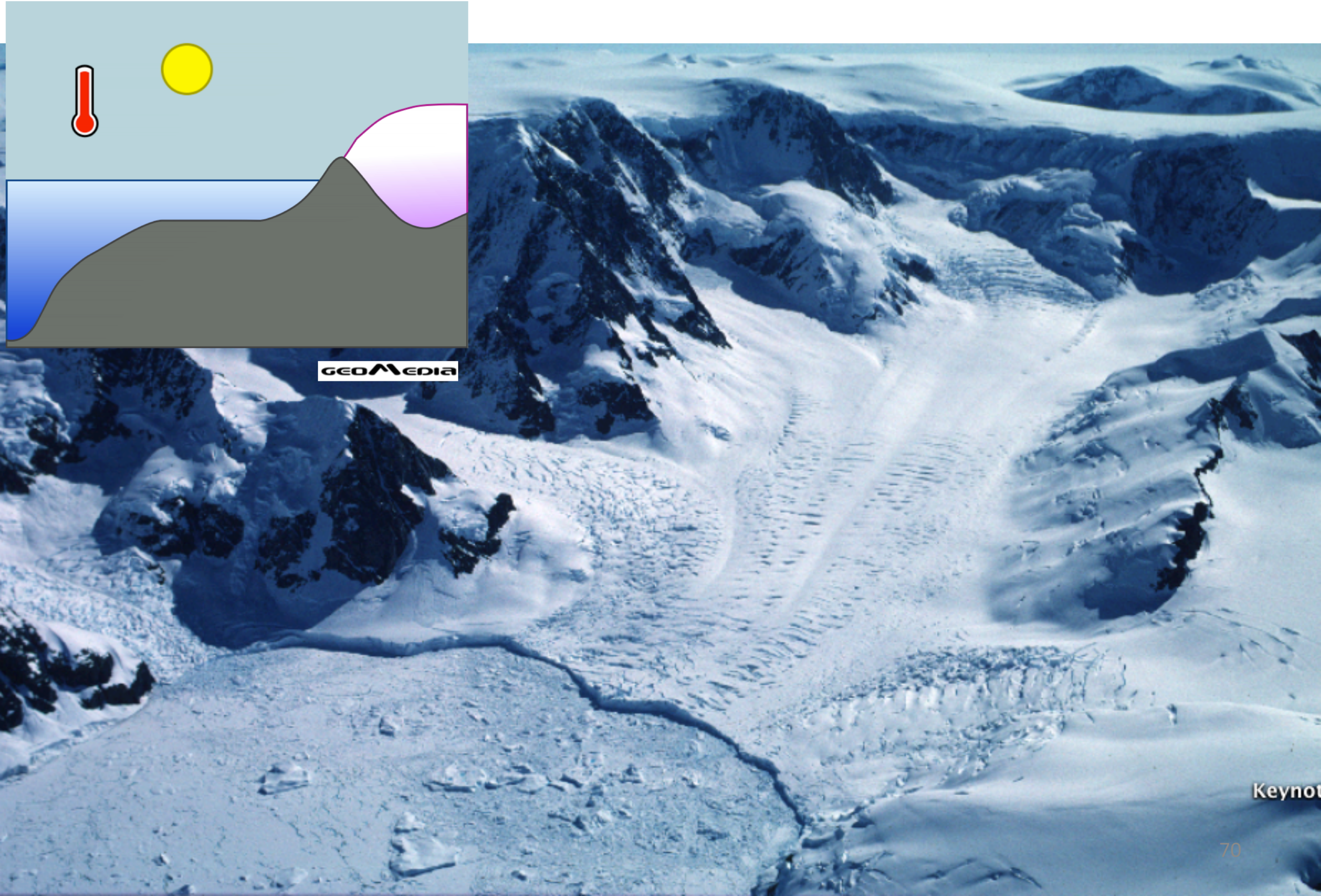
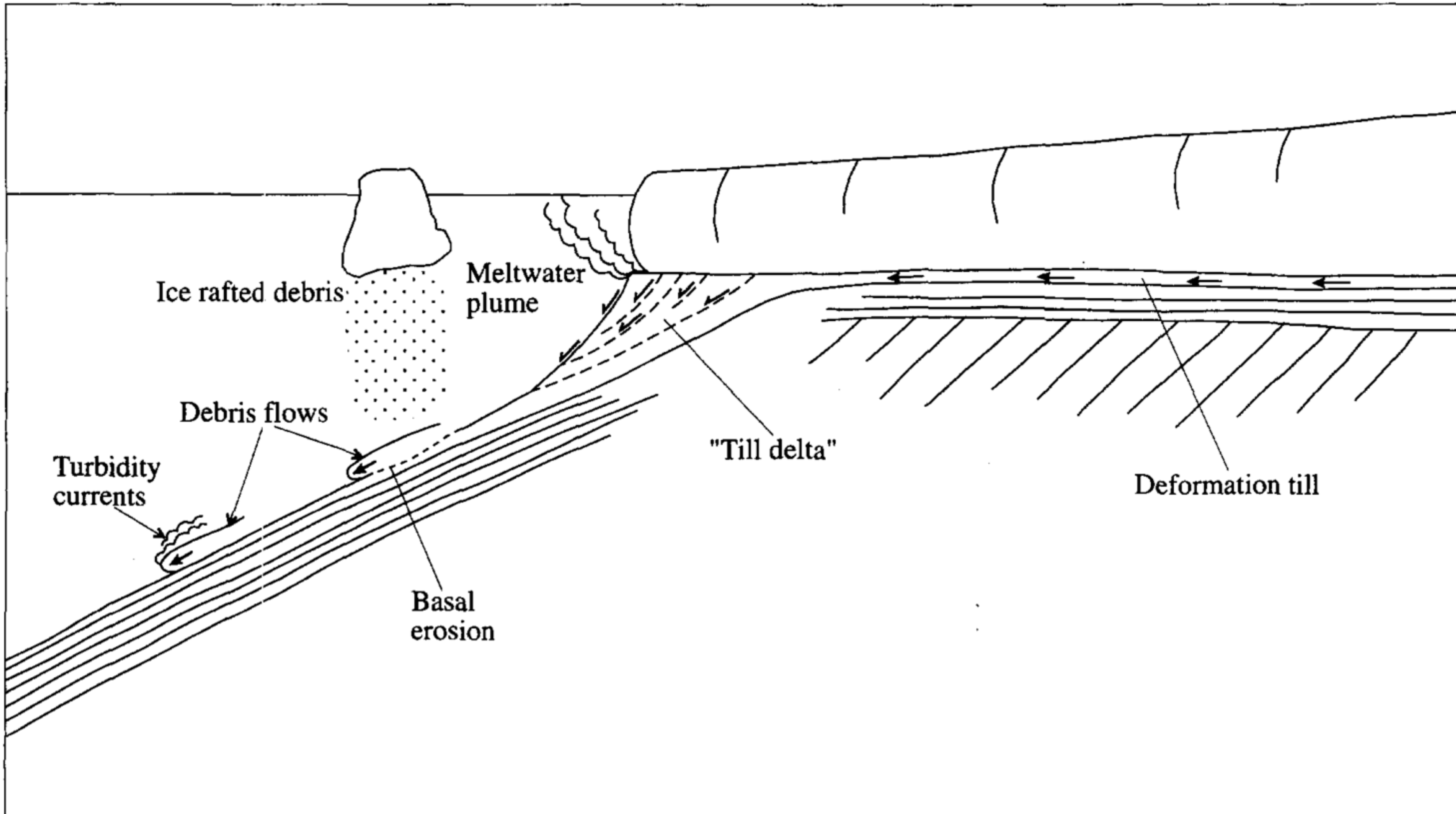
ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS

