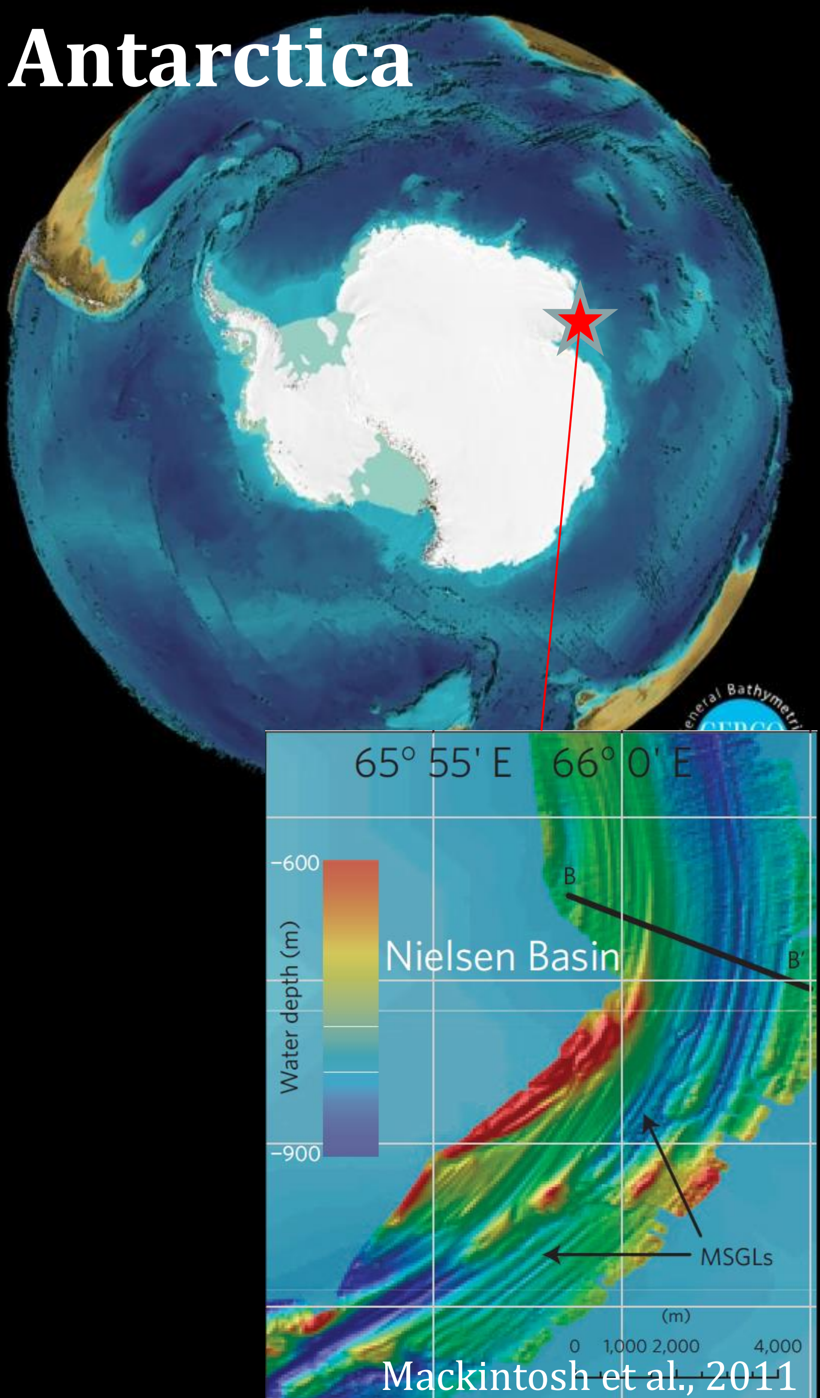
Photo: Jack Ives

Eskers – modern glaciers

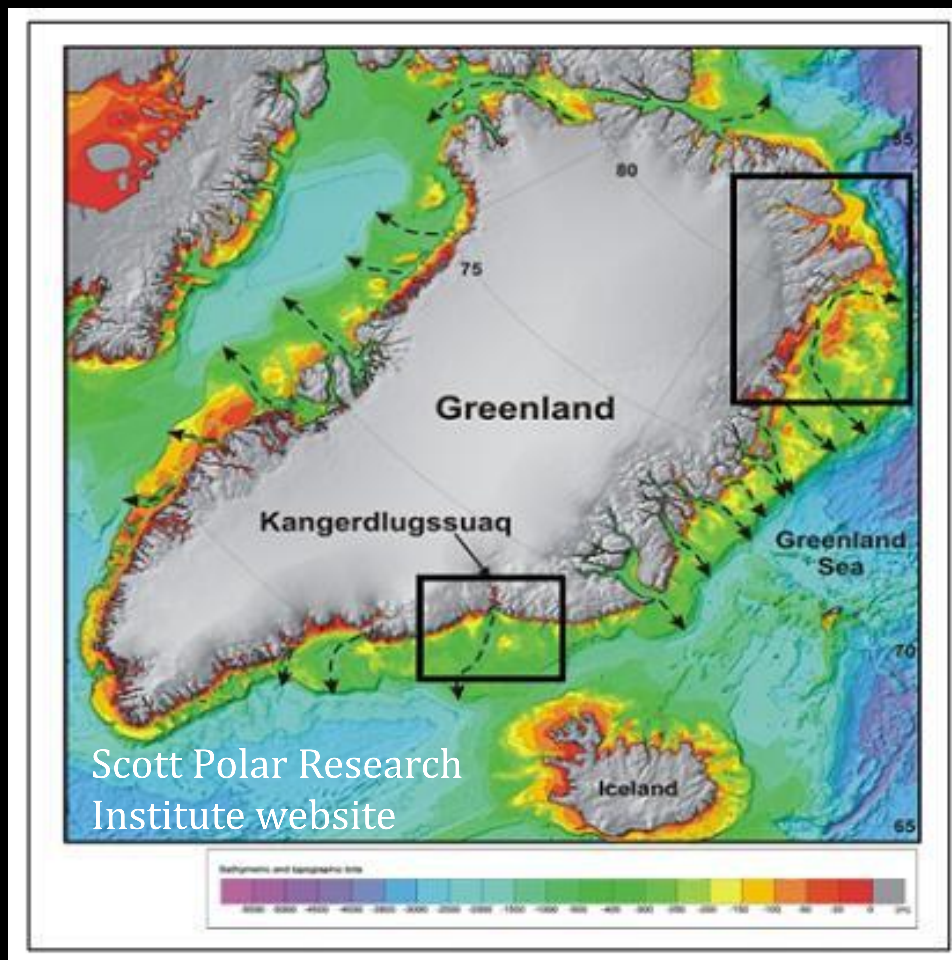
-Rare!
-Small!

Antarctica

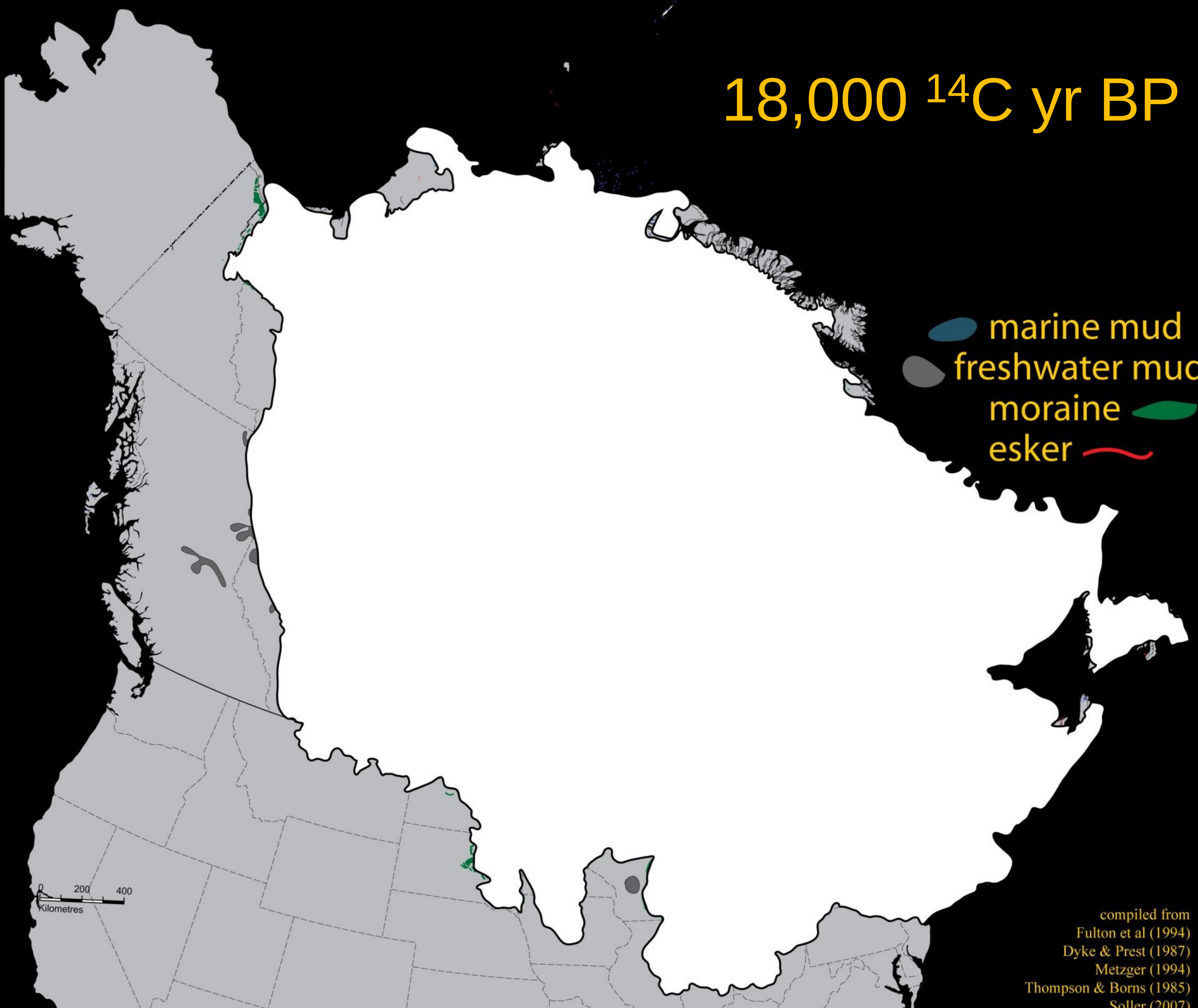


No eskers

Greenland

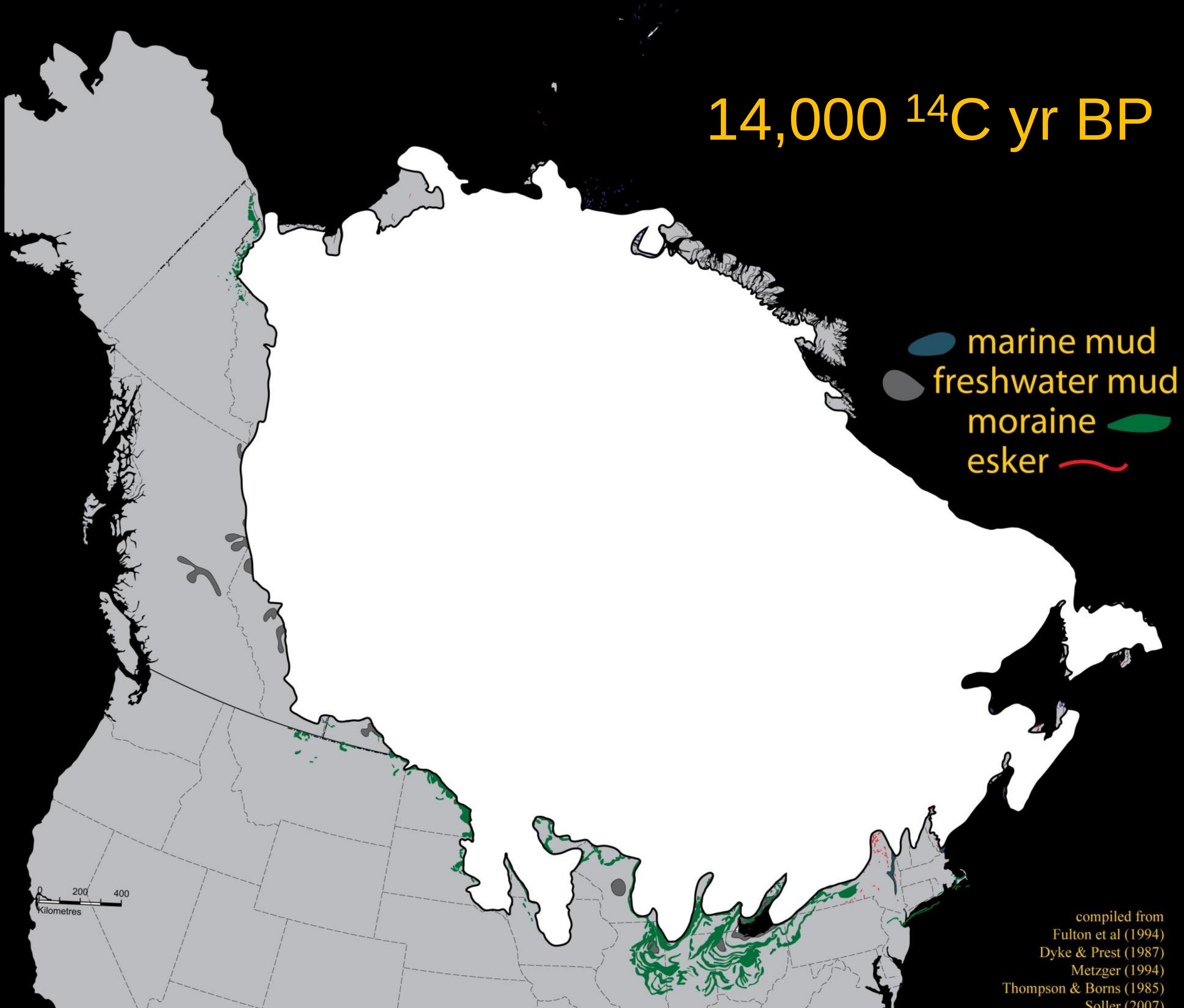


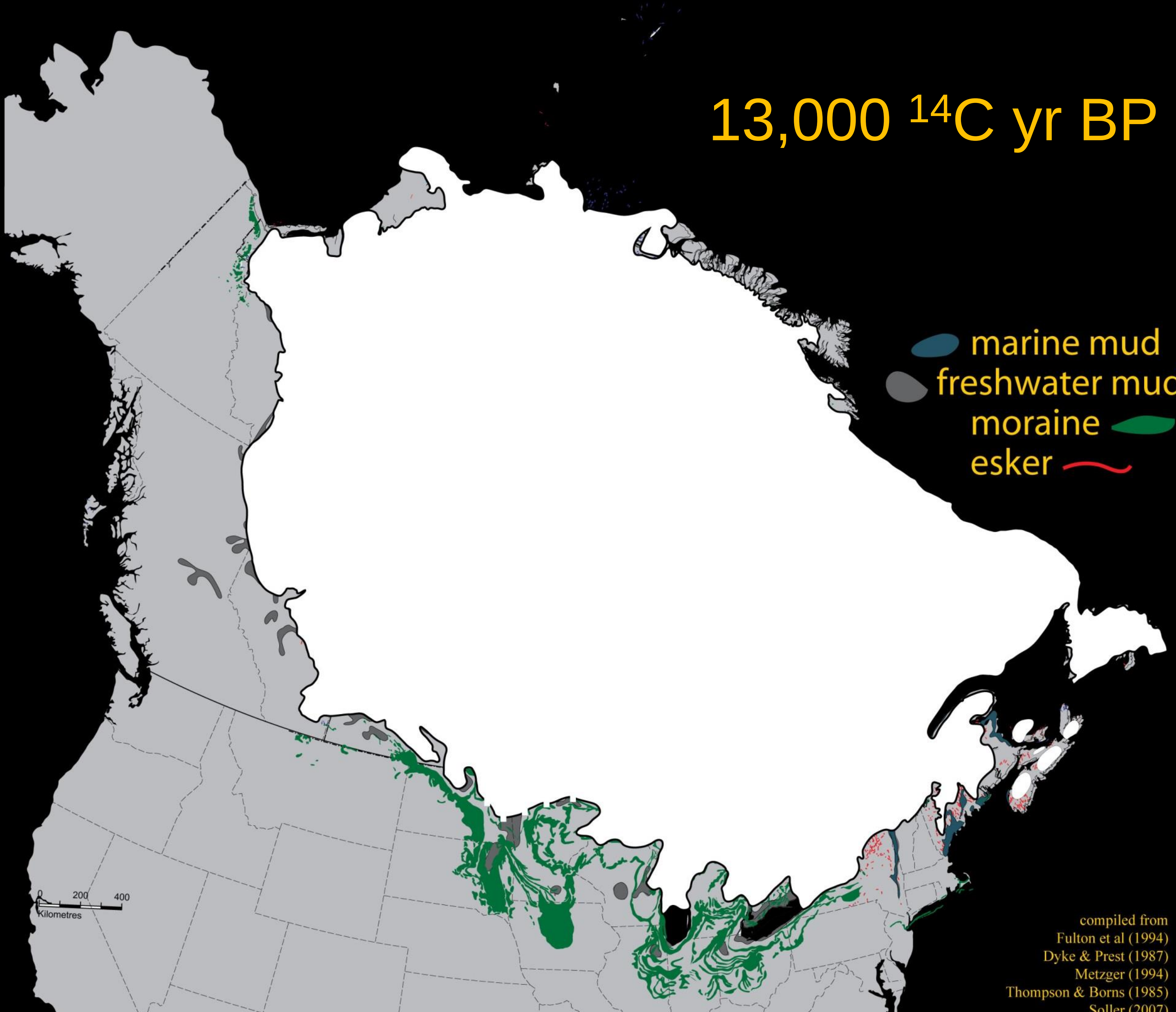
18,000 ^{14}C yr BP

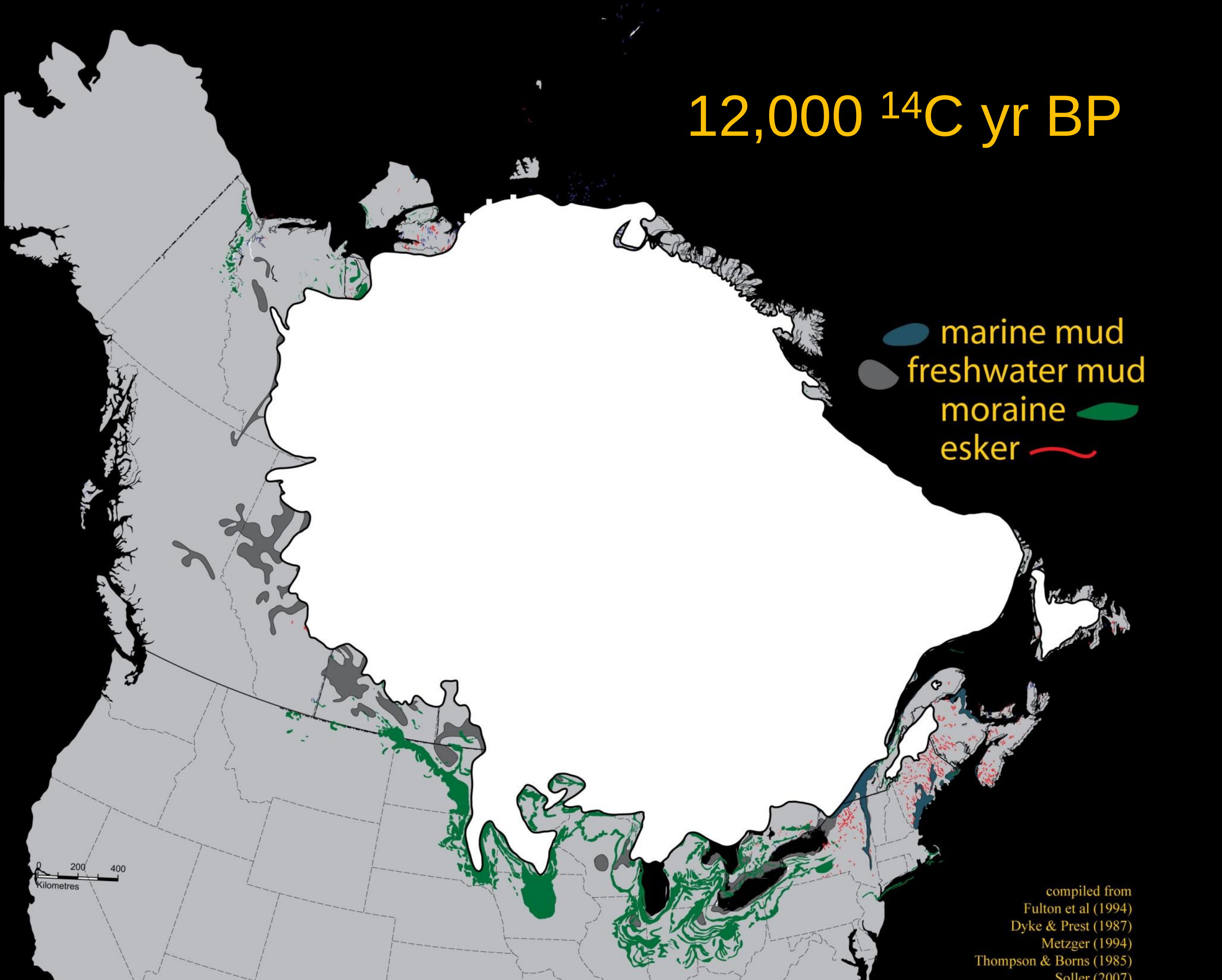


compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)

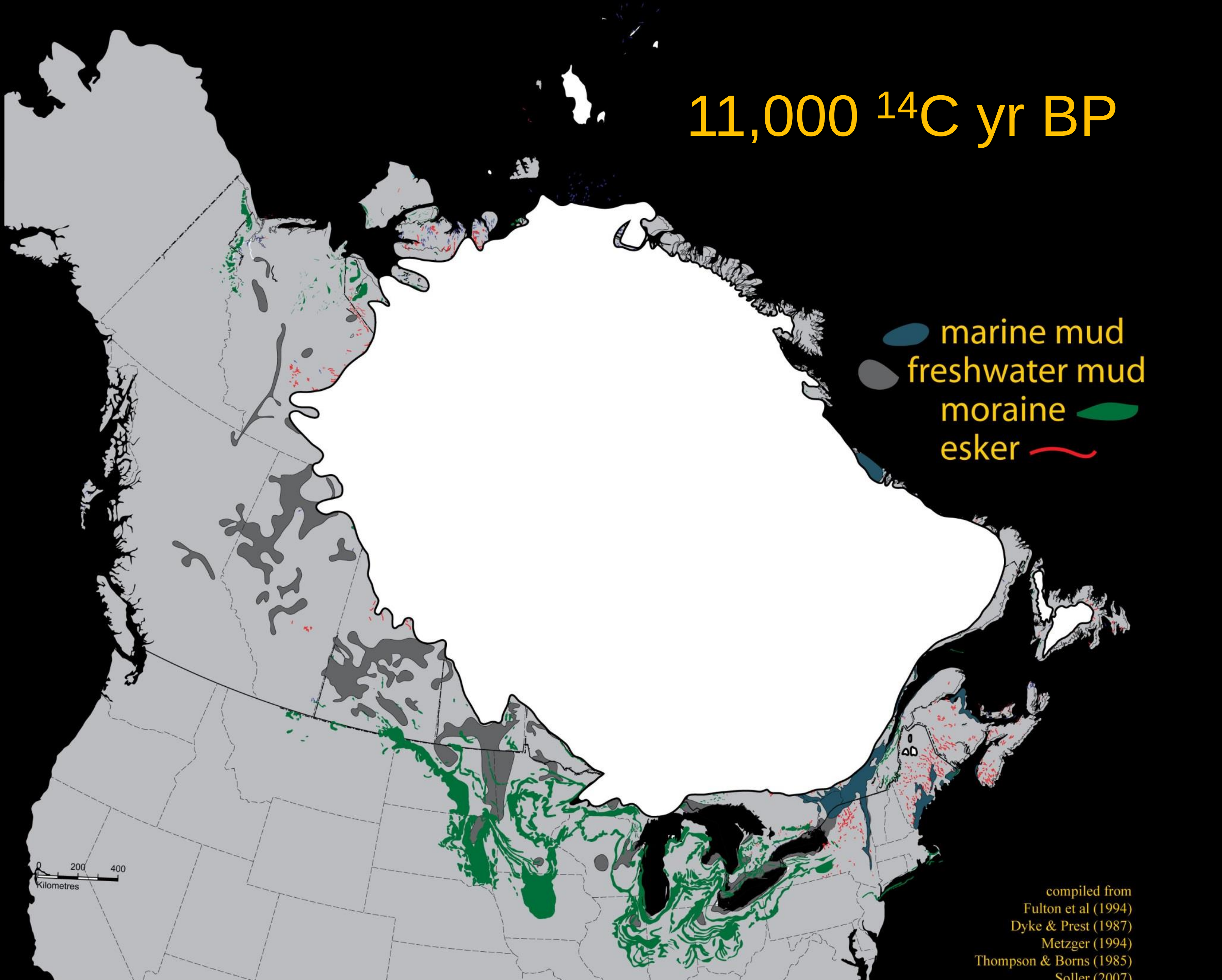
14,000 ^{14}C yr BP

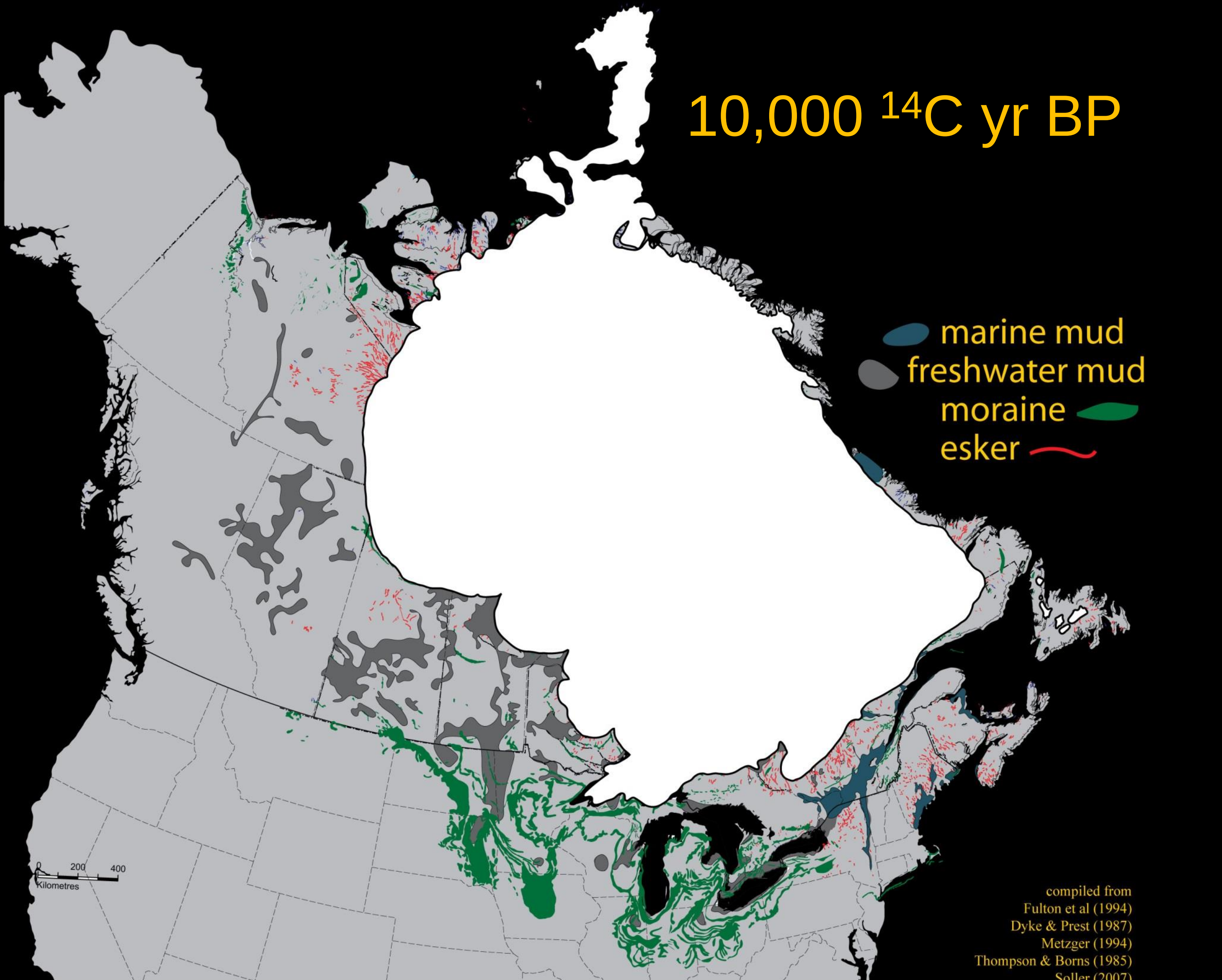


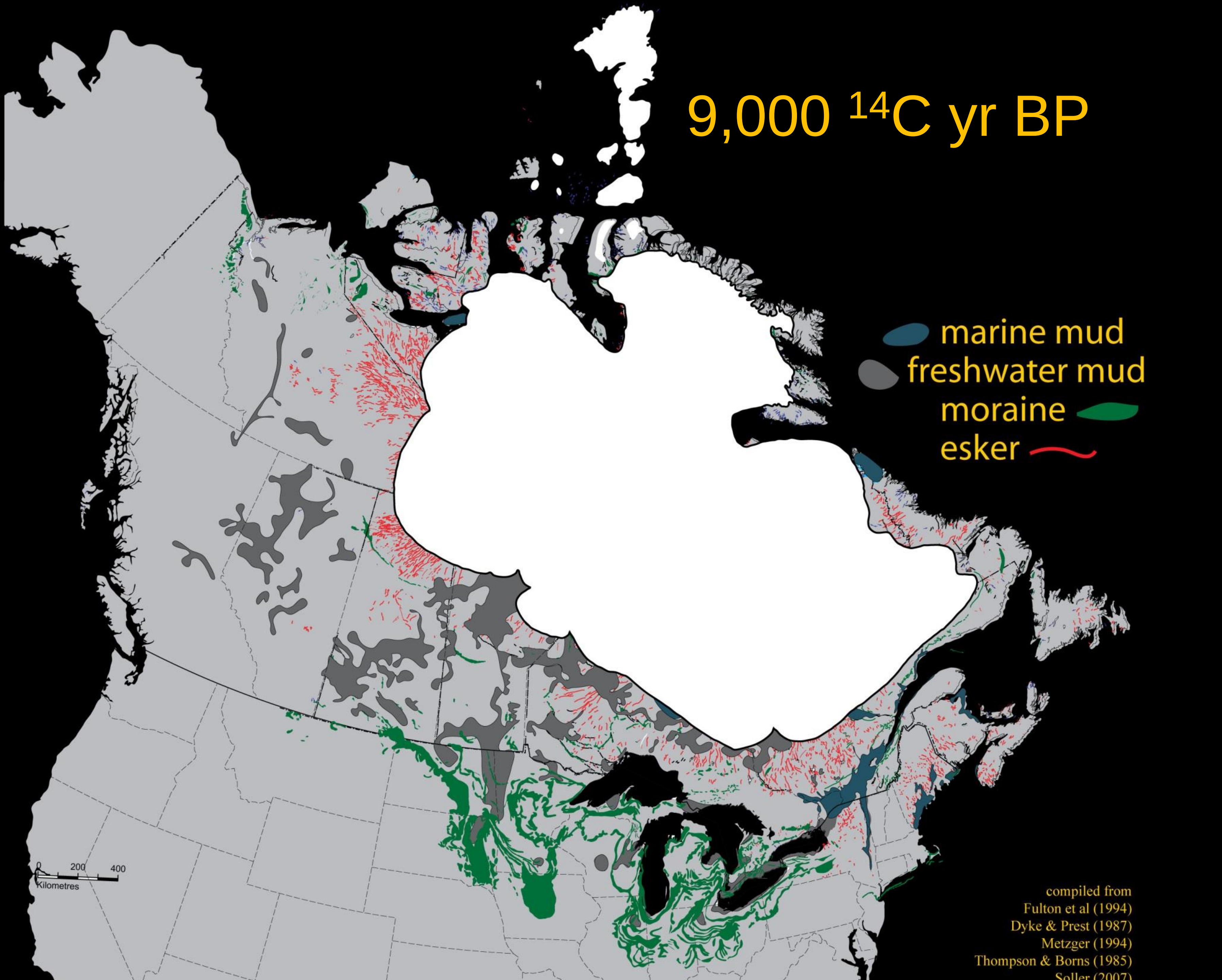

13,000 ^{14}C yr BP
marine mud
freshwater mud
moraine
esker
0 200 400
Kilometres
compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)


12,000 14C yr BP
marine mud
freshwater mud
moraine
esker
0 200 400
Kilometres
compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)

