Comparison of meteoric and *in situ*-produced ^{10}Be depth profiles

Evaluating erosion rates, meteoric ^{10}Be flux, and the steady state assumption

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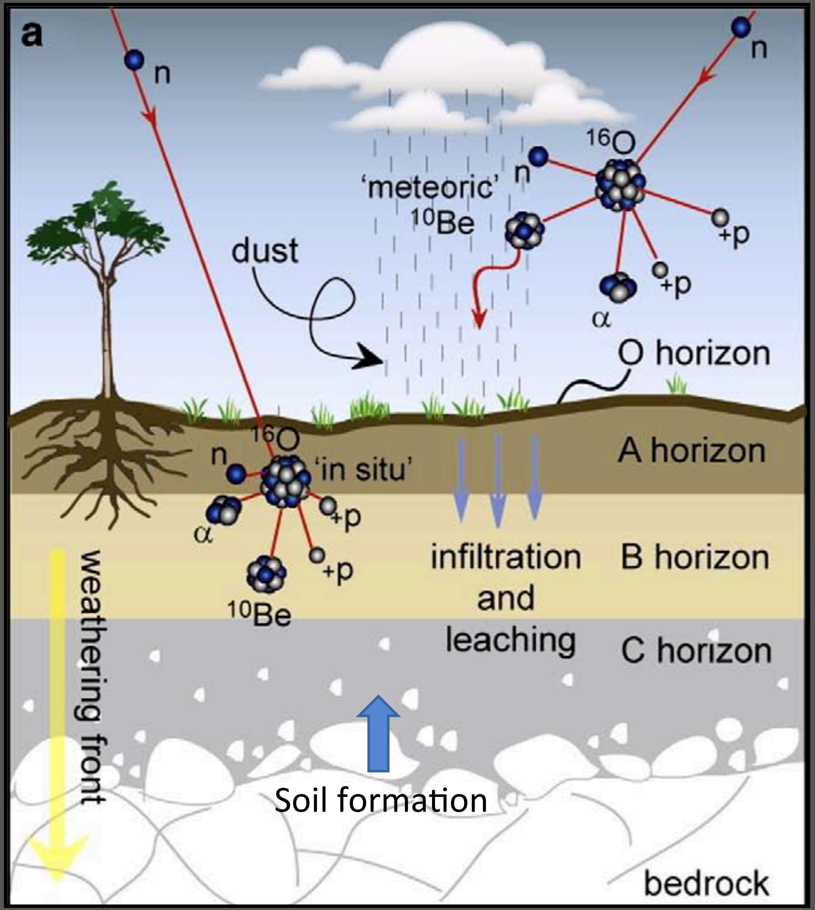
NSF

^{10}Be nuclide production and depth profiles



Willenbring & von Blanckenburg (2014)

Differences in production rate

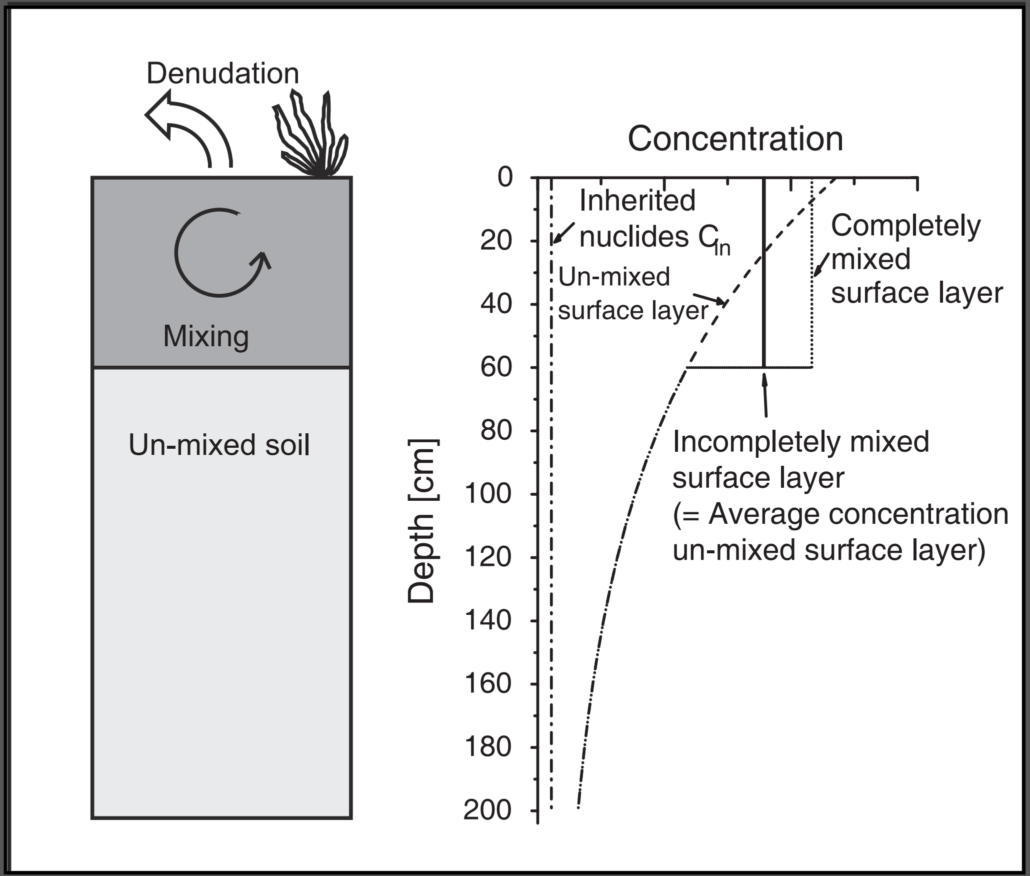
Delivery mechanism

Environmental conditions

Motivation

- Meteoric ^{10}Be easier to measure
- Applicable to a much wider range of environments than *in situ*
- Possibility of using archives to determine rates from the past