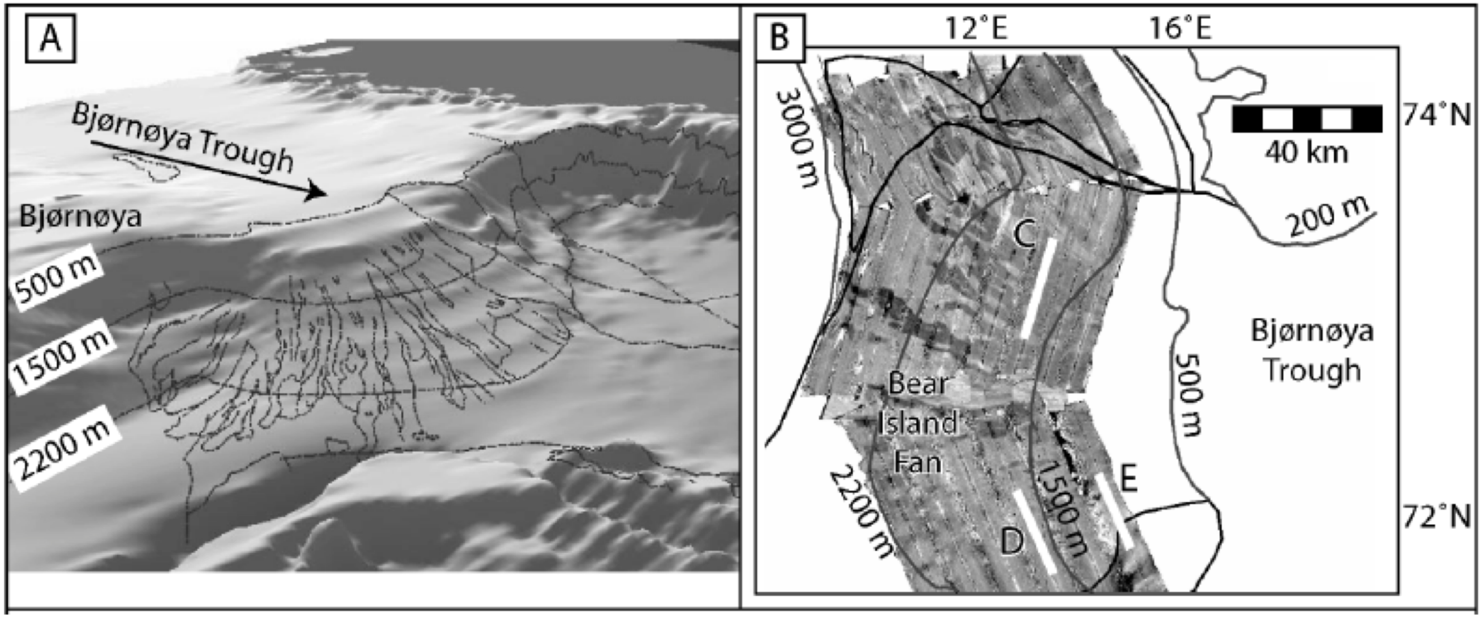
TWO MAIN SEDIMENTARY AGENTS

ICE STREAM PUSH: GLACIAL MAXIMA DEBRIS FLOWS



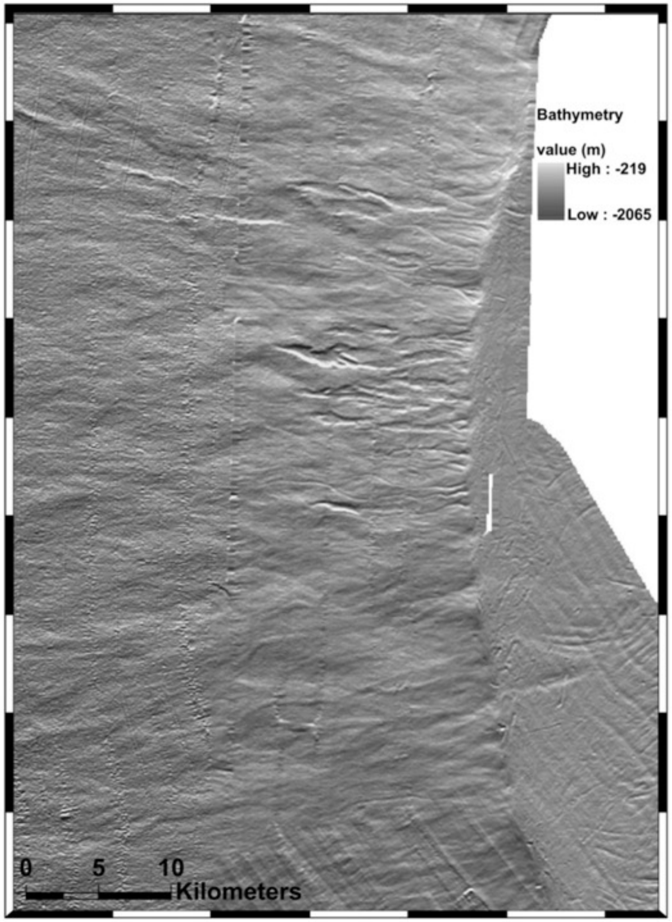

Ice rafted debris
Meltwater plume
