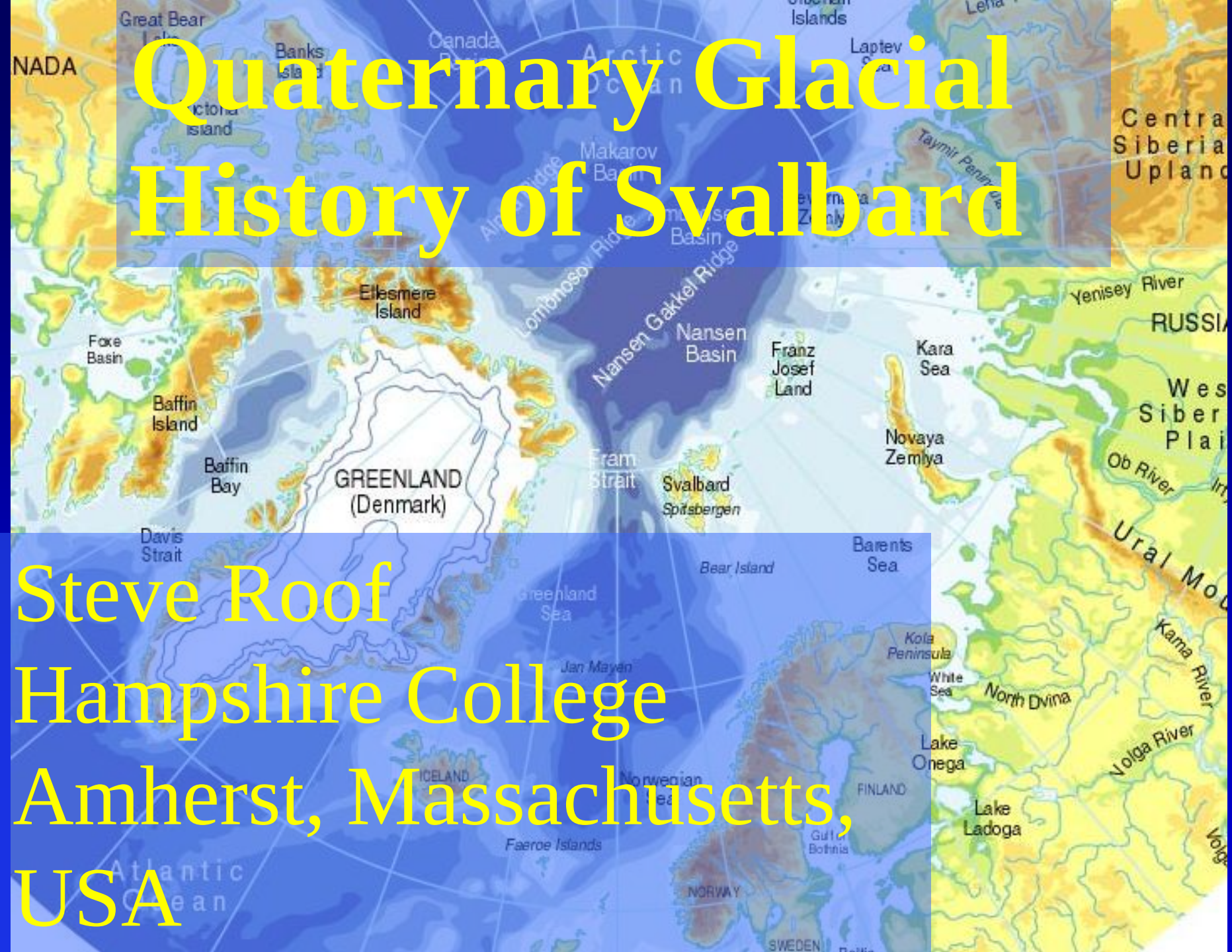
Quaternary Glacial History of Svalbard



Steve Roof
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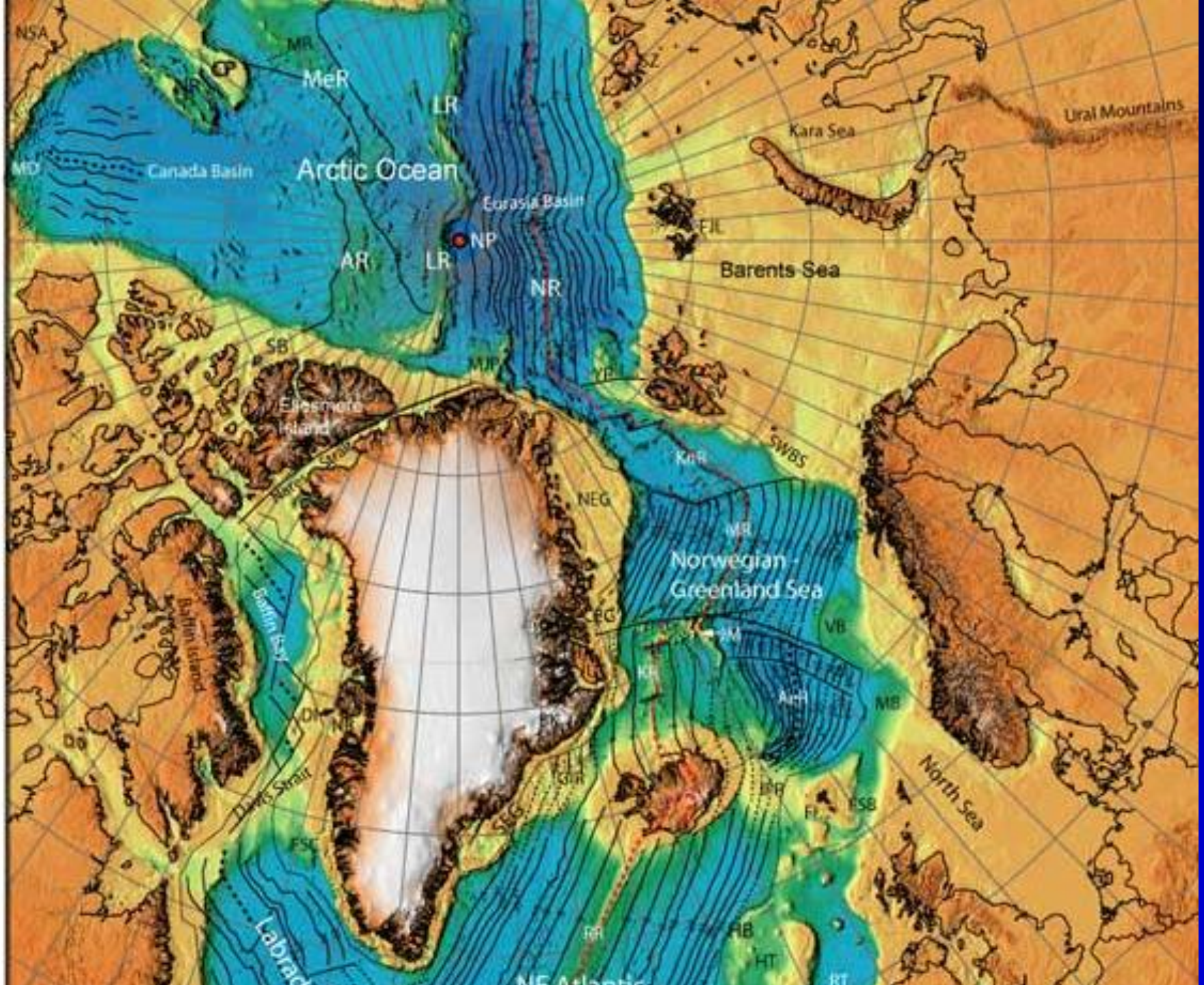
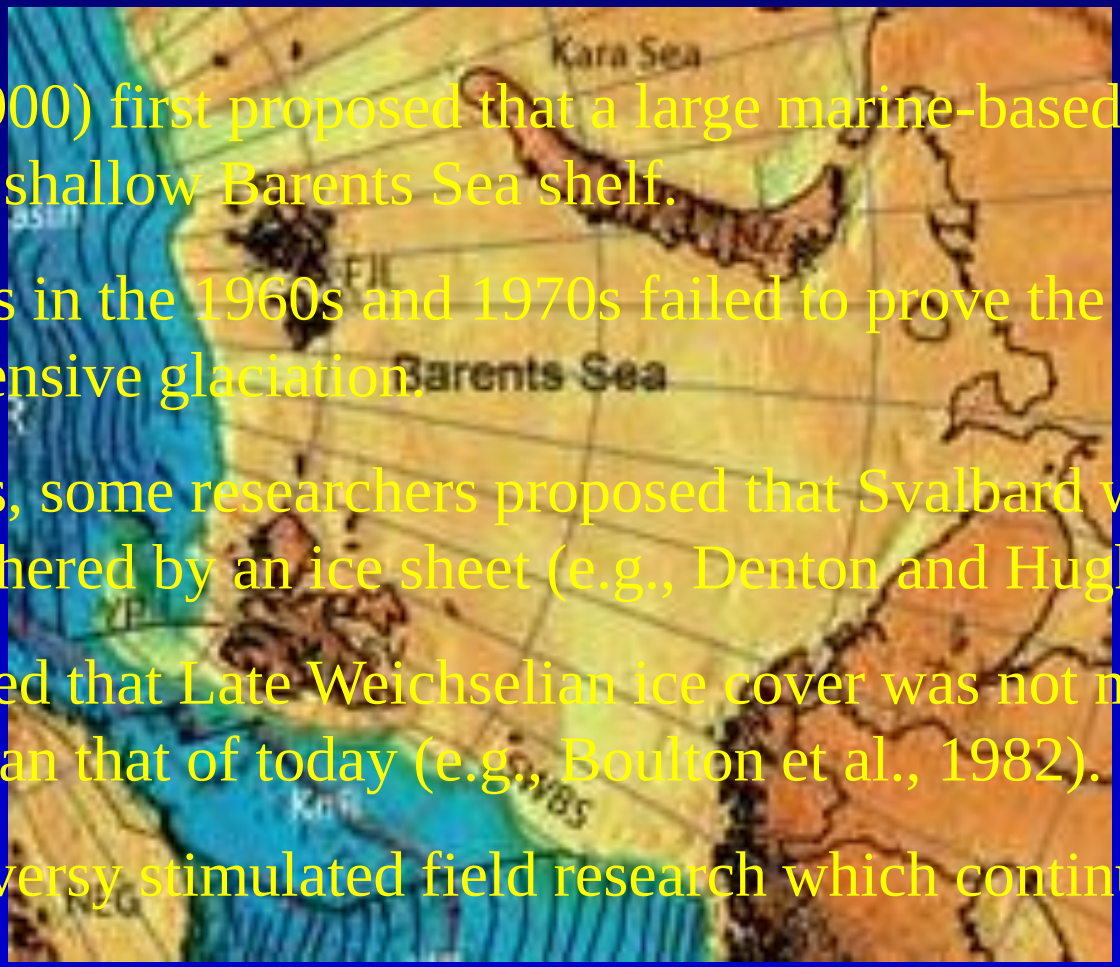

NSA
MR
MeR
LR
MD
Canada Basin
Arctic Ocean
Eurasia Basin
NP
AR
LR
NR
Kara Sea
Ural Mountains
FIL
Barents Sea
SB
MJP
YP
Ellesmere Island
KaR
SWBS
NEG
MR
Norwegian - Greenland Sea
Baffin Bay
Baffin Island
EG
VB
KR
AnR
MB
DI
NF
Davis Strait
GIR
IFR
FI
FSB
North Sea
FSC
Labrador
IR
RB
HT
RT
NE Atlantic

“For the last three decades, the extent of the Late Weichselian ice sheet over Svalbard and the Barents Sea has been subject to one of the most fascinating scientific discussions regarding the glacial history of the Arctic” (Landvik et al., 1998)



De Geer (1900) first proposed that a large marine-based ice sheet covered the shallow Barents Sea shelf.

Field studies in the 1960s and 1970s failed to prove the existence of such an extensive glaciation.

In the 1980s, some researchers proposed that Svalbard was almost totally smothered by an ice sheet (e.g., Denton and Hughes, 1981).

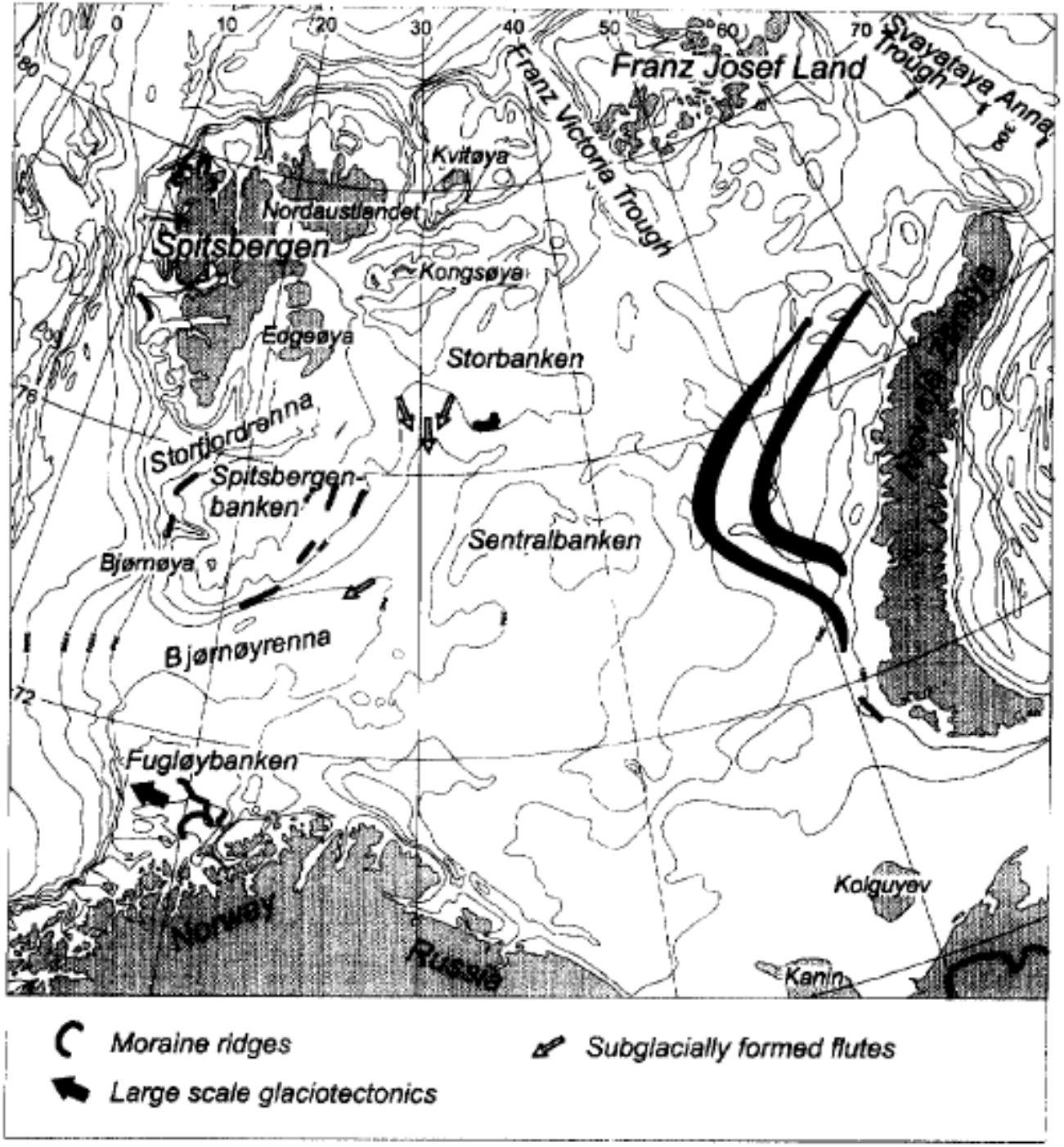
Others argued that Late Weichselian ice cover was not much extensive than that of today (e.g., Boulton et al., 1982).

This controversy stimulated field research which continues today!

What evidence can be found to help reconstruct past ice sheets?

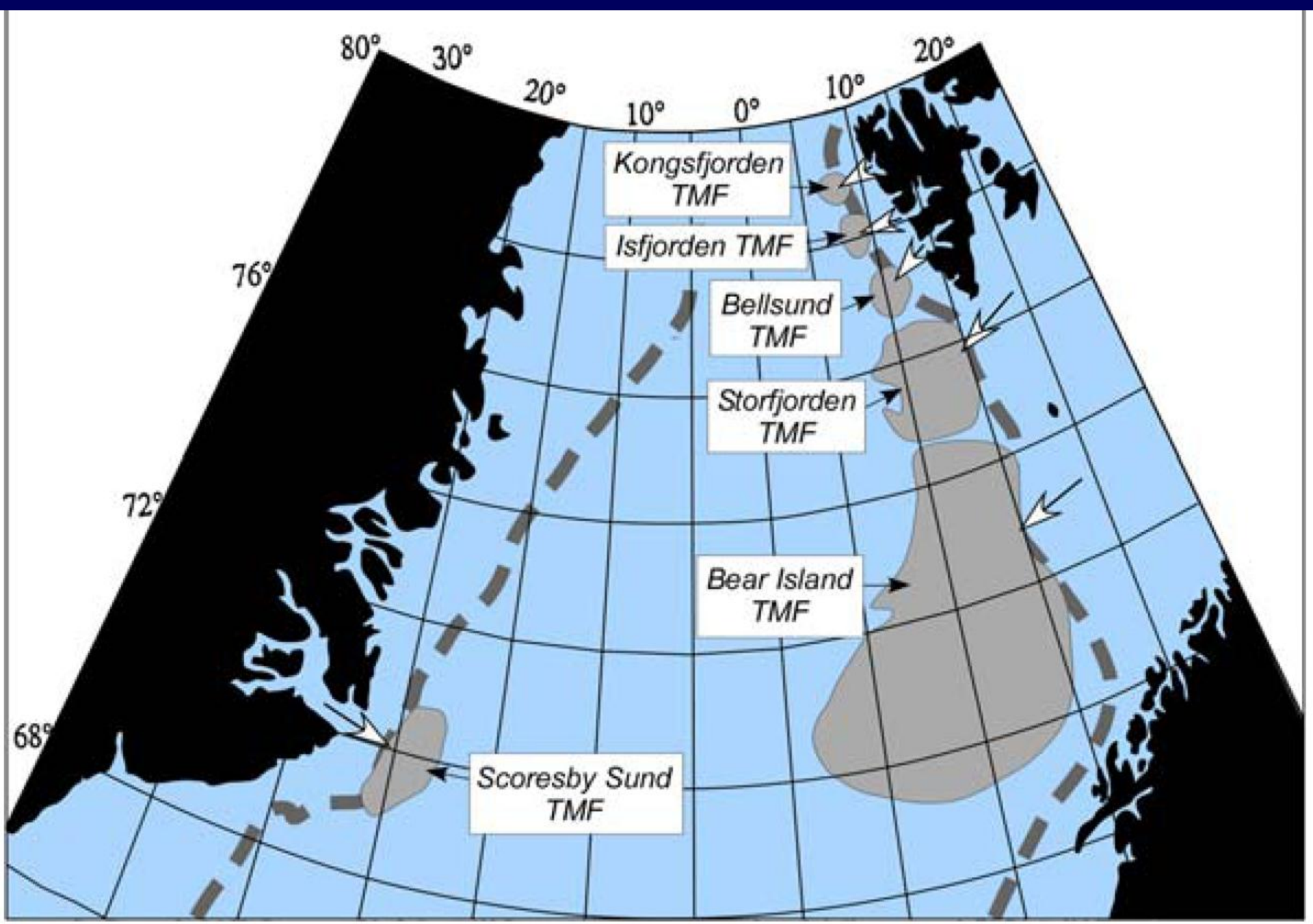
1) Large-scale geomorphic features
2) Land-based stratigraphy
3) Marine-based stratigraphy
4) Isostatic depression/rebound
5) Landform exposure dating

http://toposvalbard.npolar.no/



Large scale geomorphic features related to the Late Weichselian ice sheet in the Svalbard-Barents Sea area

