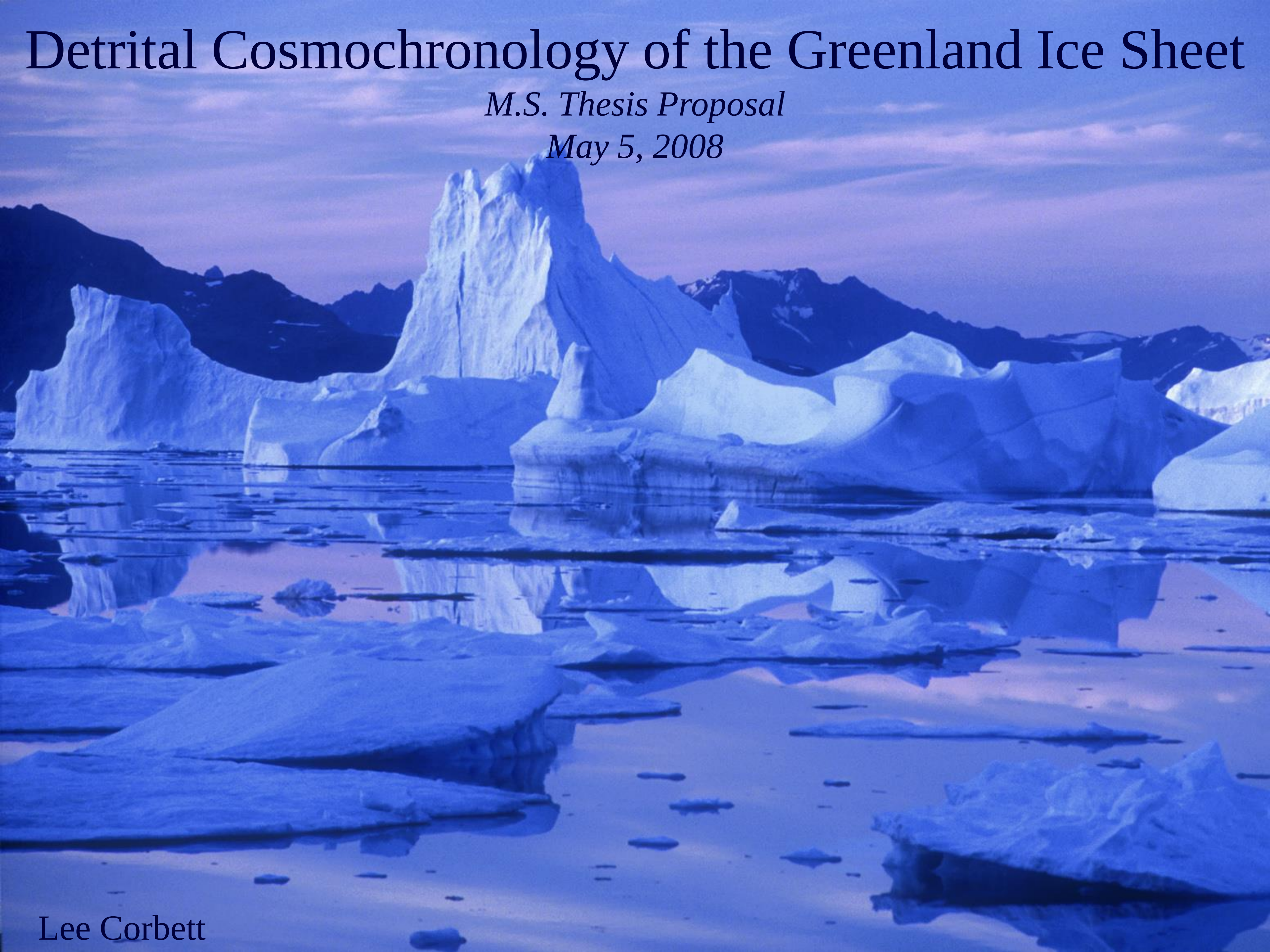
Detrital Cosmochronology of the Greenland Ice Sheet

M.S. Thesis Proposal

May 5, 2008



Lee Corbett

Overview

Unanswered questions:

Has the Greenland Ice Sheet been stable in size over time?

If not, how many times has it melted significantly?

How extreme are melting events?

What is the spatial distribution of melting?

Synopsis of this project:

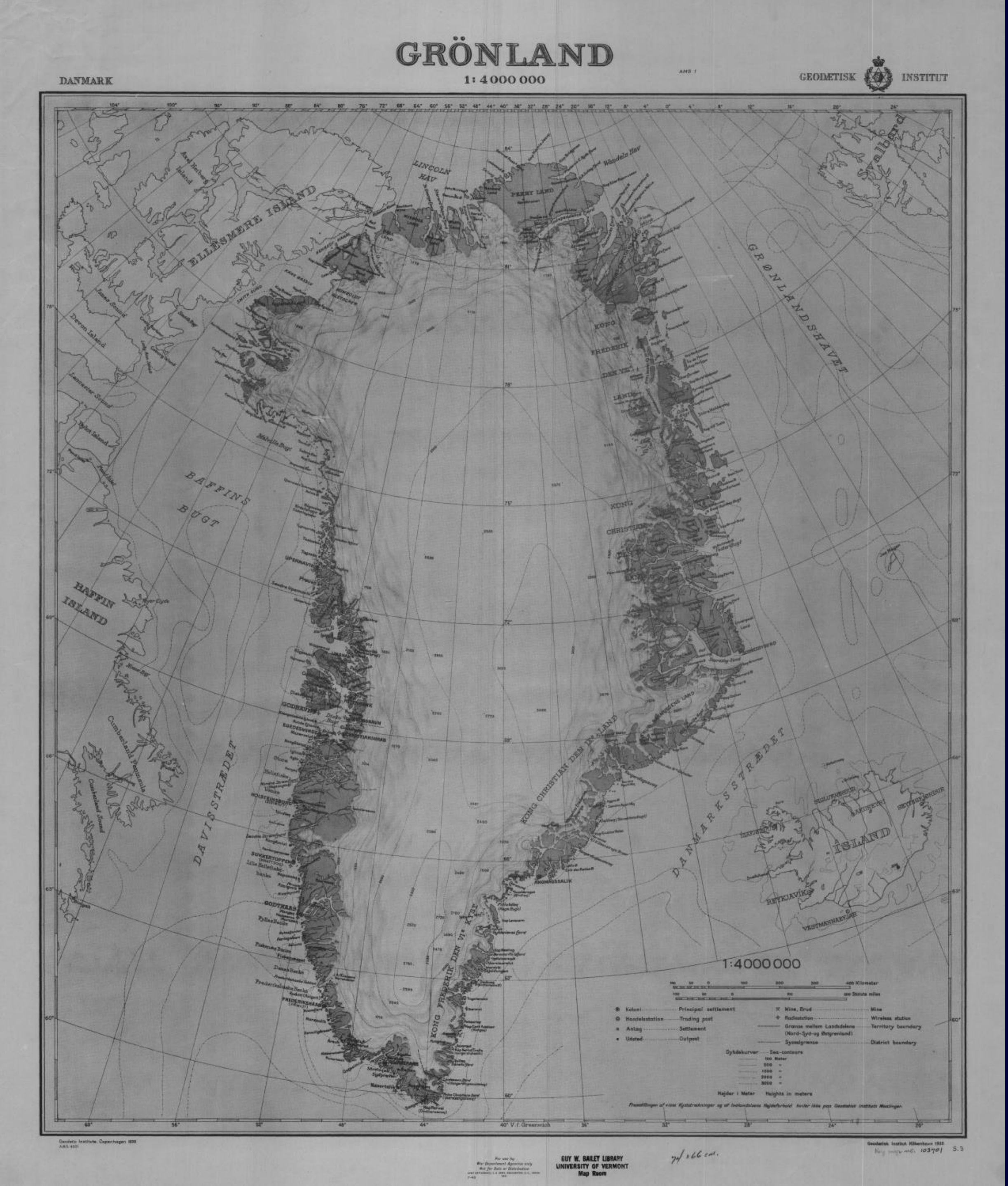
Use cosmogenic burial dating to assess times when the Greenland Ice Sheet was smaller than its current extent.