Debris flows
Turbidity currents
"Till delta"
Deformation till
Basal erosion

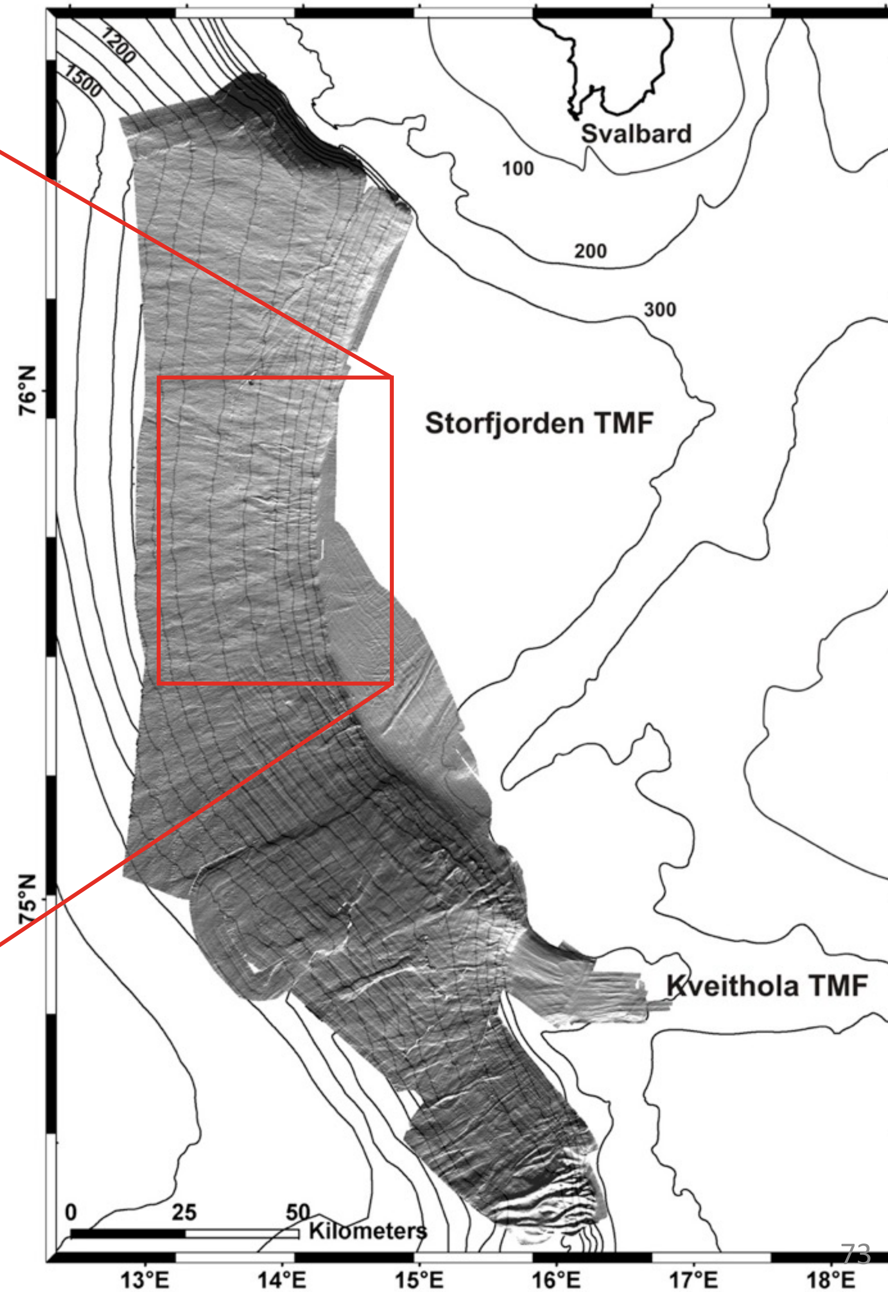
Evidence of subglacially derived debris flow deposits in acoustic back-scatter data