^{10}Be nuclide production and depth profiles



Schaller et al. (2009a)

Constrain:

- depositional age
- rates of denudation/erosion
- evaluate steady-state conditions
- $^{10}Be_{met}$ flux

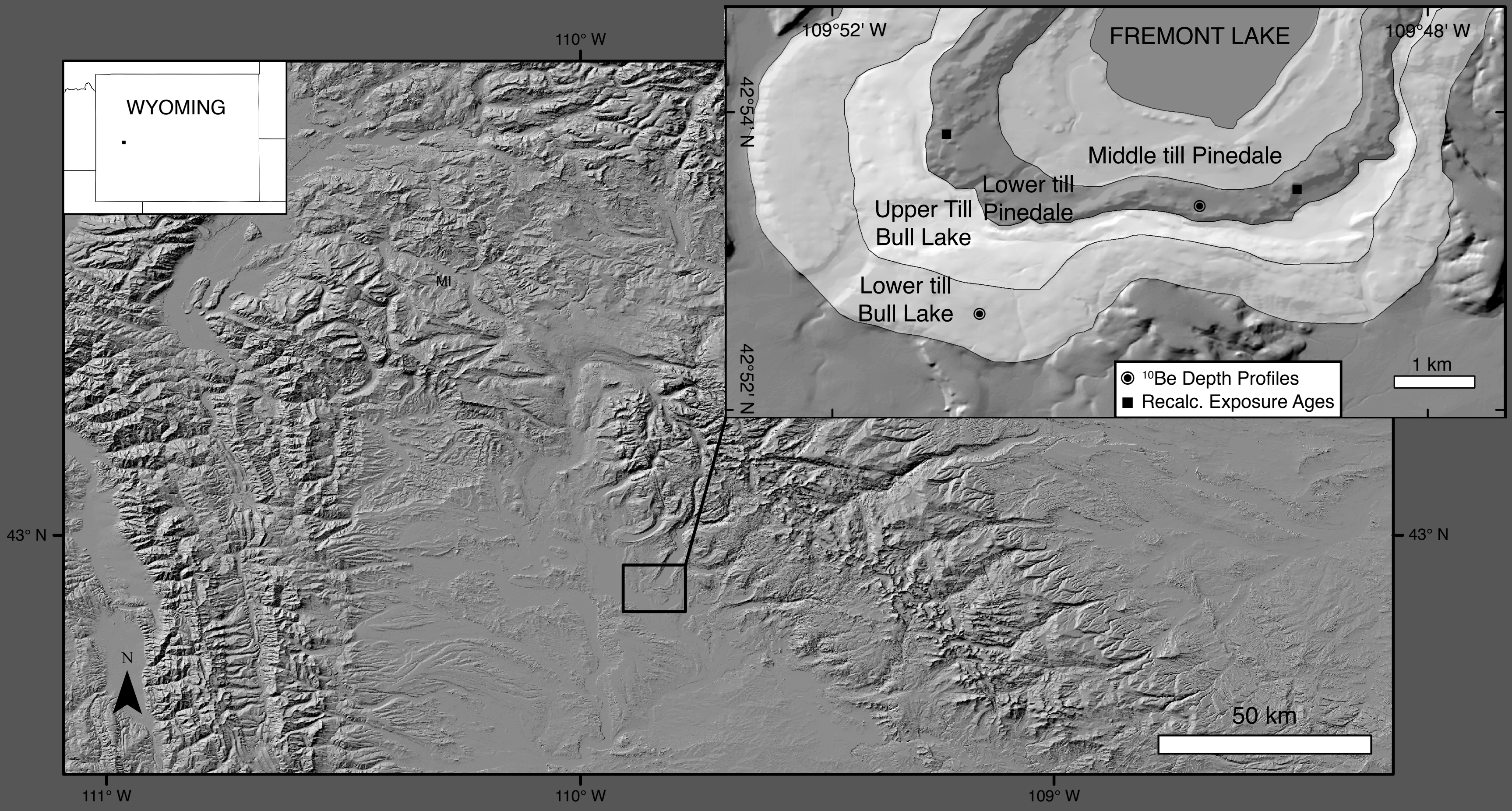
Top down (meteoric)

vs.

Bottom up (*in situ*)

Do they capture the same signal?

