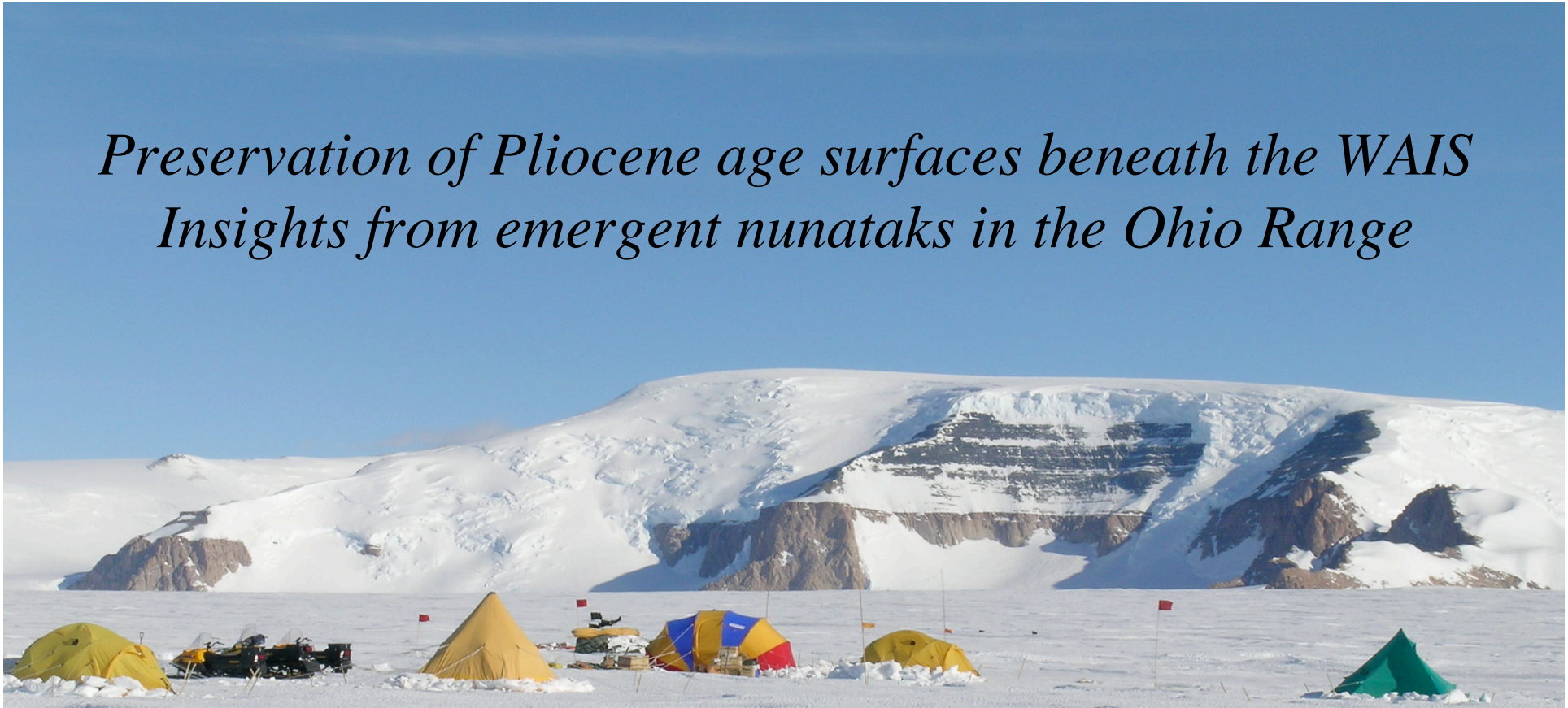
Preservation of Pliocene age surfaces beneath the WAIS Insights from emergent nunataks in the Ohio Range



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Introduction

If the ice sheet were largely removed during the last interglacial, what would we find at the bottom of the WAIS divide or elsewhere revealing this history?

1) What did West Antarctica look like? Where was the ice margin?

2) When did the collapse happen and how long did it last?

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How can cosmogenic nuclides be used to address these questions?

Introduction

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1) Areas below sea level (Deglaciated).

   Marine sediments/tills in troughs

   Scoured bedrock/tills on topographic highs

2) Areas above sea level

   Glaciated areas

   Ice-free areas (exposed to cosmic radiation)

Subglacial geography

Where would we expect to find exposed bedrock in West Antarctica if the ice sheet collapsed?

Areas with topography similar to present ice free areas:

1) Areas near sea level.

   Debris fans, beaches and shore lines.

2) High ground

   Ridges, cliffs.