O´Cofaigh et al. , 2003, Boreas

Continental margin morphology





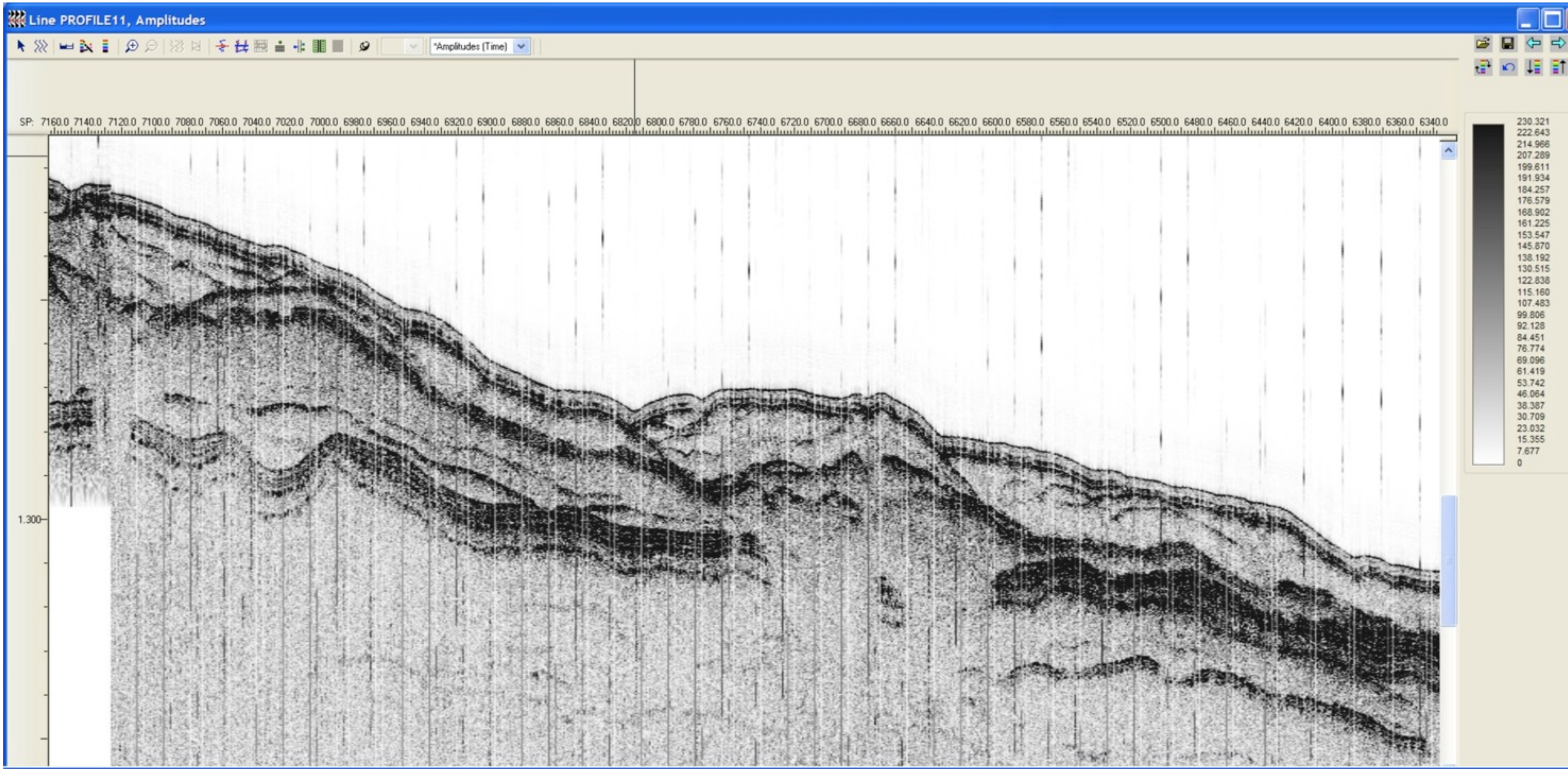
On the shelf

- Three main depositional lobes
- Glacial lineations
- Iceberg ploughmarks

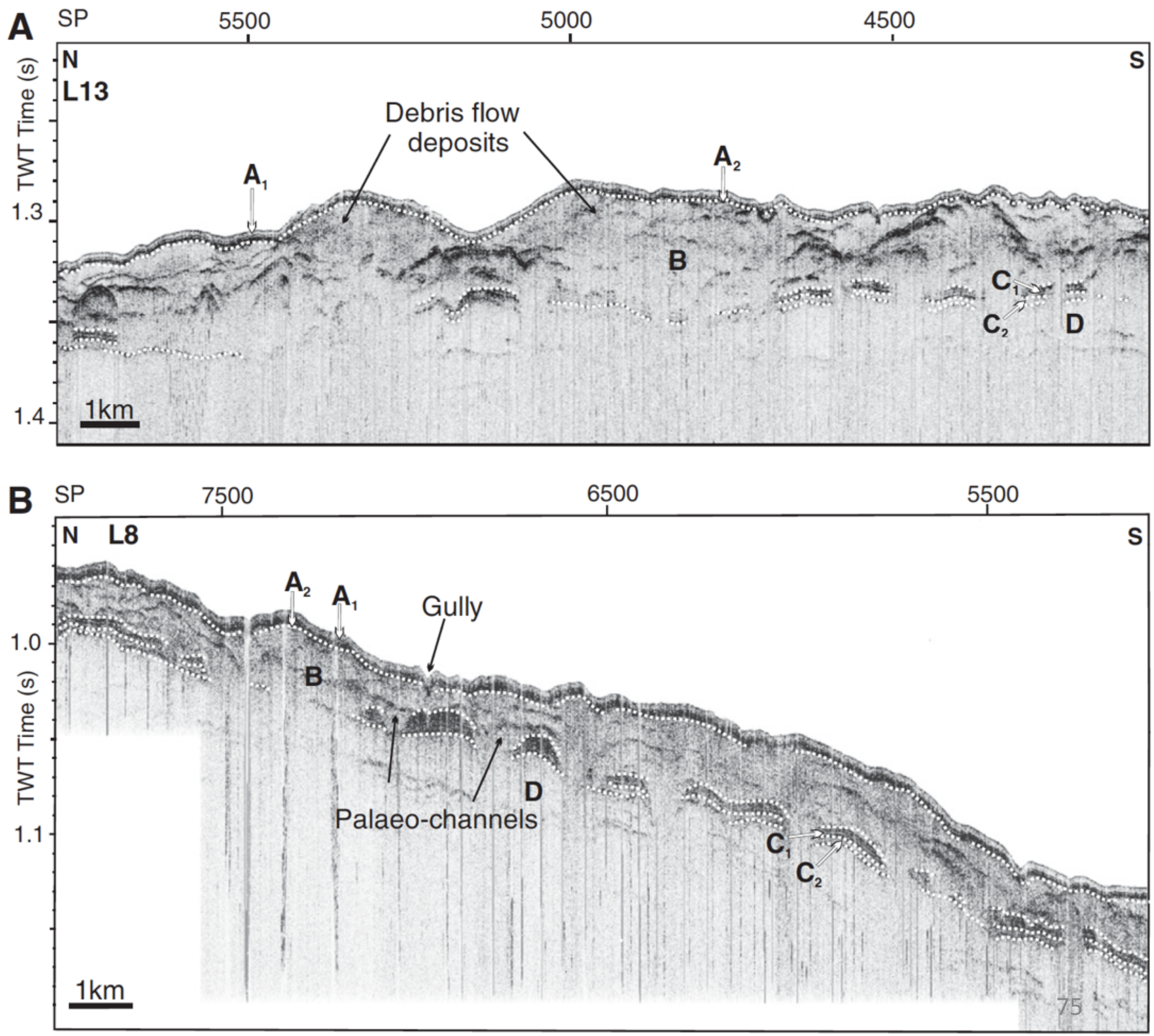