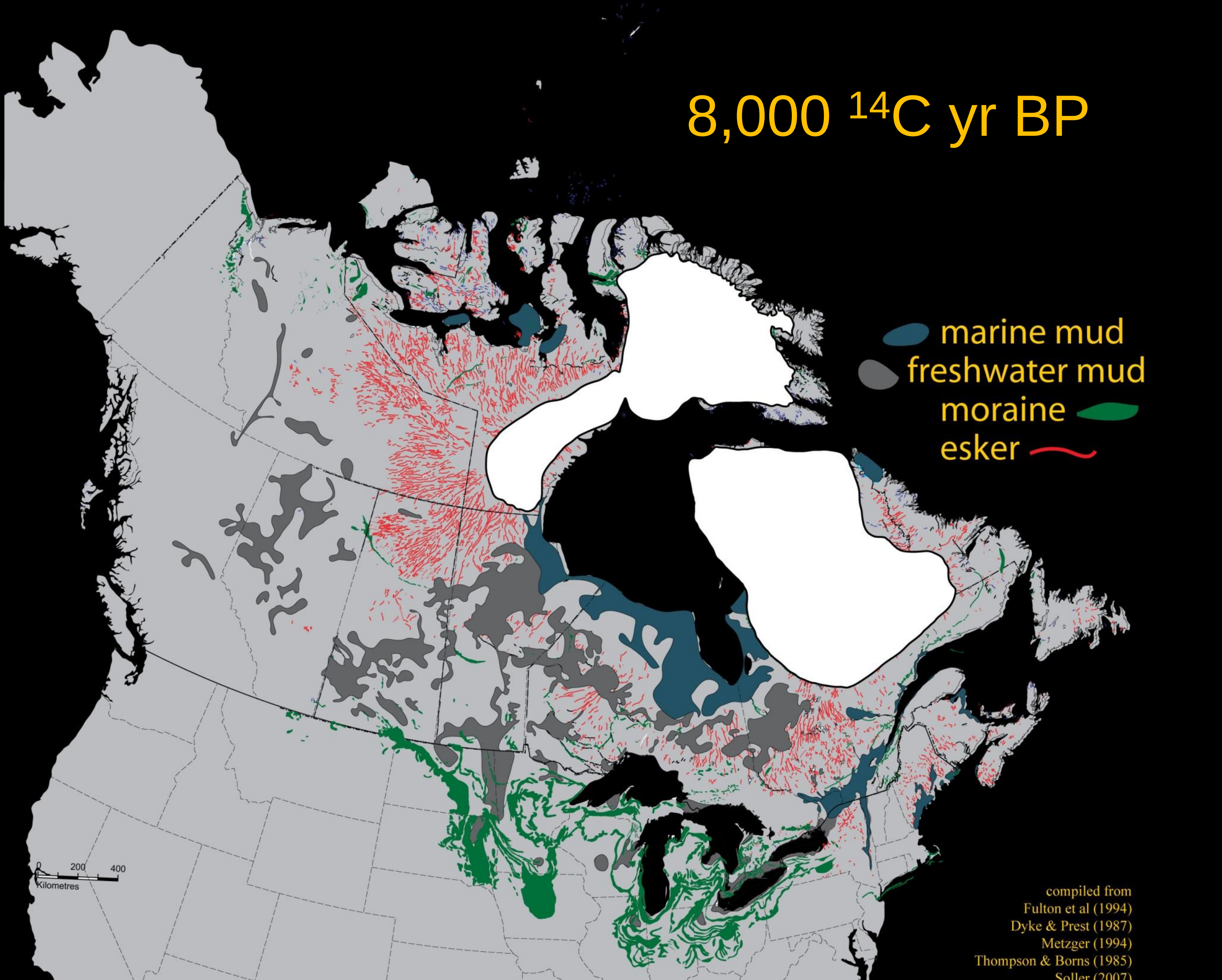
11,000 ^{14}C yr BP

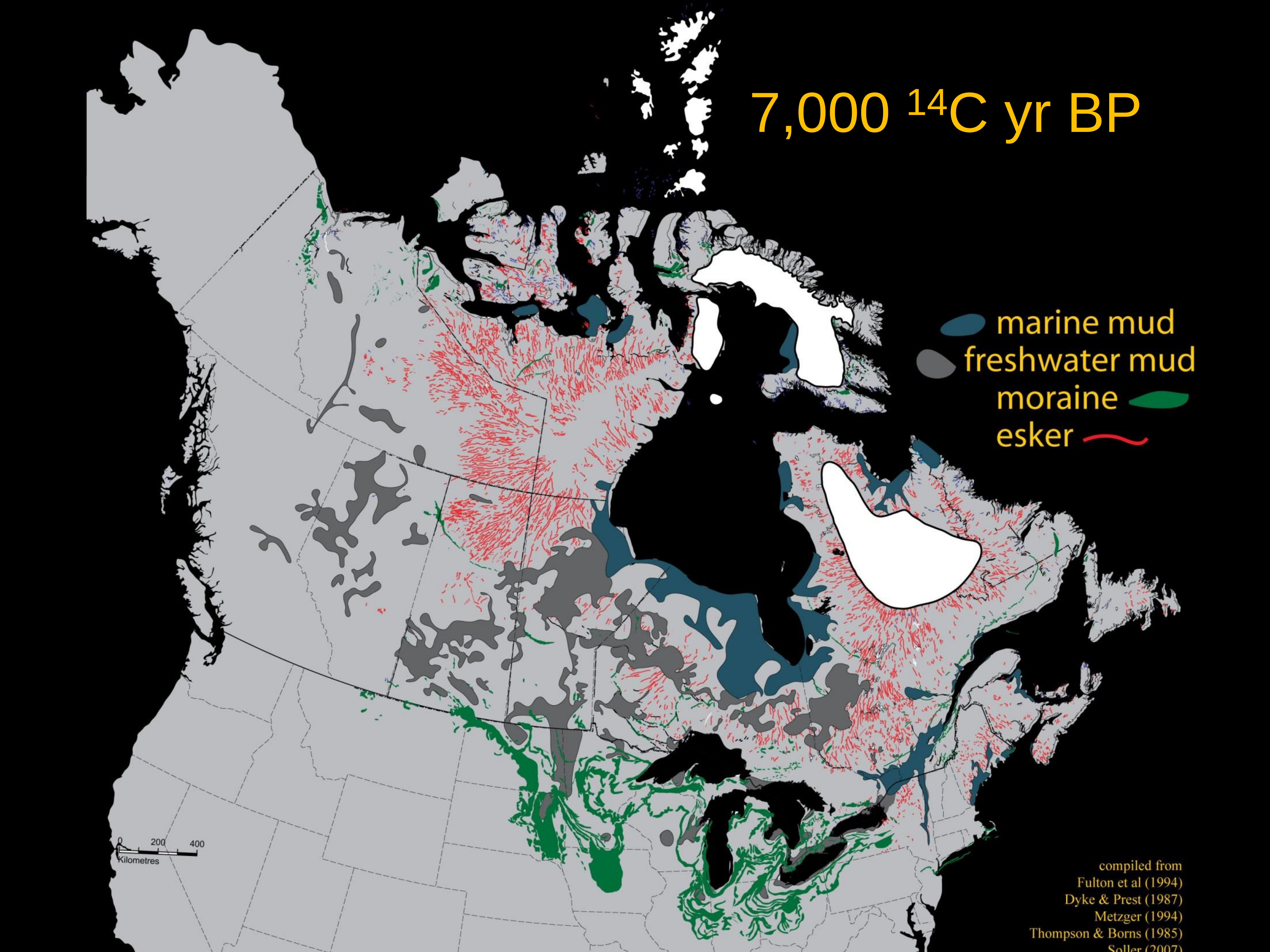


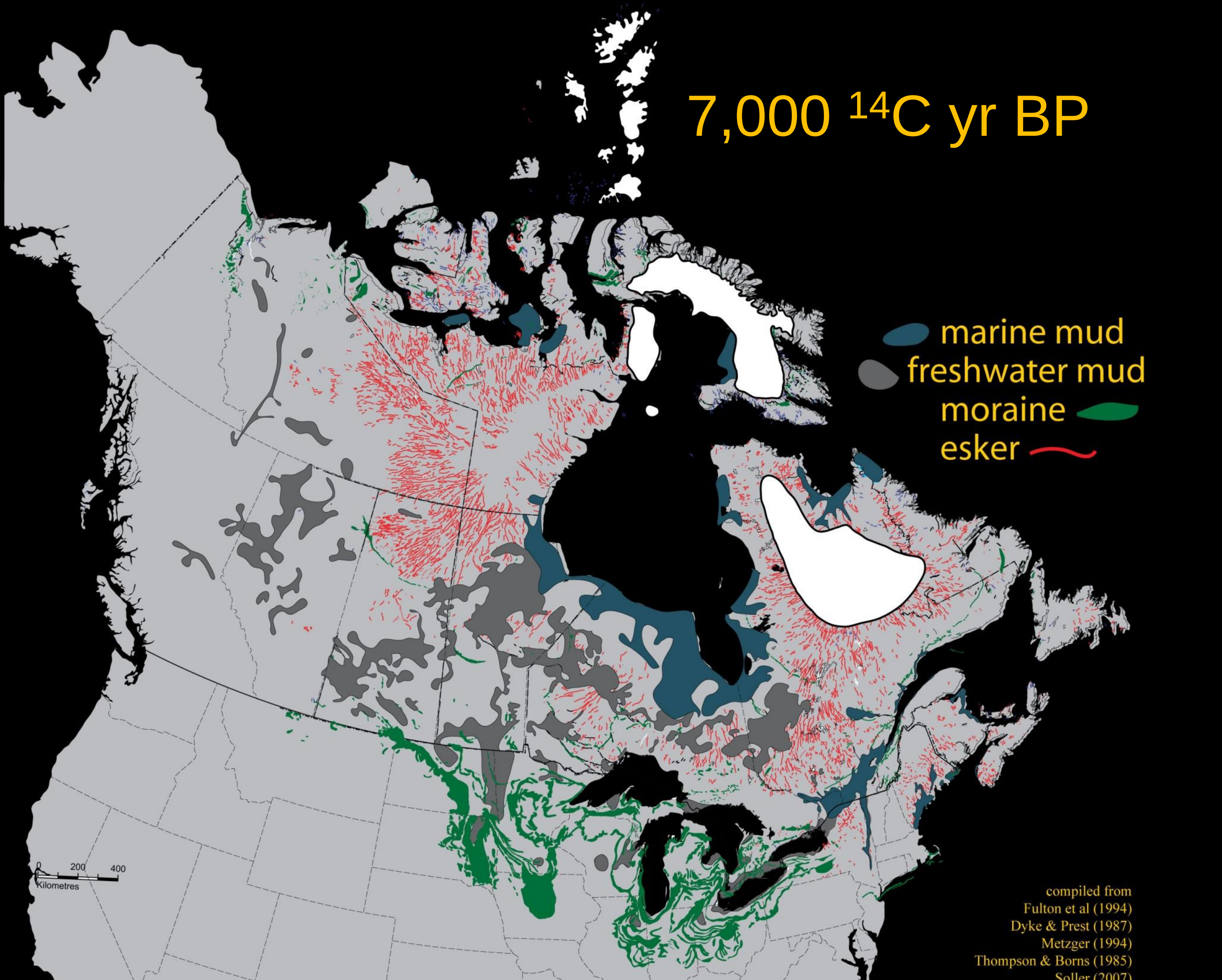

10,000 14C yr BP
marine mud
freshwater mud
moraine
esker
0 200 400
Kilometres
compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)

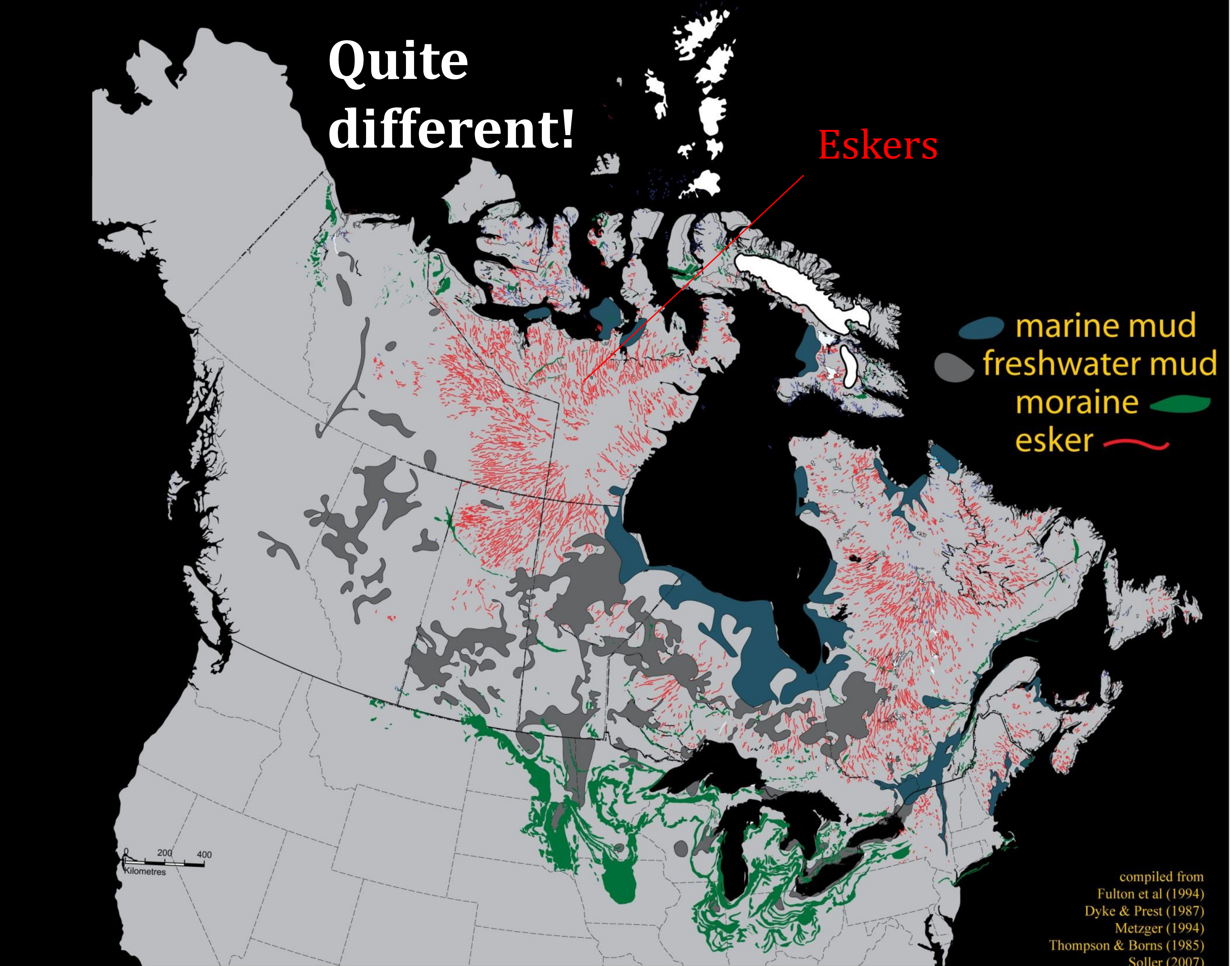


9,000 14C yr BP
marine mud
freshwater mud
moraine
esker
0 200 400
Kilometres
compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)


8,000 ^{14}C yr BP
marine mud
freshwater mud
moraine
esker
0 200 400
Kilometres
compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)


7,000 ¹⁴C yr BP
marine mud
freshwater mud
moraine
esker
0 200 400
Kilometres
compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)


7,000 ¹⁴C yr BP
marine mud
freshwater mud
moraine
esker
0 200 400
Kilometres
compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)


Quite different!
Eskers
marine mud
freshwater mud
moraine
esker
0 200 400
Kilometres
compiled from
Fulton et al (1994)
Dyke & Prest (1987)
Metzger (1994)
Thompson & Borns (1985)
Soller (2007)

Esker myths and misconceptions

Don Cummings
DCGeo Consulting
Adjunct Research Professor, Carleton University

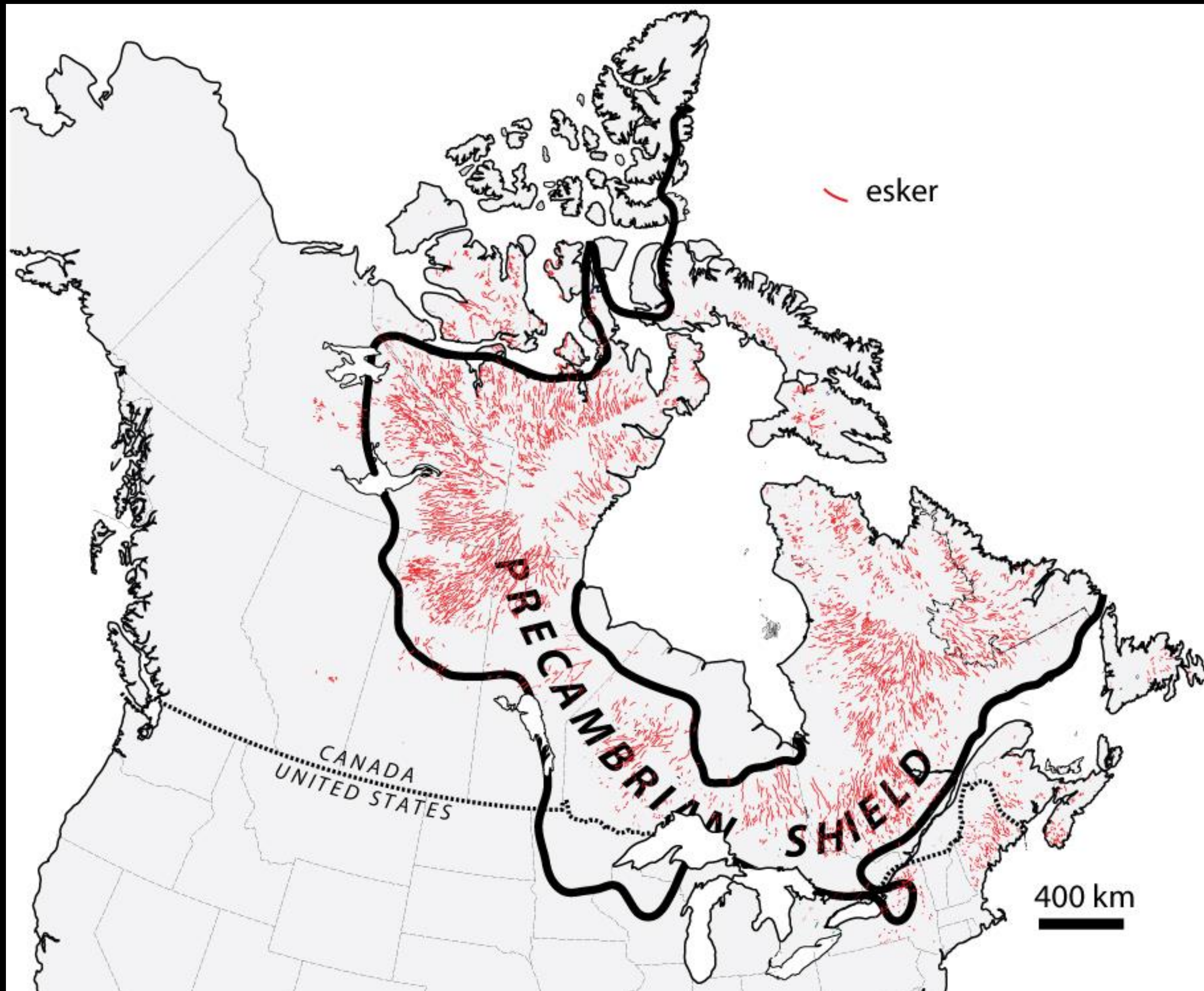
Talk outline

- Eskers: A primer
- Myths and misconceptions
- Future work

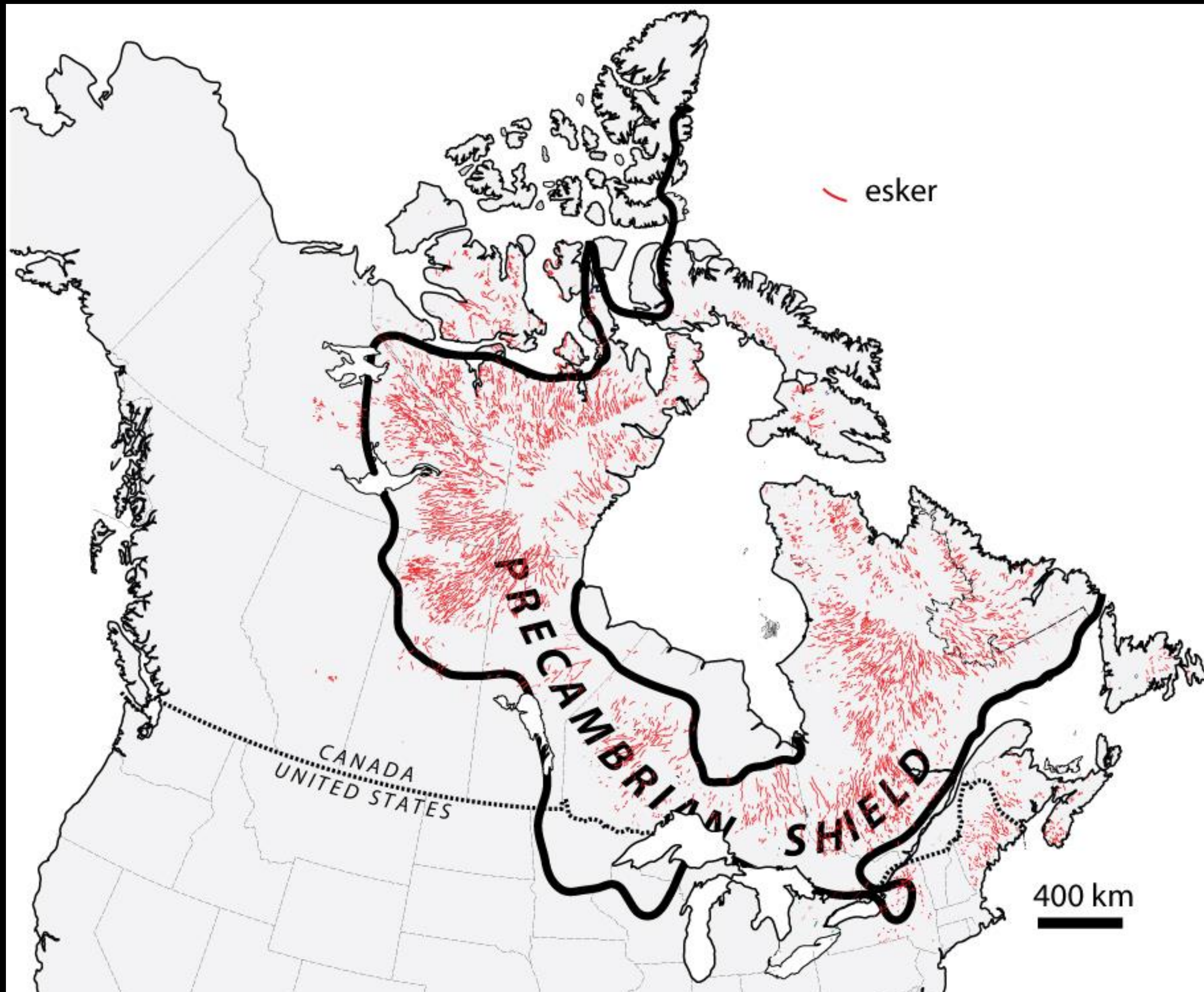
Eskers: A primer

Eskers

- -LIS behaviour
- -Minex
- -Drinking water
- -Aggregate
- -Wildlife
- -Archeology

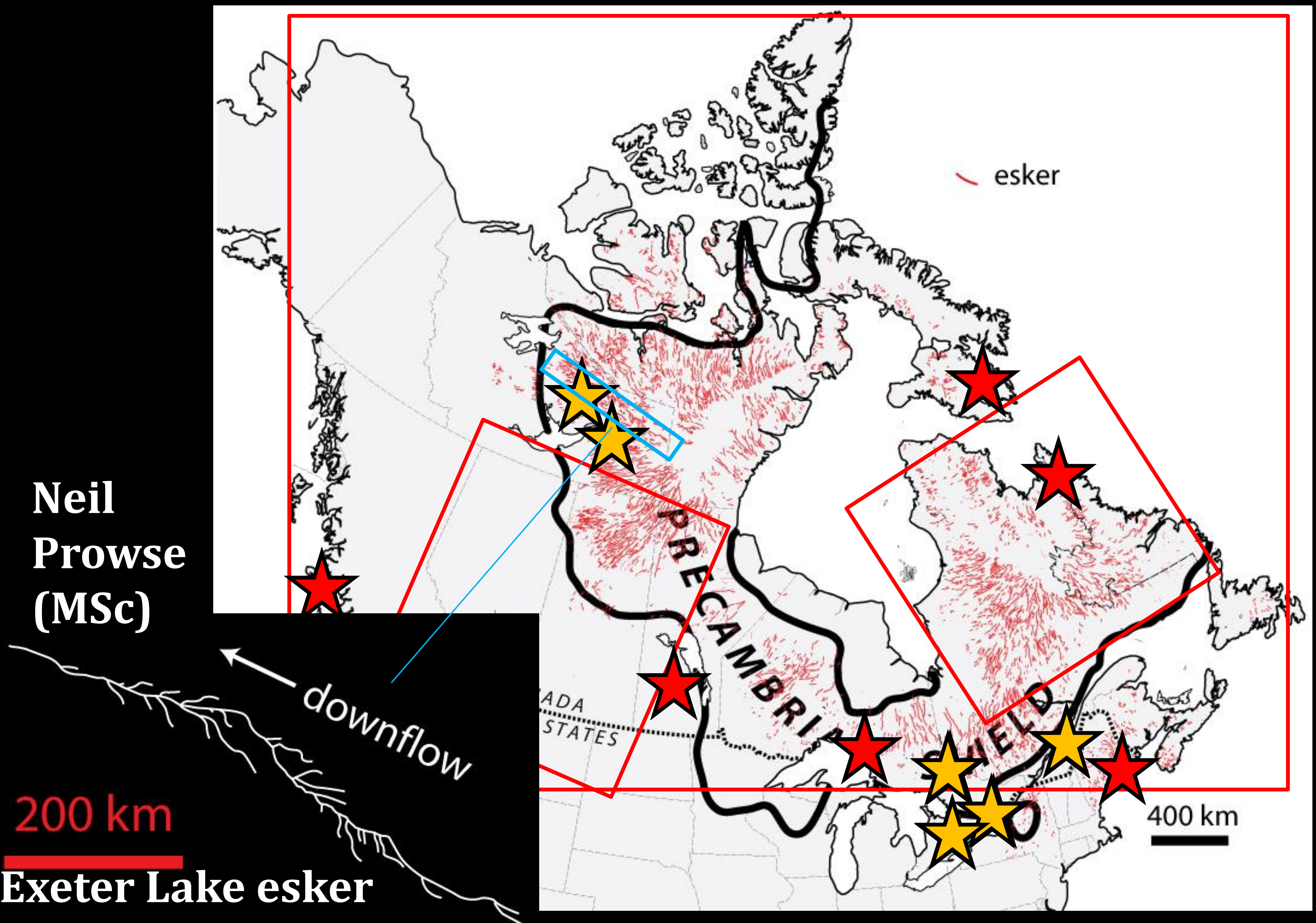


My work to date



My work to date

Neil Prowse (MSc)



Exeter Lake esker

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 6560

Eskers as Mineral Exploration Tools: An Annotated Bibliography

D.I. Cummings, H.A.J. Russell, D.R. Sharpe, and B.A. Kjarsgaard

2010

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Eskers as mineral exploration tools

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ABSTRACT

Eskers are commonly sampled for indicator minerals during drift prospecting campaigns on the Precambrian Shield. However, a literature review reveals that indicator mineral dispersal in esker sedimentary systems is poorly understood. As a result, exploration companies lacking their own proprietary knowledge are left with little basis for understanding how to collect esker samples or how to interpret esker data. Based on the literature review, and drawing insights from a broader body of literature on modern glaciers, laboratory experiments, and gravel-bed streams, a preliminary conceptual framework for esker sedimentary systems is established to address these issues. A research strategy is then outlined, one whose objective is to fill knowledge gaps and, in doing so, improve the effectiveness of mineral exploration in glaciated terrain.

Contents

1. Introduction

Eskers are common in glaciated terrain (Fig. 1; Levasseur, 1995; Brennand, 2000). They are, along with stream sediments and till, one of three principal media sampled during drift prospecting to identify indicator mineral dispersal trains downflow of mineral deposits (Fig. 2). Esker sampling is a proven method: it has led to the discovery of several kimberlites (Lee, 1968), including the Lac de Gras kimberlite field, home to Canada's first diamond mine (Krajick, 2001; Kjarsgaard and Levinson, 2002). Although commonly associated with diamond exploration, esker sampling can be used to explore for any mineral deposit type that yields a characteristic suite of indicator minerals (e.g., Ni–Cu–PGE deposits; Averill, 2009). Given this, one might expect that indicator mineral dispersal in esker sedimentary systems is a well researched and well understood phenomenon. However, based on the paucity of published literature on the subject, we suggest this is not the case. Exploration companies lacking 'in-house' knowledge are faced with two major, unanswered questions.

Question 1 – esker sampling methods
How should eskers be sampled for indicator minerals?

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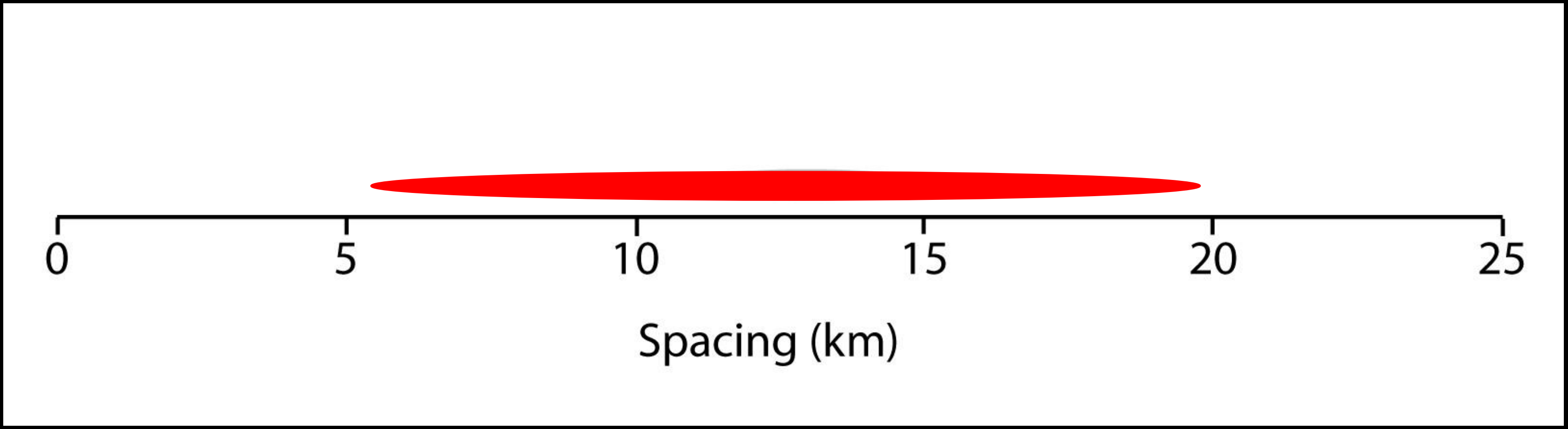
Review of >100 years of esker literature

Eskers are shoestring-shaped ridges of stratified sediment.

They are best developed on the Precambrian Shield.

Like spokes on a wheel, most Shield eskers radiate out from two centres, forming two huge radial arrays.

Spacing between eskers is relatively constant—typically 5-20 km (Aylsworth & Shilts, 1989; Bolduc, 1992).

