Università di Trieste
Corso di Laurea in Geologia

Anno accademico 2017 - 2018

Geologia Marina

Parte III

Modulo 3.3 Sistemi deposizionali polari

Docente
A. Camerlenghi

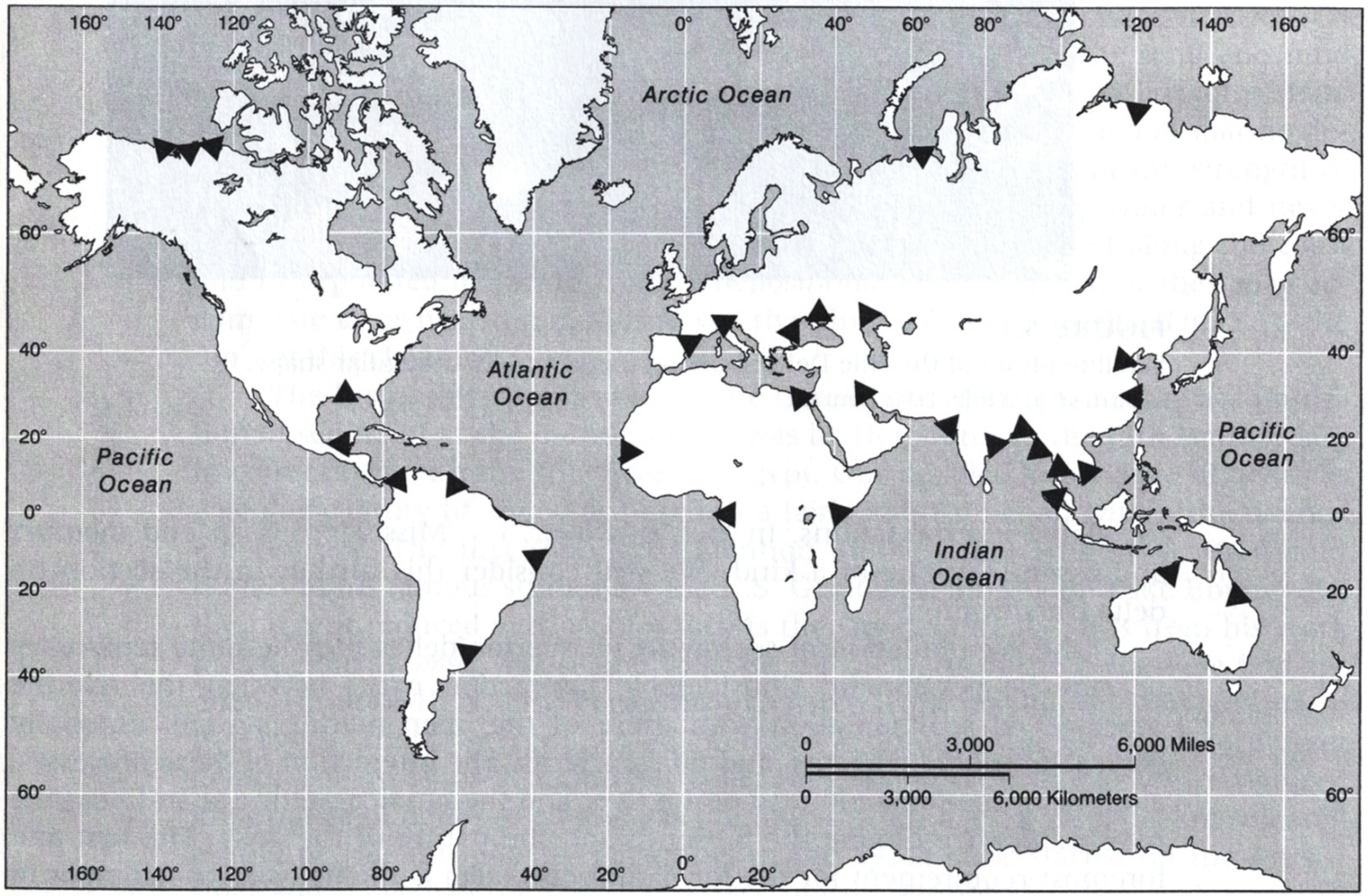
OUTLINE

- River-dominated marine sedimentary systems
- River versus ice sheet sediment source
- Ice sheet-dominated sedimentary systems
  - **Ice streams**
  - **Paleo ice streams**
    - Onshore evidence
    - Offshore evidence
  - **Trough-mouth fans**
    - Two main sedimentary agents
      - Ice stream push: Glacial maxima debris flows
      - Melt water
        - Tunnel valleys
        - Meltwater plumes and plumites
  - **Grounding-zone wedges**
- Sea ice sediment transport
- Contourites
- Turbidites
- Mass transport deposits

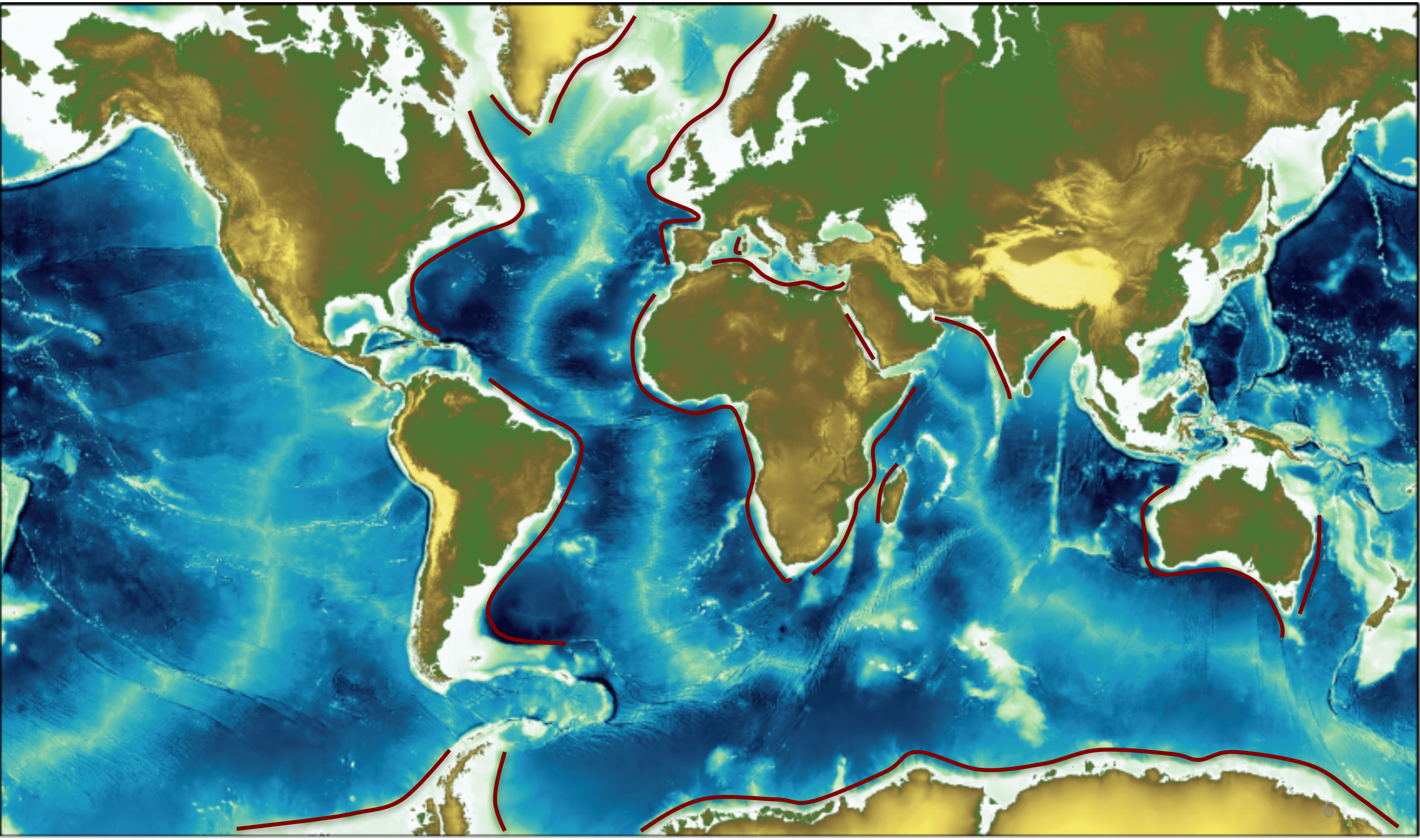
RIVER-DOMINATED MARINE SEDIMENTARY SYSTEMS

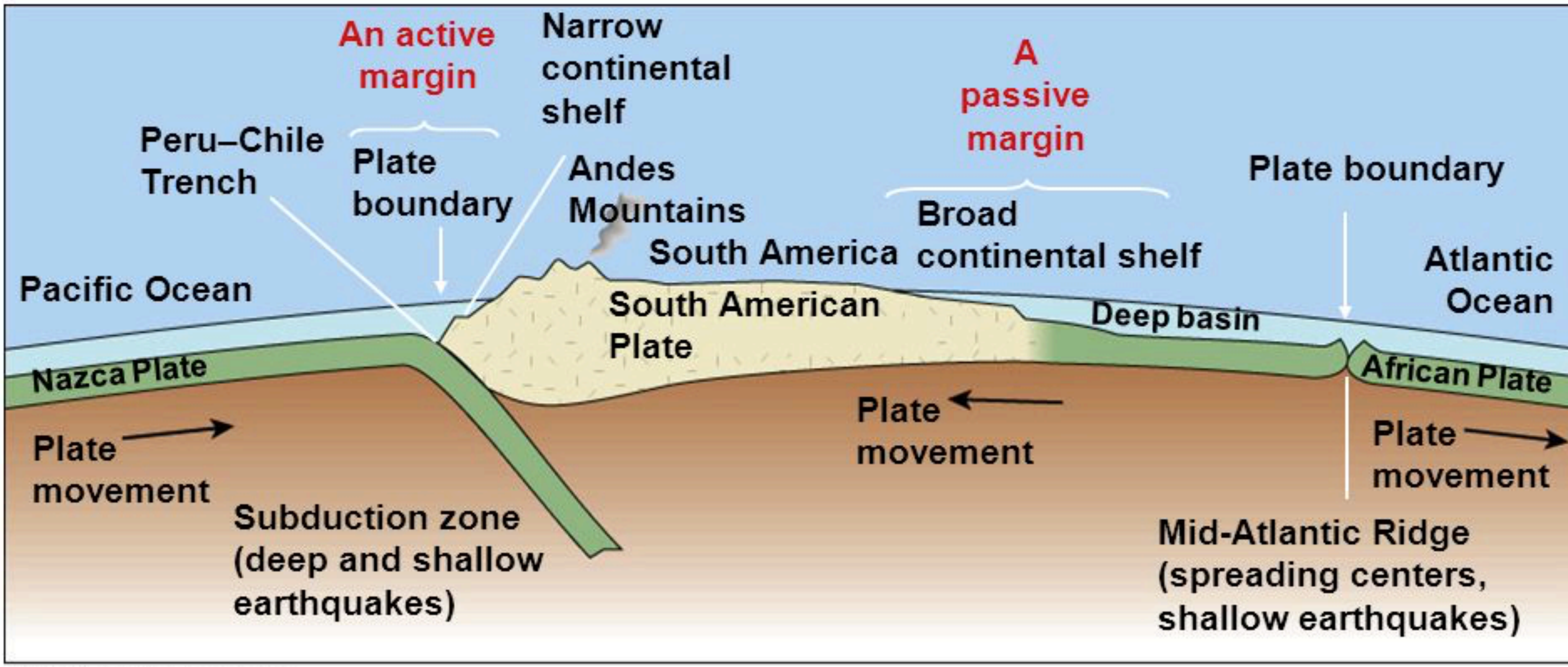

WORLD
Major River & Lakes
ARCTIC OCEAN
NORTH AMERICA
Yukon
Mackenzie
Great Bear Lake
Great Slave Lake
Hudson Bay
Winnipeg
L. Superior
Missouri
St. Lawrence
Snake
L. Michigan
L. Huron
L. Ontario
L. Erie
Great Salt Lake
Arkansas
Colorado
Mississippi
Rio Grande
Gulf of Mexico
Caribbean Sea
NORTH ATLANTIC OCEAN
PACIFIC OCEAN
SOUTH AMERICA
Amazon
São Francisco
L. Titicaca
Paraguay
Uruguay
Parana
SOUTH ATLANTIC OCEAN
EUROPE
L. Ladoga
Baltic Sea
Volga
Ural
Danube
Black Sea
Caspian Sea
Mediterranean Sea
Euphrates
AFRICA
Niger
Nile
Red Sea
L. Chad
Congo
L. Victoria
L. Tanganyika
L. Nyasa
Zambezi
Orange
ASIA
Yenisey
Lena
Kolyma
Angara
Lake Baikal
Sea of Okhotsk
Amur
Irtysh
Aral Sea
L. Balkhash
Yellow River
Yangtze
Indus
Brahmputra
Ganges
Arabian Sea
Bay of Bengal
Krishna
Xun Jiang
Mekong
PACIFIC OCEAN
INDIAN OCEAN
AUSTRALIA
L. Eyre
Darling
SOUTHERN OCEAN
LEGEND
International Boundary
Major River
Major Lake
0 1000 2000 Km
0 500 1000 Miles
Copyright © 2013 www.mapsofworld.com
(Updated on 4th June, 2013)

Global Distribution of Deltas



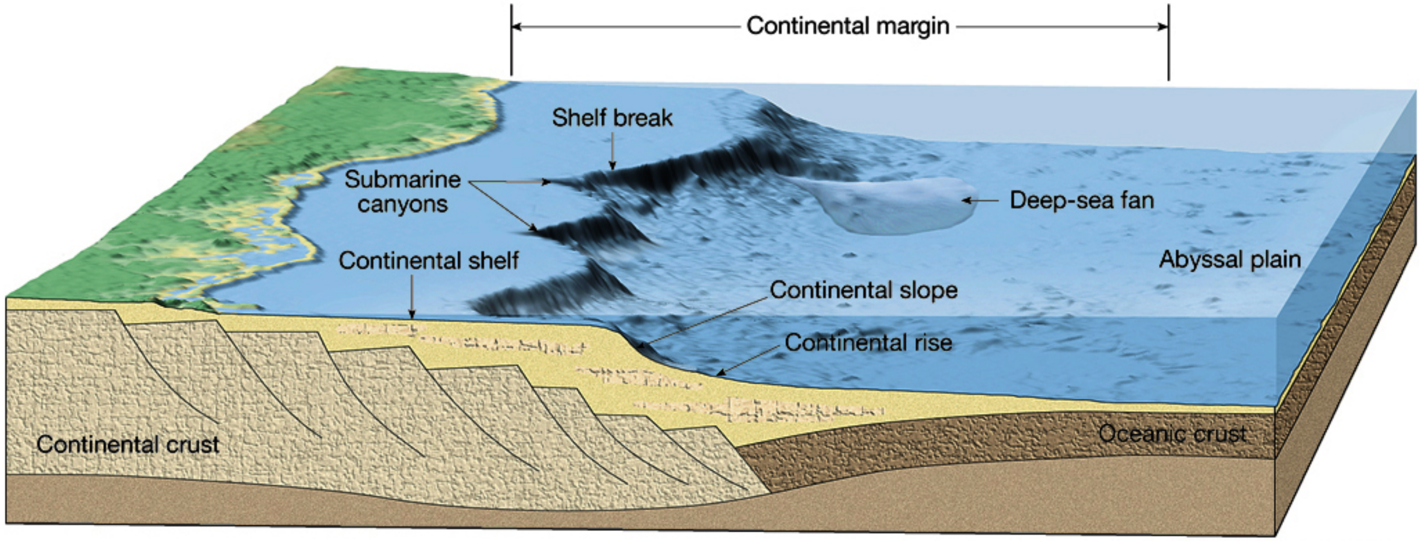
Rifted margins are found in the Entire Atlantic Ocean (except Barbados and South Shetland subduction zone), Antarctica, Arctic, and Indian Ocean




An active margin
Narrow continental shelf
A passive margin
Peru–Chile Trench
Plate boundary
Andes Mountains
Plate boundary
Broad continental shelf
South America
Atlantic Ocean
Pacific Ocean
South American Plate
Deep basin
Nazca Plate
African Plate
Plate movement
Plate movement
Plate movement
Subduction zone (deep and shallow earthquakes)
Mid-Atlantic Ridge (spreading centers, shallow earthquakes)

RIFTED PASSIVE MARGINS

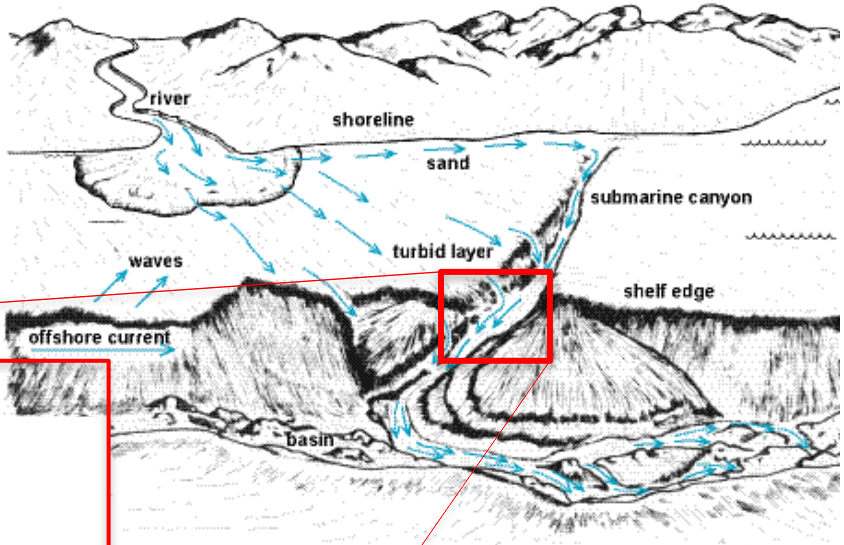
Rifted passive margin create the accommodation space for hosting the largest sedimentary accumulations in the world oceans, including the river-dominated Arctic Ocean

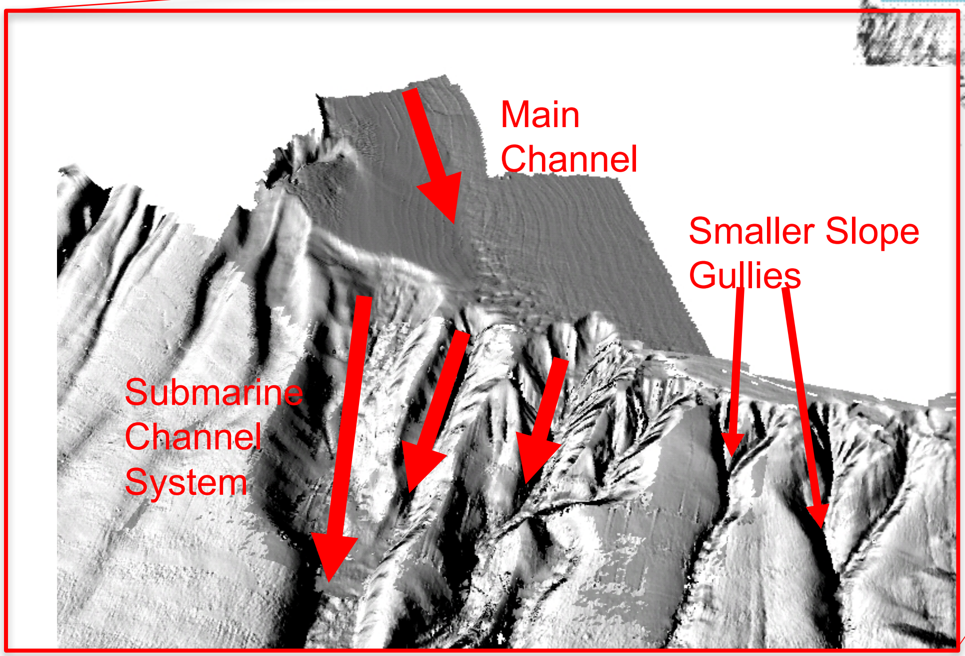


TASA Graphic Arts, 2002

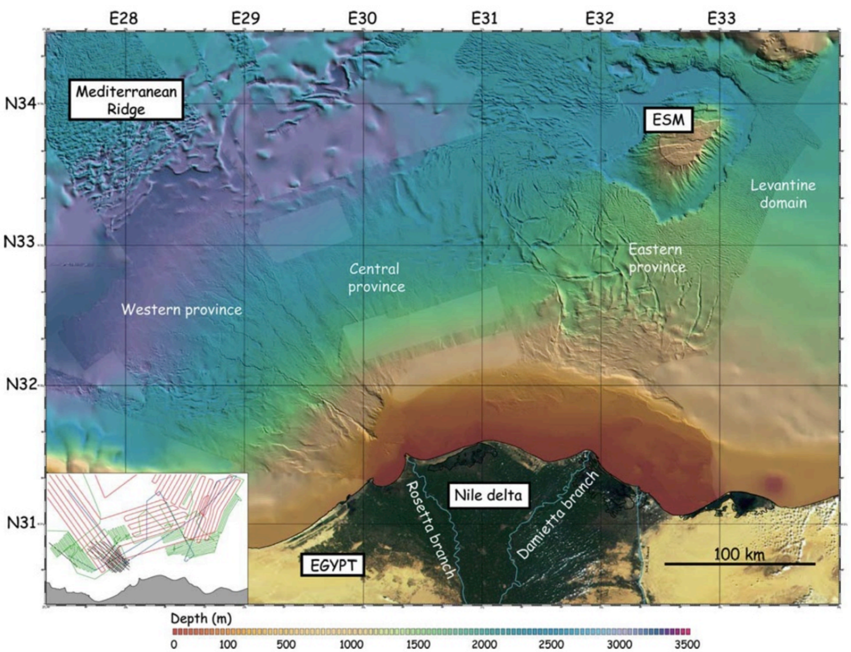
RIVER DOMINATED marine sedimentary systems

- Rivers are point-source
- Sediment transport and deposition controlled primarily by <u>sea level changes</u>
- River deltas
- Deep Sea Fans
- Submarine Canyons
- Deep Sea Channels



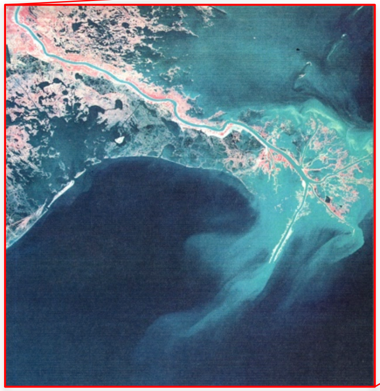


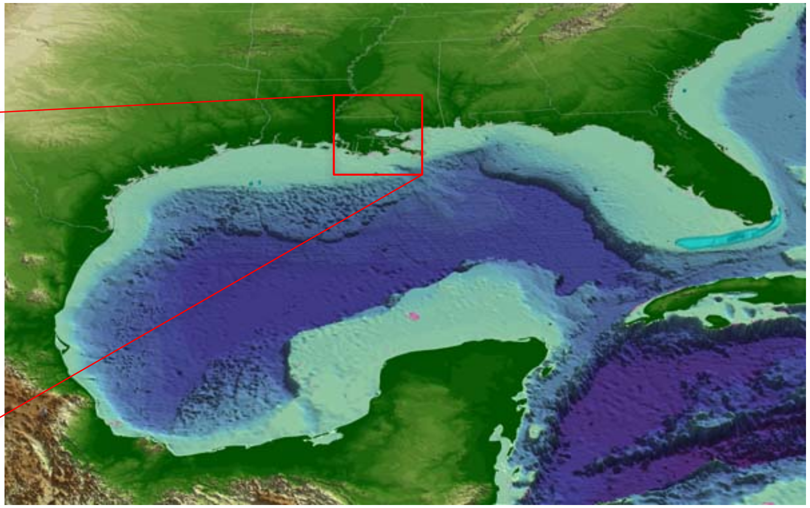
Deep sea fans



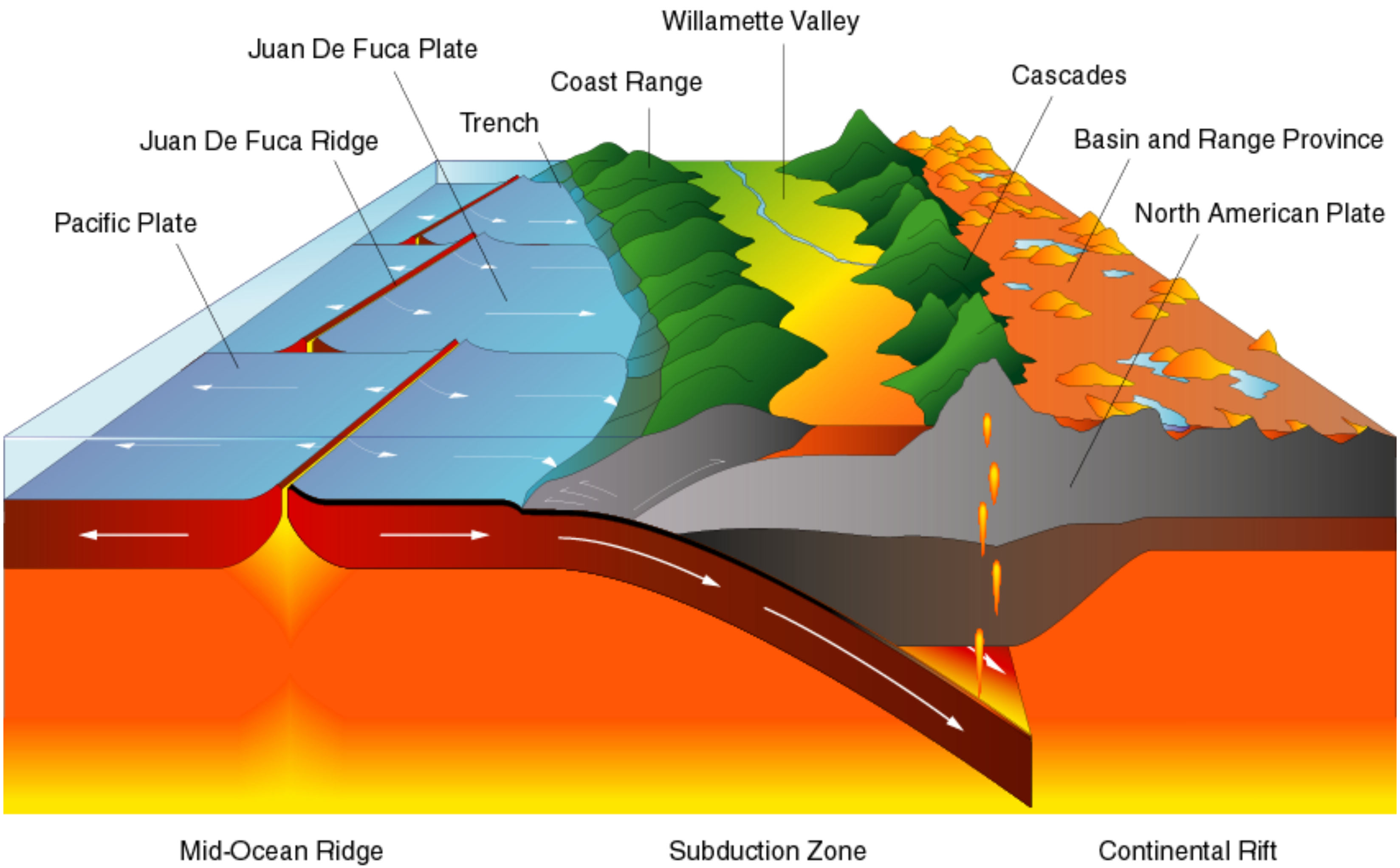
Nile, Loncke et al., 2006

Indus and Bengal

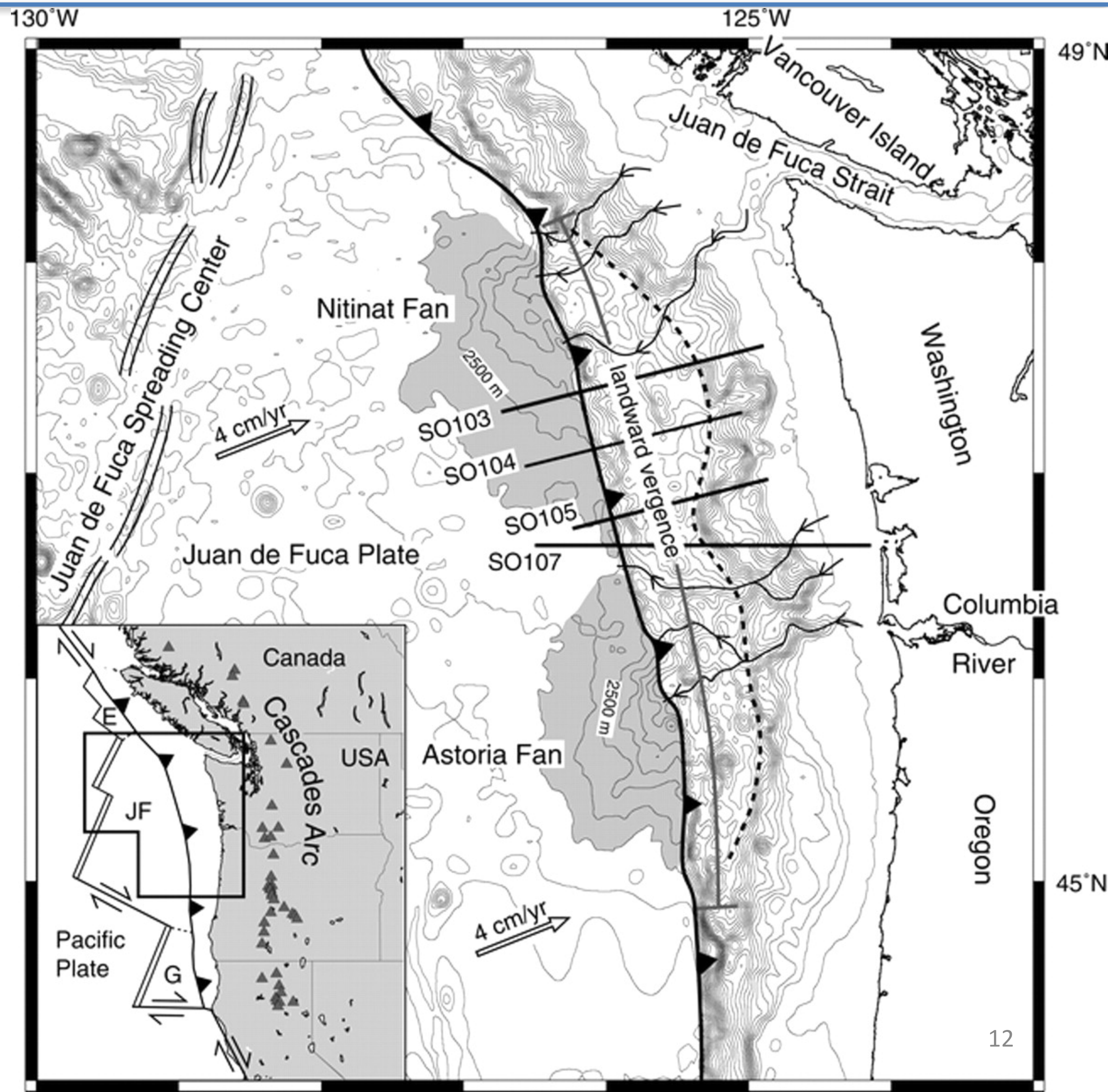




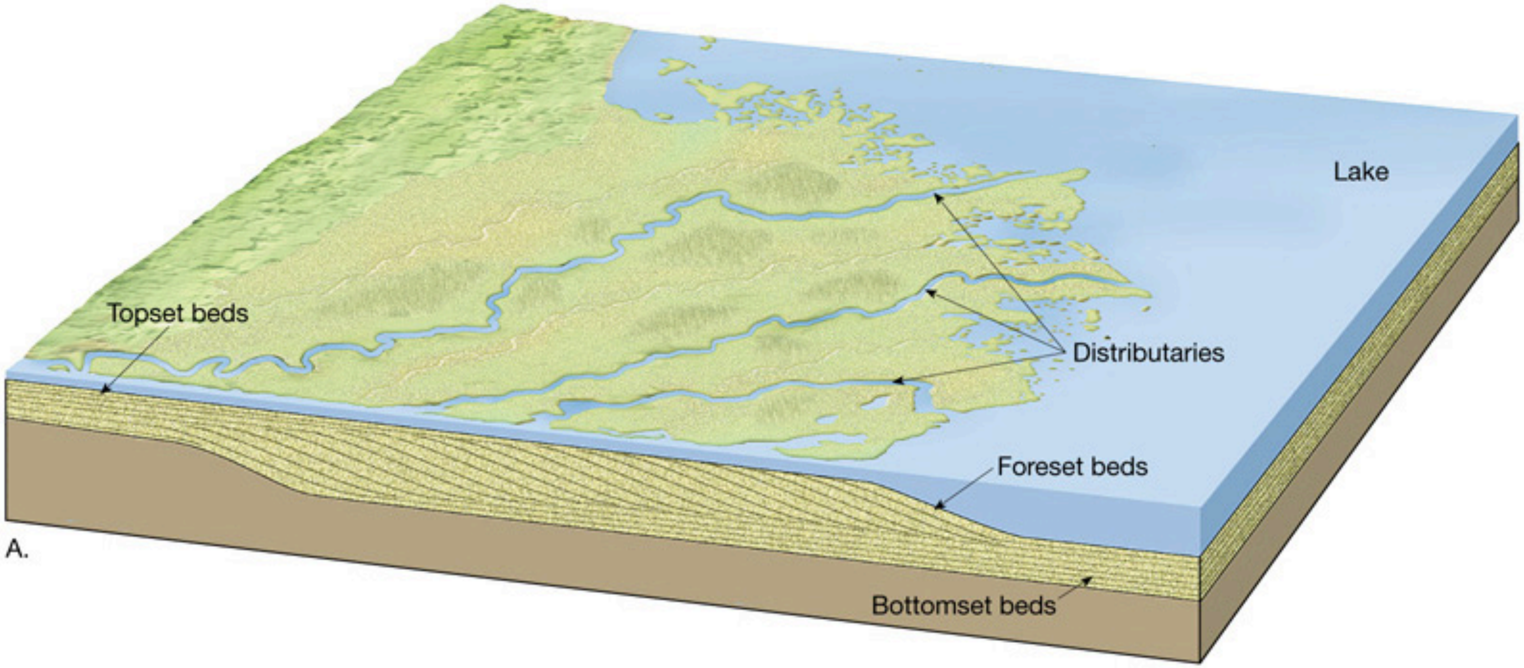
Mississippi


Willamette Valley
Juan De Fuca Plate
Coast Range
Cascades
Trench
Basin and Range Province
Juan De Fuca Ridge
North American Plate
Pacific Plate
Mid-Ocean Ridge
Subduction Zone
Continental Rift

ALSO ON ACTIVE MARGINS

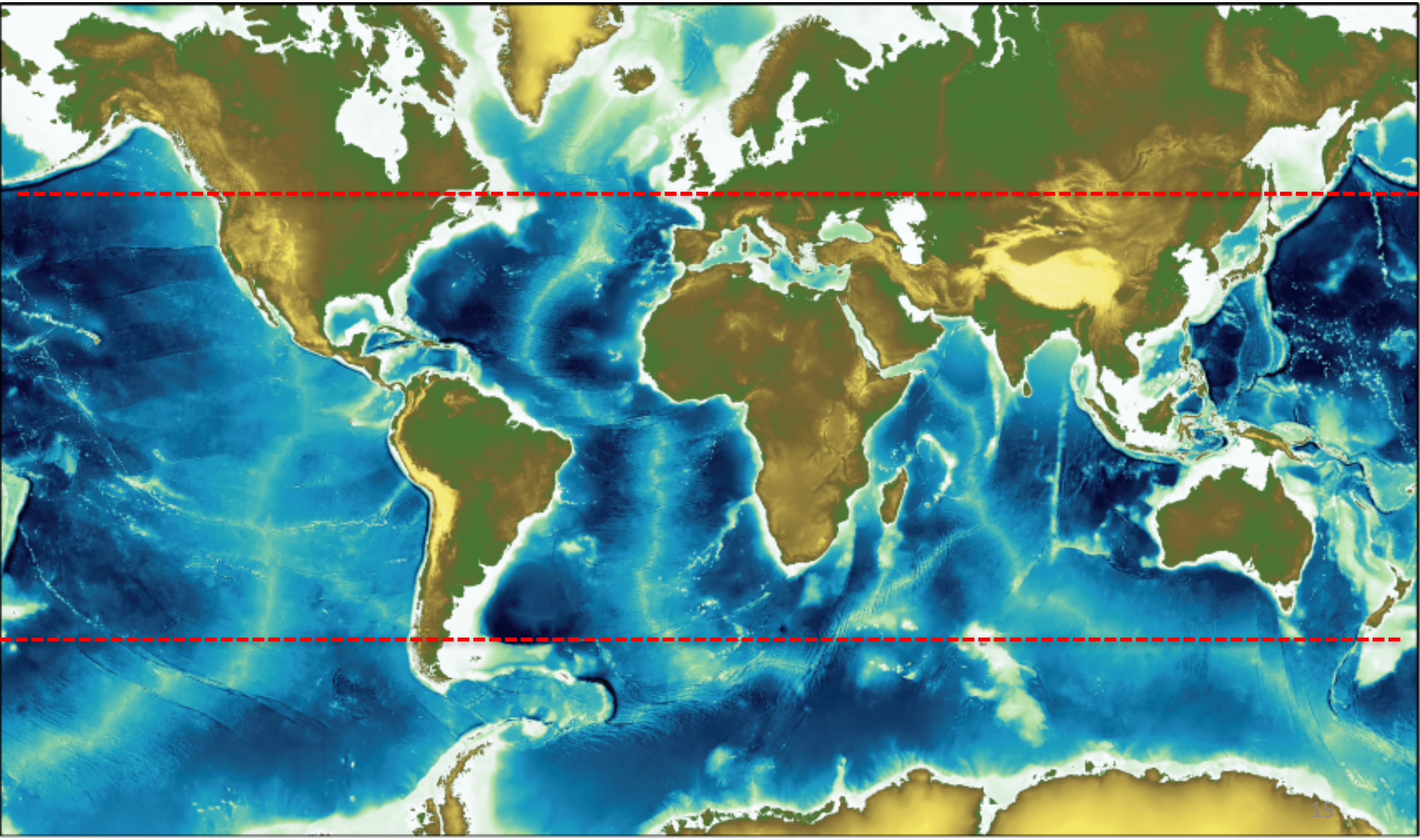


IN RIVER-DOMINATED MARINE SEDIMENTARY SYSTEMS SEDIMENTS ARE MOSTLY **SAND**



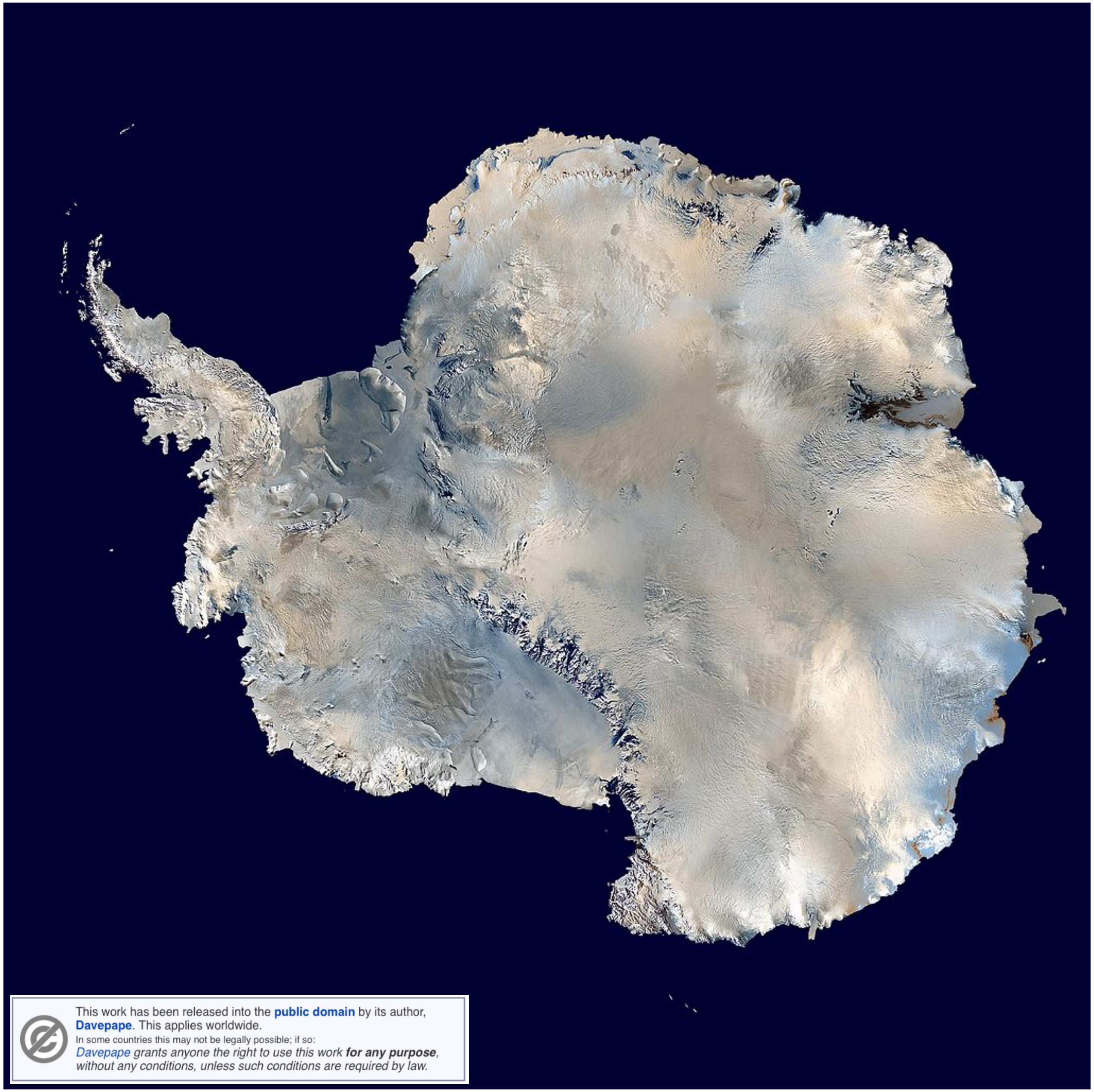
RIVER VERSUS ICE SHEET SEDIMENT SOURCE

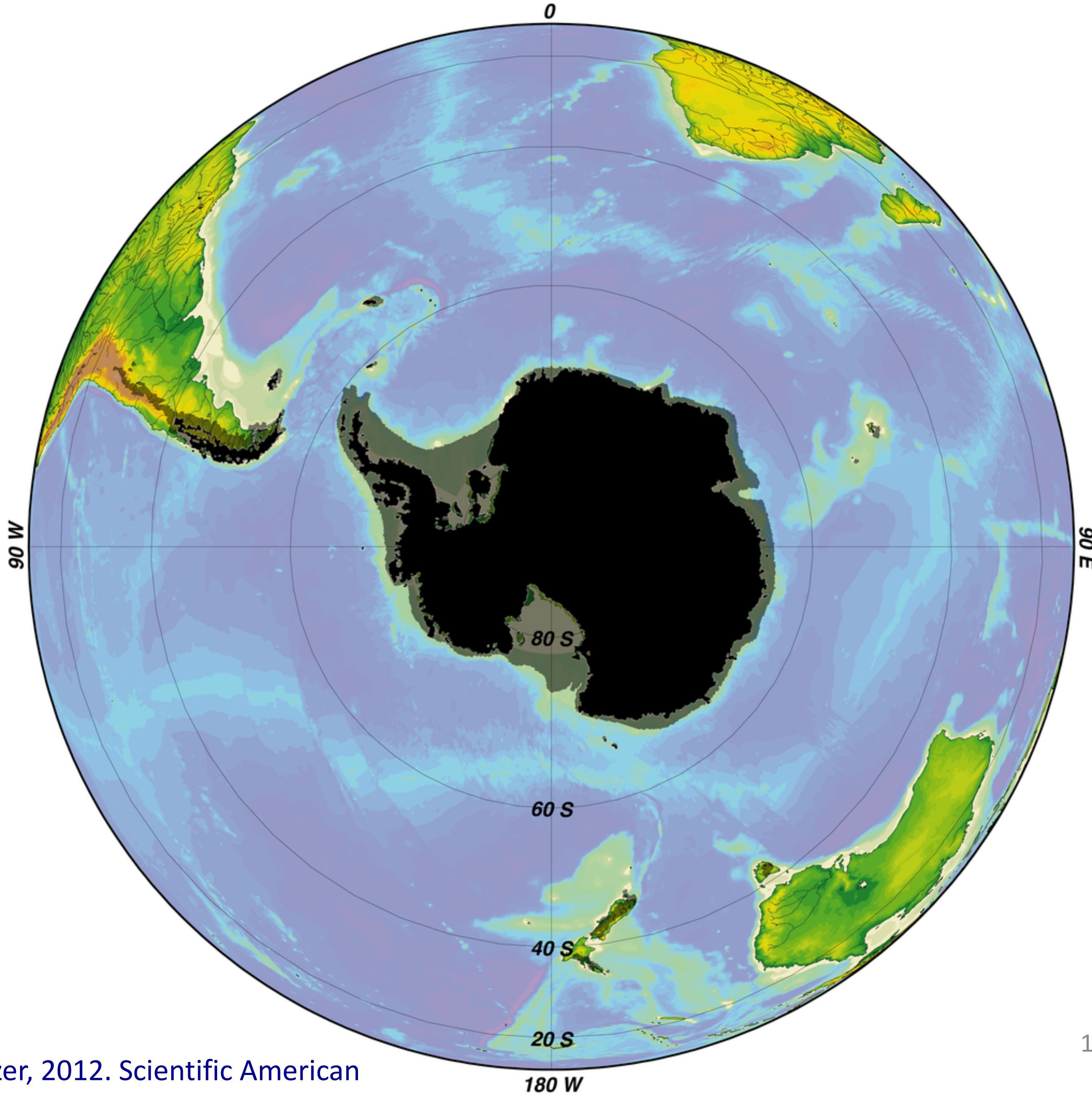
Rifted margins are found in the Entire Atlantic Ocean (except Barbados and South Shetland subduction zone), Antarctica, Arctic, and Indian Ocean