Landvik et al., 1998



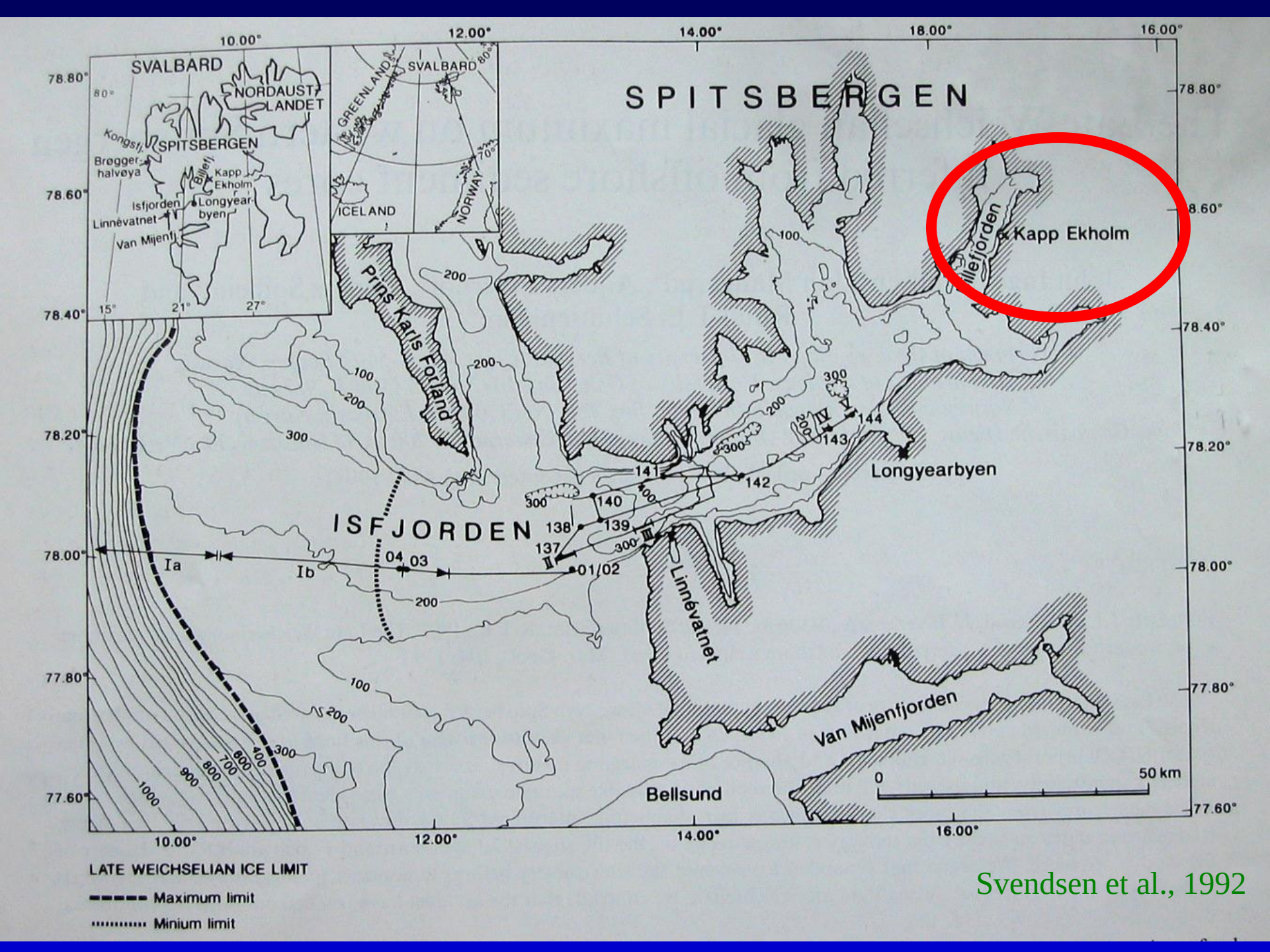
modified from Vorren et al. 1989 in Ingolfsson, 2011

Land-based stratigraphy -

Potentially good evidence but may be ambiguous!

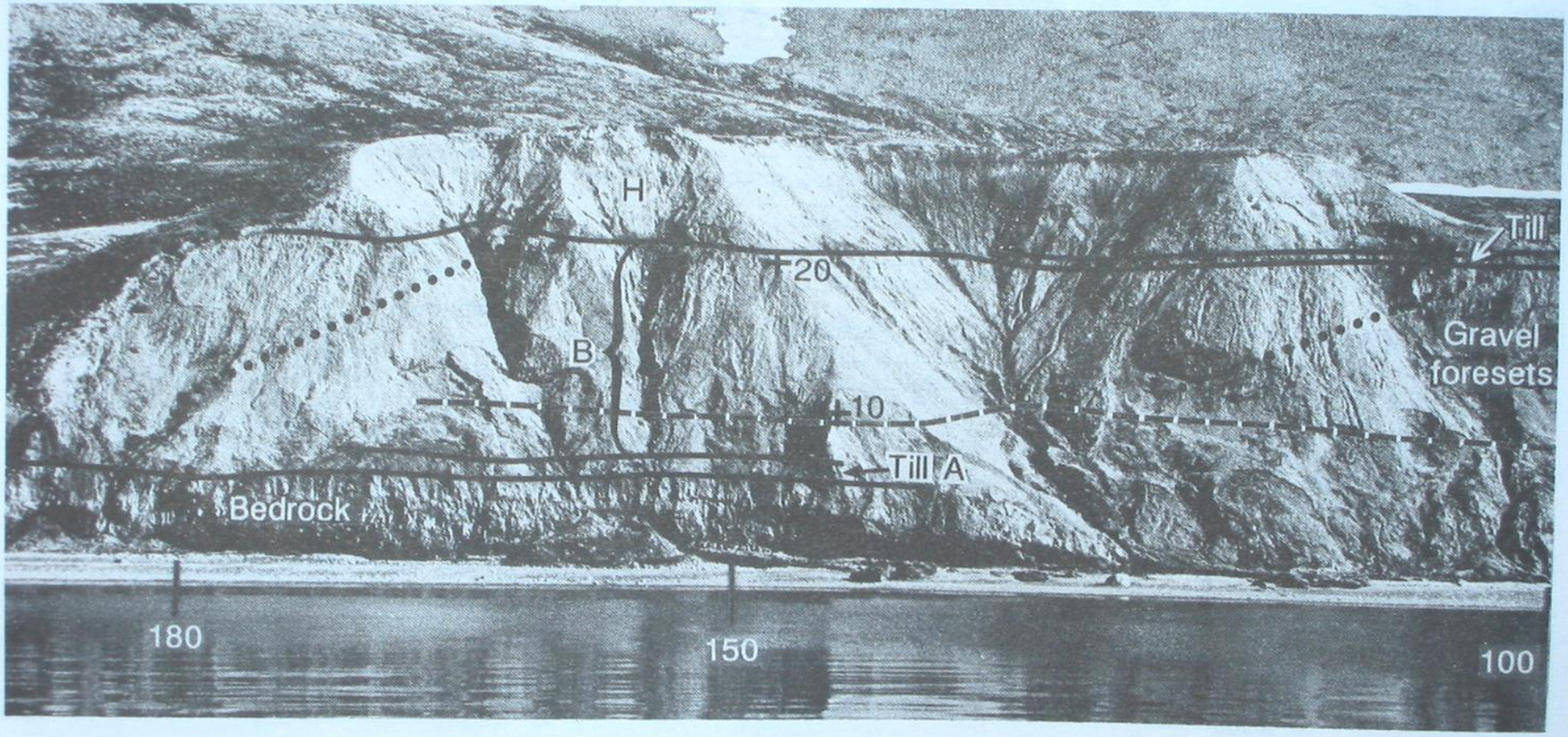
Interpretations are interpretive!!

Age control may be difficult

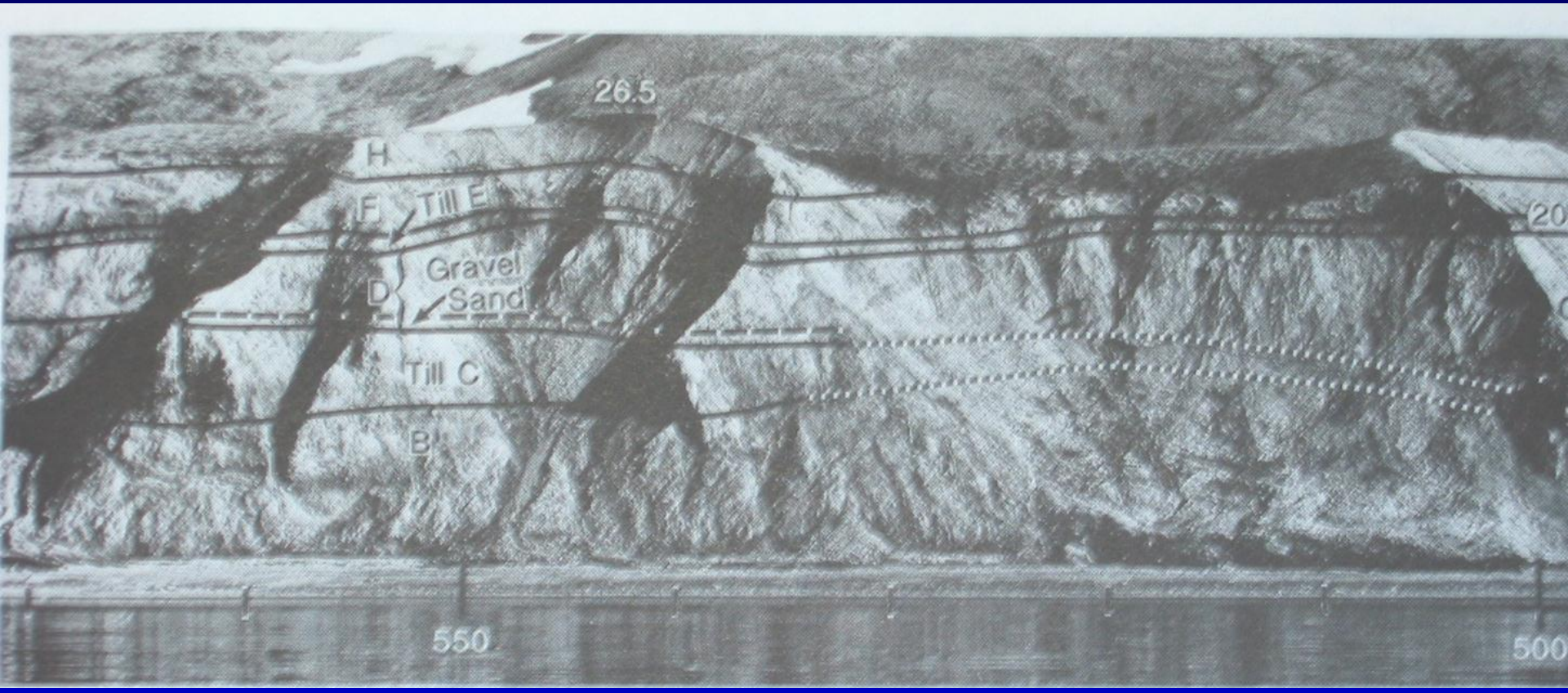


Svendsen et al., 1992

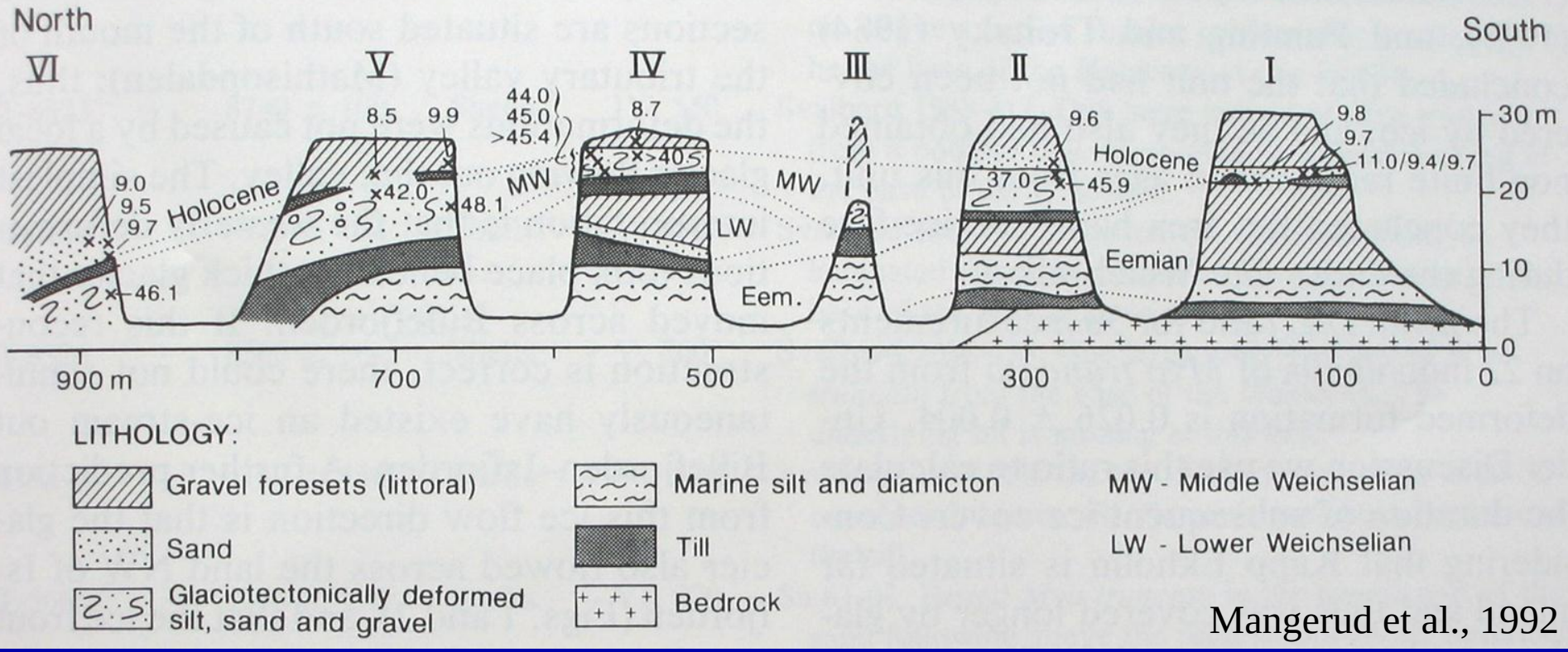
Kapp Ekholm sections



Mangerud & Svendsen 1992



Mangerud & Svendsen 1992

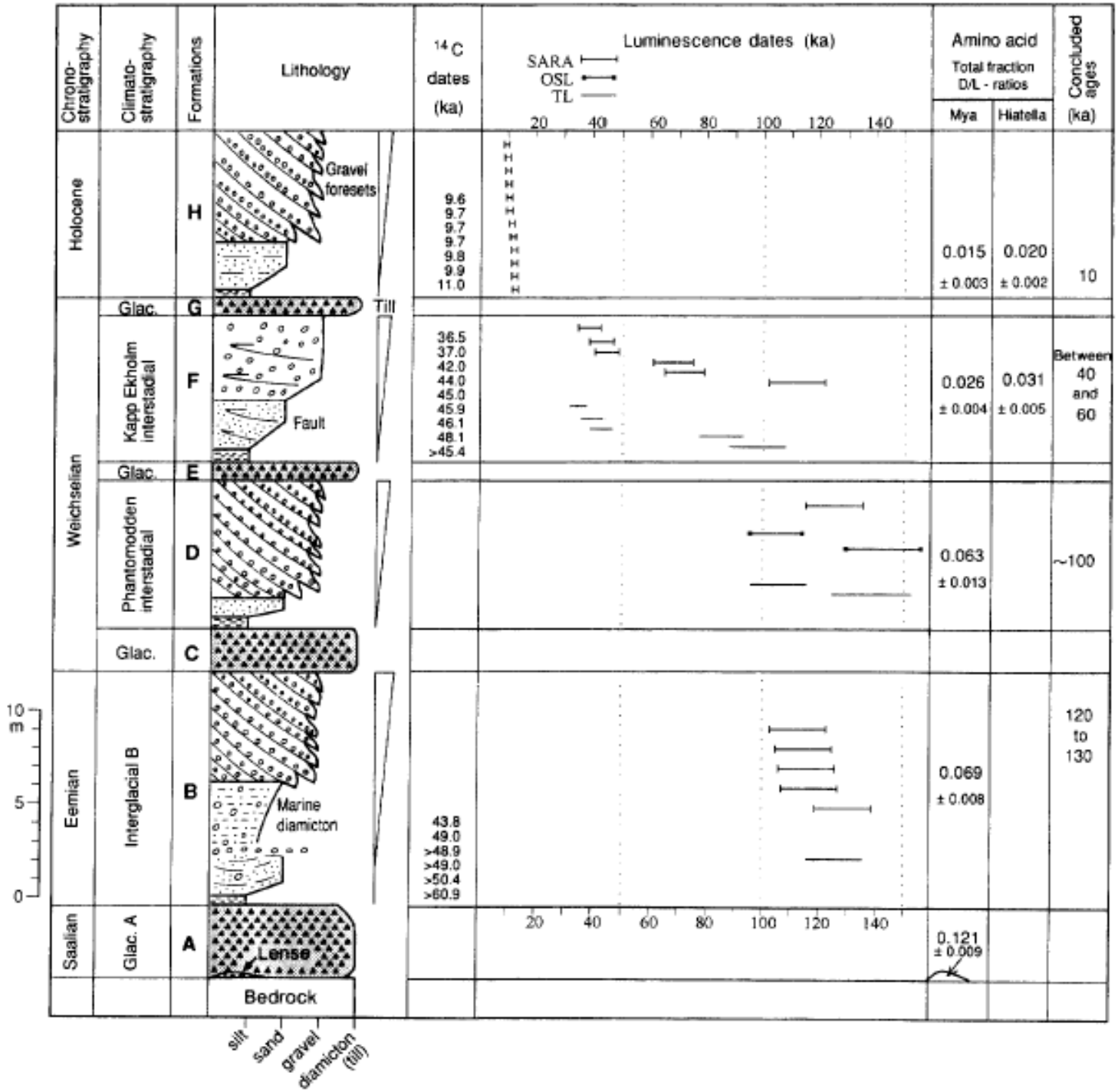


Mangerud et al., 1992

A simplified profile of the sections at Kapp Ekholm. Stippled lines between each section show the correlations made during fieldwork. Note that the youngest till is found between sections V and VI only, but an unconformity could be mapped to the south, between the deformed and Holocene formations.

Earlier researchers concluded glacial ice had NOT overridden these sections, implying a limited extent for Late Weichselian ice extent on western Svalbard. But Mangerud et al found glacially-deformed sediments near the top interpreted as demonstrating over-riding by Late Weichselian ice sheets.

Composite sratigraphy of the Kapp Ekholm sections. Four coarsening-upwards sequences are identified indicating four glacial advances

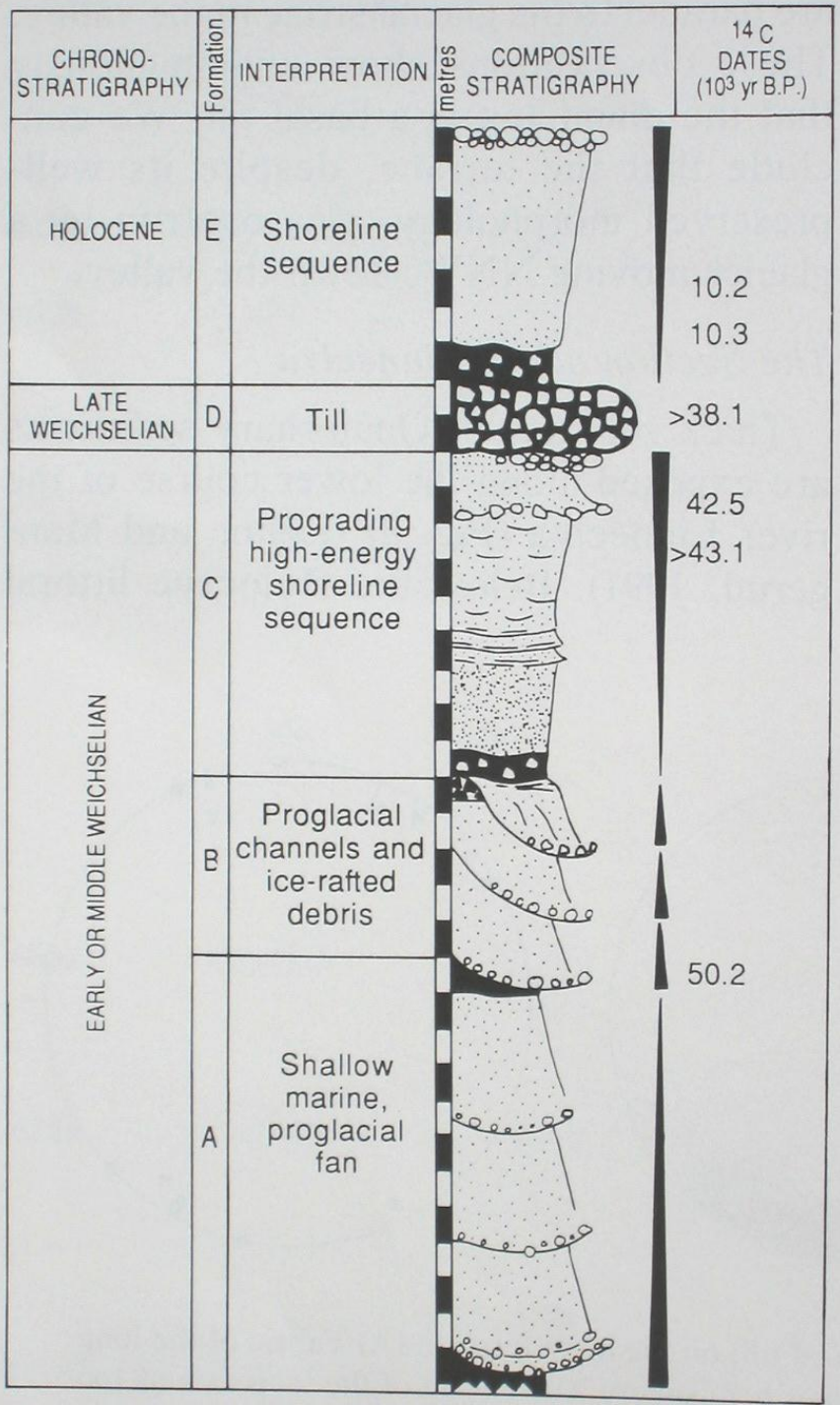


Mangerud et al., 1998

Conclusions of Mangerud et al. from the Kapp Ekholm Section:

1) During interglacials, mollusks in fjords indicate open water; glaciers on Svalbard could not have been much larger than present
2) Basal till units indicate the site was overrun by glaciers between each of the marine episodes.
3) Coarsening up sequences are caused by isostatic depression that required regional ice sheet glaciation, not advances of puny fjord glaciers.
4) Ambiguous amino-acid racemization dates suggest the Late Weischelian glaciation lasted 10,000 years and the preceeding glaciation may have lasted 40,000 years.