An ideal situation for comparison



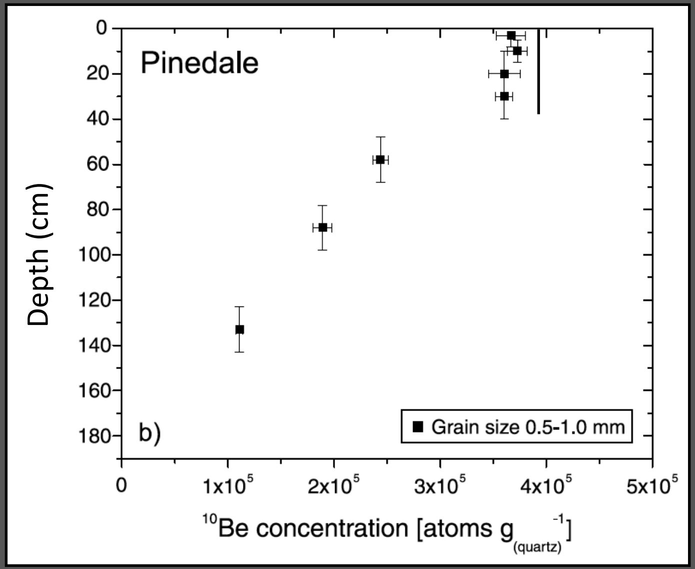
Pinedale & Bull Lake Terminal Moraines

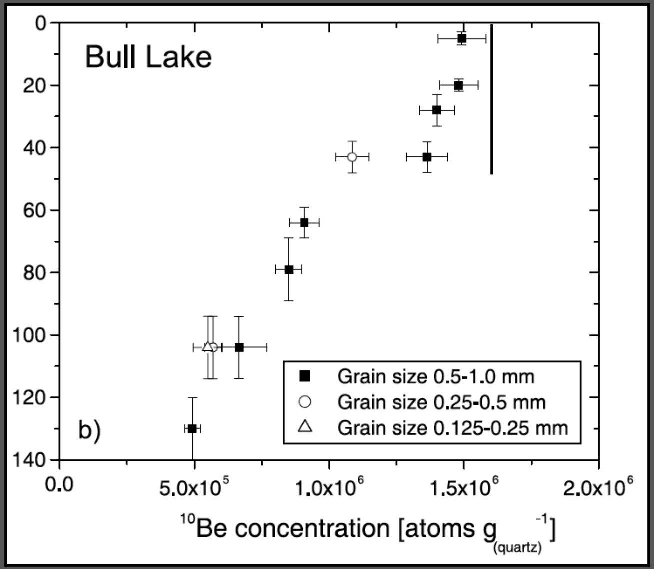
Well characterized:
- *Grain sizes*
- *Weathering indices*
- *Soil properties*

Independently constrained:
- *Landform ages*
- *Denudation rates*

Clow et al. (almost submitted)

In situ ^{10}Be depth profiles, rates





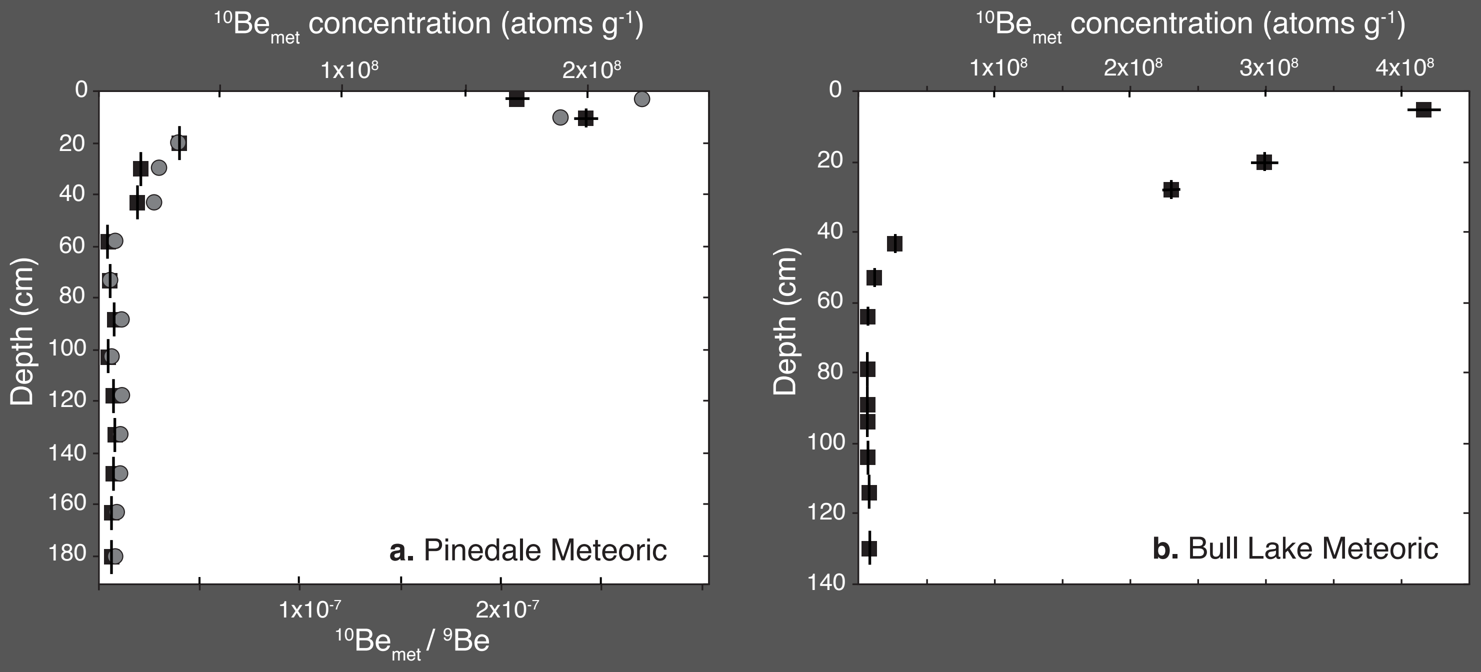
- Mixing depth -- Bull Lake incomplete?
- Ages comparable
- Constant or transient denudation
- Remove weathering component (Schaller et al. 2009b)

Recalculated average effective erosion rates (mm ky^{-1})

	Pinedale	*Bull Lake*
Constant	12.6	6
Transient	26.9	10
Average	**19.7**	**8**

Schaller et al. (2009a)

Meteoric ^{10}Be depth profiles



- Rapid exponential decay
- No correlation with clay content
- Inherited concentrations
  - Incomplete glacial resetting likely
- Lack of soil mixing signal
  - Differing diffusion coefficients?
  - Swamping due to advection?