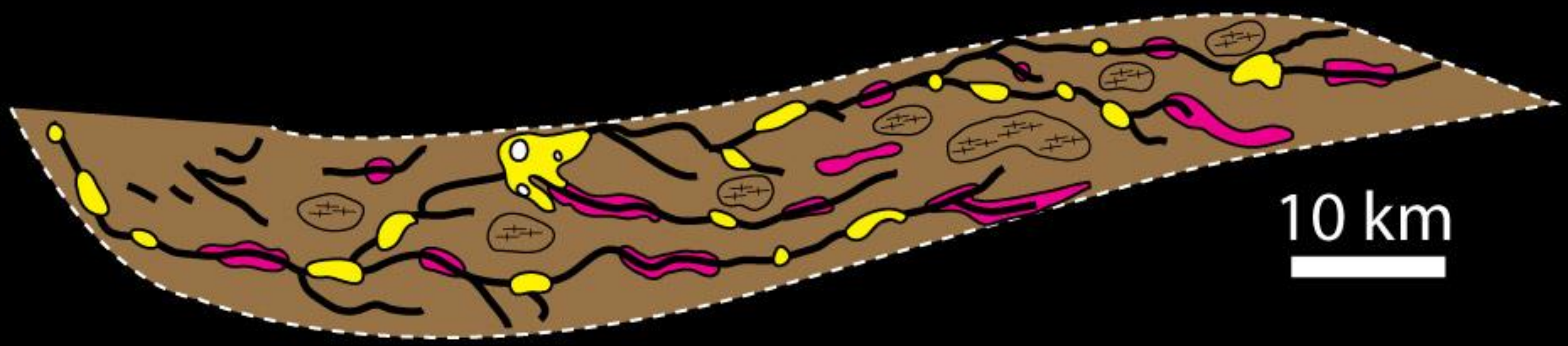


Esker spacing in Labrador and Keewatin
(Aylsworth and Shilts, 1989; Bolduc, 1992)

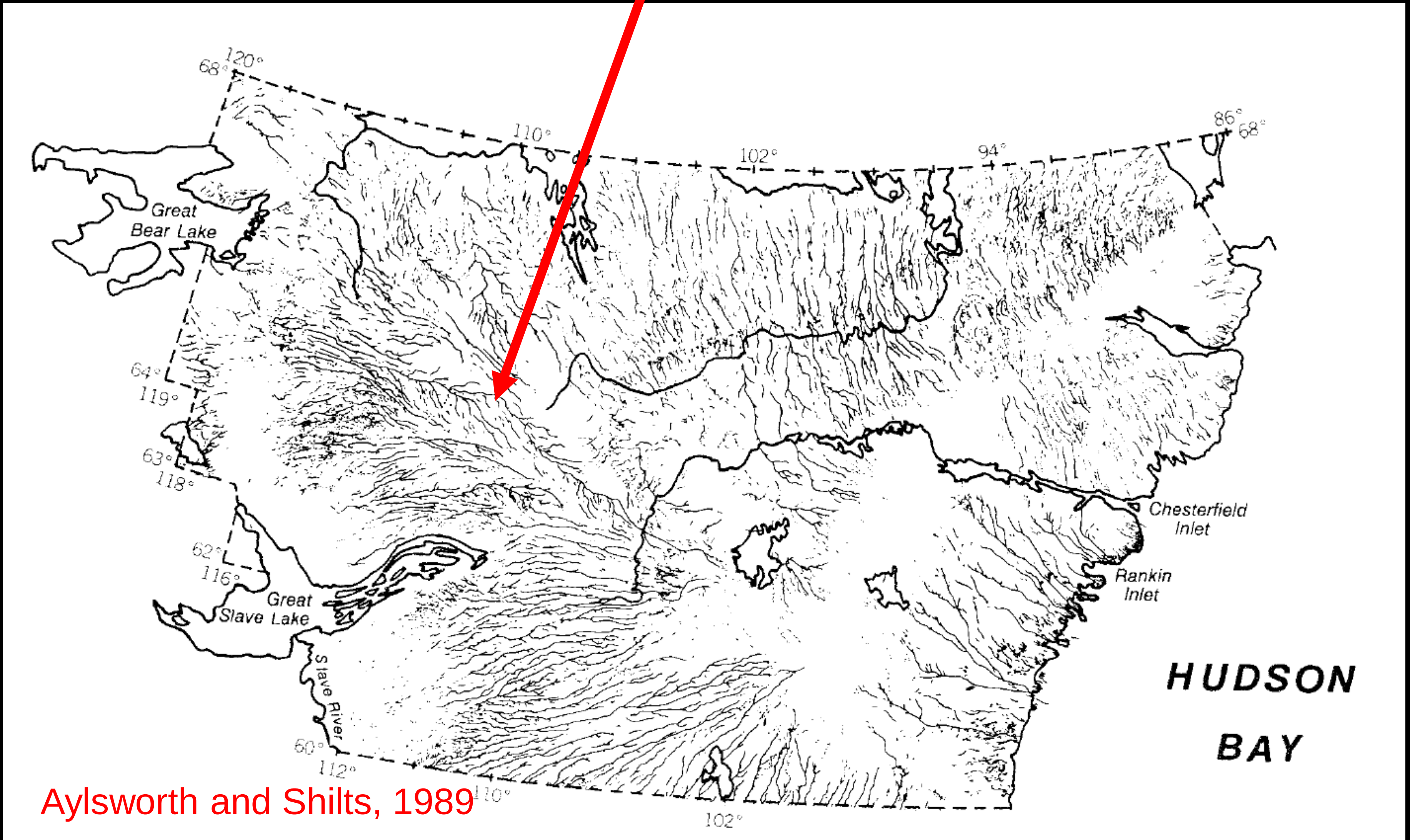
Much different than rivers!

Let’s zoom in...

When traced outward from array centres, eskers tend to join together, forming tributary-like **tree-shaped networks**.



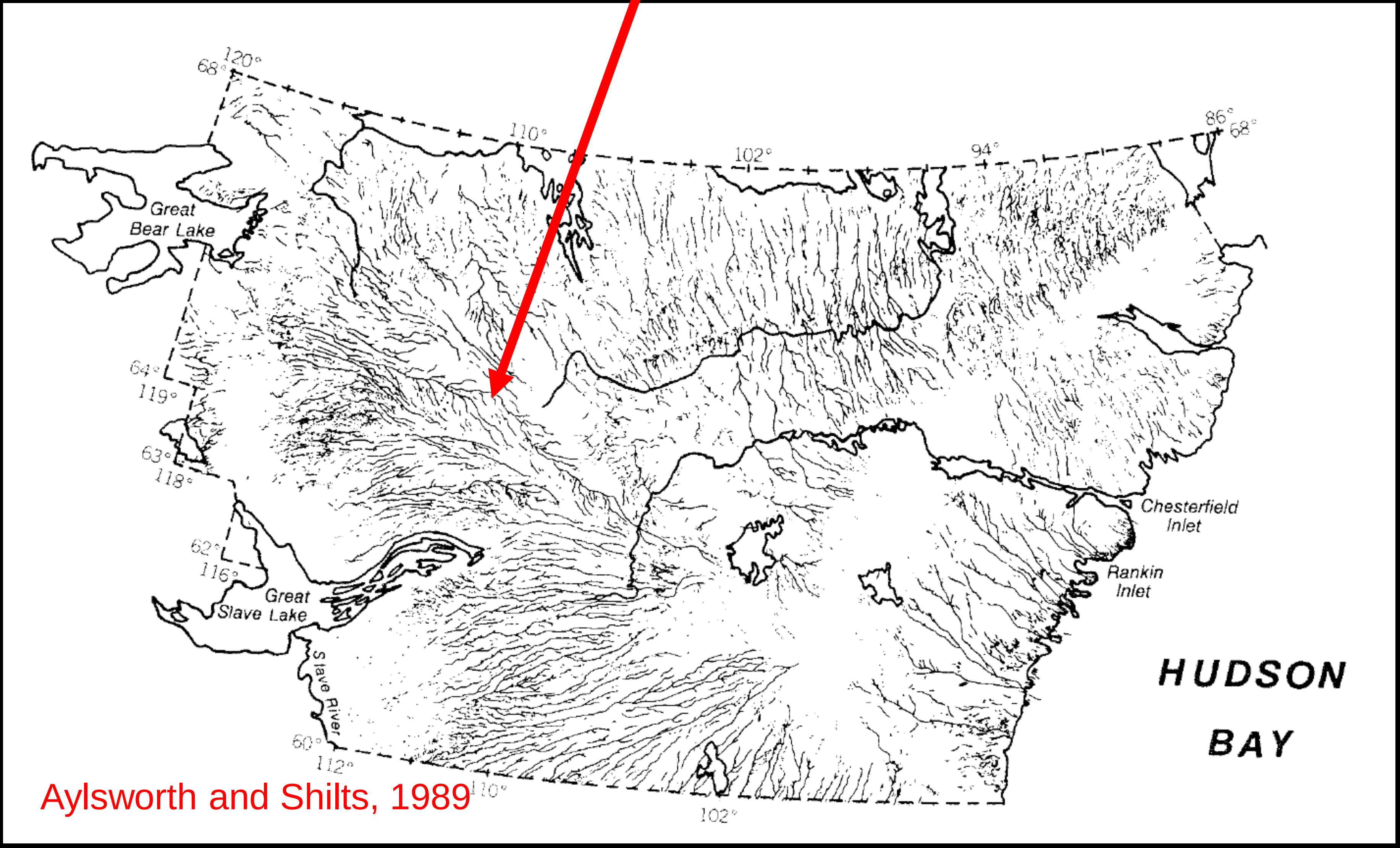
The tributary networks tend to be very elongate…



Aylsworth and Shilts, 1989

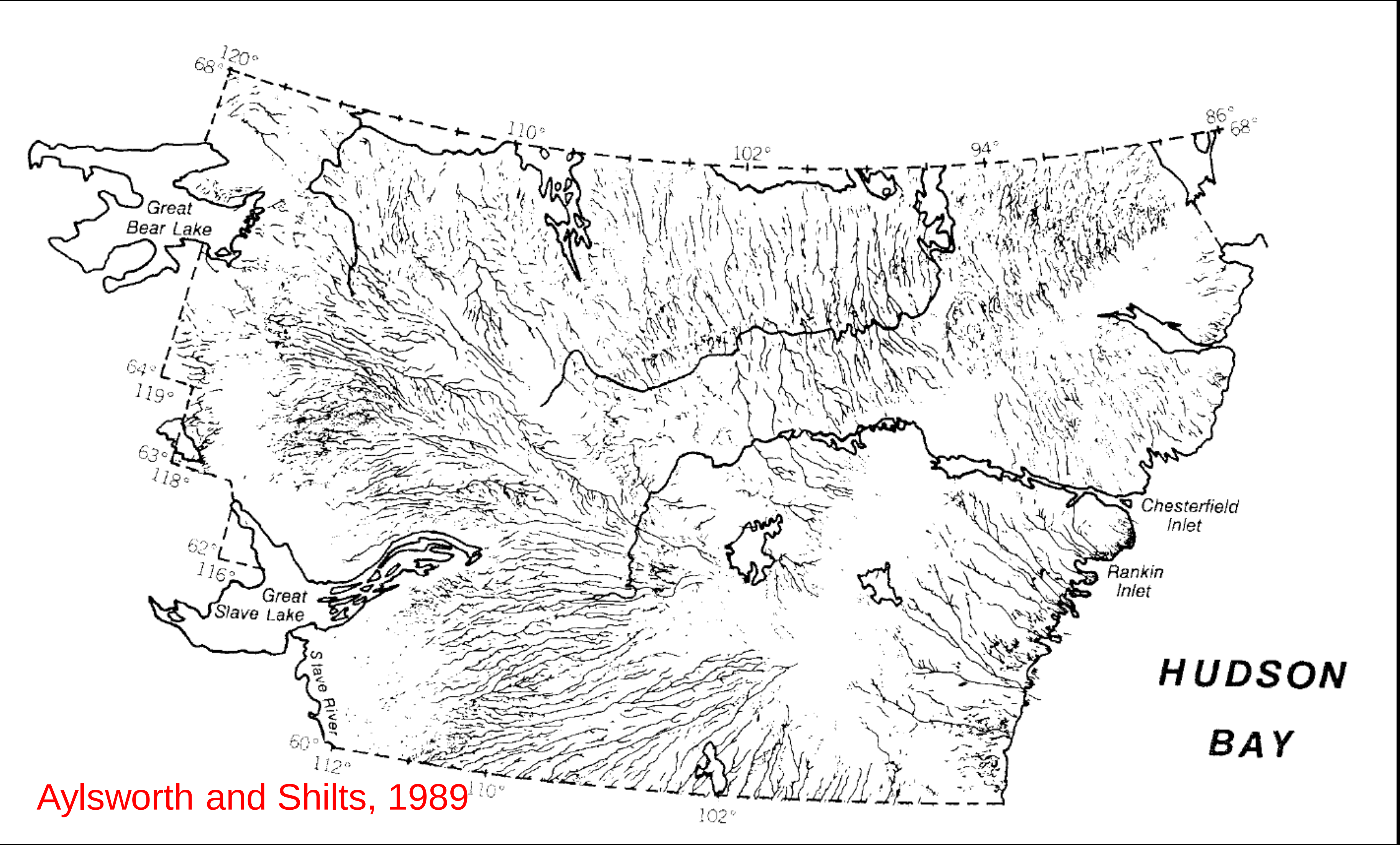
…much more elongate than large stream networks.

Also, unlike large rivers, which increase in cross-section downflow, esker networks show **no systematic increase in cross-sectional area** along their lengths.



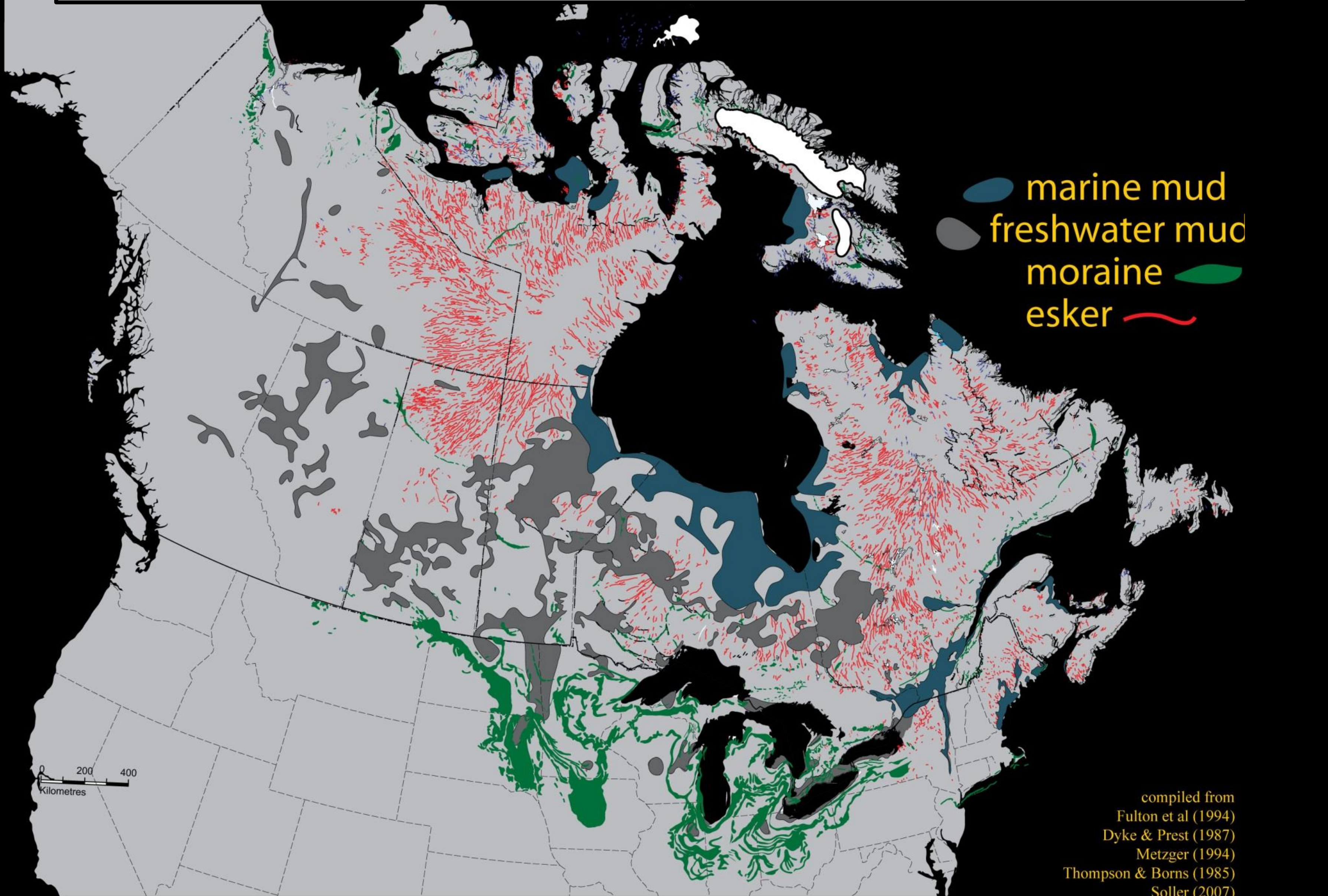
Aylsworth and Shilts, 1989

Gaps are common.

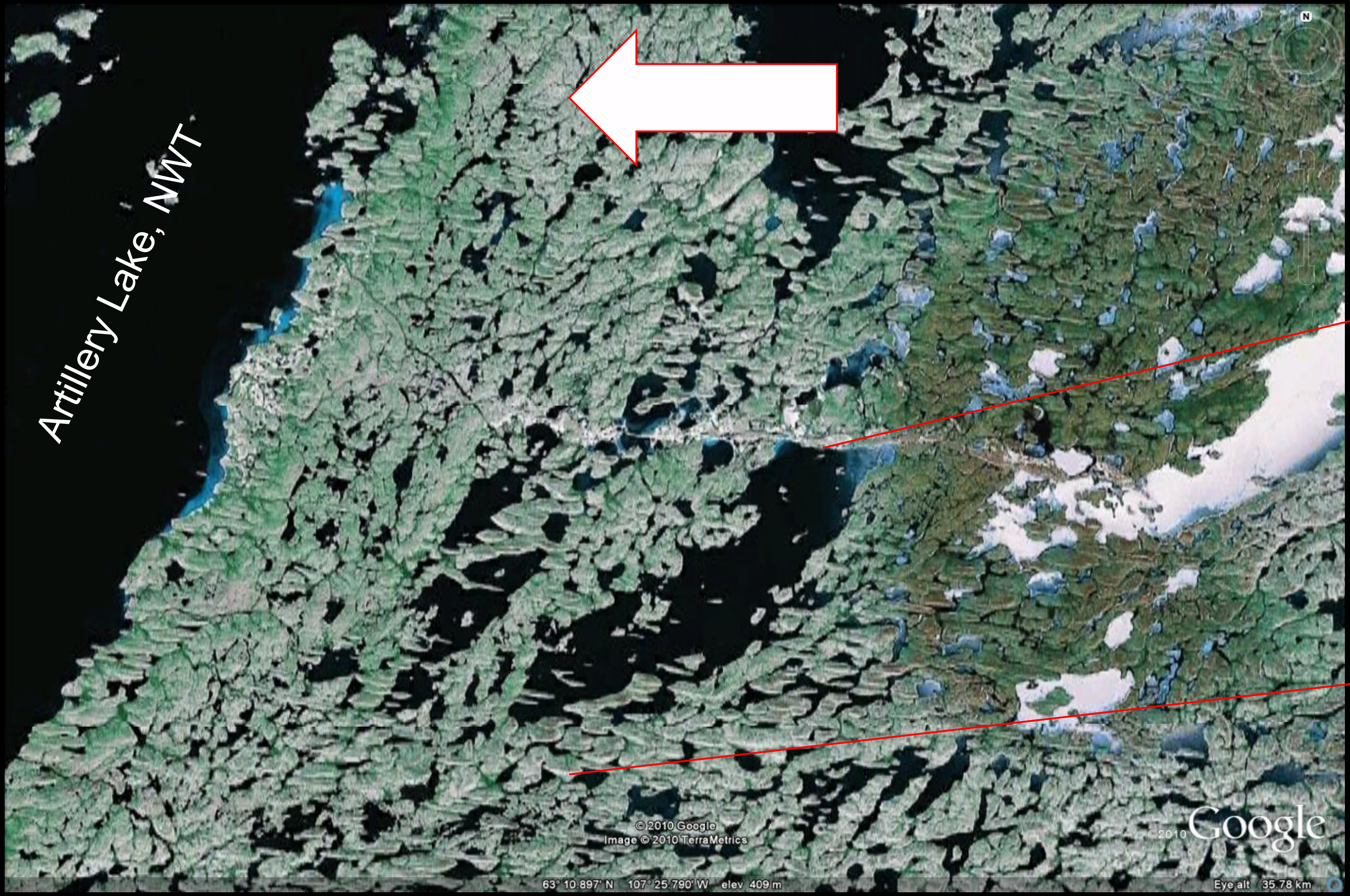


Aylsworth and Shilts, 1989

Also in contrast to large rivers, **fans** (e.g., deltas, outwash fans) commensurate with the size of eskers are typically lacking at esker termini.

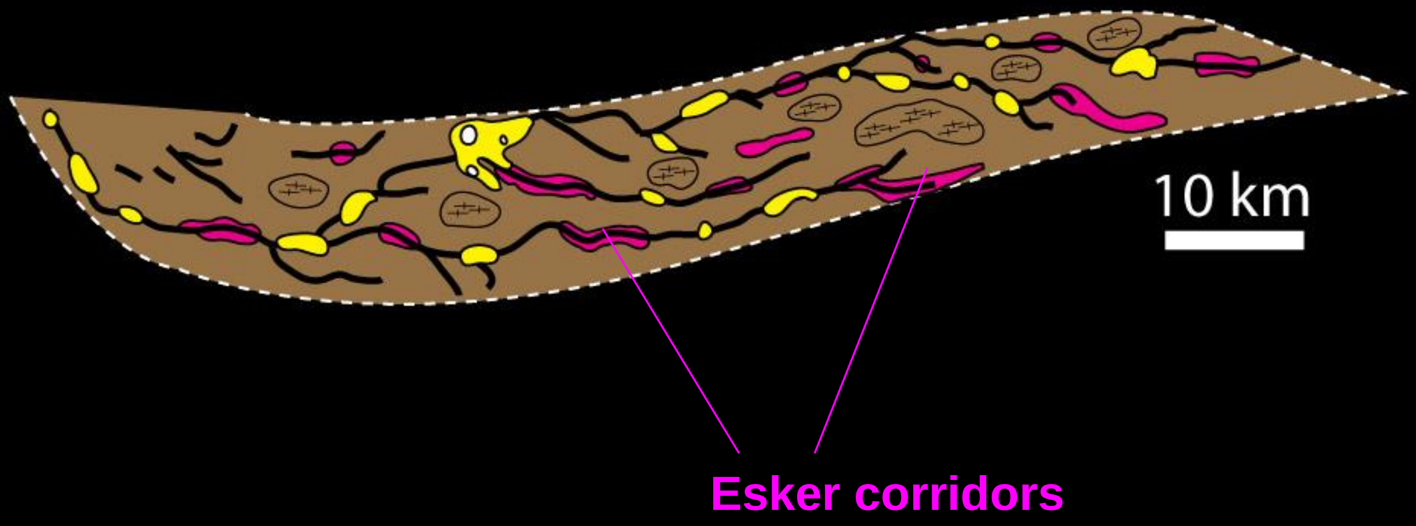


Eskers typically trend parallel to drumlins (+/- a few 10s of degrees).

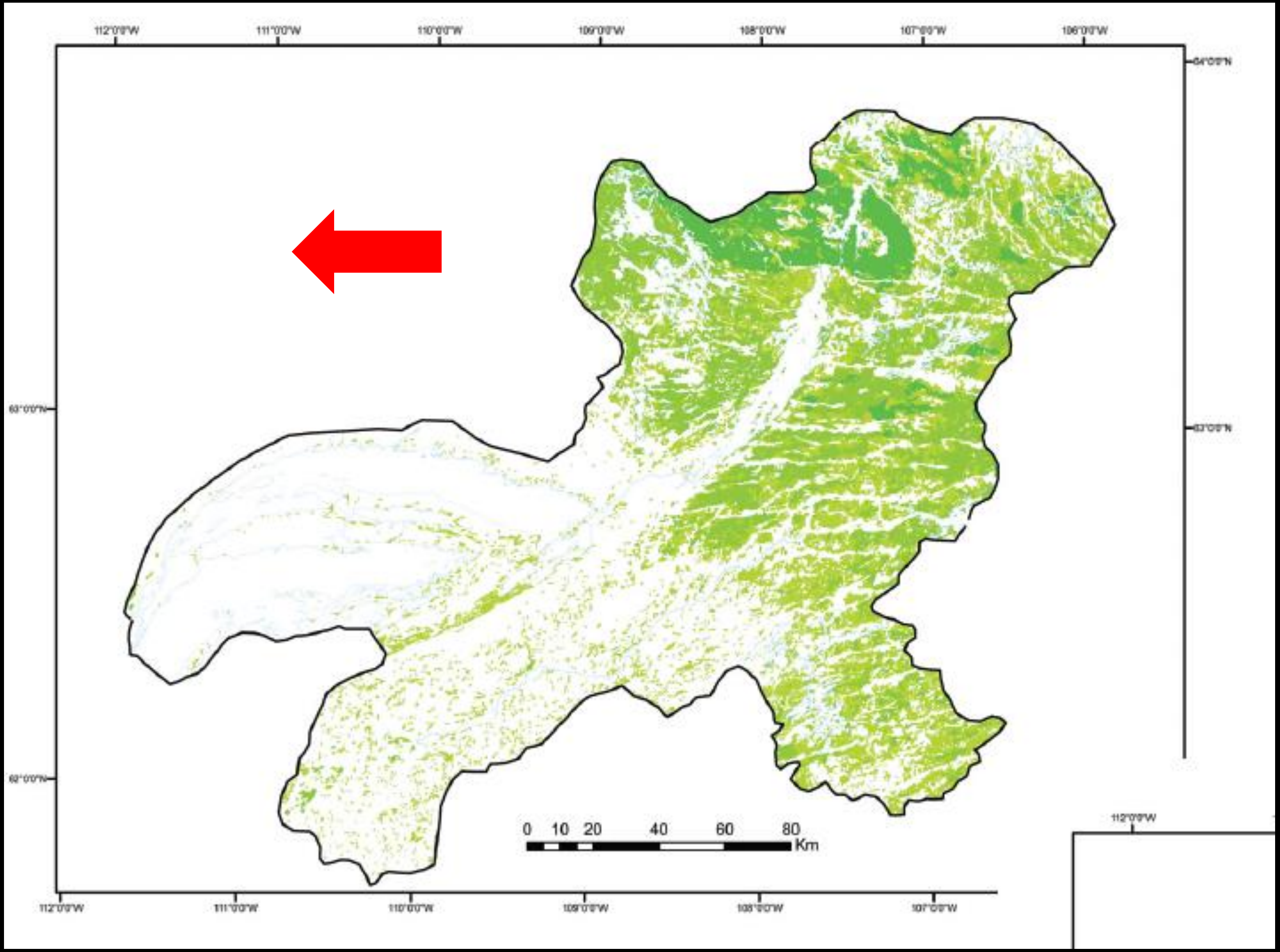


East Arm, NWT

And they commonly sit in discontinuous channels eroded through till to bedrock (esker corridors).

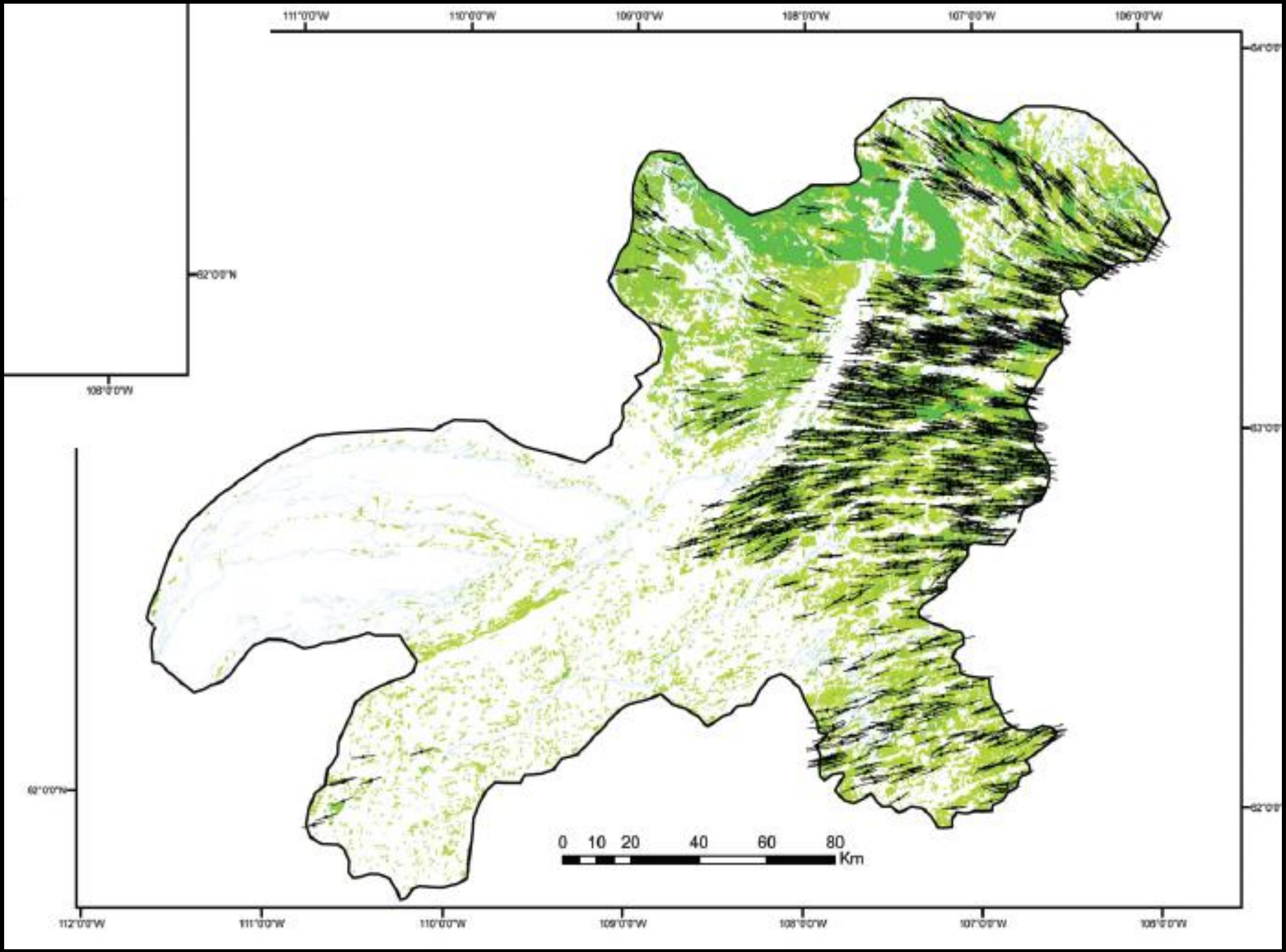


Esker corridors, Artillery Lake, NWT
(Kerr et al., 2013)



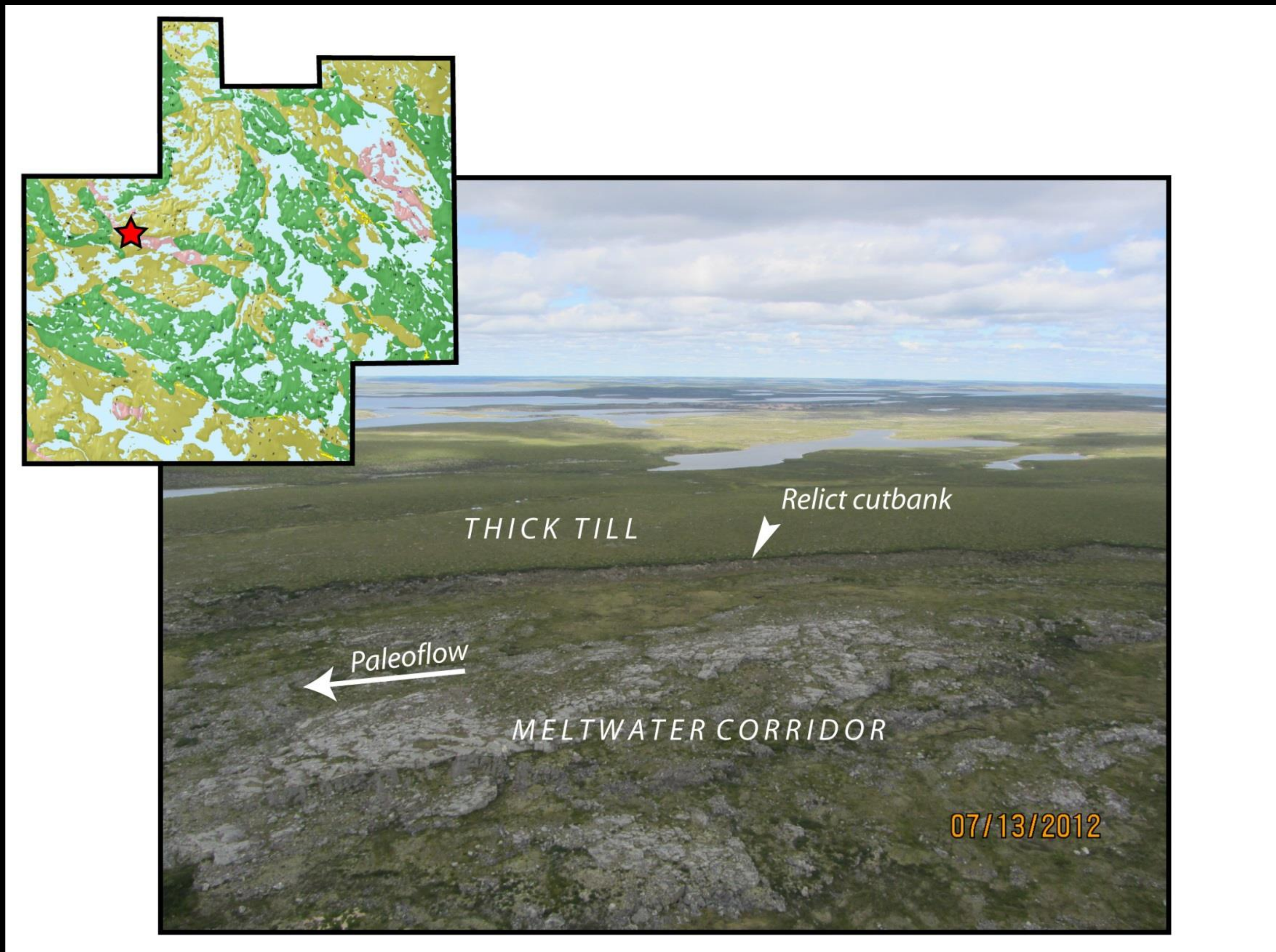
Esker corridors, Artillery Lake, NWT

(Kerr et al., 2013)