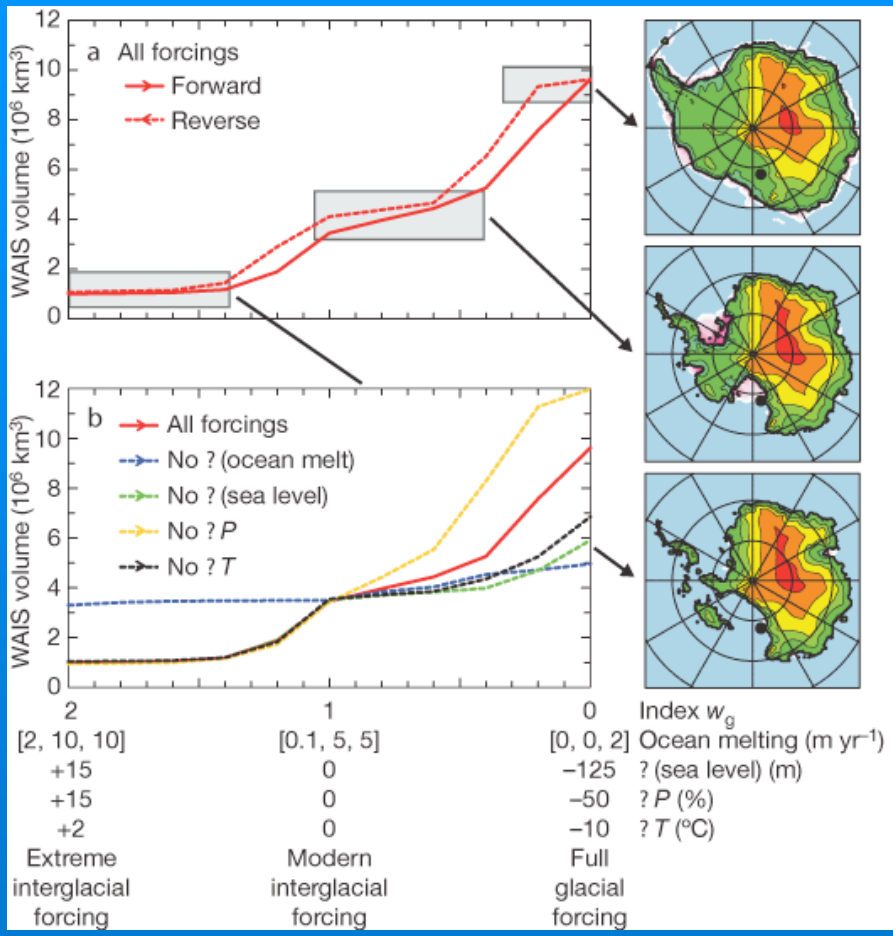
Subglacial geography

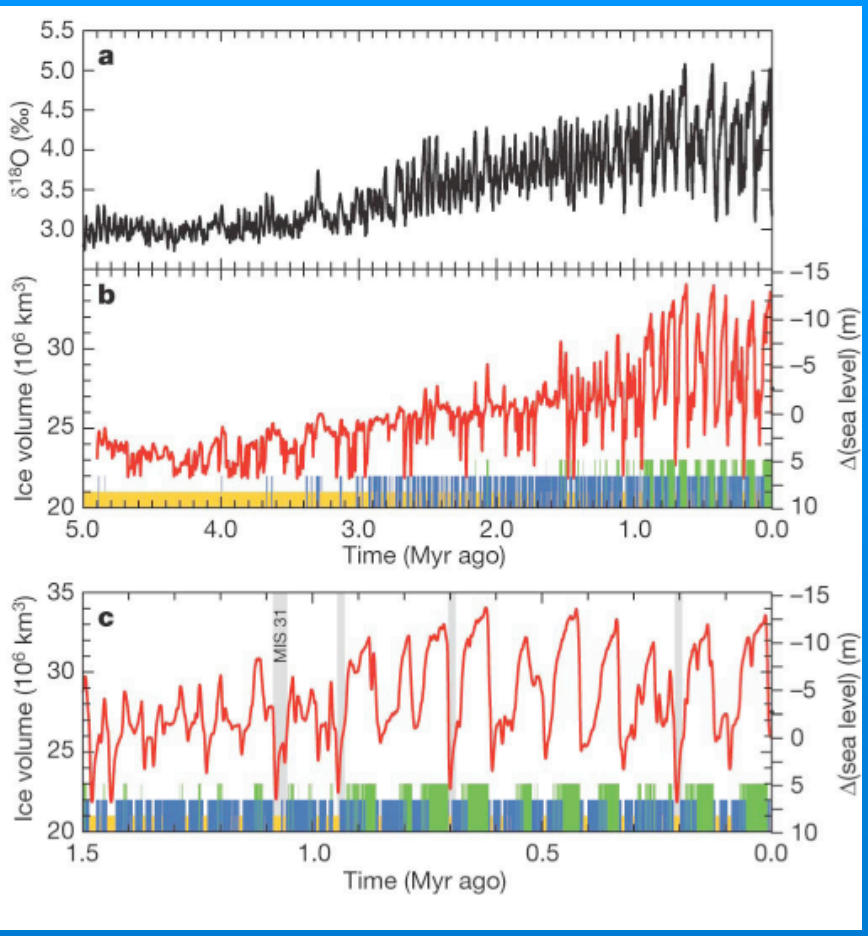
If there was open water in interior west Antarctica, there are Penguins remains under the WAIS.

Remains of pre-LGM rookery exist on Franklin Island

WAIS extent during the Pliocene

From Pollard and DeConto 2009





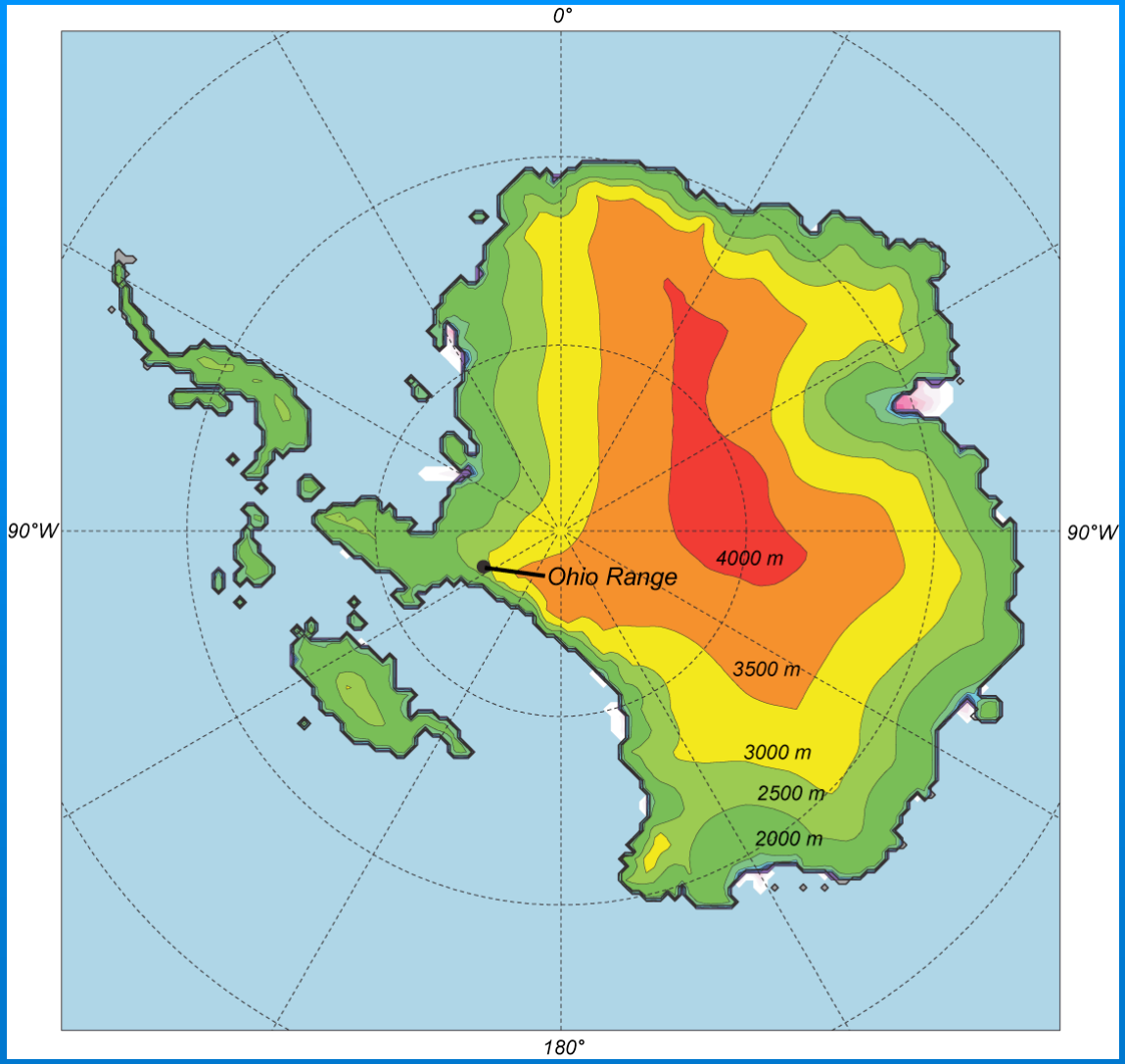
Model results and Andrill data indicate that the WAIS generally remained in the collapse configuration during the Pliocene.

WAIS extent during the Pliocene

From Pollard and DeConto 2009

Ice persisted in areas where bedrock elevations are above sea level such as the Ohio Range.

Absent buttressing ice in the deep troughs, and warmer faster flowing ice, ice elevations in the remaining ice caps was likely lower than present.



The Ohio Range Escarpment

Exposed Bedrock occurs in local ablation areas that result from the interaction of prevailing winds and topography

The Ohio Range Escarpment

Weathered bedrock extends down to present ice surface

The Ohio Range Escarpment

Weathered bedrock extends below present WAIS surface

The Ohio Range Escarpment

The weathered surfaces were buried by the WAIS ~10 ka.
The exposure ages of the weathered bedrock are 1-4 Ma

Pliocene bedrock surface near the WAIS

Glacial erosion by cold based ice is minimal.

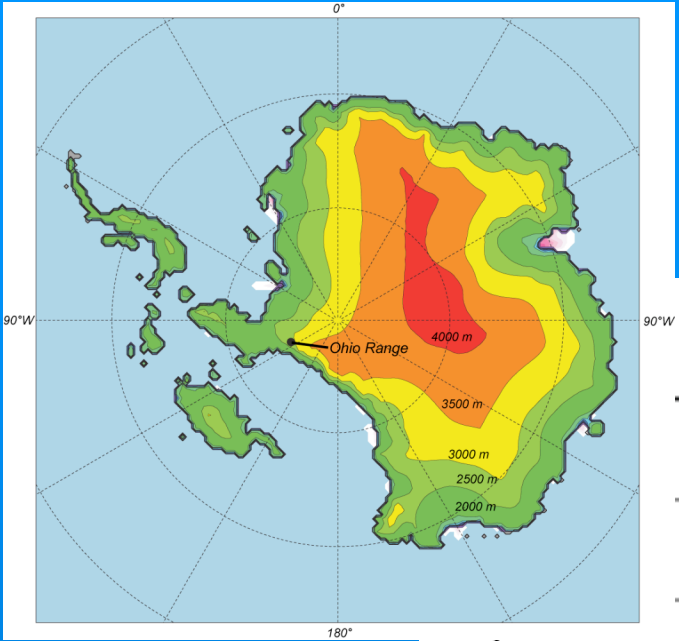
Pliocene bedrock surface near the WAIS

The only observed striation in the Ohio Range.