Clow et al. (almost submitted)

Erosion rate calculations

We calculate the local erosion rate via two methods

Inventory *Density*

$$E = Q-(I\lambda)/ N_{surf}\rho$$

’Inventory Method’ (Brown, 1987)

Flux *Surficial Concentration*

$$E = Q / N_{surf}\rho$$

‘Nsurf Method’ (Willenbring & von Blanckenburg, 2010)

However, an accurate estimation of $^{10}Be_{met}$ flux is crucial for obtaining accurate erosion rates

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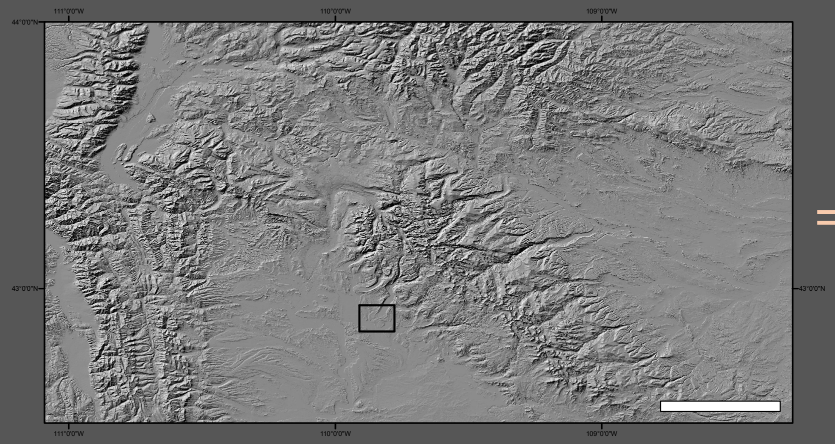
Heikkila & von Blanckenburg (2015)



= **1.5** x 10^6 at/cm^2/yr

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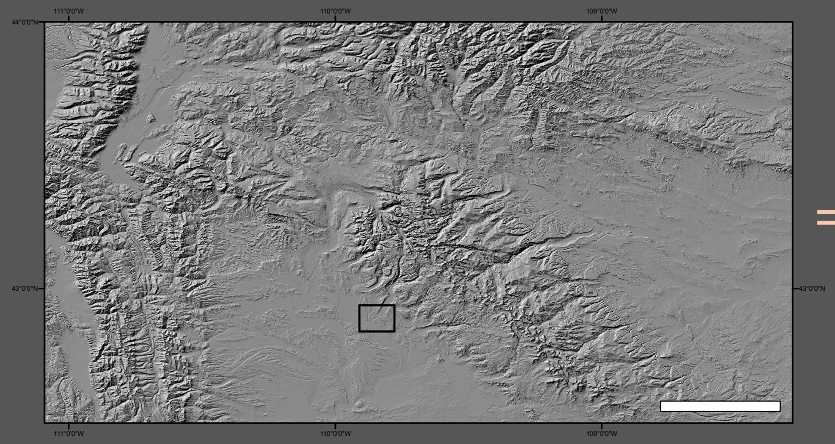
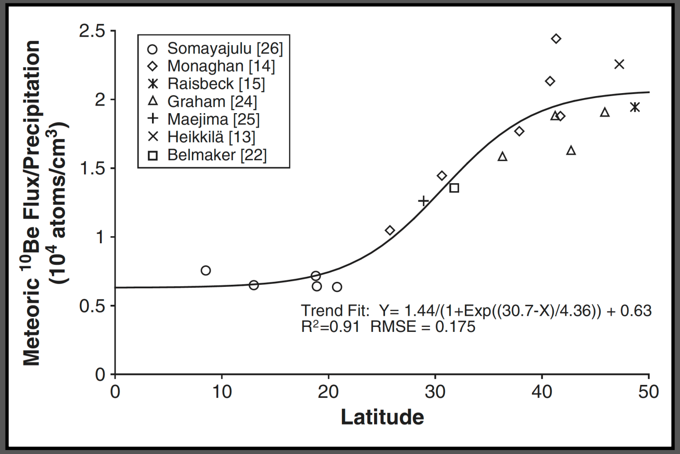


= **1.5** x 10^6 at/cm^2/yr

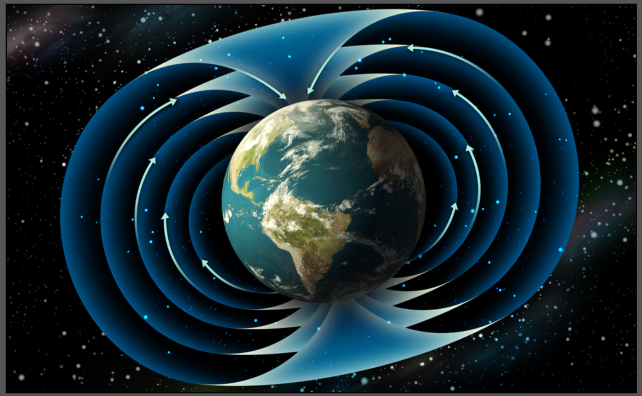
Graly et al. (2011)



= **0.55** x 10^6 at/cm^2/yr

Factors influencing Graly flux estimate

Uncorrected → Precipitation Correction → Precipitation + Paleointensity Correction