Downstream from Linnevatnet, Linneelva exposes nice sections of marine, fluvial, and glacial sediments



Composite stratigraphic section from exposures along Linneelva between Linnevatnet and coast.

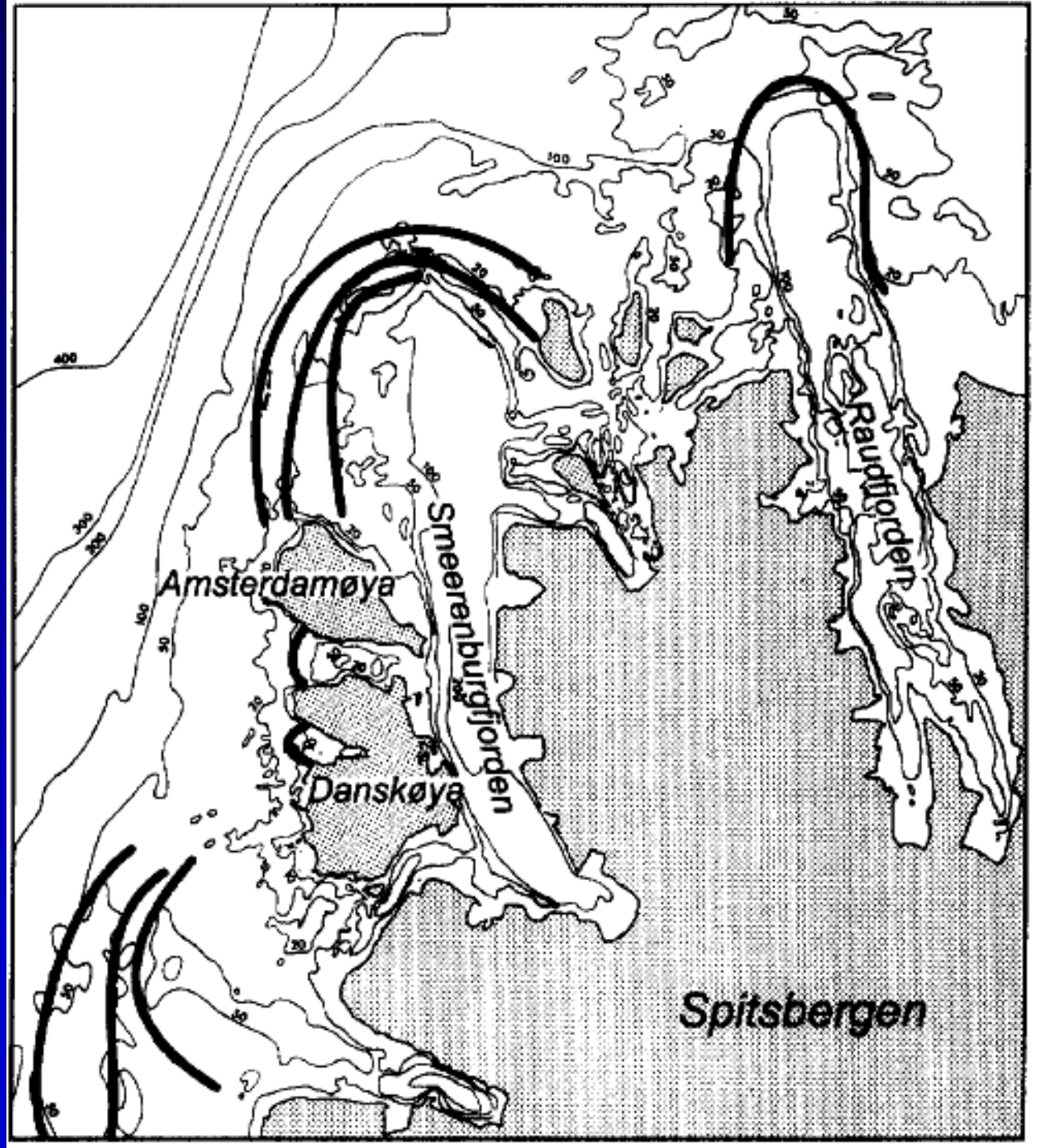
Below the Holocene shoreline sequence (E) is a nice subglacial till (D). Below that is a high-energy beach deposit (C) reflecting a dropping sea level, presumably resulting from isostatic depression associated with an earlier glacial advance represented by the till at the base of unit C.

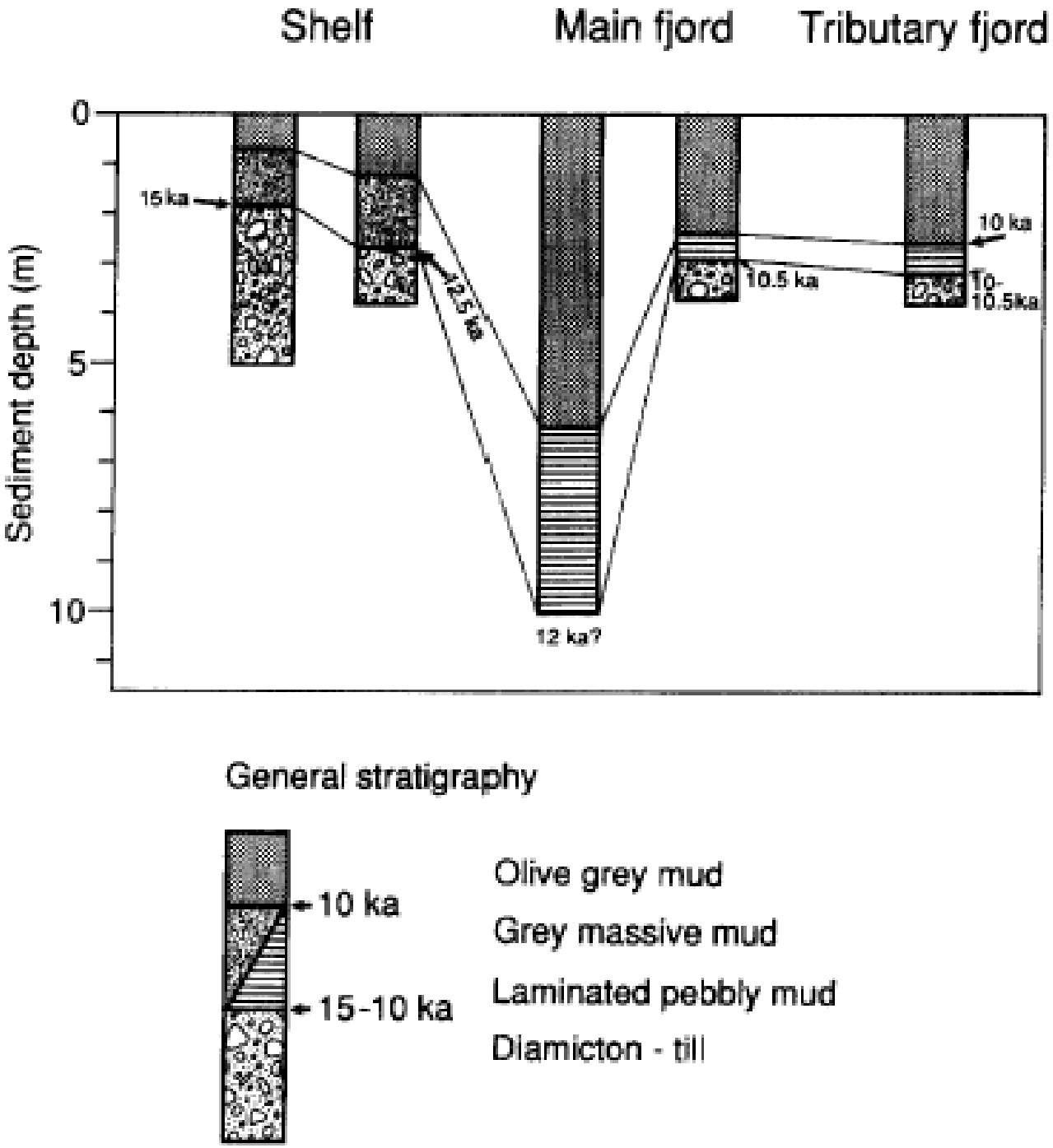
From Mangerud et al., 1992

Marine-based evidence of ice sheet extent

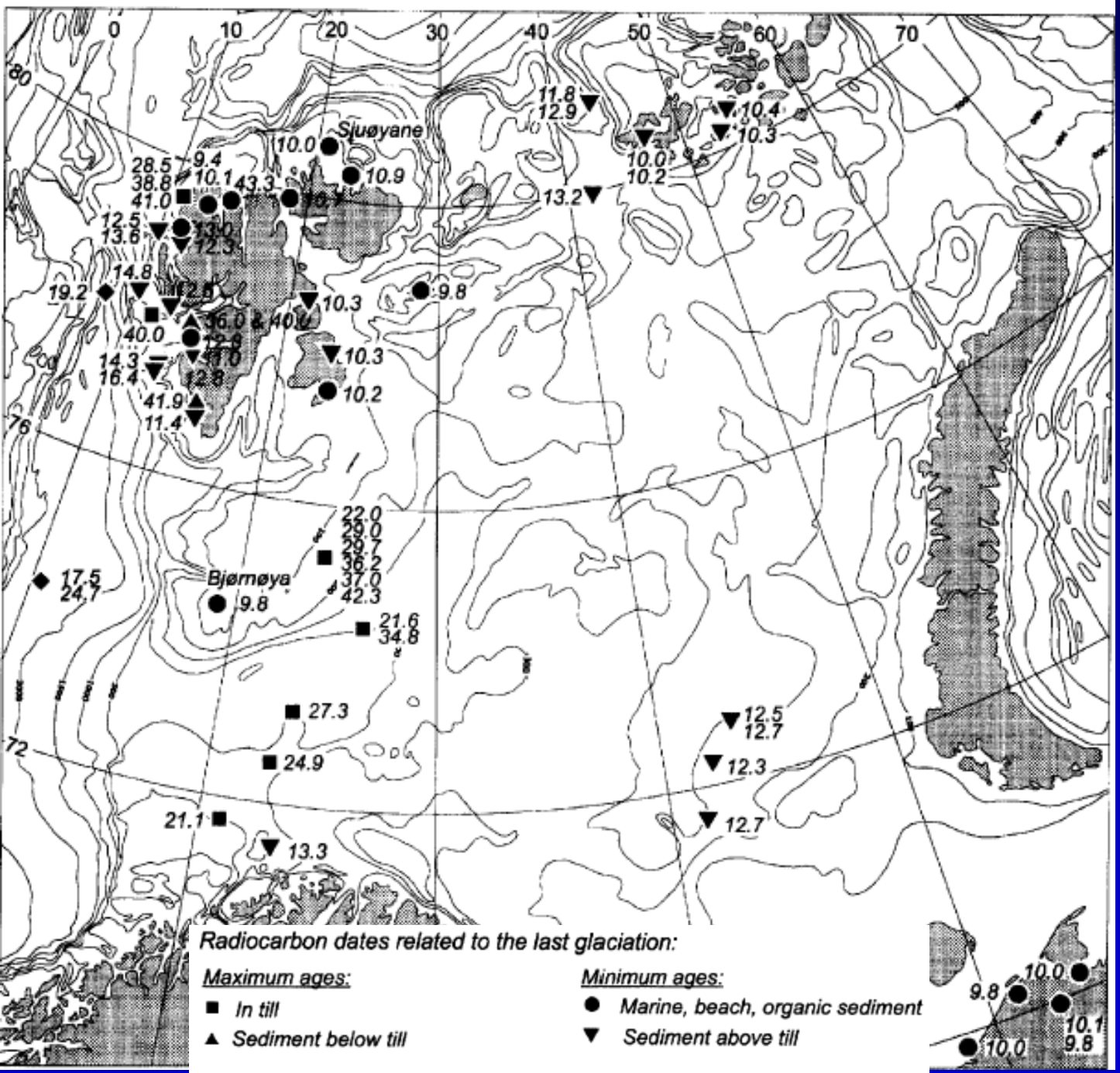
Submarine lobes off the coast of northwest Spitsbergen

Landvik et al., 1998



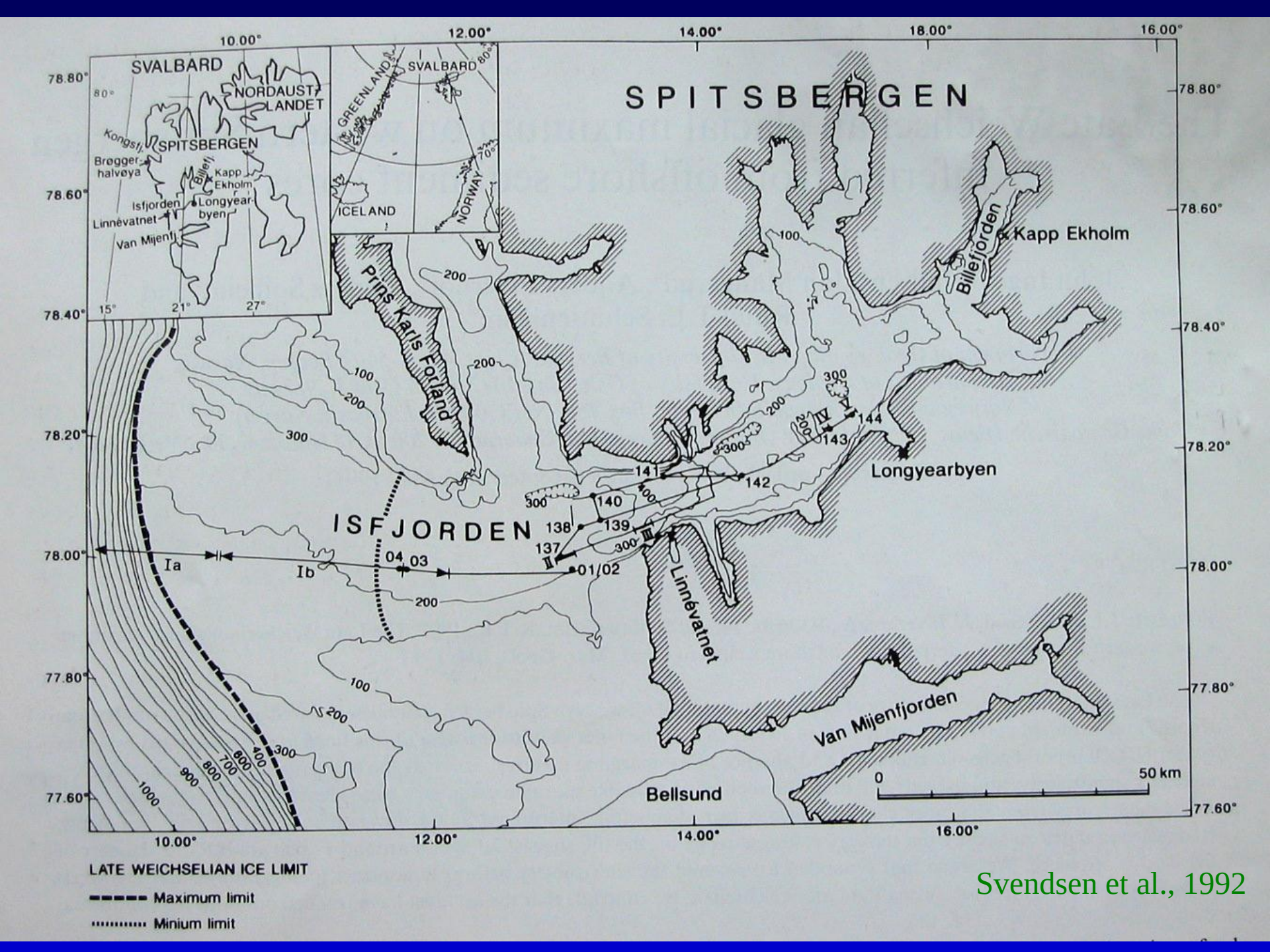


Elverhoi et al. (1998) show how marine sediment cores from Isfjorden and radiocarbon dating can identify the extent of timing of ice sheets in fjords and on the continental shelf.

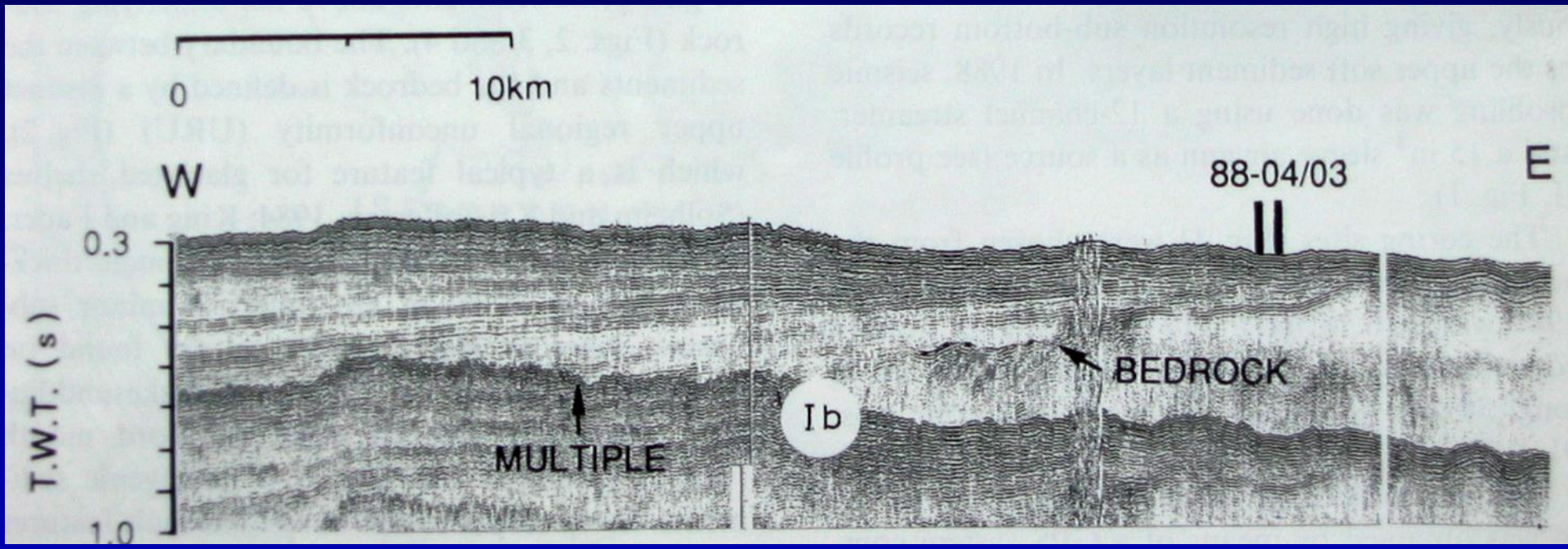


Key radiocarbon age estimates used to define the Late Wechselian ice sheet.