Antarctica:
No rivers

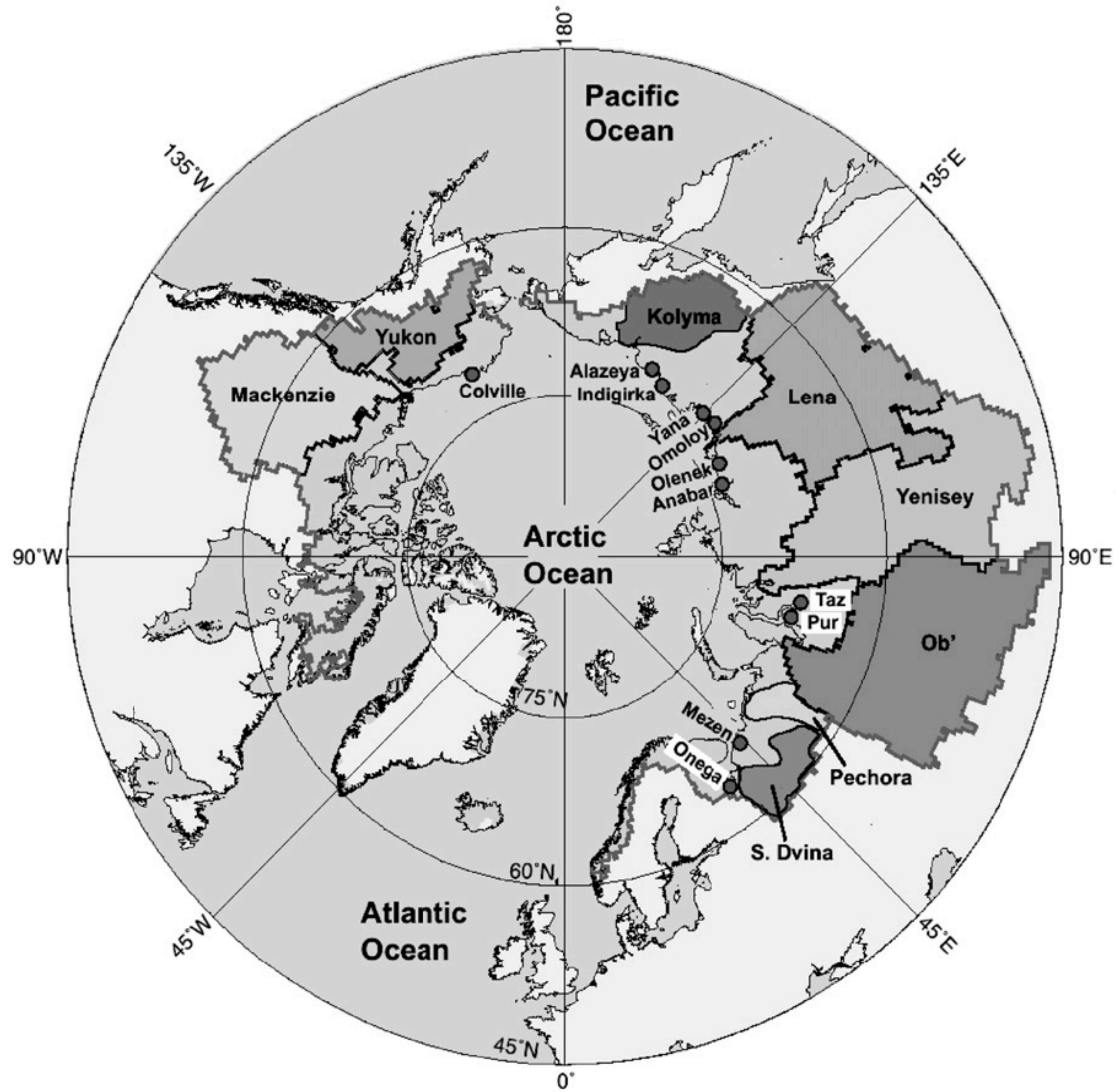
Only ICE-SHEET DOMINATED Sedimentary input to the oceans





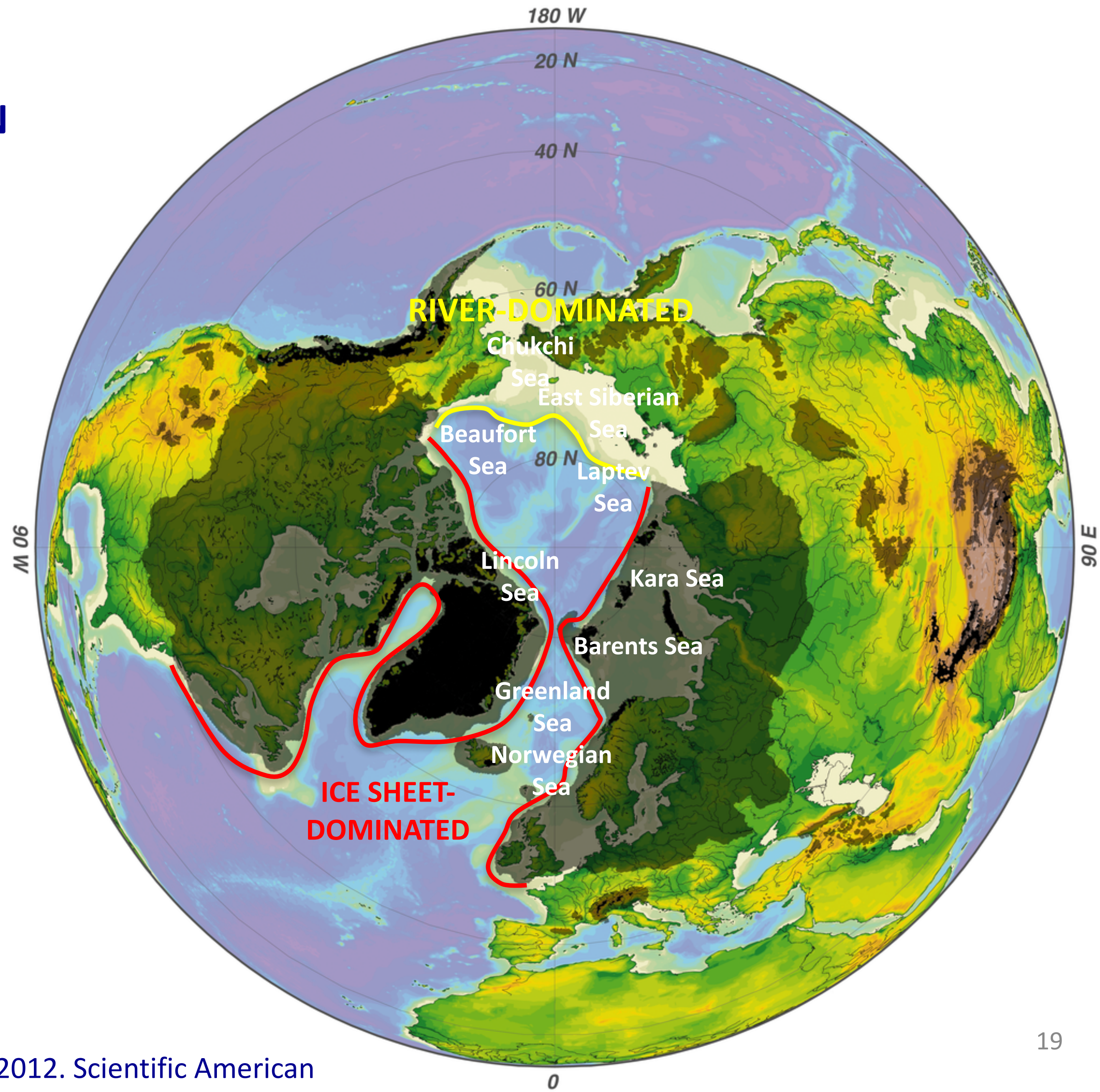
Hannes Grobe/AWI, from Frazer, 2012. Scientific American

RIVERINE INPUT IN THE ARCTIC OCEAN (During interglacials)



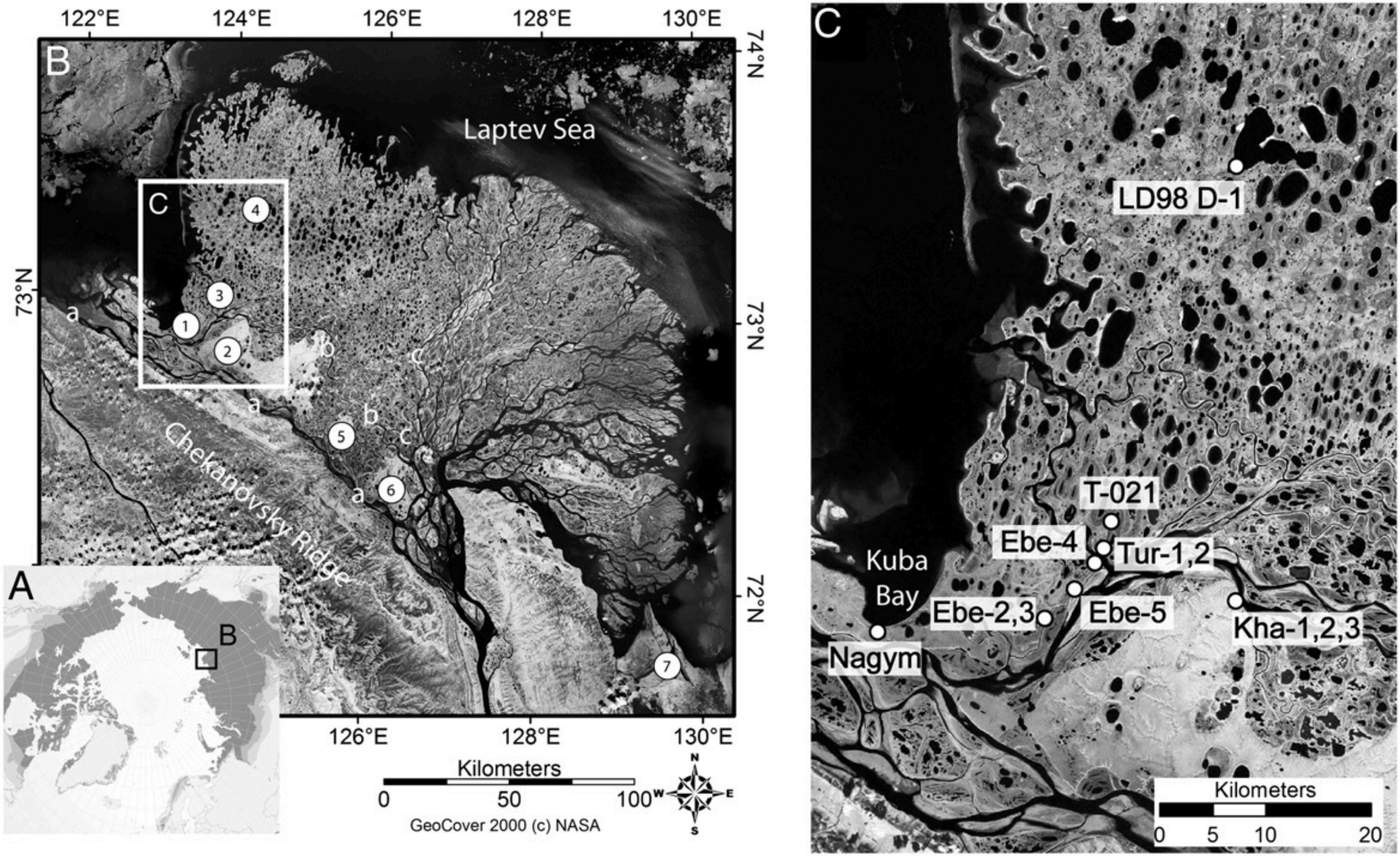
Stein, 2008

RIVERINE INPUT
IN THE ARCTIC OCEAN
(During glacials)



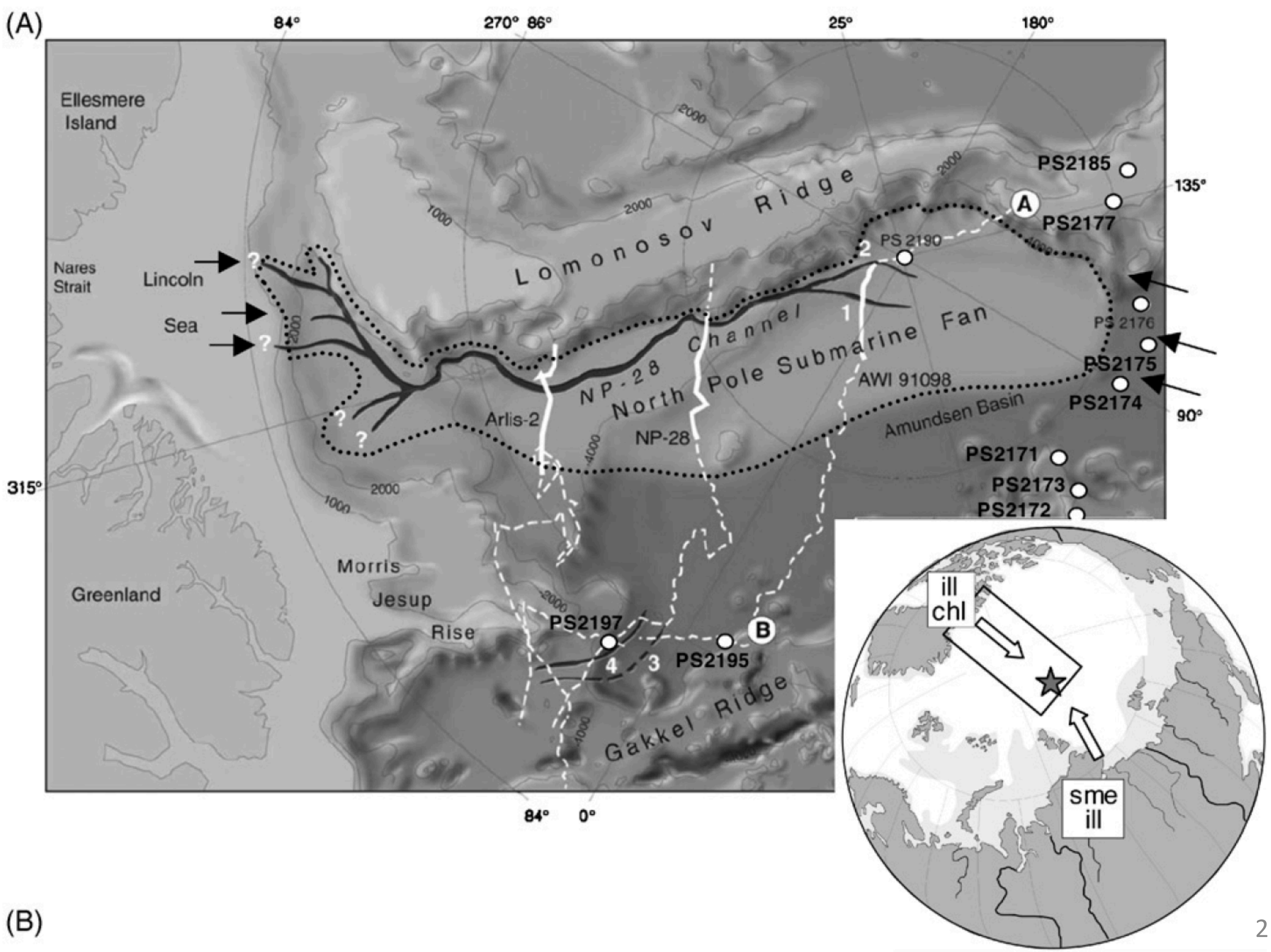
Hannes Grobe/AWI, from Frazer, 2012. Scientific American

Lena Delta Today



Schirrmeister, L., et al., 2011.

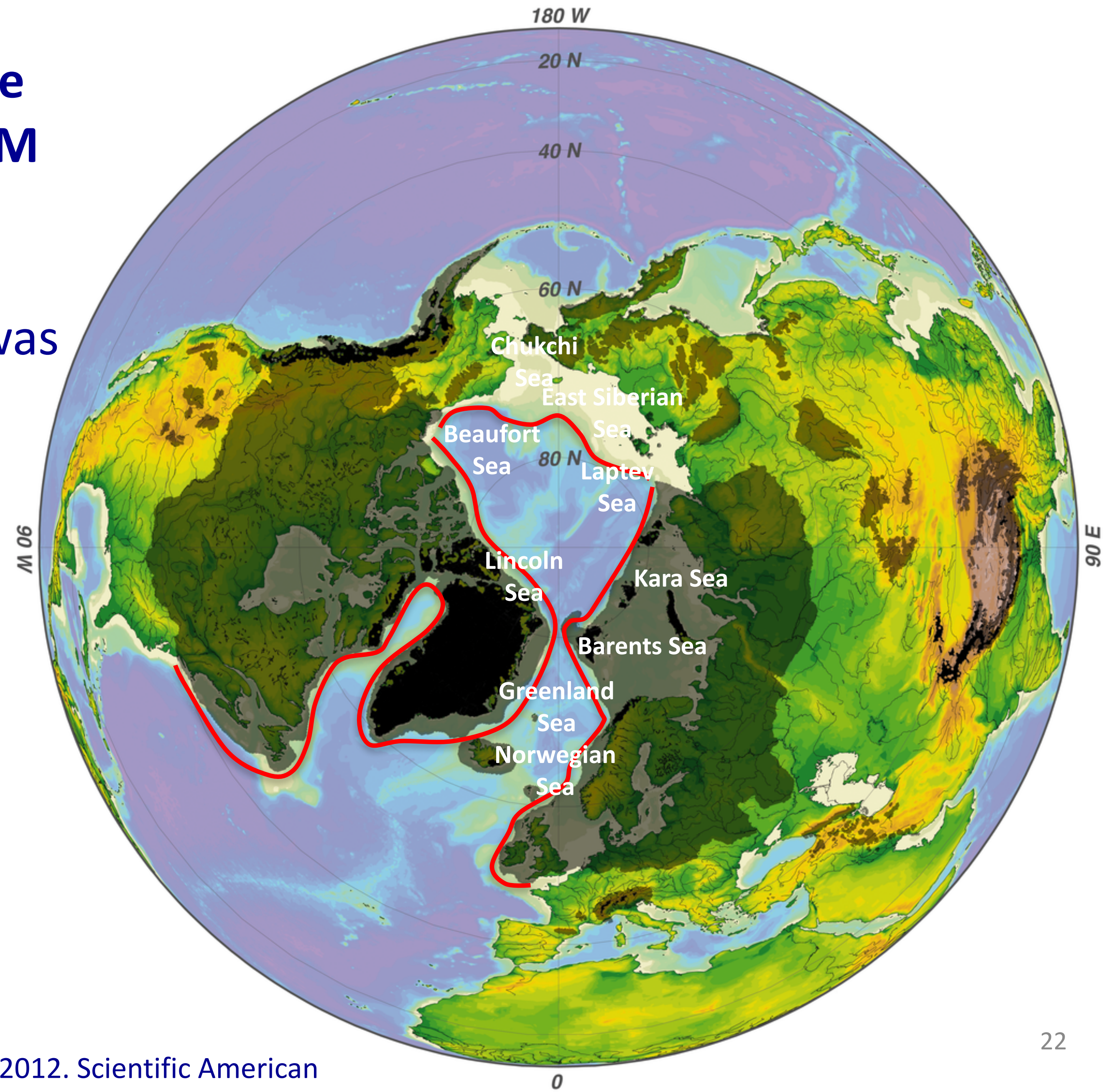
Evidence of Deep Sea fan deposition in the deep Arctic Basin (likely river induced by riverine sedimentary input)



Stein, 2008

Approximate shore line during the LGM

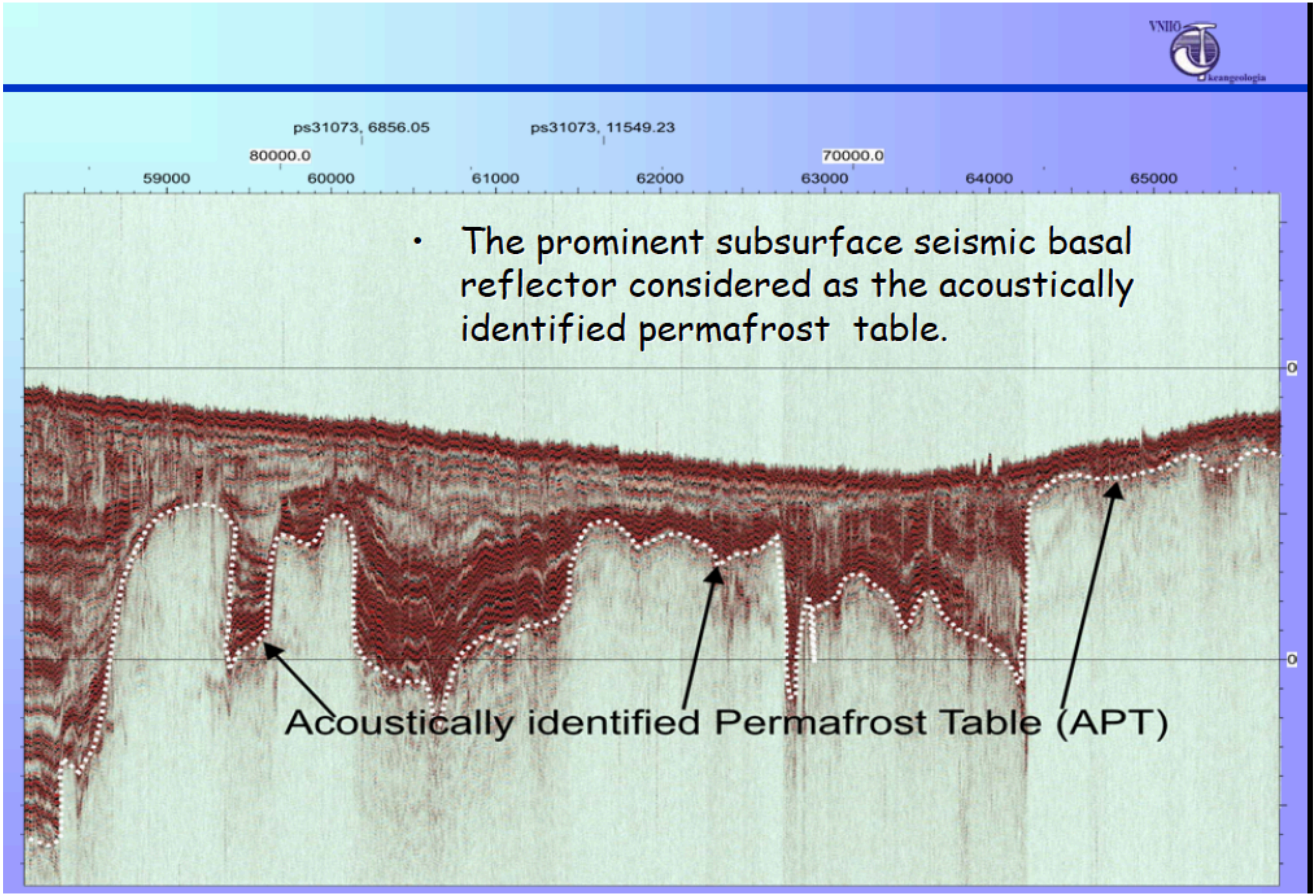
Not all the Arctic continental shelf was covered by the ice sheet



Hannes Grobe/AWI, from Frazer, 2012. Scientific American

The e continental shelf not covered by ice sheets was exposed to cold temperatures = **Permafrost**.
With deglaciations, these permafrost-bearing shelves were flooded by seawater (+120m sealevel rise) leaving a **relict permafrost** layer below the seabed. Still present today, though slowly thawing

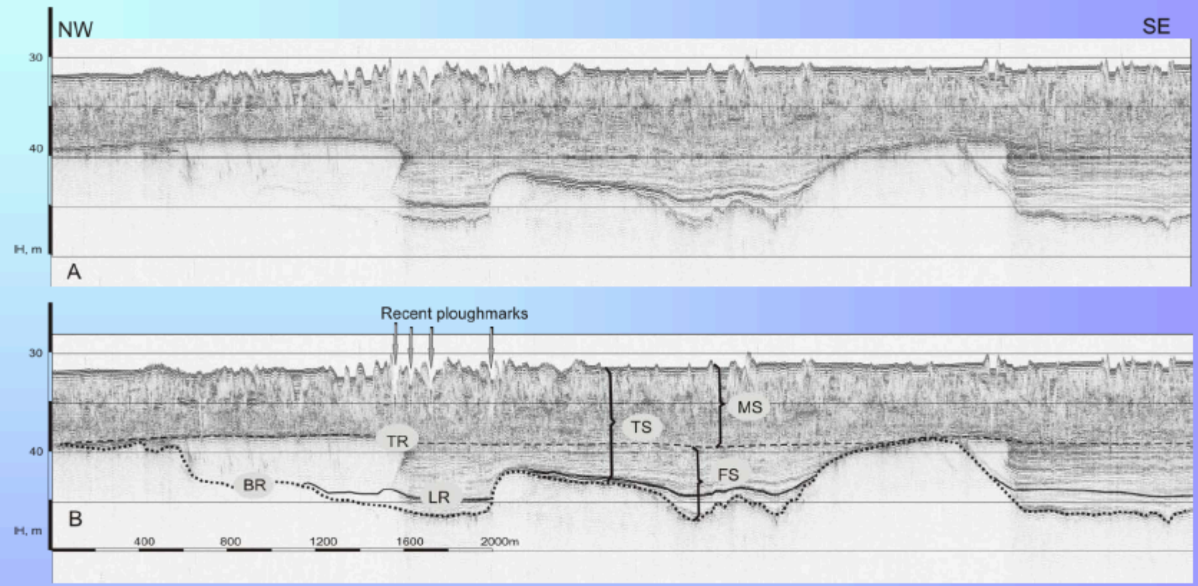
Collet et al., 2011



Rekant P., Portnov A., Gottschalk J., Cherkashev G., et al

Pergamon COST Action

Further study



General seismic facies pattern:
Basal Reflector (**BR**) is clearly seen in the lower part of the seismic-acoustic section. Stratified Transgressive Sequence (**TS**) is bedded on top and divided by the Top Reflector (**TR**) into the Fill Sequence (**FS**) of the depression and Marine Sequence (**MS**). A distinct reflector (**LR**) in the lower part of FS, related to the peat horizon within thermokarst lake deposits

VNIIO keangeologia

P. Rekant. et al., 2009. In the: System of the Laptev Sea and the Adjacent Arctic Seas : Modern and Past Environments

Rekant P., Portnov A., Gottschalk J., Cherkashev G., et al

Pergamon COST Action

Wolker Rachov et al., 2007, EOS. Pergamon COST Action

PERGAMON

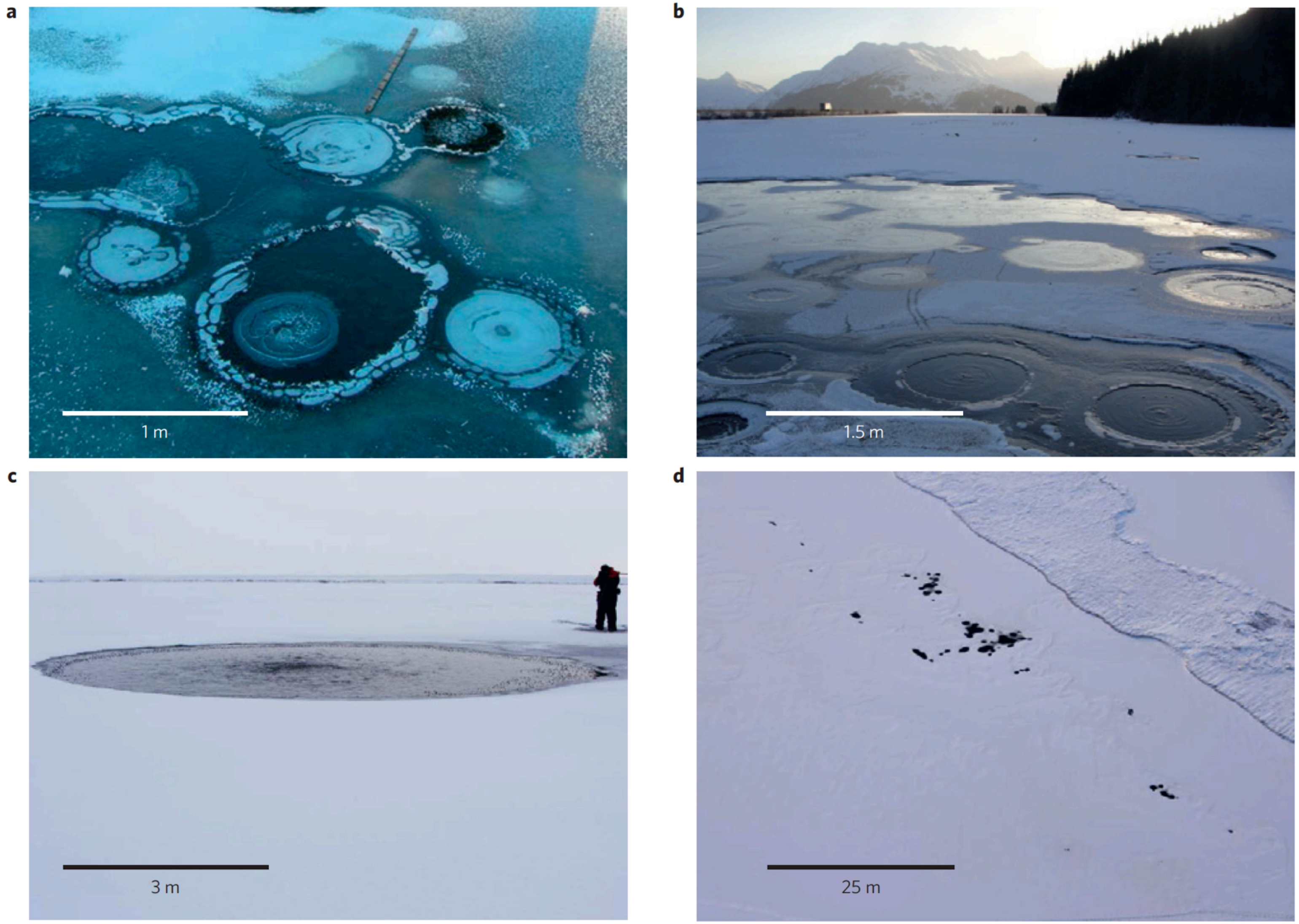
GFZ
Helmholtz Centre
POTSDAM

AWI

Pergamon COST Action

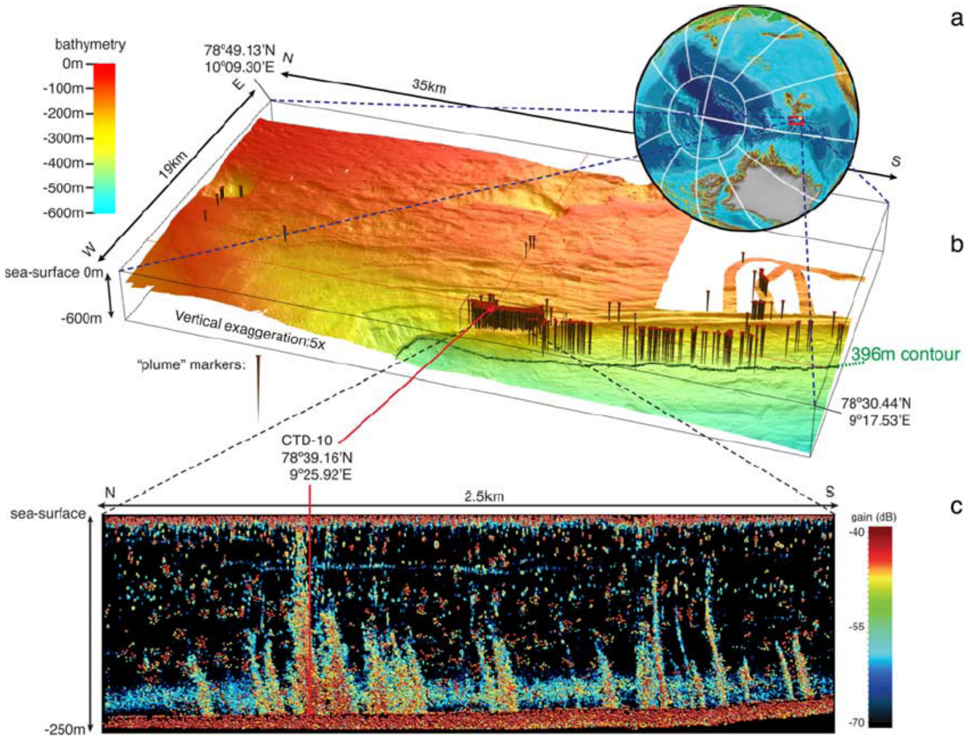
Ice on an Alaskan lake captures methane
Marianne Lavelle, The National Geographic. December 2012
Photo Mark Thiessen

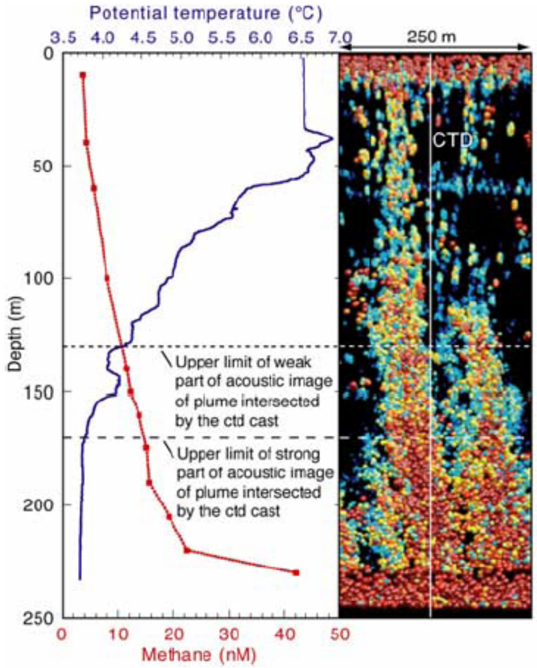
World ocean review: The impacts of hydrate mining