DrPawluk.com

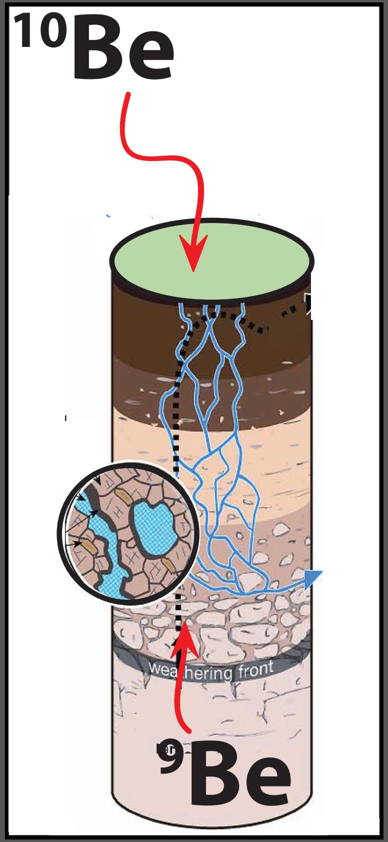
Modeled precipitation rates ~200% higher during LGM
(Birkel et al., 2012)

Relative paleointensity over last 140 ky was 20-40% of present, on average
(Pigati and Lifton, 2004)

Flux rates **27%** and **38%** higher for Pinedale and Bull Lake, respectively

Be mobility effects?

Profiles have surficial pH of ~5.5; must consider retention of Be on calculated erosion rates using von Blanckenburg et al. (2012) equation:



$$\textbf{Erosion rate}_{(\textbf{desorption})} = \textbf{Erosion rate} - \textbf{Q/Kd}$$

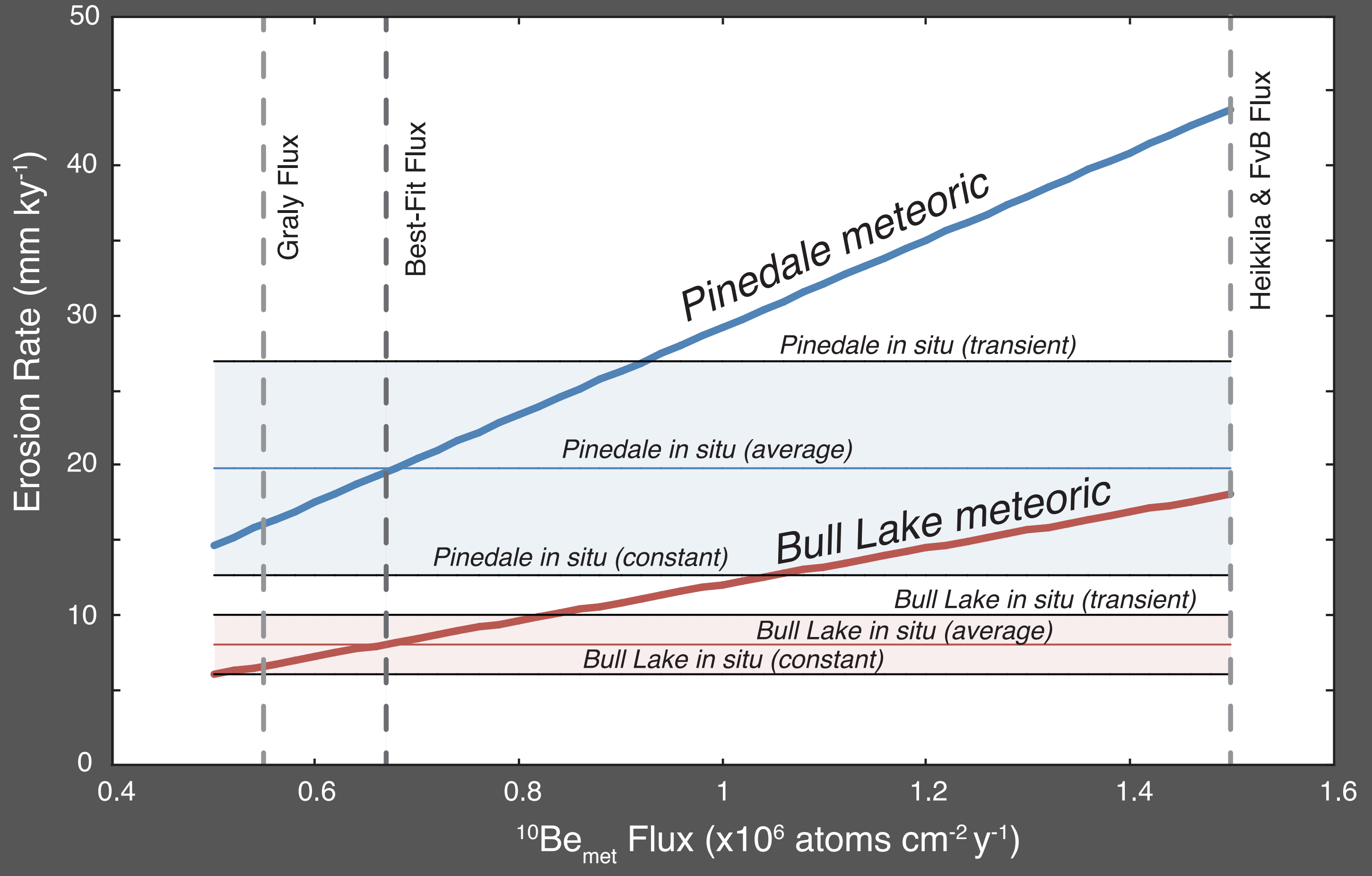
Q = 0.283 m/yr (modern precip. rate)

Kd = ~ 1-100 L/g (Boschi & Willenbring, 2016)

This leads to an erosion rate correction of **-0.7 to -1.8%**

Even if we double our estimate for Q, it is still < -3.5%

Flux and erosion rate comparison



From predicted flux of Graly et al. (2010)