Landvik et al., 1998



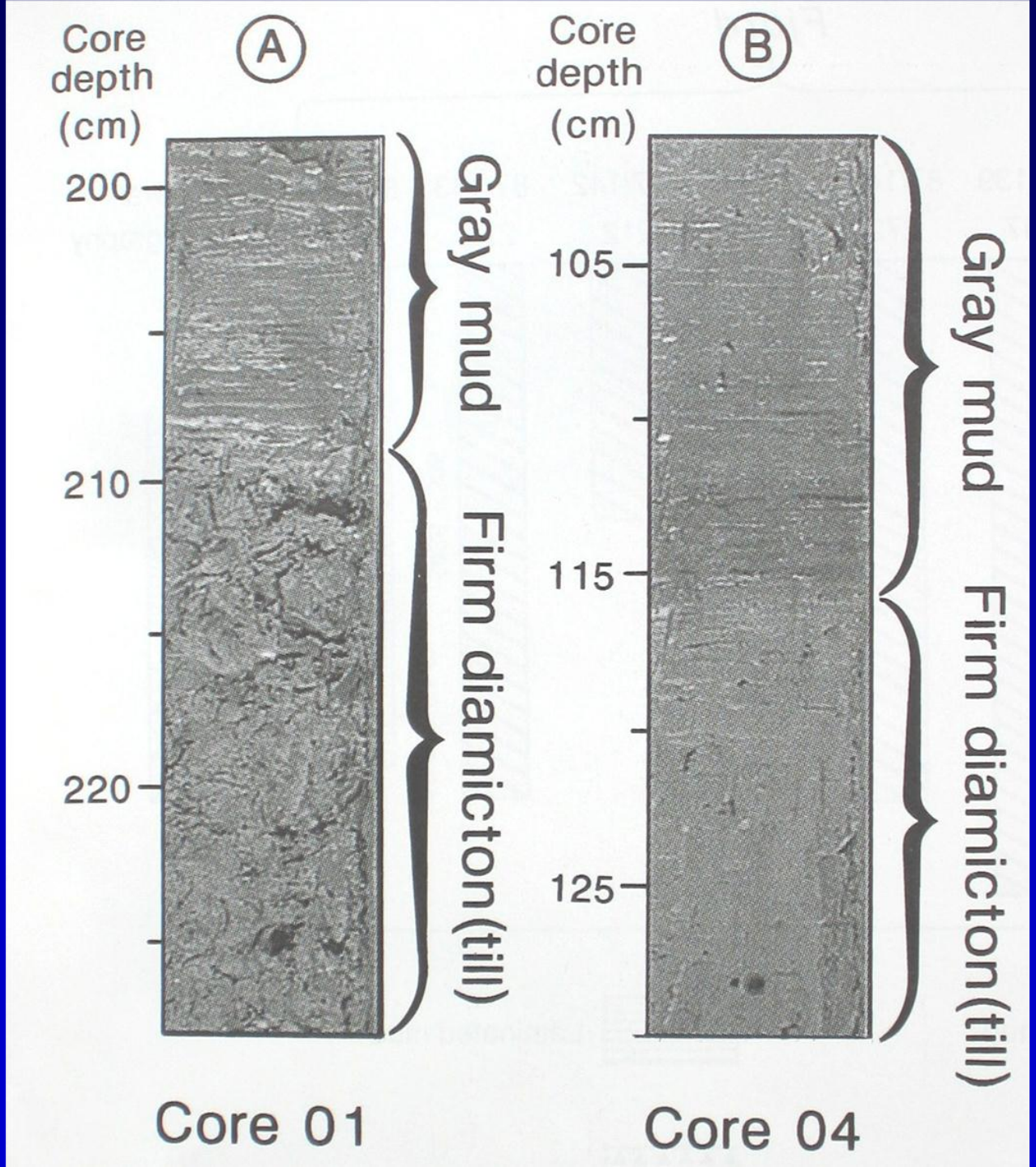
Svendsen et al., 1992



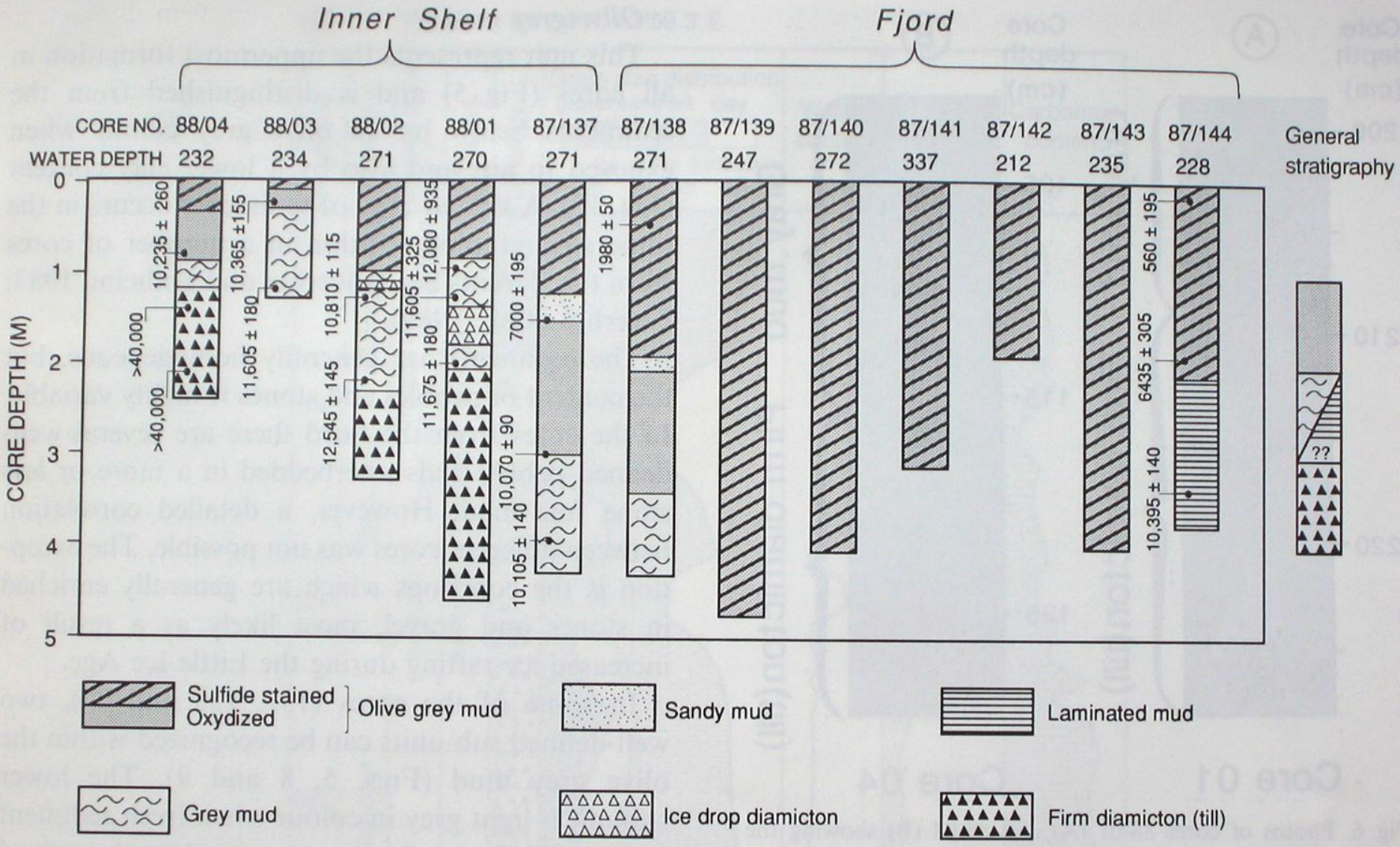
Svendsen et al., 1992

Seismic profiles across the West Spitsbergen shelf (west of Isfjorden). Note the thick wedge of sediments above bedrock on the outer shelf.

The uneven topography on the outer 35 km is interpreted as a moraine complex.

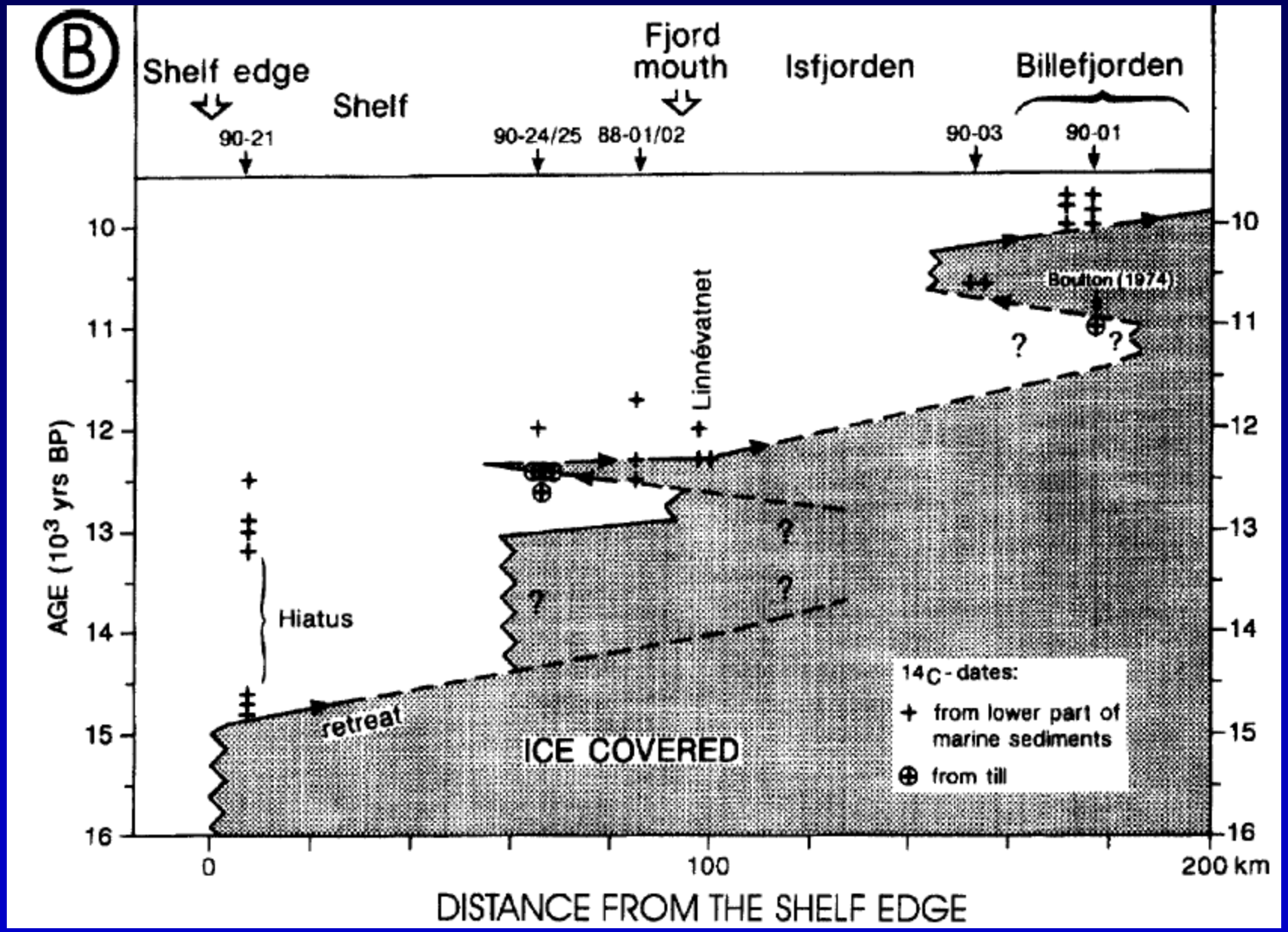


Svendsen et al., 1992



Composite lithostratigraphy and sediment cores from Isfjorden and the adjacent shelf.

Svendsen et al., 1992



From many marine sediment cores, the position of the ice sheet on the shelf edge can be reconstructed over time (Landvik et al., 1998)

Conclusions

(1) Sediment cores from the continental shelf to the west of Isfjorden sampled a firm diamicton, interpreted as till.

(2) Above the firm diamicton follows soft glaci-marine mud which probably started to accumulate shortly after the shelf became ice free. Radiocarbon dated molluscs from the base of the mud indicate that deglaciation occurred around 12,500 yrs B.P.

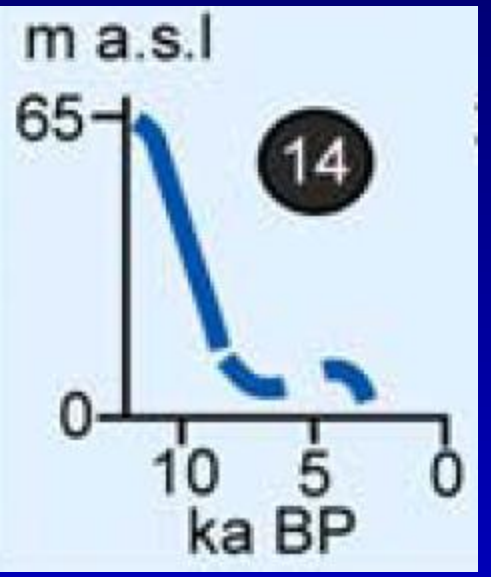
(3) The ice front during the Late Weichselian glacial maximum reached beyond the cored sites, more than 40 km off the coast.

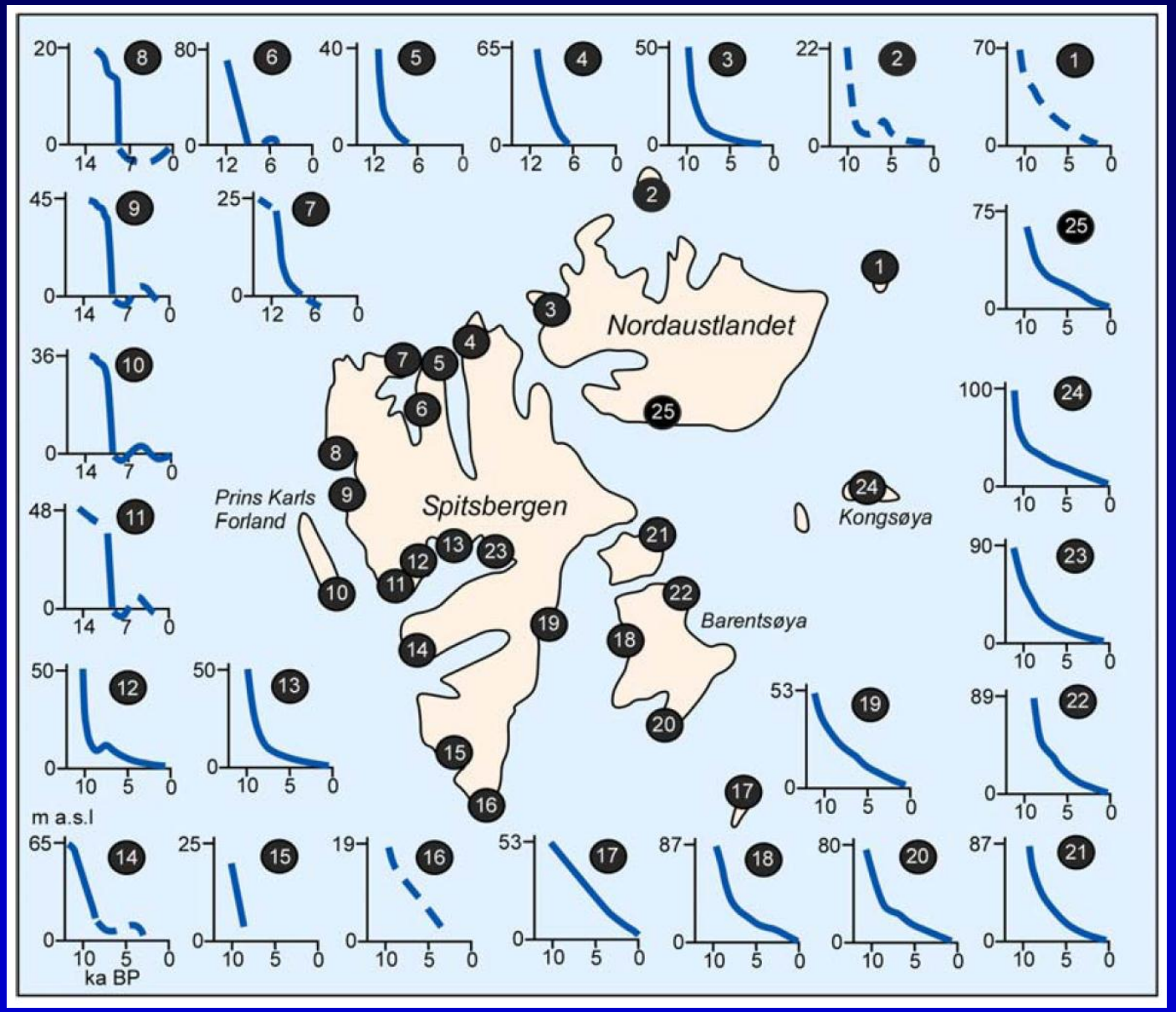
(4) The ice front probably reached all the way to the shelf edge during the Late Weichselian glacier advance.

Acknowledgement

Svendsen et al., 1992

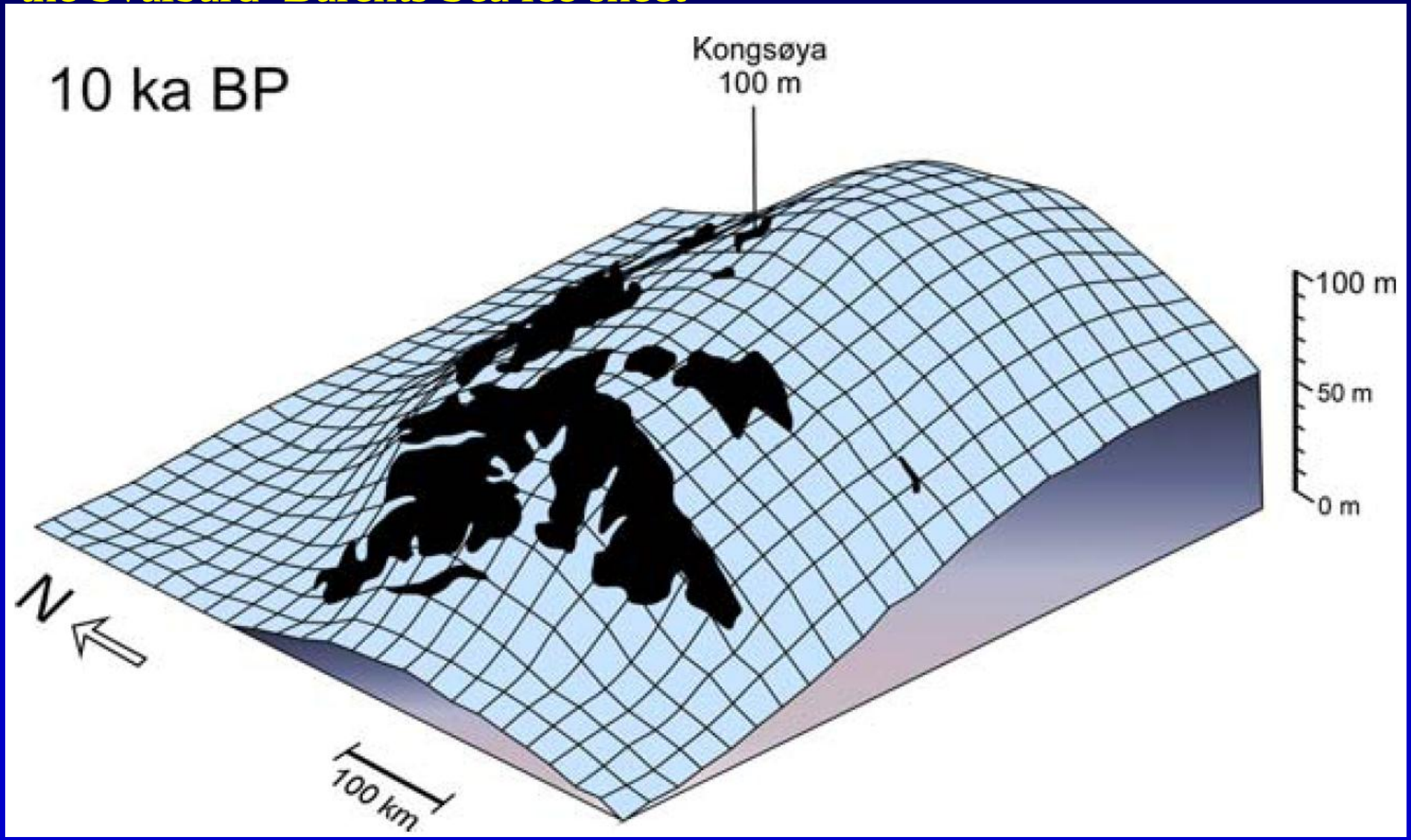
Relative sea-level curves show how the crust has rebounded after glacier retreat