Anthony et al., 2012, Nature Geoscience

DEEP WATER METHANE RELEASE FROM GAS HYDRATES RESERVOIRS





Westbrook et al., 2009, GRL

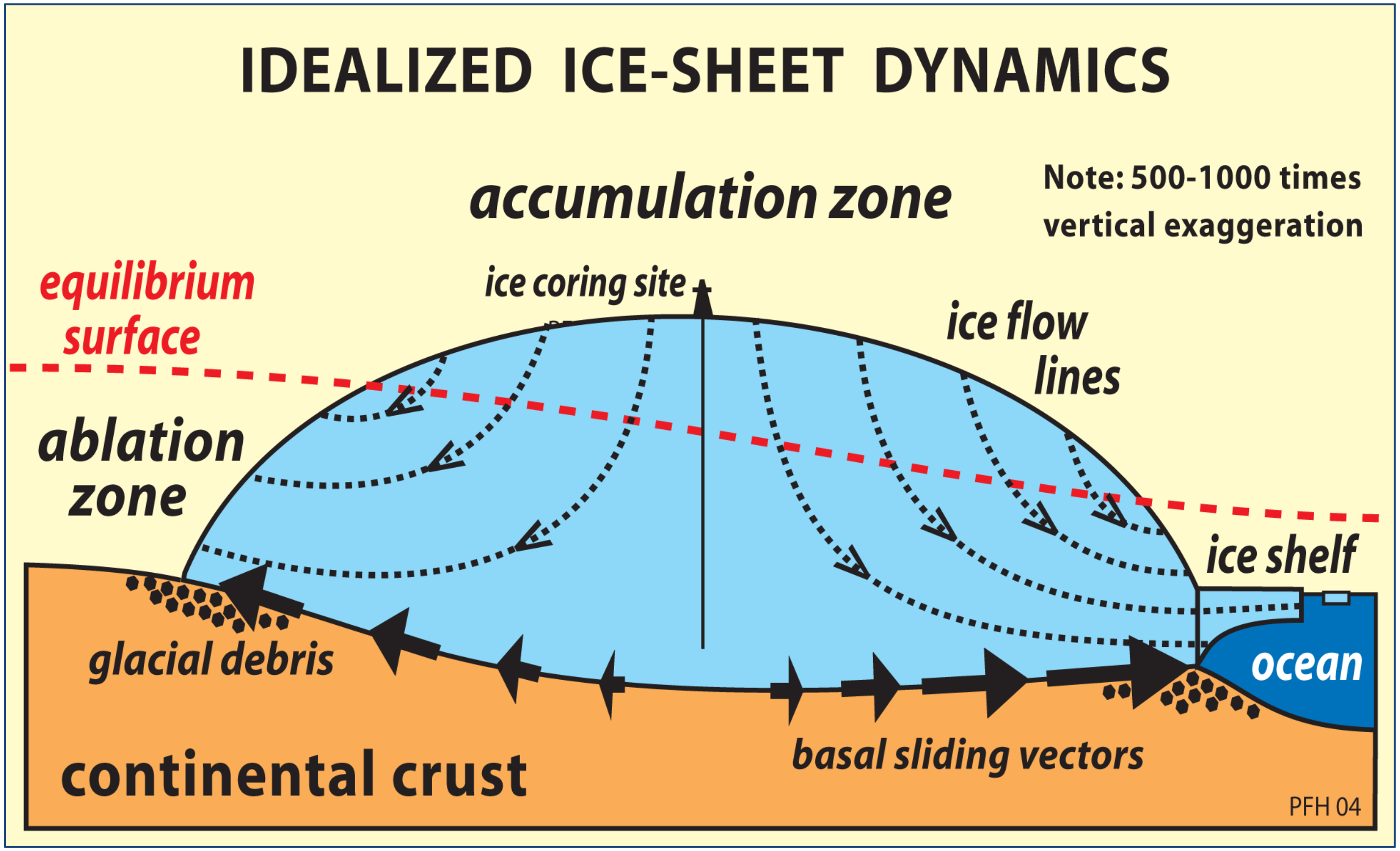
RIVER DOMINATED:

- Continental shelf edge modulated by sea level
- Deep Sea Fans
- Sand dominated
- Gentle slope
- Sub-sea permafrost

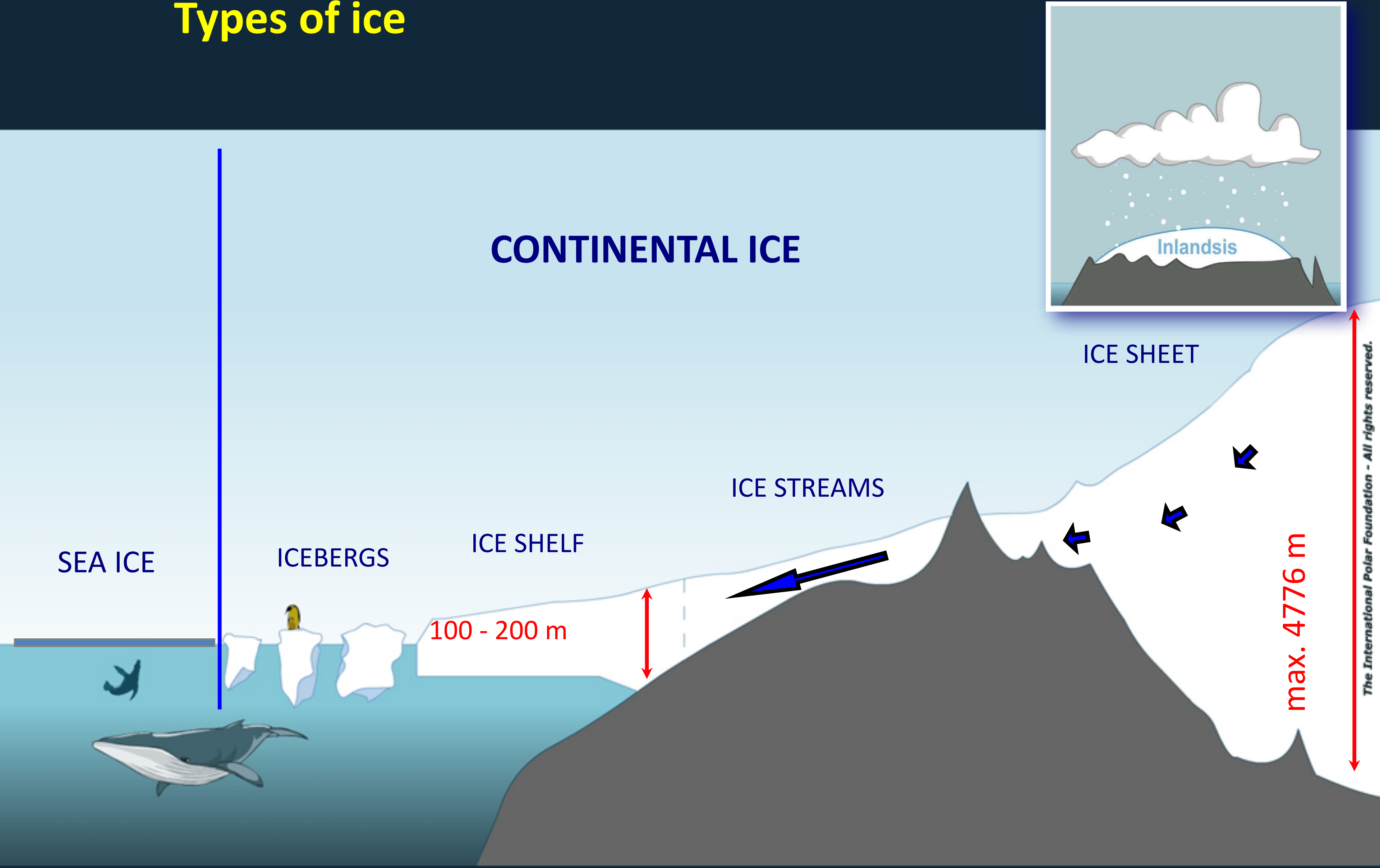
ICE SHEET DOMINATED:

- **Continental shelf edge modulated by Ice sheets at glacial maxima**
- **Trough-mouth fans**
- **Clay dominated**
- **Steep slope**
- **No subsea permafrost**

ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS


IDEALIZED ICE-SHEET DYNAMICS
accumulation zone
Note: 500-1000 times
vertical exaggeration
equilibrium
surface
ice coring site
ice flow
lines
ablation
zone
ice shelf
glacial debris
ocean
continental crust
basal sliding vectors
PFH 04

Types of ice


CONTINENTAL ICE
Inlandsis
ICE SHEET
ICE STREAMS
ICE SHELF
ICEBERGS
SEA ICE
100 - 200 m
max. 4776 m
The International Polar Foundation - All rights reserved.


ARCTIC OCEAN
Sea ice


ANTARCTICA
Sea ice
U. S. COAST
11

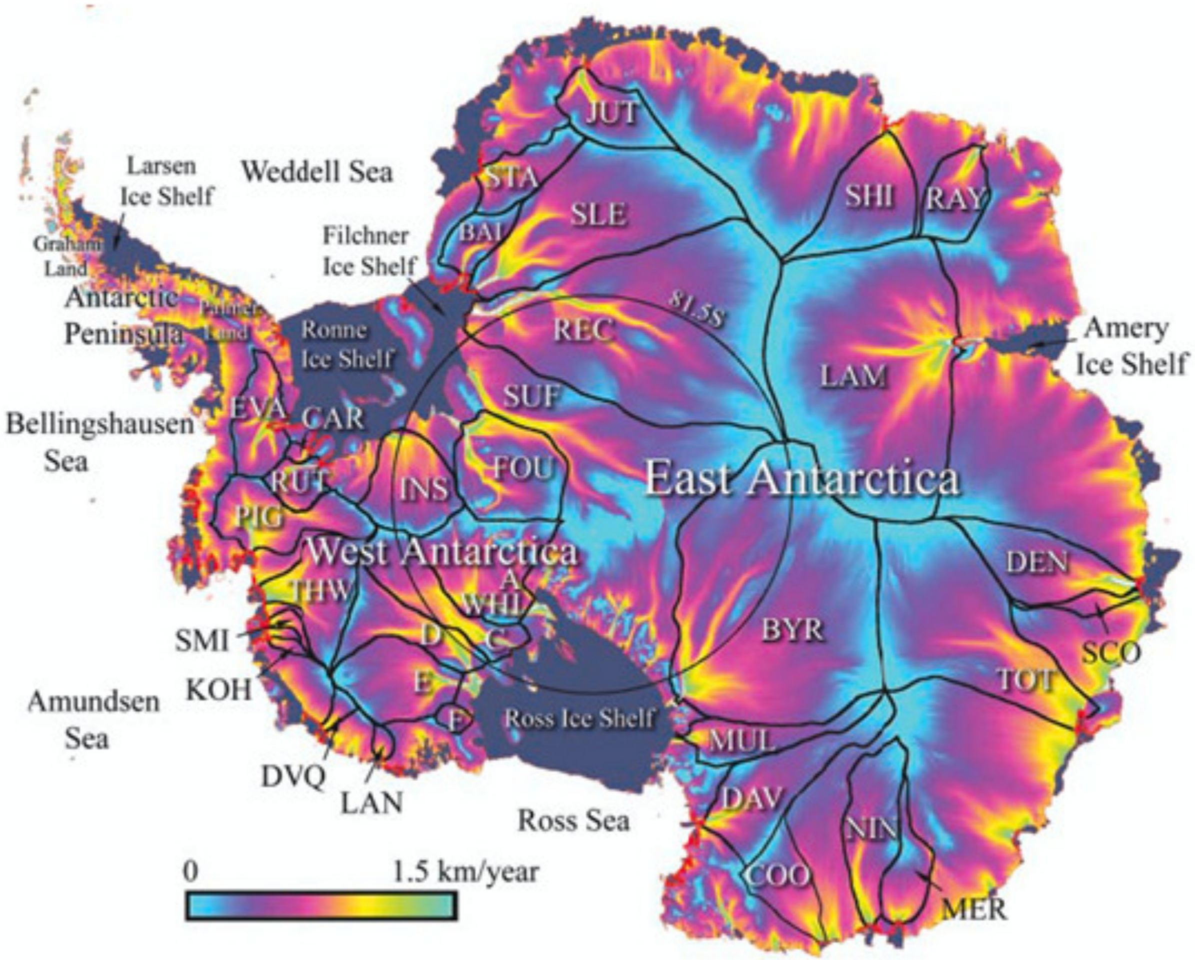
ANTARCTICA
Ice sheet


ANTARCTICA
Icebergs and sea ice

ANTARCTICA
Ice sheet and icebergs

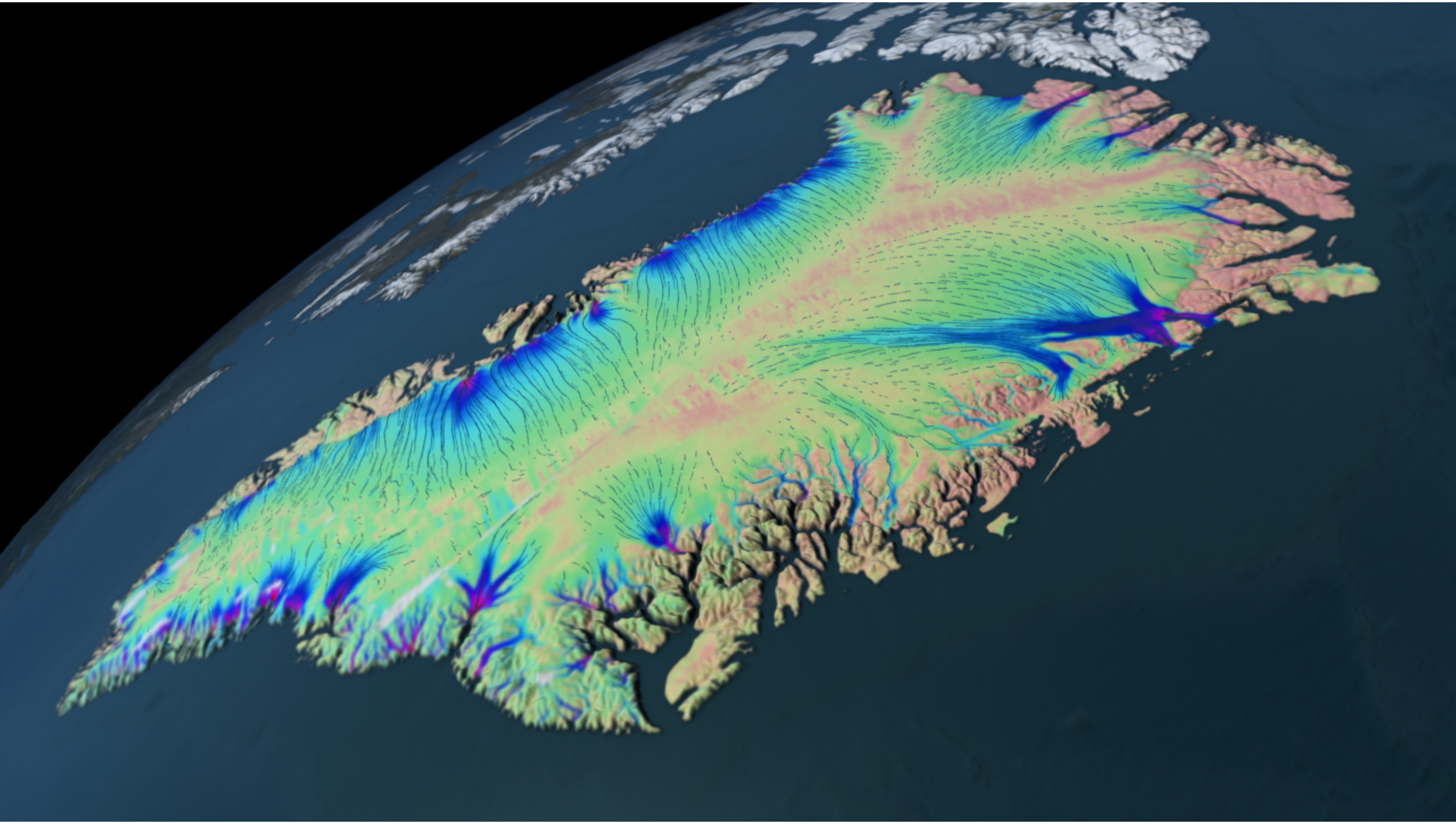
ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS

ICE STREAMS

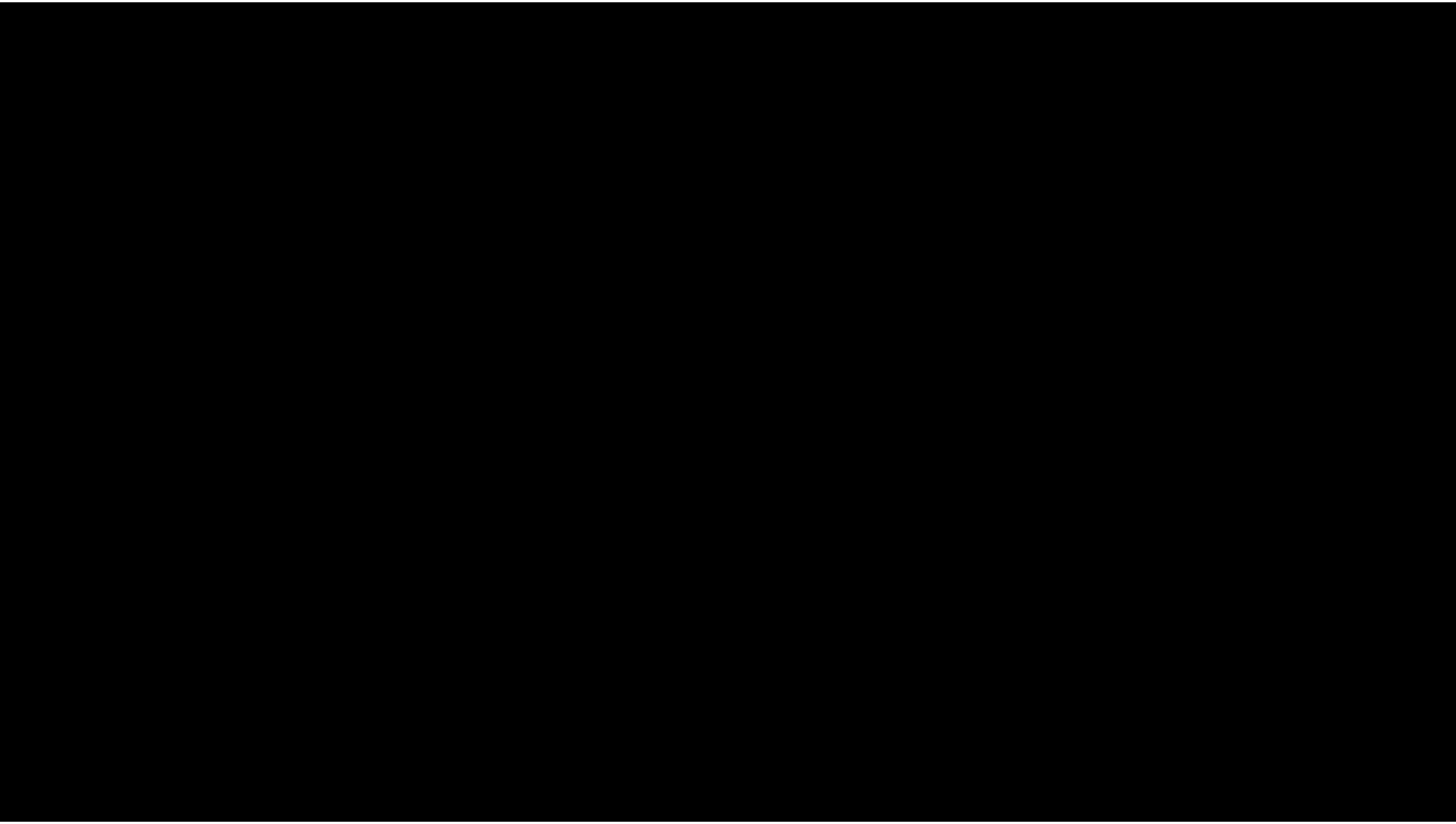


Source http://www.ipy.org/index.php?/ipy/detail/asaid

Author R. Bindschadler.

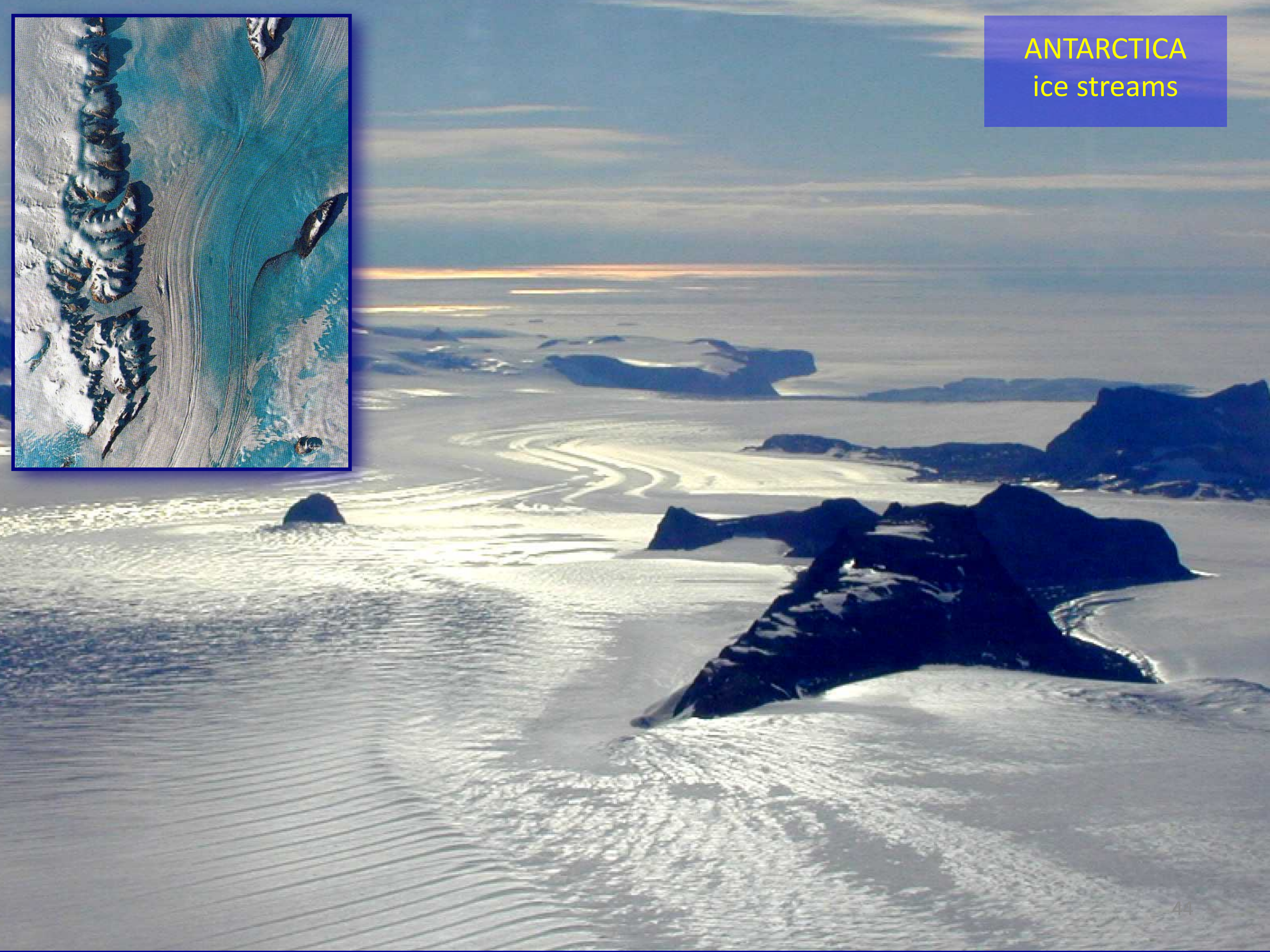


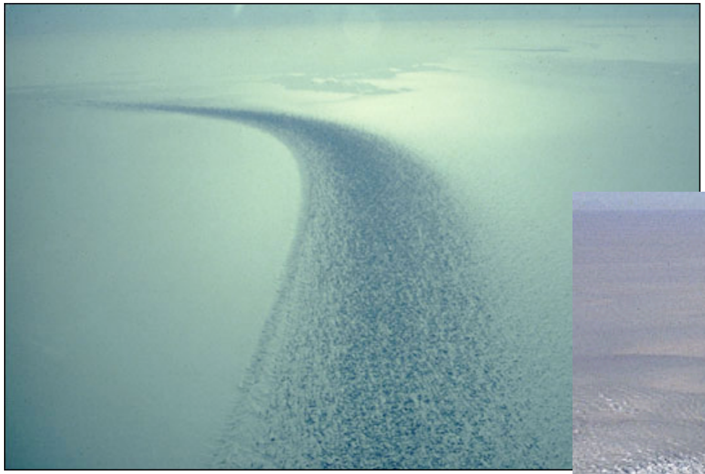
NASA's Goddard Space Flight Center
Greenland photos courtesy of NASA/GSFC/Jefferson Beck



NASA's Goddard Space Flight Center
Greenland photos courtesy of NASA/GSFC/Jefferson Beck

ANTARCTICA
ice streams



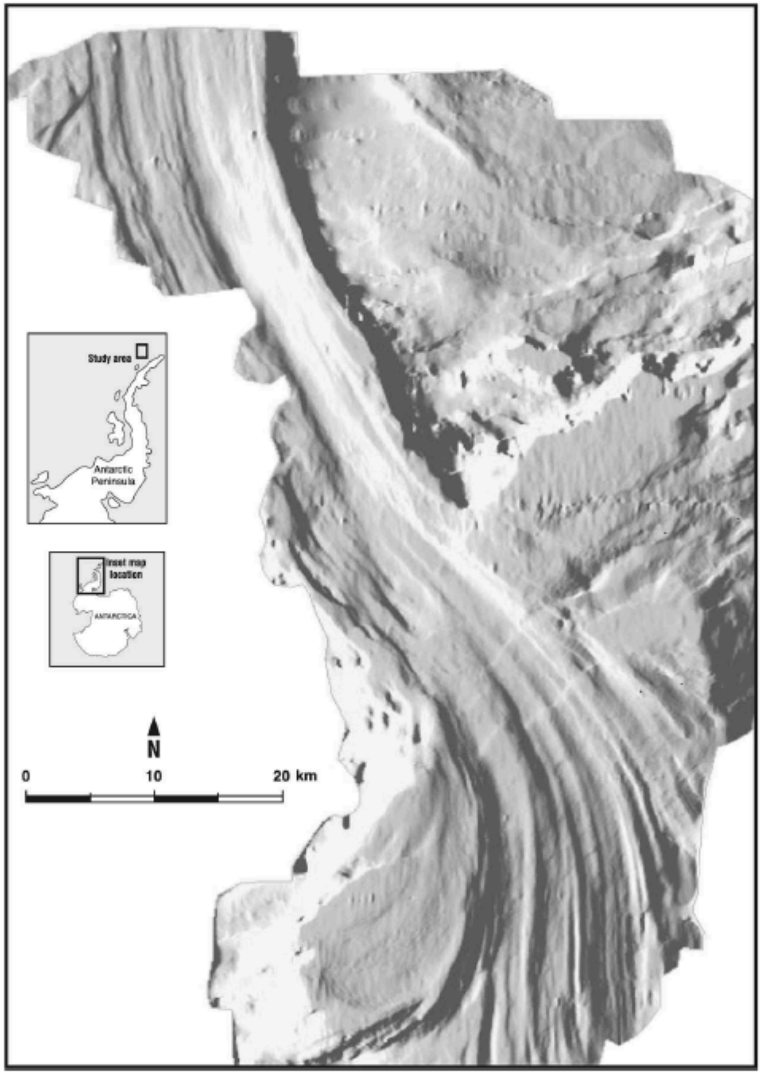


Two ice streams separated by a zone of more sluggish ice in Wilkes Land, Antarctica. The ice embayment coincides with the zone of sluggish ice -- on either side of it the ice is moving much faster, and has pushed out across the coast in distinct tongues.

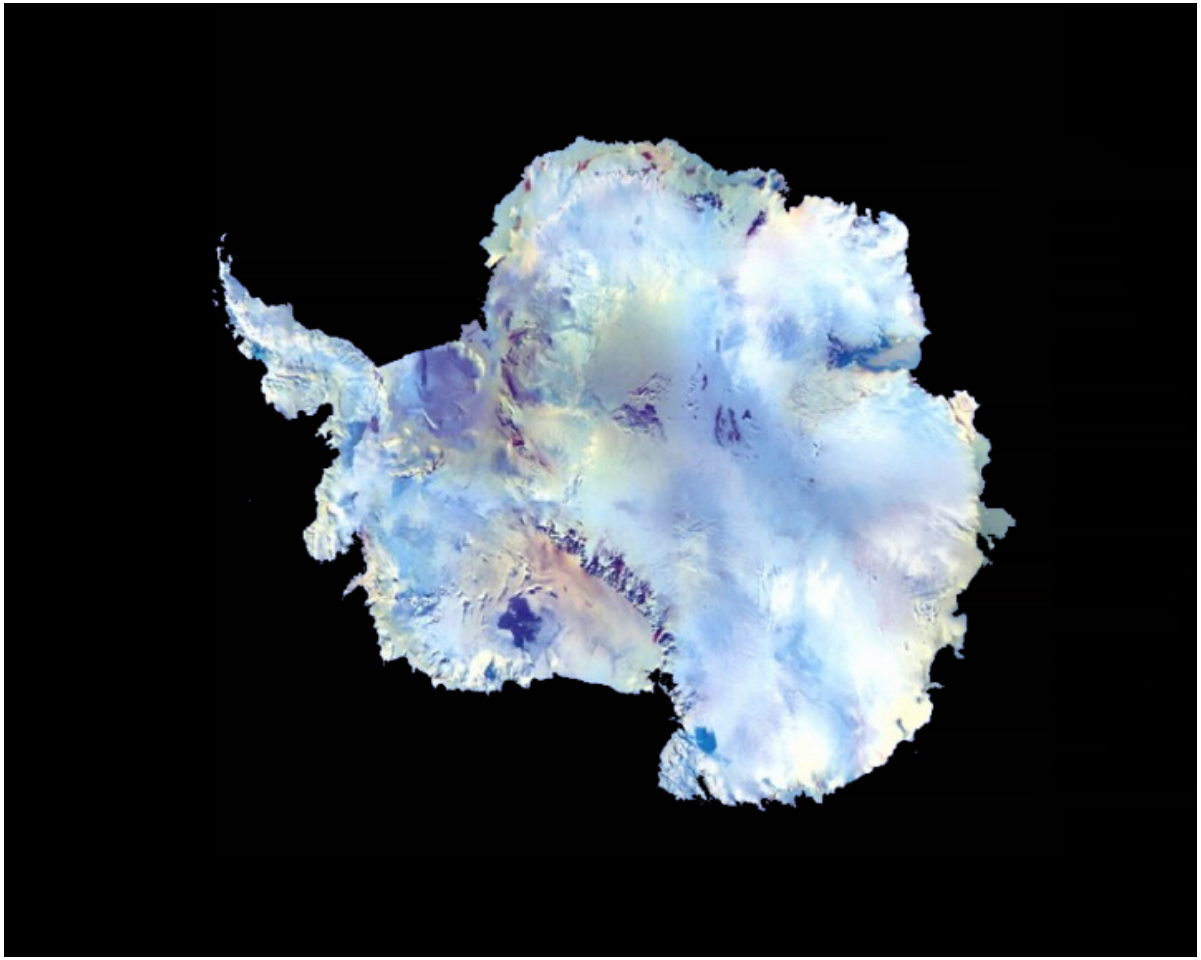
ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS

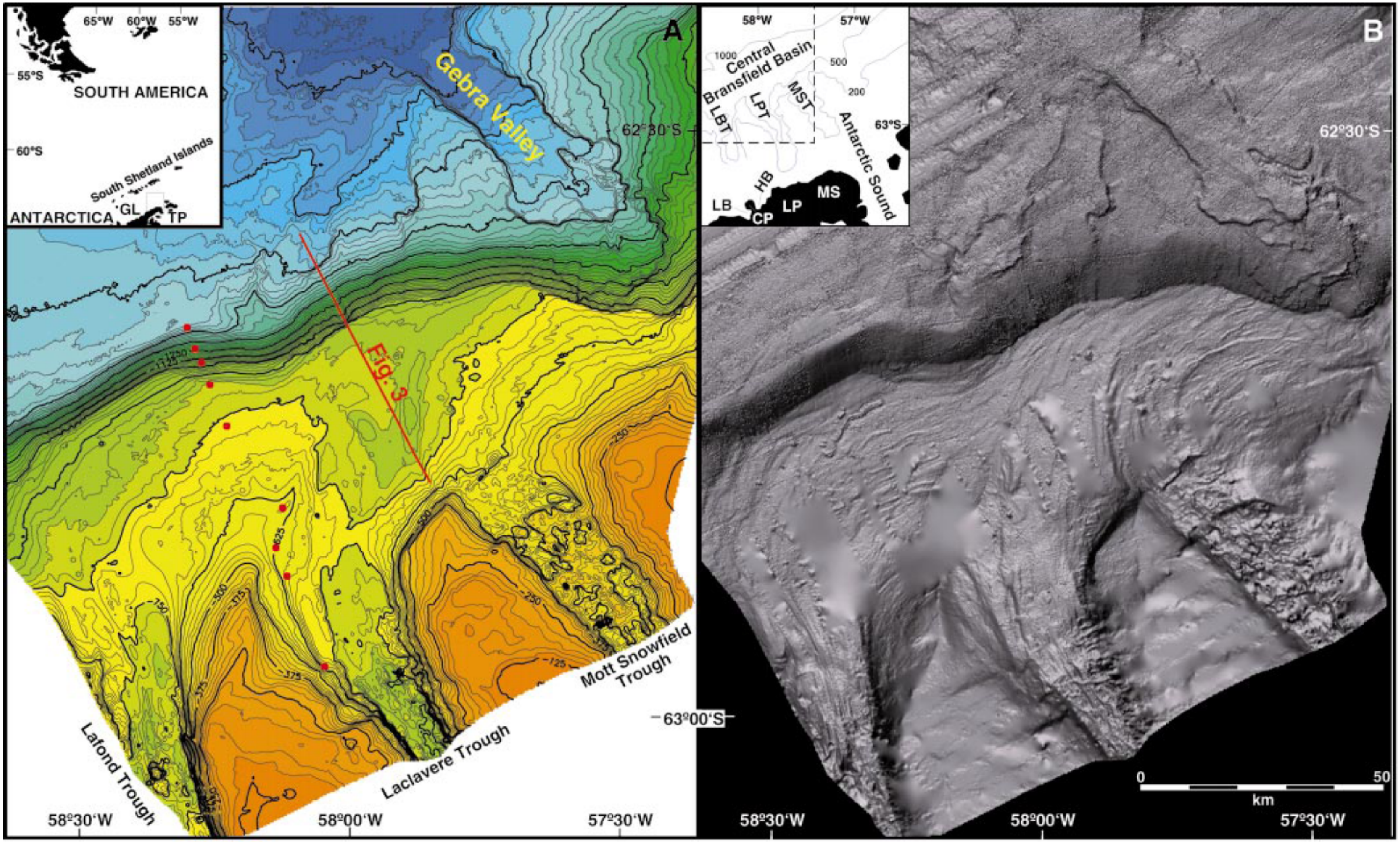
PALEO ICE STREAMS
Offshore evidence

MEGA-SCALE GLACIAL LINEATIONS

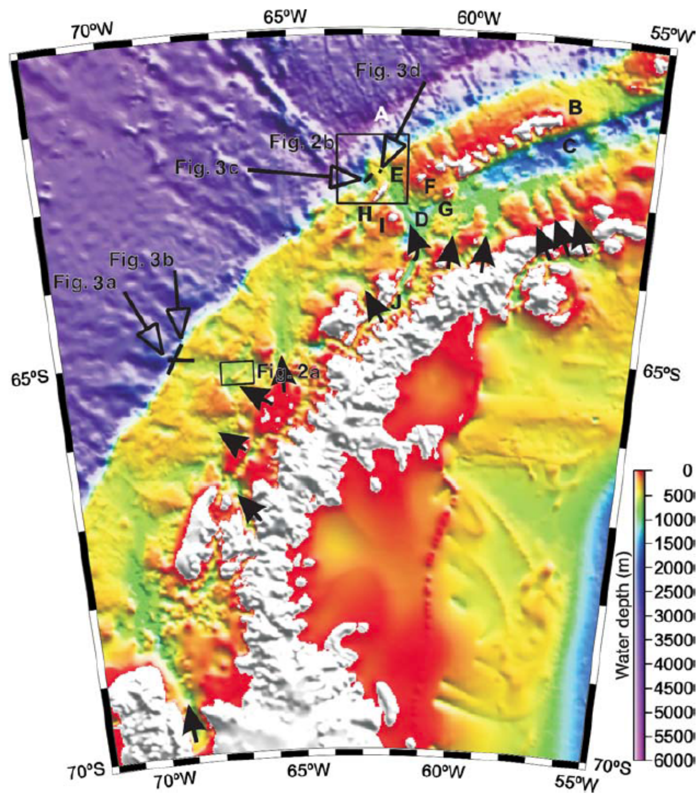


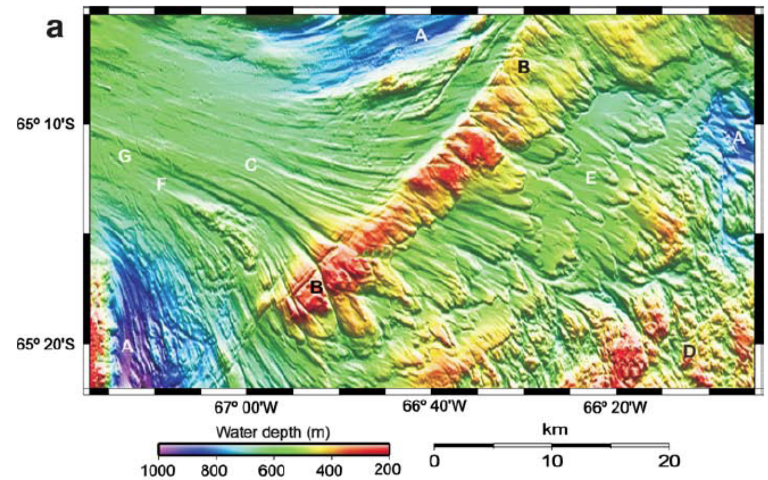
Stokes and Clark_2001_QSR

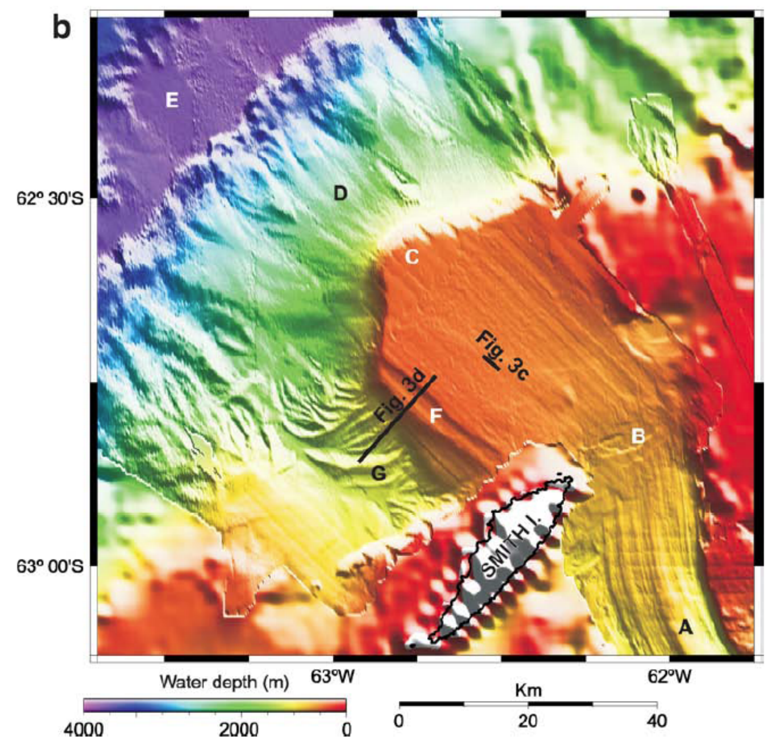




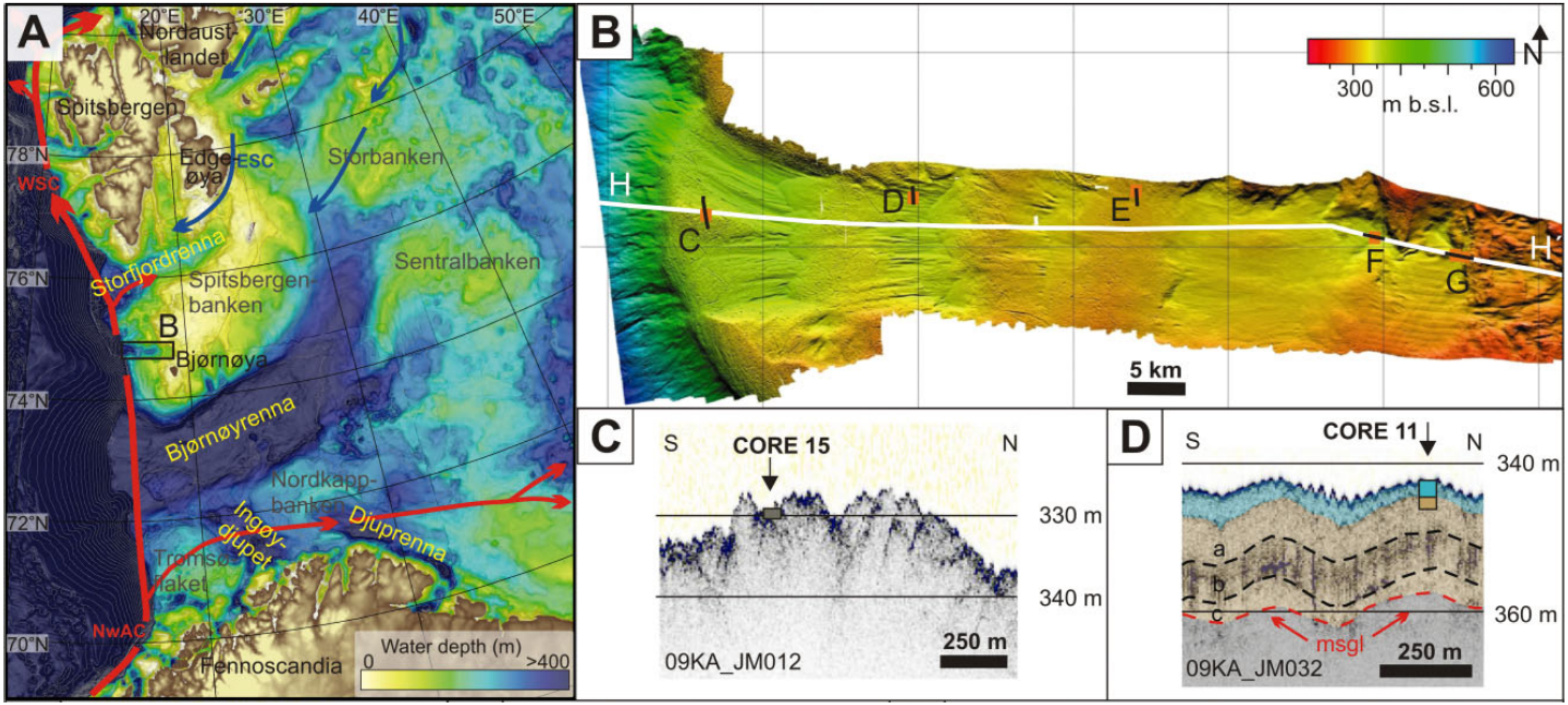
Canals et al., 2002



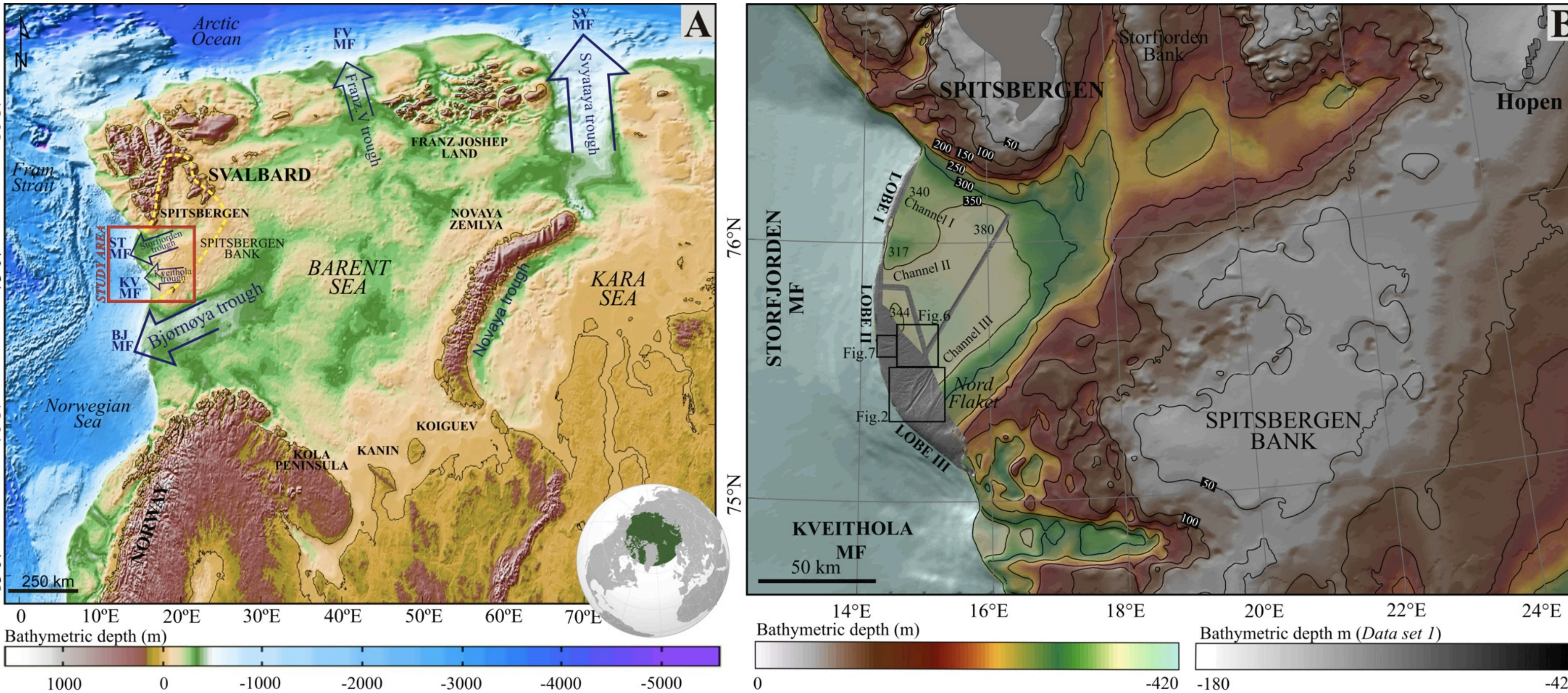


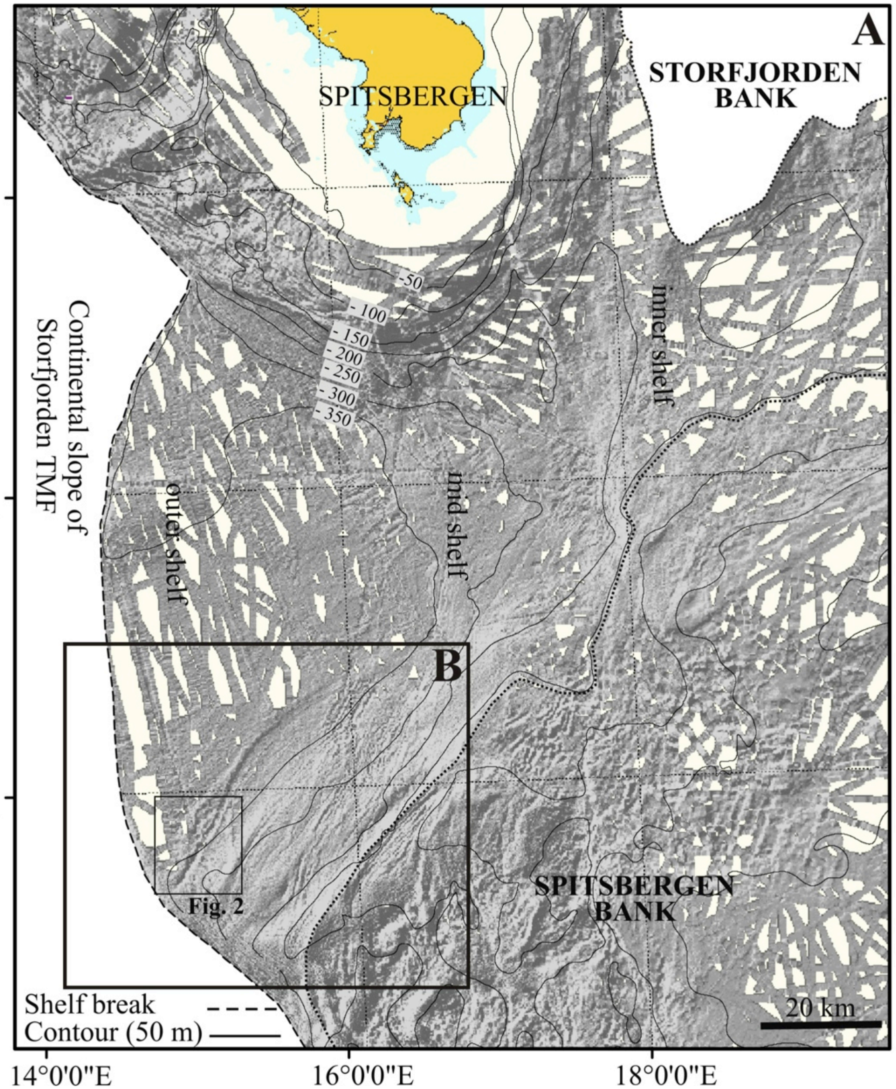


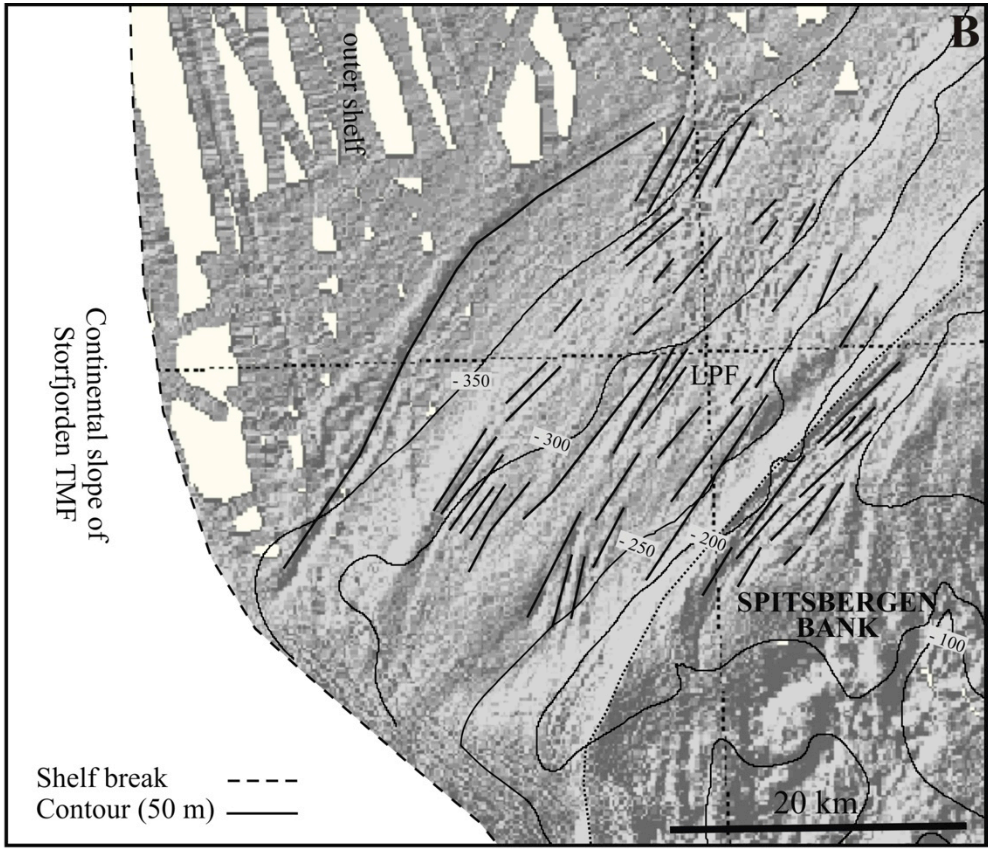
The COHIMAR/SEDANO Scientific Party, 2003



Ruther et al., 2011


A
Arctic Ocean
FV MF
SV MF
Franz V trough
Svyataya trough
FRANZ JOSHEP LAND
SVALBARD
Fram Strait
SPITSBERGEN
SPITSBERGEN BANK
STUDY AREA
ST MF
KV MF
BJ MF
Bjørnøya trough
BARENT SEA
NOVAYA ZEMLYA
Novaya trough
KARA SEA
Norwegian Sea
KOIGUEV
KANIN
KOLA PENINSULA
NORWAY
250 km
80°N
75°N
70°N
65°N
0
10°E
20°E
30°E
40°E
50°E
60°E
70°E
Bathymetric depth (m)
1000
0
-1000
-2000
-3000
-4000
-5000
B
Storfjorden Bank
SPITSBERGEN
Hopen
LOBE I
Channel I
Channel II
Channel III
LOBE II
LOBE III
Fig.6
Fig.7
Fig.2
Nord Flaket
STORFJORDEN MF
KVEITHOLA MF
SPITSBERGEN BANK
50 km
76°N
75°N
14°E
16°E
18°E
20°E
22°E
24°E
Bathymetric depth (m)
0
-420
Bathymetric depth m (*Data set 1*)
-180
-420

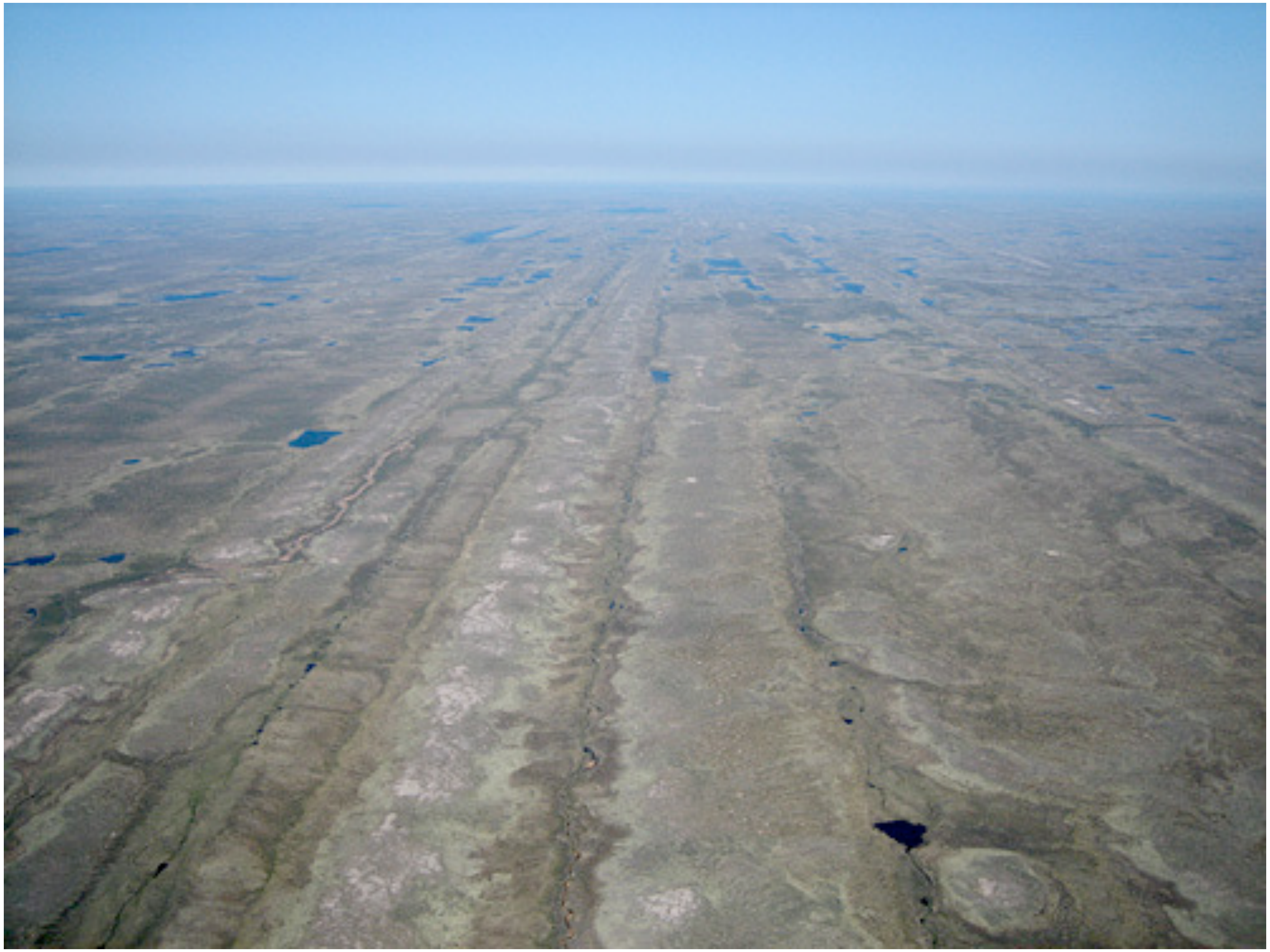




Pedrosa et al., unpublished. Based on Olex Data Set

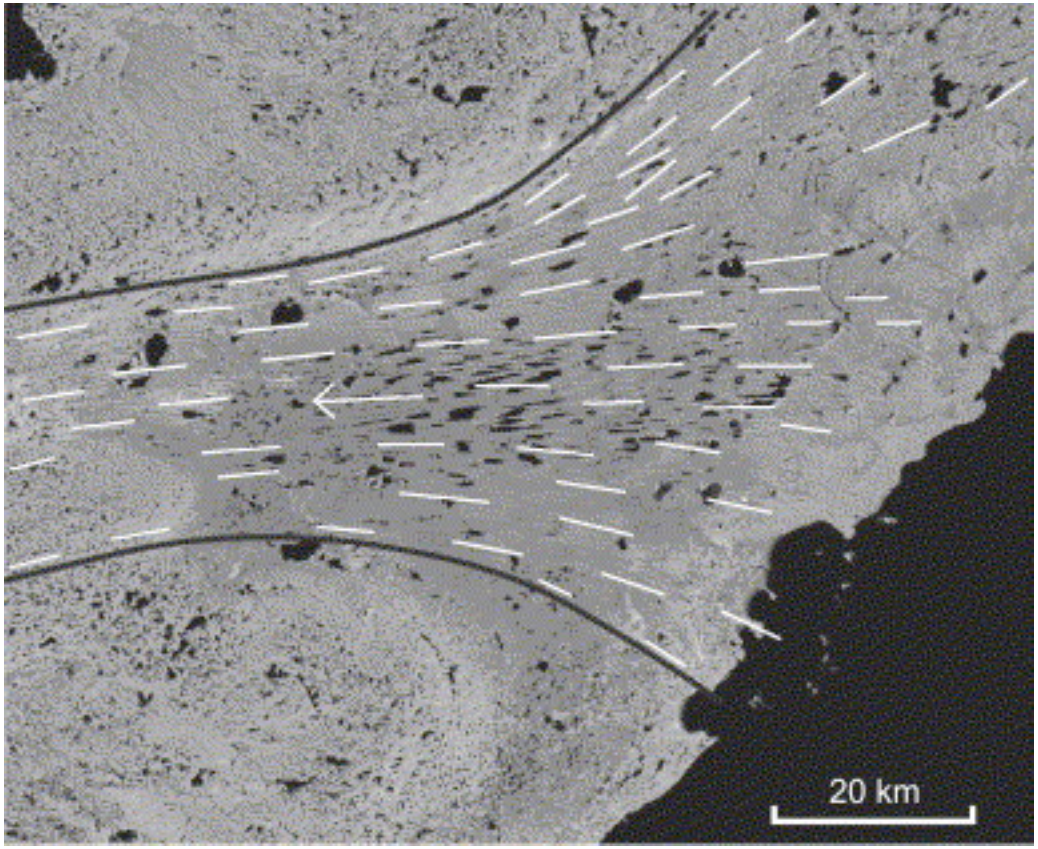
ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS

PALEO ICE STREAMS
Onshore evidence



Mega-scale glacial lineations from a palaeo-ice stream landsystem in Northern Canada. Photograph: C. Stokes

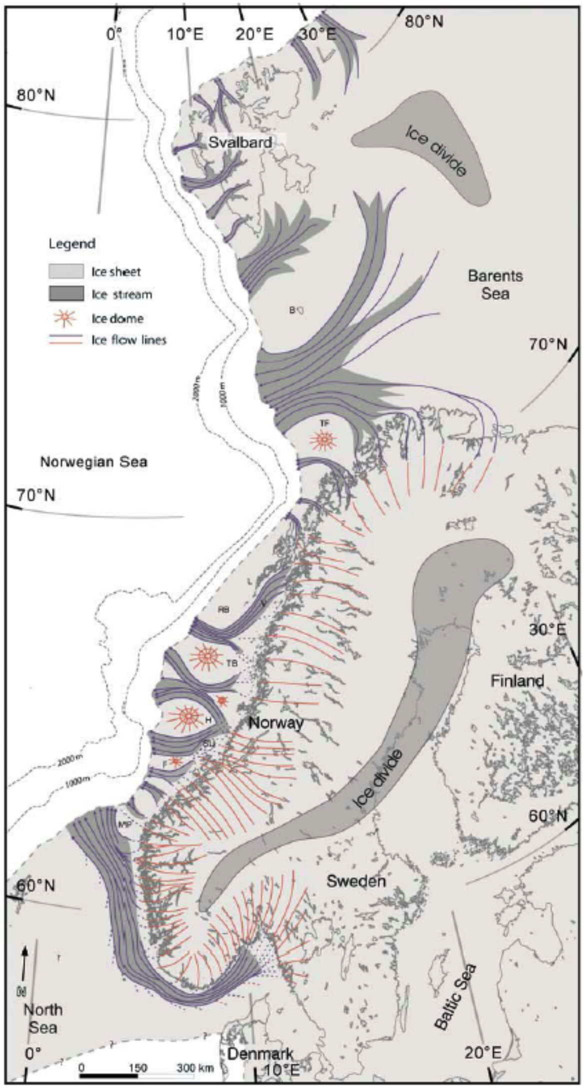
Glacial Landsystems Working Group (GLWG) Durham University http://www.dur.ac.uk/geography/qec/research_groups/glwg/

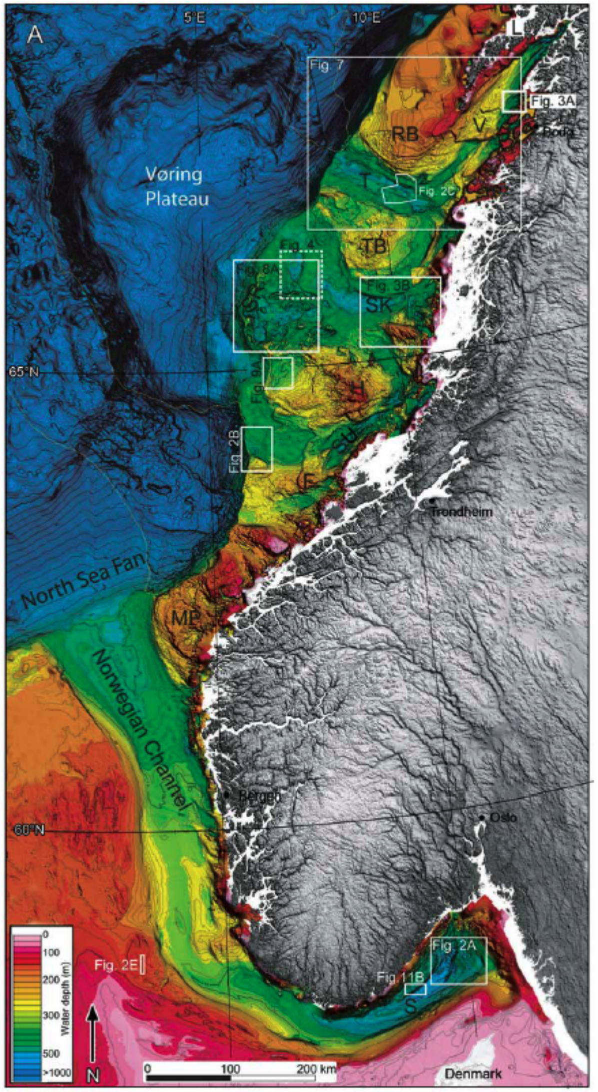


Head convergence of former Haldane Ice Stream northwest of Great Bear Lake, Canada (Winsborrow et al., 2004).

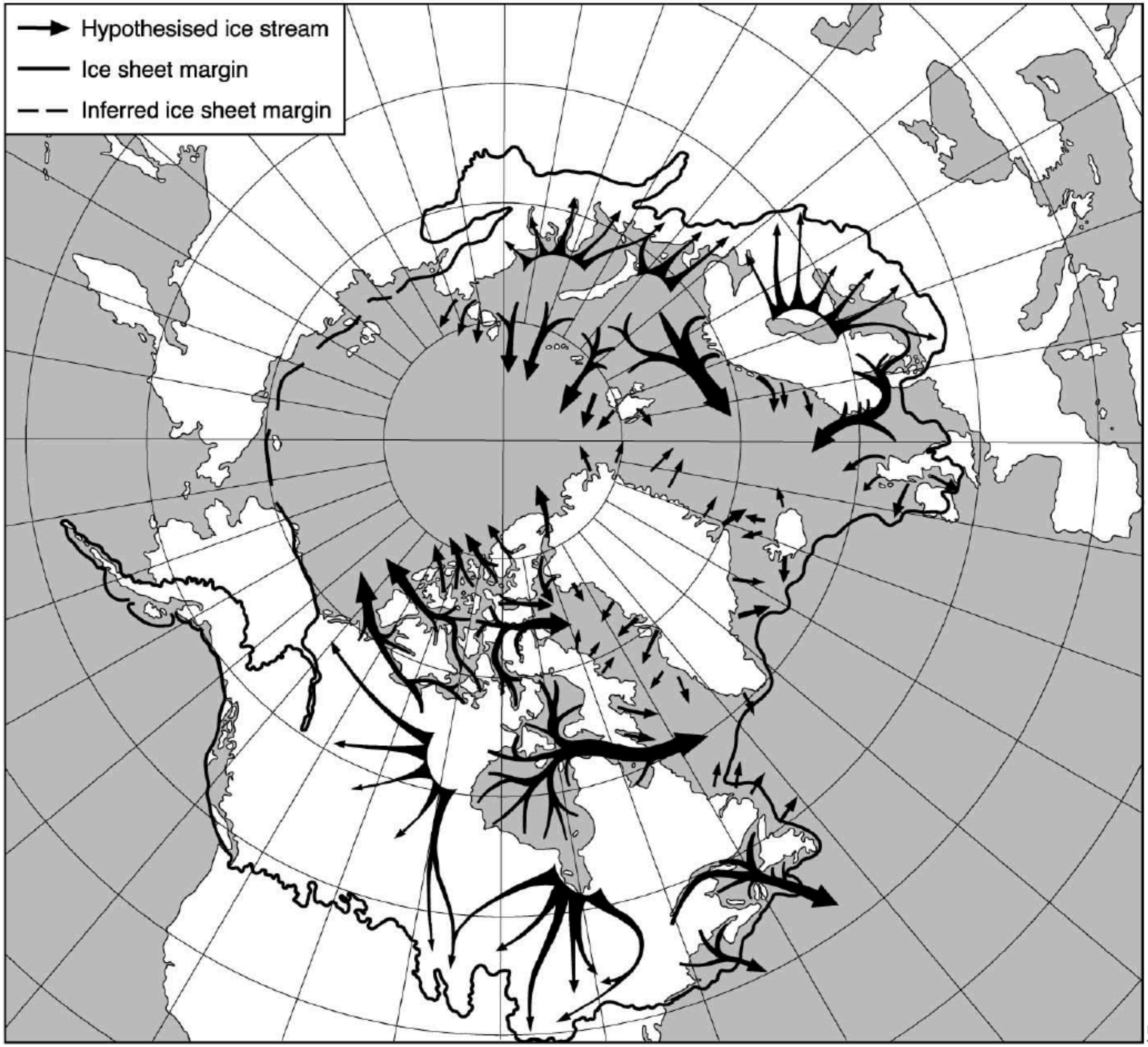
Klemana and Glasserb, 2007

Onshore and offshore Evidence of ice streams



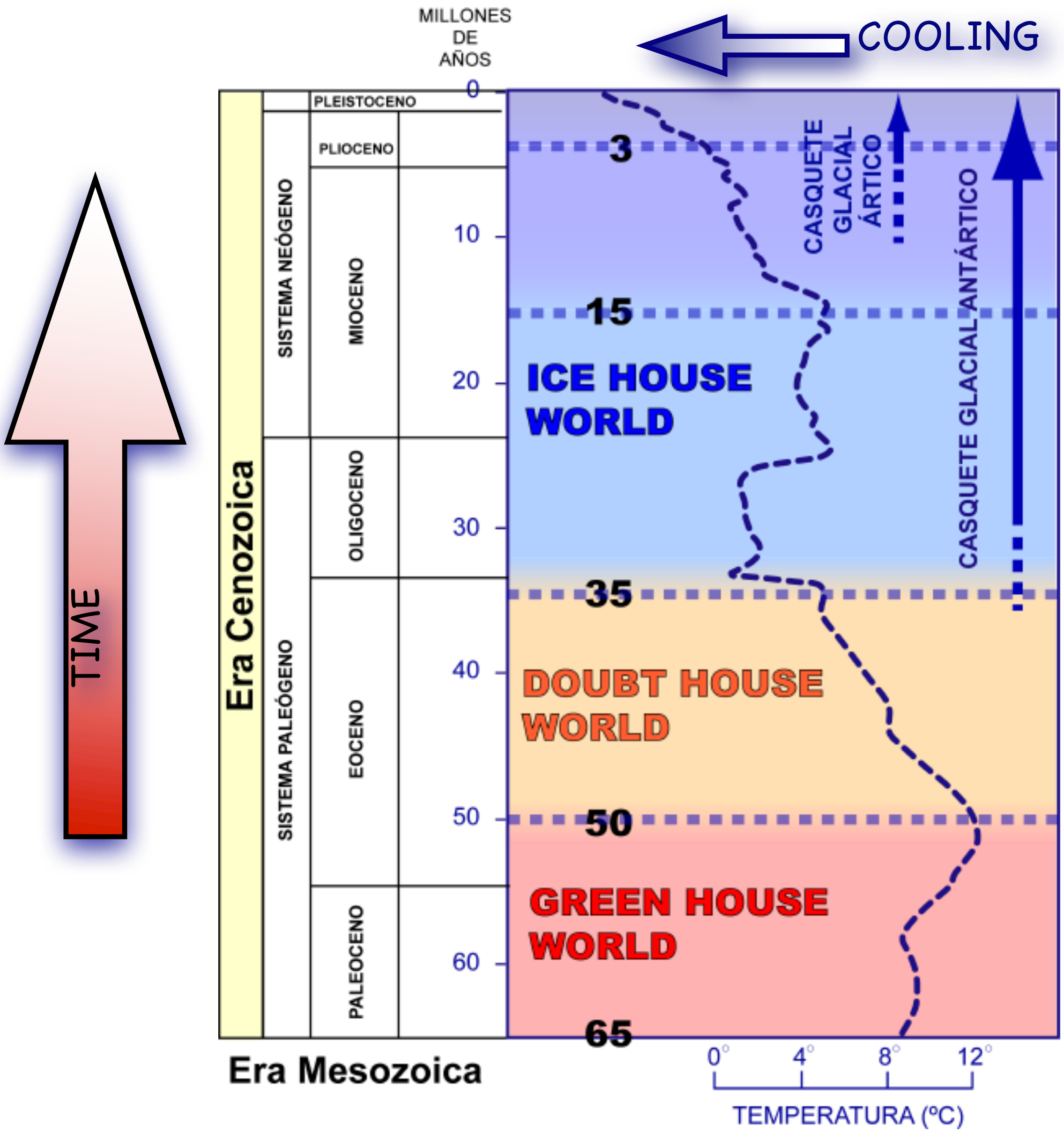


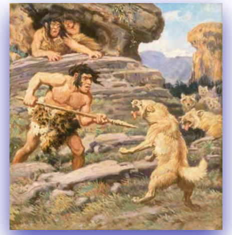
Ottesen et al., 2005

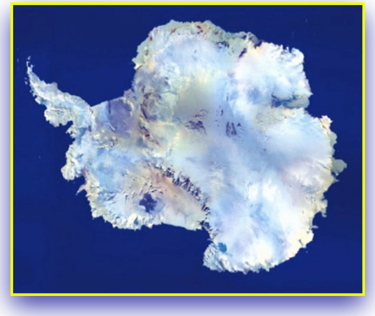


Stokes and Clarke, 2001

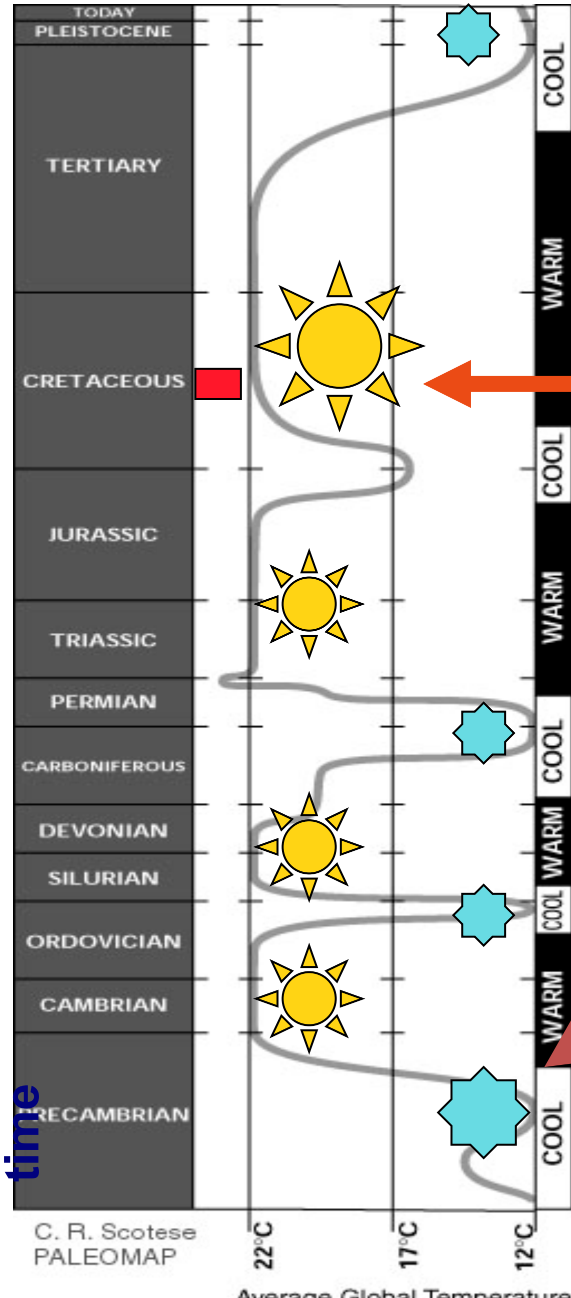
Global cooling in the last 50 million years approximately

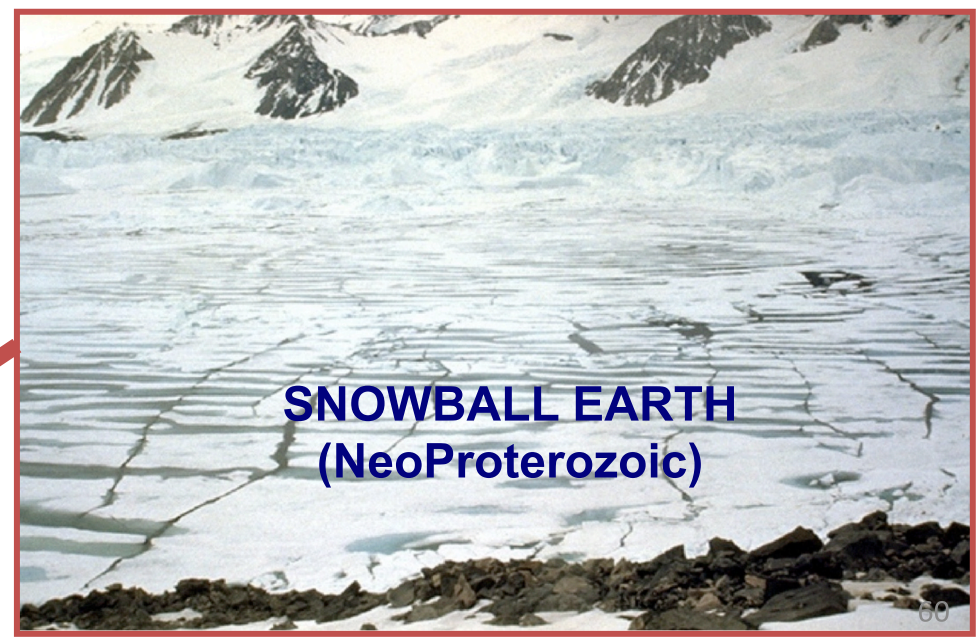




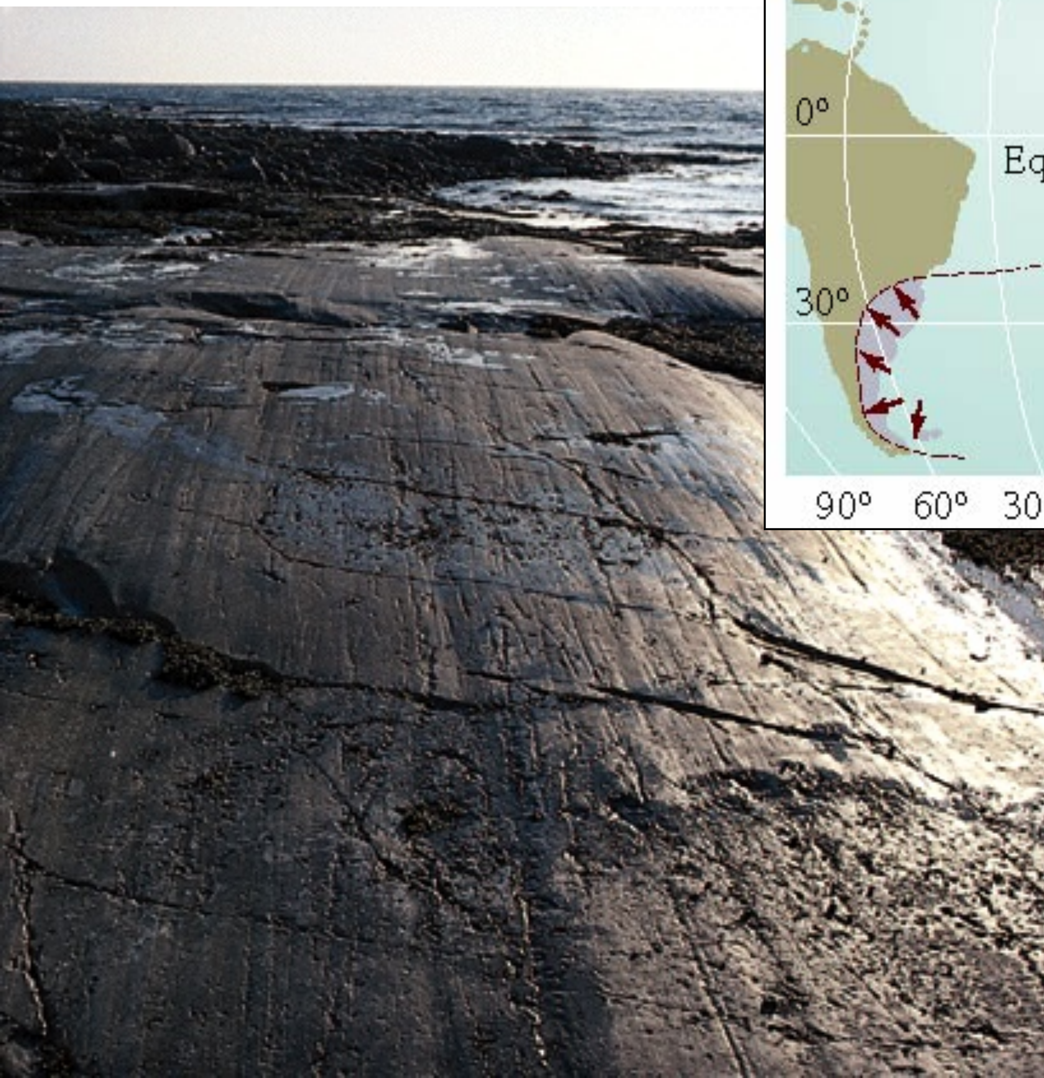


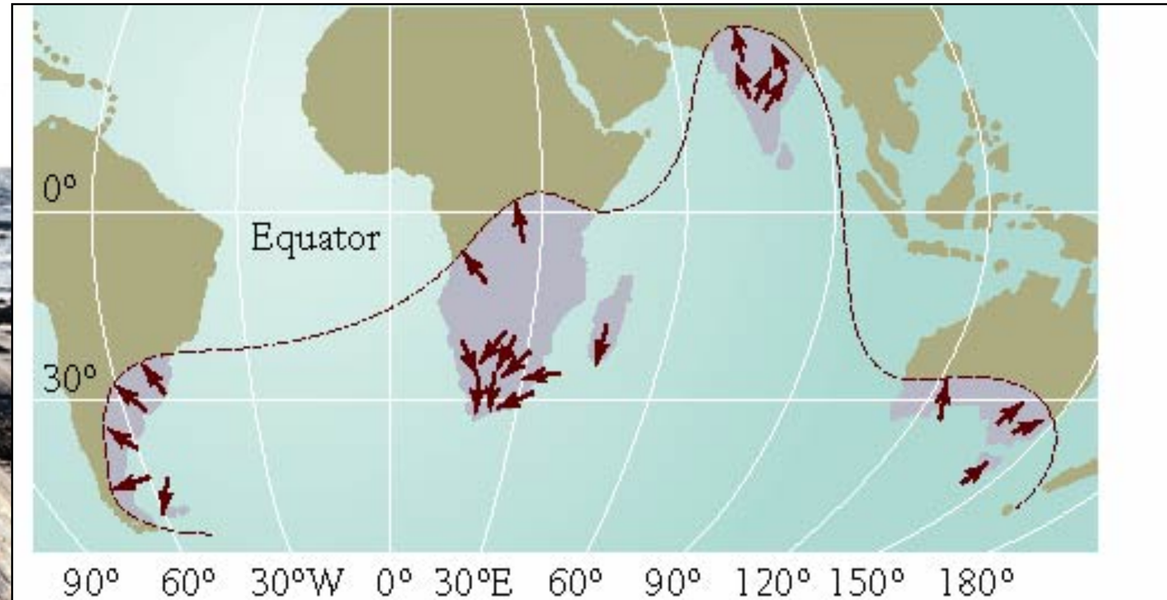
Extreme climates throughout the geological time