On the slope

- Gullies
- Channels
- Debris mounds
- Landslides

Evidence of subglacially derived debris flow deposits in seismic reflection

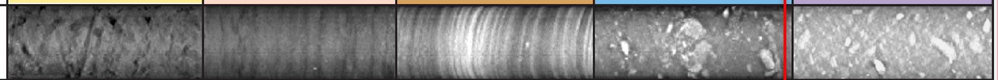


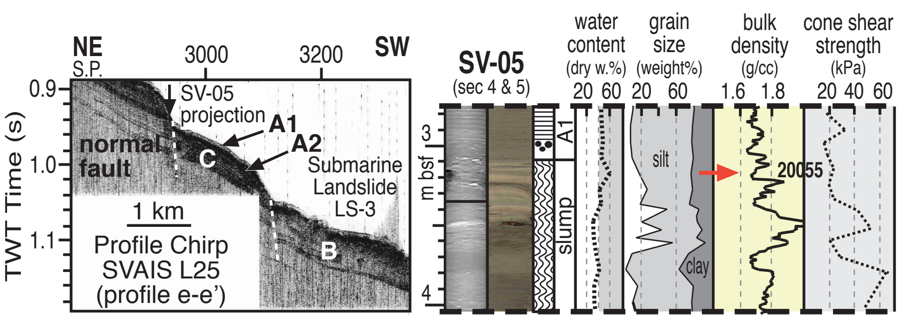
Glacial Debris Flows