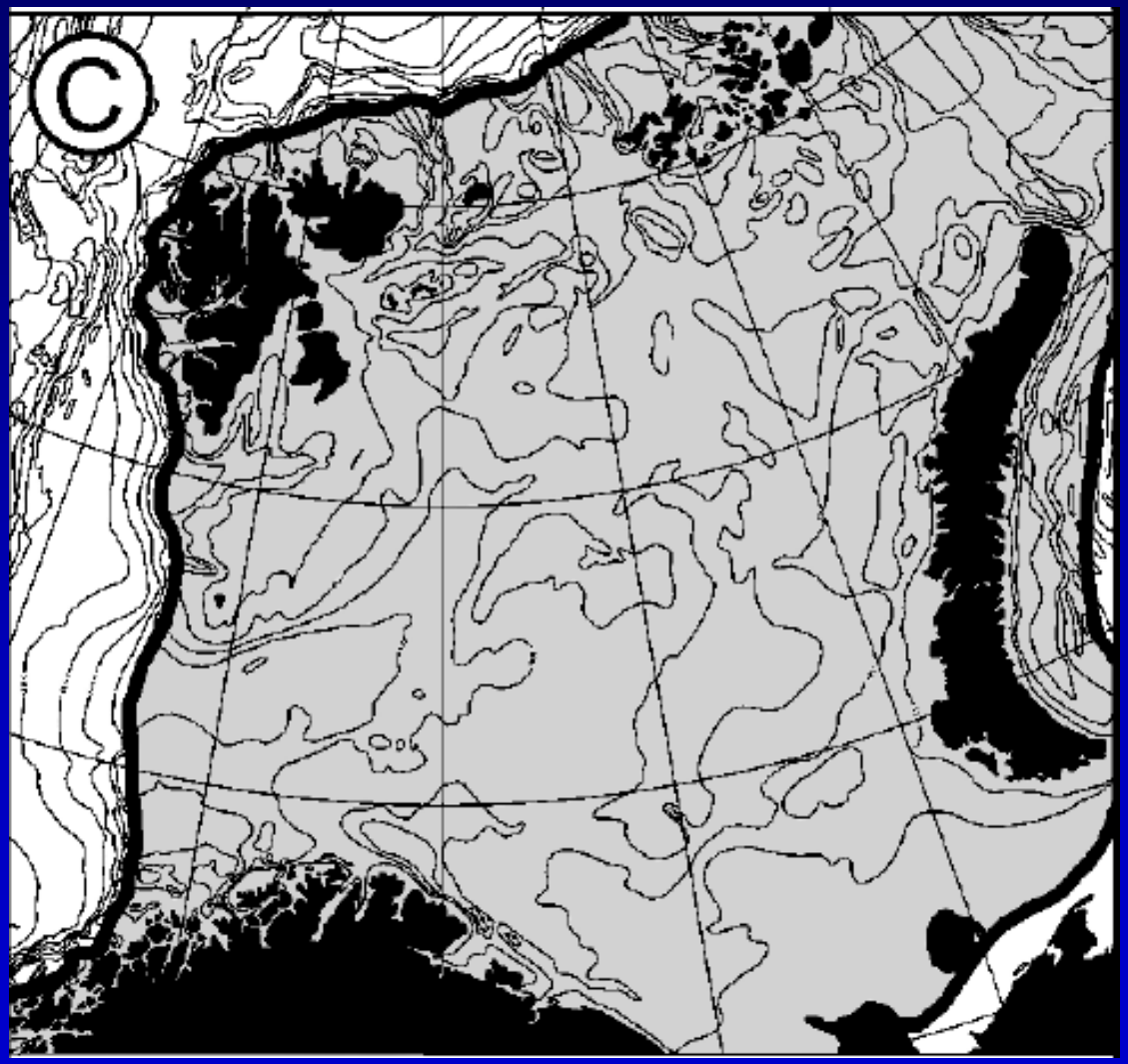
modified from Forman et al. 2004 in Ingolfsson, 2011

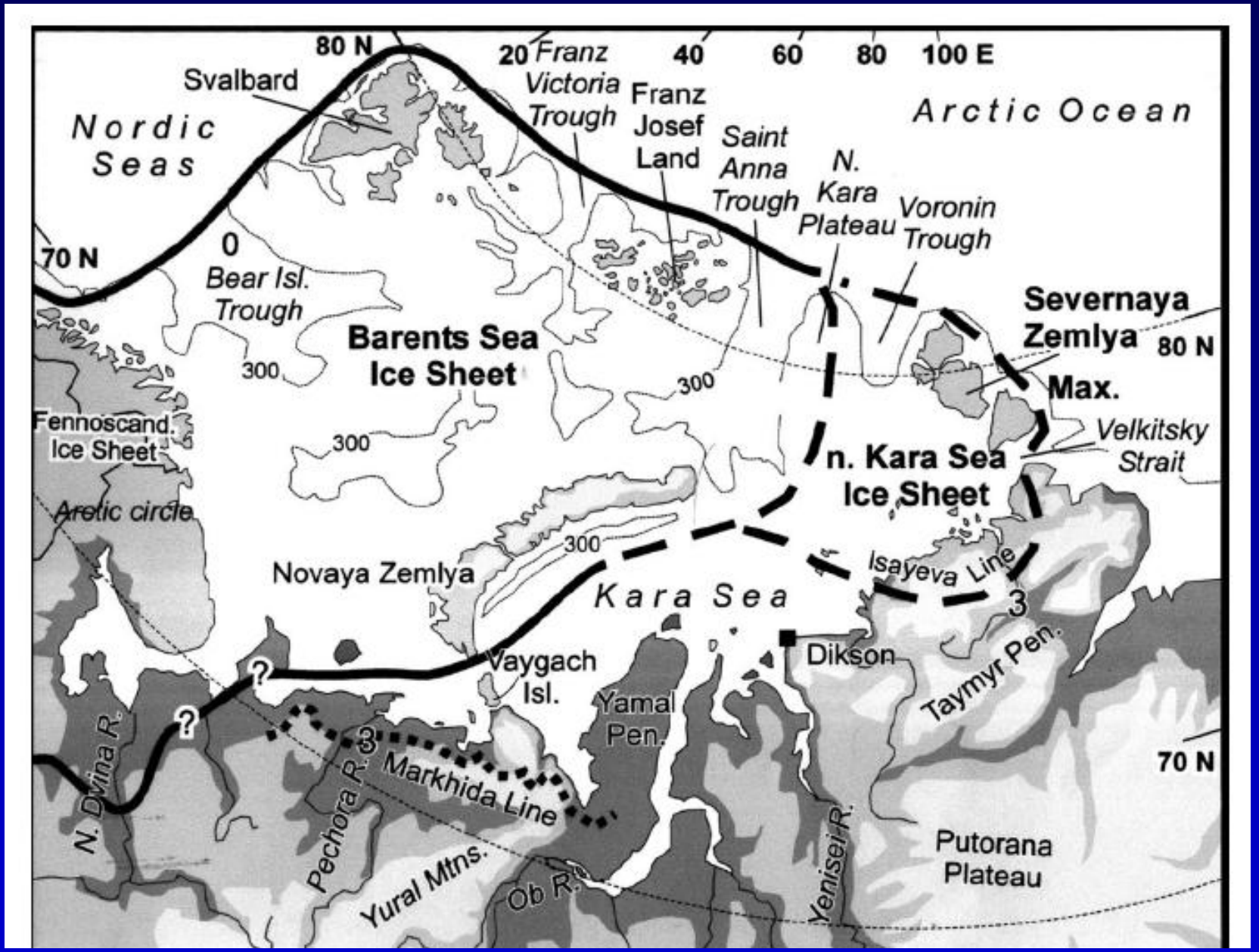
The pattern of postglacial raised beaches combined with well-dated relative sea-level curves fingerprints the isostatic depression caused by the Svalbard–Barents Sea ice sheet



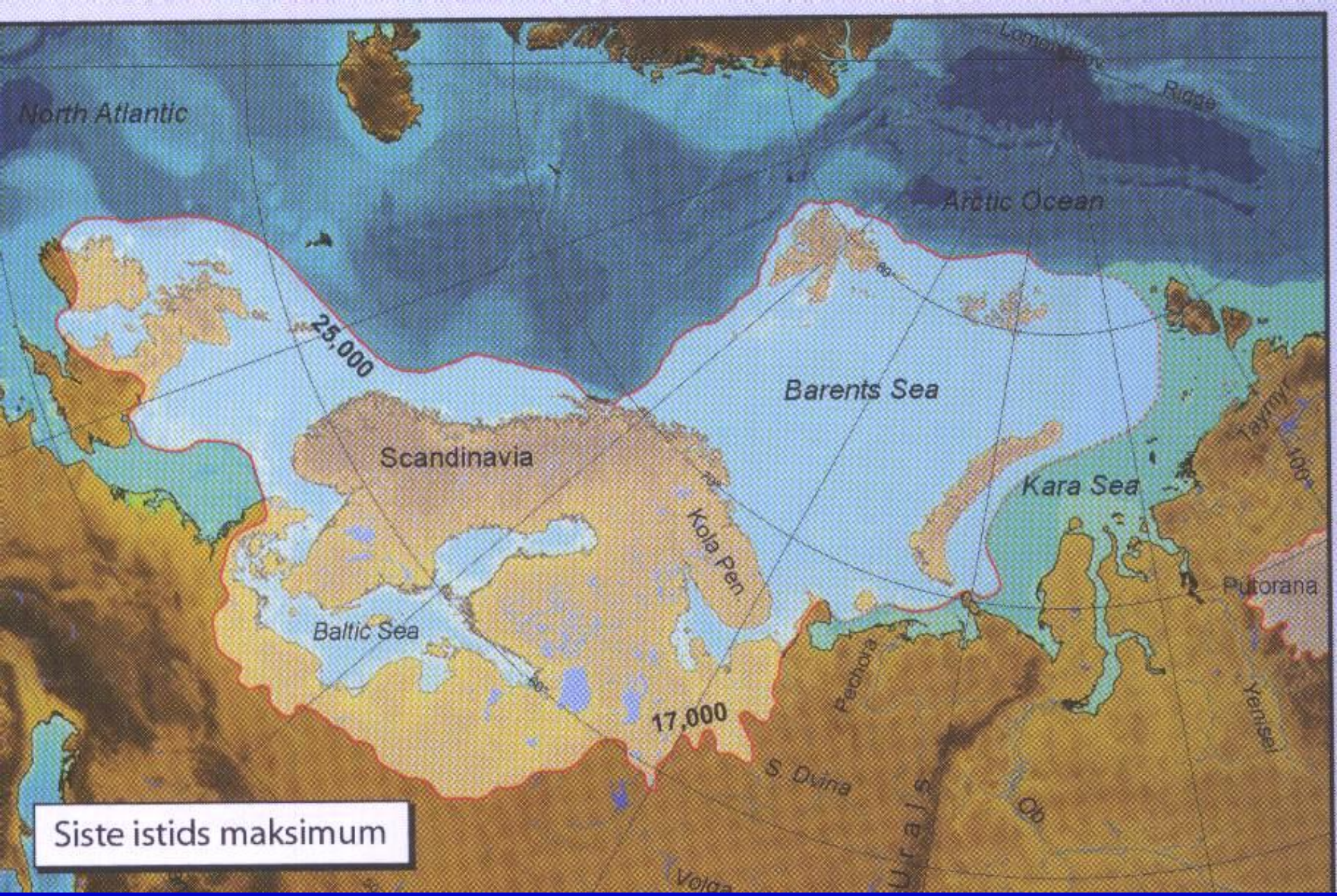
modified from Bondevik 1996 in Ingolfsson, 2011

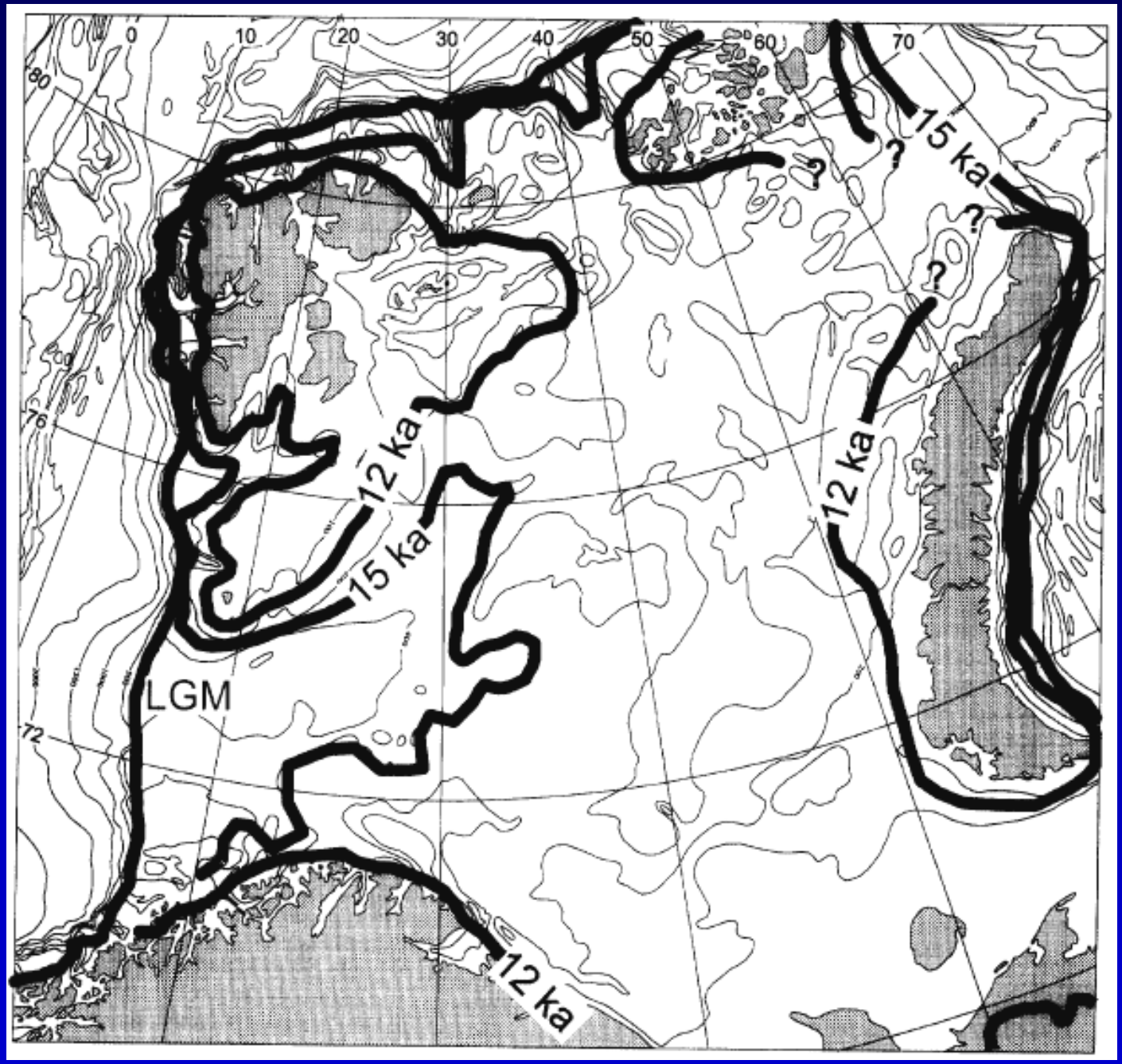
The land and marine stratigraphic evidence provides a nice reconstruction of the overall extent and thickness of the Late Weichselian ice-sheet





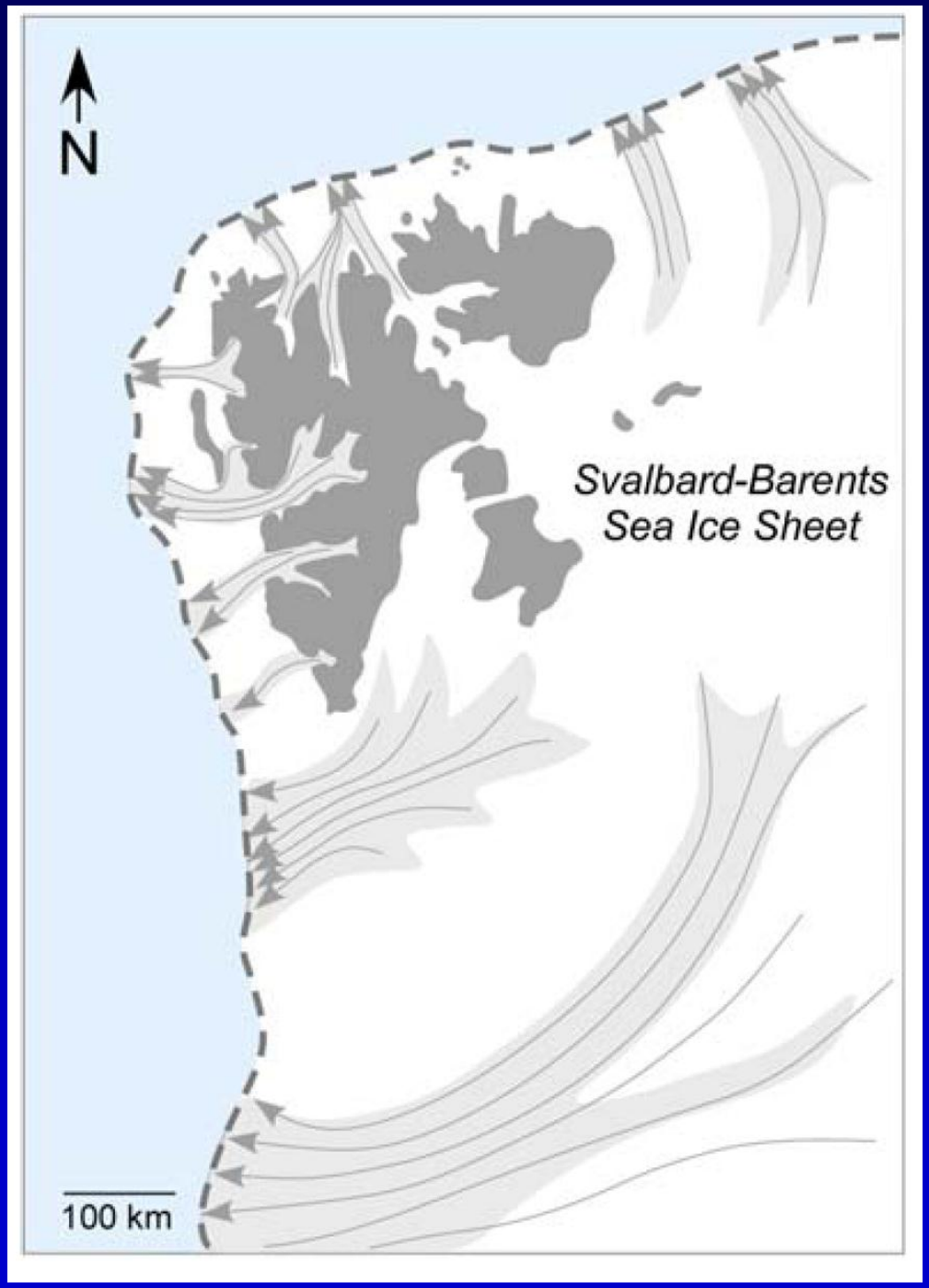
Late Weichselian ice sheet limits in northern Eurasia.
From Forman et al. 2004


North Atlantic
Arctic Ocean
Lomonosov Ridge
25,000
Barents Sea
Scandinavia
Kara Sea
Taymyr
100°
Kola Pen
Baltic Sea
Putorana
Pechora
17,000
S. Dvina
Ob
Yensei
Urals
Siste istids maksimum



Reconstructed ice extent for LGM. The 12ka margin is based mainly on deglaciation dates, the 15ka margin is more speculative.