Evidence of Continental Drift





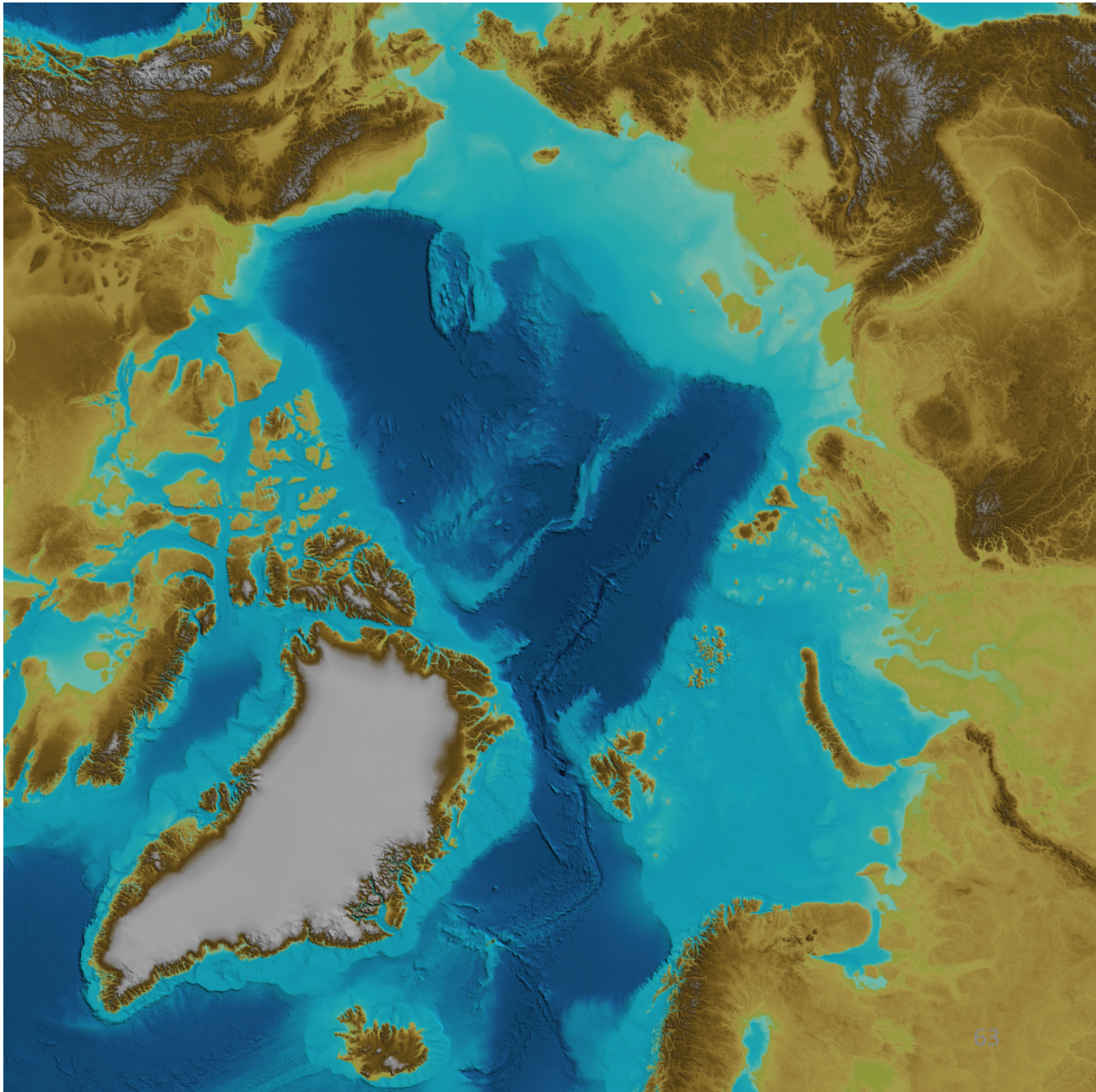
- **Stratigraphic Evidence**
  - Glaciers
    - Orientation of glacial markings on all continents suggest they were linked

ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS

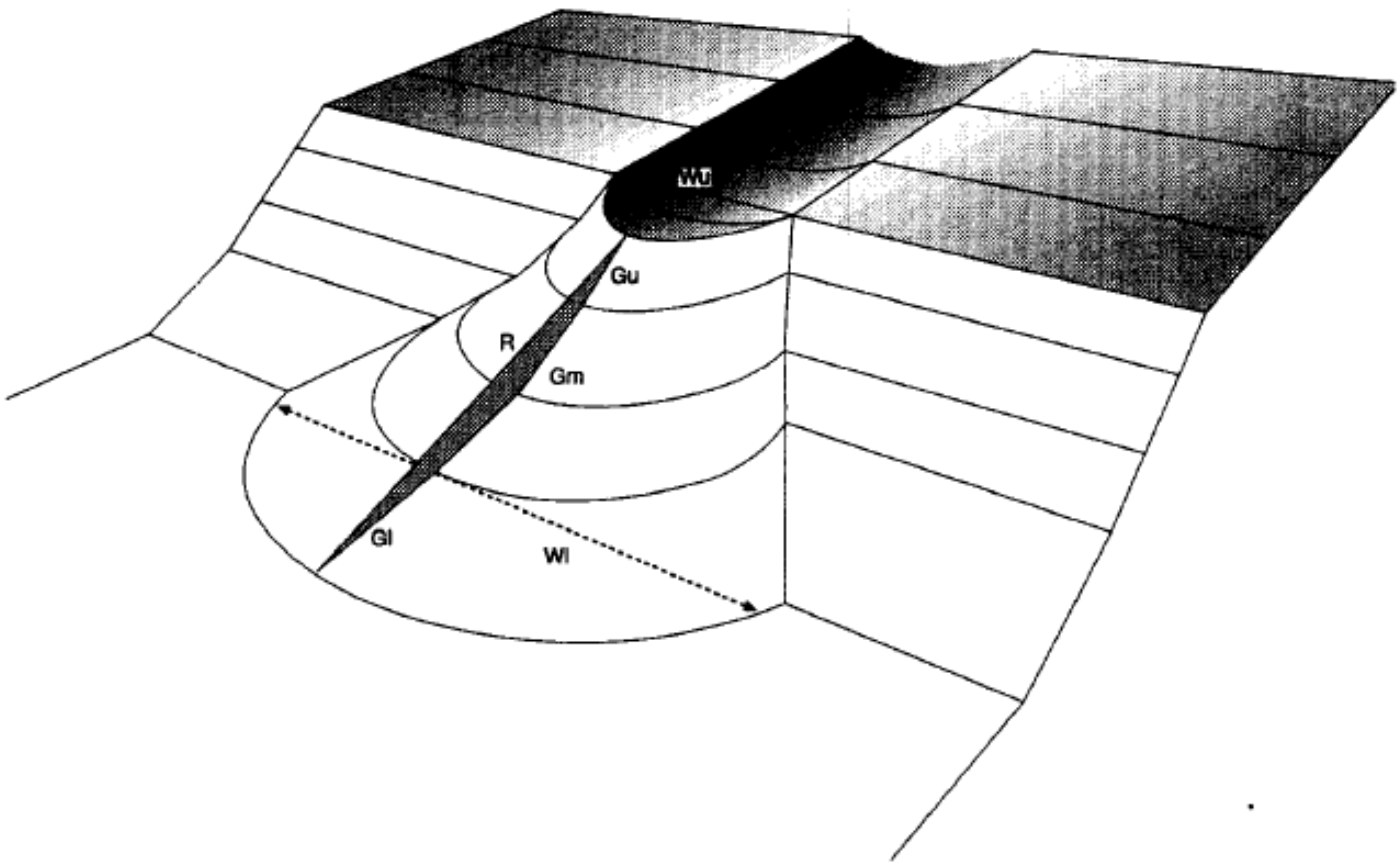
TROUGHS-MOUTH FANS

TOPOGRAPHY

Note presence of TMF on Arctic and northern Atlantic margins

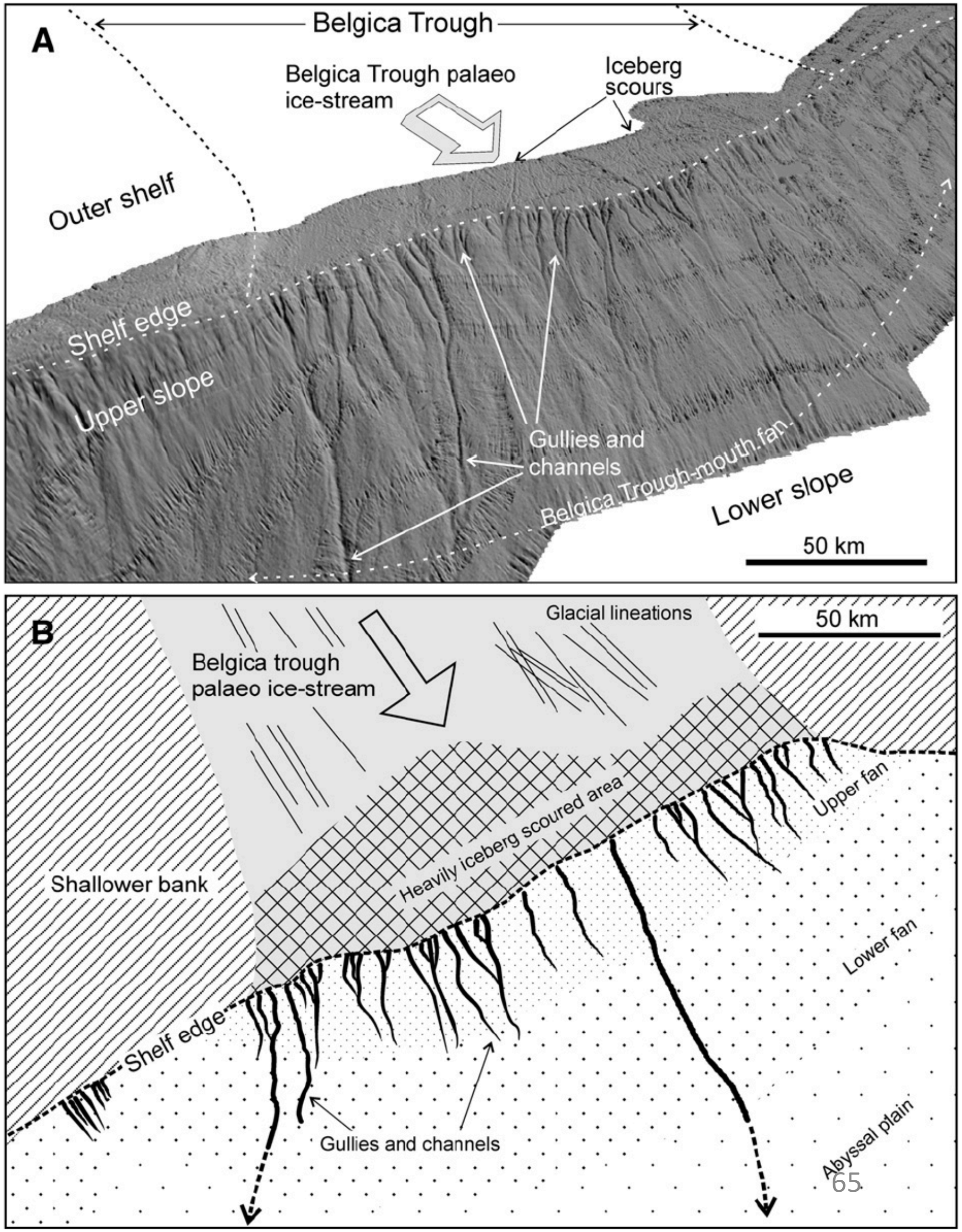


IBCAO v.3 DTM
Jakobbson et al., 2013

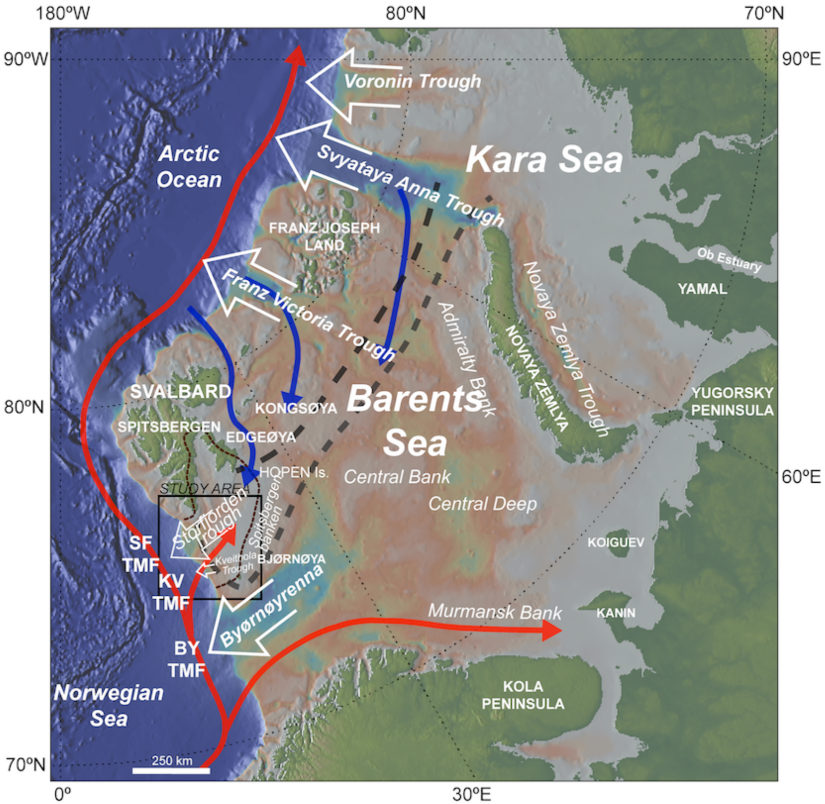


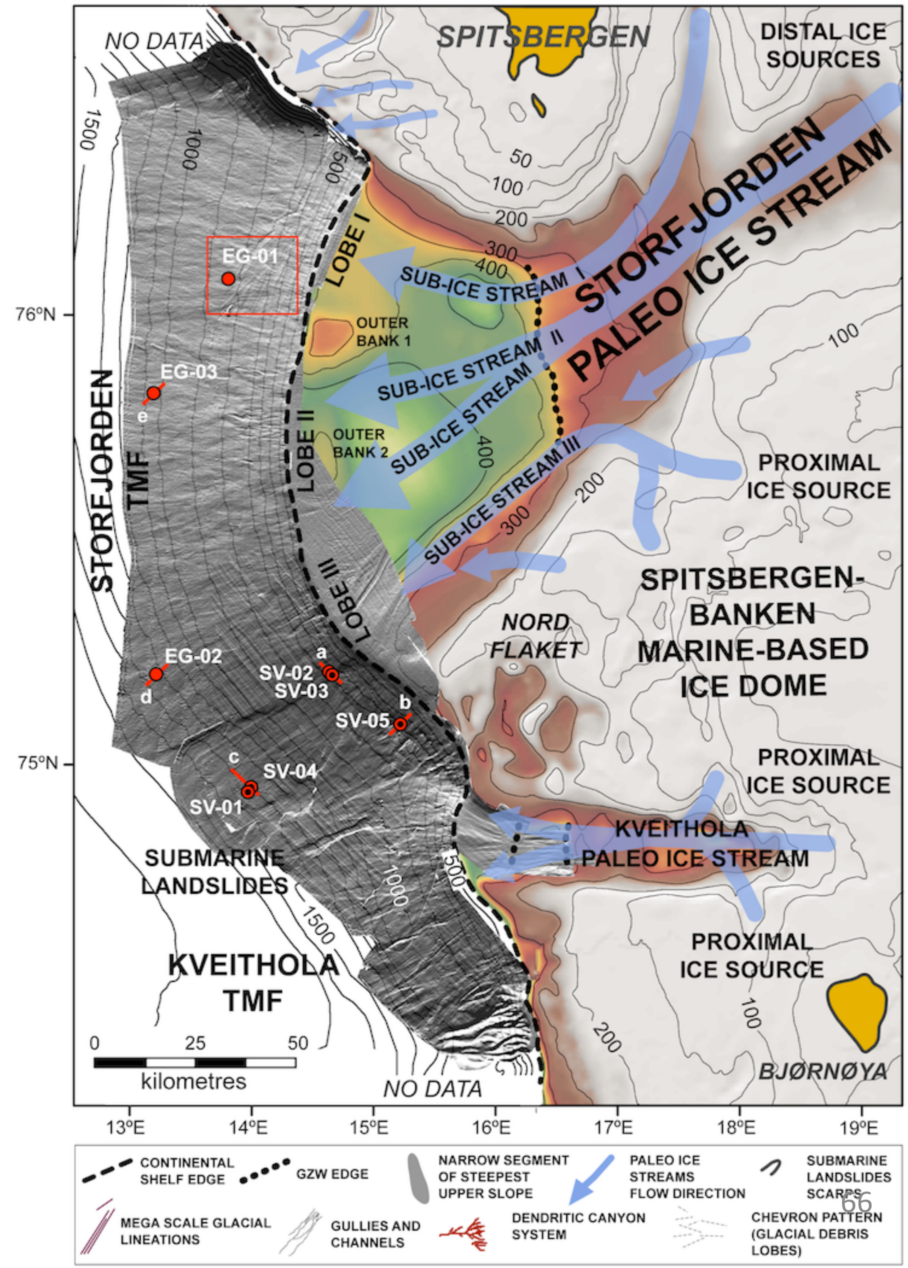
Vorren and Laberg, 1997

Bellingshausen Sea,West Antarctica: The Belgica Fan

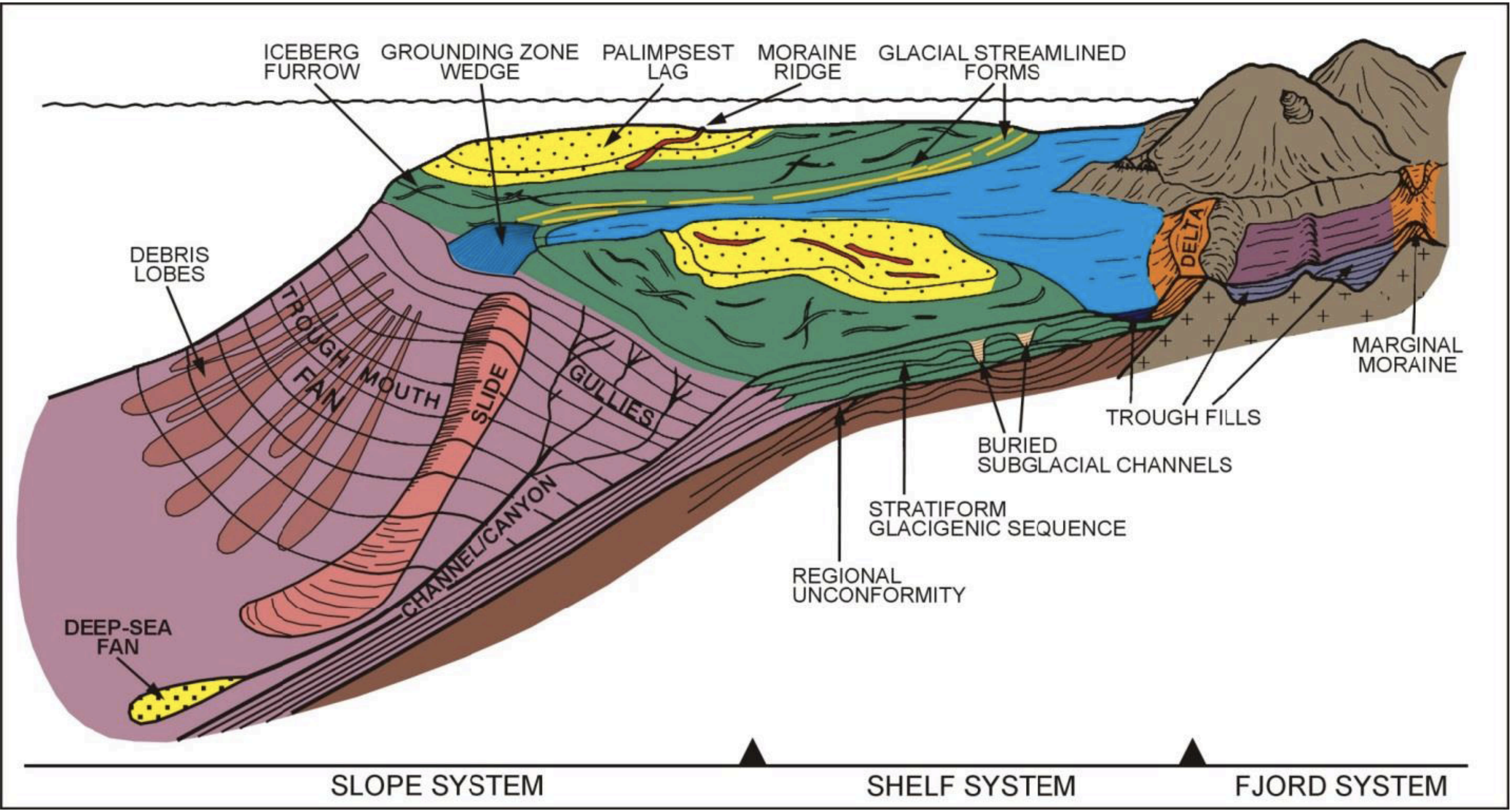


STORFJORDEN TMF
NW BARENTS SEA

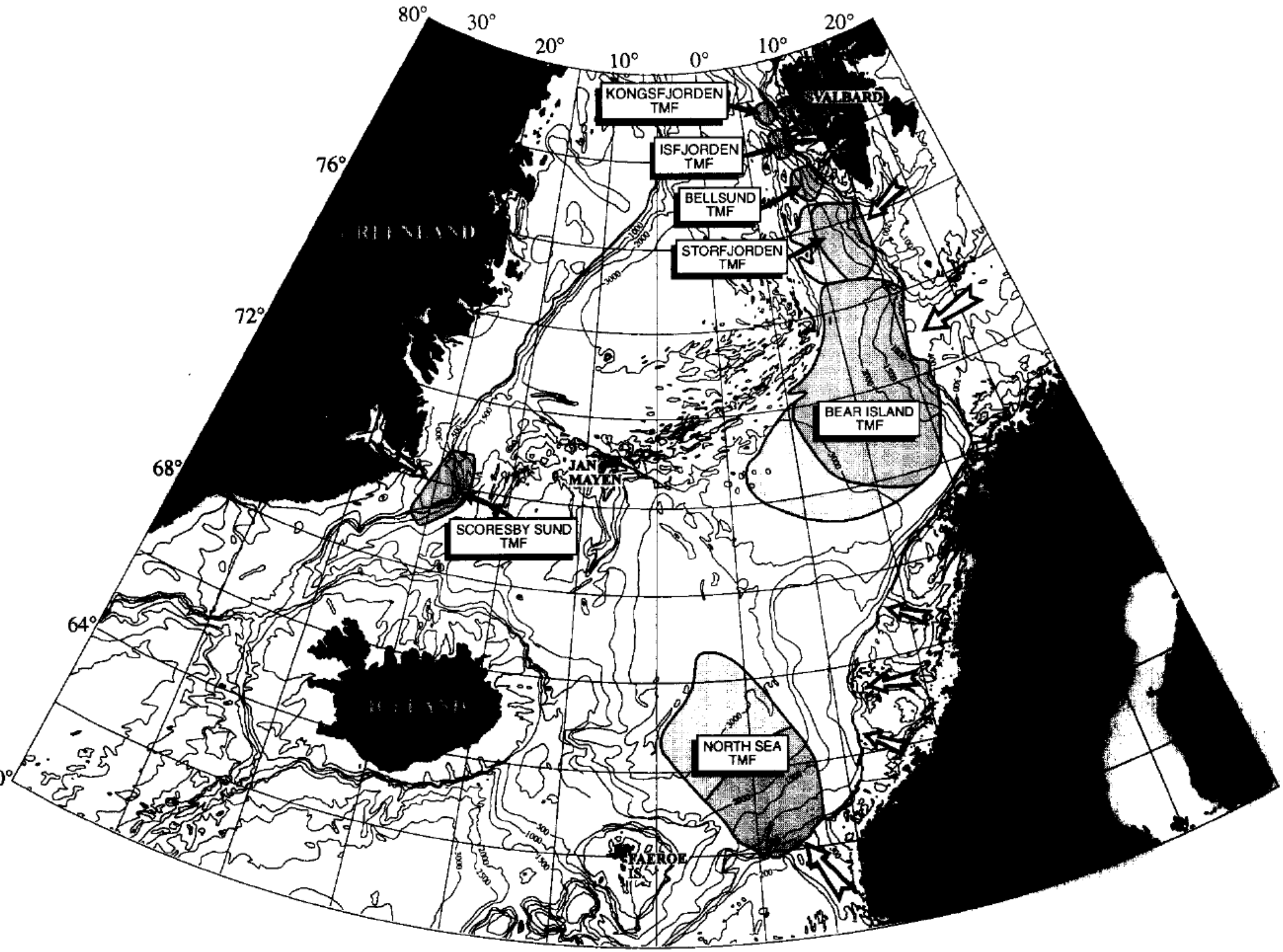




Lucchi et al., in press


ICEBERG FURROW
GROUNDING ZONE WEDGE
PALIMPSEST LAG
MORAINE RIDGE
GLACIAL STREAMLINED FORMS
DEBRIS LOBES
TROUGH MOUTH FAN
SLIDE
GULLIES
CHANNEL/CANYON
DELTA
MARGINAL MORAINE
TROUGH FILLS
BURIED SUBGLACIAL CHANNELS
STRATIFORM GLACIGENIC SEQUENCE
REGIONAL UNCONFORMITY
DEEP-SEA FAN
SLOPE SYSTEM
SHELF SYSTEM
FJORD SYSTEM

Vorren, 2003

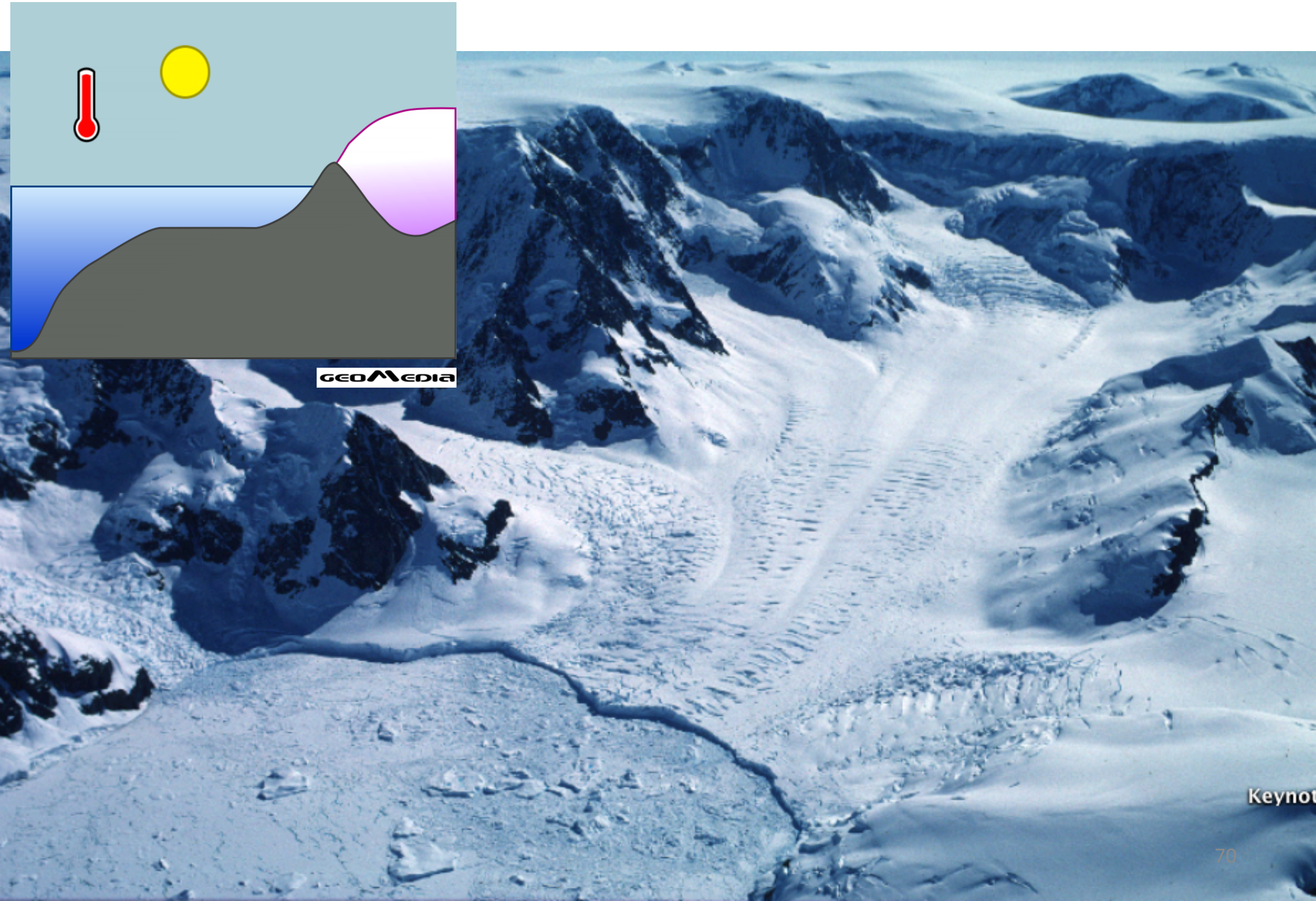


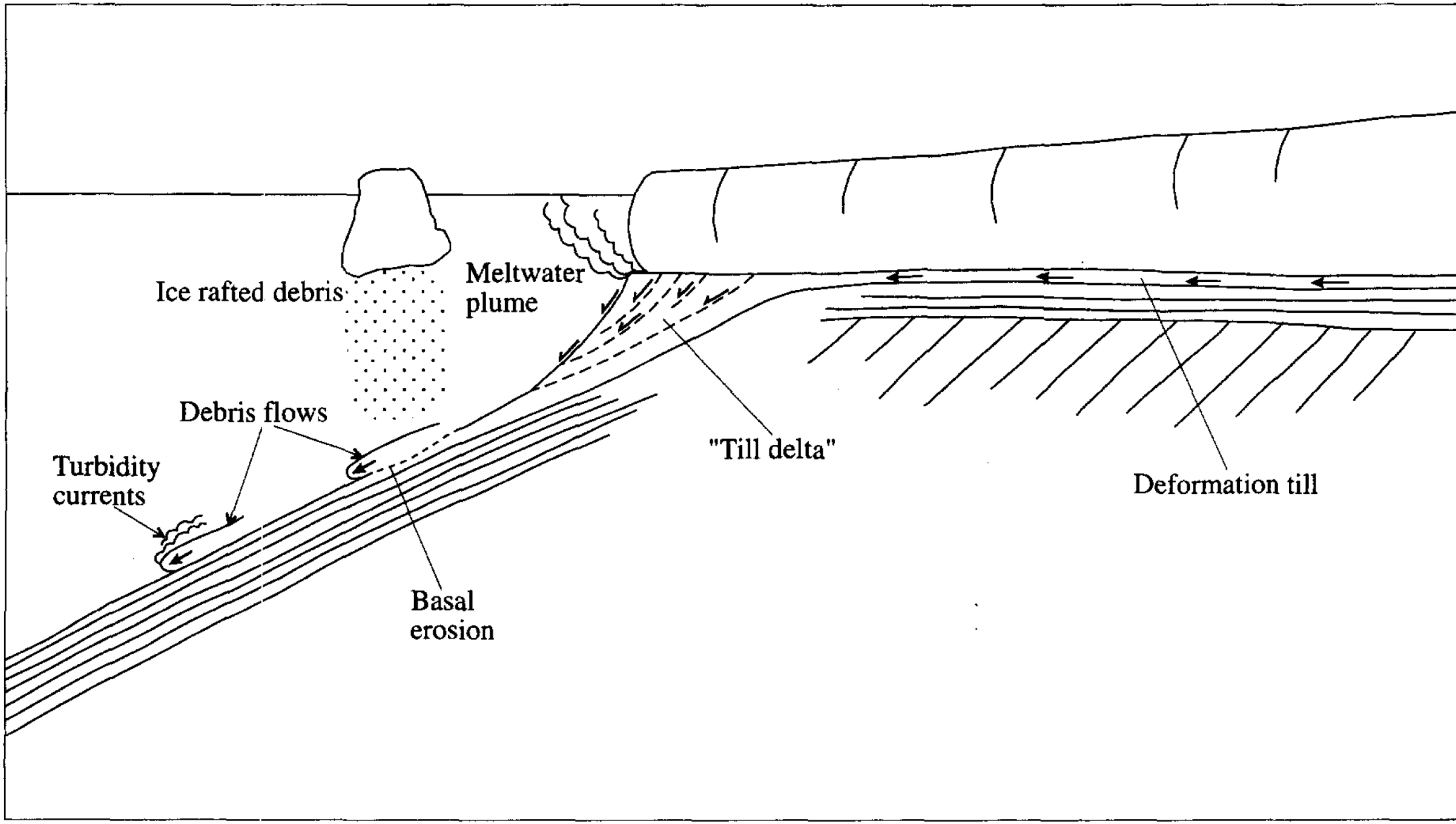
Vorren and Laberg, 1997

ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS

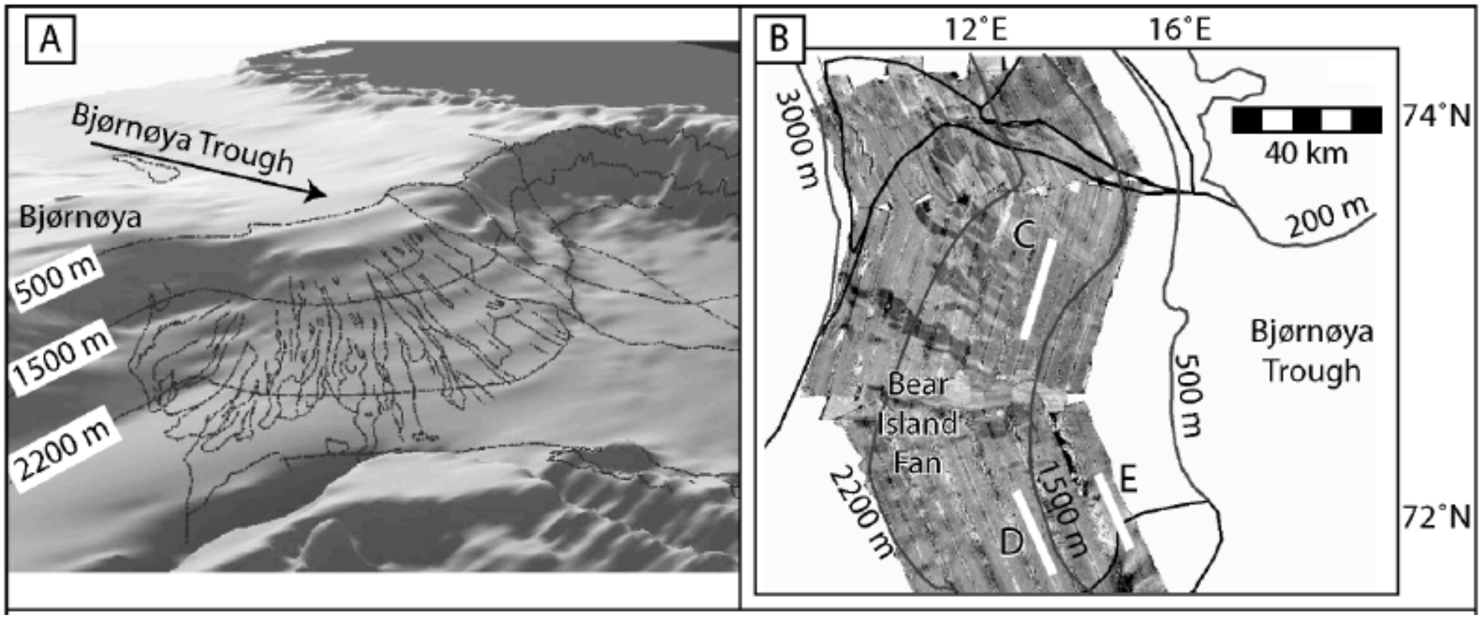
TWO MAIN SEDIMENTARY AGENTS

ICE STREAM PUSH: GLACIAL MAXIMA DEBRIS FLOWS


GEOMEDIA
Keynot

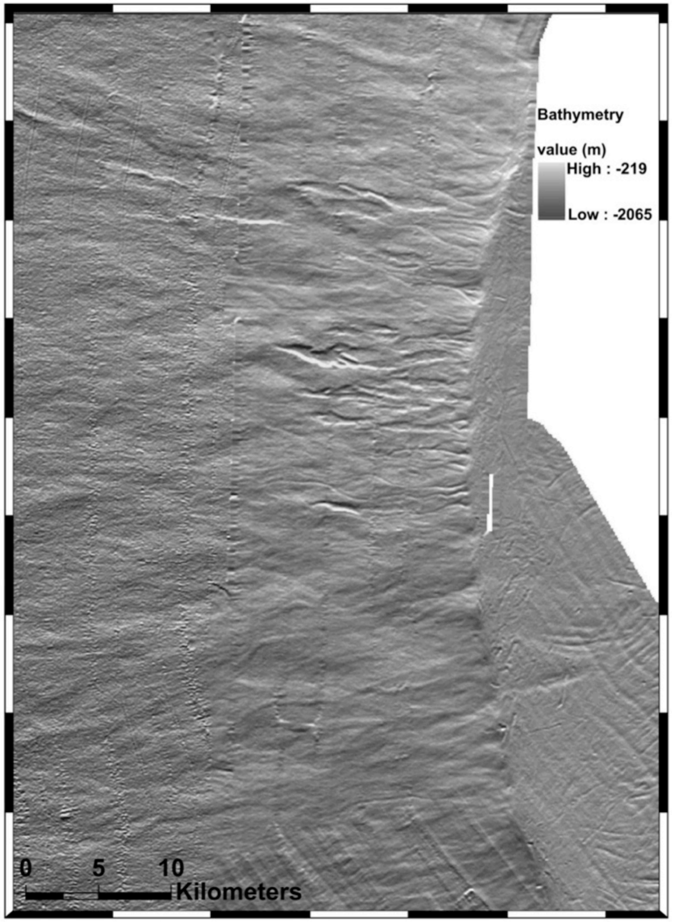

Ice rafted debris
Meltwater plume
Debris flows
Turbidity currents
"Till delta"
Deformation till
Basal erosion

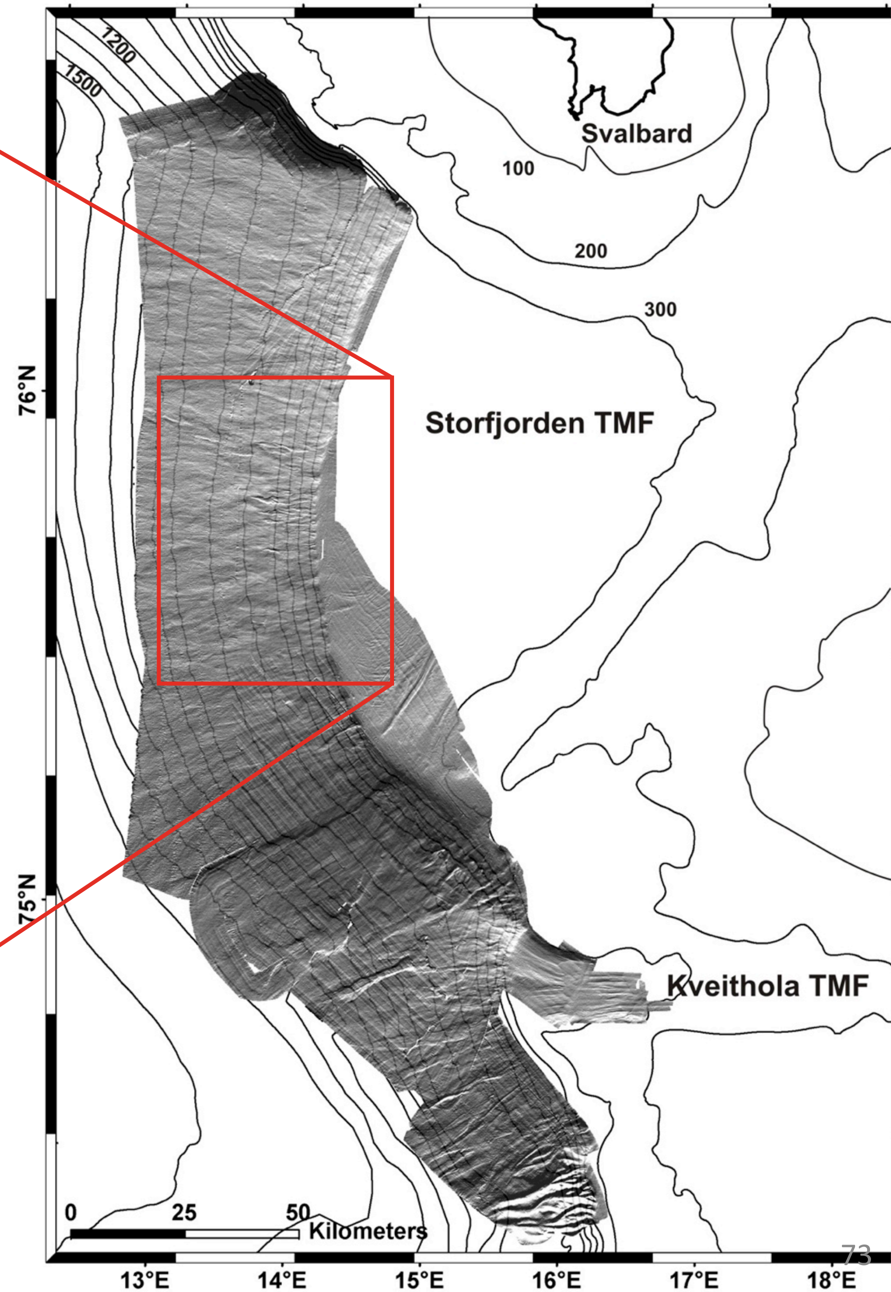
Evidence of subglacially derived debris flow deposits in acoustic back-scatter data