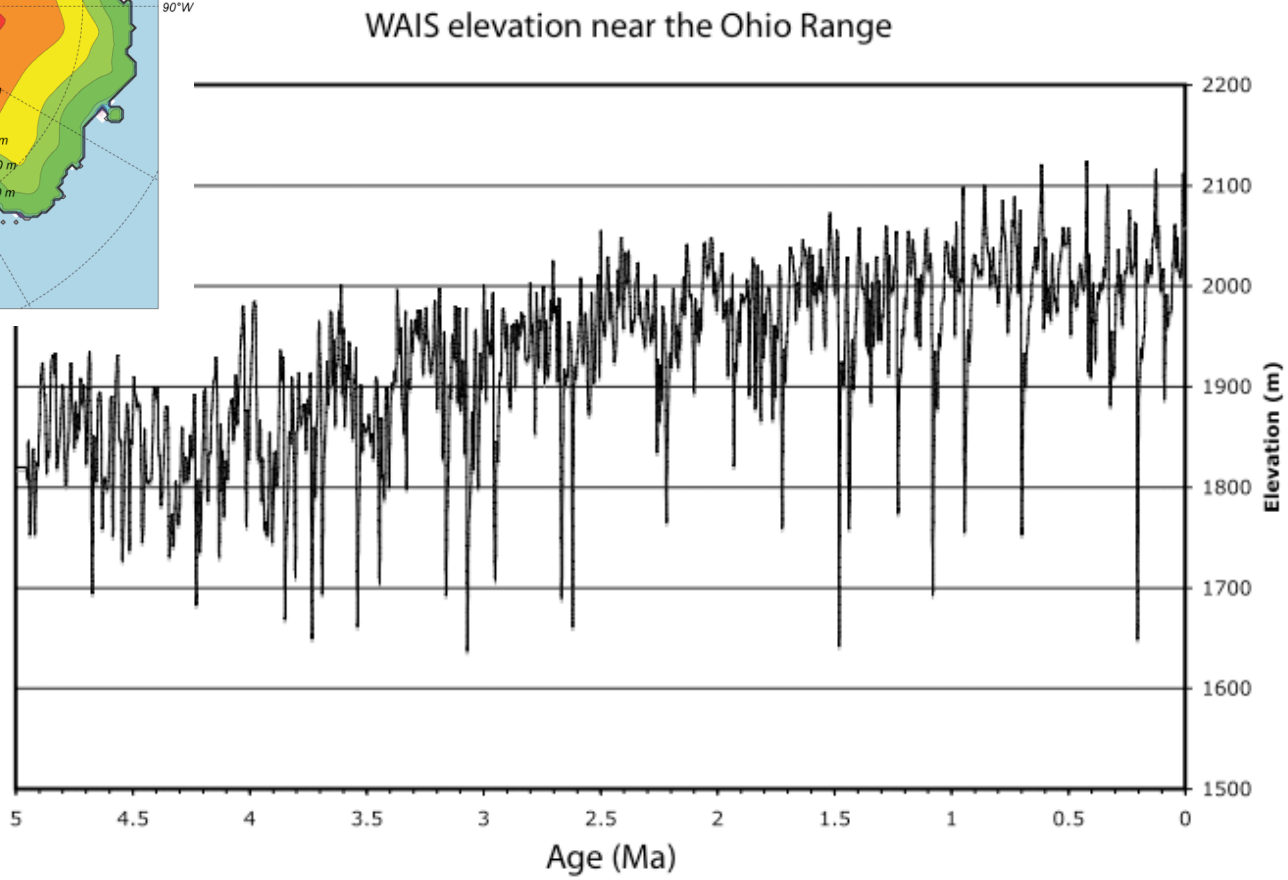
The Ohio Range Escarpment

How far beneath the present WAIS surface does the Pliocene age surface extend?

WAIS extent during the Pliocene



Mean Pliocene elevations at the Ohio Range may have been only ~200m lower.



There may be a Pliocene trimline preserved beneath the WAIS

Cosmogenic nuclides beneath the WAIS

Cosmogenic nuclides are formed when cosmic rays (neutons) interact with atoms in rocks near the Earth's surface.

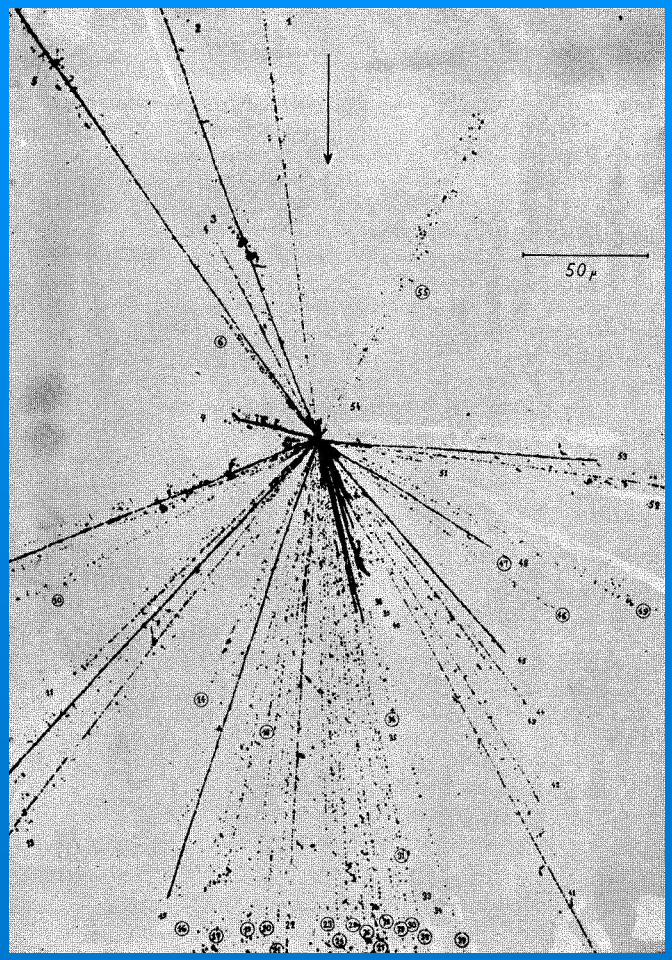
In spallation reactions, the nucleus of the target atom is split, forming different elements.

The neutron flux decreases exponentially with depth.

Cosmogenic nuclide production is negligible at depths >2m.

Both stable and radioactive nuclides are produced.

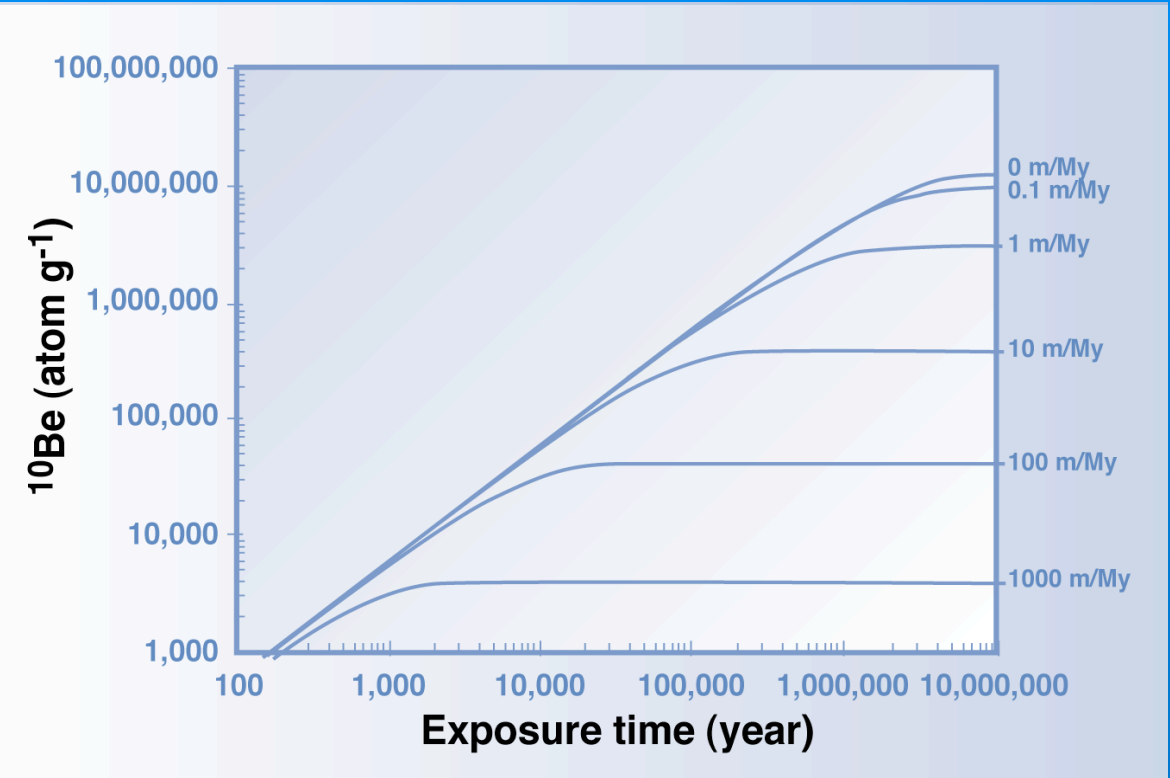
^{3}He, ^{21}Ne, ^{10}Be, ^{26}Al, ^{36}Cl, ^{14}C



