ørkendalen moraines is 6,800±320 yr BP. The ages of the Ørkendalen moraines adjacent to the LIA moraines indicate that the GIS was smaller than present from 6,540±190 yr BP to ~1850 AD. During this time, when temperatures were warmer than present, the margin of the GIS was likely 5-20 km behind its current position.⁸ Our Ørkendalen moraine ages agree with 6,800±300 yr BP⁸ (p=0.94, n=9) and are significantly different than 400-2,000 yr BP¹⁰ (p<0.0001, n=9).

We will return to Kangerlussuaq in July 2011 to collect more samples from the Ørkendalen moraines and sample the Kegen and LIA moraines. We will develop a detailed chronology of the GIS margin during the Holocene, enabling us to calculate retreat rates of the GIS during warmer than present conditions.

VI. References

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