O´Cofaigh et al. , 2003, Boreas

Continental margin morphology





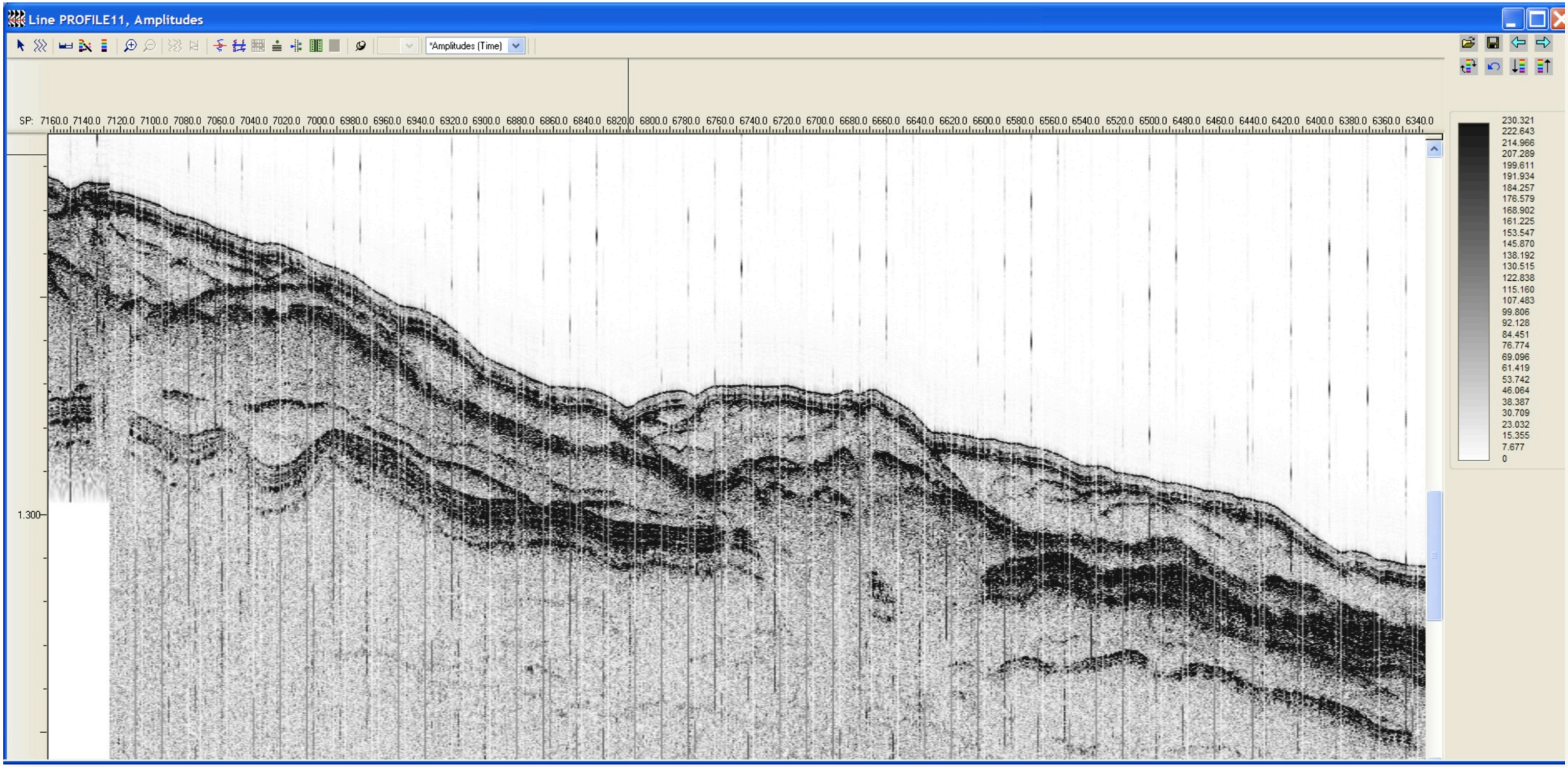
On the shelf

- Three main depositional lobes
- Glacial lineations
- Iceberg ploughmarks

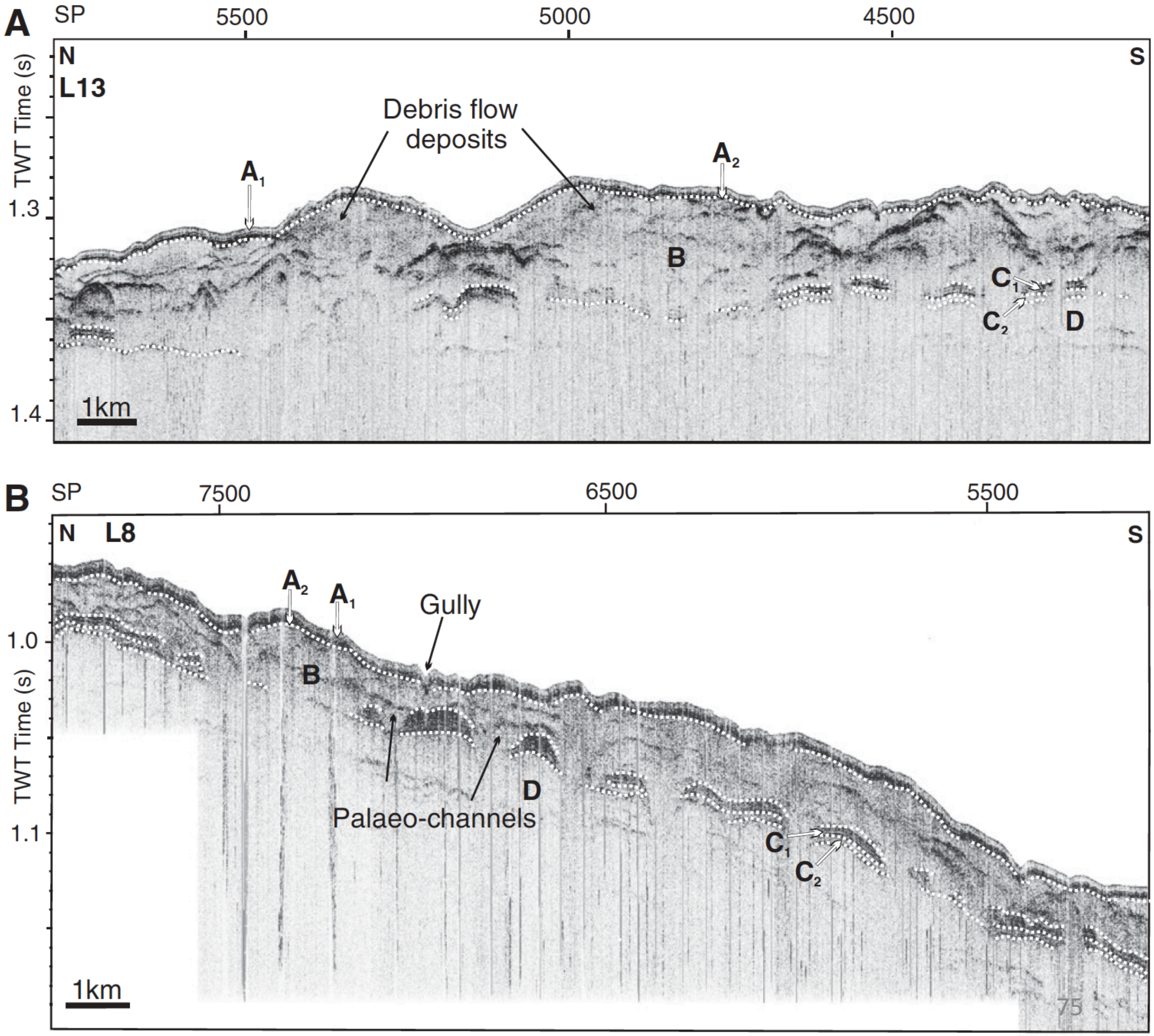
On the slope

- Gullies
- Channels
- Debris mounds
- Landslides

Evidence of subglacially derived debris flow deposits in seismic reflection

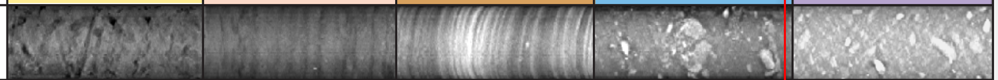


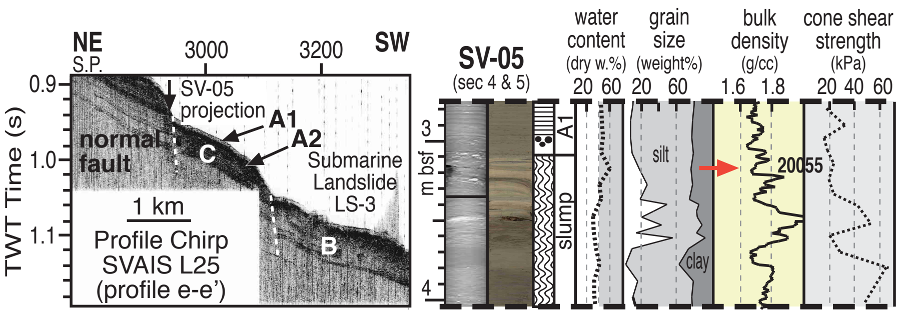
Glacial Debris Flows
In sub-bottom
Profiler record,
Stofjorden TMF
(NW Barents Sea)

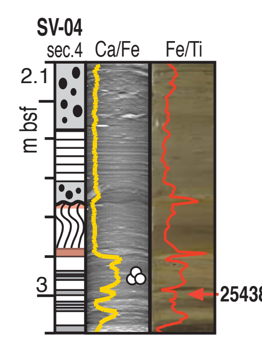


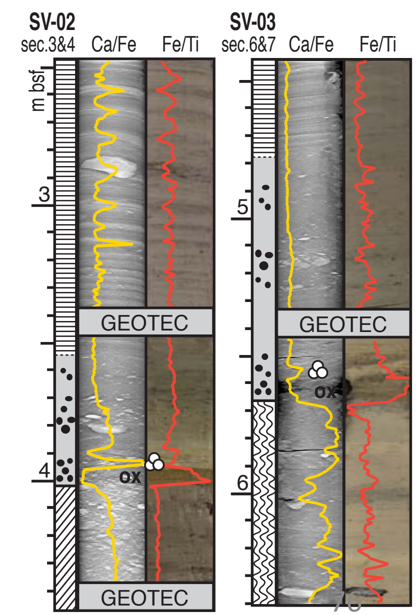
Pedrosa et al., 2011

SEDIMENT LITHOFACIES

Lithofacies	HEAVILY BIOTURBATED	CRUDELY LAYERED	INTERLAMINATED laminated mud and sandy layers	STRUCTURELESS WITH IRD	MASSIVE DIAMICTON
X-radiograph					
colour	light brown	light gray	MUD / SAND olive gray	grayish brown/ olive grey	very-dark grey
water content (wet weight %)	55-60% (129-150%)*	55-60% (129-150%)*	MUD 33% (41%)* / SAND 29% (49%)*	30-40% (40-70%)*	<20% (<24%)*
bulk sediment density (g cc-1)	very low 1.4-1.5	very low 1.5-1.6	MUD mid-low 1.7-1.8 / SAND high 2	moderate 1.8	high 2.2
mean grain size	7.7 ø F-silt	7.8 ø F-silt	MUD 7.5 ø F-silt / SAND 6.5 ø M-silt	U.slope 6.9ø M-silt M.slope 7.8 ø F-silt	matrix 6.5 ø M-silt & cm-thick pebbles
undrained shear strength	2-4 kPa	2-8 kPa	4-12 kPa	20 kPa	up to 44 kPa
magnetic susceptibility	20-30 SI	30 SI	MUD 15-20 SI / SAND up to 40 SI	15-30 SI	13 SI
Corg (%) Org. Matter (%)	0.83 1.50	0.80 1.44	1.14 2.06	1.19 2.14	1.37 2.47
Corg/Ntot (OM provenance)	6-8 marine	6-8 marine	>12 continental	>12 continental	>12 continental
CaCO3 content (%)	10-23	3-10	MUD 2-3 / SAND 3	2-3	4-5
bioclasts	calcareus and siliceus	mainly siliceus	barren	almost barren	rare reworked bioclasts





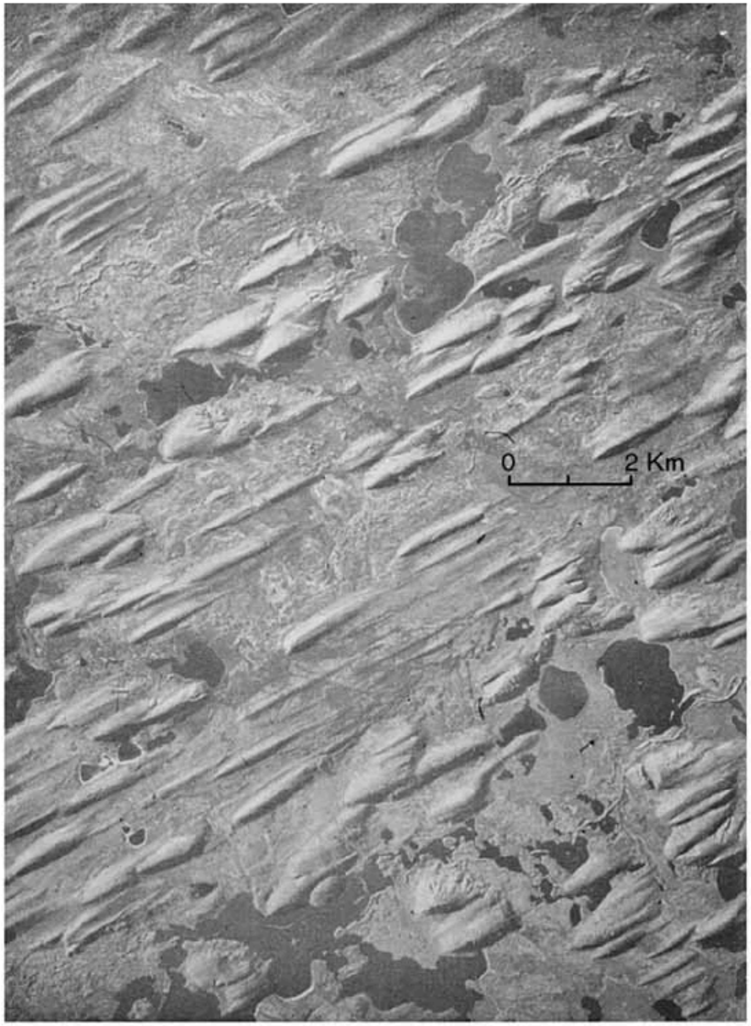


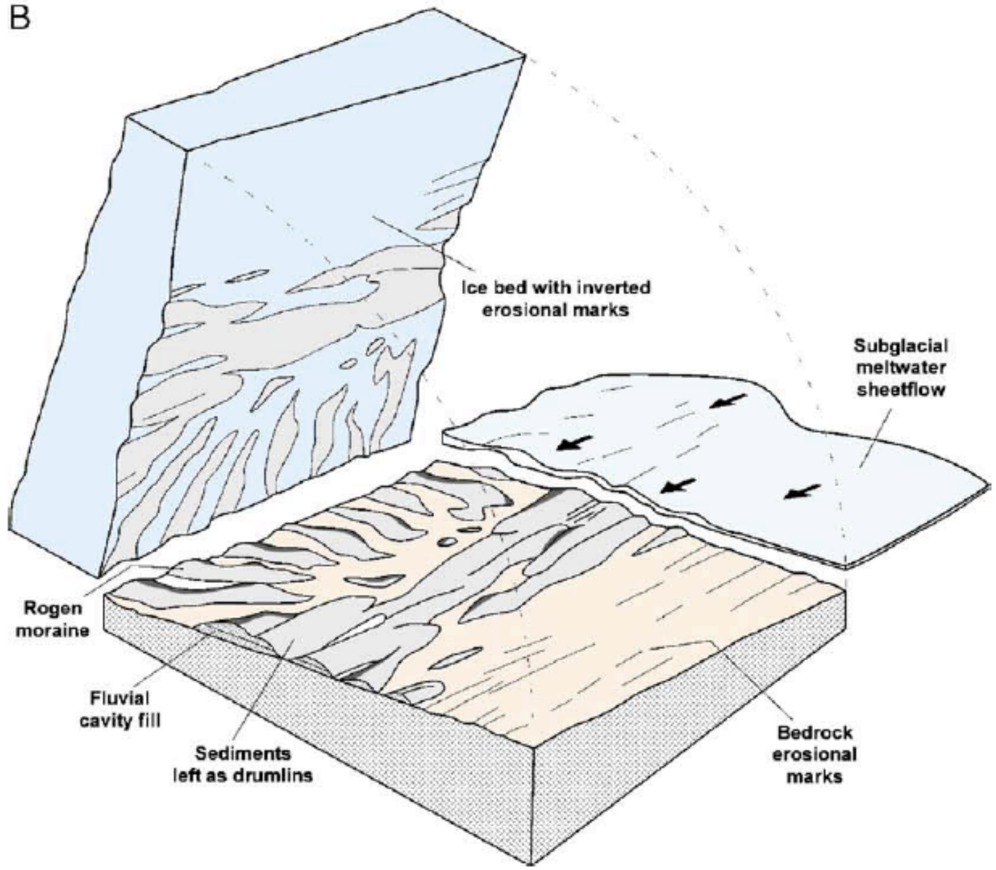
Lucchi et al.,2012

ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS

TWO MAIN SEDIMENTARY AGENTS:

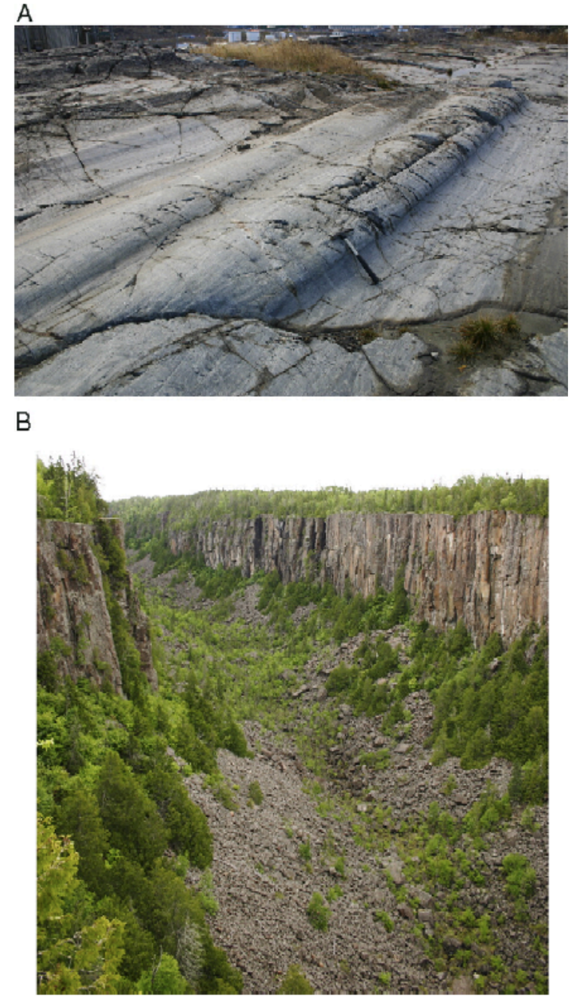
MELTWATER


0
2 Km


B
Ice bed with inverted erosional marks
Subglacial meltwater sheetflow
Rogen moraine
Fluvial cavity fill
Sediments left as drumlins
Bedrock erosional marks

Eyles, 2006

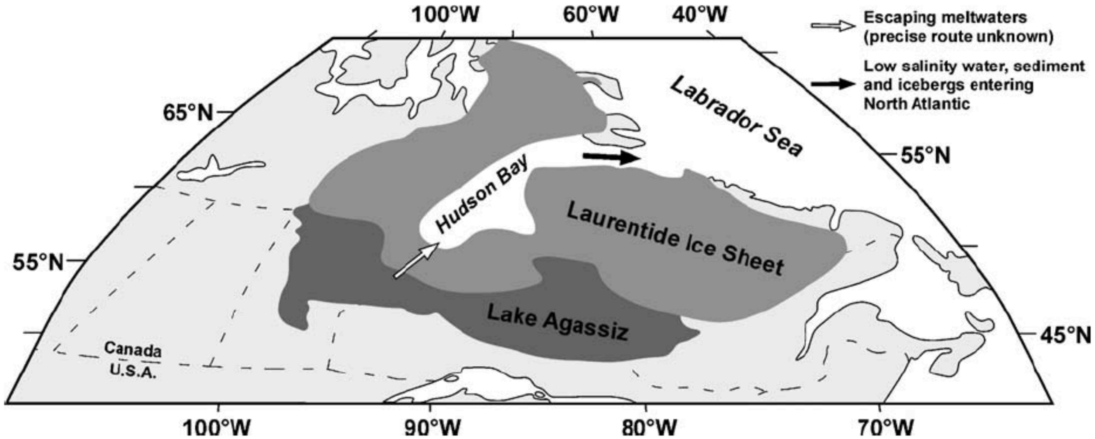
Large flute (A) and drumlin (B) Saskatchewan Glacier, Alberta

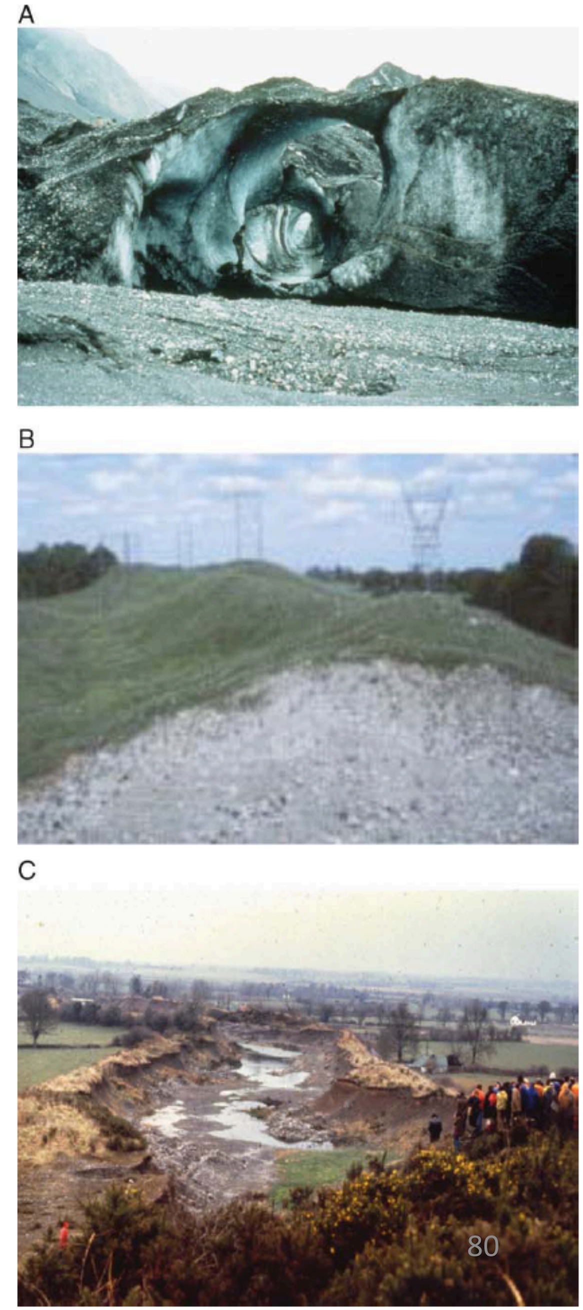


(A) Glacially sculpted bedrock surface at Sudbury, Ontario.
(B) Ouimet Canyon, near Thunder Bay, Ontario, cut by meltwaters. The canyon is 500 m wide and 70 m deep.

Eyles, 2006

Catastrophic meltwater discharge

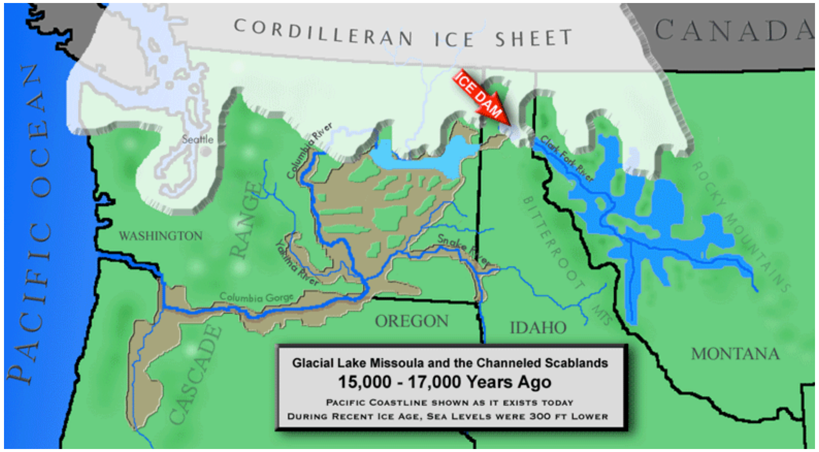




(A) Englacial conduit at Kviarjokull Glacier, Iceland, figure for scale. Eskers are the sediment-plugged remains of conduits (#3, Fig. 2) and form sinuous ridges built of fluvioglacial sands and gravels (B); in C an esker has been completely excavated for aggegate exhuming the lower part of the conduit floor on which it was deposited.

Eyles, 2006

(MEGA-FLOODS EVENTS Missoula glacial lake breakout)



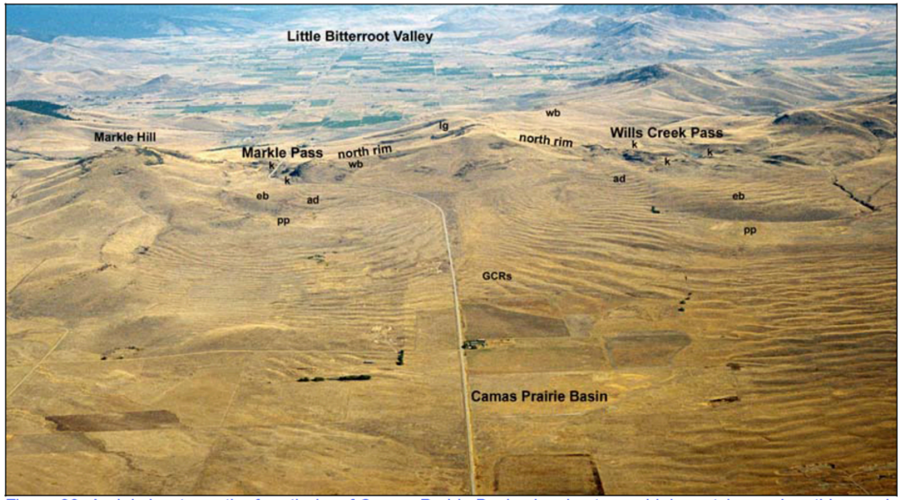


Figure 39–Aerial view to north of north rim of Camas Prairie Basin showing two sublake notches. ad, antidunes;eb, expansion bar; GCRs, giant current ripples; k, kolk pits; lg, lee gravels; pp, 'plunge pool'; wb, washover bar.

Figure 56—The Bellevue Erratic in the Willamette Valley, OR. The 160-ton block of Belt argillite was rafted across four states in a huge chunk of glacier torn from the ice dam.

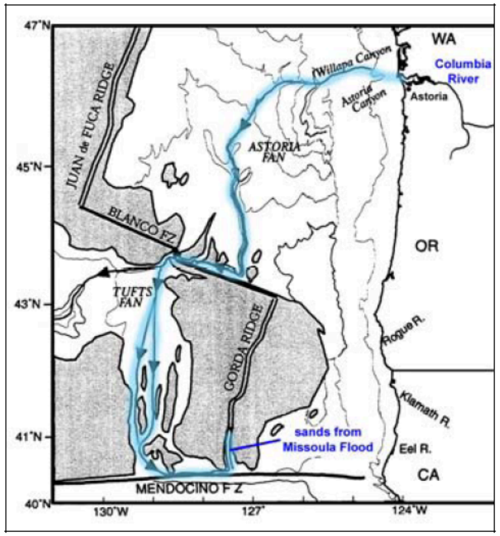


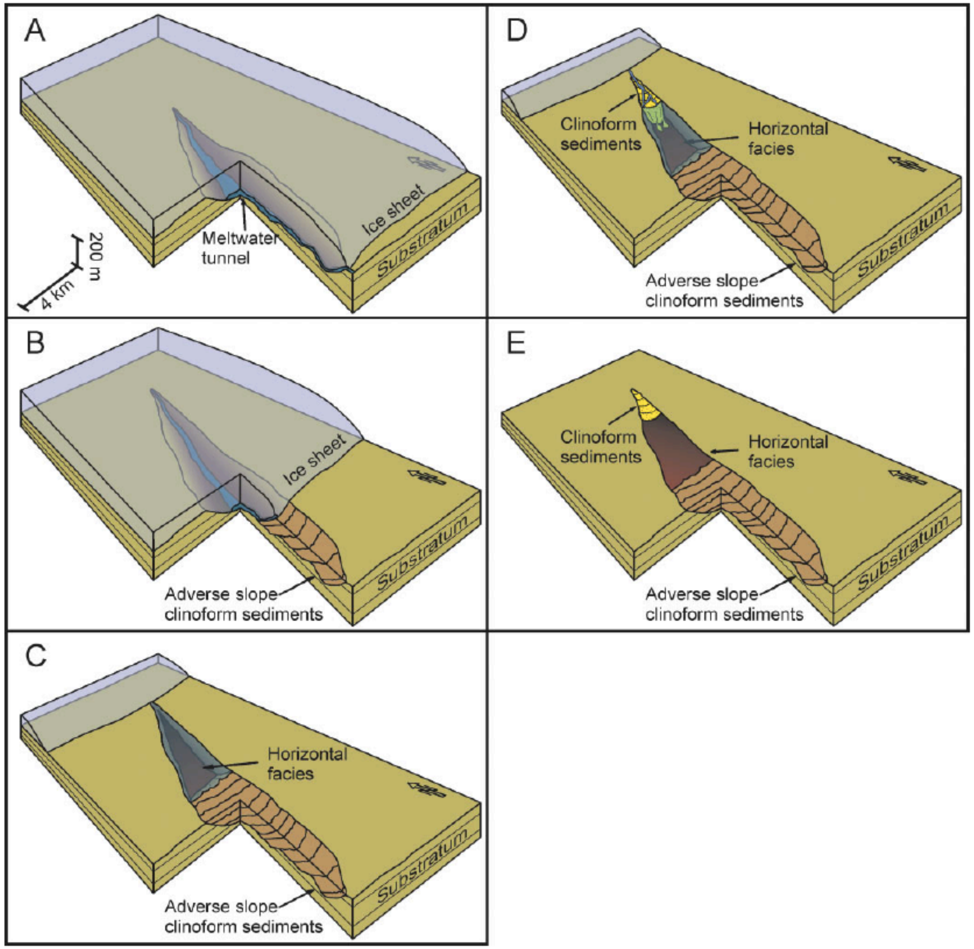
Figure 57—Floodwaters and entrained sediments created turbid currents that swept across the Pacific Ocean floor for 700 miles [1100 km][Zuffa and others, 2000].

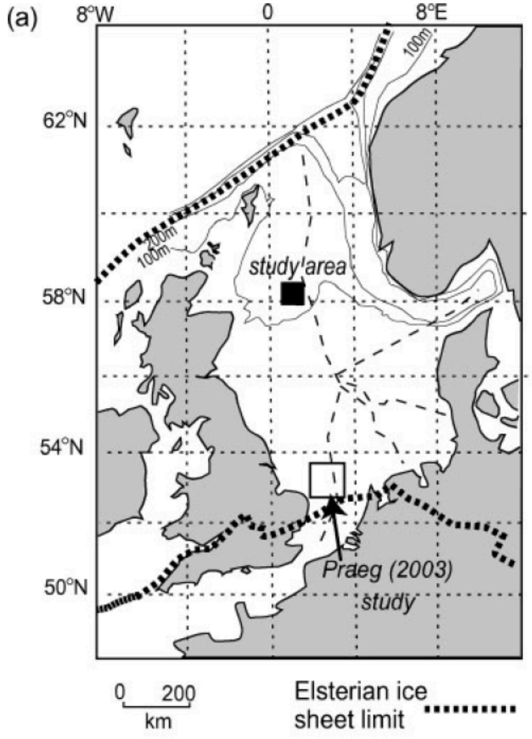
Keenan Lee, Colorado School of Mines, 2009

MELTWATER

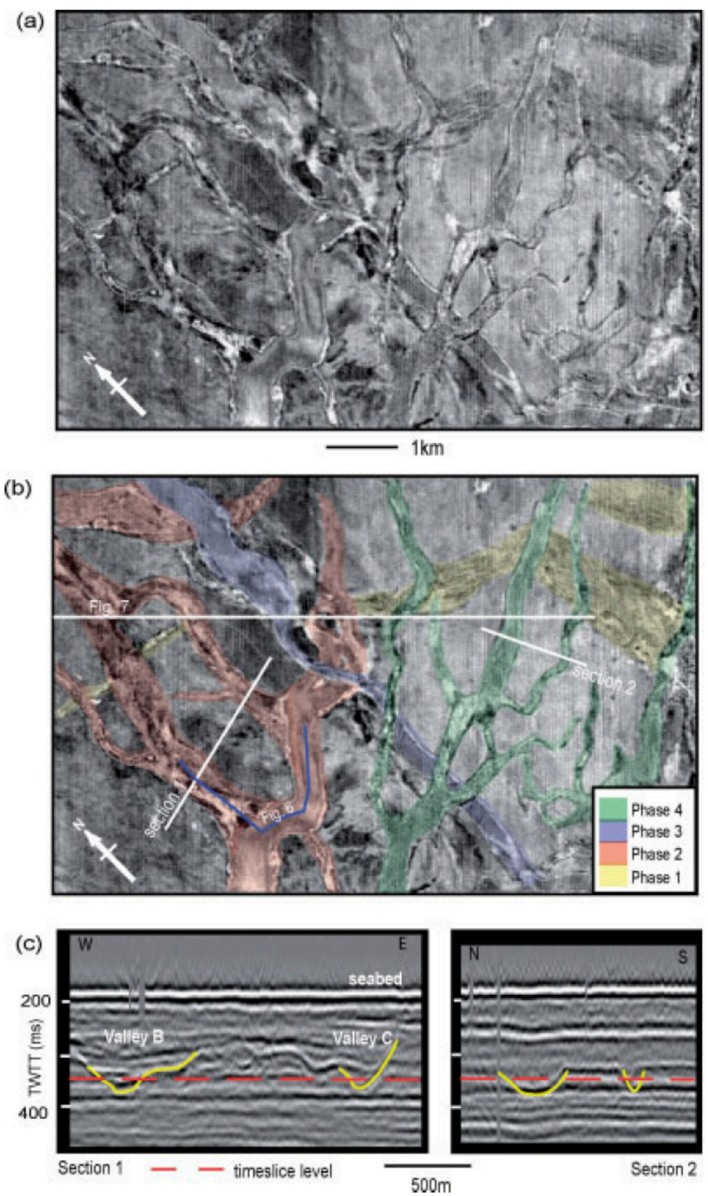
TUNNEL VALLEYS

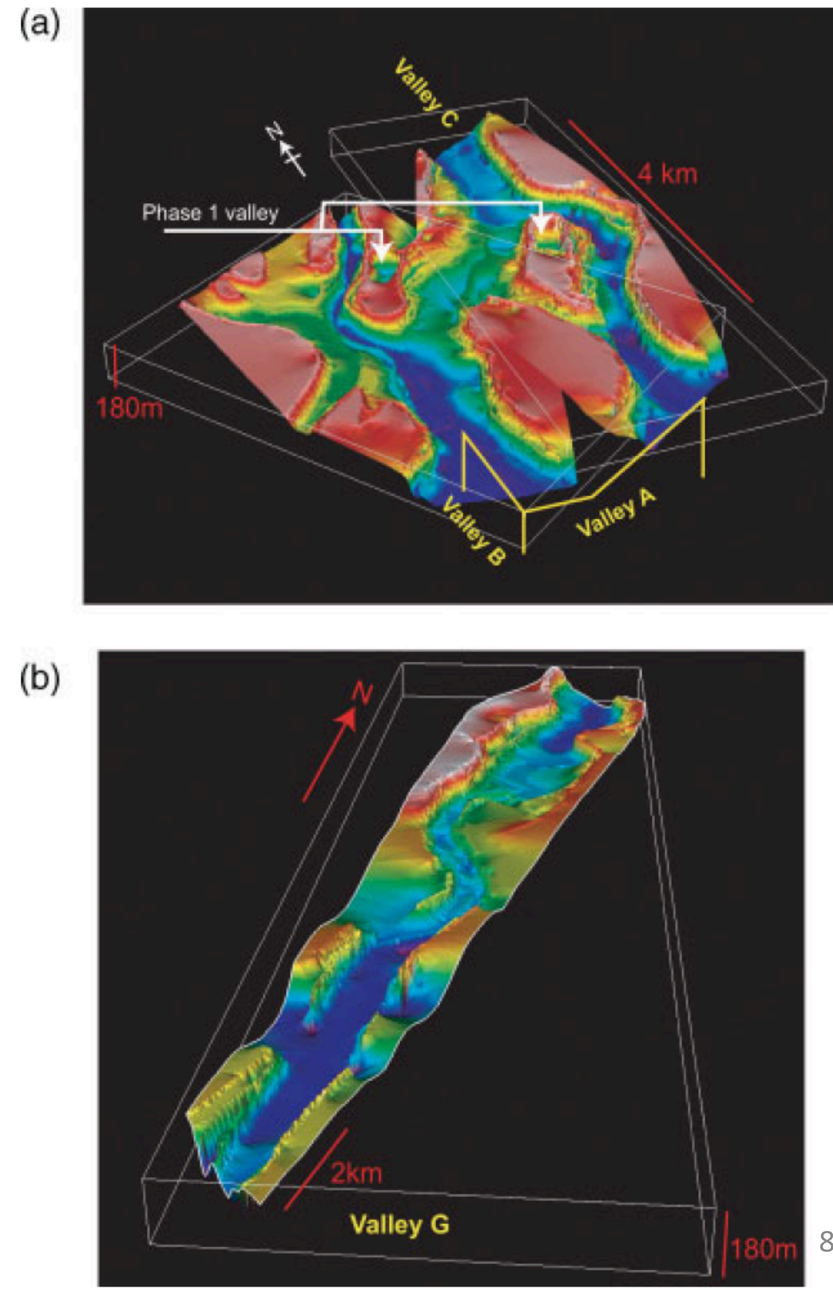
Pleistocene subglacial tunnel valleys in the central North Sea basin: 3-D morphology and evolution