Cosmogenic nuclides beneath the WAIS

Steady State Erosion of radioactive isotopes

$$N = \frac{P}{\lambda + E/L}\left(1 - e^{-(\lambda + E/L)t}\right) \quad \xrightarrow{t=\infty} \quad \boxed{N = \frac{P}{\lambda + E/L}}$$



Production of cosmogenic isotope equals that lost by radioactive decay and erosion.

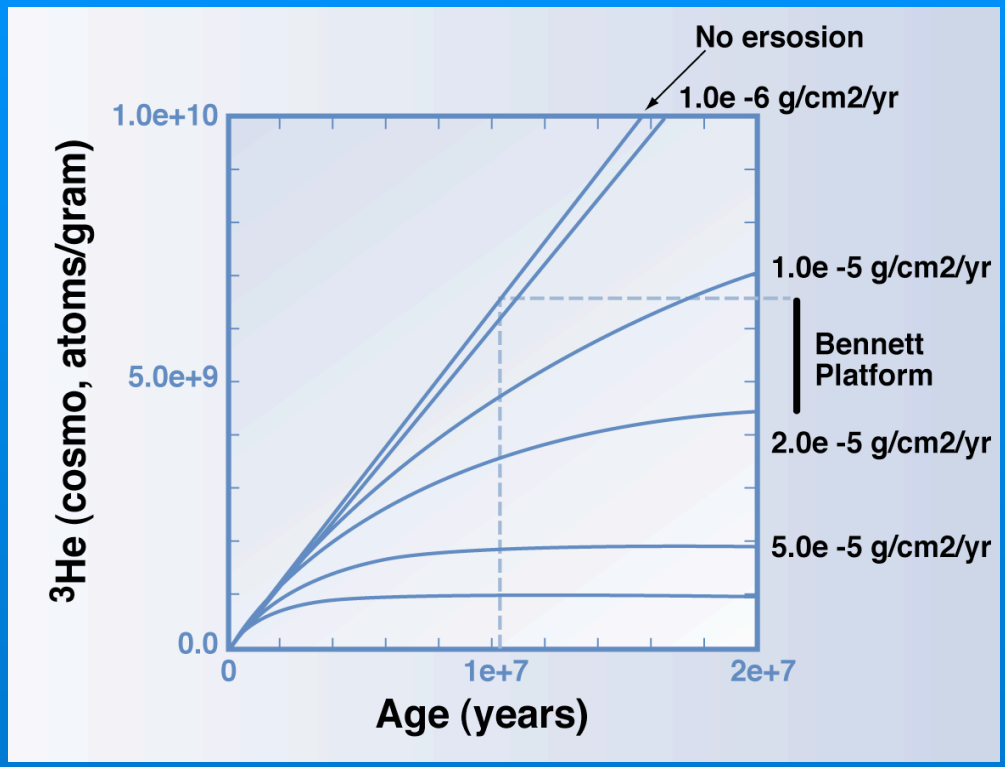
Steady state Concentration (N) depends on erosion rate (E) and decay constant (λ).

Cosmogenic nuclides beneath the WAIS

Steady State Erosion of stable isotopes

$$N = PL/E$$

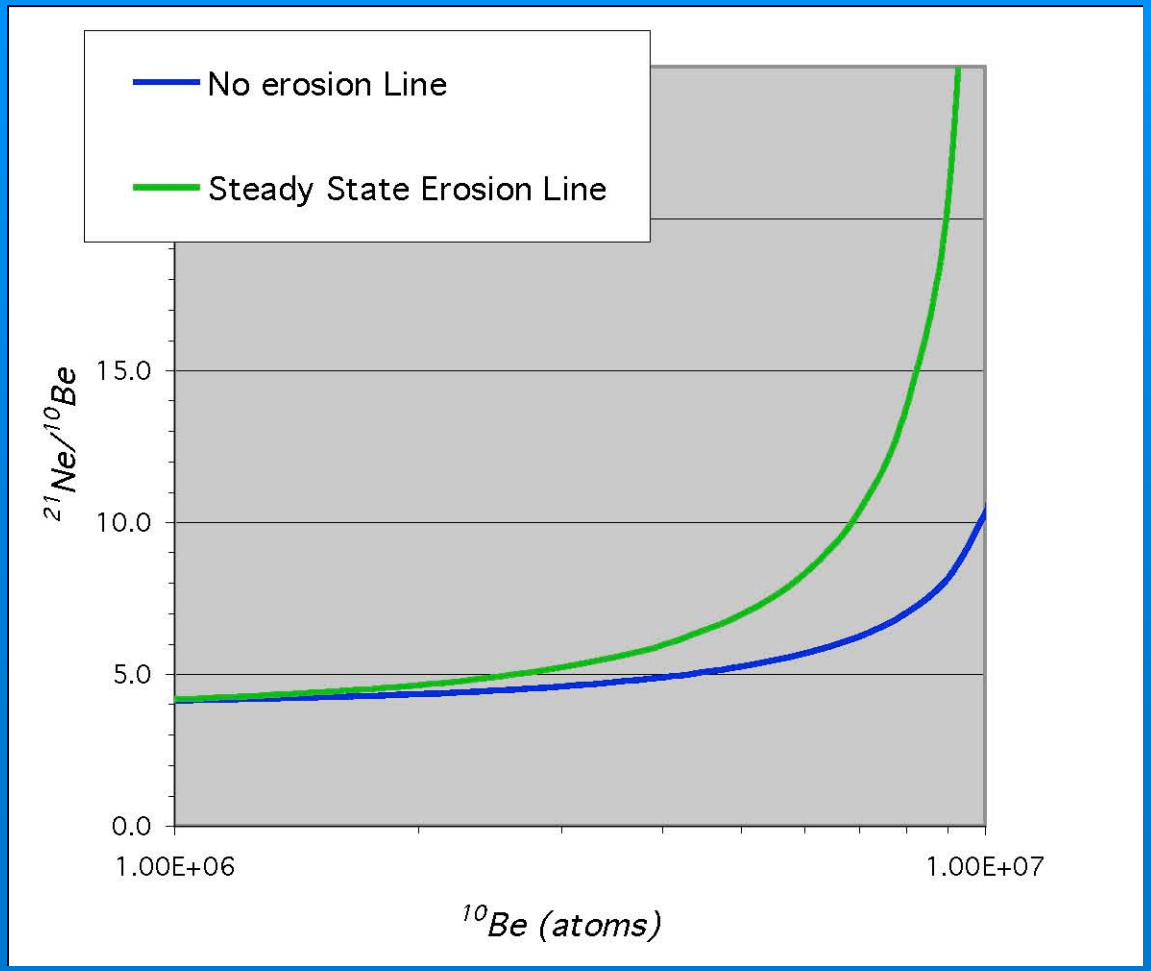
Production equals loss by erosion. The time required to reach steady state concentration is Much longer than for radioactive isotopes.



Cosmogenic nuclides beneath the WAIS

Application of pairs of Cosmogenic Isotopes

Measuring both ^{21}Ne and ^{10}Be allows determination of exposure age and erosion rate.