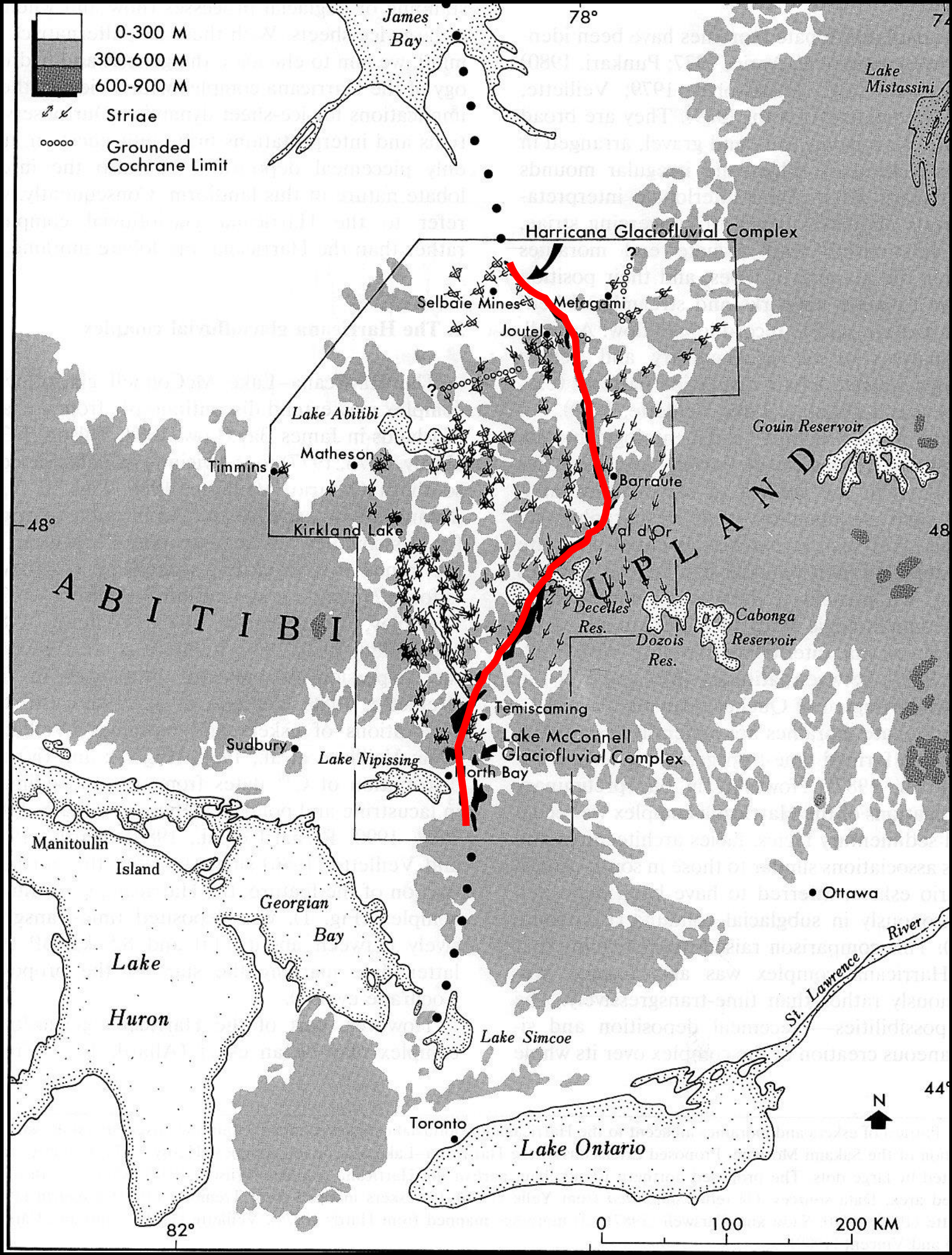


Esker corridor near Lac de Gras, NWT

(Cummings, 2013)



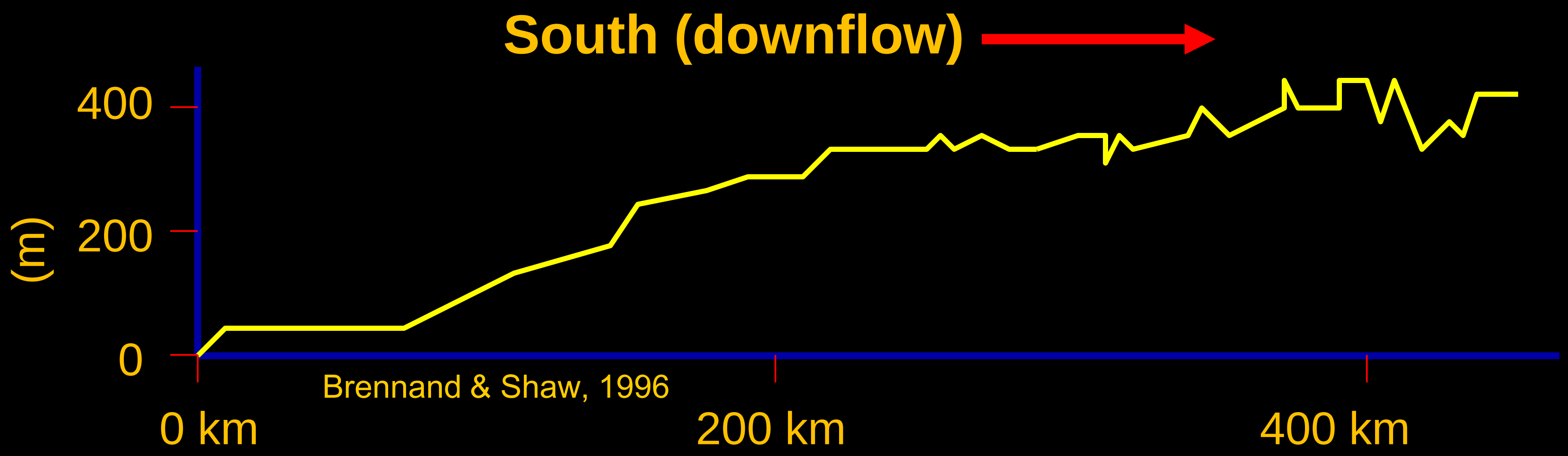
Eskers can have upslope paths or downslope paths



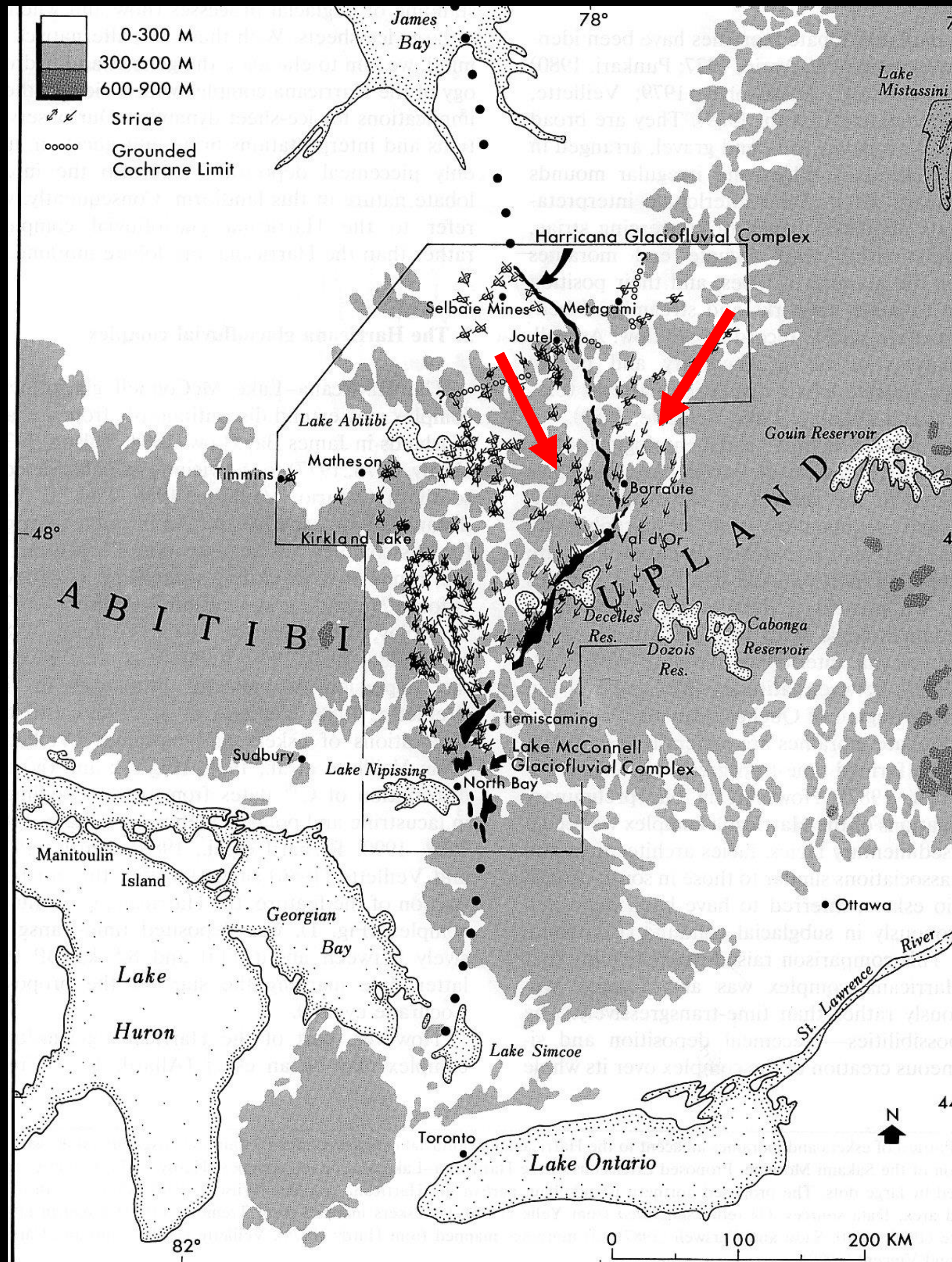
Harricana esker

Brennand & Shaw, 1996

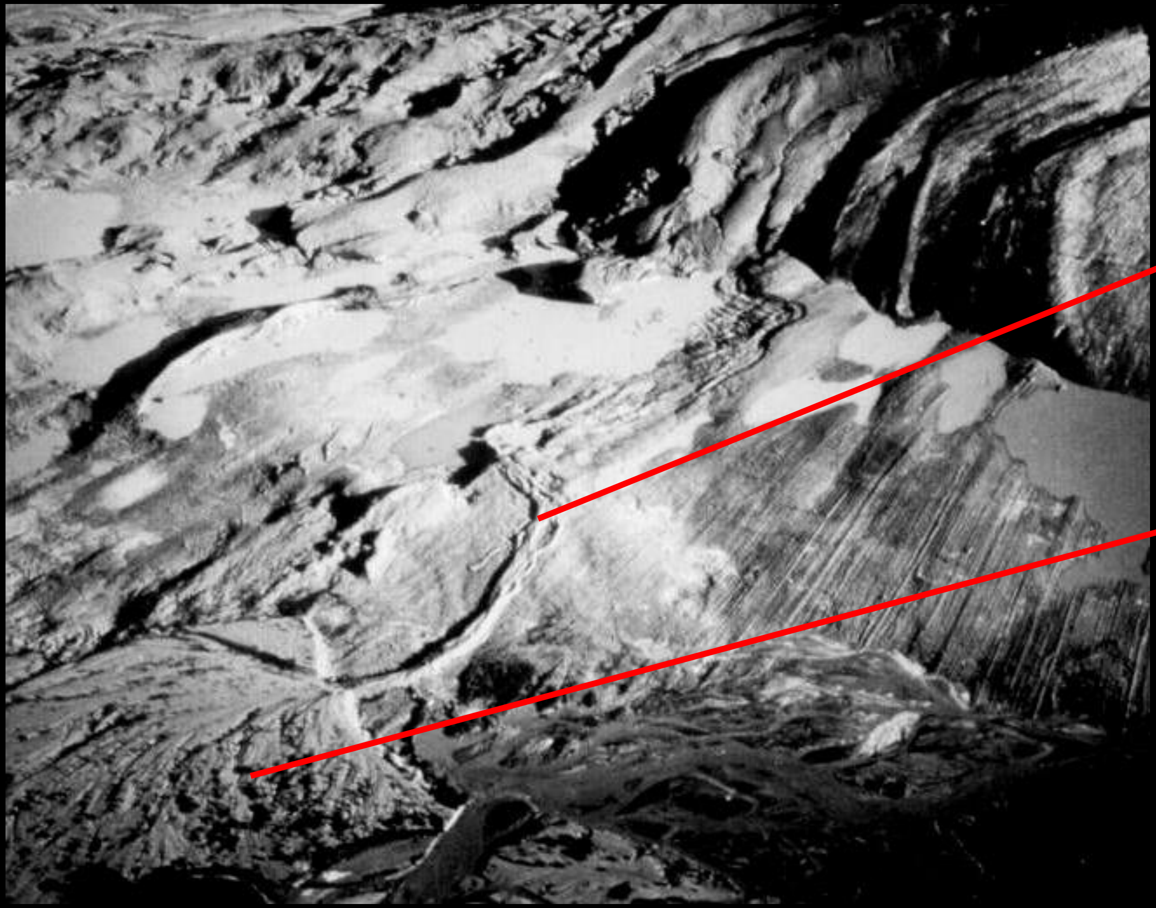
Eskers can have
upslope paths or
downslope paths



Bedrock striae can converge obliquely toward esker



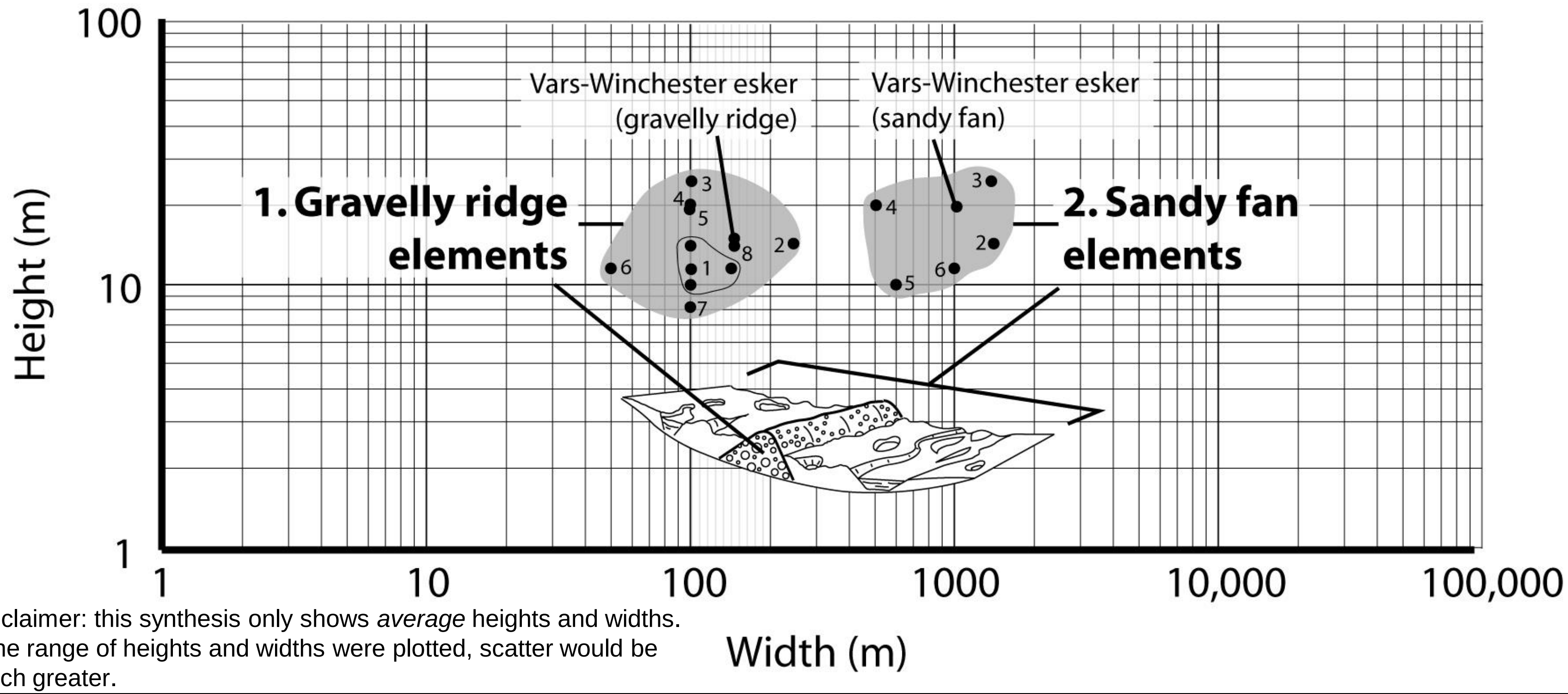
Esker complexes typically consist of two "building block" morphological elements: a central ridge element, commonly gravelly, and broader sediment bodies (fans), commonly sandy.



Esker

Woodworth Glacier, Alaska

Irrespective of geographic location, the central ridge elements tend to, on average, be similar in height and width. The fan elements show a similar trend.



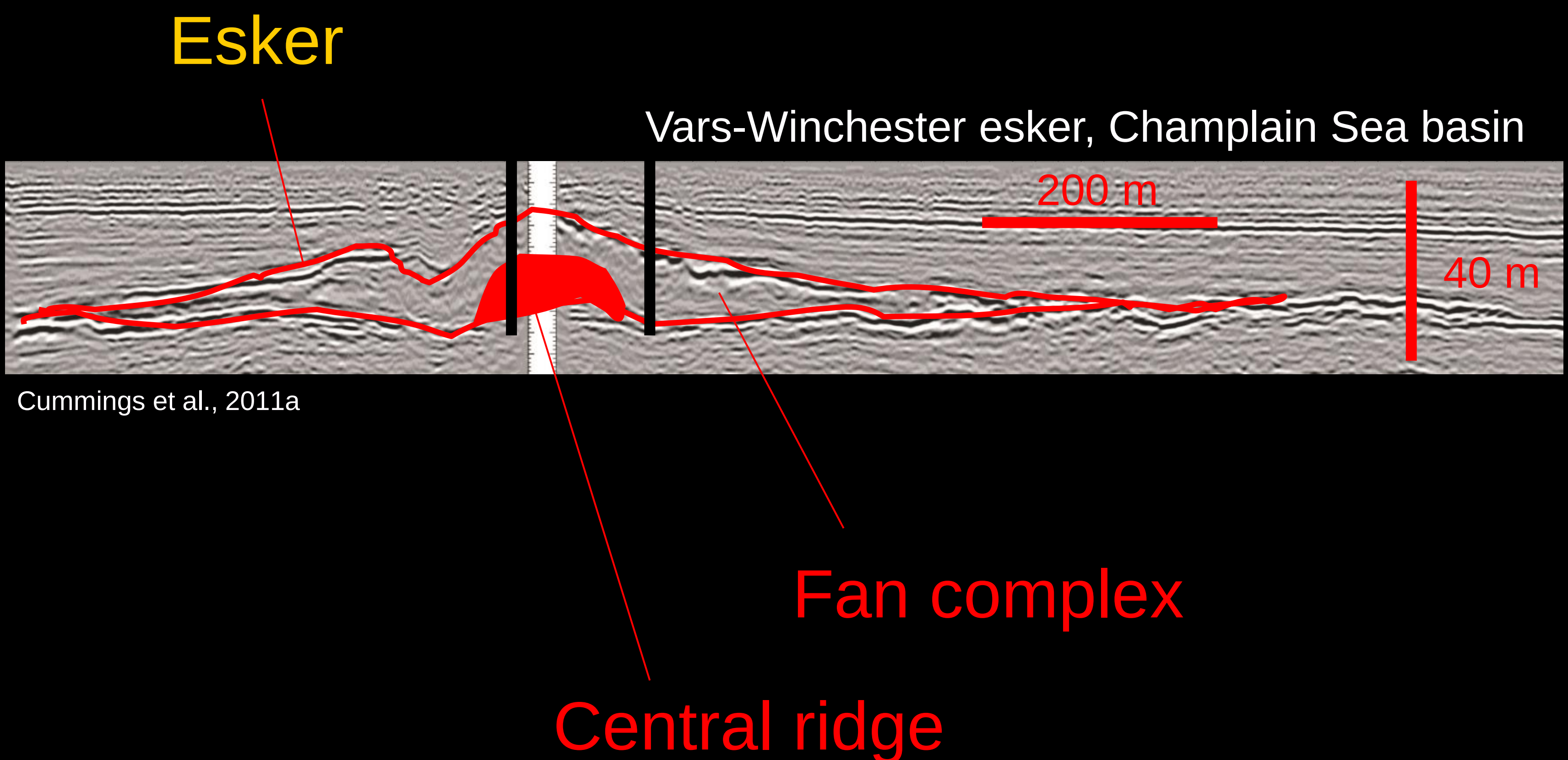
Disclaimer: this synthesis only shows *average* heights and widths. If the range of heights and widths were plotted, scatter would be much greater.

Cummings et al., 2011

(Discussion point: why are the cross sections of eskers so constant, especially compared to those of streams on the modern landscape?)

STRATIGRAPHY

Where stratigraphic data are available, fan elements are commonly superimposed on central ridge elements.

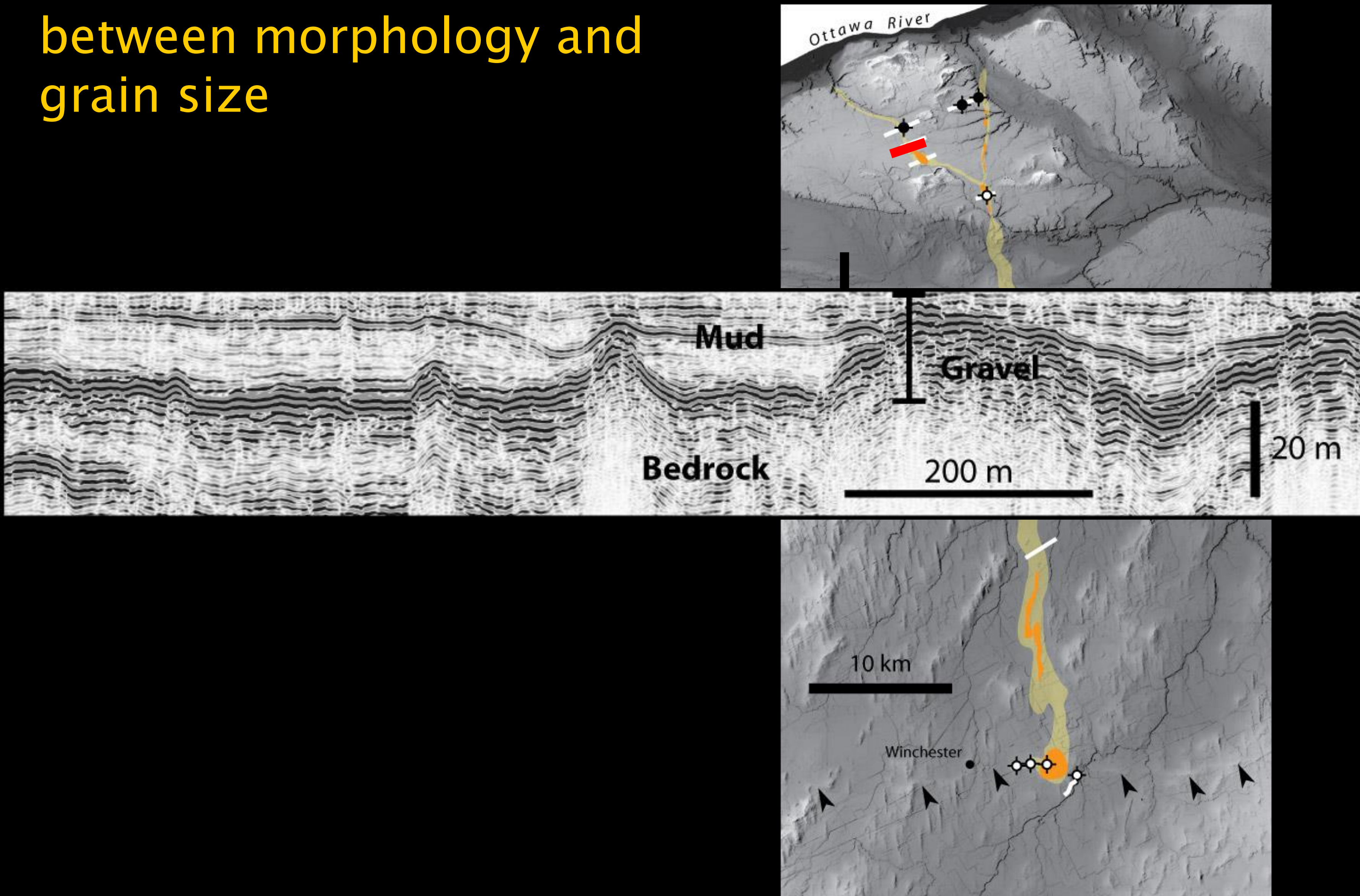


Cummings et al., 2011a

The central ridge contains the coarsest sediment in the esker (typically gravel). It represents the most "proximal" facies.