Pinedale : 16 mm ky^{-1}

Bull Lake : 6.5 mm ky^{-1}

20% Off

From Heikkila & von Blanckenburg (2015)

Pinedale : 43.8 mm ky^{-1}

Bull Lake : 18 mm ky^{-1}

220% Off

From best-fit flux of 0.67 x 10^6 at/cm^2/yr

Pinedale : **19.6 mm ky^{-1}**

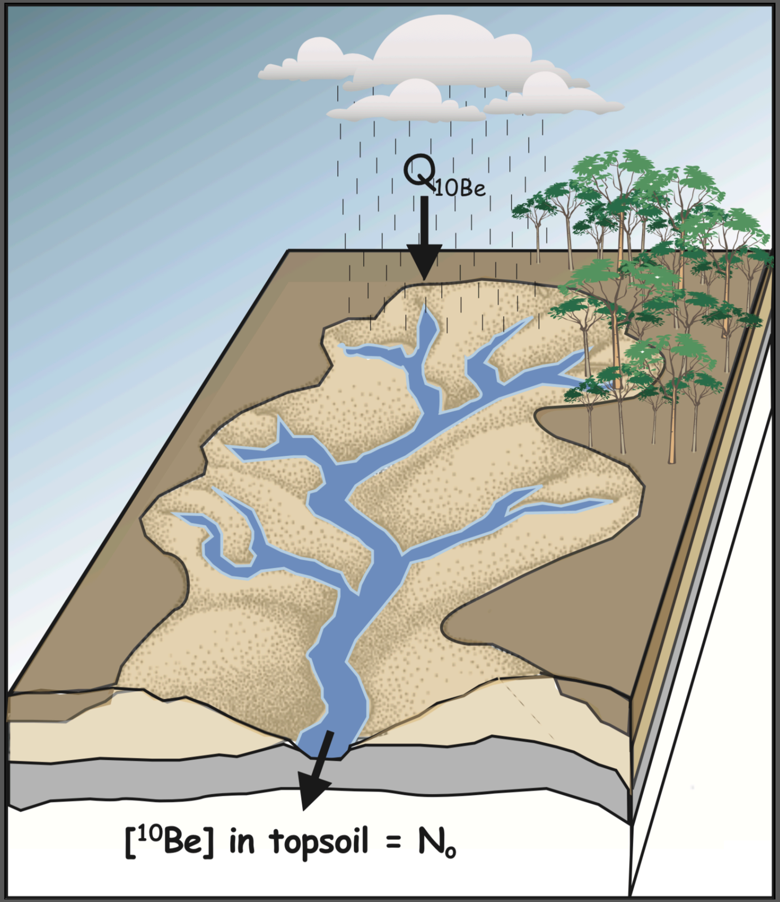
Bull Lake : **8 mm ky^{-1}**

Within 1%

Rates between N_{surf} and Inventory method are virtually identical

Clow et al. (almost submitted)

The steady state assumption



Erosion rates from each method identical

Why would the rates match?

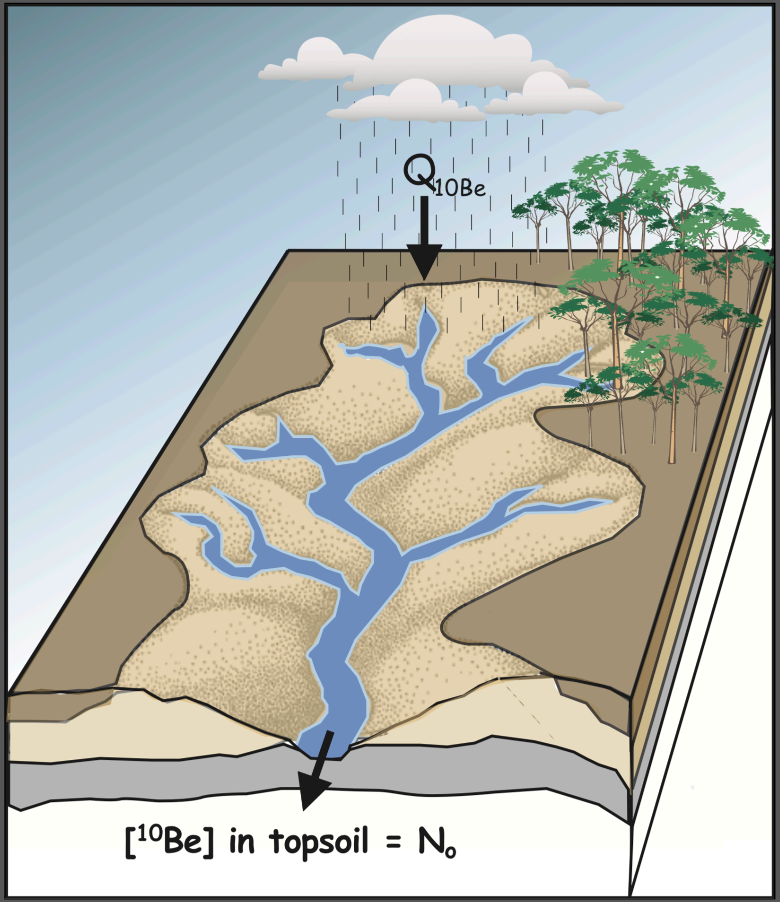
A

Steady state has been achieved and *Kd* does not have an appreciable effect

or

$^{10}Be_{met}$ adsorption is affecting both the surface and the depth profile the same

The steady state assumption



Erosion rates from each method identical

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Conclusions

- Best-fit meteoric ^{10}Be flux of **0.67 x 10^{6} at cm^{-2} yr^{-1}**
  - Falls within estimates of 0.5 and 1.5 x 10^{6} from other methods
- Meteoric ^{10}Be erosion rates of **19.6 mm ky^{-1}** and **8 mm ky^{-1}** for the Pinedale and Bull Lake moraines, respectively
  - Agree remarkably well (±1%) with in situ-produced ^{10}Be erosion rates
  - Independent flux estimates lead to considerable range (-20% to +220%)
- No mixing signal observed in meteoric profiles
- Minimal (1-2%) loss of Be due to dissolution
- Steady state appears to have been achieved with this system

Questions?