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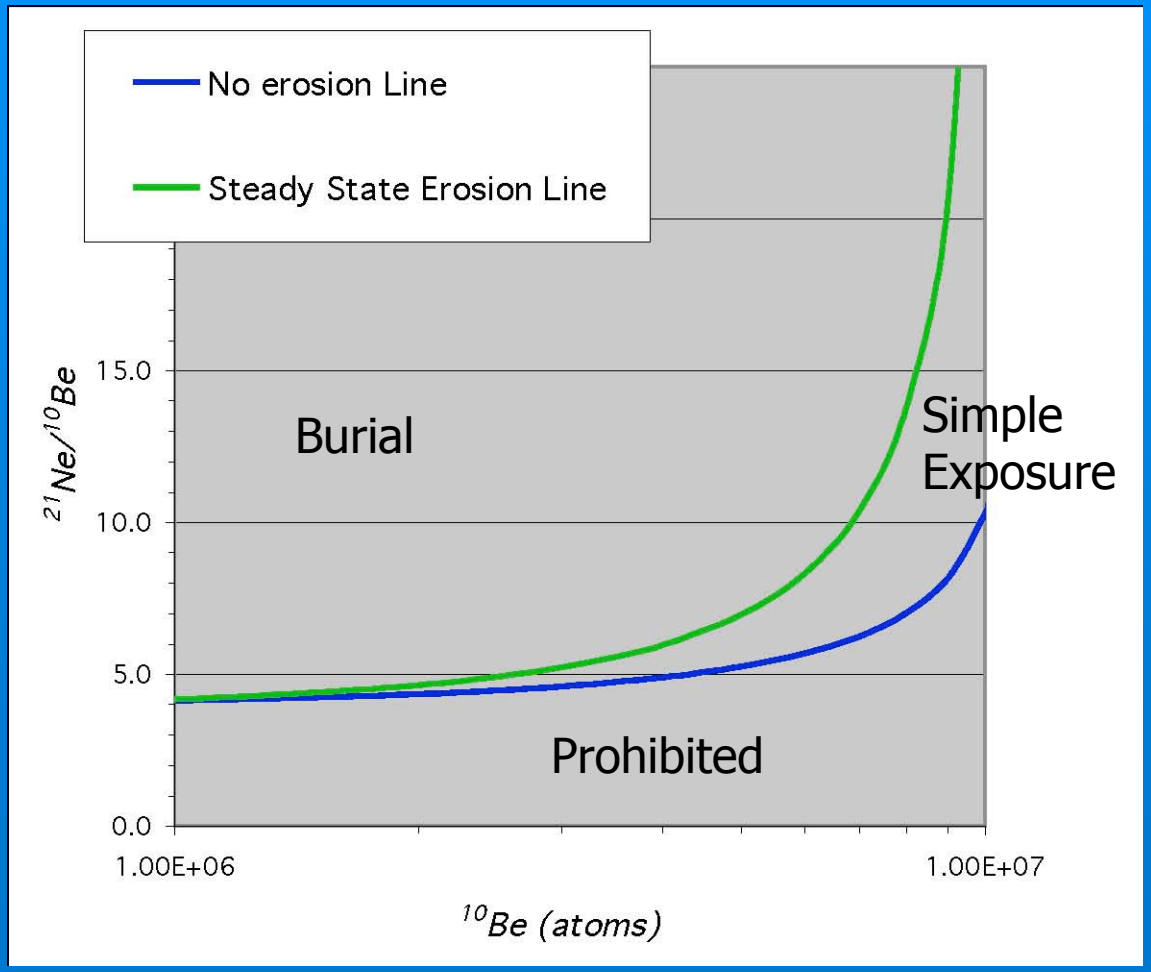
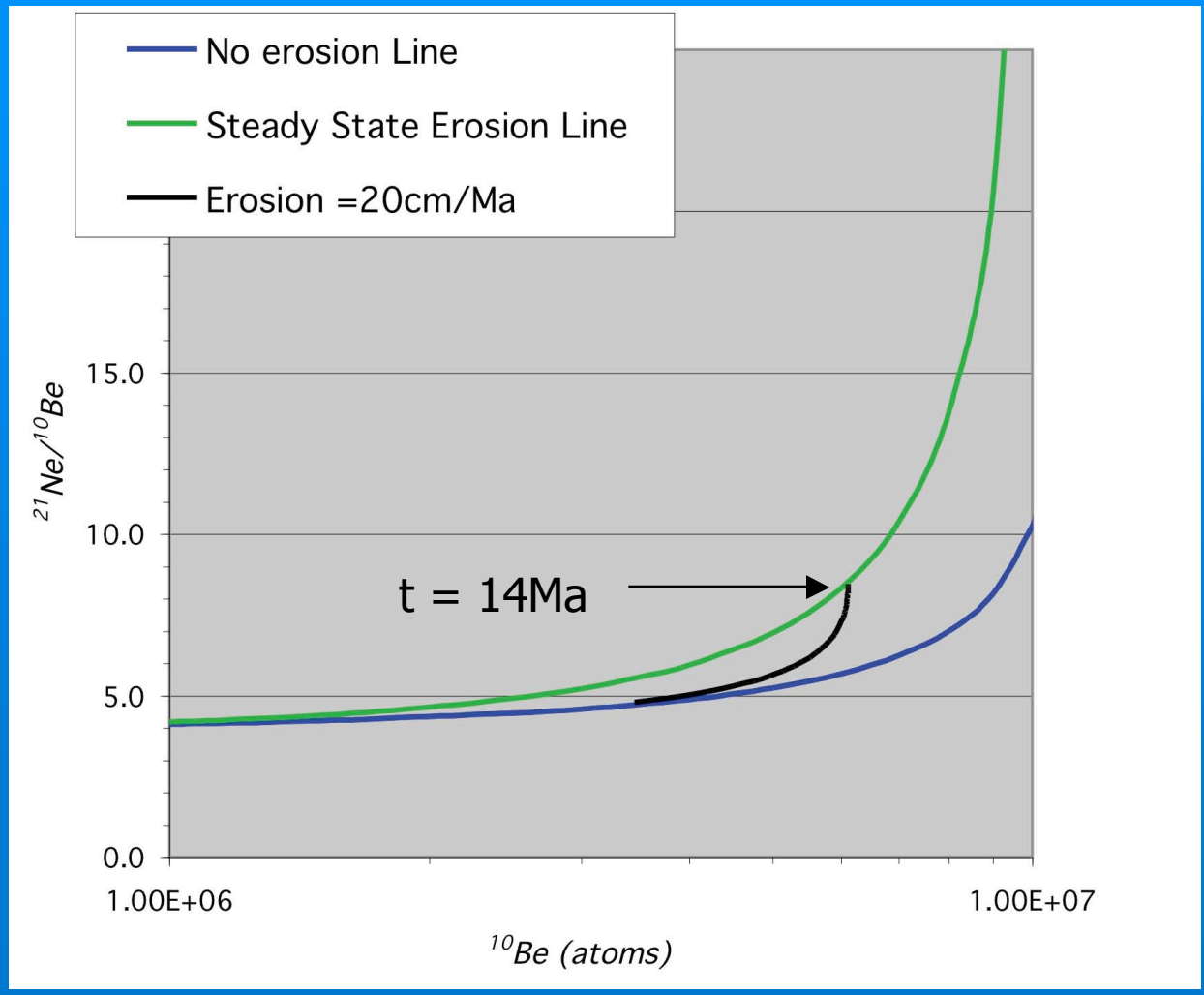