There is a correlation between morphology and grain size

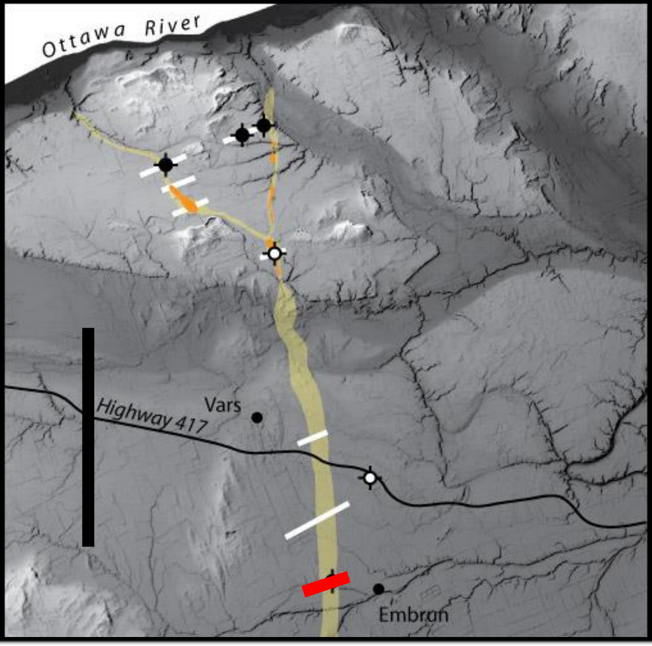
Vars-Winchester esker

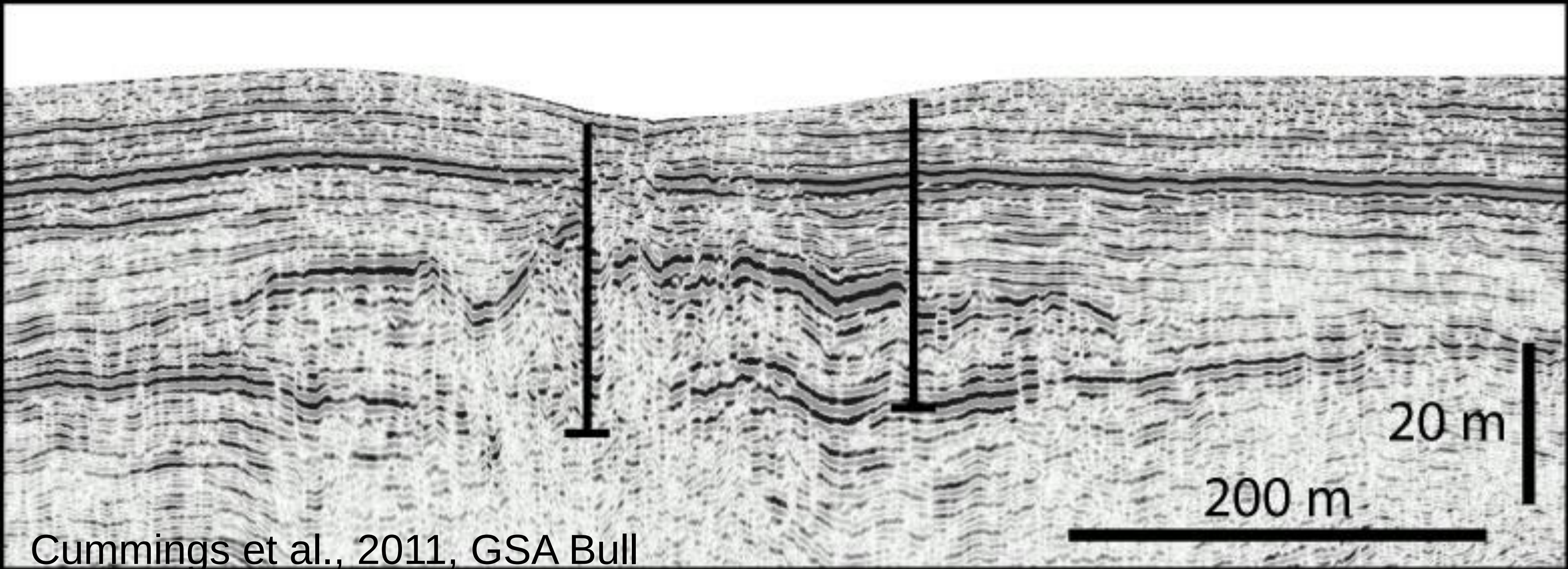


Cummings et al., 2011a, GSA Bull

There is a correlation between morphology and grain size

Vars-Winchester esker

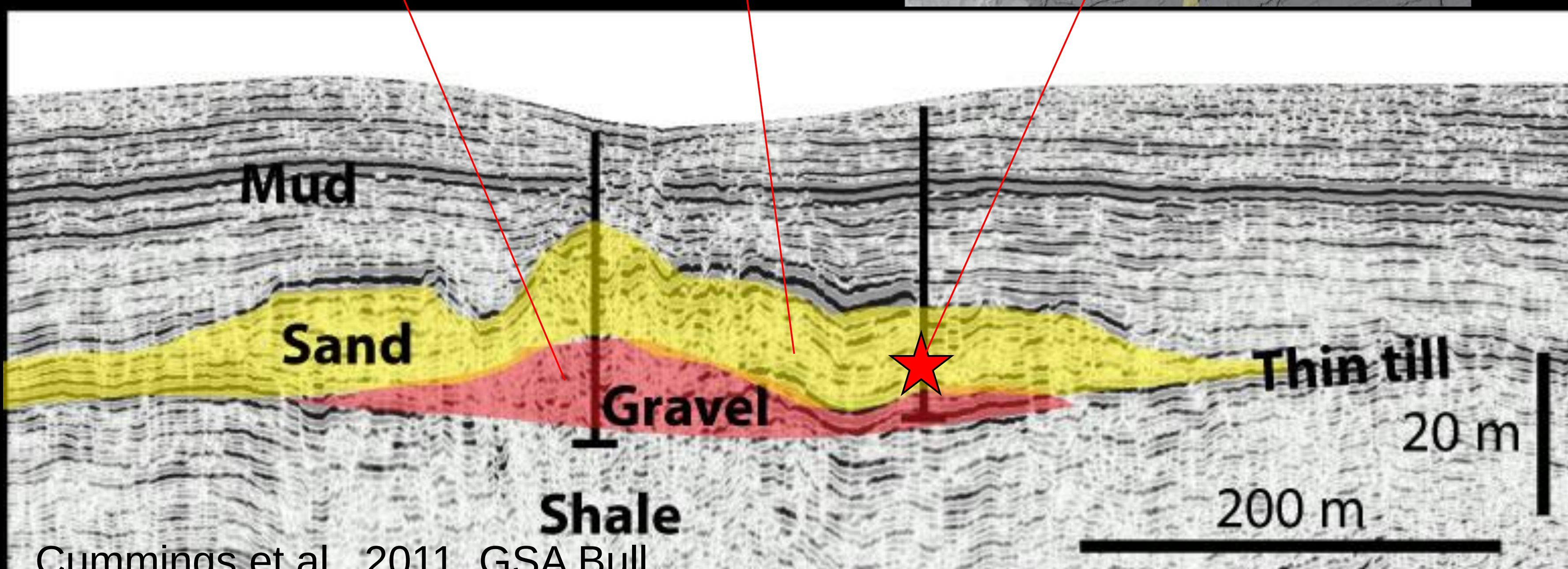




Cummings et al., 2011, GSA Bull

Correlation between morphology and grain size

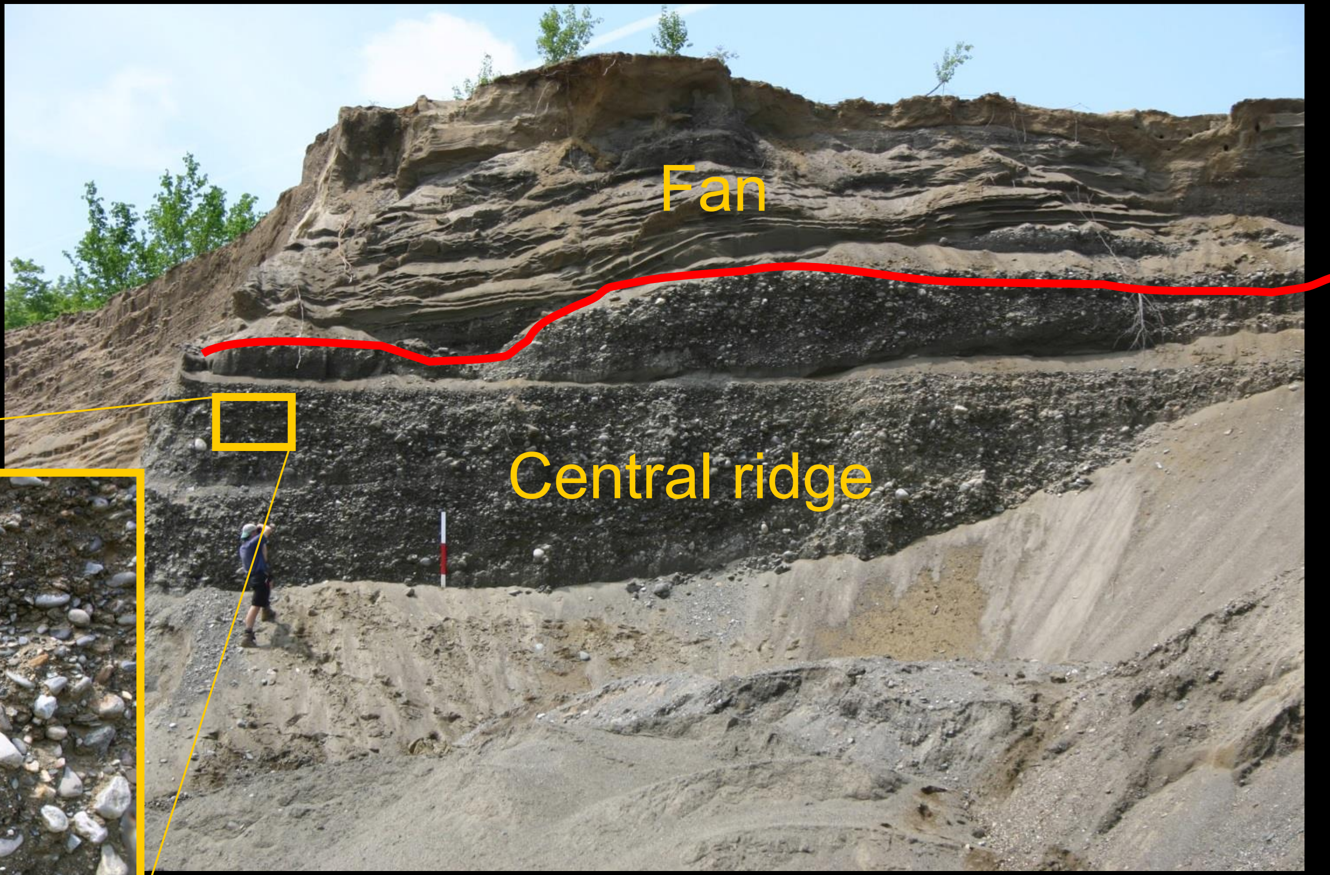
Central ridge



Cummings et al., 2011, GSA Bull

Leonard Rd Esker

Maine

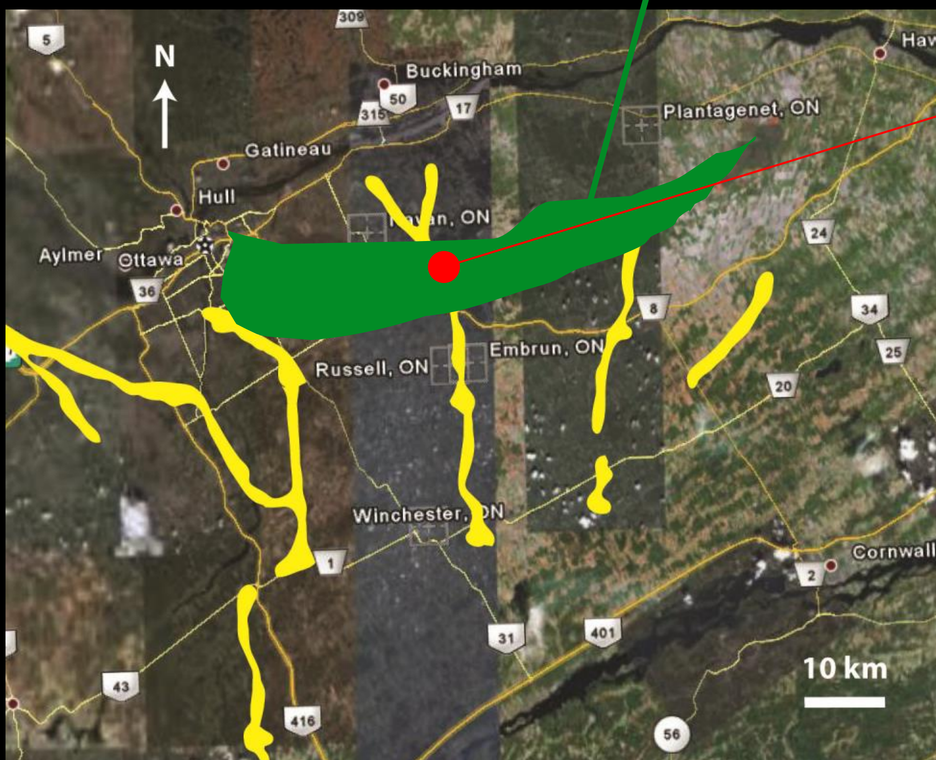


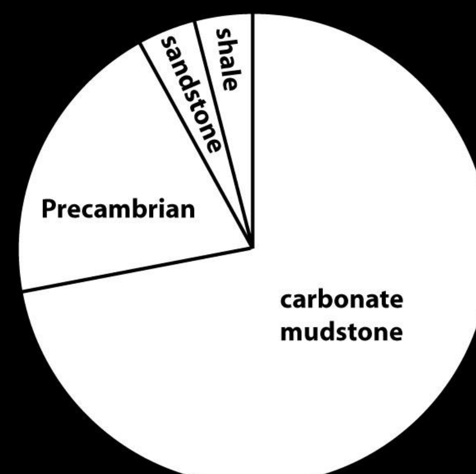
Lithology of gravel in central ridge is commonly similar to that of adjacent/subjacent bedrock and till.

Winchester-Vars esker

Magladry Road pit

Shale





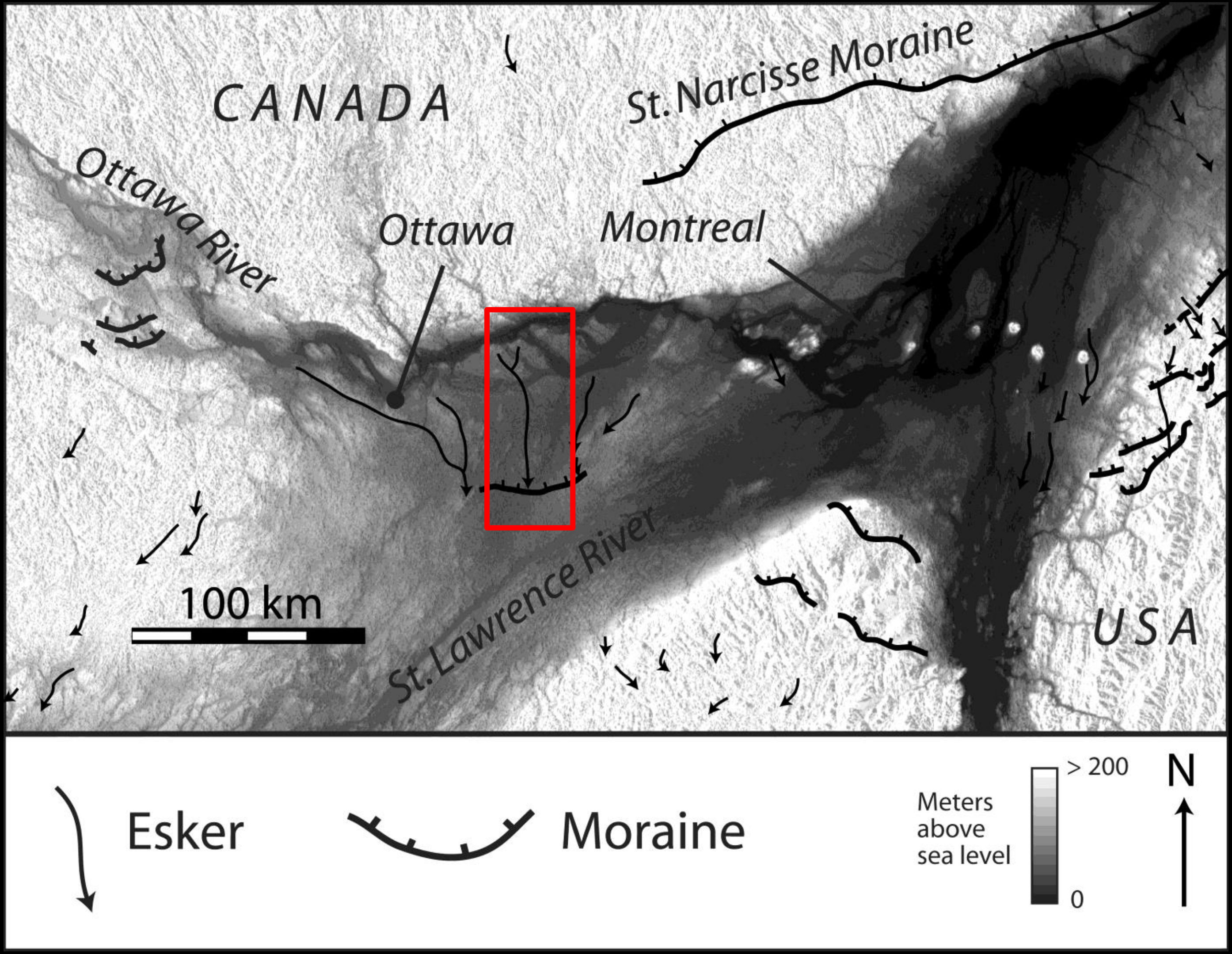
However, in contrast to the till, gravel clasts in the esker are invariably well rounded and striae-free. Even friable lithologies such as shale are surprisingly well rounded.

BEFORE

AFTER

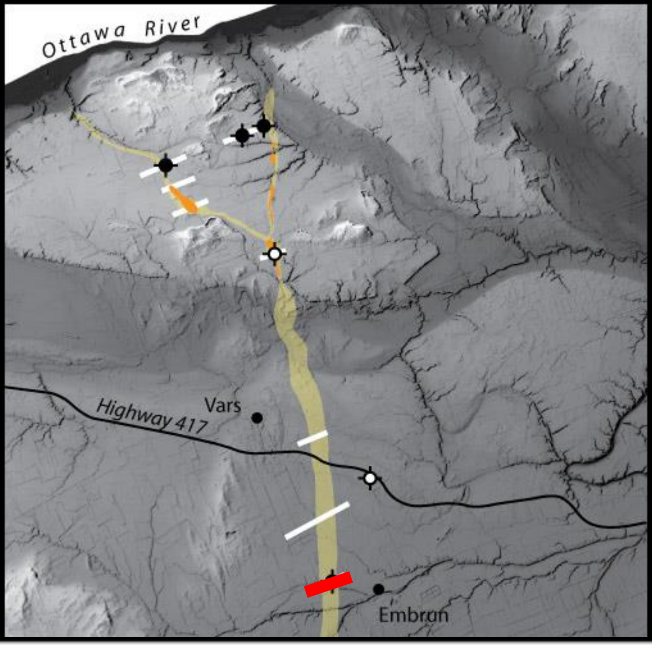
The morphology and internal heterogeneity of fan elements differs in different depositional settings

By contrast, in low-lying glaciated basins fan elements are mound-shaped.



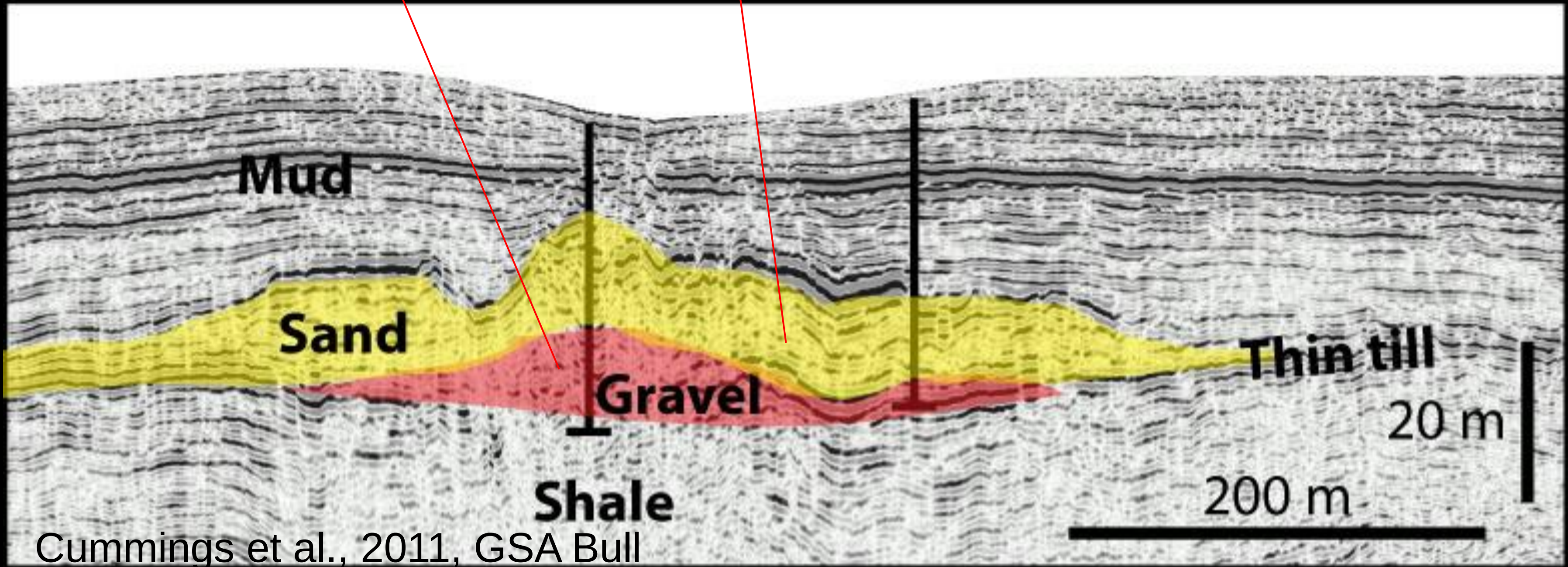
Cummings et al., 2011a

By contrast, in low-lying glaciated basins fan elements are mound-shaped.



Central ridge

Fan



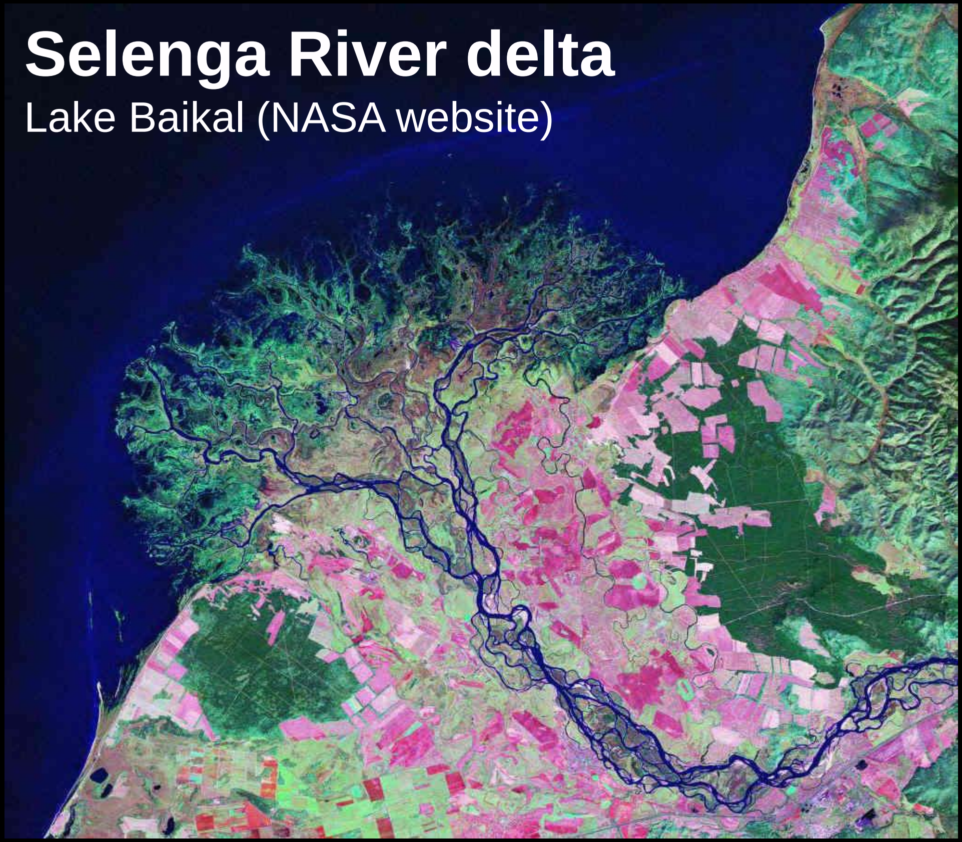
Cummings et al., 2011, GSA Bull

Climbing ripples

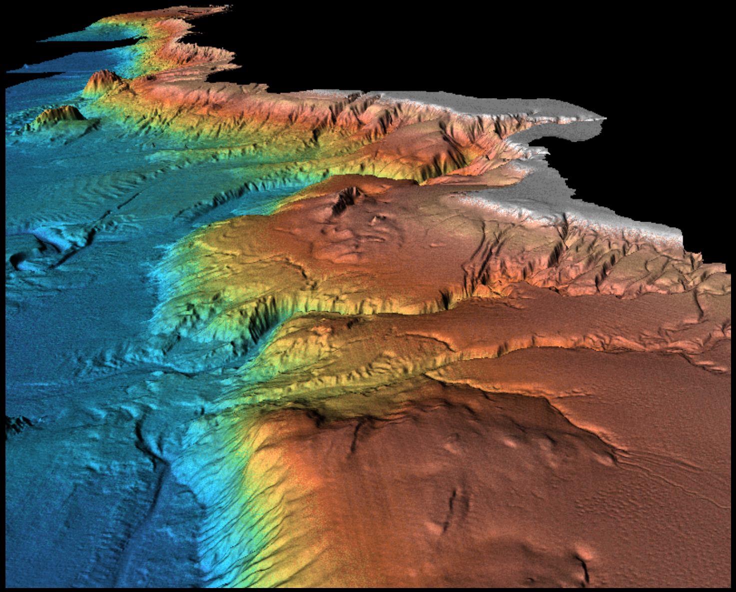
Fans in Champlain Sea appear to be deposited by **energetic, sediment-charged flows**. Facies are similar to sandy deep-sea turbidite fans and lahars.

Eskers: Interpretation

Esker systems are a type of "channel-fan system".
At their most fundamental level, they are analogous to rivers and their deltas, and slope canyons and basin-floor turbidite fans.

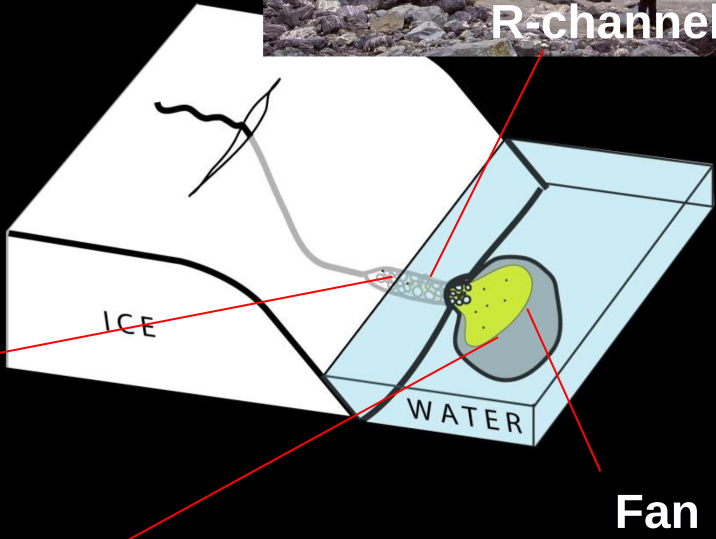


Continental margin
California (L. Pratson)



Here is the basic scenario most researchers invoke to explain esker deposition.

(NOTE: The proglacial area may be subaqueous (as depicted in cartoon) or subaerial; irrespective, a fan-shaped sediment body will likely form.)



-Explains esker corridors
-Explains gravel lithology
-Explains converging striae
-Explains shells in fan

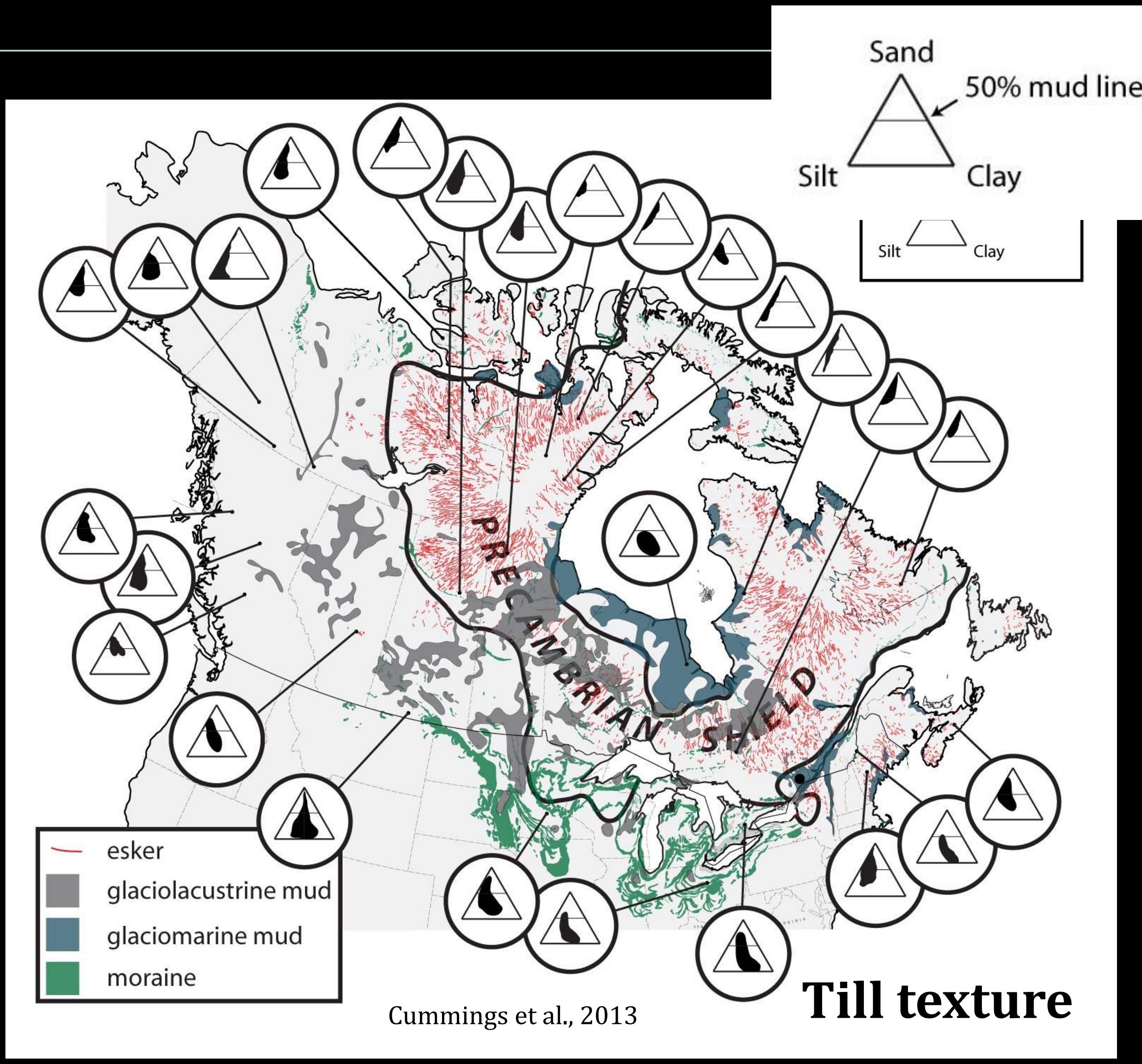
Myths and misconceptions

Myth 1 Mud is absent in esker systems (sensu lato)

Myth 1 Mud is absent in esker systems (sensu lato)

Mud should actually be the dominant component in most esker *systems* because it is the dominant component of most **tills**.

Absence of mud where eskers are present needs to be accounted for.

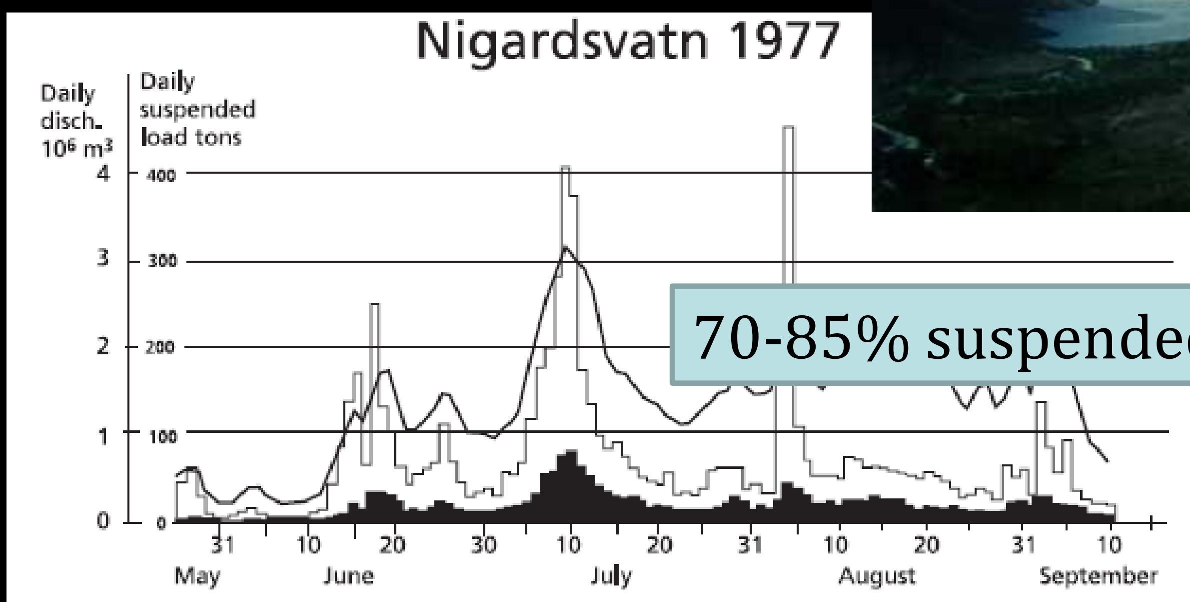


Cummings et al., 2013

Myth 1 Mud is absent in esker systems (sensu lato)

Proglacial lakes trap **mud**.

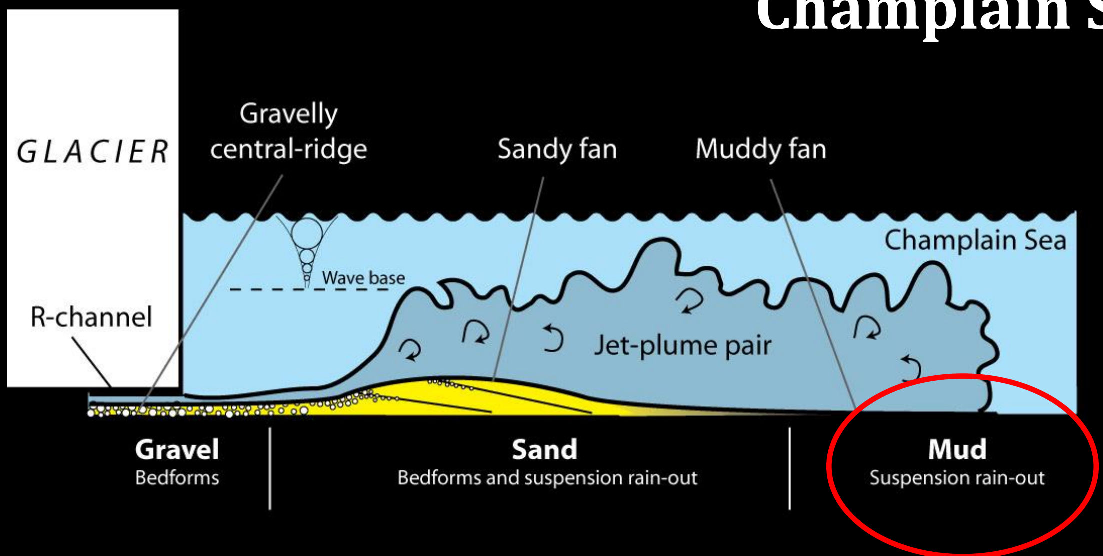
Ostrem et al., 2005



70-85% suspended load trapped

Myth 1 Mud is absent in esker systems (sensu lato)

Vars-Winchester esker, Champlain Sea basin



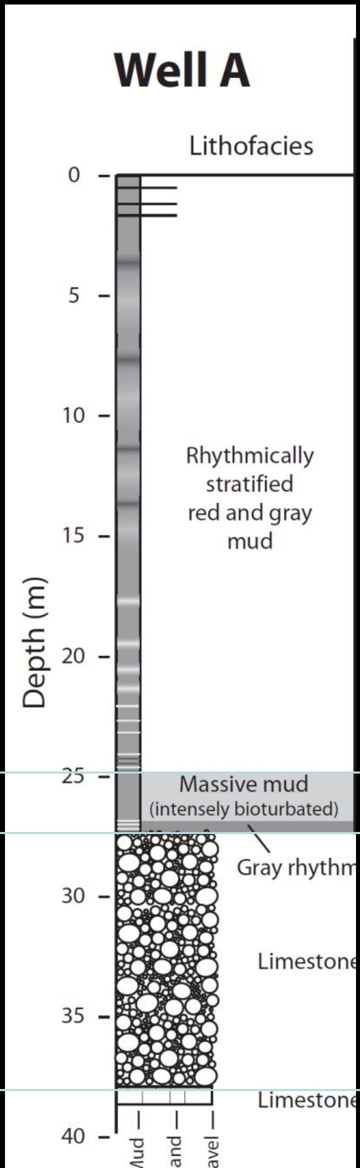
In the **Champlain Sea**, the esker-associated carbonate-rich mud onlaps the esker, forming the base of the glaciomarine mud package.