Landvik et al., 1998



Reconstruction of a more dynamic ice sheet around Svalbard

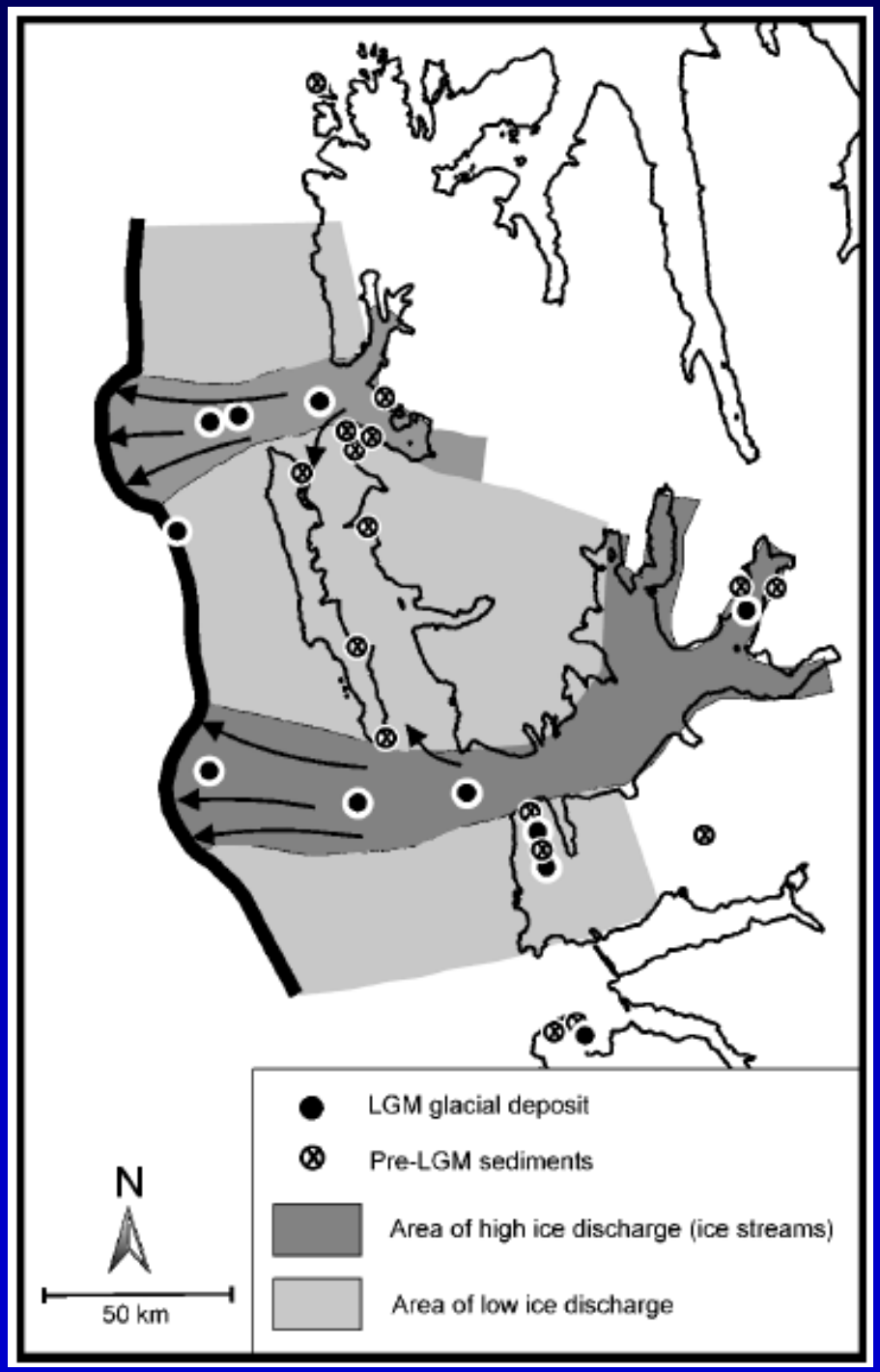
modified from Ottesen et al. 2005 in Ingolfsson, 2011

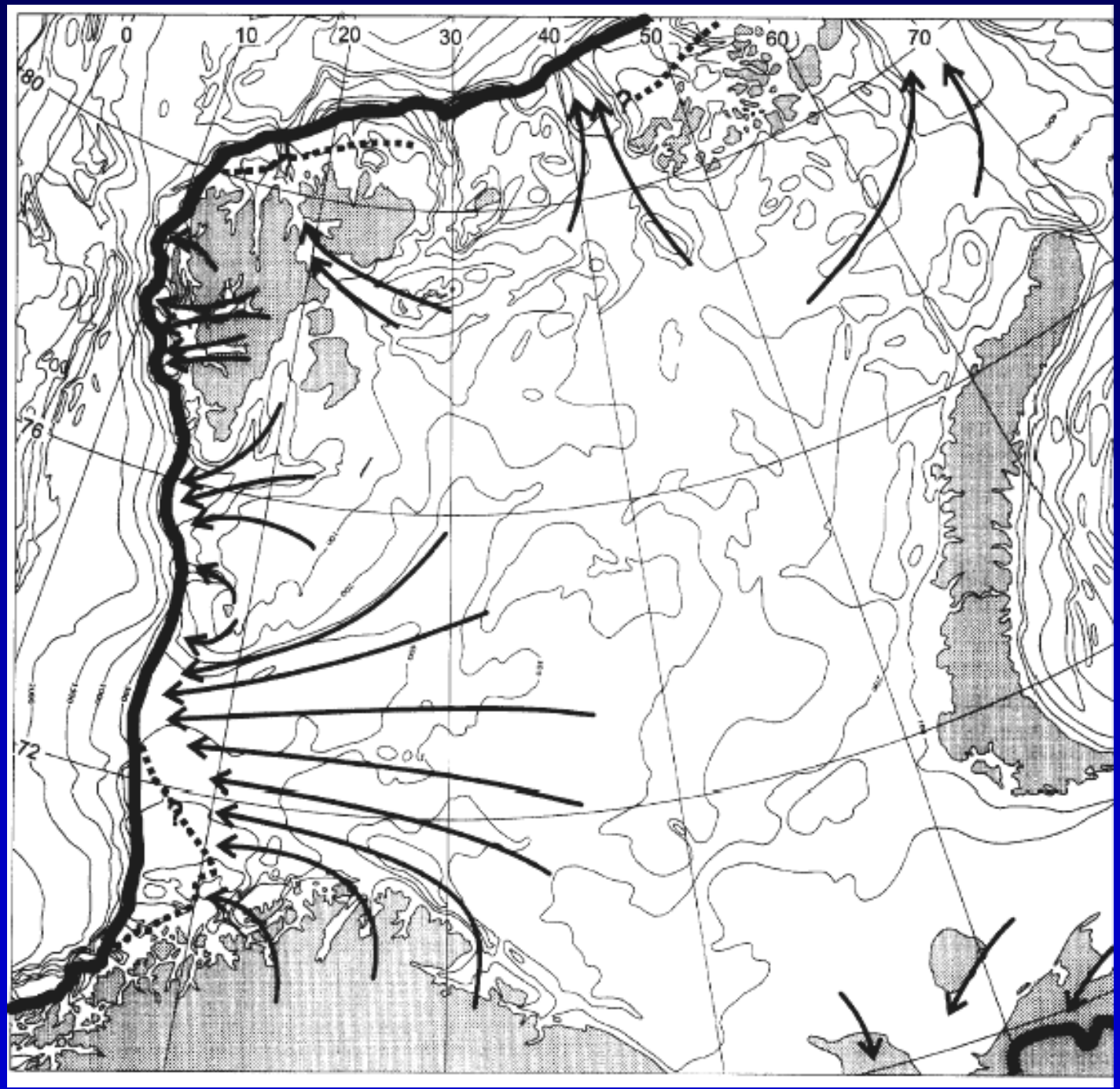
Ice-sheet configuration on the western Svalbard shelf and coastal region during the Last Glacial Maximum.

Darker shading shows area fast-moving ice streams;

Lighter shading shows areas covered by "dynamically less active" glaciers and ice caps.

Landvik et al. 2005





Reconstruction of the margins of the Late Wechselian Svalbard-Barents ice sheet. Dotted lines show minimum proven extent, flow lines are based on geomorphological evidence

Landvik etal., 1998

But wait! Does the evidence tell us whether the ice sheets fully covered Svalbard?

Were there ice-free areas during glaciations?

Maybe just small nunataks?

Or perhaps larger refugia where plants and animals survived glacial advances?

Based on Be^{10} exposure dating, Landvik et al. (2003) determined that ice-free nunataks existed on the islands of northwest Svalbard during the Late Weichselian glacial advance.

The last ice sheet that completely covered the islands retreated >80 kyrs ago.

During the Late Weichselian glacial advance, the coastal lowlands were glaciated and the major fords and troughs controlled glacier flow

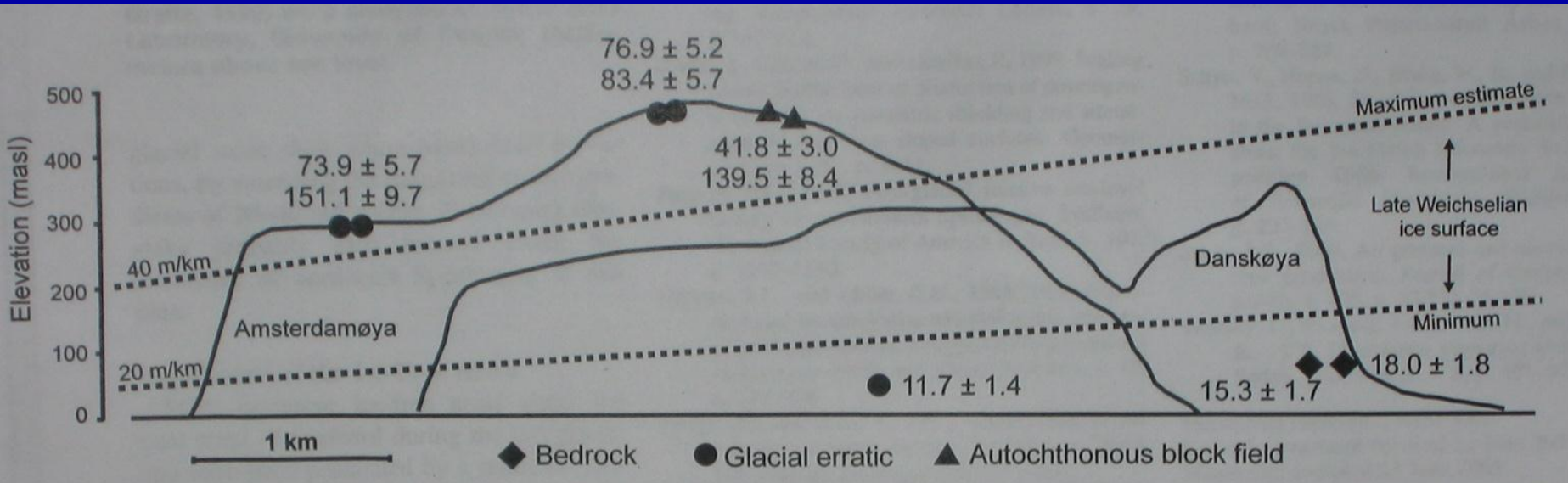
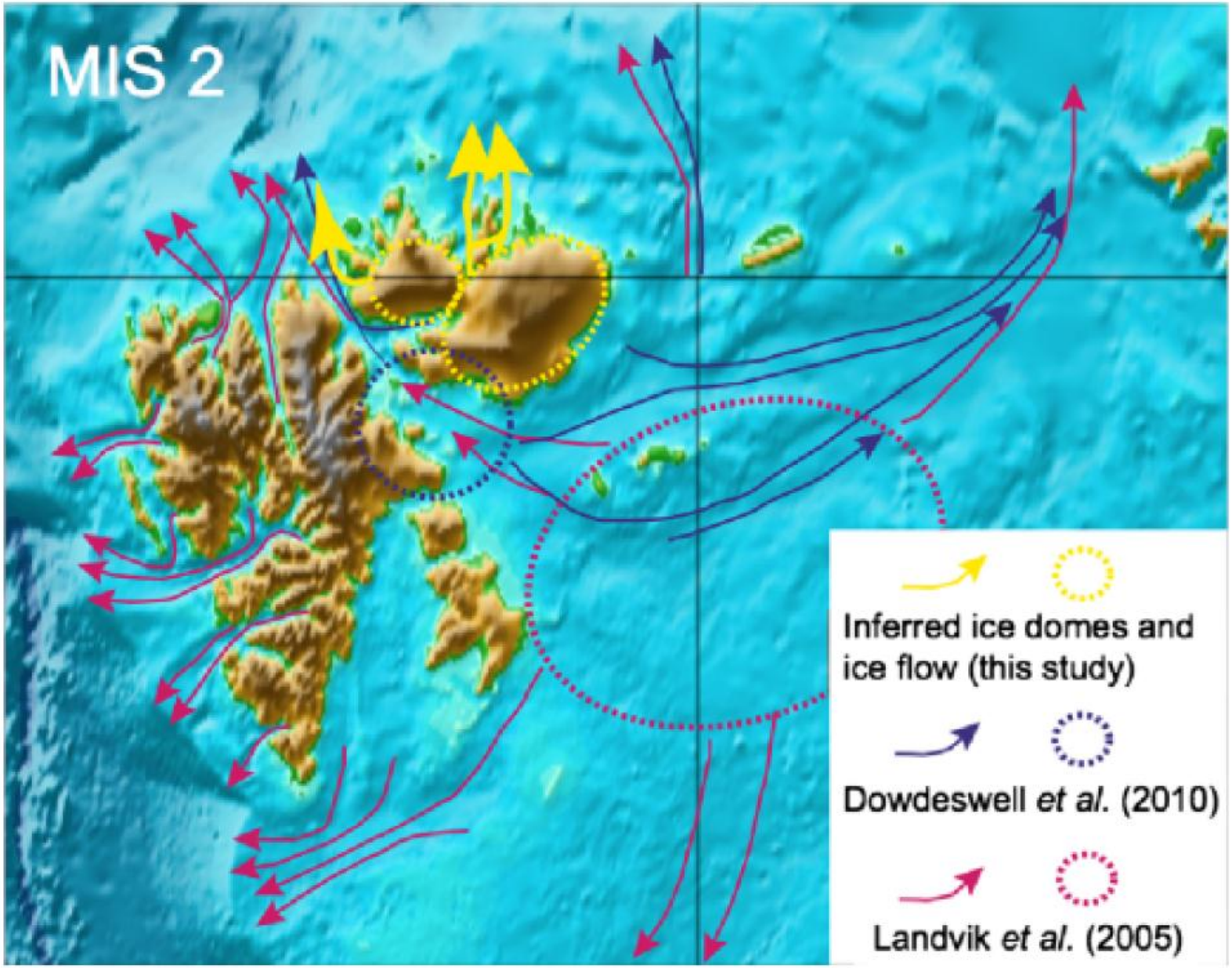


Figure 3. Topographic profiles of Amsterdamøya and Danskøya (see location in Fig. 1) with all dated samples (exposure ages shown are in ka; masl—meters above sea level). Minimum and maximum estimates of late Weichselian ice-sheet surface are shown.

Hormes et al 2011, Cosmogenic radionuclide dating indicates ice-sheet configuration during MIS 2 on Nordaustlandet Svalbard



http://toposvalbard.npolar.no/

A Geographical-Historical Outl ×

www.unis.no/10_STUDIES/1020_Courses/Arctic_Geology/ag_204_more_info/Ole/SvalbardOutline.htm

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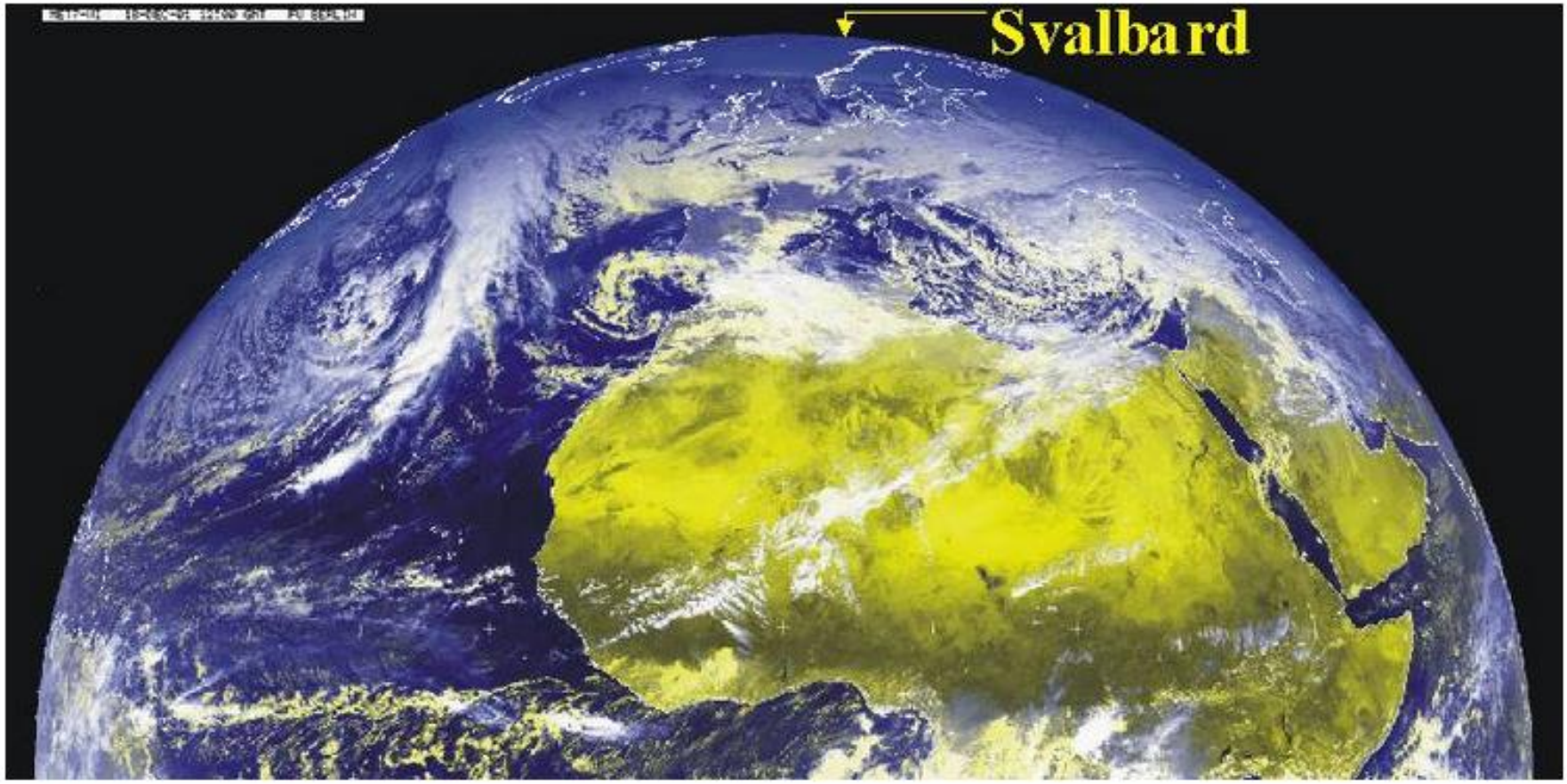
A Geographical-Historical Outline of Svalbard

by Ole Humlum, UNIS, Department of Geology, Svalbard, Norway



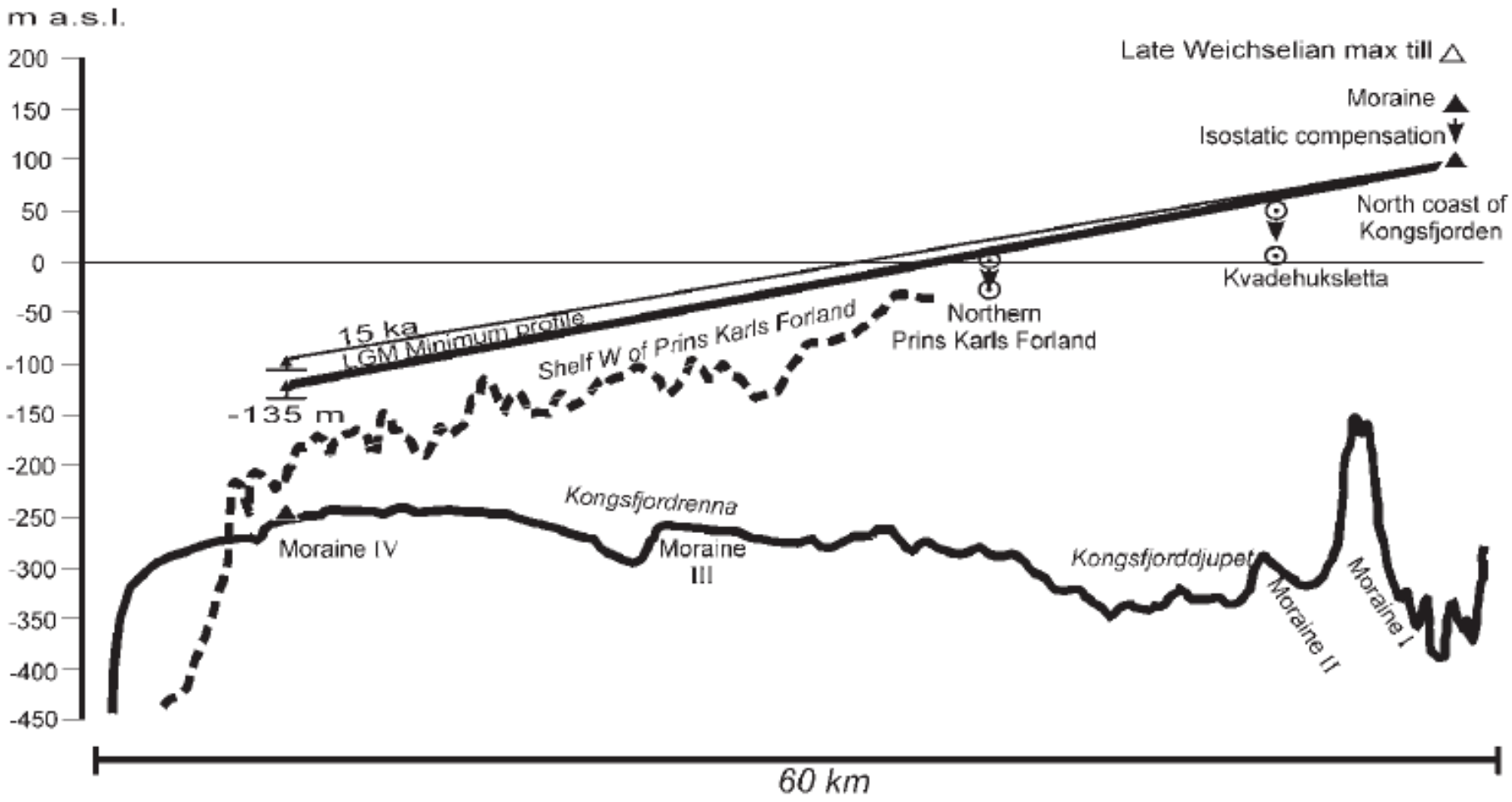


Fig. 7. Reconstructed lowest possible ice surface profile along Kongsfjorden and Kongsfjordrenna. See text for details.