Goals

1.) Adapt the burial dating technique to make it applicable to this project.

2.) Infer information about ice sheet history by sampling clasts from three different locations on the ice sheet margin.

3.) Use this knowledge to better understand how modern climate warming might impact the ice sheet.



Ice Sheet Facts:

Covers 81% of Greenland

Land area: 1.7 x 10^6 km^2

Thickness: 3400 m at center

Ice volume: 2.8 x 10^6 km^3

10% of Earth's fresh water

6-7 m sea level equivalent

Sample Sites:

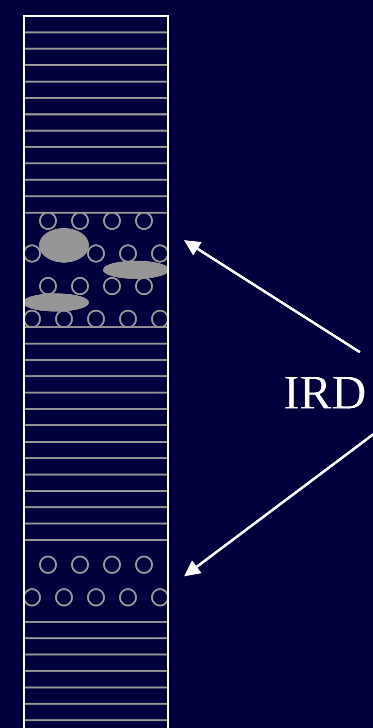
Northernmost:
Upernavik
72°47’02” N
Hypothesized melting: small

Middle:
Ilulissat
69°13’00” N
Hypothesized melting: ?

Southernmost:
Kangerlussuaq
66°00’38” N
Hypothesized melting: great

The Onset of Glaciation

- Oldest widespread ice rafted debris (IRD) in the North Atlantic dates to ~2.4 Ma (Shackleton et al., 1984)
- Oldest IRD near Greenland dates to ~7 Ma (Larsen et al., 1994)
- Glaciation began ~10 Ma, early Late Miocene (Larsen et al., 1994)

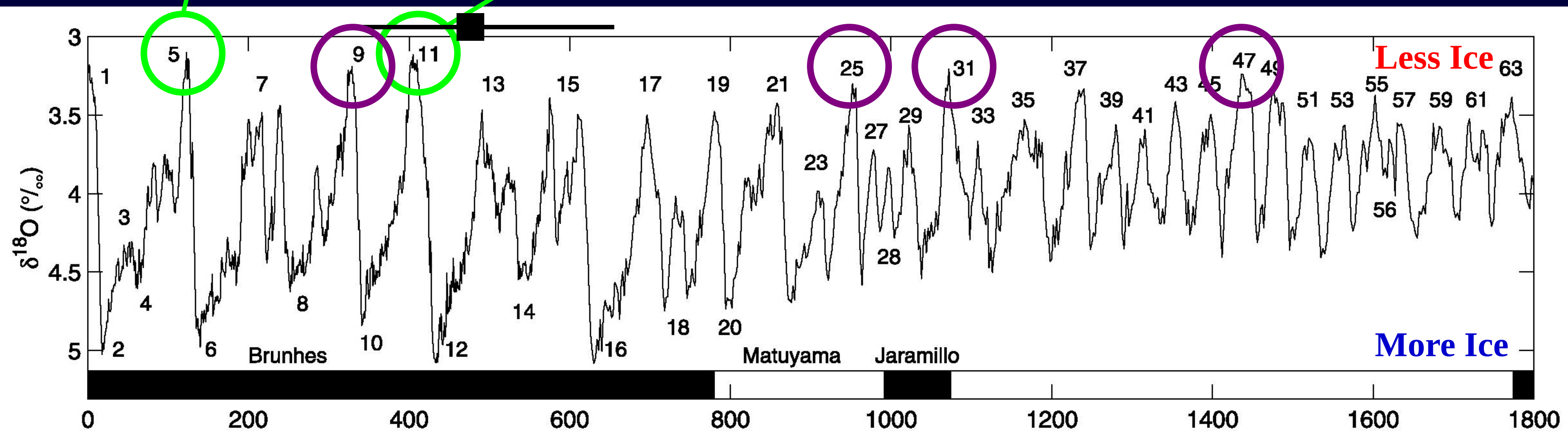


History of the Greenland Ice Sheet:

Variability in Ice Sheet Extent

Minimum ice volume
Letreguilly et al. (1991), Cuffey and Marshall (2000), Overpeck et al. (2006), Otto-Bliesner et al. (2006)
Ice sheet modeling