Carbonate-poor mud

ESKER SYSTEM

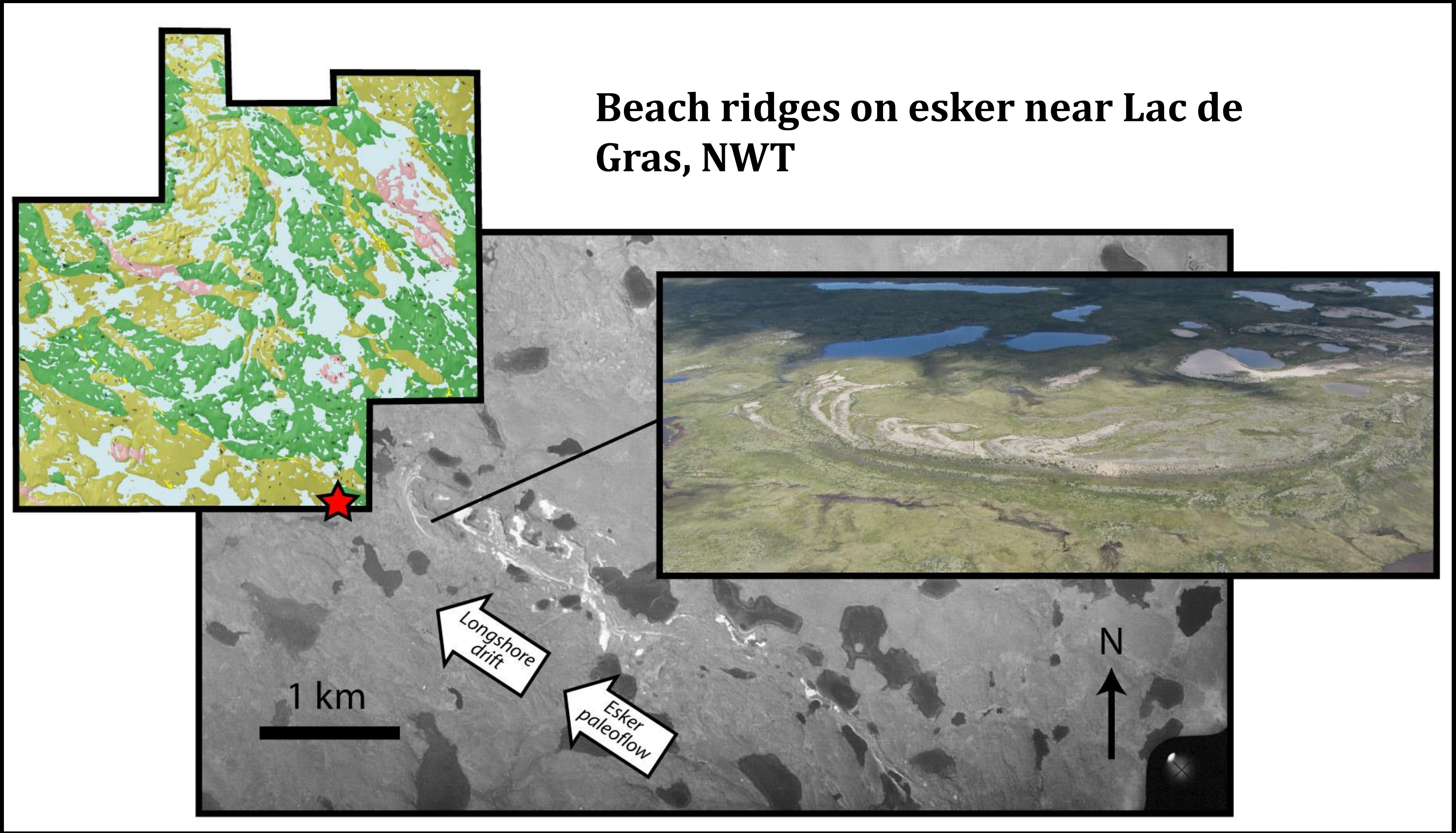
Carbonate-rich mud

Carbonate-rich gravel



Cummings et al., 2011a

Myth 1 Mud is absent in esker systems (sensu lato)



Cummings et al., 2013

Where's the "missing" mud in the Arctic?

Myth 1 Mud is absent in esker systems (sensu lato)

Where's the mud?

Not much in till?
Carried away by proglacial streams?
Bypassed area through long R-channels?
Cryoturbated into the till?

Myth 1 ~~Mud is absent in esker systems (sensu lato)~~

If one assumes that eskers are derived primarily from till and/or debris-rich basal ice, mud should actually be the **dominant grain size** in most esker sedimentary systems. Absence of mud where eskers are present (e.g., Keewatin) needs to be accounted for.

Applications

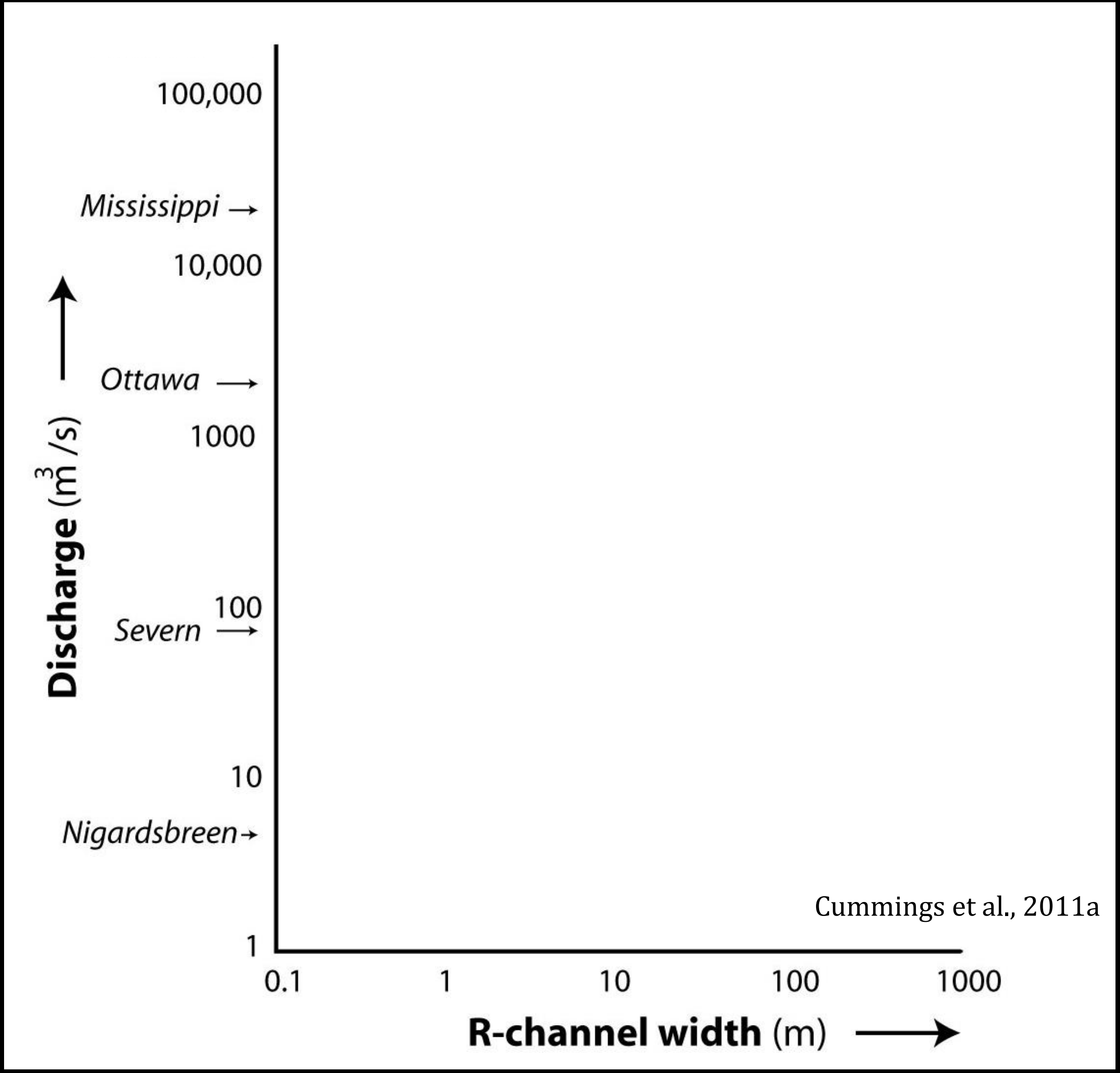
-mineral exploration

-aggregate assessment

Myth 2 Eskers form during exceptionally high (or low) discharges

*Exceptionally high or low magnitude

Myth 2 Eskers form during exceptionally high (or low) discharges



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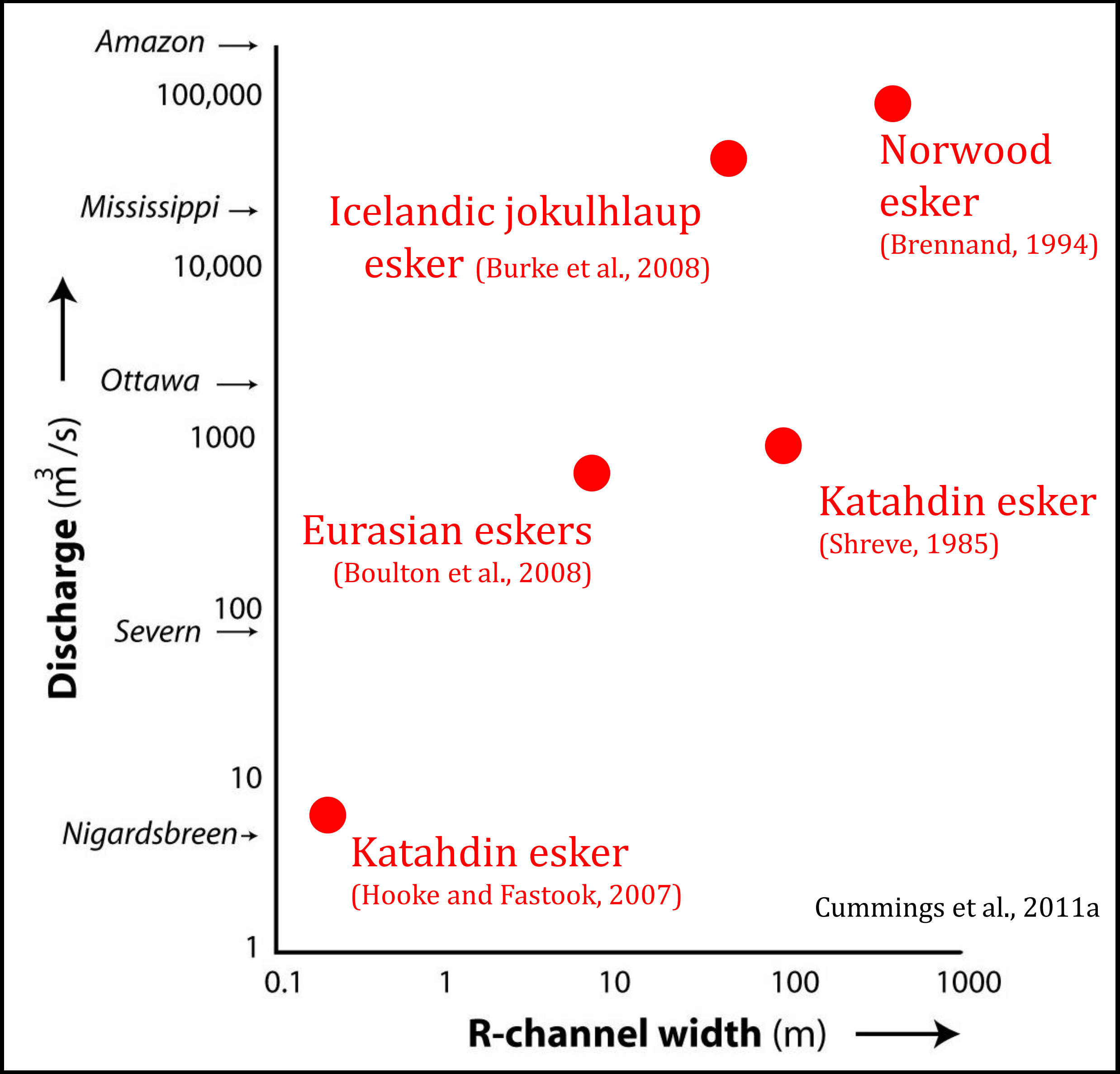
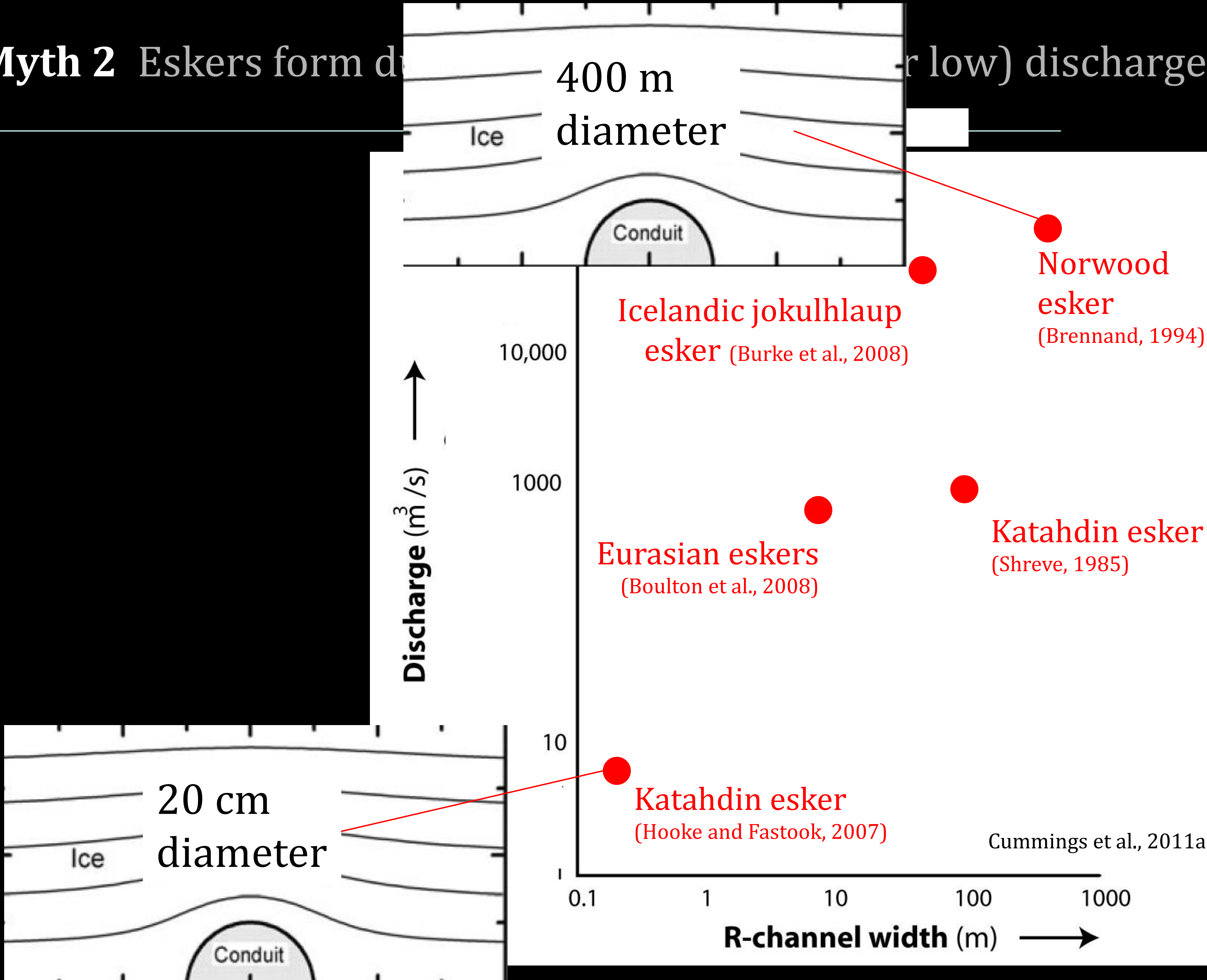
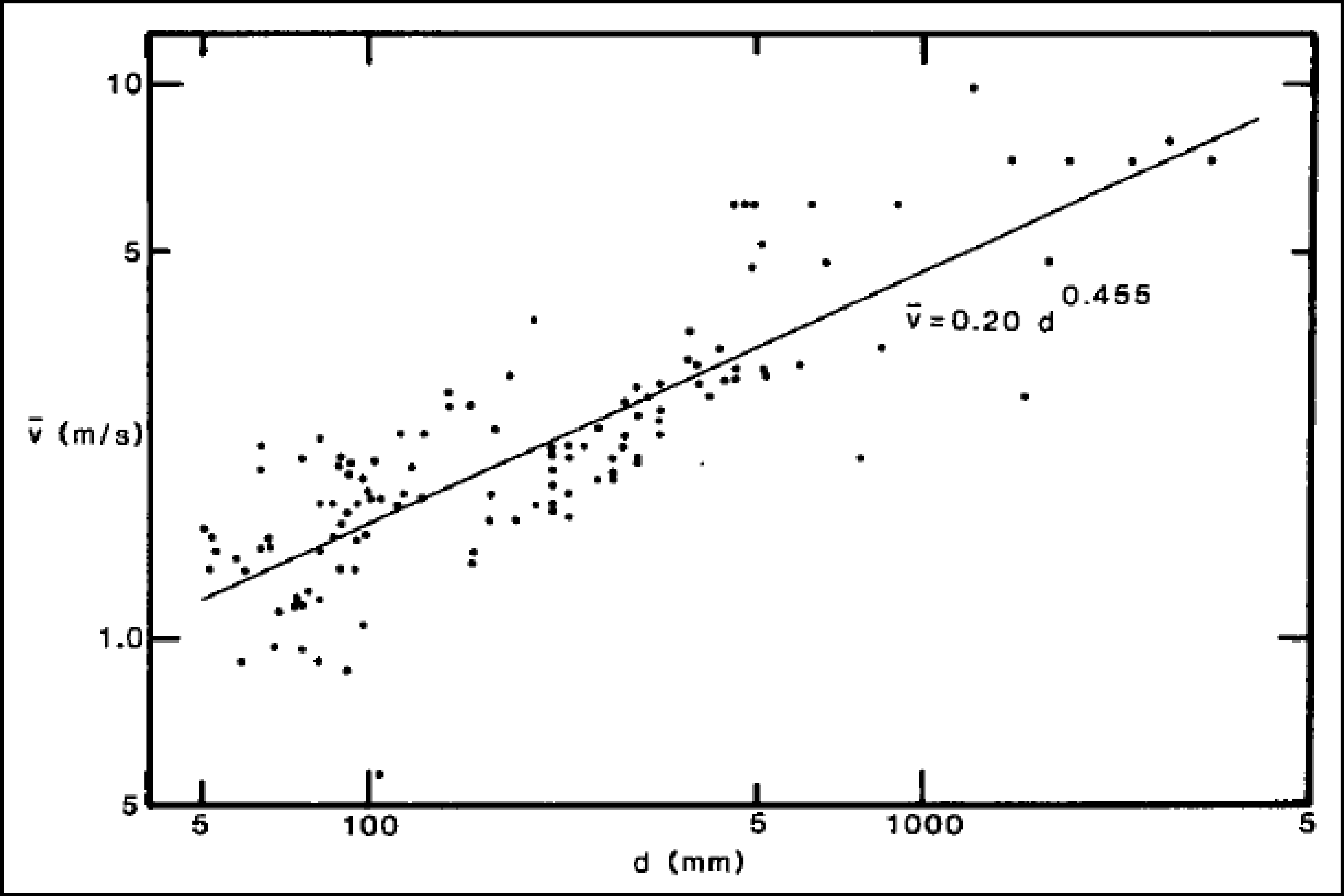


Myth 2 Eskers form d r low) discharges



Myth 2 Eskers form during exceptionally high (or low) discharges



Velocity vs clast size (Costa, 1983)

Myth 2 Eskers form during exceptionally high (or low) discharges

Vars-Winchester esker -- **Paleodischarge estimate**

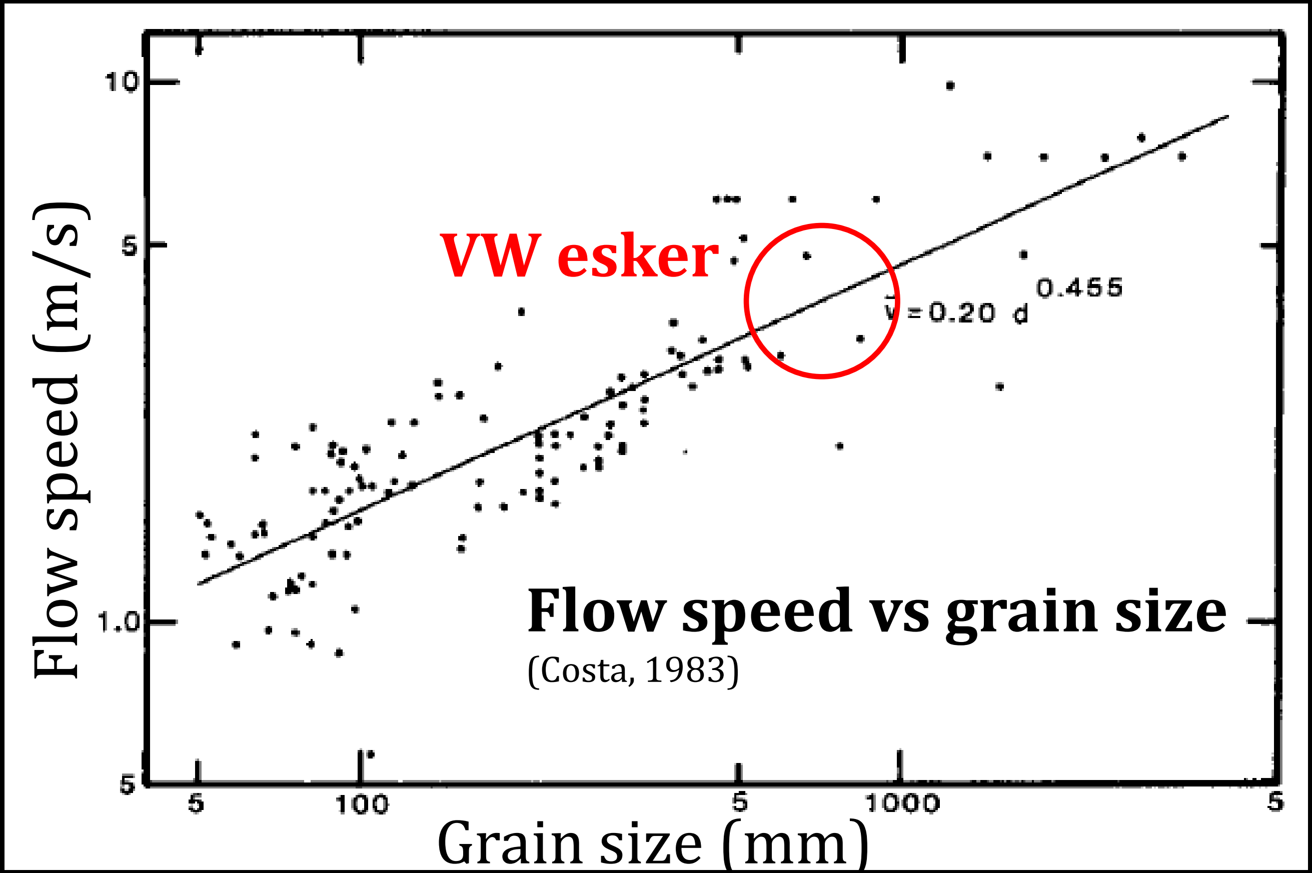
-R-channel width → 10 to 100 m (bed widths, dune:flow depth ratios)

Myth 2 Eskers form during exceptionally high (or low) discharges

Vars-Winchester esker -- **Paleodischarge estimate**

-R-channel width → 10 to 100 m (bed widths, dune:flow depth ratios)

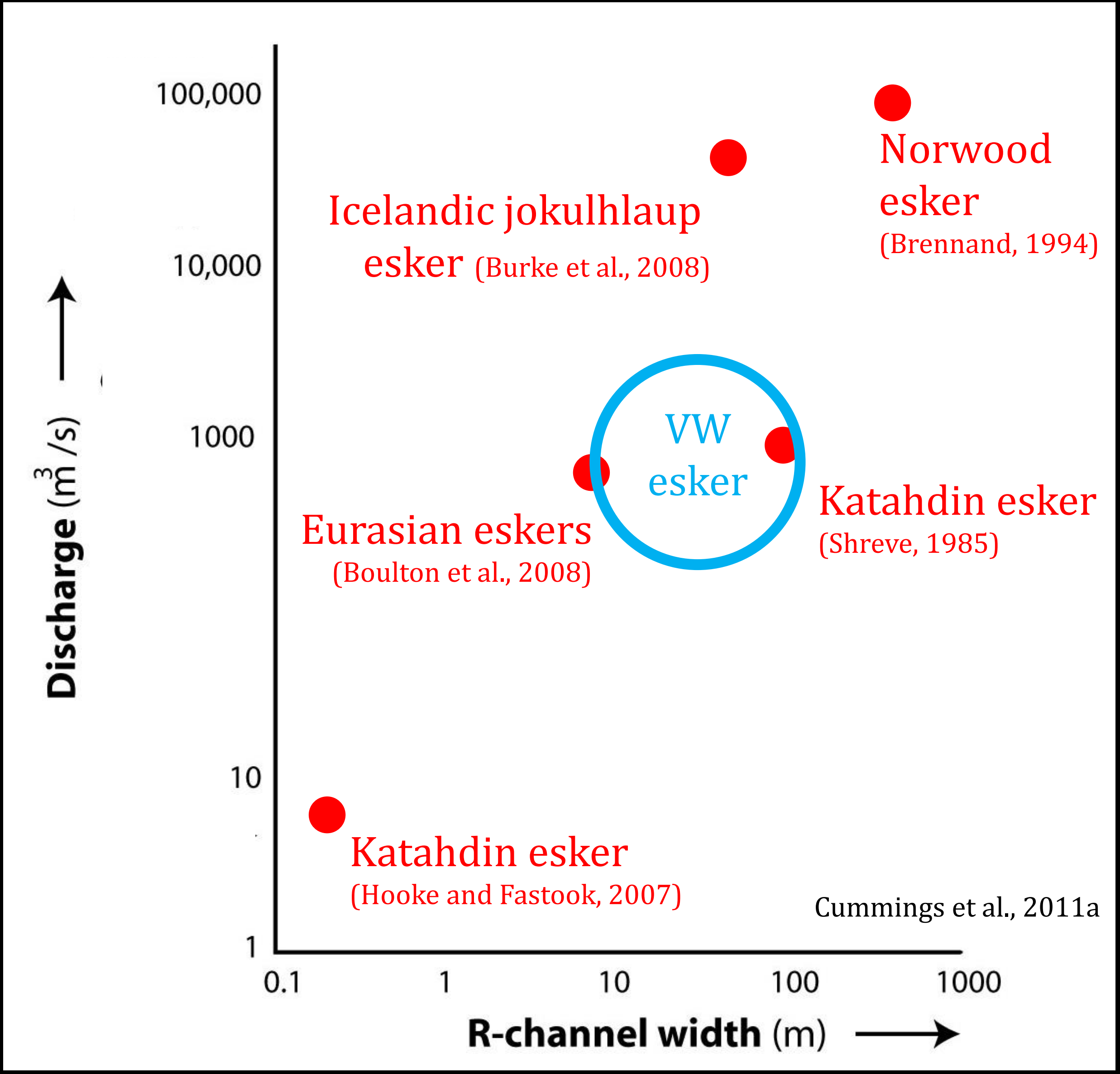
-Flow velocities → several m/s (cobbles with rare small boulders)



Myth 2 Eskers form during exceptionally high (or low) discharges

<u>Paleodischarge</u>

Similar to modern Ottawa River



Myth 2 ~~Eskers form during exceptionally high (or low) discharges~~

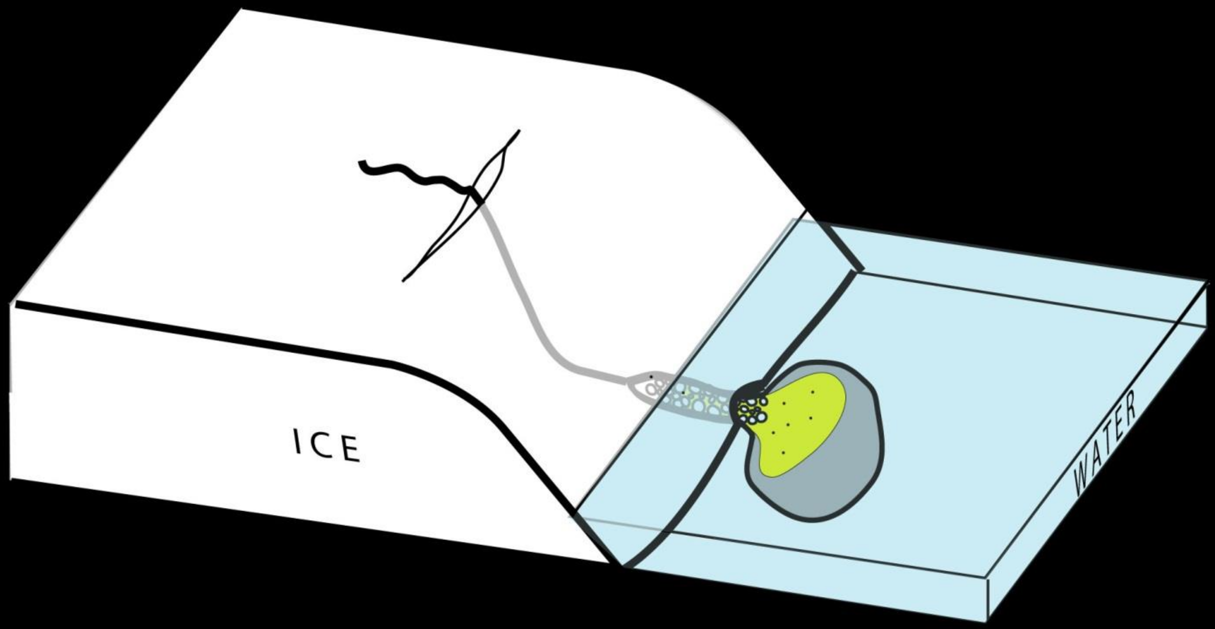
Previous extreme paleodischage estimates (high or low) for eskers are unlikely.

Constant esker spacings and x-sections suggest a narrower range of paleodischarges.