Acknowledgements

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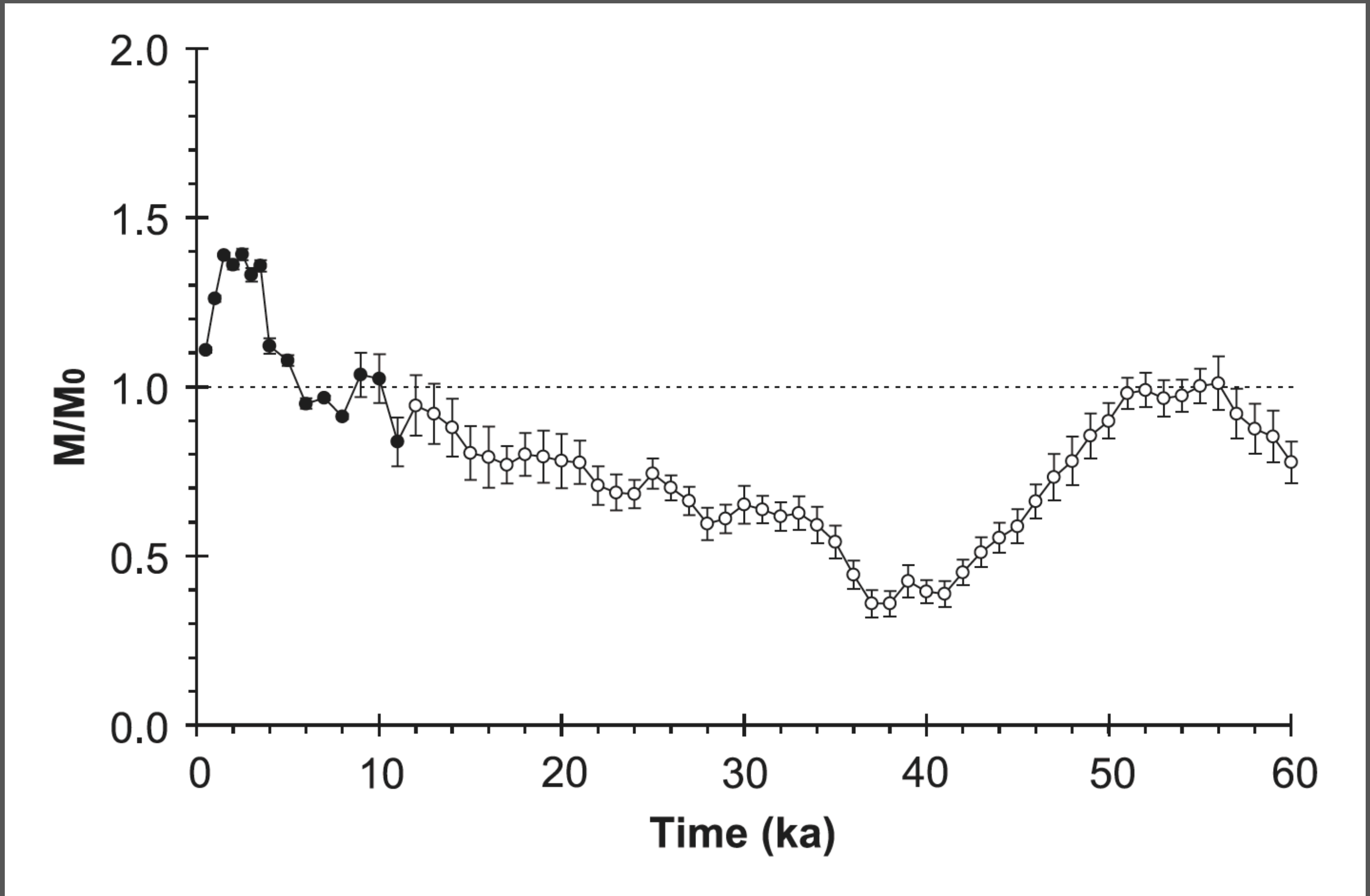
Additional Slides



Pigati and Lifton (2004)