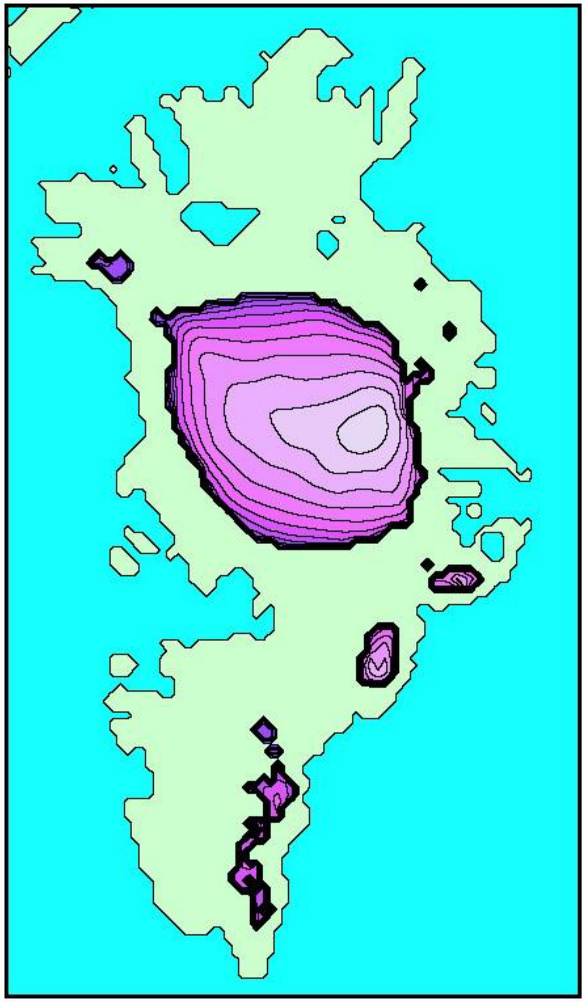
Minimum ice volume
Nishiizumi et al. (1996)
Cosmogenic burial dating on GISP2 rock

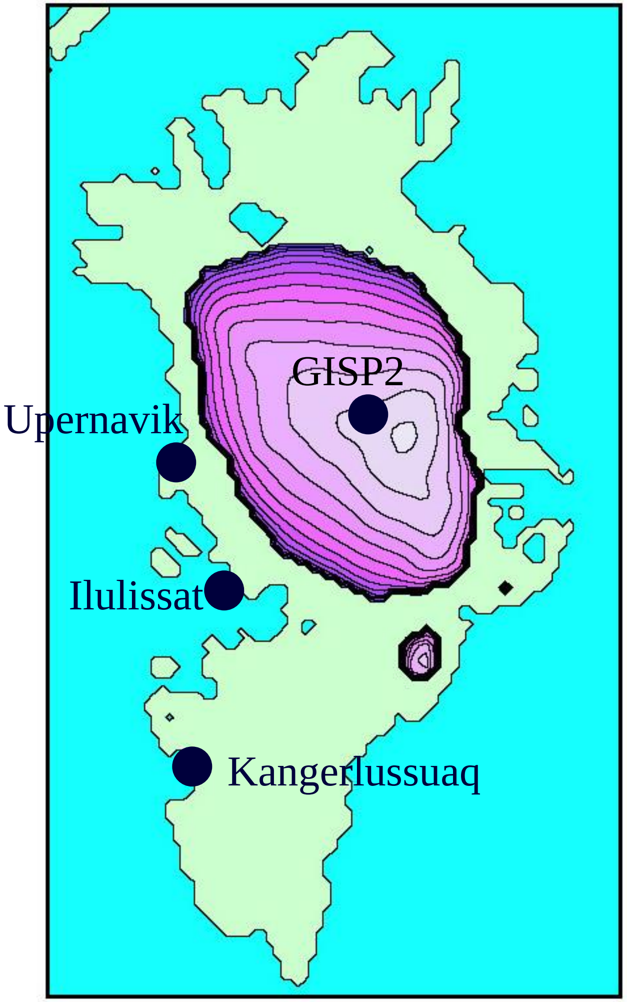


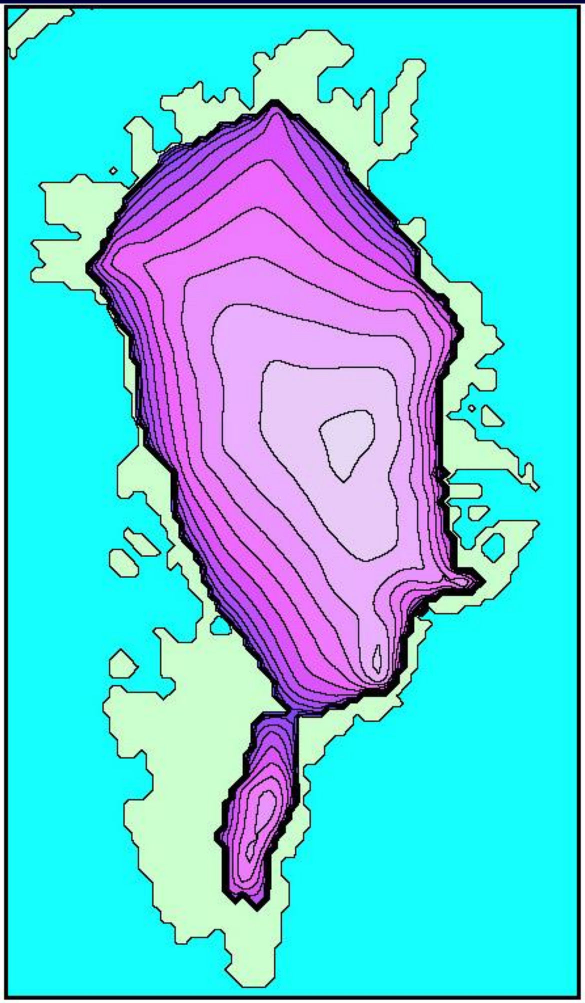
Marine Oxygen Isotope Stages from Lisiecki and Raymo (2005)

History of the Greenland Ice Sheet:

Modeling the Eemian







Eemian ice extent models from Cuffey and Marshall (2000)

Cosmogenic Nuclide Dating:

Terrestrial Cosmogenic Nuclides

TCN	**Production Rate** **(k_p)** (atoms $gSiO_2^{-1}$ $year^{-1}$)	**Half-Life** (years)	**Decay Constant** **(k_d)** ($year^{-1}$)
^{10}Be	5.2	1.3 Ma	5.33×10^{-7}
^{26}Al	31.2	0.7 Ma	9.90×10^{-7}
^{36}Cl	Varies by composition*	0.3 Ma	2.31×10^{-6}
^{14}C	50	.005 Ma	1.21×10^{-4}

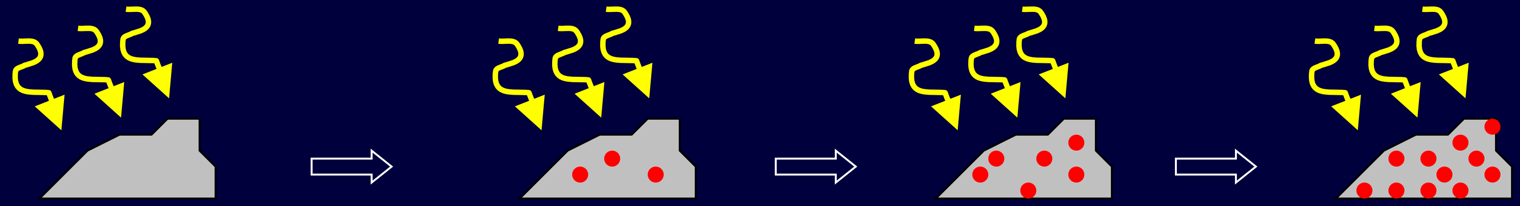
* ^{36}Cl production is measured in atoms mol^{-1} $year^{-1}$