Myth 3 Long eskers form in long R-channels

Long-tunnel model

Tunnel length = esker length



Hummel (1874)
Flint (1930)
Shreve (1985)
Brennand & Shaw (1996)

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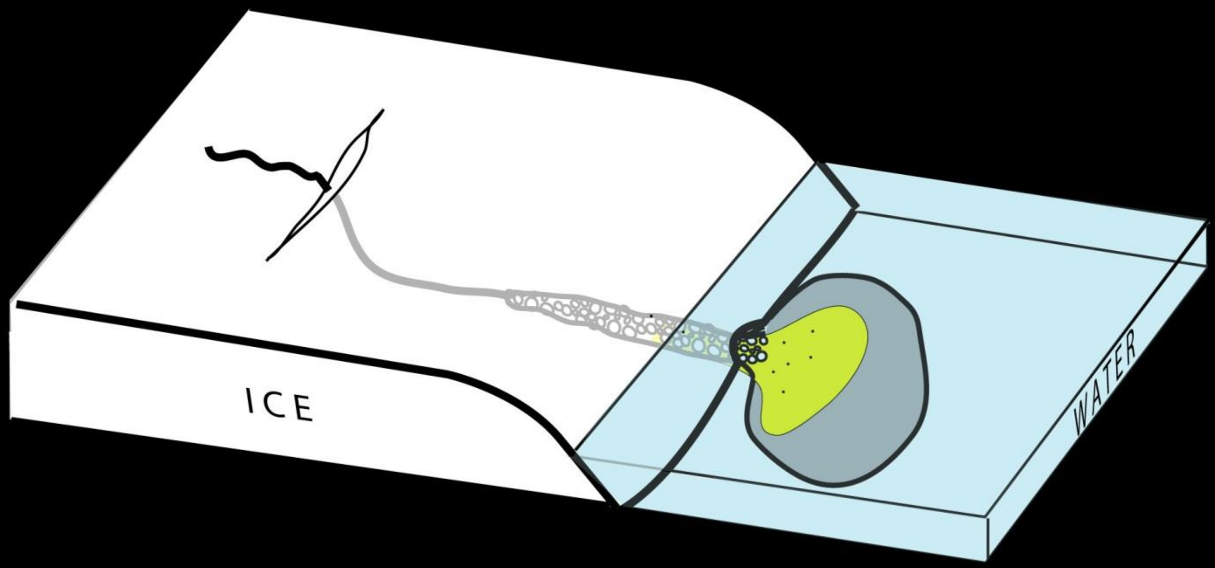

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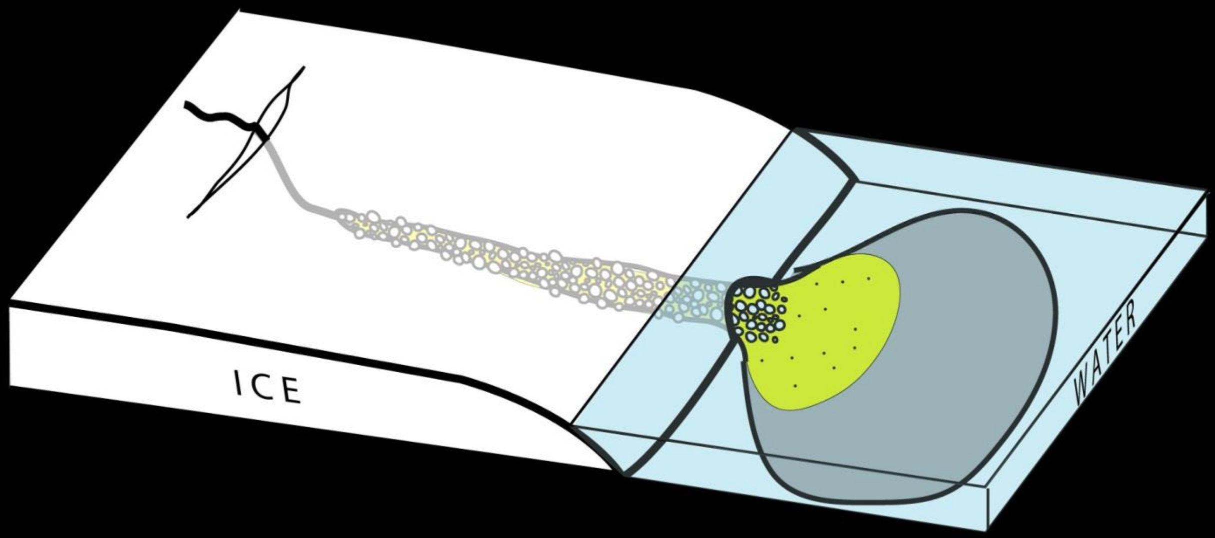
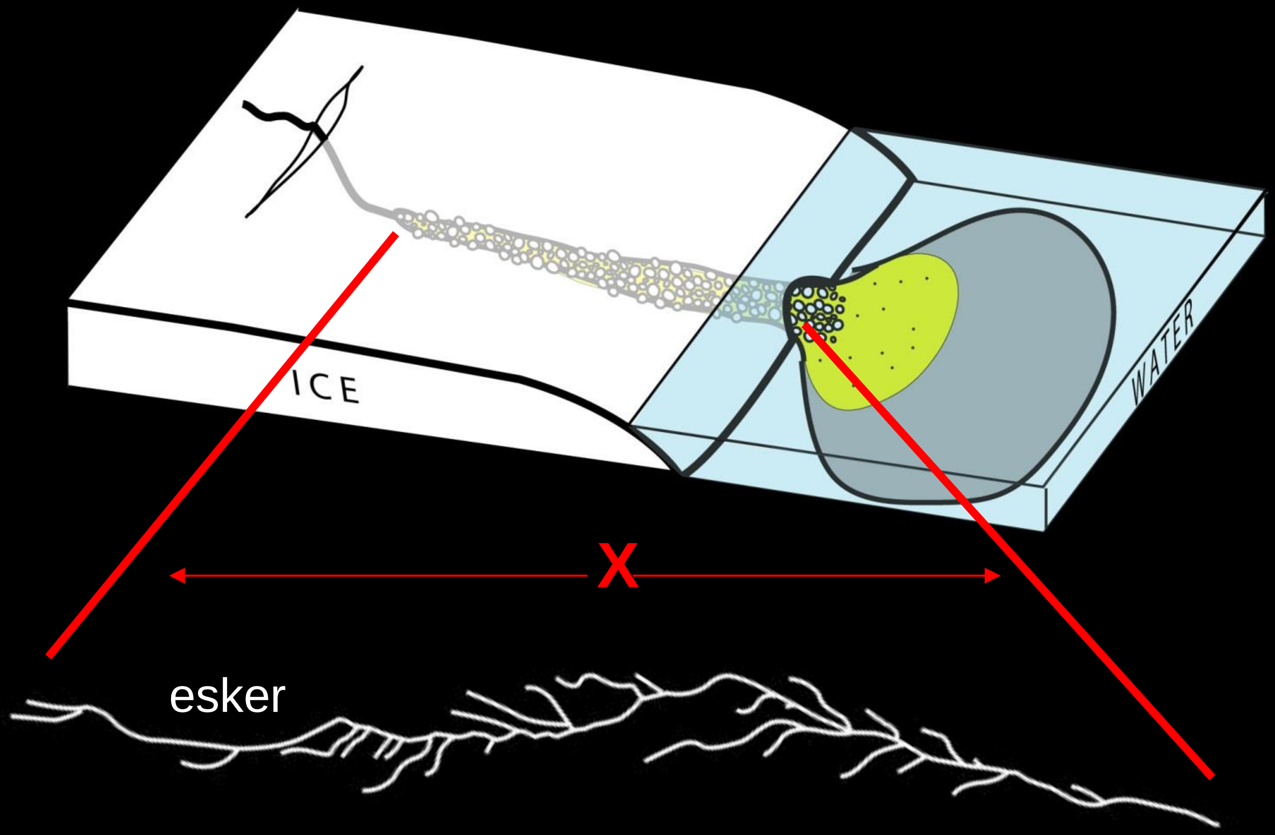


Hummel (1874)
Flint (1930)
Shreve (1985)
Brennand & Shaw (1996)

Exploration significance

Long distance dispersal possible (esp. suspended load).



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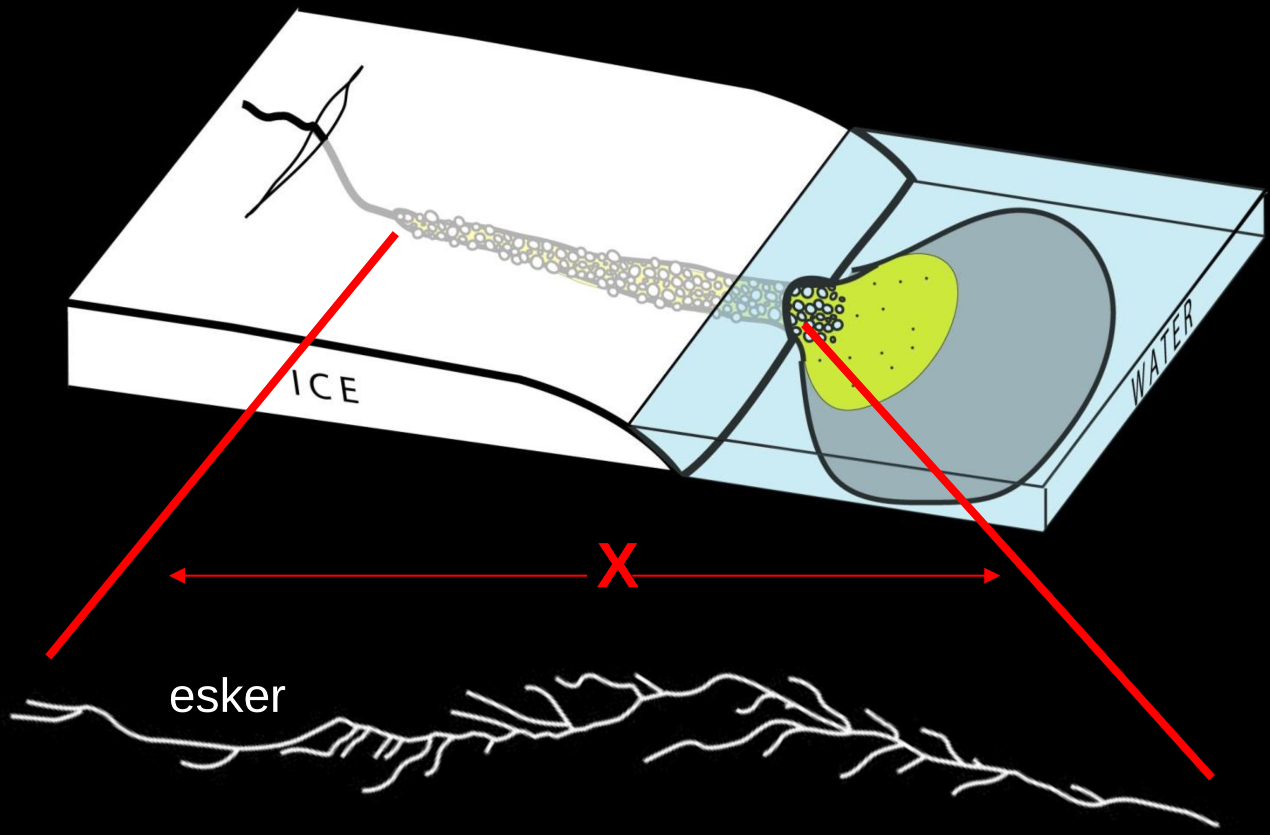
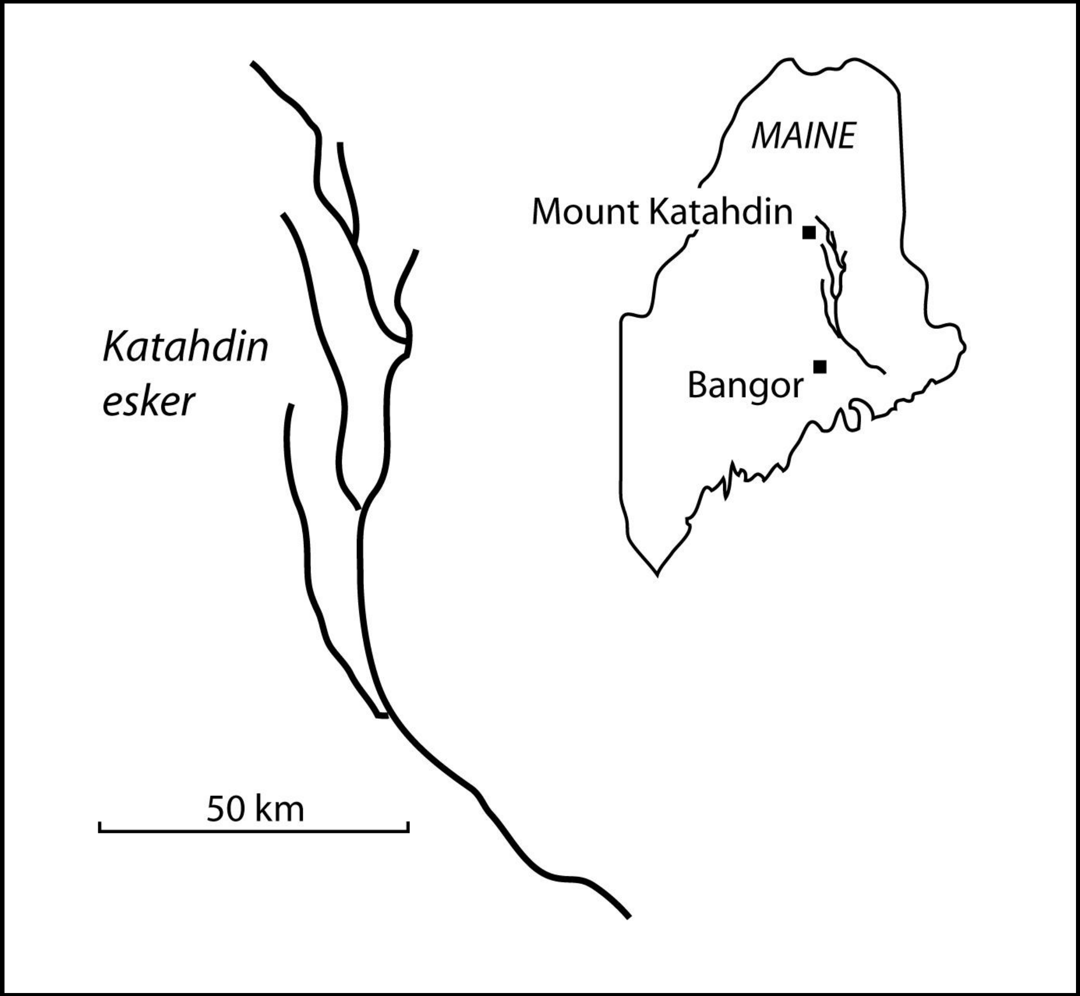


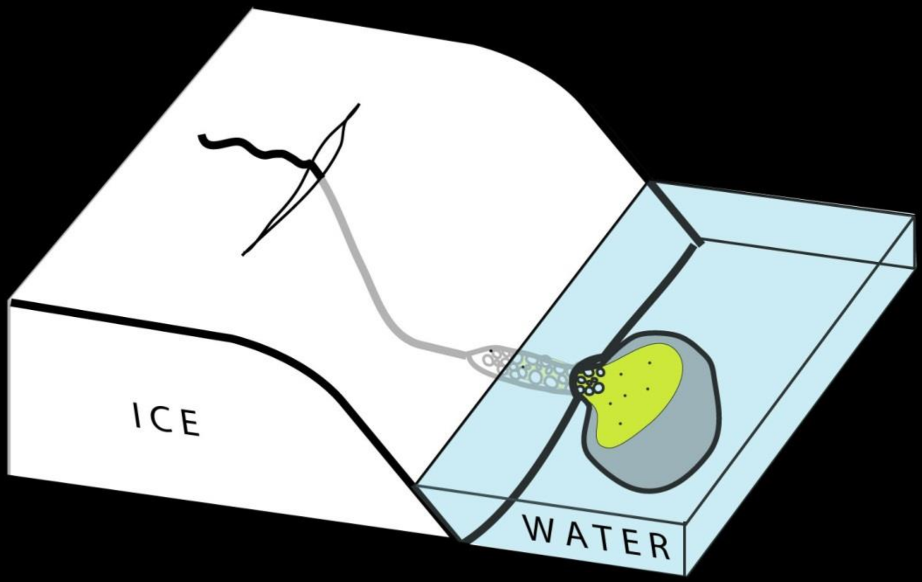
Shreve (1985):	X ~ 150 km
Brennand & Shaw (1996):	X ~ 500 km



Shreve (1985)
Katahdin esker composed of one single ~150 km long segment

Short-tunnel model

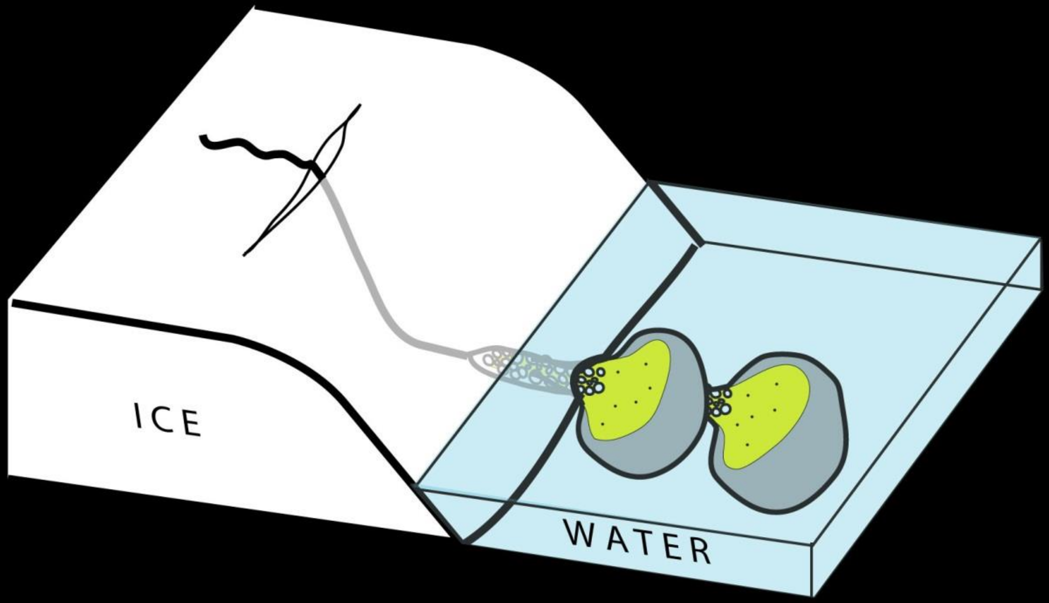
Tunnel length << esker length



De Geer (1912)
Banerjee & MacDonald (1975)
St. Onge (1984)
Shilts (1973, 1984)
Hooke & Fastook (2007)

Short-tunnel model

Tunnel length << esker length



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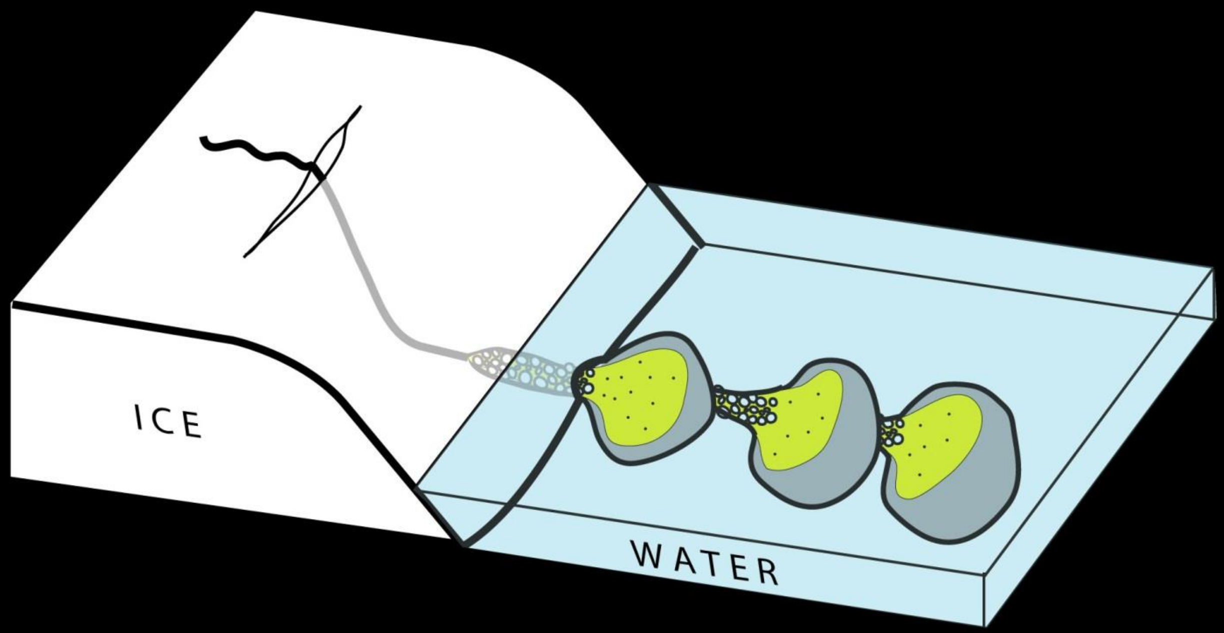

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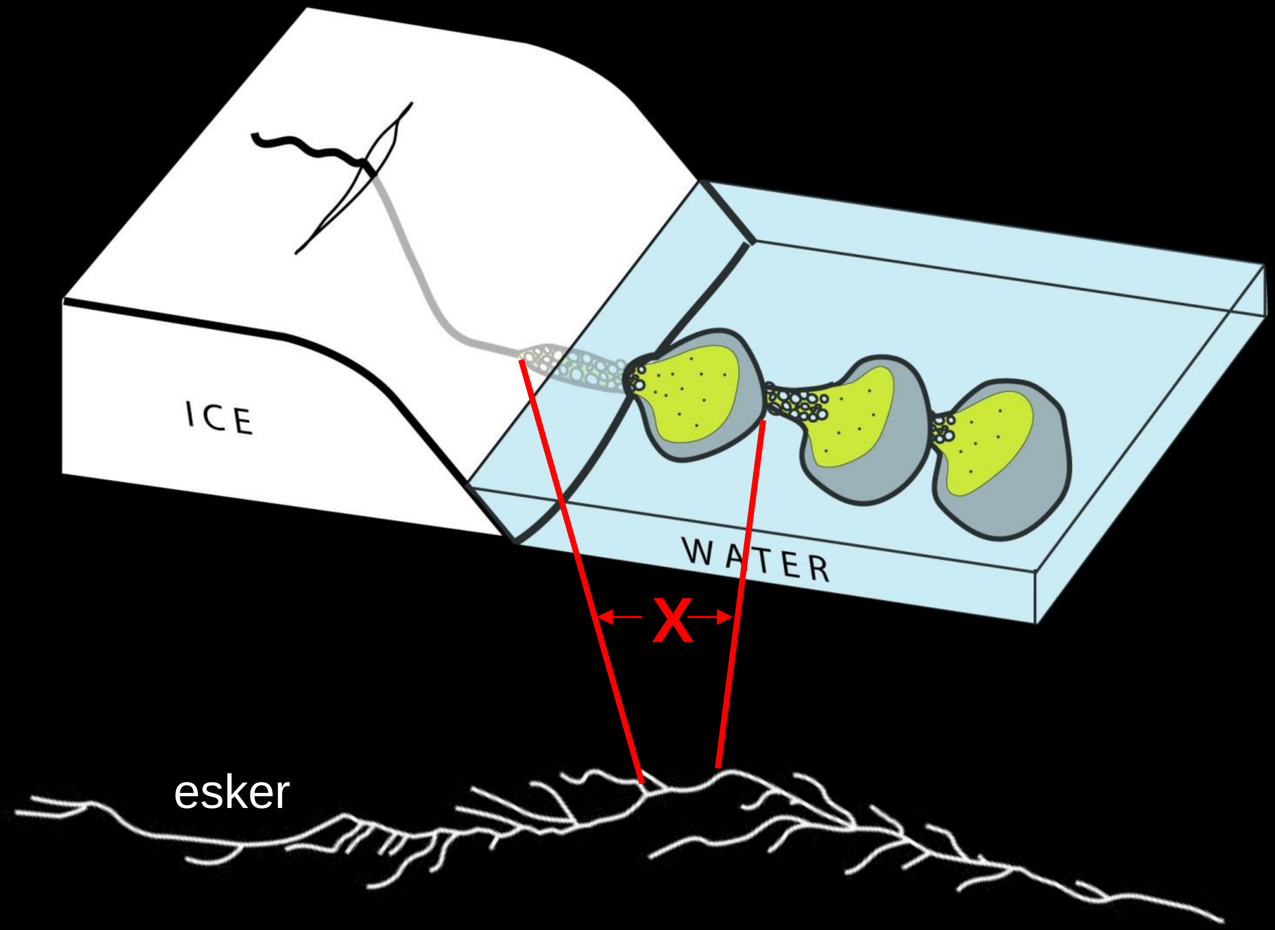
Hooke & Fastook (2007)

Exploration significance

Limited dispersal distance for all grain sizes (mud, sand & gravel).



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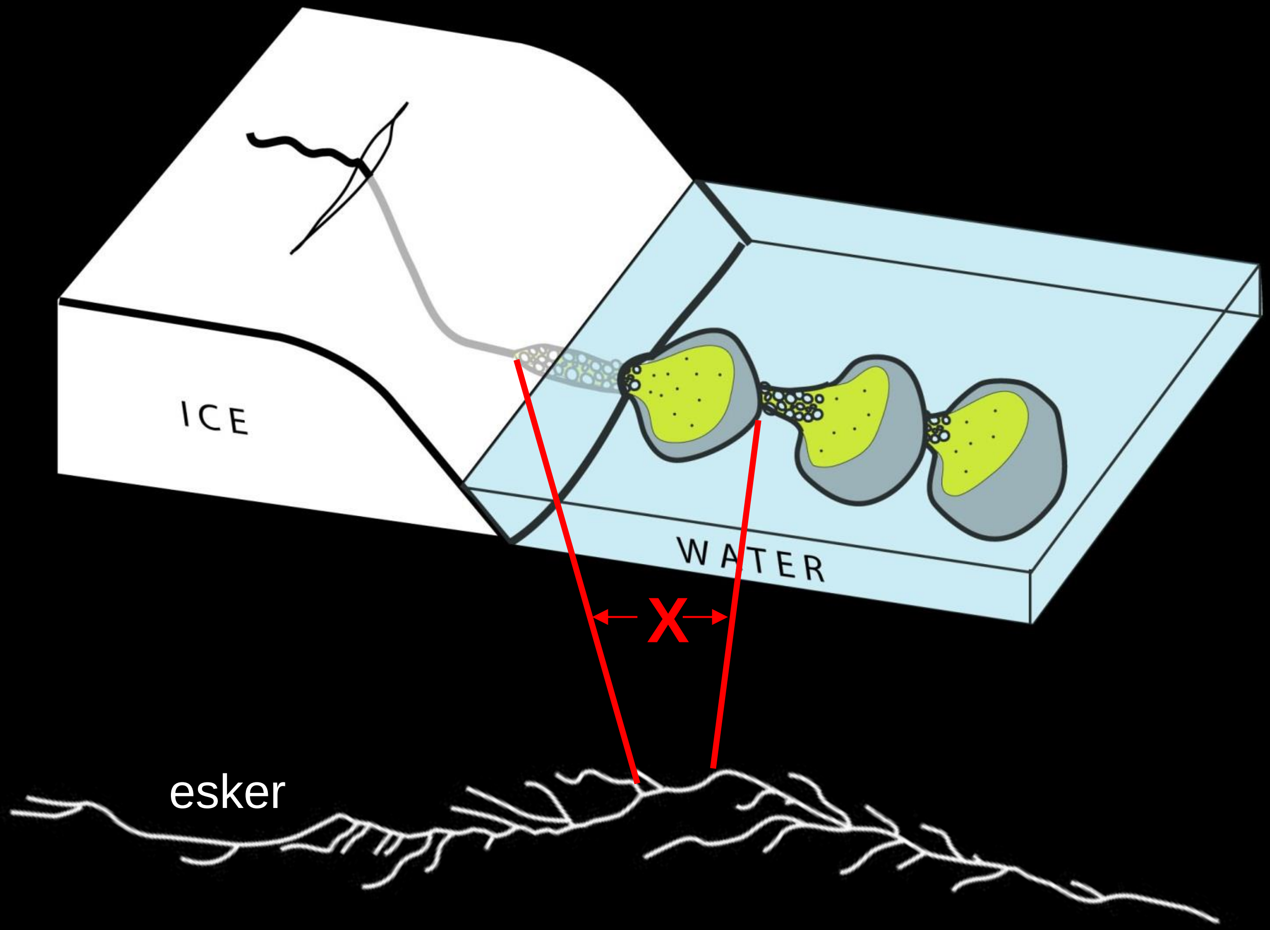
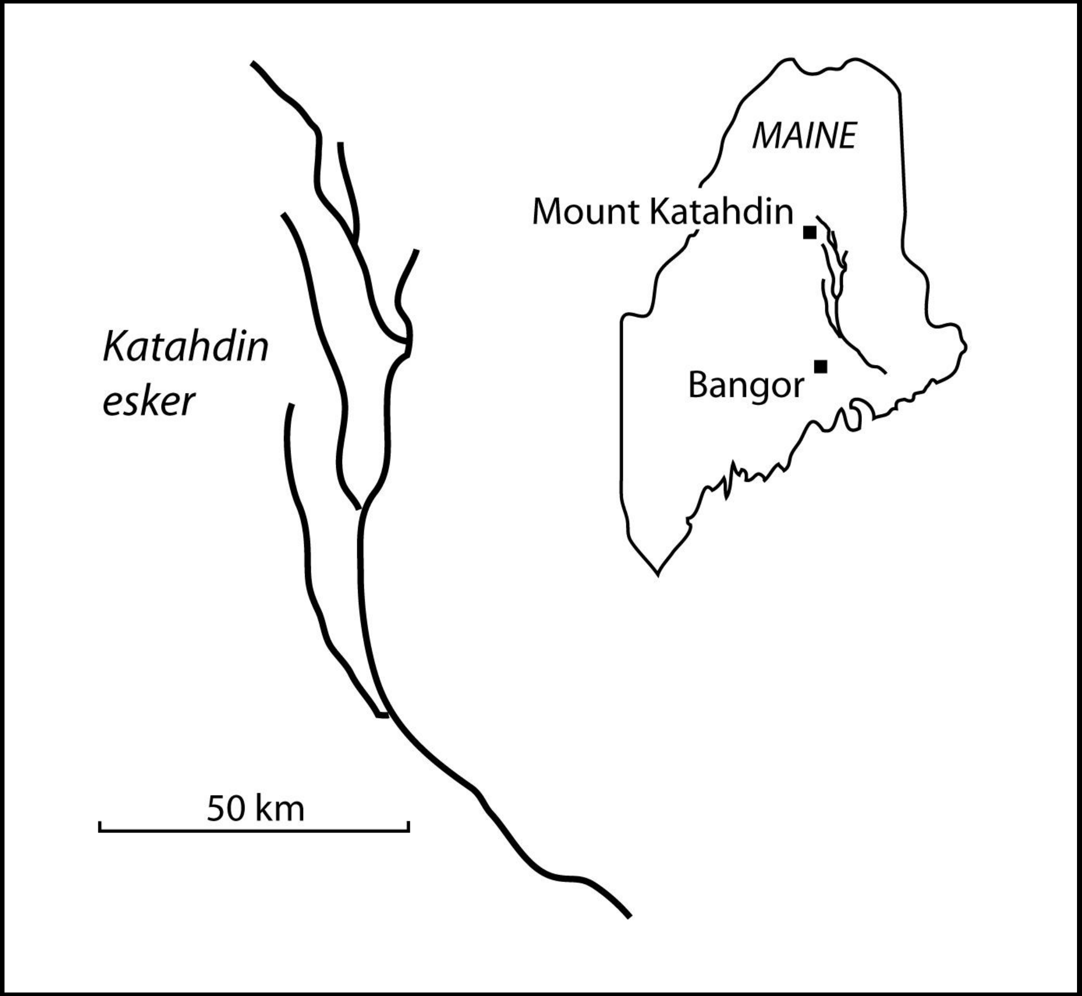


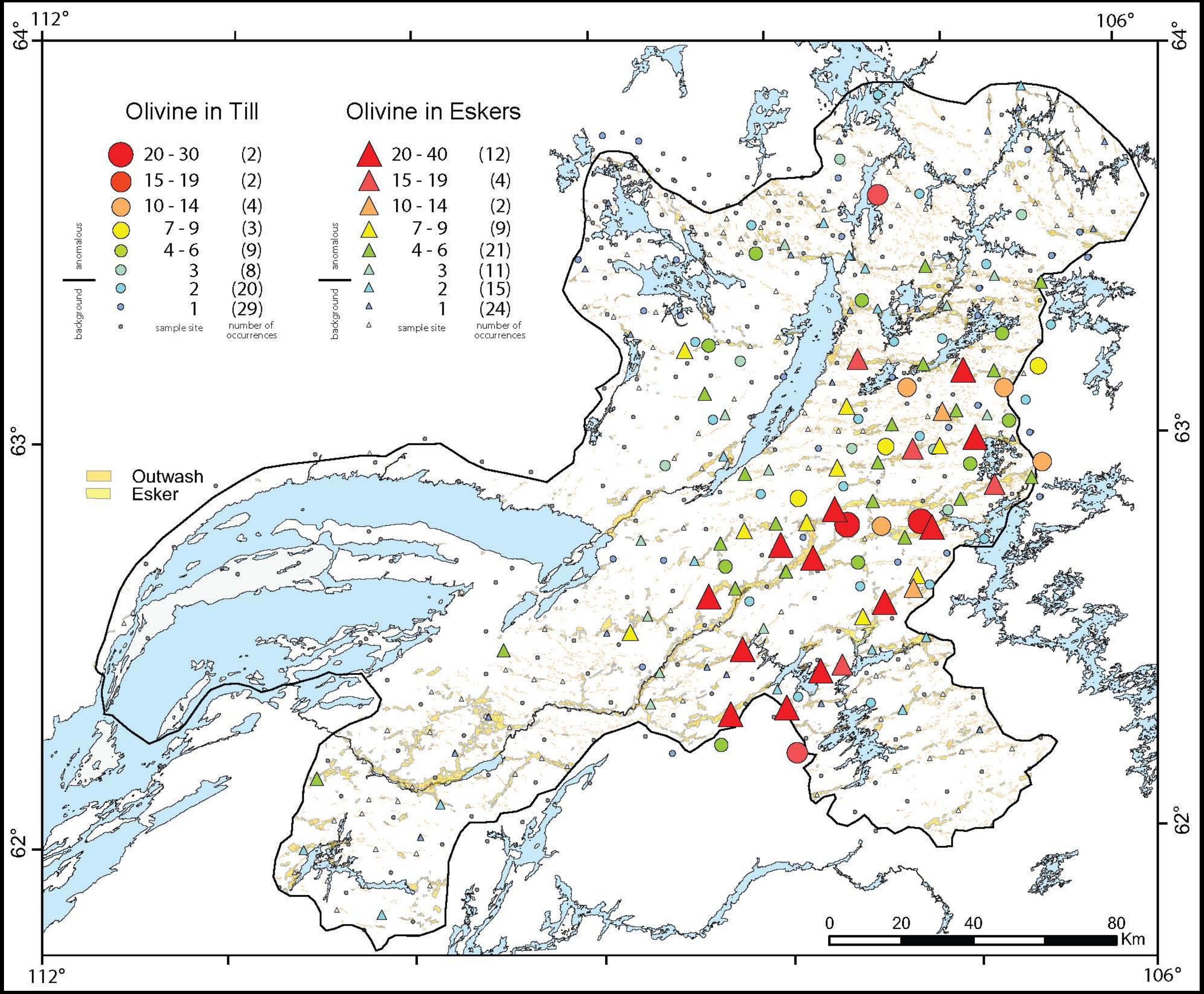
St. Onge (1984):	X = 1-2 km
Hooke & Fastook (2007):	X = 5 km



Hooke & Fastook (2005)
Katahdin esker composed of multiple segments, each ~5 km long

