Preliminary ^{10}Be Chronology for the Last Deglaciation of the Western Margin of the Greenland Ice Sheet

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1. ABSTRACT

On the largest ice free land of Western Greenland (Fig. 1) we identified a 170 km long eastward transect from the town of Sisimiut on the coast to the Isunguata Sermia Glacier ice margin (Fig. 2). In addition, one of the glacial valleys (Fig. 3) was selected for the large-scale dating and terrain mapping.

In the general study area, ice cover extended beyond the present day coastline during the larger parts of the Sisimiut glaciation of Late Wisconsinan-Weichselian age. During the course of deglaciation, the Inland Ice margin progressively recessed about 170 km east in the study area. Frequent halts or re-advances interrupted the retreat and formed extensive moraine systems: Sisimiut (associated to the Younger Dryas cold event), Taserqat, Sarfartôq-Advedtleq, Fjord, Umîvît-Keglen, and Ørkendalen (close to the modern ice margin). The chronology of the deglaciation in western Greenland is based on the relationship between the moraine systems and relative sea level, and thus can be constrained by AMS radiocarbon dating when appropriate material is available. However, only a few dates are published and the samples were collected within ten kilometers from the ice margin, precluding any comprehensive reconstructions of the ice sheet deglaciation history.

We present here the first results of surface exposure dating and terrain mapping for this previously unexplored area. The surface exposure ages constrain a preliminary chronology for the last deglaciation of the western margin of the Greenland Ice Sheet. Satellite imagery complemented with ground measurements and observations define the geomorphological settings that allow the reconstruction of the pattern of ice margin retreat as well as the variation of the ice sheet thickness.

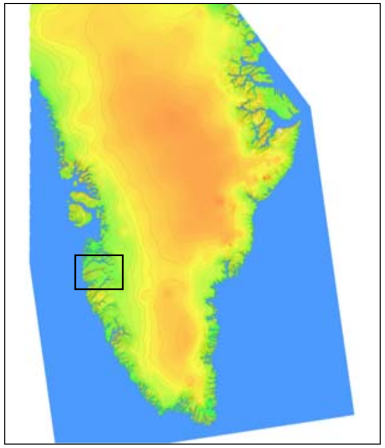

Fig. 1: General view of Greenland and study area.

TABLE 1: Sample characteristics and exposure ages.

Sample ID	Height above ground (m)[a]	Latitude (degree N)	Longitude (degree W)	Altitude (m)	[10 Be] (atoms/g)[b]	Scaling Factor[c]	Corrected production Rate (atom.yr^{-1}. g^{-1})[d]	^{10}Be Age (kyr)[e]
GRE-1	1.00	66.9880	53.7358	385	4.61E+05	1.48	7.29	*64.2 ± 256.6*
GRE-2	2.00	67.1621	53.0075	721	1.85E+05	2.00	9.83	18.9 ± 3.6
GRE-3	0.00	67.1621	53.0075	721	2.91E+05	2.00	9.79	30.0 ± 1.4
GRE-4	0.00	67.2375	52.1744	1118	1.41E+06	2.80	13.96	103.3 ± 3.9
GRE-5	0.80	67.3231	51.3692	687	8.01E+04	1.94	9.46	8.5 ± 3.5
GRE-6	2.10	67.4368	50.1713	576	6.31E+04	1.76	8.72	7.3 ± 1.3
GRE-7	0.40	67.4264	50.1523	682	1.19E+05	1.93	9.50	12.6 ± 1.4
GRE-8	0.80	67.4264	50.1523	682	1.14E+05	1.93	9.60	11.9 ± 1.4
GRE-9	1.40	67.4235	50.2051	539	7.92E+04	1.70	8.44	9.4 ± 0.6
GRE-10	3.10	67.4254	50.2008	442	5.96E+04	1.56	7.81	7.6 ± 1.7
GRE-11	1.90	67.4289	50.2105	439	6.42E+04	1.55	7.64	8.4 ± 1.2
GRE-12	1.80	67.4291	50.2126	437	6.77E+04	1.55	7.75	8.8 ± 0.6

[a] Height of zero meter corresponds to bedrock sample.
[b] ^{10}Be/^{9}Be ratios were measured at the PRIME Lab facility, relative to the Nishiizumi standard.
[c] Scaling factor accounts for the mode of production of ^{10}Be atoms at the boulder surface: 97.8% by spallation and 2.2% by muon capture.
[d] We used an assumed production rate of 5.1 ± 0.3 atom/g/yr and scaled it for each sample location and thickness.
[e] Analytical uncertainties (propagated at ± 1σ level) include a procedural blank of 1.32 ± 0.12 × 10^{4} atom/g.

2. HYPOTHESES

The Greenland Ice Sheet has the potential to contribute 5 to 6 meters of relative sea level by melting. The release of even a fraction of the water stored in the ice sheet would have dramatic consequences for populated coastal regions. Future global warming trends used in current models result in a negative mass balance for the warm-climate Greenland Ice Sheet. In order to assess quantitatively to what extent such a melting event can happen in the future it is necessary to understand the history of the past ice sheet fluctuations during the last deglaciation.