Cosmogenic Nuclide Dating:

Exposure Dating vs. Burial Dating

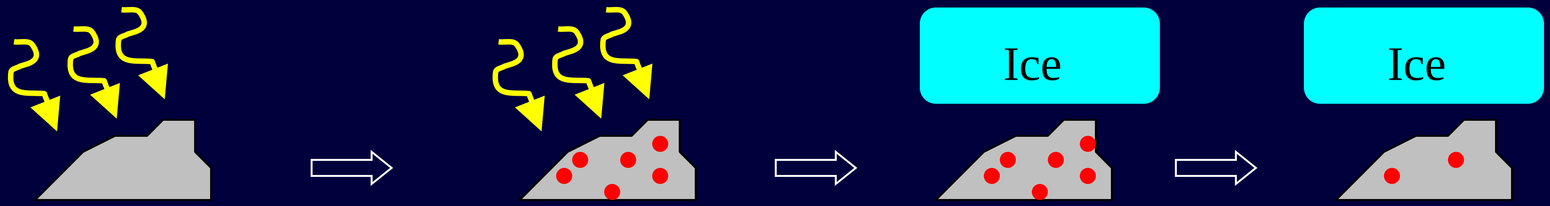
Exposure Dating:

Use TCN concentration to determine how long a surface has been exposed to cosmogenic radiation



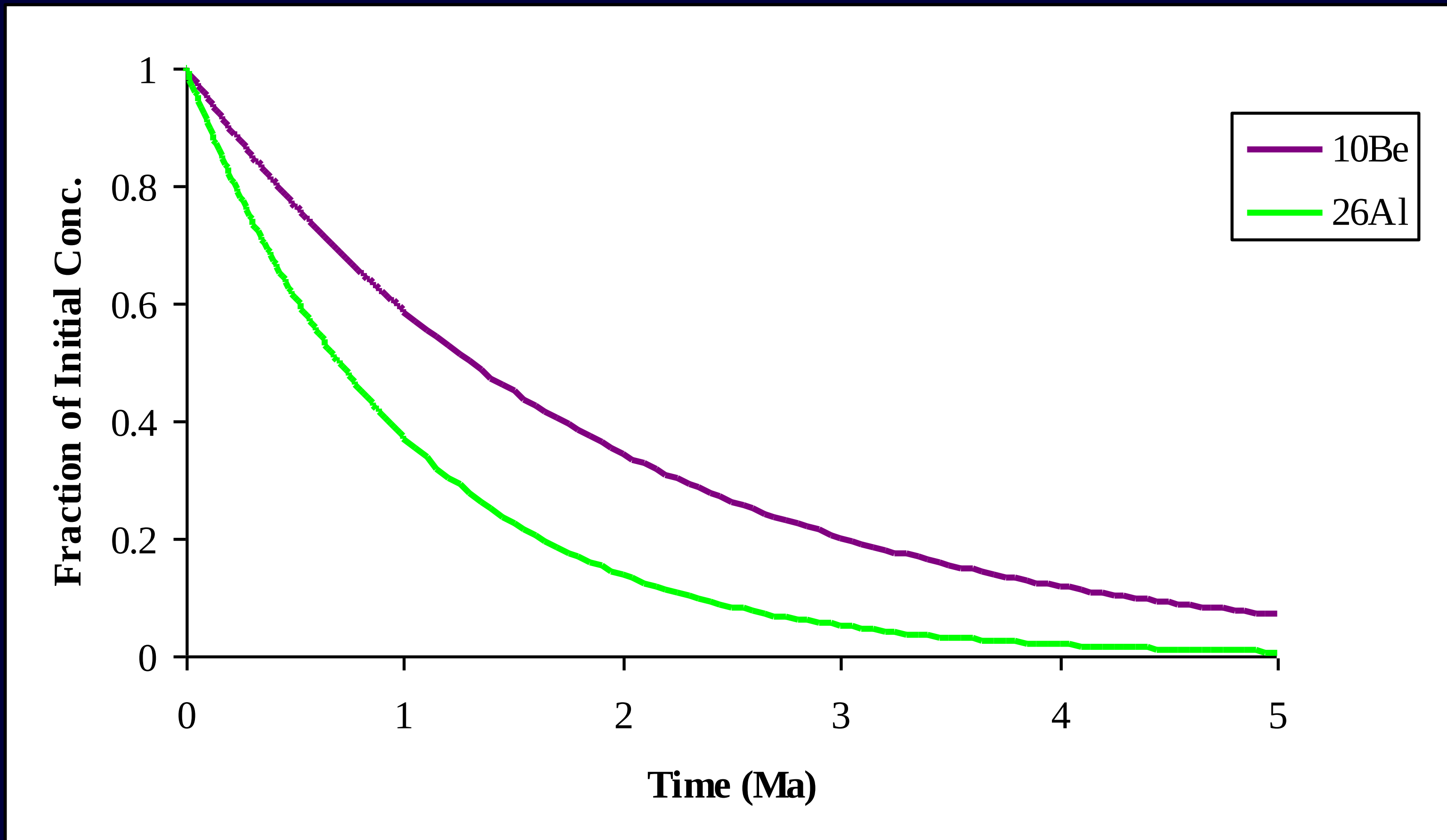
Burial Dating:

Use TCN concentration to determine how long a surface has spent exposed versus how long it has spent shielded



Cosmogenic Nuclide Dating:

Decay of TCNs

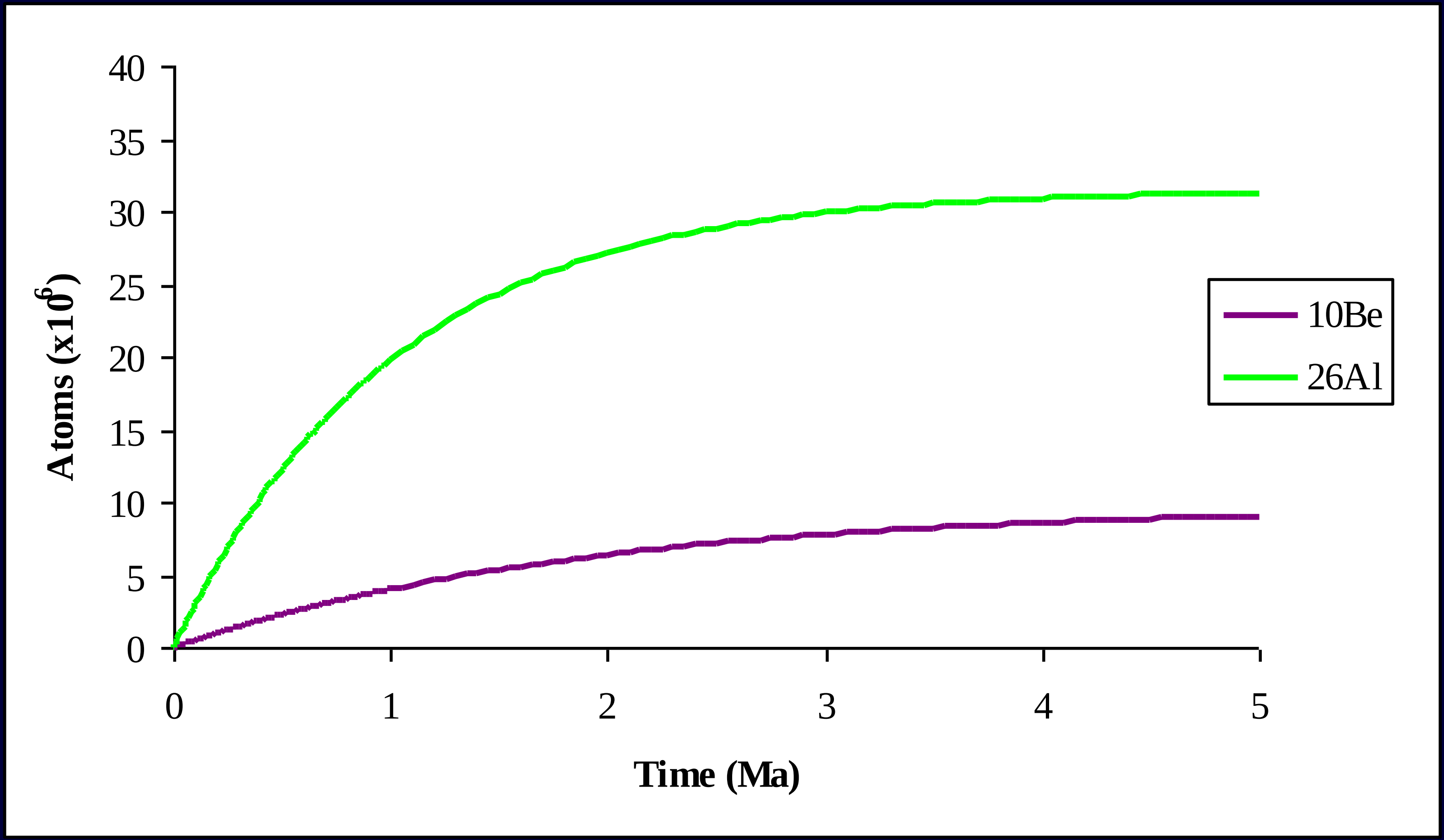


$$[Be] = [Be]_0 e^{-k_{dBe} t}$$

$$[Al] = [Al]_0 e^{-k_{dAl} t}$$

Cosmogenic Nuclide Dating:

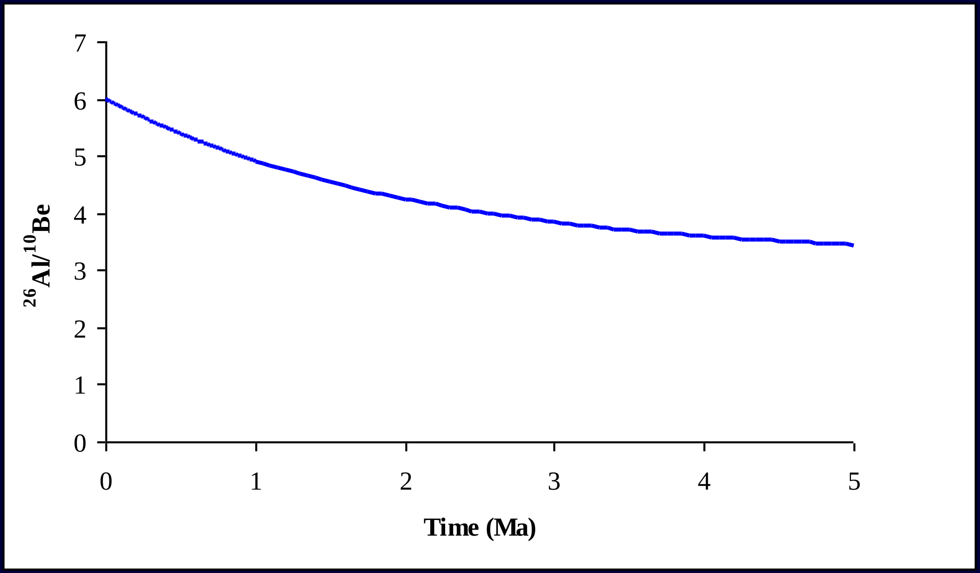
Production + Decay: Constant Exposure

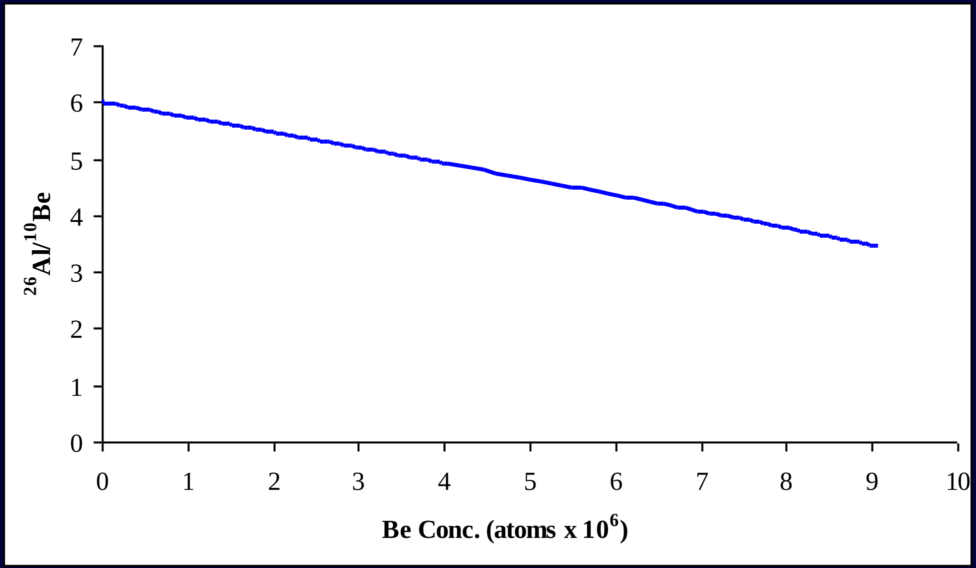


$$[Be] = (k_{pBe}/k_{dBe})(1-e^{-k_{dBe}t})$$
$$[Al] = (k_{pAl}/k_{dAl})(1-e^{-k_{dAl}t})$$

Cosmogenic Nuclide Dating:

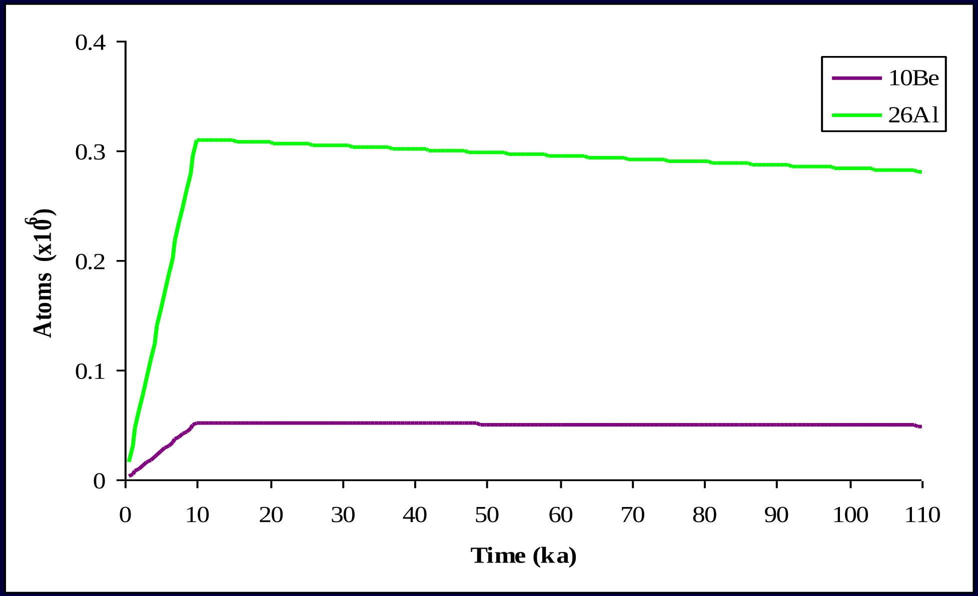
The $^{26}Al/^{10}Be$ Ratio, Constant Exposure



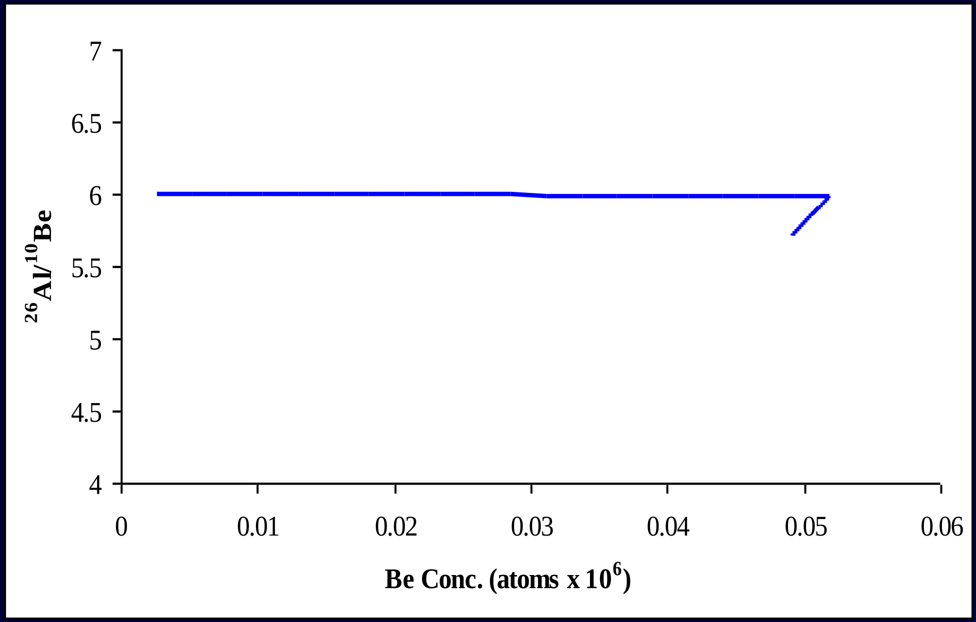


Cosmogenic Nuclide Dating:

Simple Burial

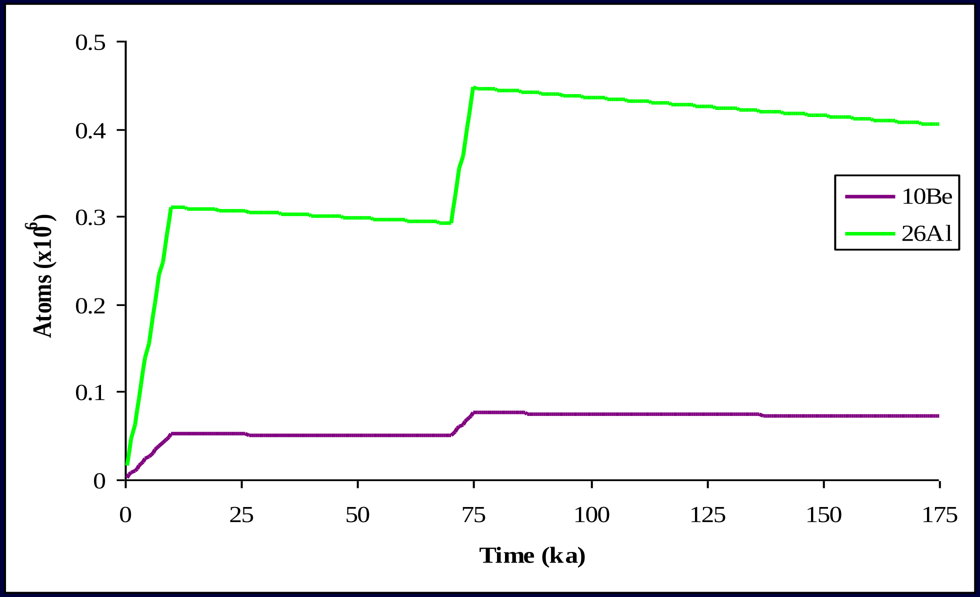


Exposure for 10 ka
Burial for 100 ka

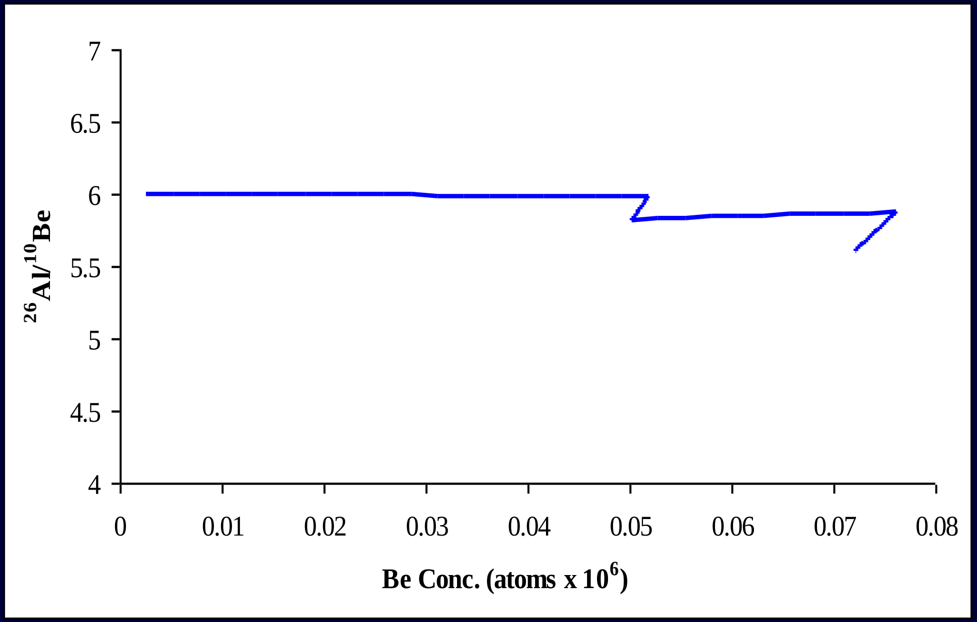


Cosmogenic Nuclide Dating:

Complex Burial

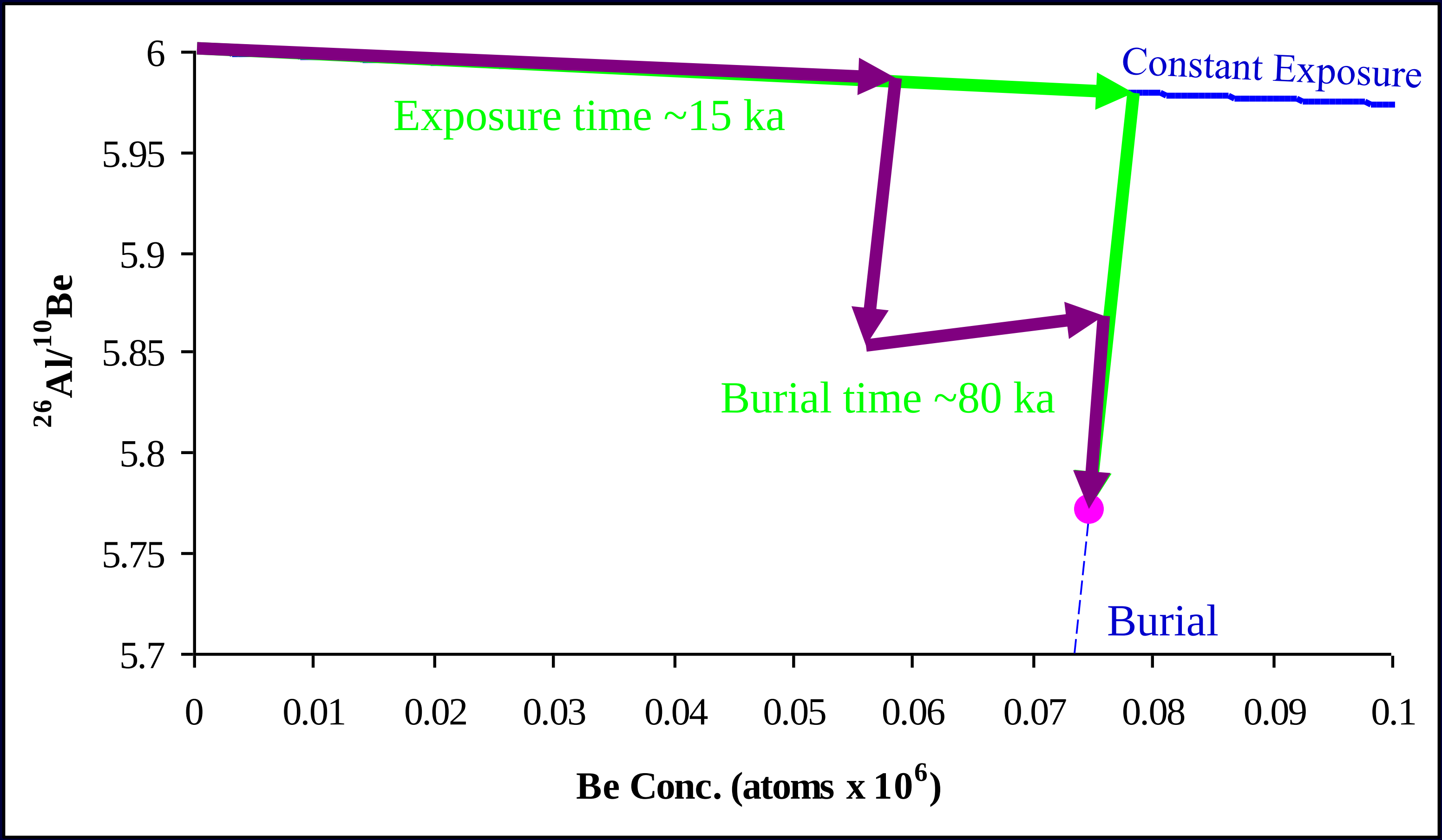


Exposure for 10 ka
Burial for 60 ka
Exposure for 5 ka
Burial for 100 ka



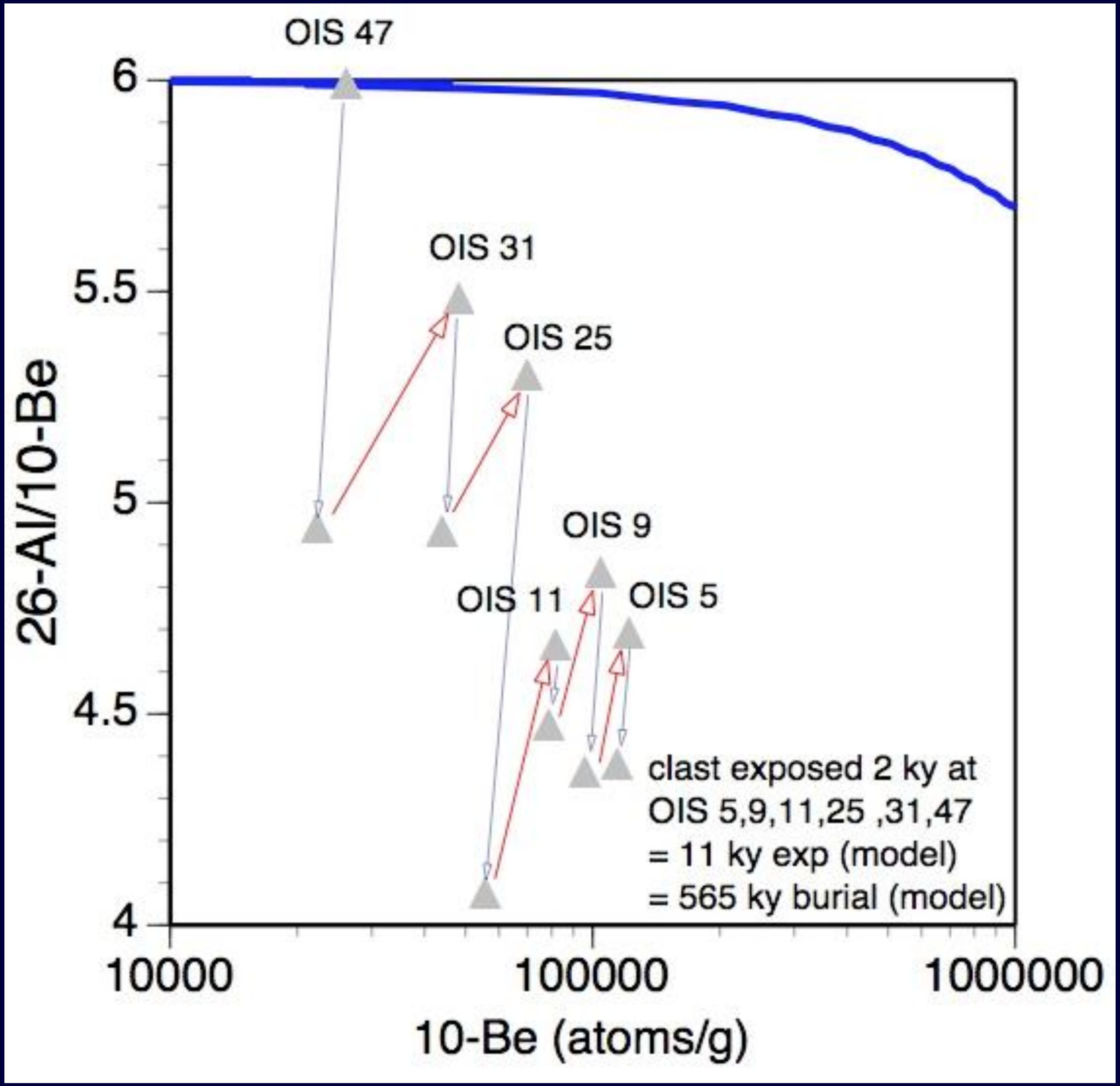
Cosmogenic Nuclide Dating:

Dating an Unknown



Cosmogenic Nuclide Dating:

"Worst Case" Scenario

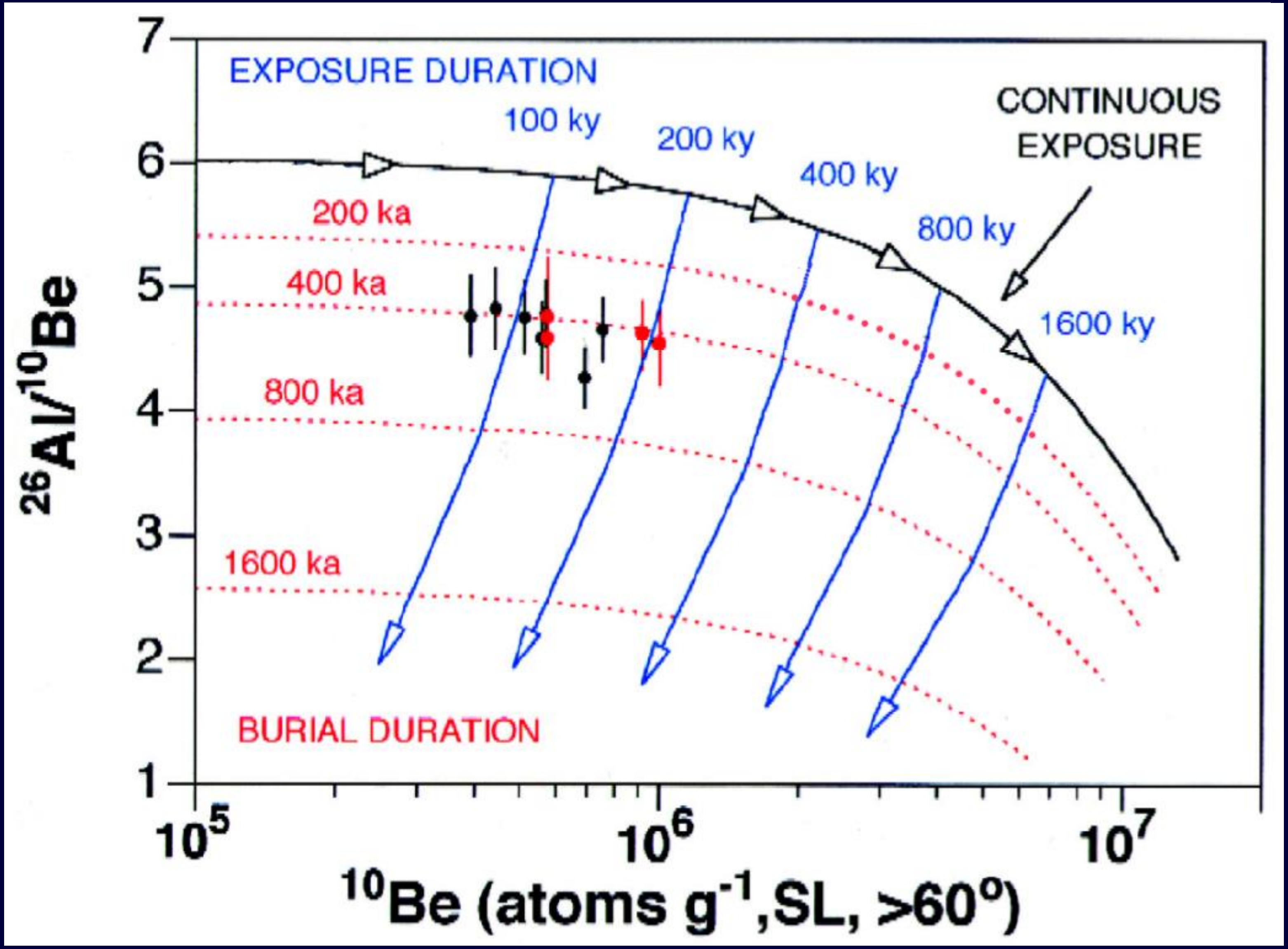


Methods:

Fieldwork

Ice sheet margin images from Knight et al., 2002

Methods:
Data Analysis



Data from outcrops in Baffin Island (black) and Minnesota (red) (Bierman, 1999)

Methods and Timeline

Spring 2008: Preparation for the field season

July 2008: Fieldwork

Late summer 2008 through Winter 2009: sample preparation and mineral separation

Winter 2009 through Summer 2009: sample analysis

Fall 2009 through Spring 2010: analysis, writing, presentation

Acknowledgements

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Collaborators:
Paul Bierman
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