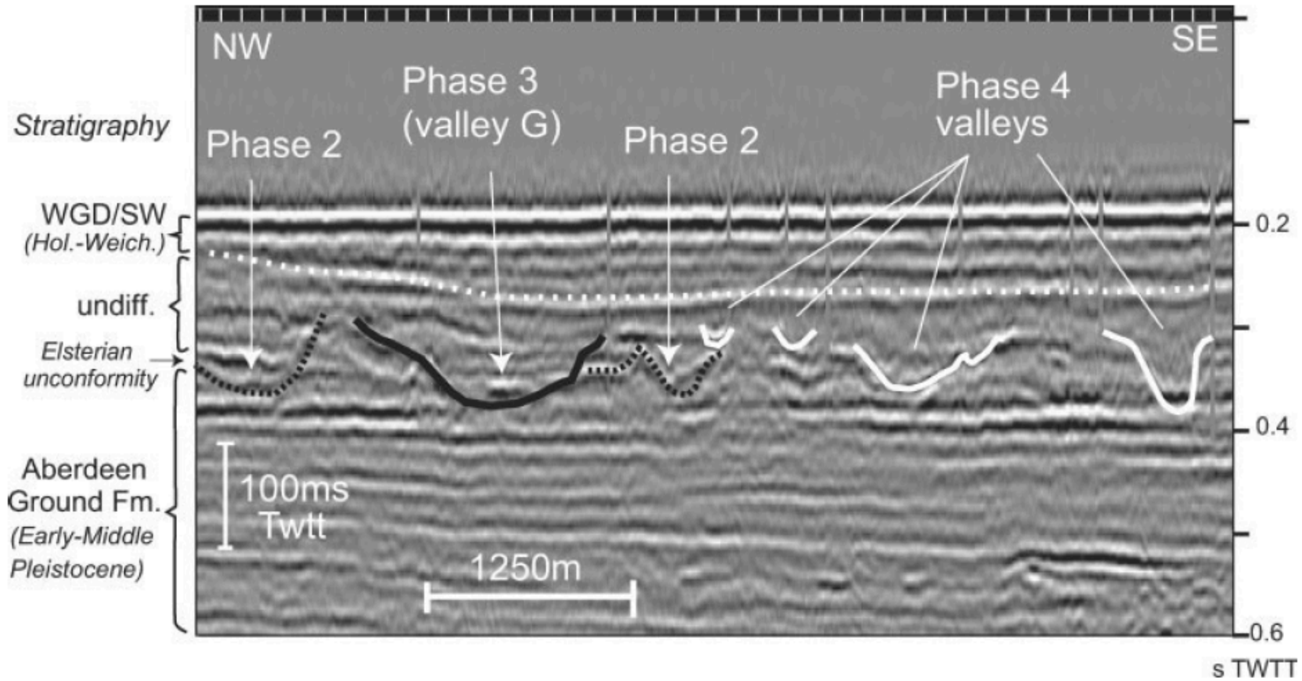


Bojer Kristensen et al., 2008, *Earth Surf. Process. Landforms*

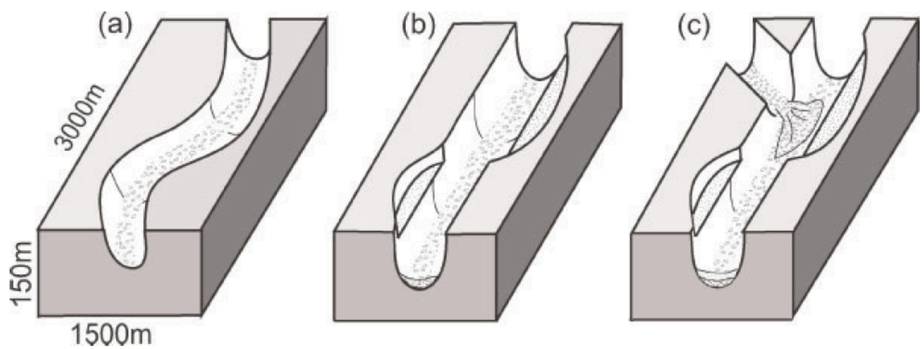




Bojer Kristensen et al., 2008, *Earth Surf. Process. Landforms*

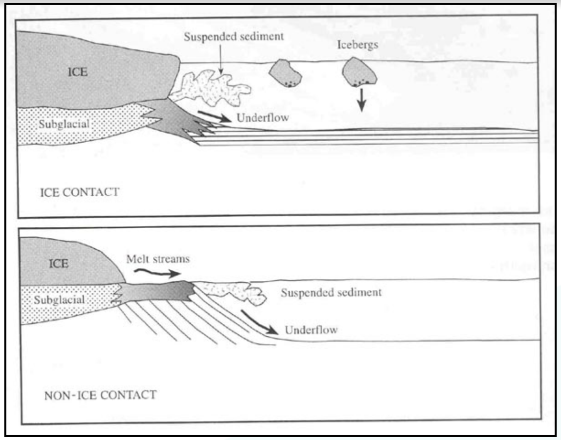


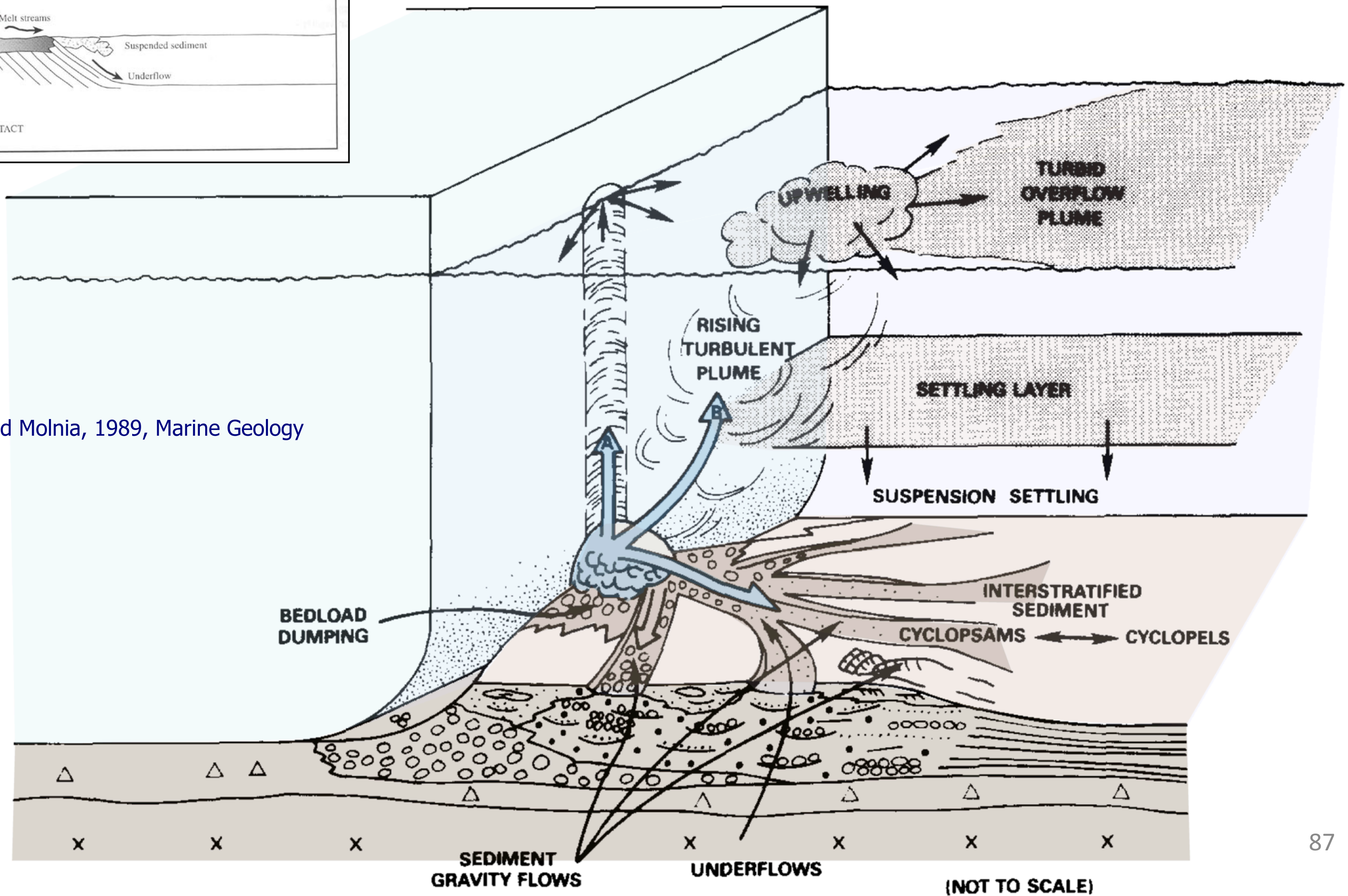
Sand fill



Bojer Kristensen et al., 2008, *Earth Surf. Process. Landforms*

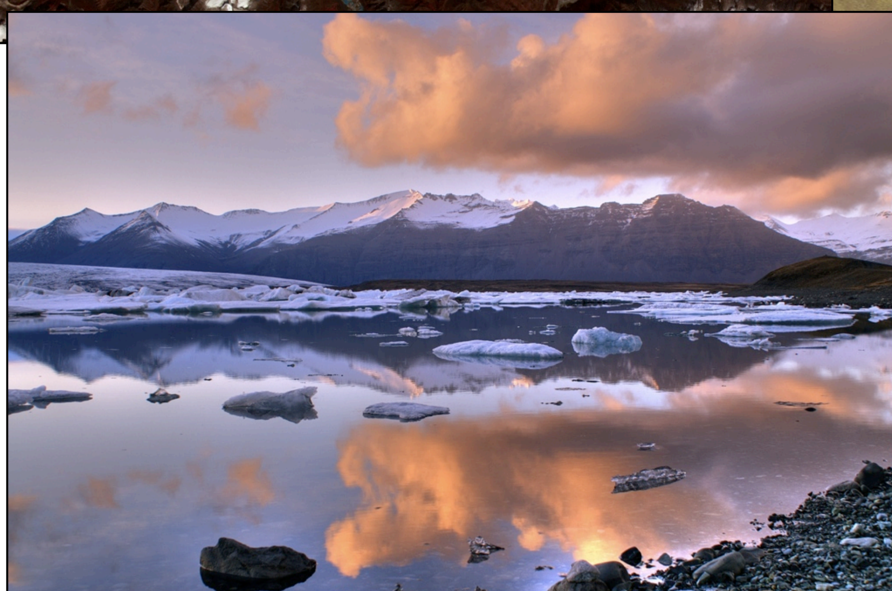
MELTWATER PLUMES and PLUMITES

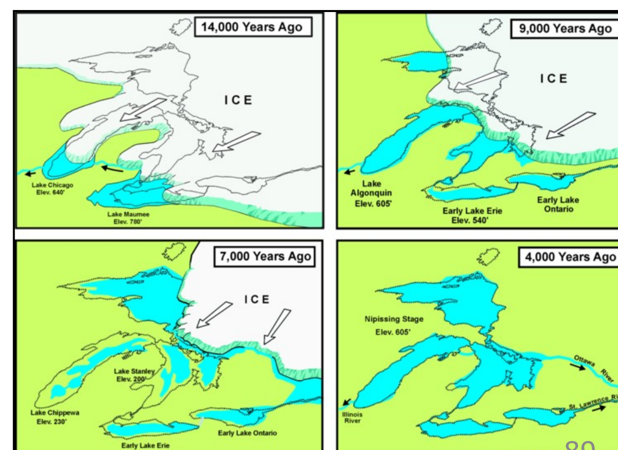




Powell and Molnia, 1989, Marine Geology

Itú, Brasil - Parque do Varvito




14,000 Years Ago
ICE
Lake Chicago
Elev. 640'
Lake Maumee
Elev. 780'
9,000 Years Ago
ICE
Lake
Algonquin
Elev. 605'
Early Lake Erie
Elev. 540'
Early Lake
Ontario
7,000 Years Ago
ICE
Lake Stanley
Elev. 200'
Lake Chippewa
Elev. 230'
Early Lake Erie
Elev. 540'
Early Lake Ontario
4,000 Years Ago
Nipissing Stage
Elev. 605'
Ottawa River
St. Lawrence River
Illinois
River
U.S. Army Corps of

SEDIMENT LITHOFACIES

Lithofacies	HEAVILY BIOTURBATED	CRUDELY LAYERED	INTERLAMINATED laminated mud and sandy layers	STRUCTURELESS WITH IRD	MASSIVE DIAMICTON
X-radiograph					
colour	light brown	light gray	MUD / SAND: olive gray	grayish brown/ olive grey	very-dark grey
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magnetic susceptibility	20-30 SI	30 SI	MUD: 15-20 SI / SAND: up to 40 SI	15-30 SI	13 SI
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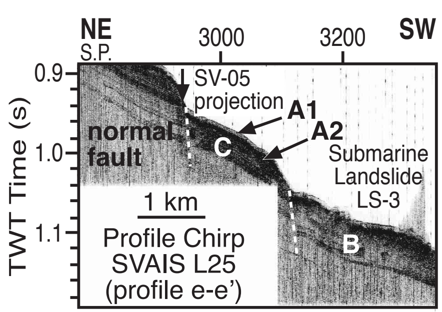
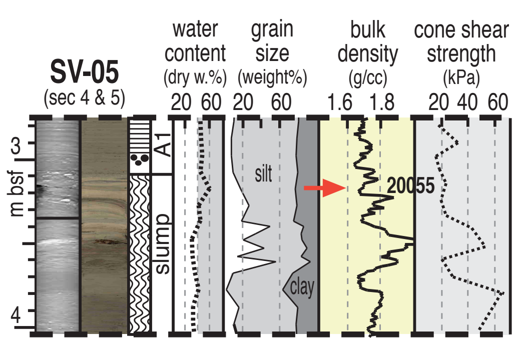
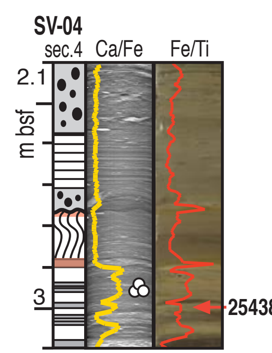
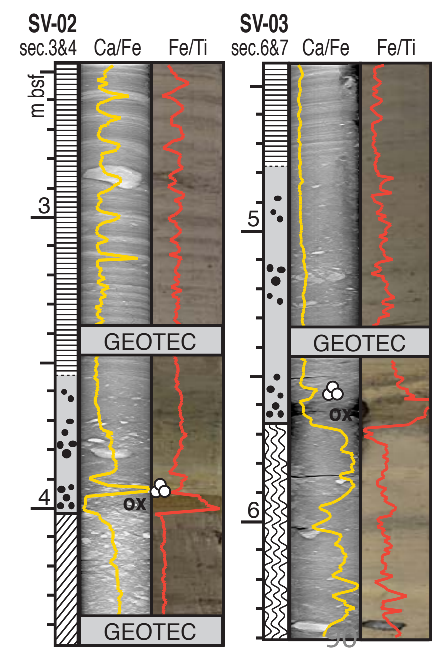
Corg/Ntot (OM provenance)	6-8 marine	6-8 marine	>12 continental	>12 continental	>12 continental
CaCO3 content (%)	10-23	3-10	MUD: 2-3 / SAND: 3	2-3	4-5
bioclasts	calcareus and siliceus	mainly siliceus	barren	almost barren	rare reworked bioclasts

EVIDENCE OF MELTWATER OUTBURST EVENTS IN THE MARIEN SEDIMENTARY RECORD (see case-study by Lucchi)

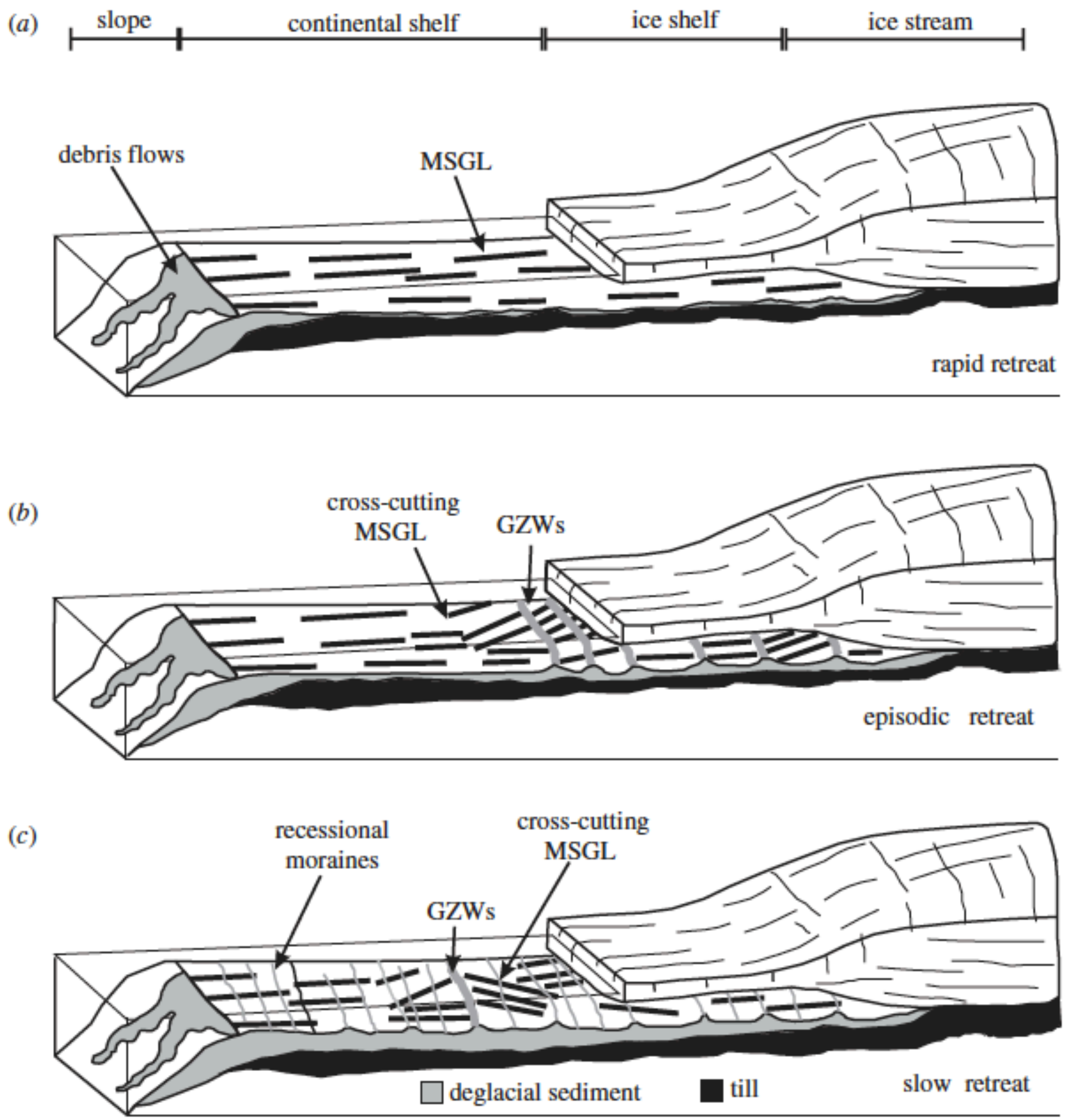




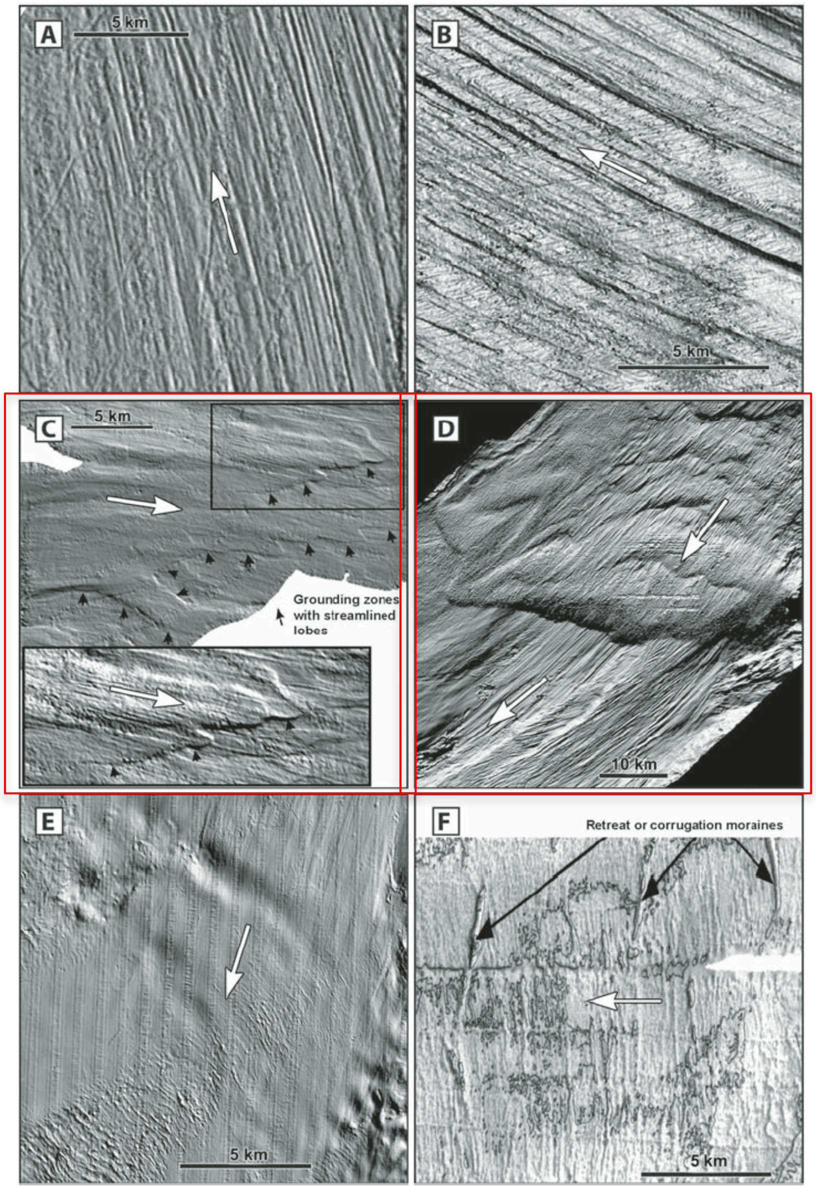




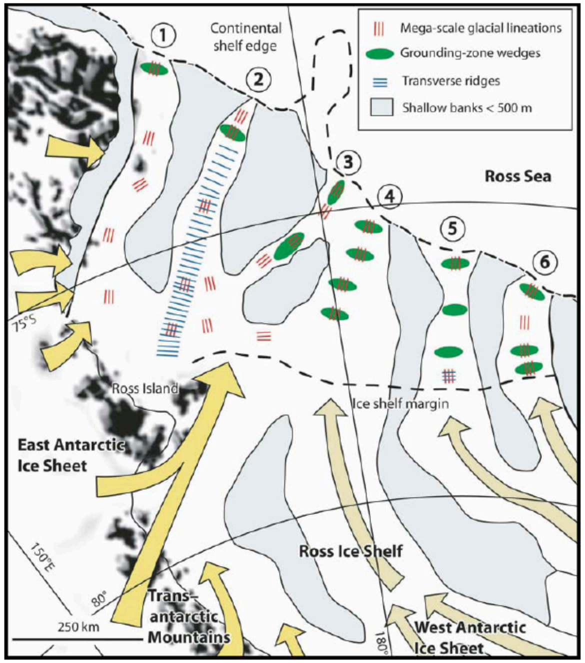
GROUNDING-ZONE WEDGES

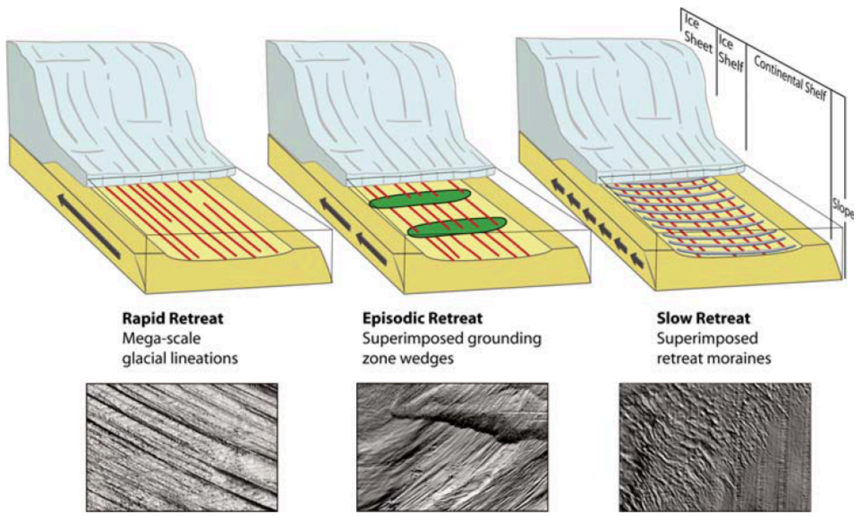


O'Cofaigh, 2012. Phil. Trans. R. Soc. A



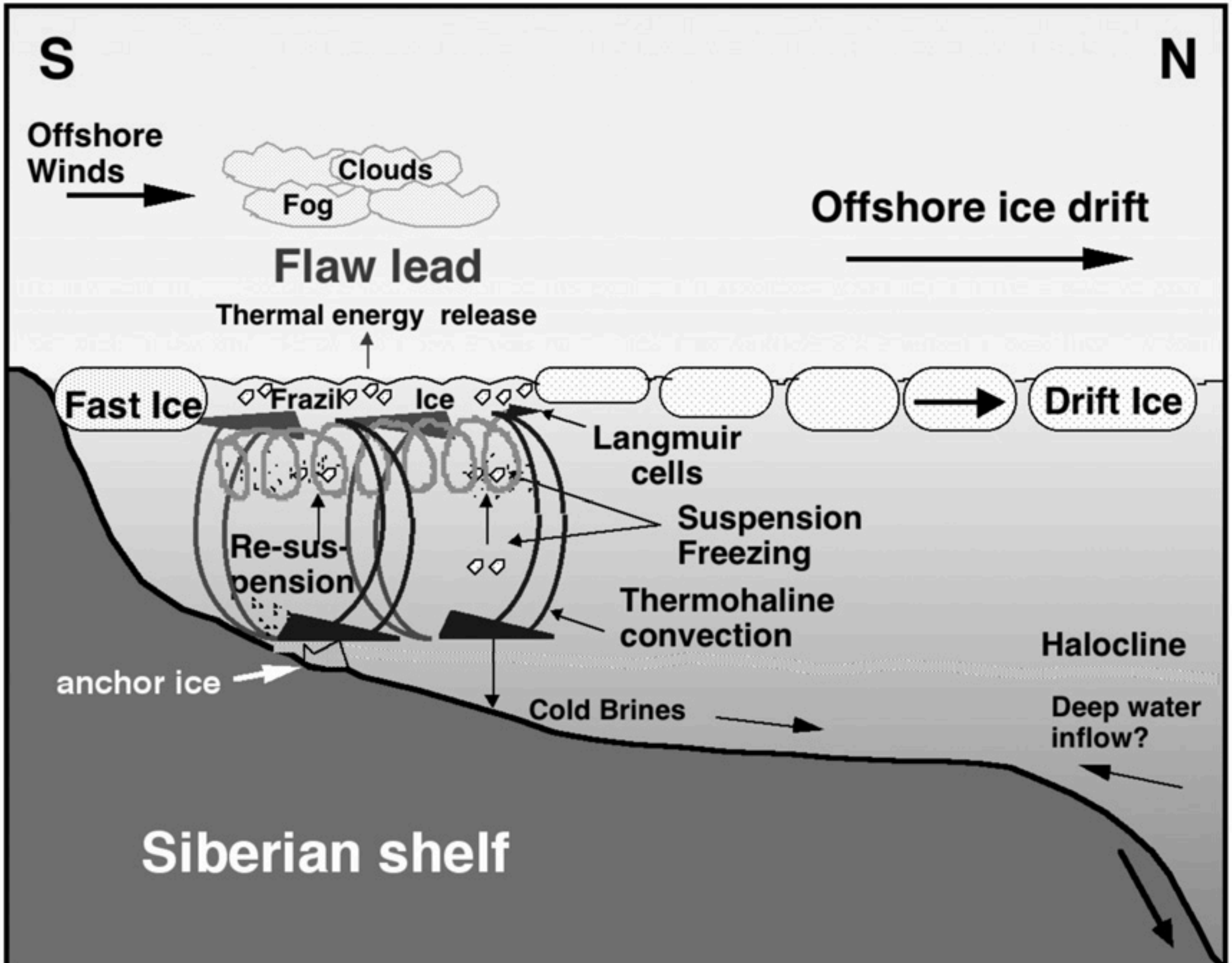
SEE CASE STUDY BY Rebesco)



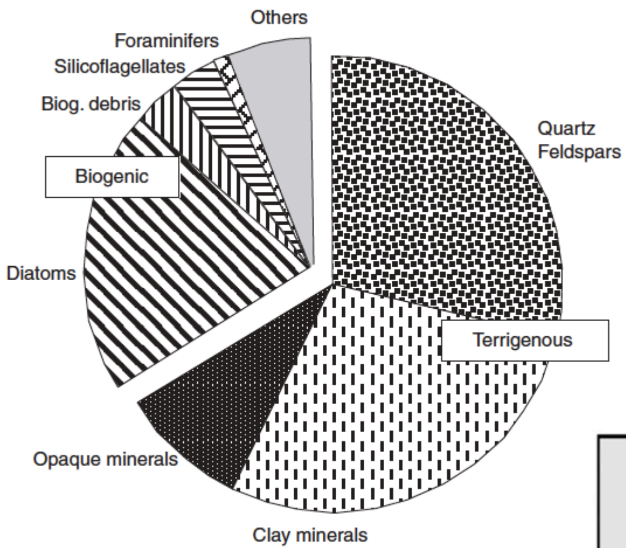


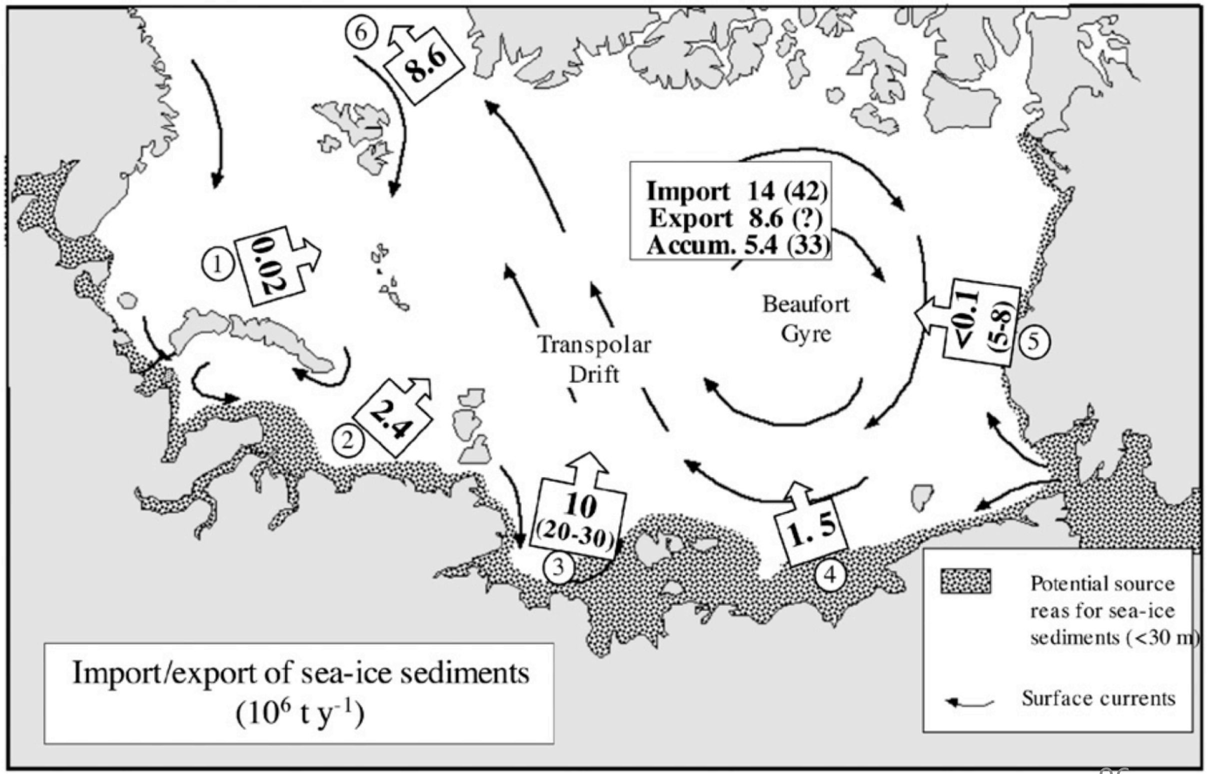
Dowdeswell et al. , 2009.Geology

SEA ICE SEDIMENT TRANSPORT


S
N
Offshore Winds
Clouds
Fog
Offshore ice drift
Flaw lead
Thermal energy release
Fast Ice
Frazil
Ice
Drift Ice
Langmuir cells
Suspension Freezing
Re-sus-pension
Thermohaline convection
Halocline
anchor ice
Cold Brines
Deep water inflow?
Siberian shelf

Stein, 2008

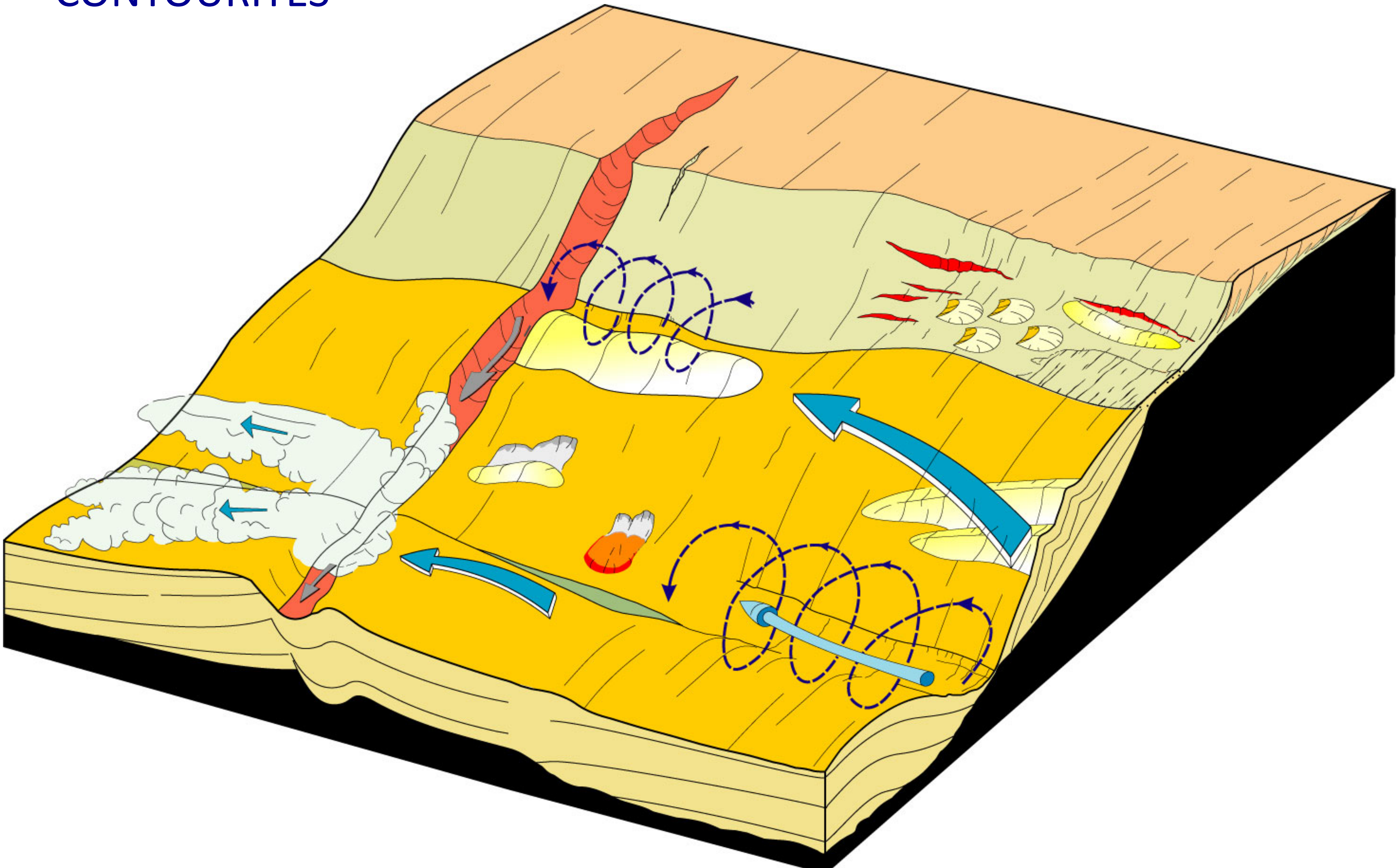

Others
Foraminifers
Silicoflagellates
Biog. debris
Biogenic
Diatoms
Quartz
Feldspars
Terrigenous
Opaque minerals
Clay minerals


Import 14 (42)
Export 8.6 (?)
Accum. 5.4 (33)
Beaufort Gyre
Transpolar Drift
0.02
2.4
10 (20-30)
1.5
<0.1 (5-8)
8.6
Import/export of sea-ice sediments (10^6 t y^{-1})
Potential source reas for sea-ice sediments (<30 m)
Surface currents

Stein, 2008

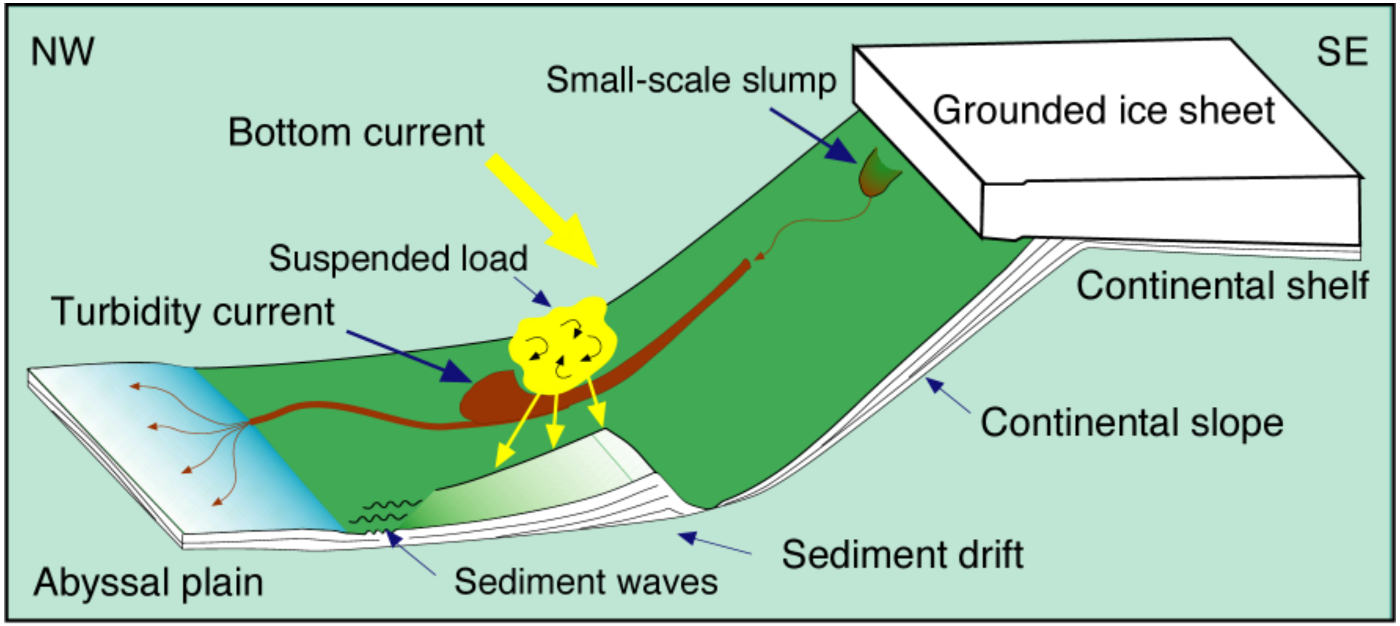
CONTOURITES

CONTOURITES

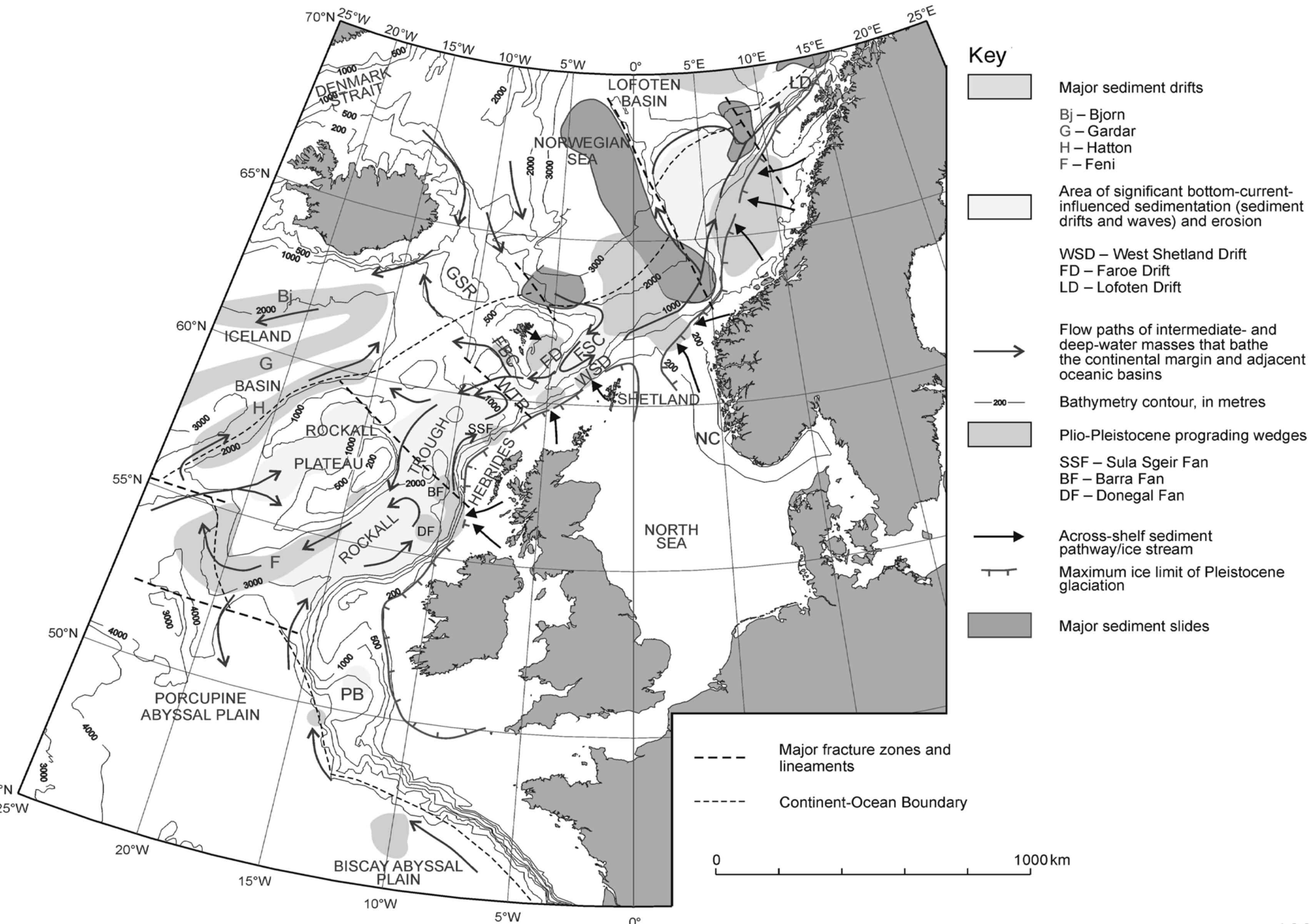


Cover image: Contourites, 2009. Edited by M. Rebesco and A. Camerlenghi, Elsevier