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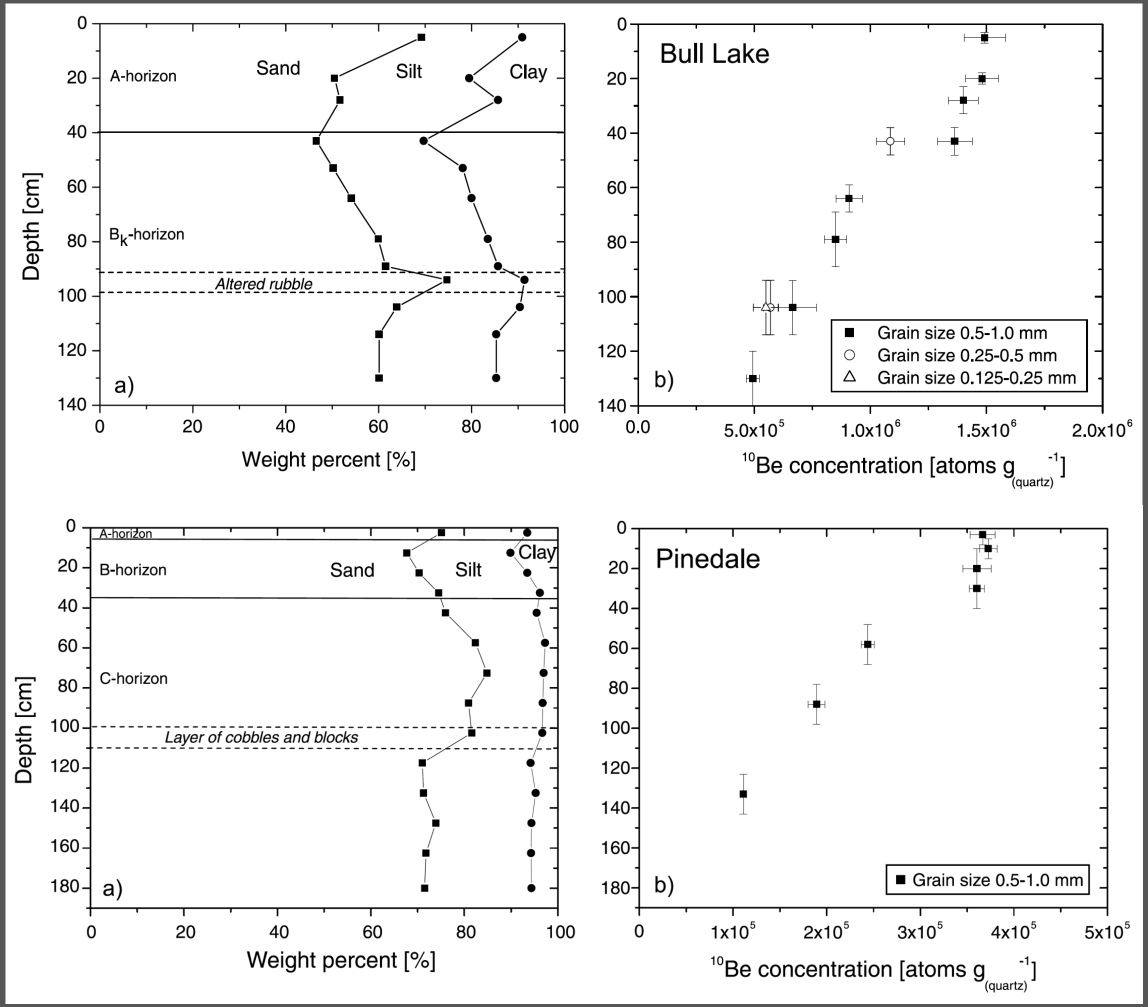

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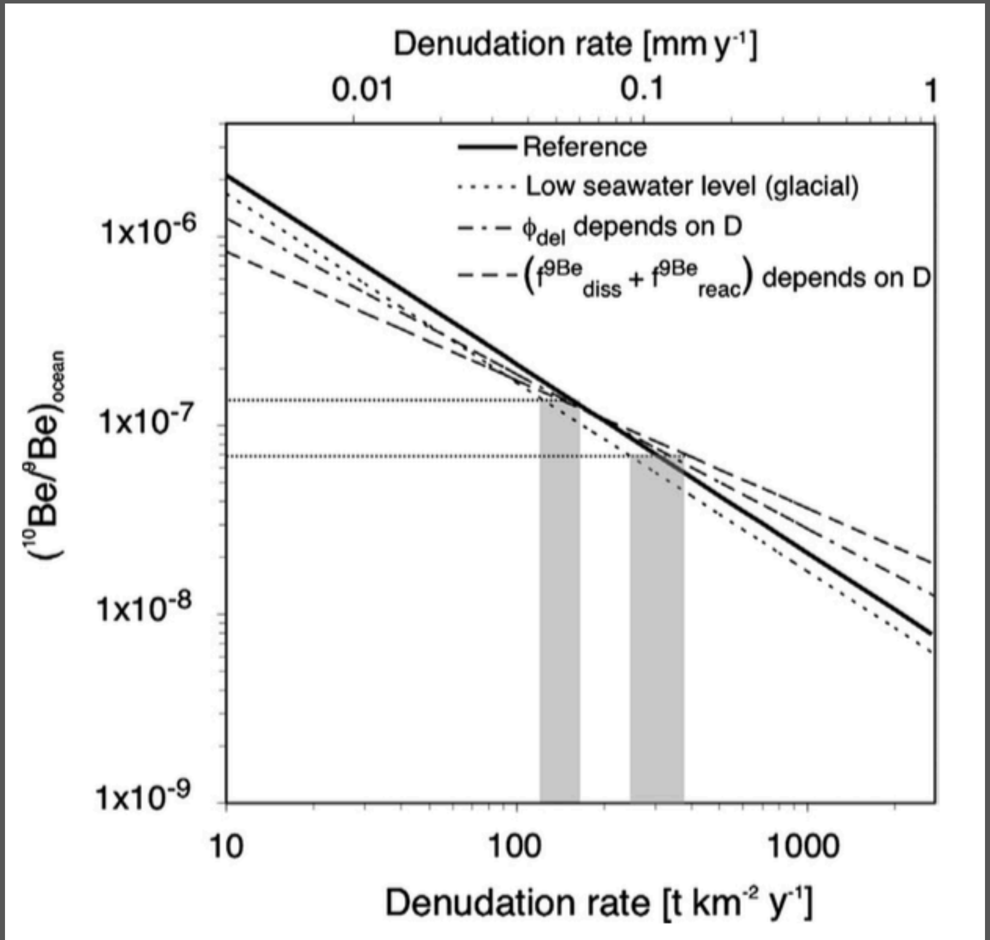

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