Landvik et al 2005

Rethinking Late Weichselian ice-sheet dynamics in coastal NW Svalbard

JON Y. LANDVIK, ÓLAFUR INGÓLFSSON, JÜRGEN MIENERT, SCOTT J. LEHMAN, ANDERS SOLHEIM, ANDERS ELVERHØI AND DAG OTTESEN

BOREAS

Landvik, J. Y., Ingólfsson, Ó., Mienert, J., Lehman, S. J., Solheim, A., Elverhøi, A. & Ottesen, D. 2005 (February): Rethinking Late Weichselian ice-sheet dynamics in coastal NW Svalbard. *Boreas*, Vol. 34, pp. 7–24. Oslo. ISSN 0300-9483.

New marine geological evidence provides a better understanding of ice-sheet dynamics along the western margin of the last Svalbard/Barents Sea Ice Sheet. A suite of glacial sediments in the Kongsfjordrenna cross-shelf trough can be traced southwards to the shelf west of Prins Karls Forland. A prominent moraine system on the shelf shows minimum Late Weichselian ice extent, indicating that glacial ice also covered the coastal lowlands of northwest Svalbard. Our results suggest that the cross-shelf trough was filled by a fast-flowing ice stream, with sharp boundaries to dynamically less active ice on the adjacent shelves and strandflats. The latter glacial mode favoured the preservation of older geological records adjacent to the main pathway of the Kongsfjorden glacial system. We suggest that the same model may apply to the Late Weichselian glacier drainage along other fjords of northwest Svalbard, as well as the western margin of the Barents Ice Sheet. Such differences in glacier regime may explain the apparent contradictions between the marine and land geological record, and may also serve as a model for glaciation dynamics in other fjord regions.

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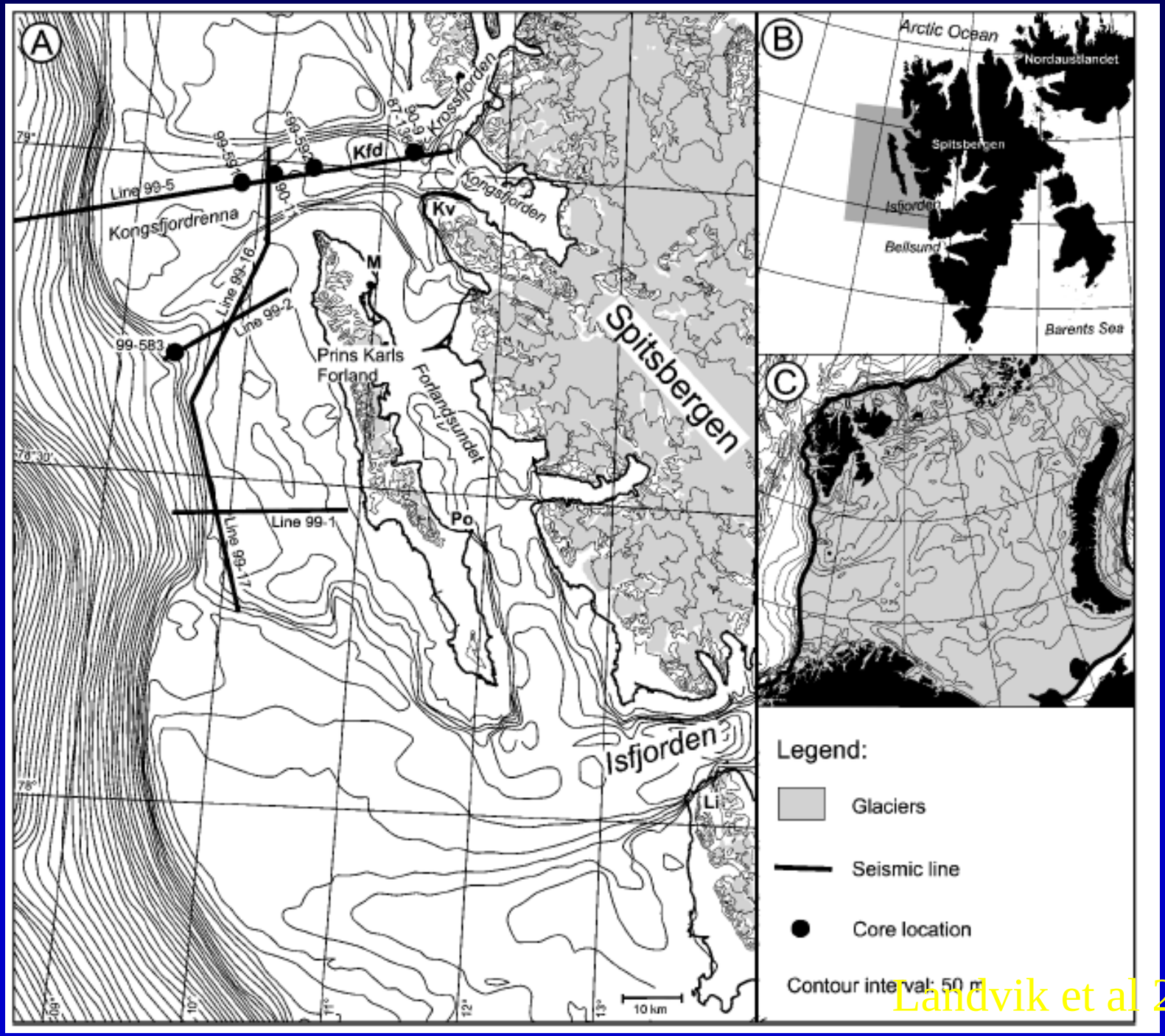
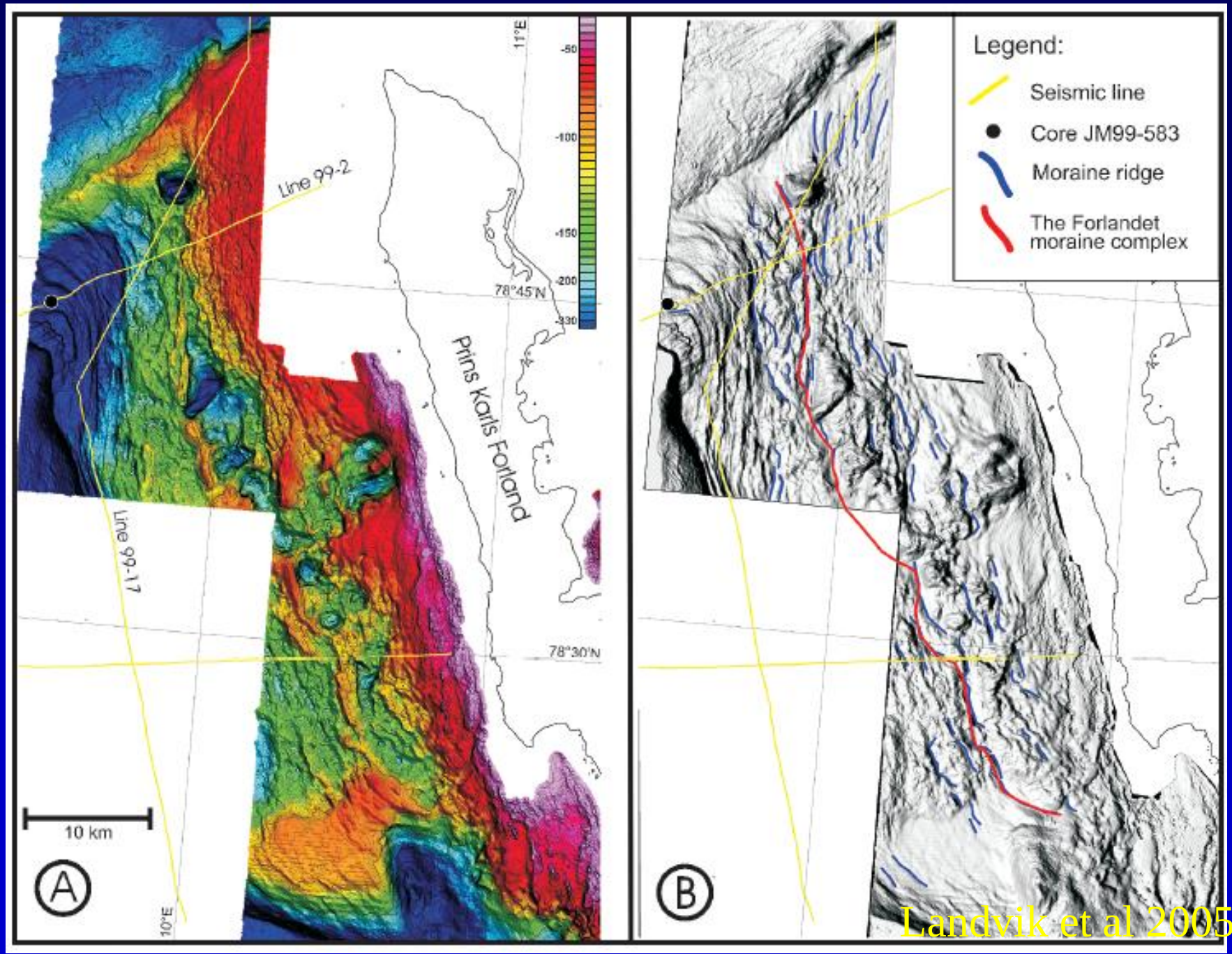
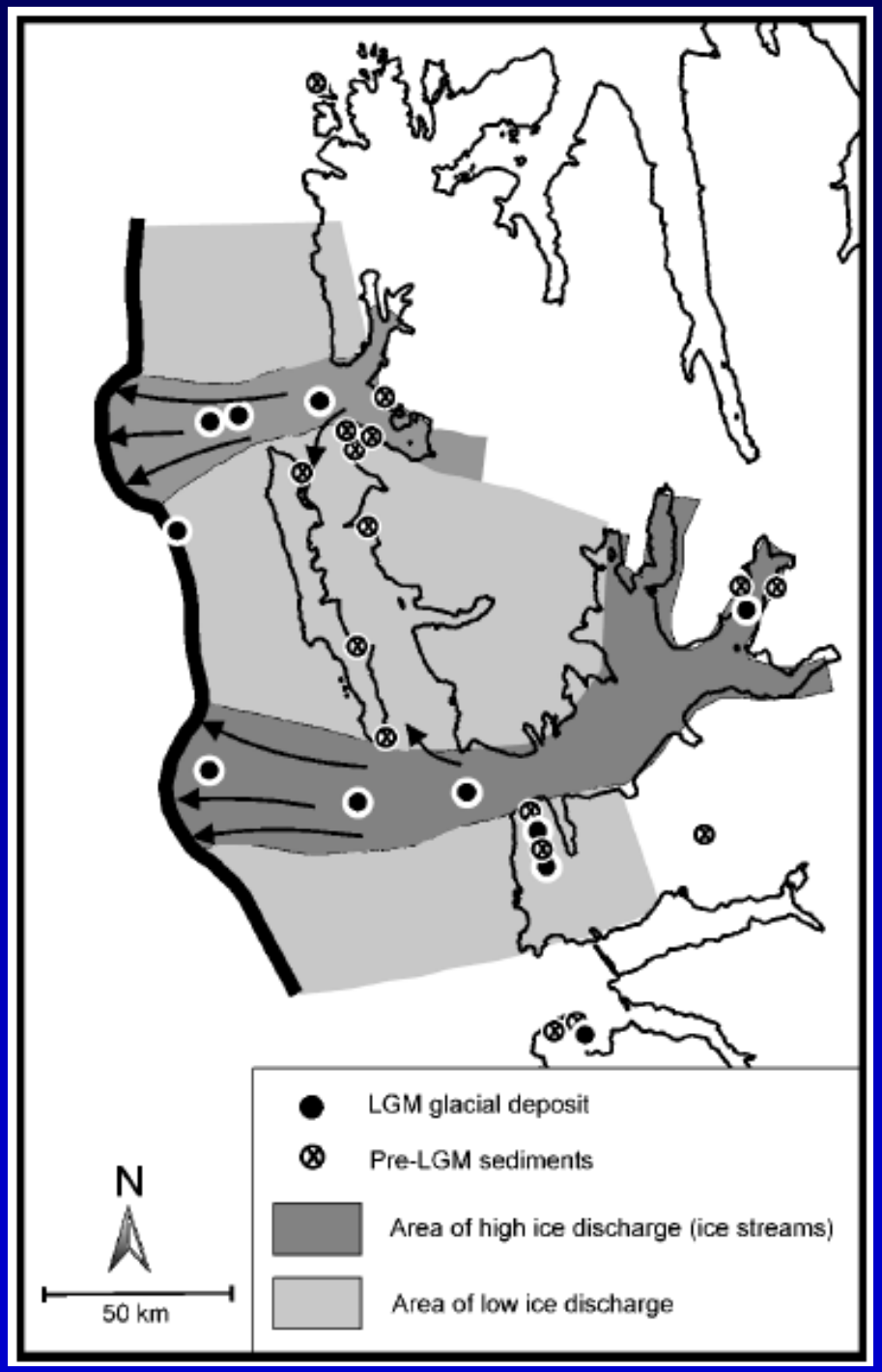
Landvik et al 2005