Cosmogenic nuclides beneath the WAIS

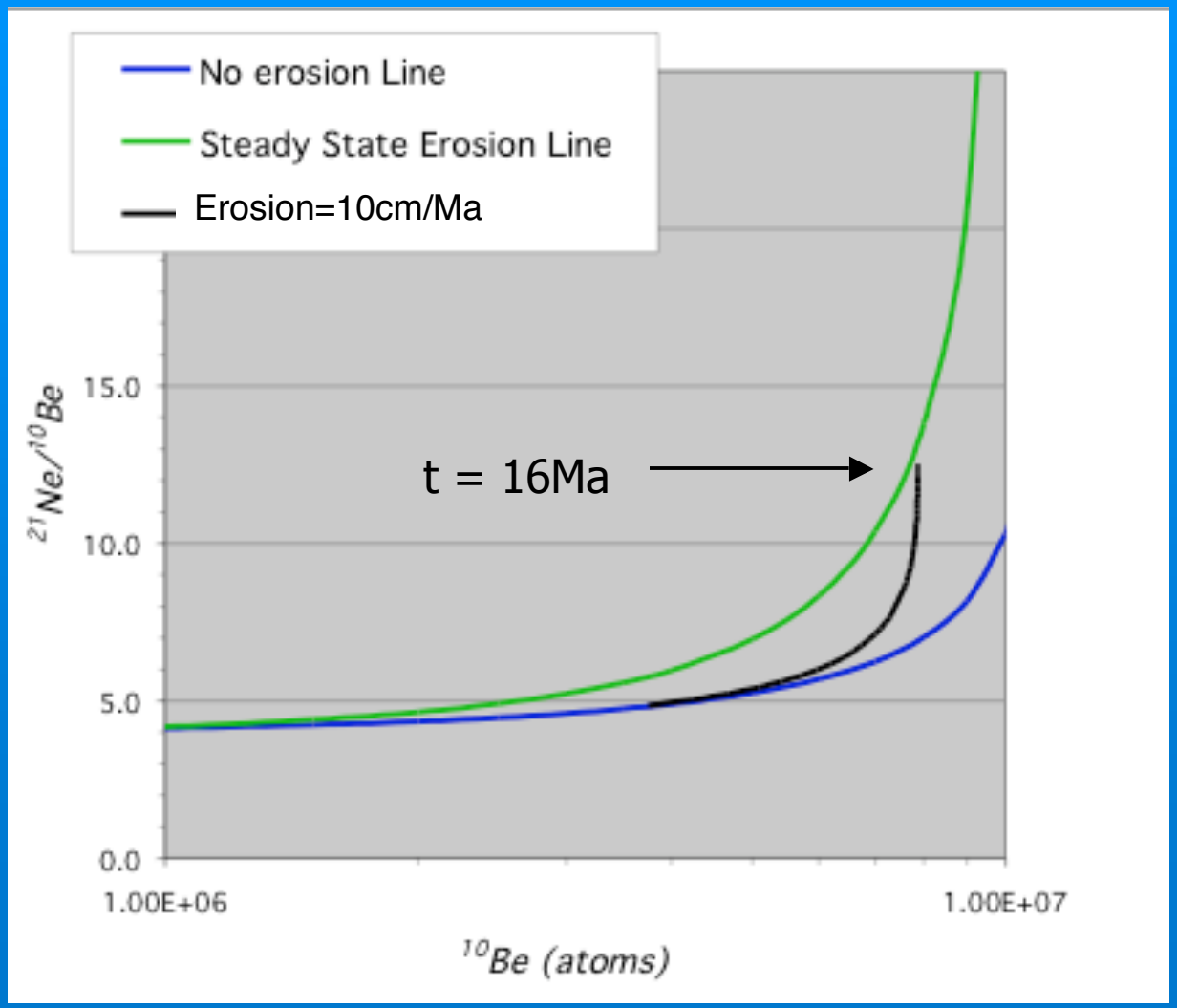
Application of pairs of Cosmogenic Isotopes

Samples having a simple exposure history will follow trajectories that lie between the no-erosion and steady state curves.