Reconstructions of the past ice sheet extent in Greenland are based on 1) the study of the marine limits and 2) the study of weathering lines. But different interpretations of these approaches prevent a clear understanding of the past ice sheet dynamics and margin retreat history.

The case of the marine limit. Previous studies show that the ice margin retreat during the last deglaciation follow a two-step process. The first process involved calving of grounded ice on the shelf driven by a rapid sea level rise at the end of the LGM. The second process involved melting of ice on the land in response to local climatic variations. The later produced a distinct isostatic uplift signal recorded by the marine limit. Radiocarbon dated marine limits are traditionally considered to give a reasonable time constraint for the deglaciation of the region. However, a documented alternative interpretation is that the marine limit can be younger than deglaciation in the outer-coast area where the uplift was the greatest.

The case of the weathering zones. Weathering zones and trimlines are classically interpreted as markers of former ice sheet height. This interpretation is now challenged by a growing body of literature which suggests that old landforms can survive glaciations by cold-based ice sheet. In this scenario, the weathering zone is interpreted to reflect the ice sheet englacial bimodal thermal regime boundaries, i.e. the boundary between a cold-based non-erosive ice and a warm-based erosive ice.

To test the two sets of competing interpretations, we propose to combine the detailed mapping of glacial features with surface exposure dating along a longitudinal transect as well as several altitudinal transects, to develop a comprehensive deglaciation history of the western sector of the Greenland Ice Sheet.

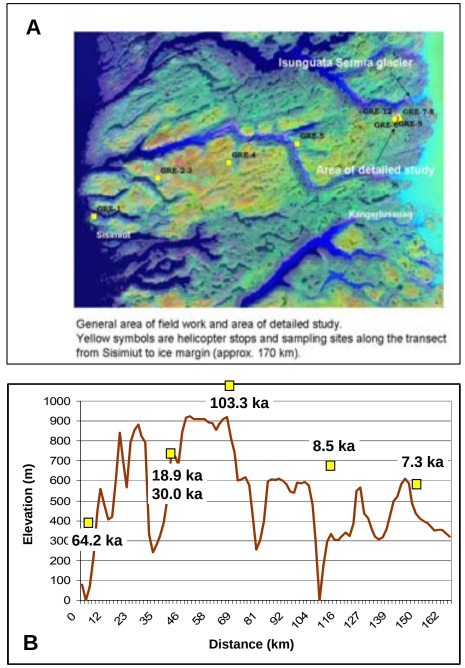

Fig. 2: **A** - General study area. **B** – Altitudinal profile from GRE-1 to the ice margin. The elevation curve is from GTOPO30 (1 km resolution data). Sampling sites are displayed at elevations recorded by GPS.

Fig. 3: Sampling along the transect.

3. PRELIMINARY RESULTS AND FUTURE WORK

Along our long transect (samples GRE-2 to GRE-5, we exclude GRE-1 for obvious analytical problems) the spread in exposure ages prevent a simple deglaciation history as suggested by the moraine systems (not identified during our pilot fieldwork). However, our preliminary results place a constraint on the maximum height reached by the ice sheet during the LGM at 720 m based on the surface exposure age of sample GRE-3 (30 ^{10}Be ka) a glacially polished quartz vein. The time deposition of sample GRE-2 (18.2 10Be ka), likely represents a minimum age as the boulder display signs of heavy weathering (debris accumulation is present at the base of the boulder), and supports broadly the altitude constraint on the ice thickness at the LGM.

In our detailed study area, an altitudinal transect from 680 m to 440 m suggests a thinning of the ice sheet of 240 m between 12.3 ^{10}Be ka (n = 2) to 8.3 ^{10}Be ka (n = 3). The clustering of exposure ages at 8.3 ^{10}Be ka on the only set of moraines found so far suggests that the ice margin in this sector of western Greenland potentially responded to the 8.2 K event.

Future work will lead us to detailed mapping work including a determination of the weathering line altitude along the coast-to-ice-margin transect, and identification of glacial features and their depositional processes in our detailed study area. We plan on an extensive surface exposure dating campaign in the frame of a collaborative project.

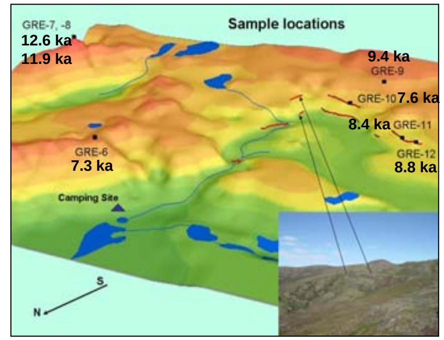

Fig. 4: Area of detailed study and moraines (red lines).

Fig. 5: Sampling of moraine deposits.