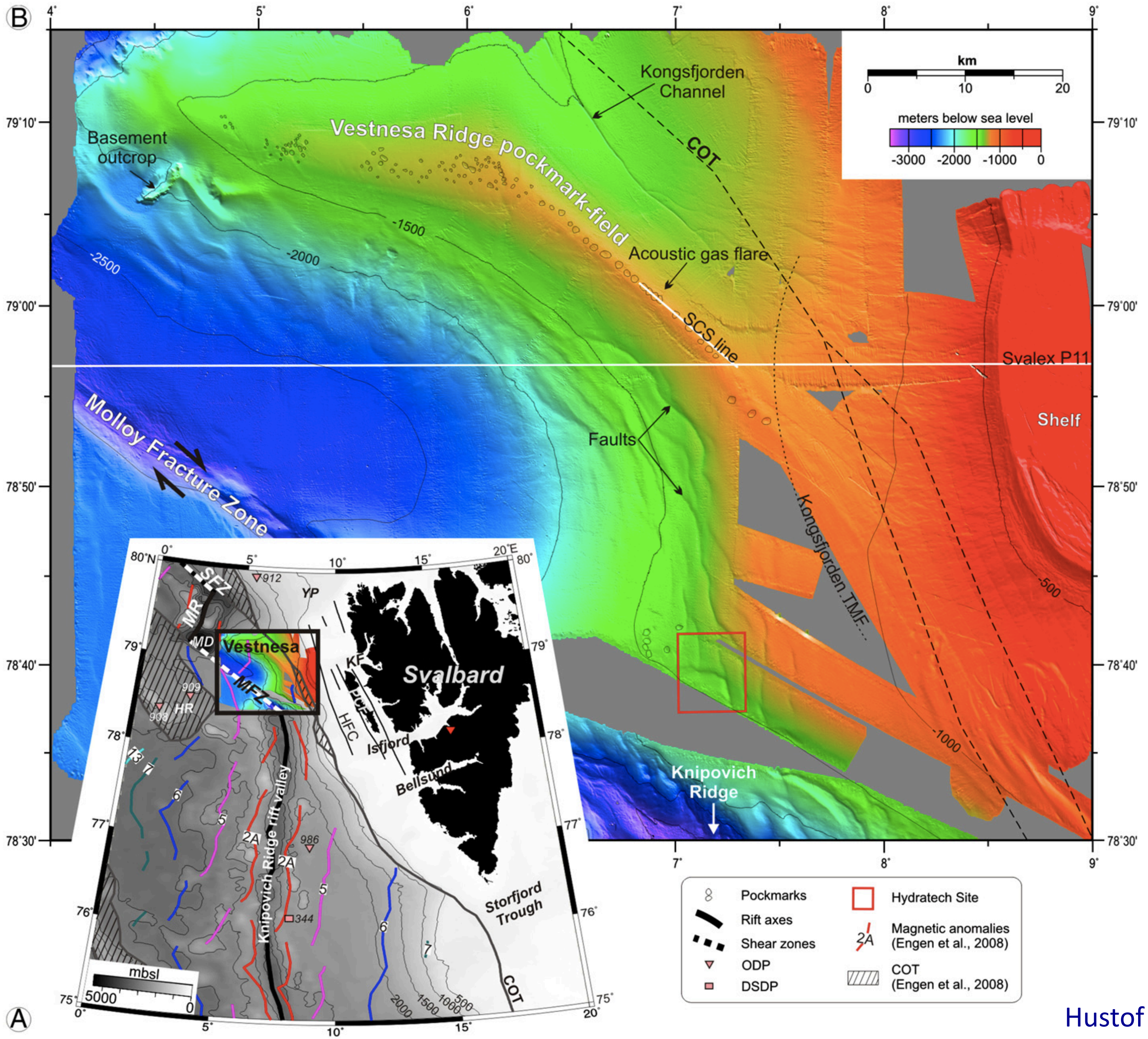
Model of glacial sedimentation on continental slope and rise on the Antarctic Margin



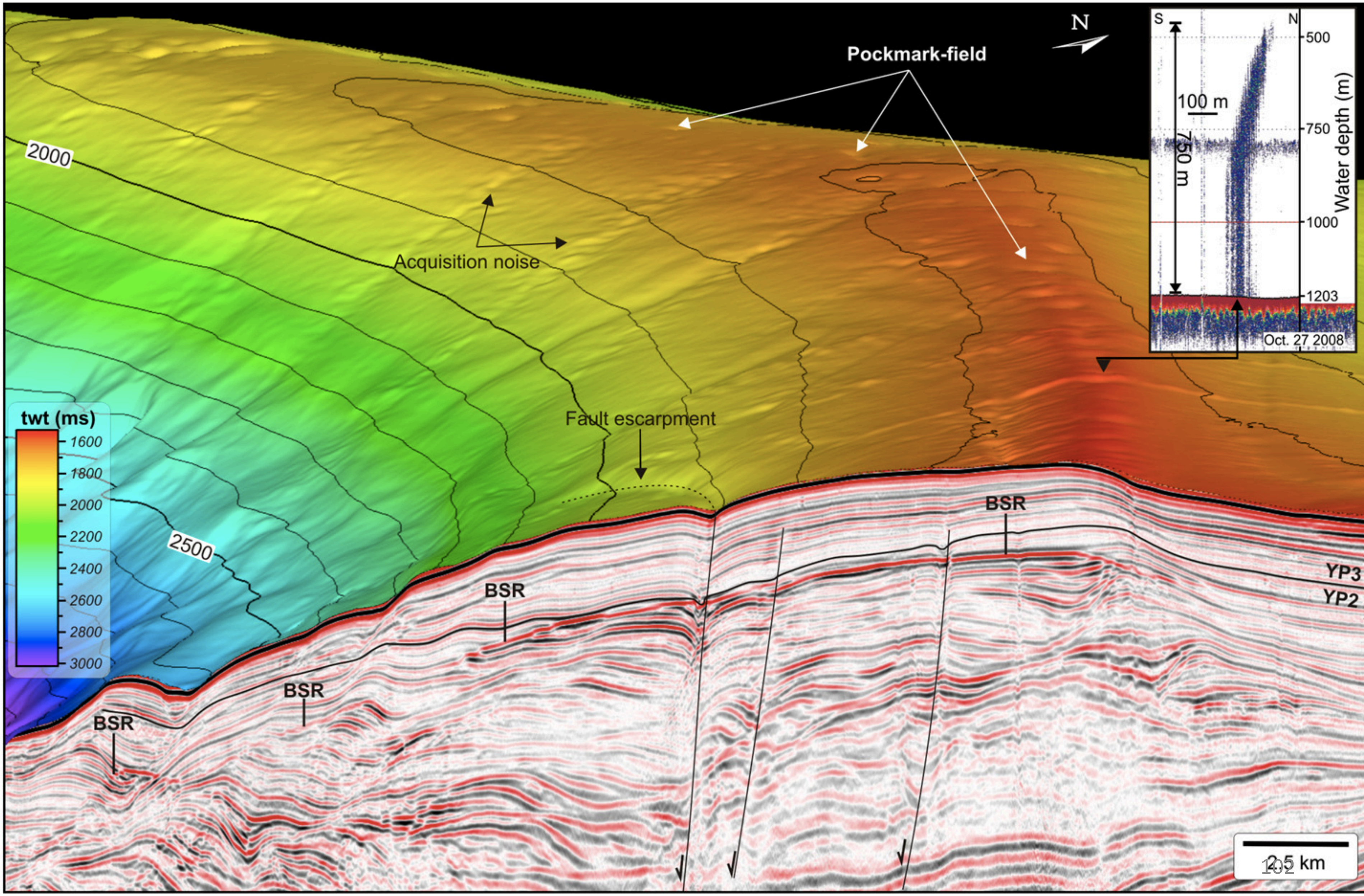
Rebesco et al., 1997



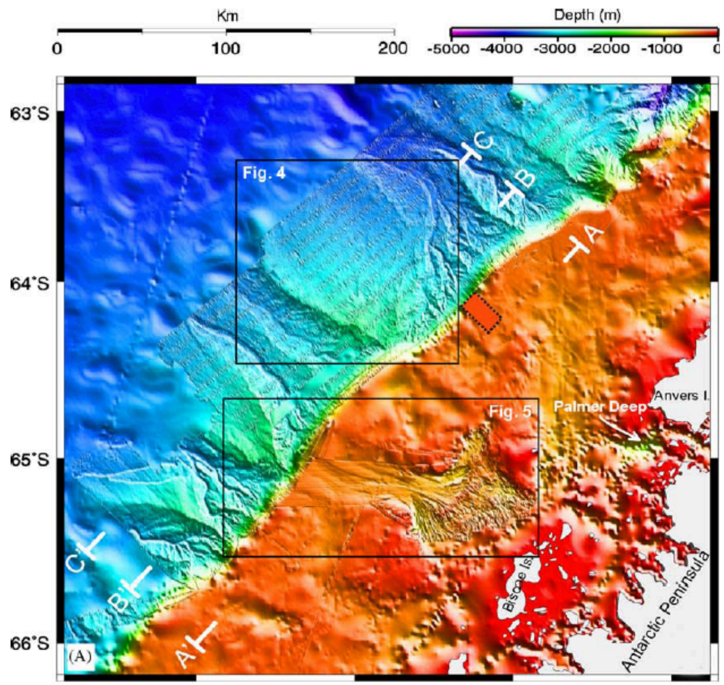
Van Weering et al., 2009.

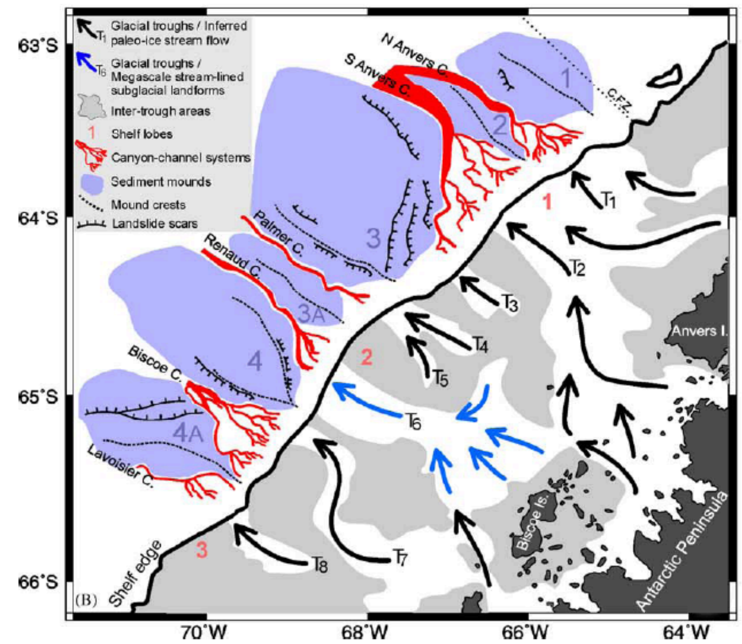


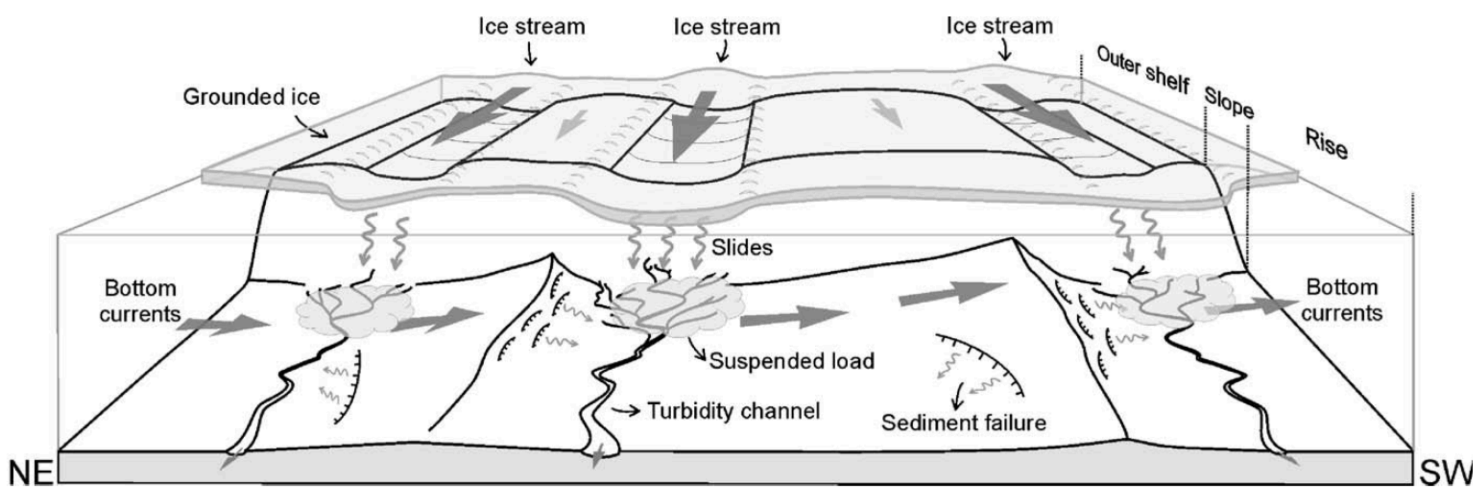
Hustof et al., 2009


Pockmark-field
N
Acquisition noise
2000
2500
Fault escarpment
BSR
BSR
BSR
BSR
YP3
YP2
twt (ms)
1600
1800
2000
2200
2400
2600
2800
3000
S
N
500
750
1000
1203
Water depth (m)
100 m
750 m
Oct. 27 2008
2.5 km

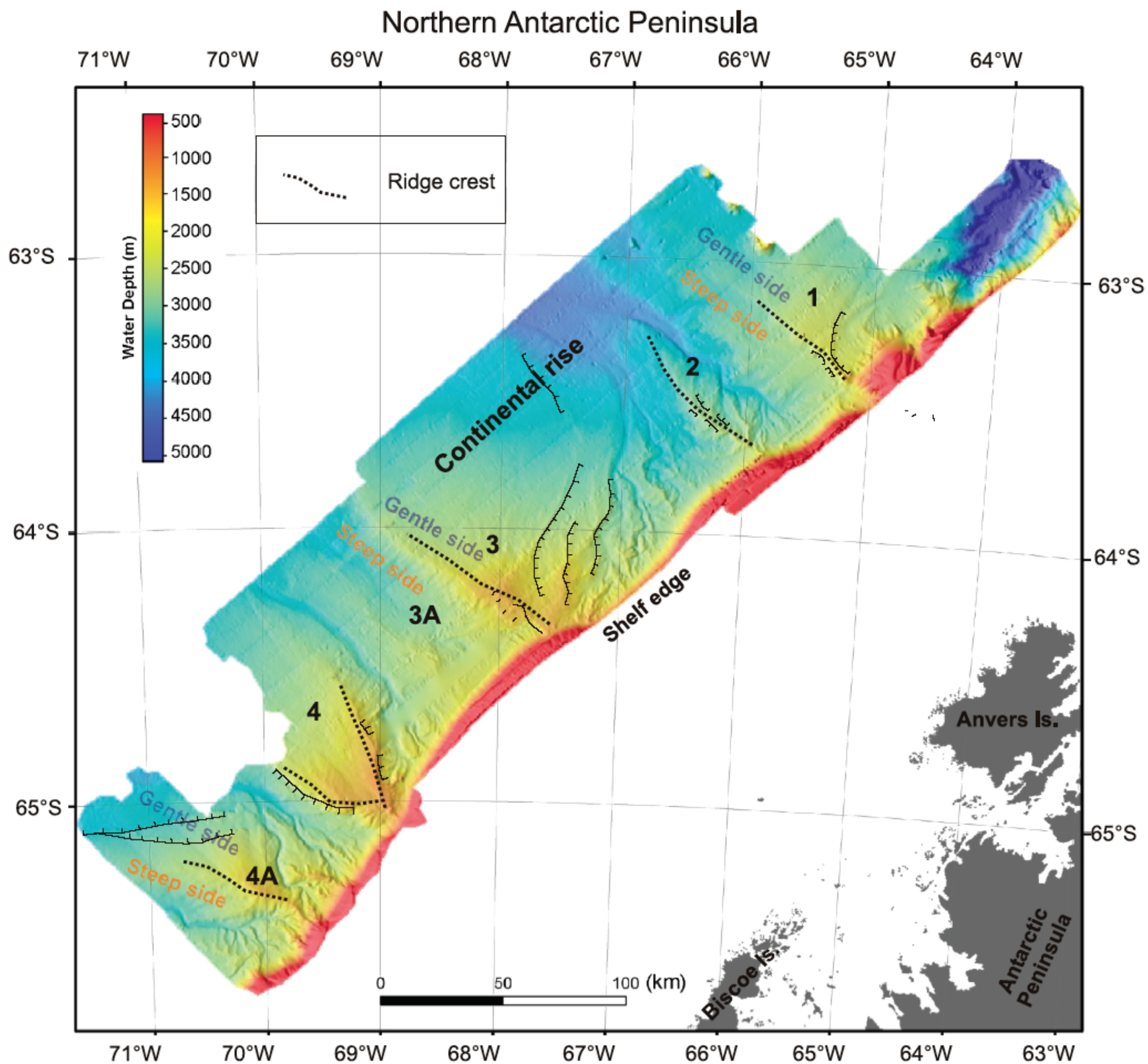
TURBIDITES



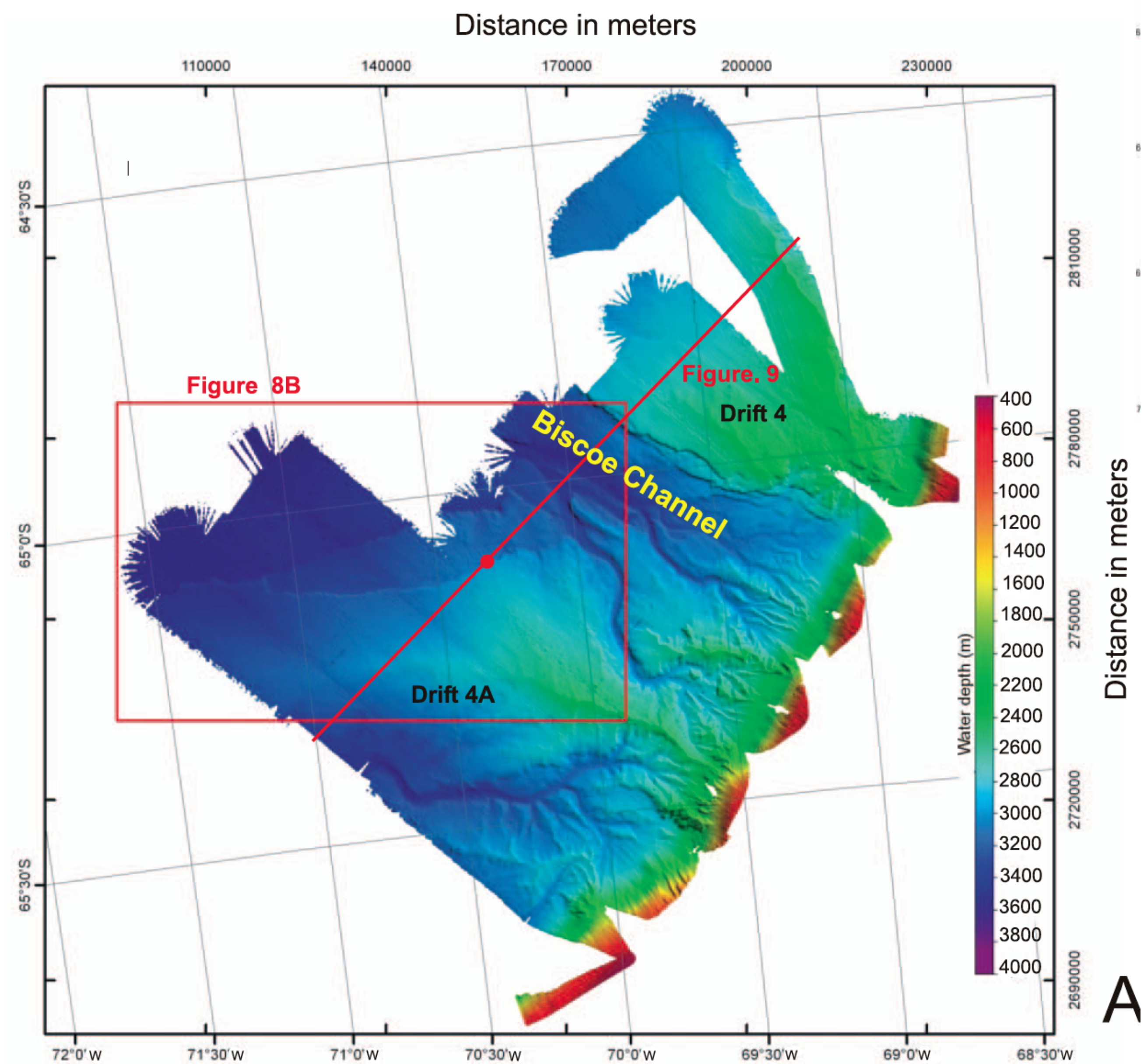




Amblas et al., QSR, 2006

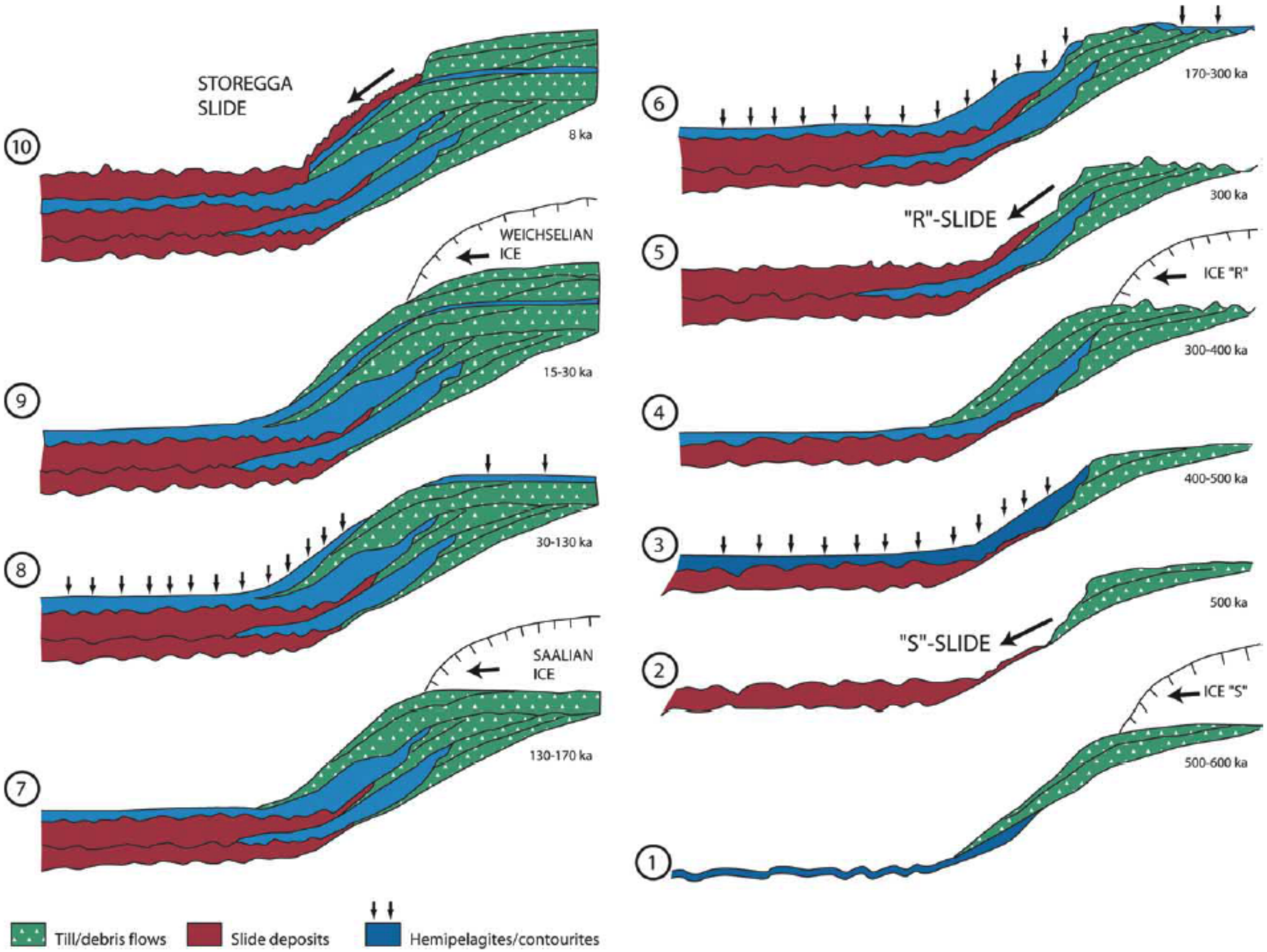


Volpi et al., 2011 SEPM Special Publication No. 96,


Distance in meters
110000
140000
170000
200000
230000
64°30'S
65°0'S
65°30'S
2810000
2780000
2750000
2720000
2690000
Distance in meters
Figure 8B
Figure. 9
Drift 4
Biscoe Channel
Drift 4A
Water depth (m)
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
72°0'W
71°30'W
71°0'W
70°30'W
70°0'W
69°30'W
69°0'W
68°30'W
A

MASS TRANSPORT DEPOSITS

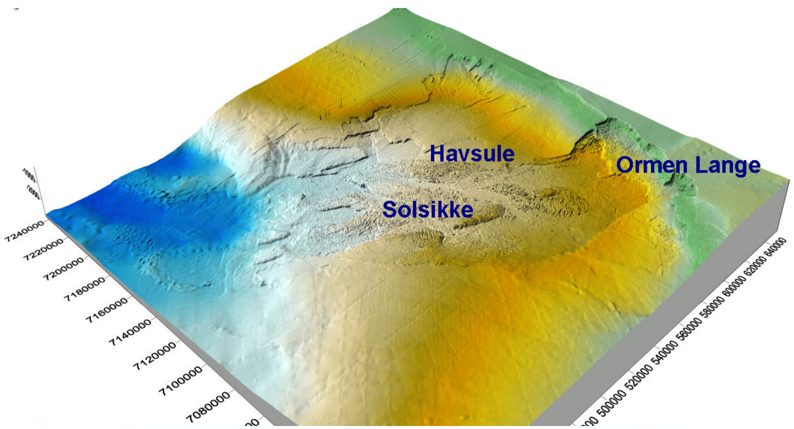
Alternation of interglacial, high water content sediment and dense glacial maximum debris flow deposits: preconditioning for slope instability

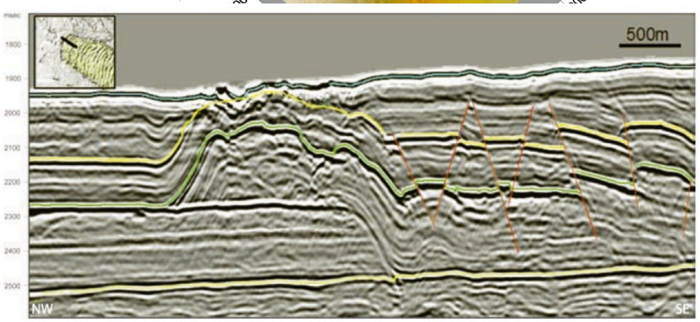


Rise et al., 2005

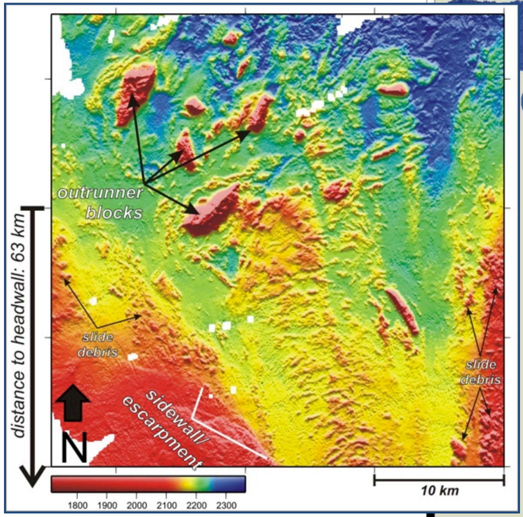
HINLOPEN/ YERMAK SLIDE
North of Svalbard

STOREGGA SLIDE
Norwegian margin

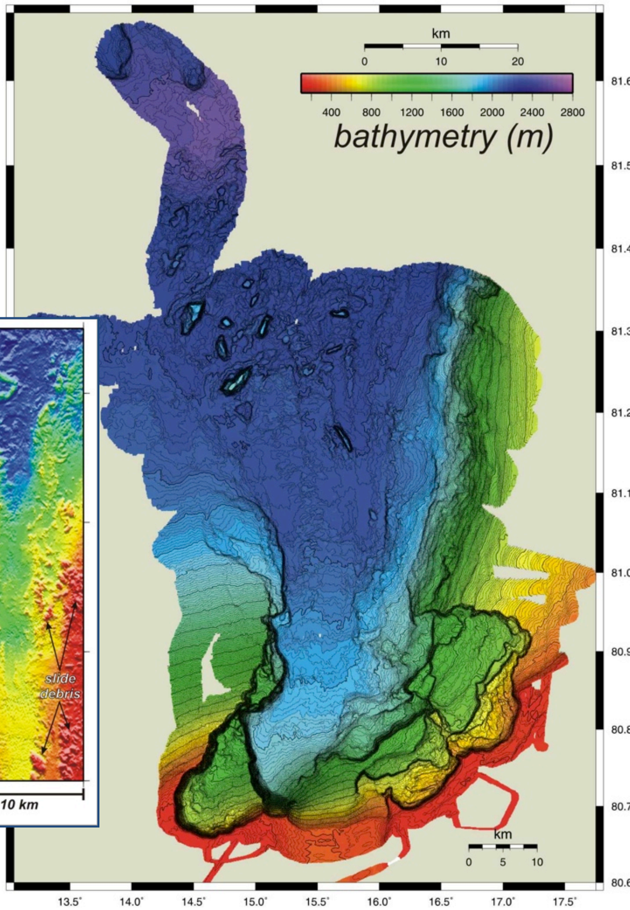


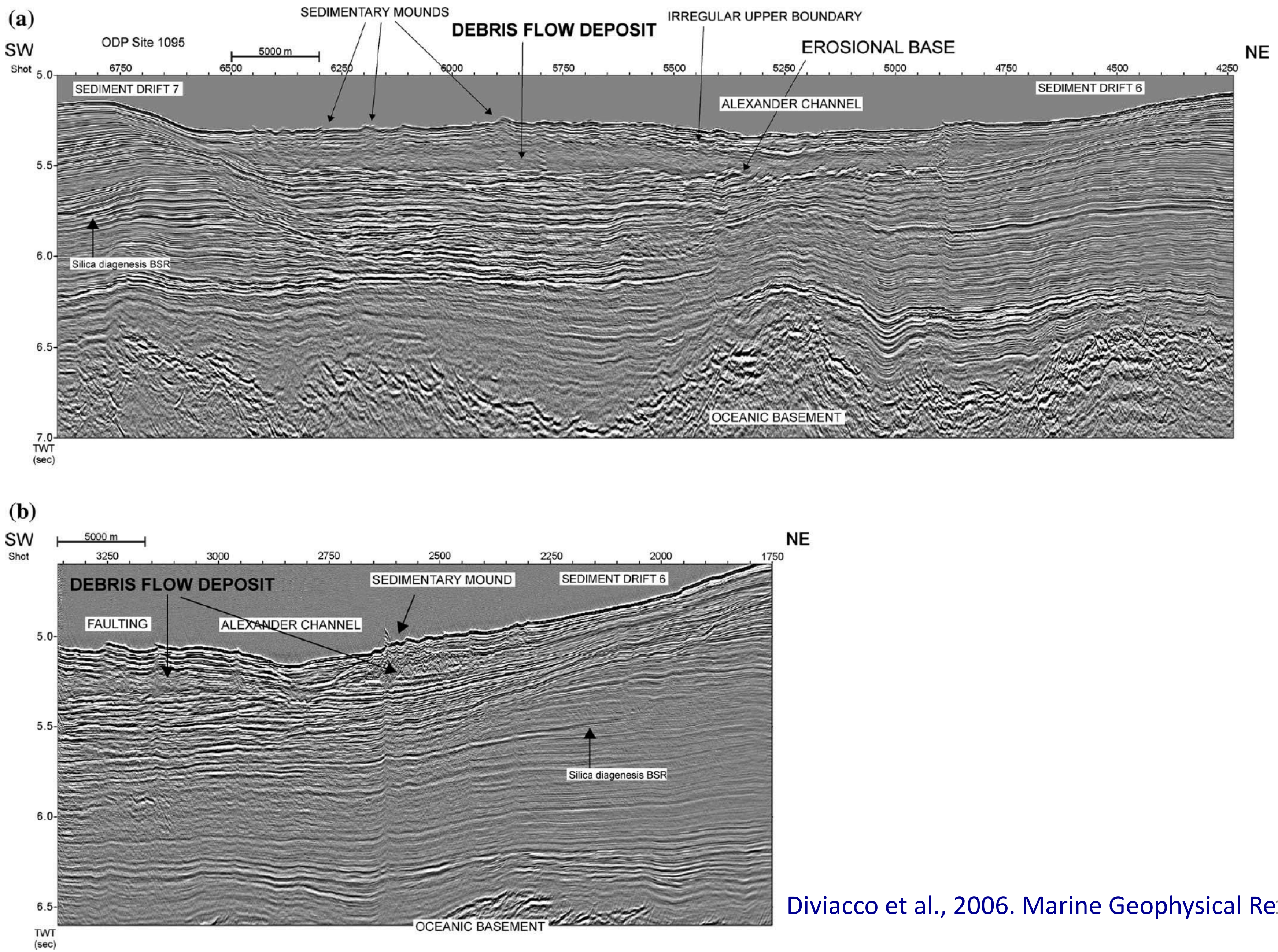


Færseth & Bjørn Helge Sætersmoen, 2008, *Norwegian J. of Geology*

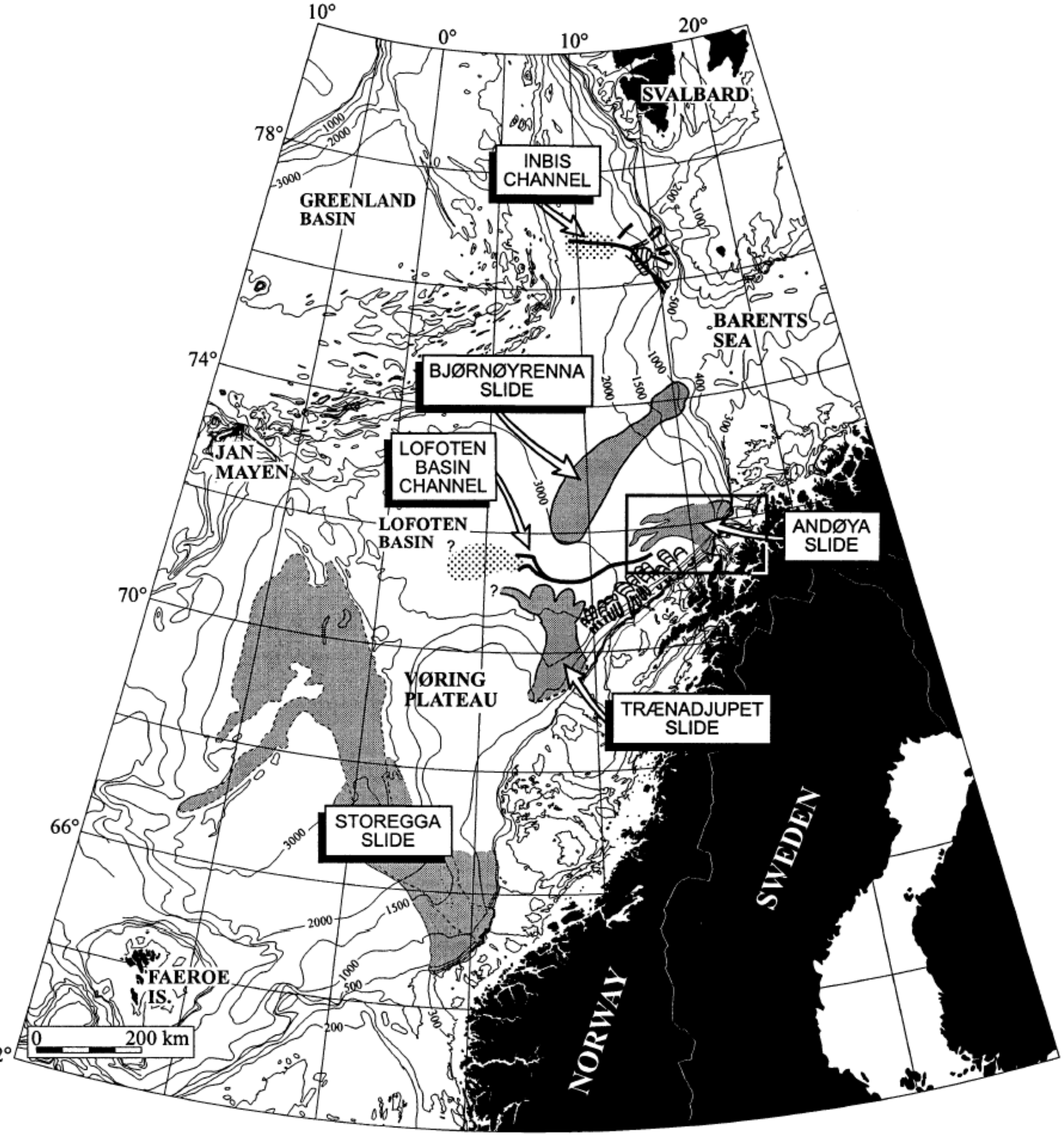


Vanneste et al., 2006, *EPSL*
Winkelmann et al., 2006, *G*[3]





Diviacco et al., 2006. Marine Geophysical Researches


SVALBARD
INBIS CHANNEL
GREENLAND BASIN
BARENTS SEA
BJØRNØYRENNA SLIDE
JAN MAYEN
LOFOTEN BASIN CHANNEL
LOFOTEN BASIN
ANDØYA SLIDE
VØRING PLATEAU
TRÆNADJUPET SLIDE
STOREGGA SLIDE
SWEDEN
NORWAY
FAEROE IS.
0 200 km
10°
0°
10°
20°
78°
74°
70°
66°
62°
1000
2000
3000
500
1500
400
300
200

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