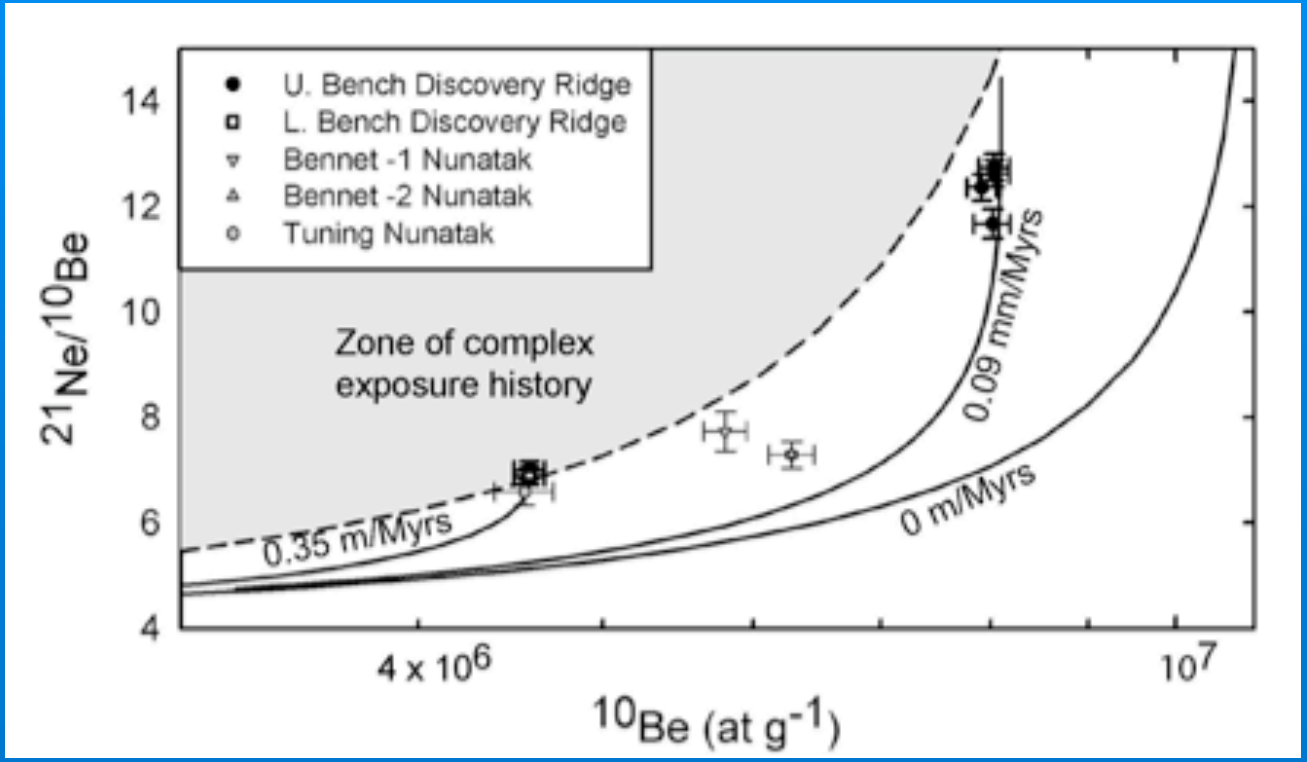
Cosmogenic nuclides beneath the WAIS

The trajectory depends on the erosion rate

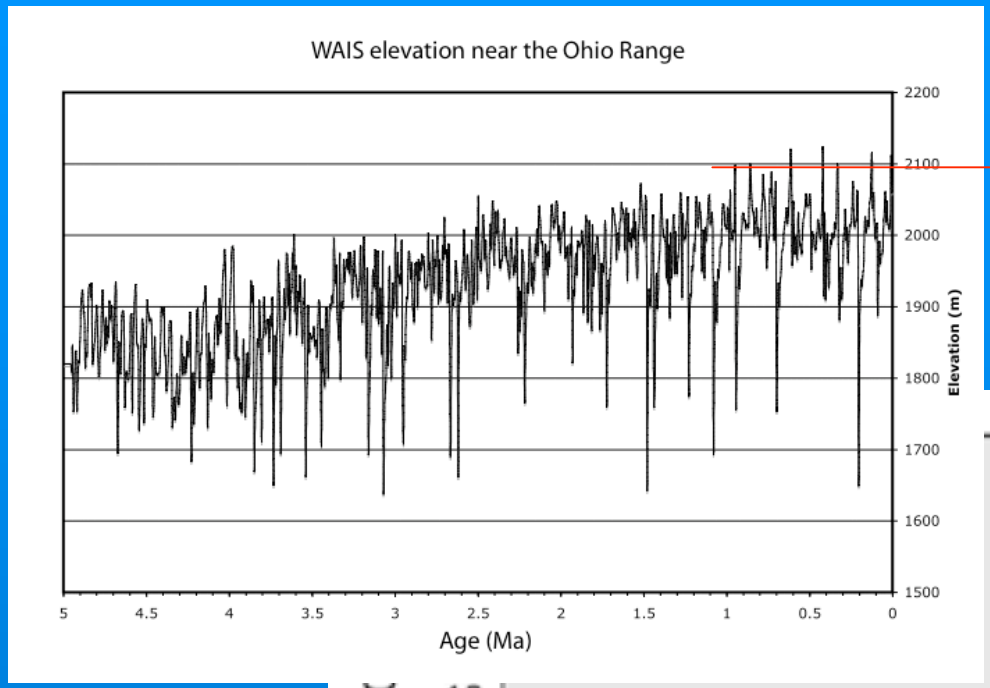


Cosmogenic nuclides on the Ohio Range Escarpment

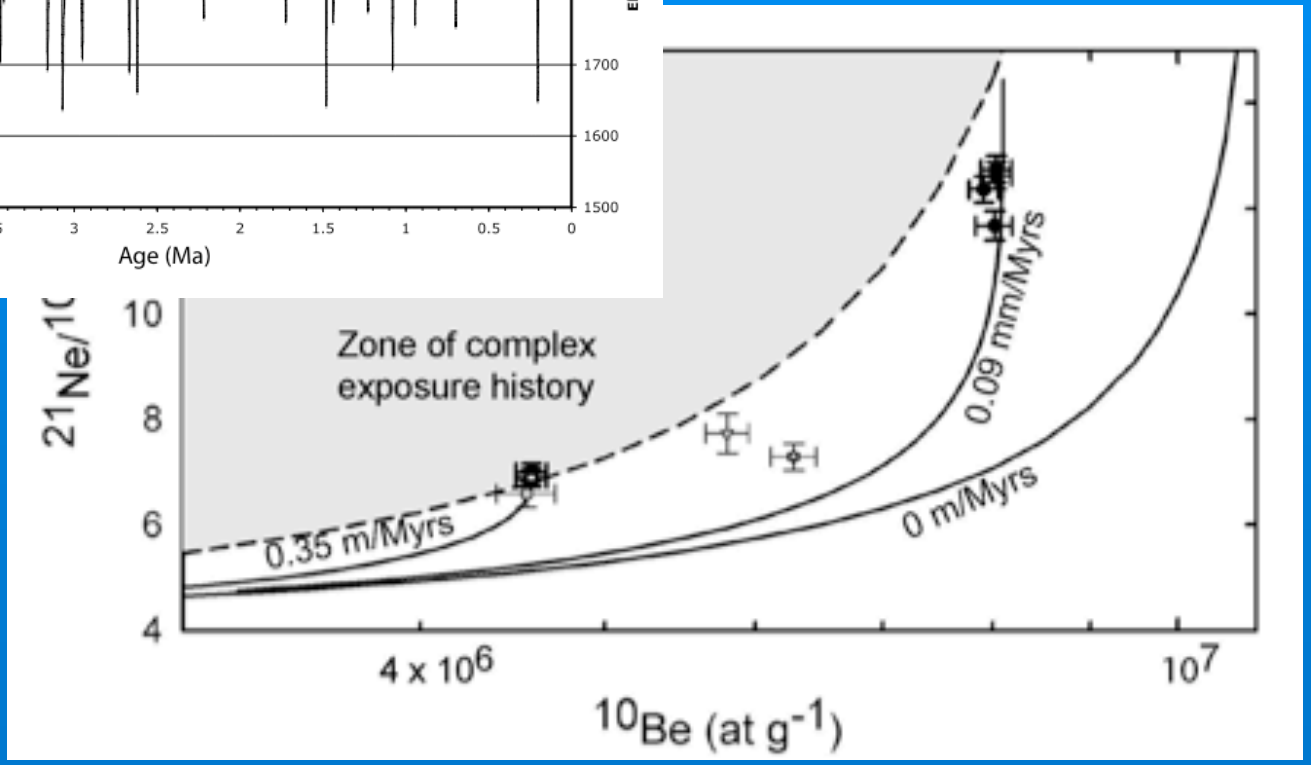
Surface exposure ages of weathered bedrock above the WAIS range from 4 to 11 Ma



Cosmogenic nuclides on the Ohio Range Escarpment



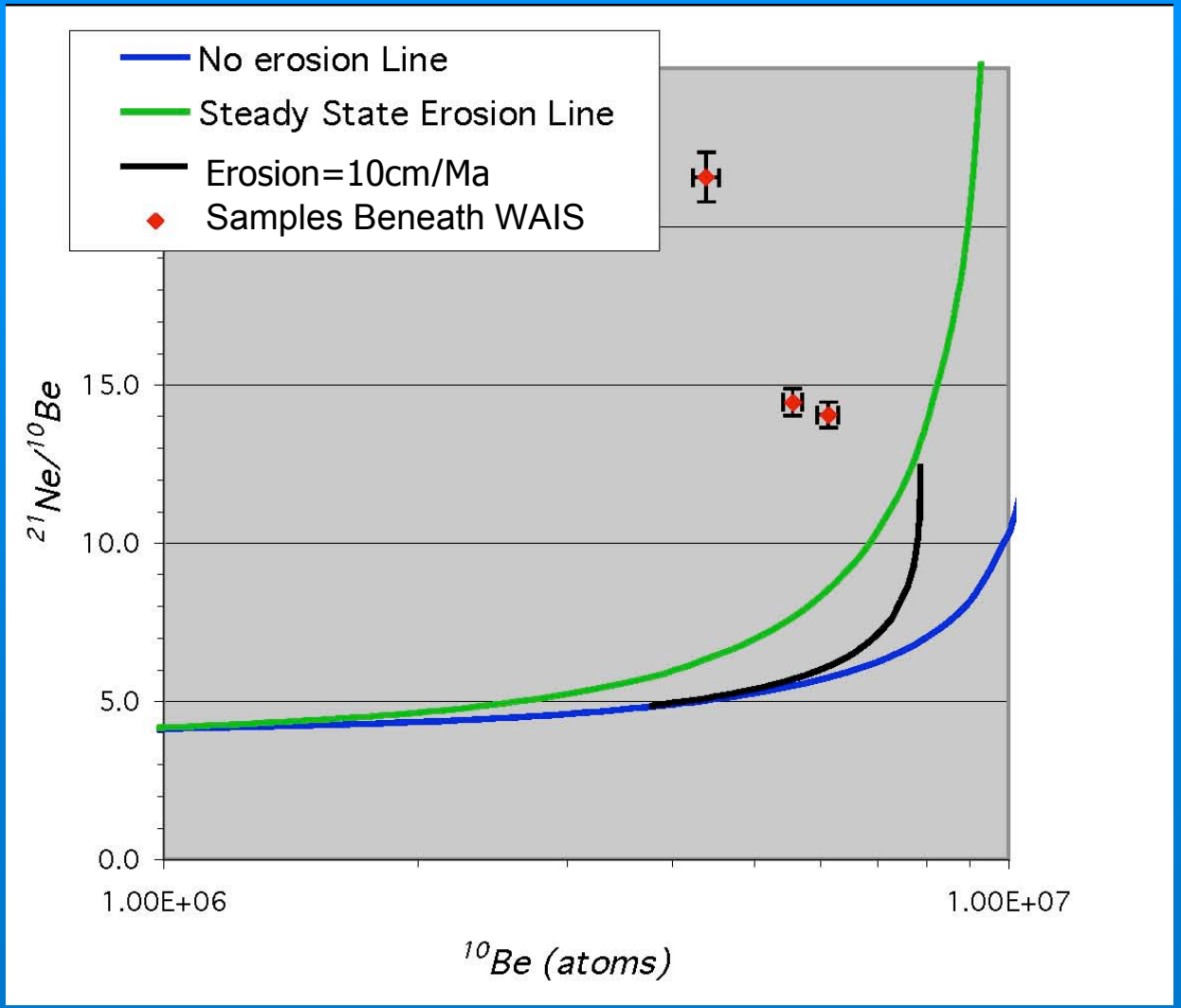
Potential cover



Cosmogenic nuclides beneath the WAIS

Assuming a simple burial history

Samples of weathered bedrock from progressively deeper depths beneath the WAIS will lie increasing farther outside the field of simple exposure.