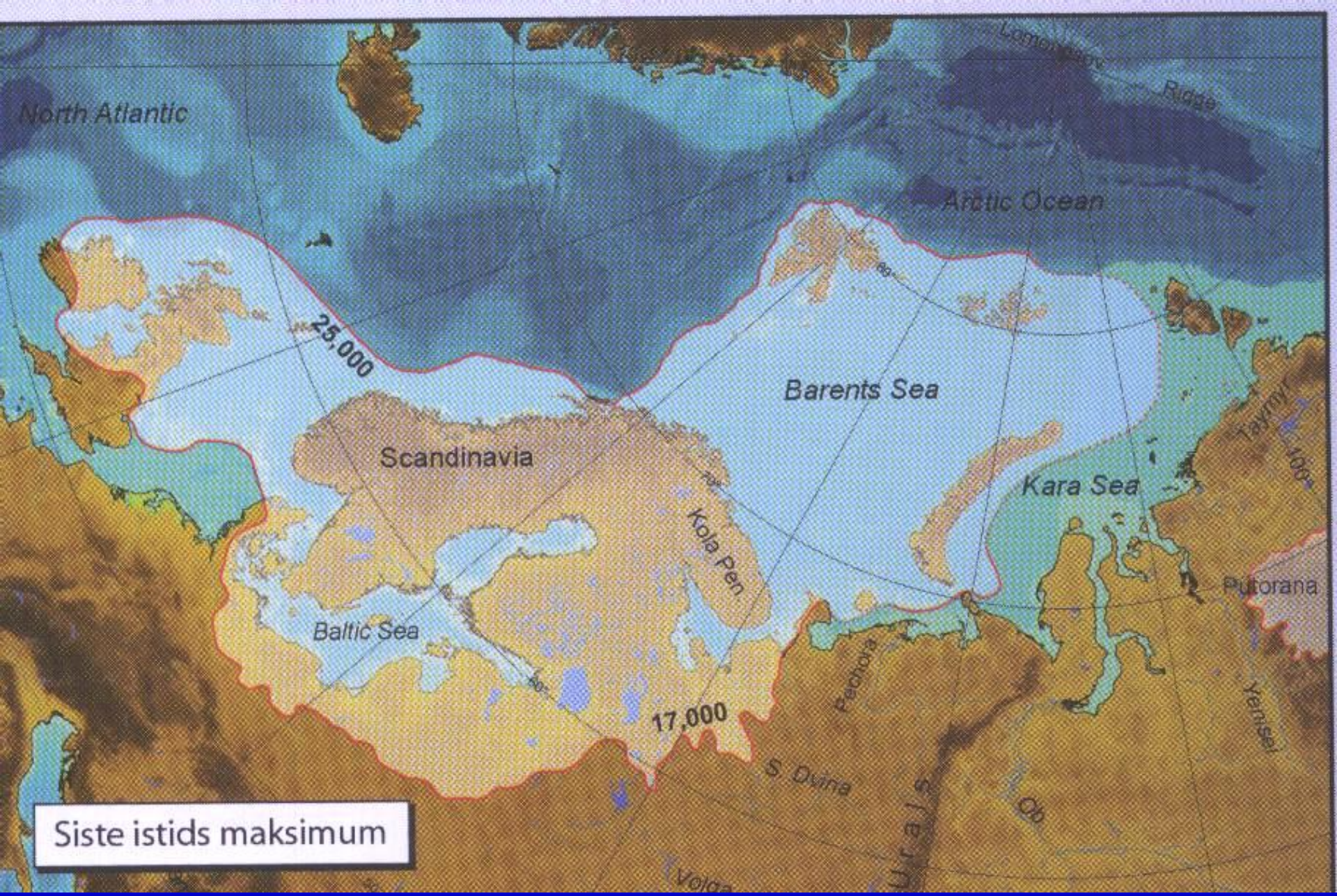
Landvik et al 2005

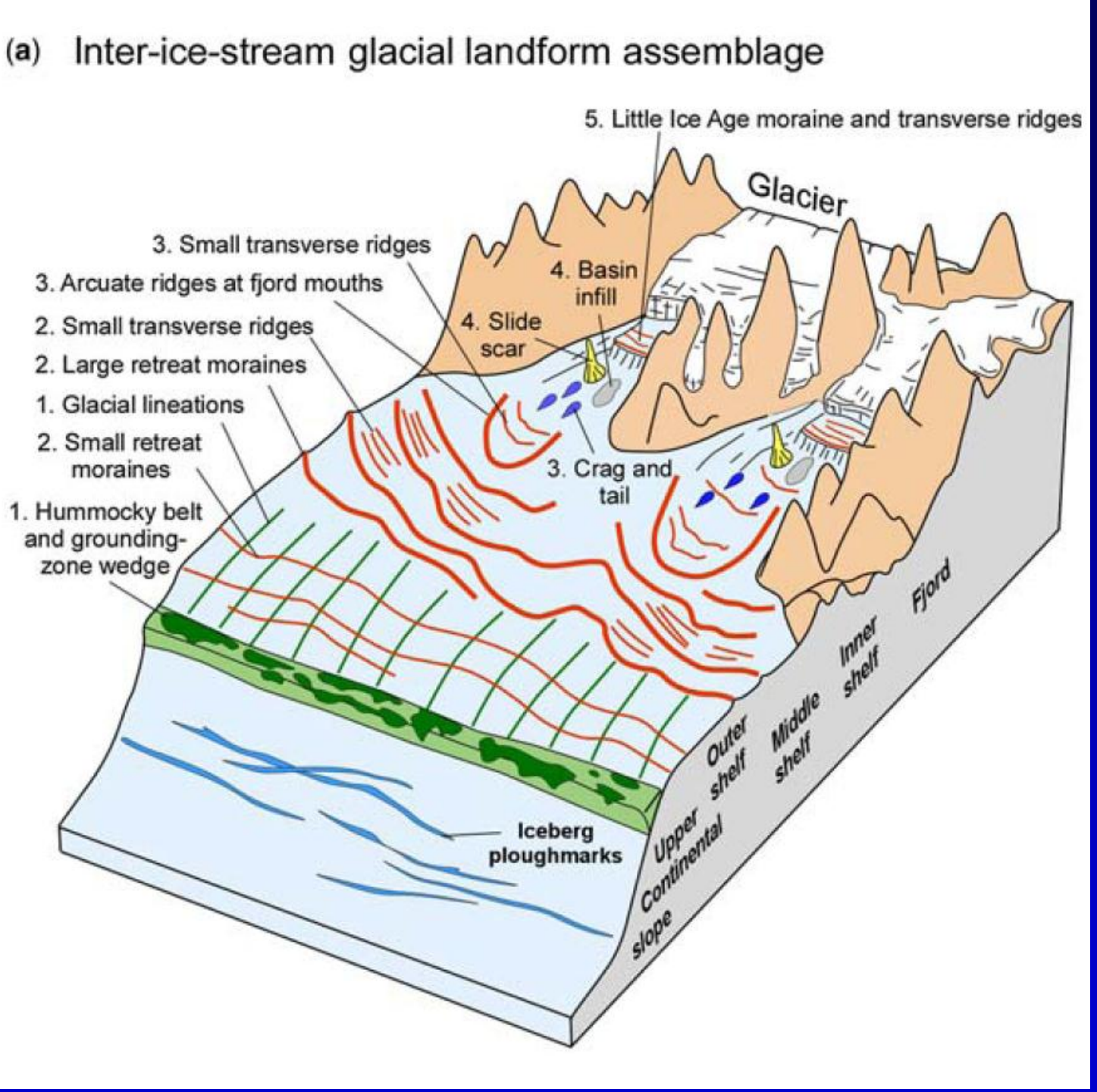


Landvik et al 2005

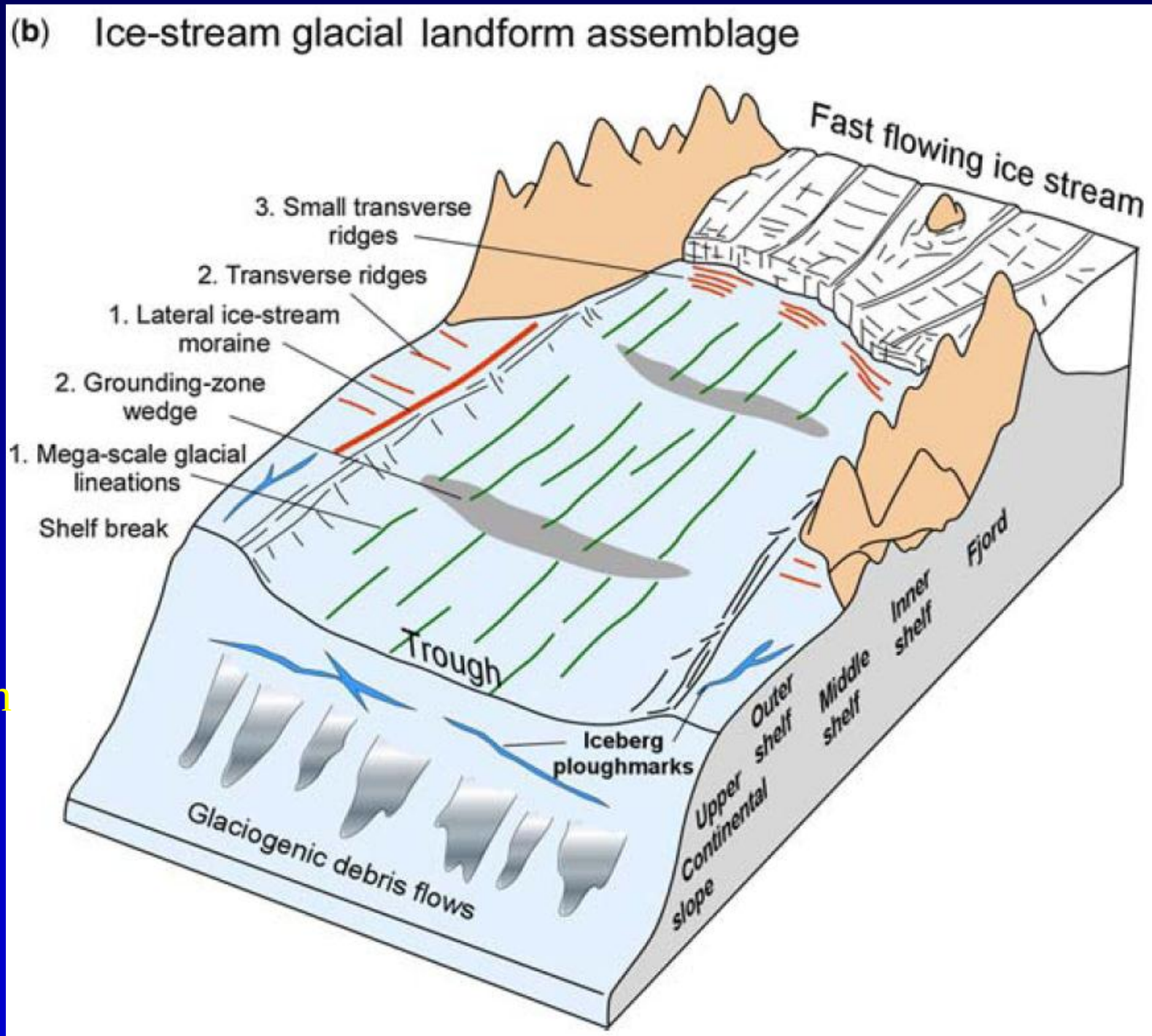


Landvik et al 2005


North Atlantic
Arctic Ocean
Lomonosov Ridge
25,000
Barents Sea
Scandinavia
Kara Sea
Taymyr
100°
Kola Pen
Baltic Sea
Putorana
Pechora
17,000
S. Dvina
Ob
Yensei
Urals
Siste istids maksimum



modified from Ottesen & Dowdeswell 2009 in Ingolfsson, 2011



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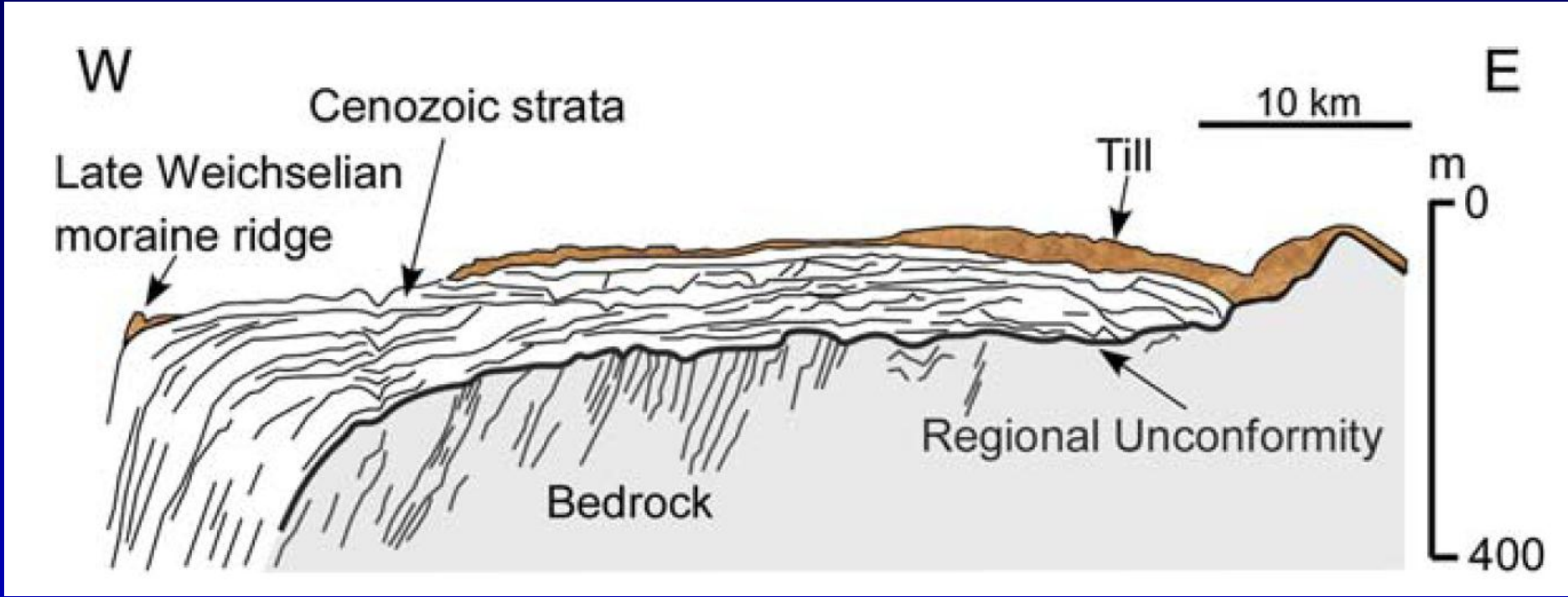

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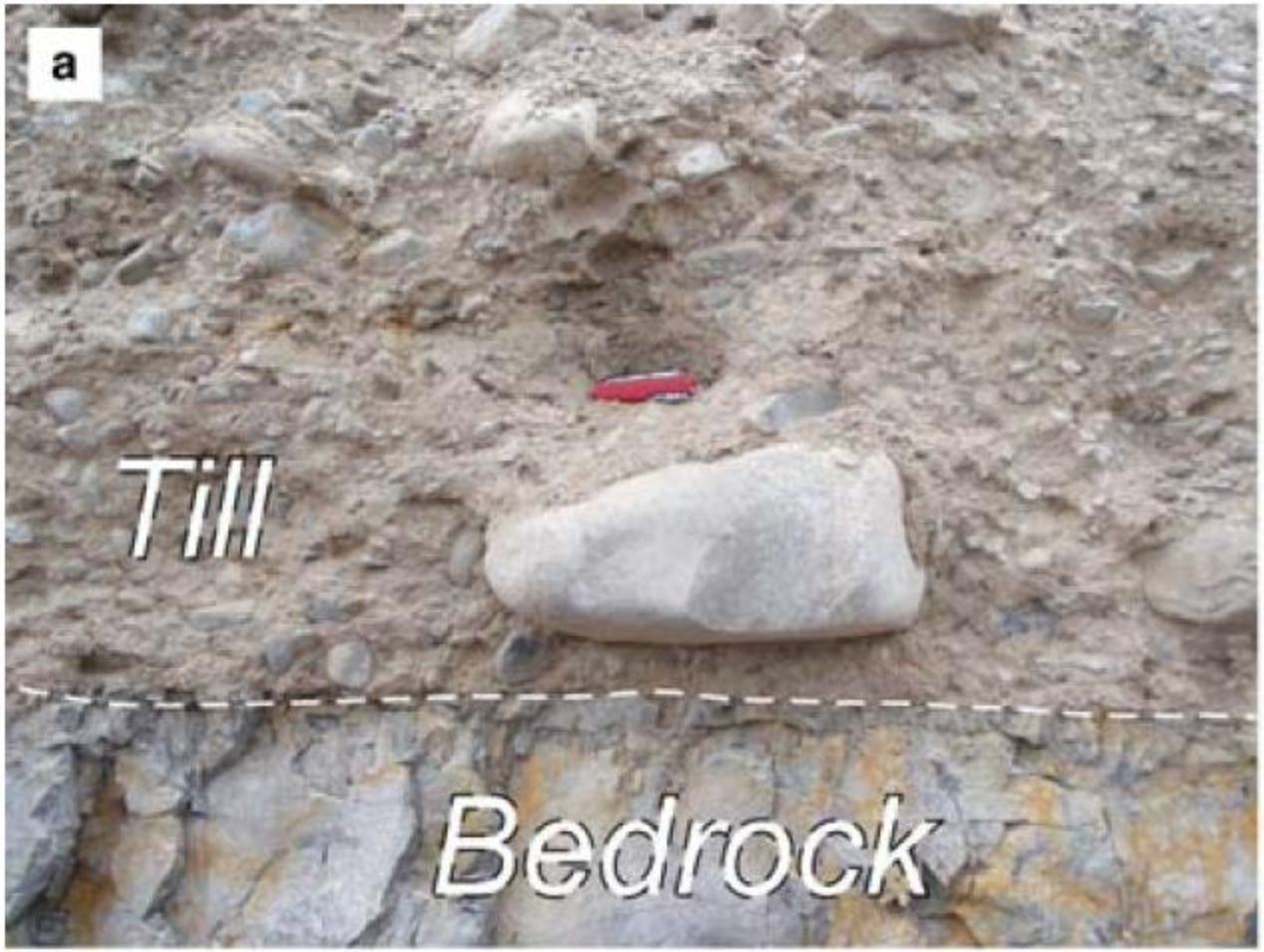
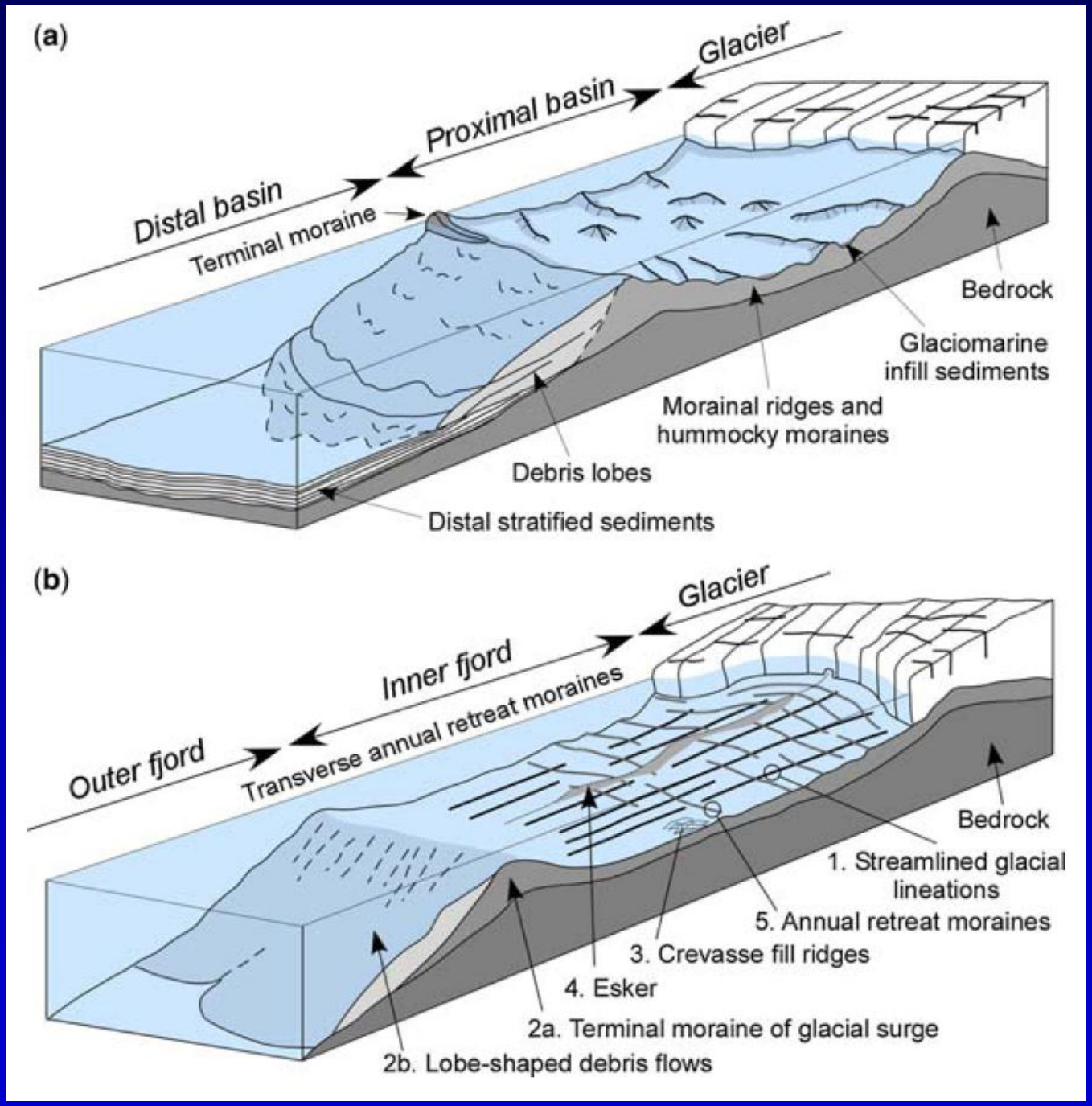
Ingolfsson, 2011


a
Till
Bedrock


b


c

fsson, 2011



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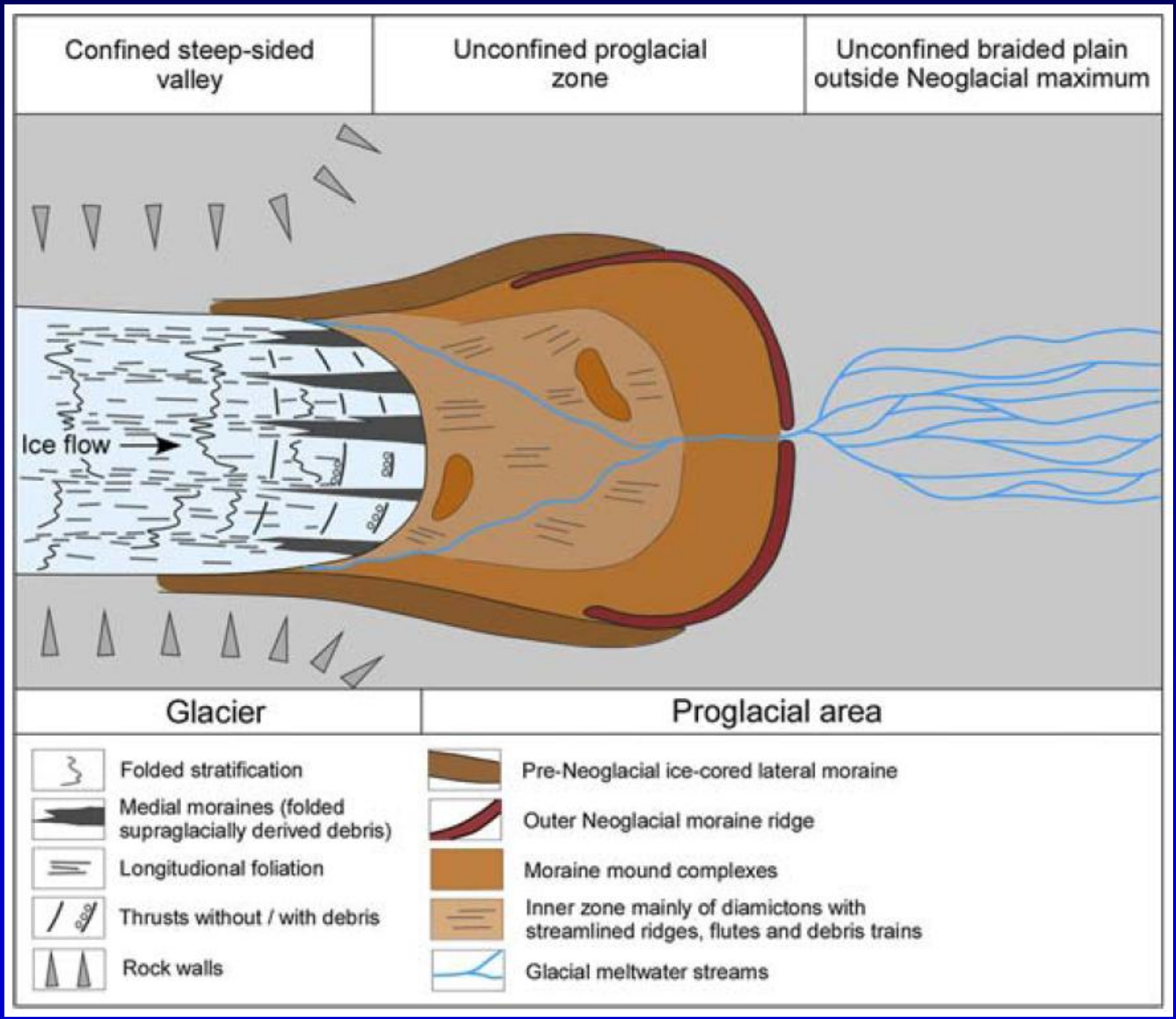

modified from Glasser & Hambrey 2003 in Ingolfsson, 2011

Fingerprints of Quaternary glaciations on Svalbard

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Abstract: Marine and terrestrial archives can be used to reconstruct the development of glacially influenced depositional environments on Svalbard in time and space during the late Cenozoic. The marine archives document sedimentary environments, deposits and landforms associated with the Last Glacial Maximum (LGM) when Svalbard and the Barents Sea were covered by continental-scale marine-based ice sheet, the last deglaciation and the work of tidewater glaciers in interglacial setting as today. The terrestrial archives record large-scale Quaternary glacial sculpturing and repeated build-up and decay of the Svalbard–Barents Sea ice sheet. The fingerprinting of Quaternary glaciations on Svalbard reflects the transition from a full-glacial mode, with very extensive coverage by the Svalbard–Barents Sea ice sheet and subsequent deglaciation, to an interglacial mode with valley, cirque and tidewater glaciers as active agents of erosion and deposition. Conceptual models for Svalbard glacial environments are useful for understanding developments of glacial landforms and sediments in formerly glaciated areas. Svalbard glacial environments, past and present, may serve as analogues for interpreting geological records of marine-terminating and marine-based ice sheets in the past.

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