Dispersal trains in till vs eskers, East Arm

Kjarsgaard et al., 2013



Dispersal trains in till vs eskers, East Arm

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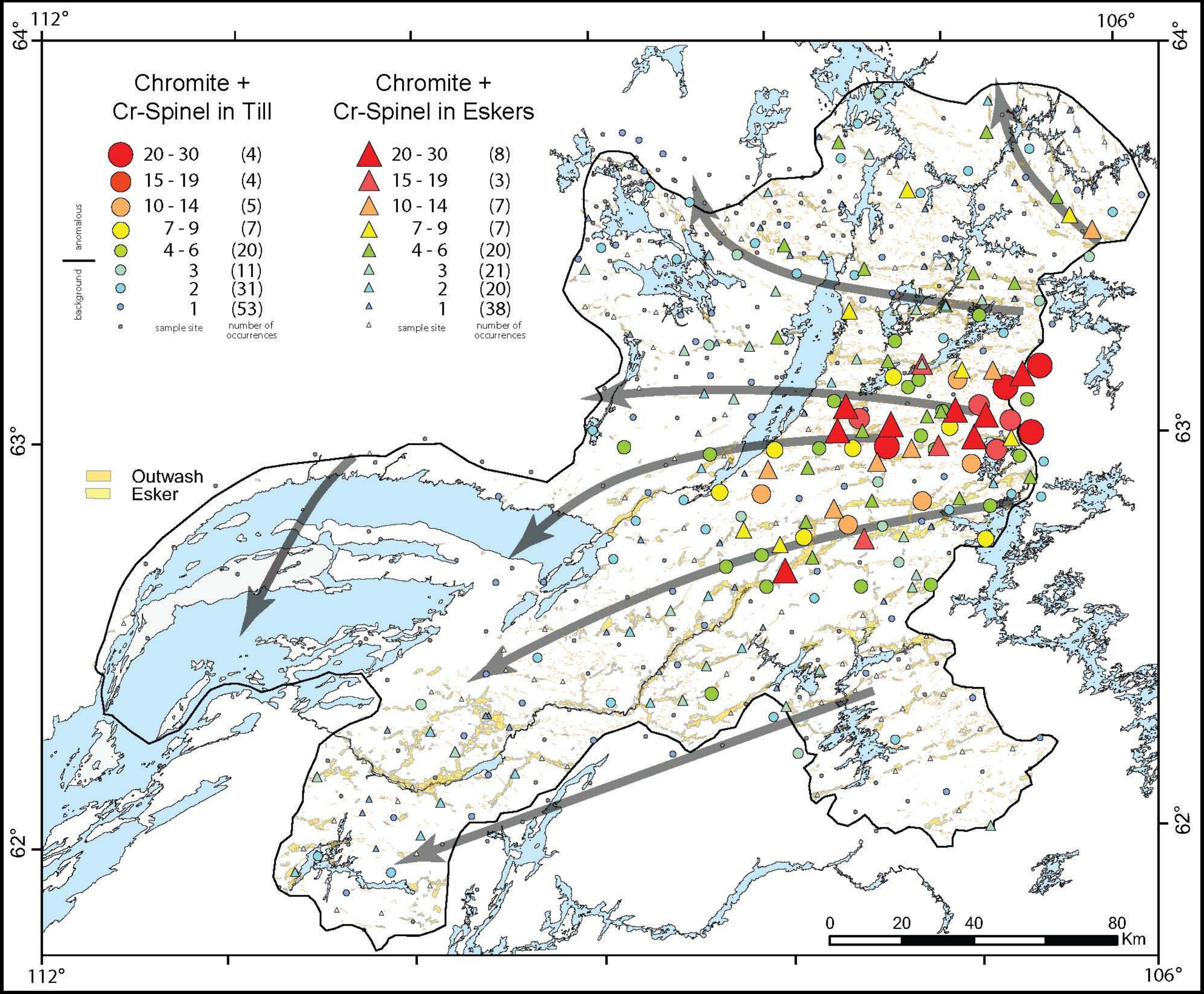
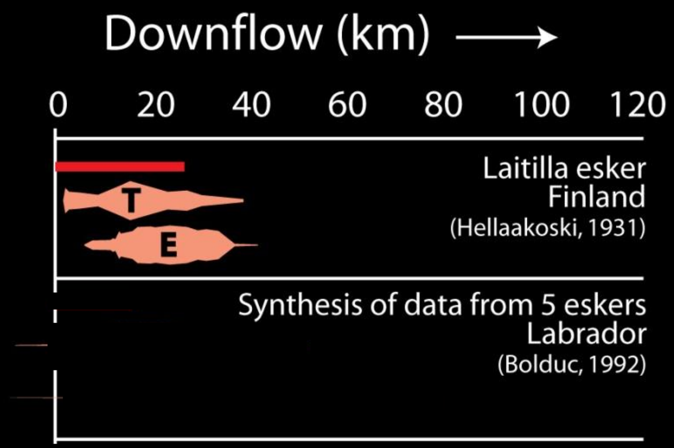


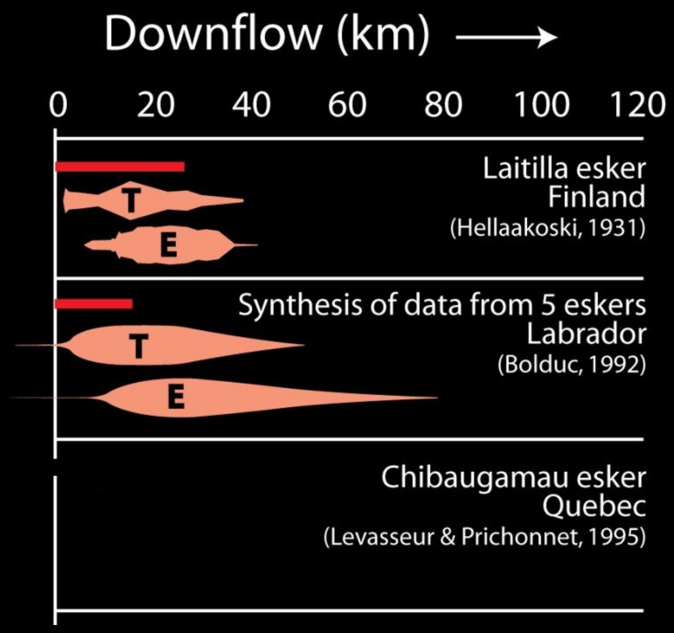
GRAVEL

Cummings et al, 2011, Earth Sci Rev



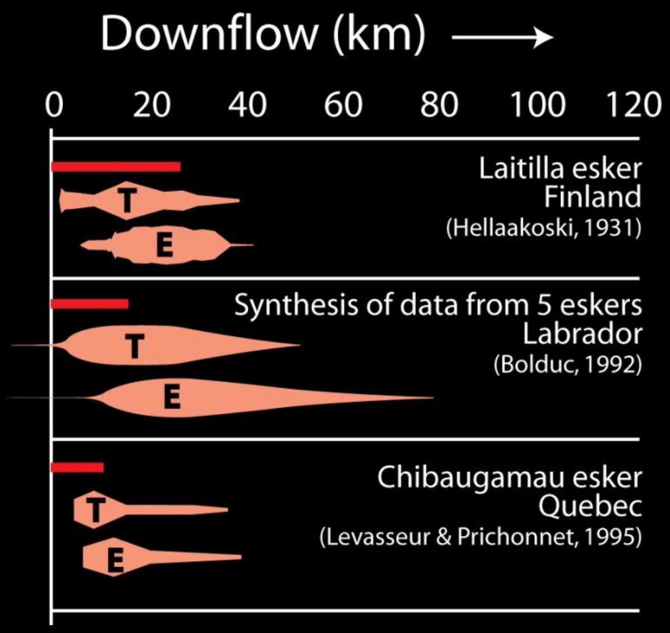
GRAVEL

Cummings et al, 2011, Earth Sci Rev



GRAVEL

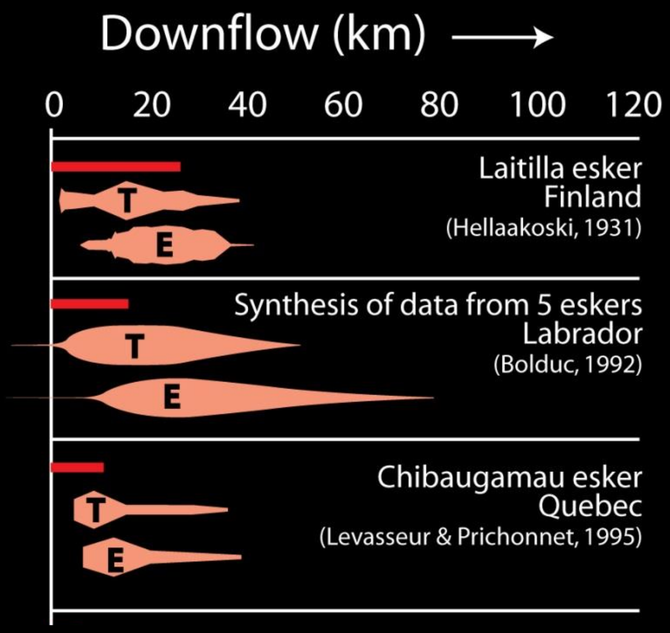
Cummings et al, 2011, Earth Sci Rev



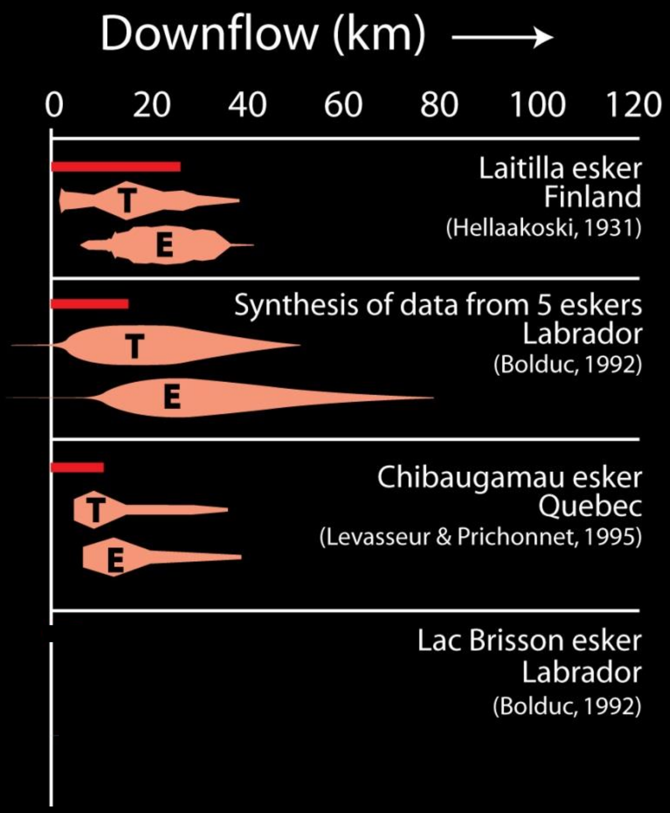
GRAVEL

Gravel seems to not to be dispersed far down-esker, typically only several km to max. 25 km past the till dispersal train (i.e., the source of IMs).

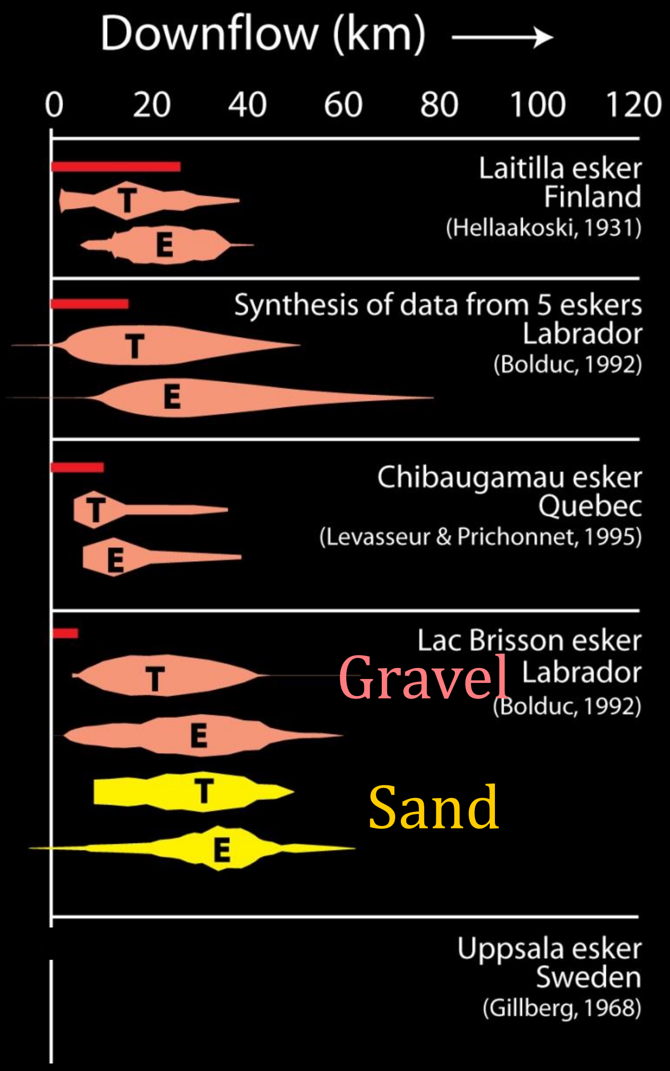
Cummings et al, 2011, Earth Sci Rev



Cummings et al, 2011, Earth Sci Rev

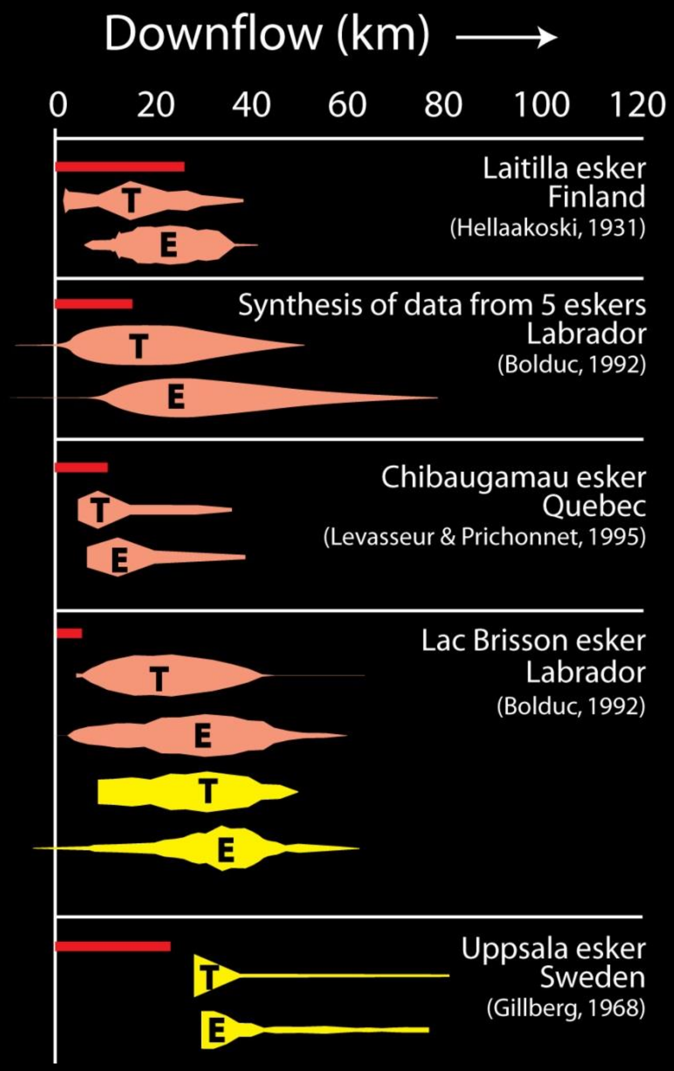


Cummings et al, 2011, Earth Sci Rev



SAND

Cummings et al, 2011, Earth Sci Rev

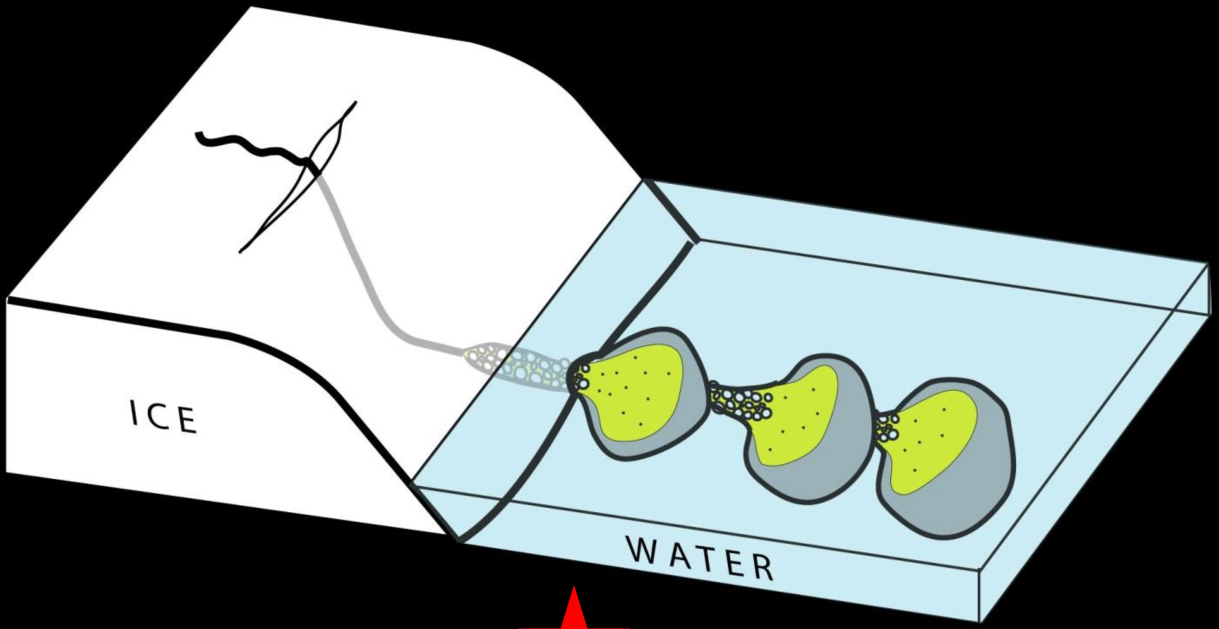


SAND
Surprisingly, sand-sized particles exhibit similar dispersal distances.

CAUTION: Only 2 “comprehensive” studies published to date.

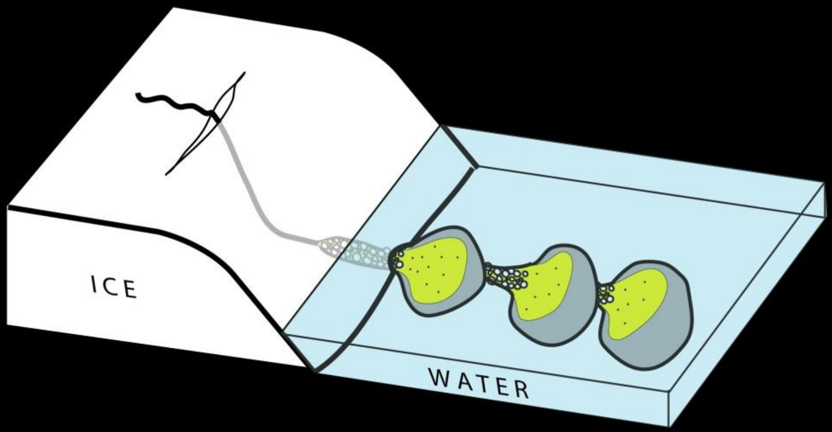
Cummings et al, 2011, Earth Sci Rev

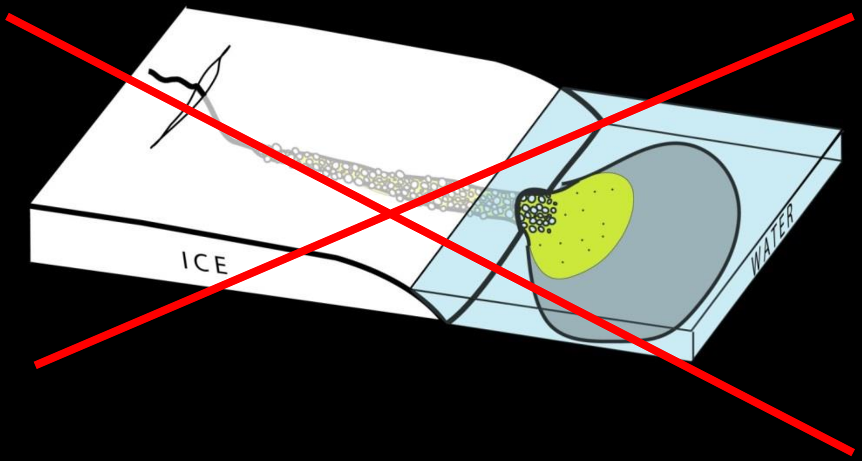
Taken by itself, provenance data seems to argue for the "**short conduit**" depositional model.
(CAUTION: ONLY TWO COMPREHENSIVE STUDIES TO DATE.)



Also helps explain…
-lack of downstream fining
-lack of downstream widening
-absence of large terminal fans
-gaps in eskers
-elongate nature of tree-shaped eskers

Myth 3 Long eskers form in long R-channels

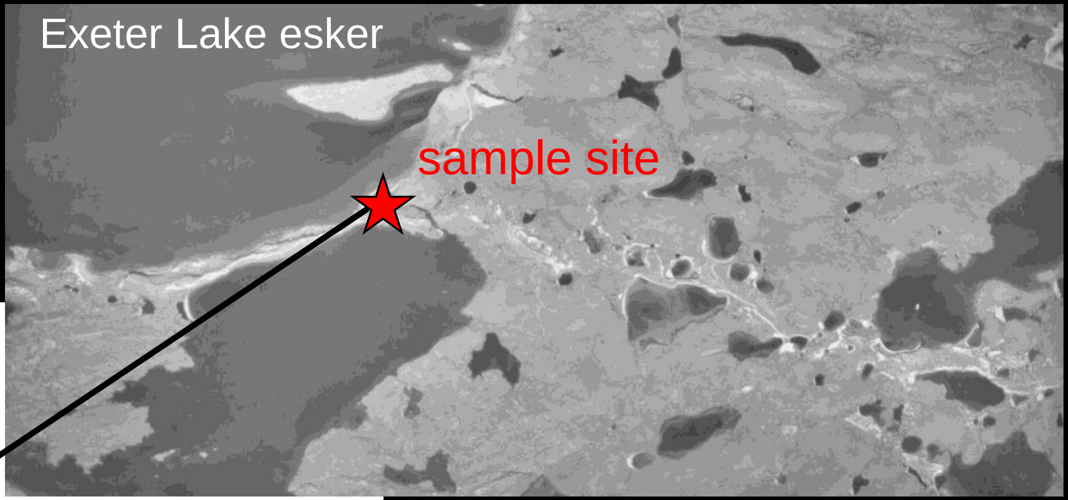


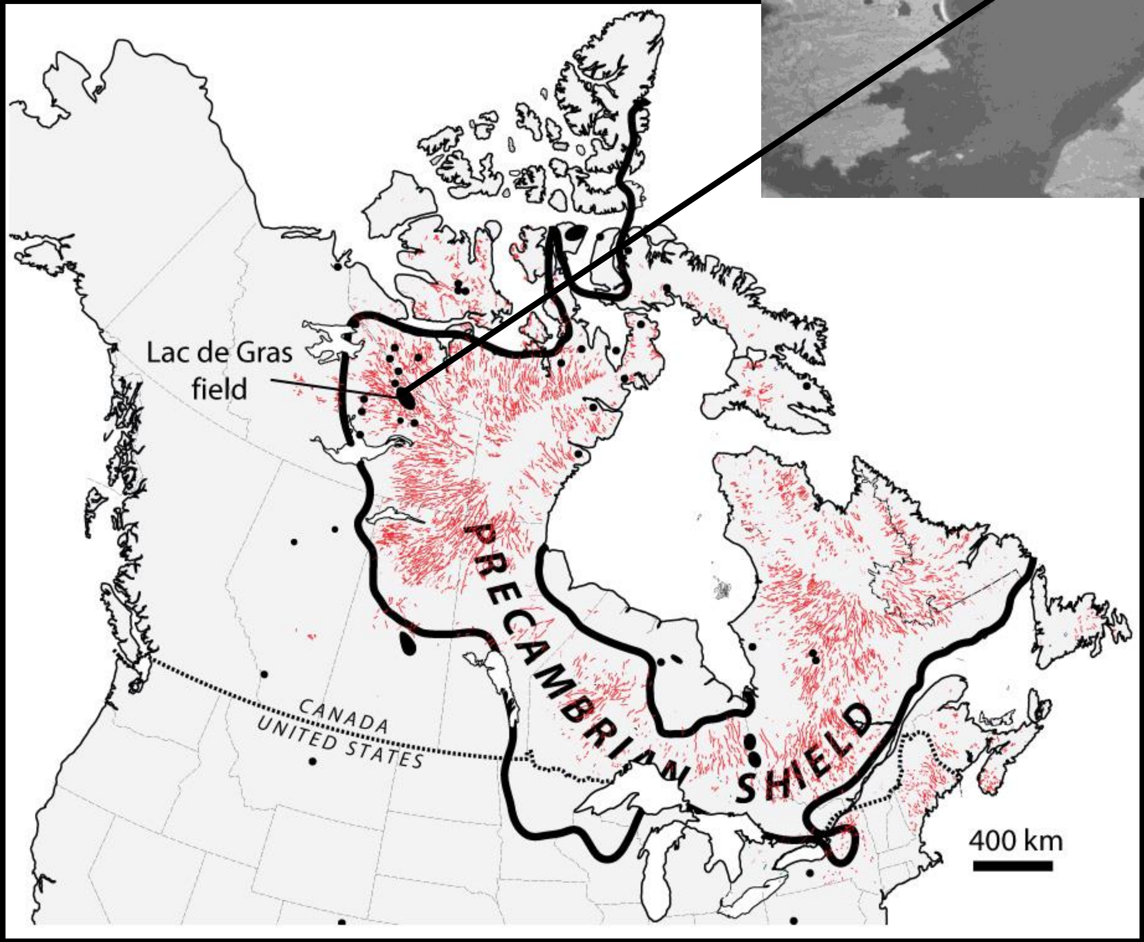


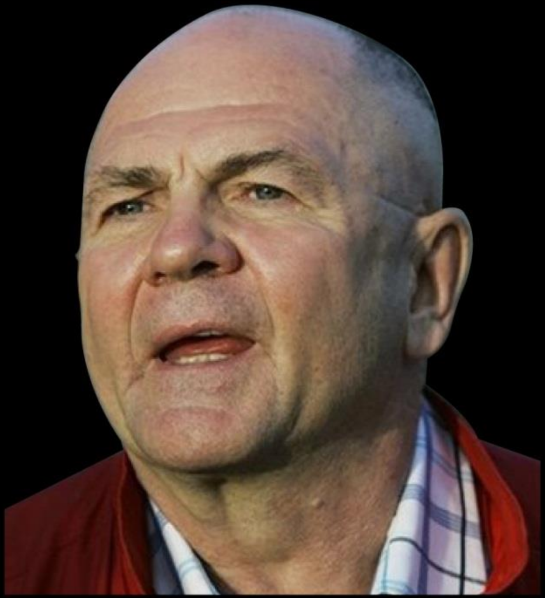
(CAUTION: <u>If data collected to date are representative.)</u>

Implications for mineral exploration

Eskers seem to provide similar information as till, but IMs are more highly concentrated







Chuck Fipke

Future work

TECHNIQUES/DATA

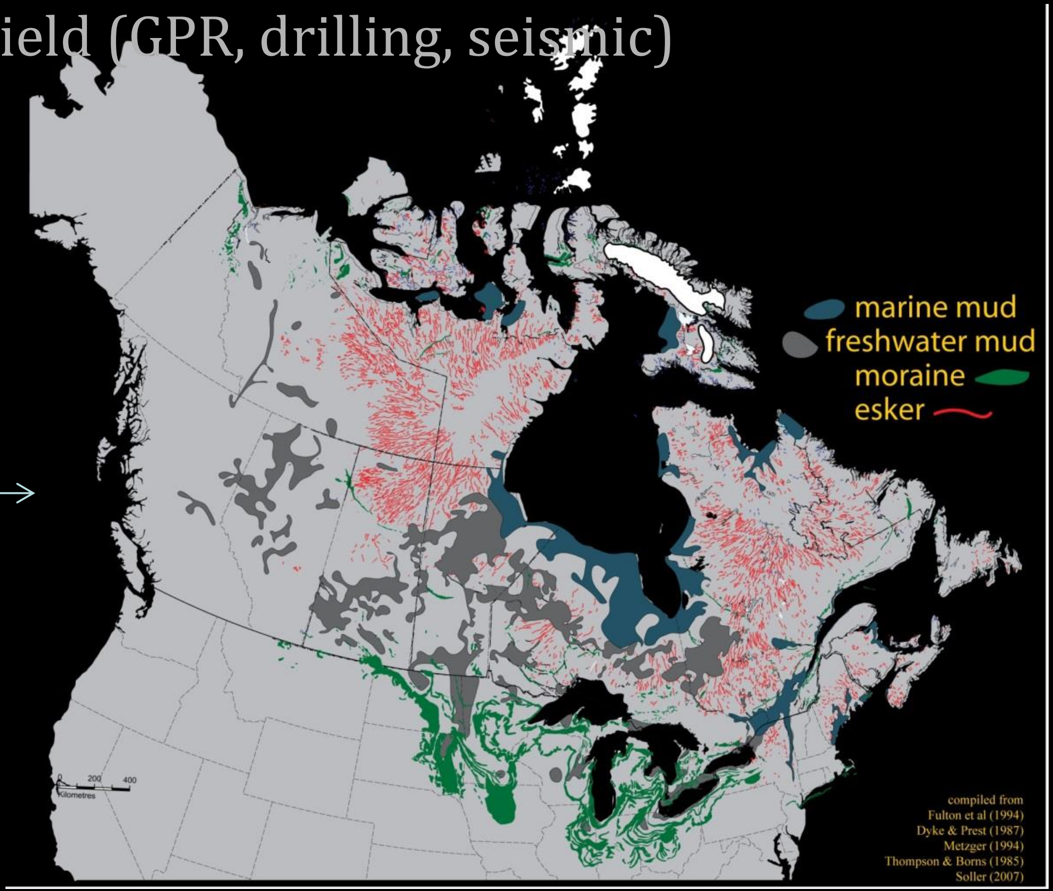
-Quantitative esker geomorphology. (Eskers are not lines on maps! No more chevron symbol! Esker volumes can be quantified; see Broscoe et al., 2013.)

-LiDAR = air photo of the future

-Boots on ground needed on Shield (downflow fining trends, provenance of finer fractions)

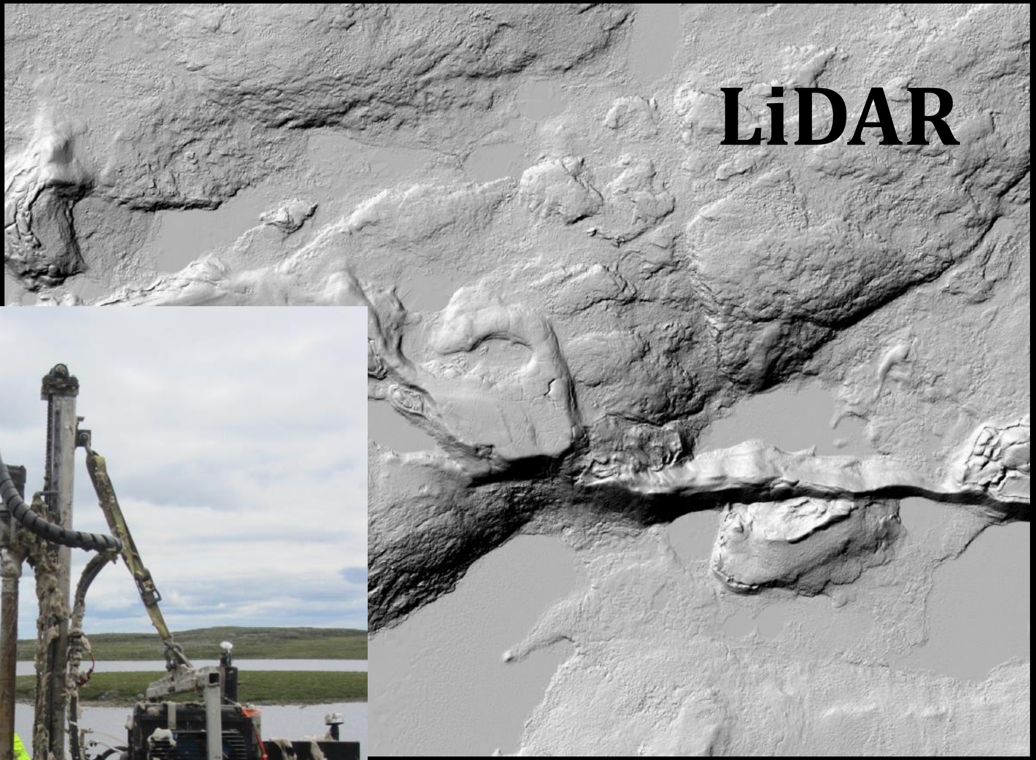
-Subsurface data needed on Shield (GPR, drilling, seismic)

How do we move past this? →



Neil Prowse, MSc candidate, Carleton

Exeter Lake esker study



Provenance

FUNDAMENTAL QUESTIONS

Mud in Arctic: where is it?

Paleodischarge: importance of jokulhlaups vs seasonal (i.e., astronomical) forcing (e.g., varves)

Esker corridors: why so big?

R-channel length. Does "short" model apply all the time? How short is short?