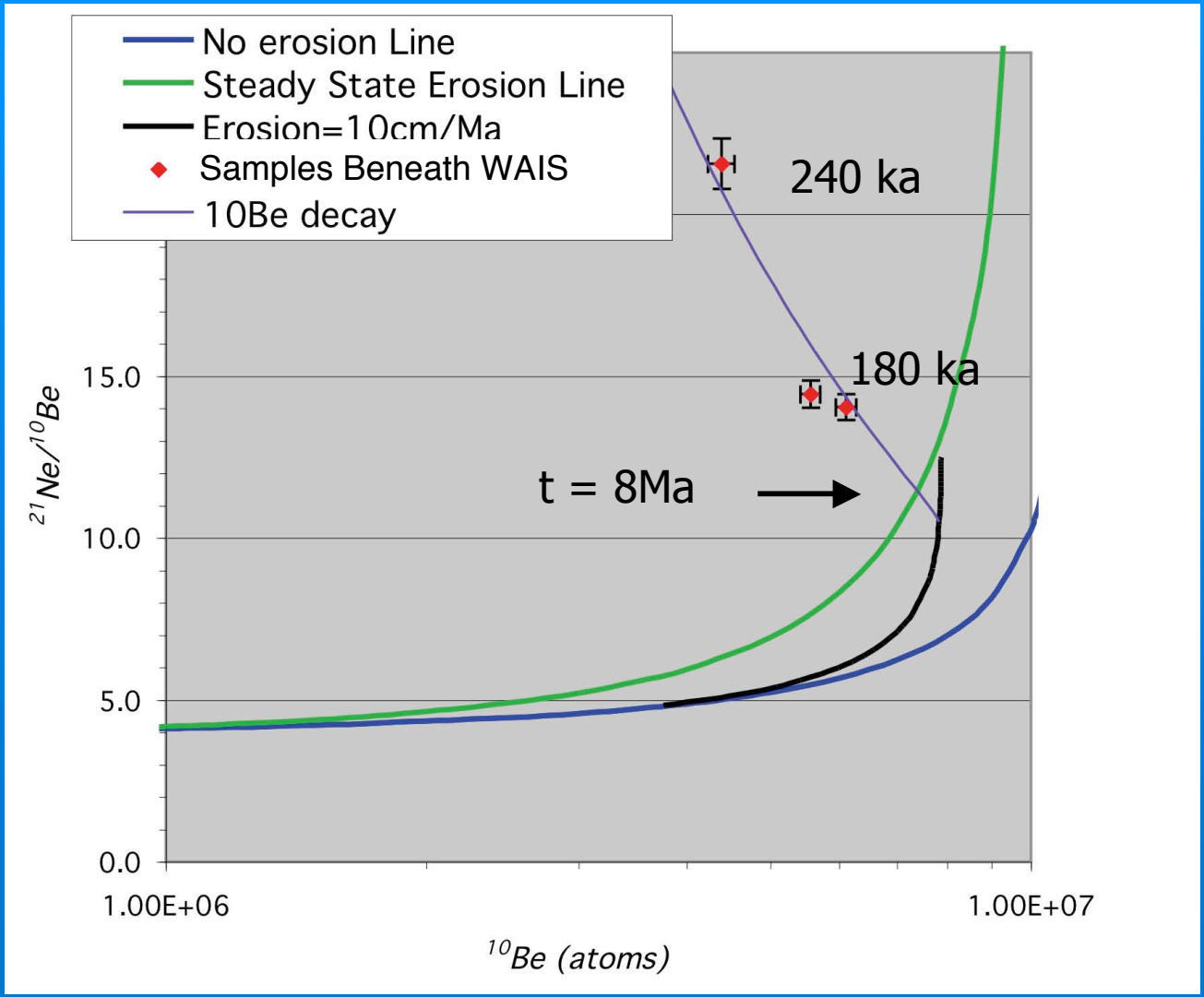


Cosmogenic nuclides beneath the WAIS

Assuming a simple burial history

When ice covers the bedrock ^{10}Be decays while ^{21}Ne remains constant.

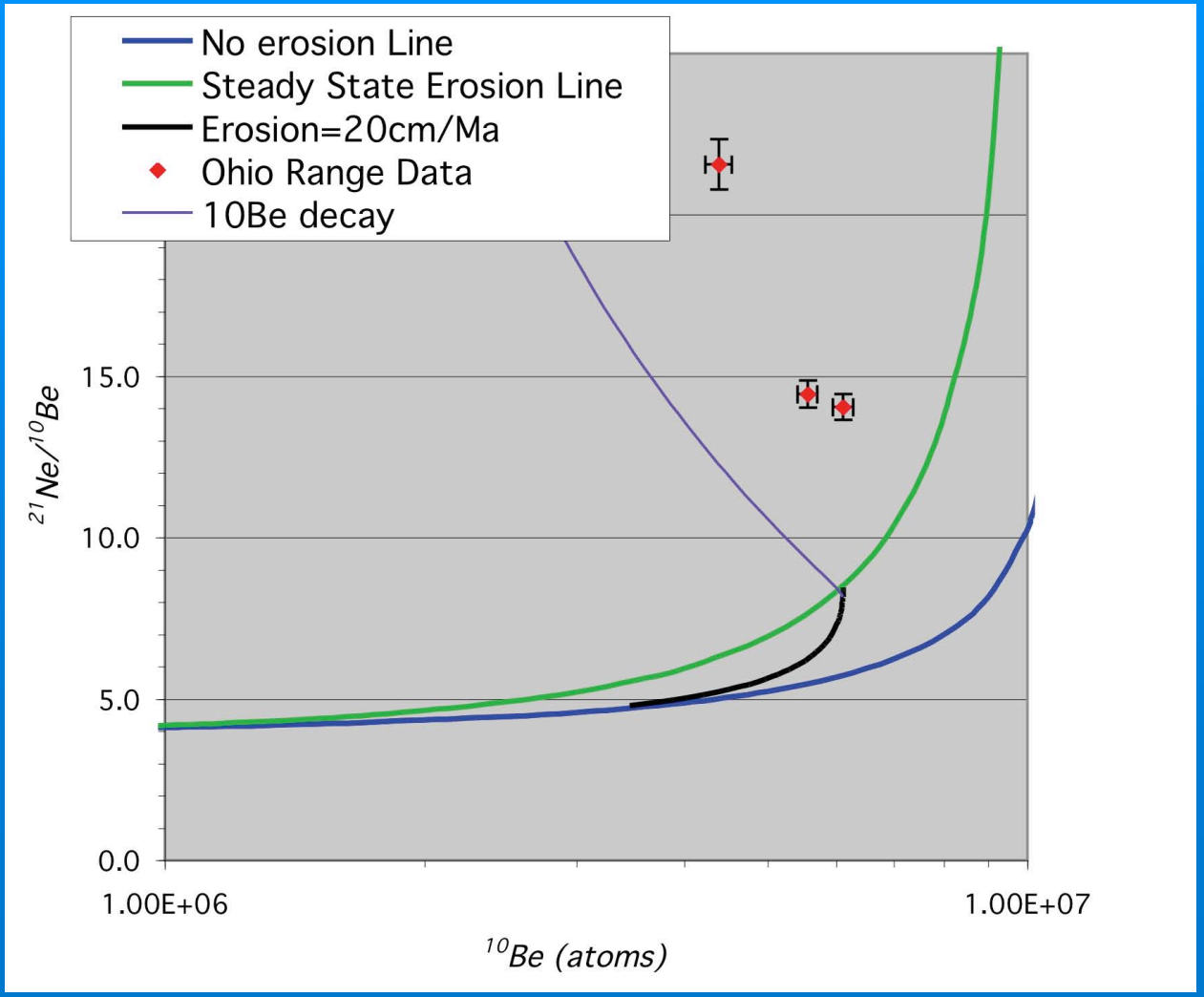
This solution is plausible but none unique.



Cosmogenic nuclides beneath the WAIS

Assuming a simple burial history

Burial trajectories provide constraints on initial exposure age/erosion rates



Conclusions

Bedrock surfaces beneath the WAIS preserve a record of exposure acquired during episodes of lesser ice extent.

A trimline corresponding to mean WAIS elevation during Pliocene may exist beneath the WAIS

Shoreline features developed during collapsed states of the WAIS may be preserved constraining collapse extent.

Cosmogenic nuclides can provide some age constraints, but are unlikely to definitively date collapse events

Cosmogenic nuclides beneath the WAIS

Cosmogenic nuclides beneath the WAIS