In sub-bottom Profiler record,
Stofjorden TMF
(NW Barents Sea)

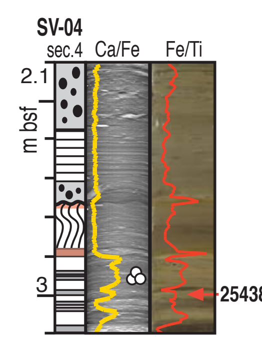


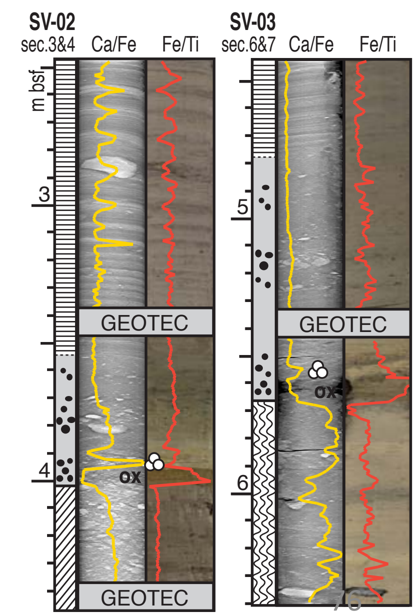
Pedrosa et al., 2011

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





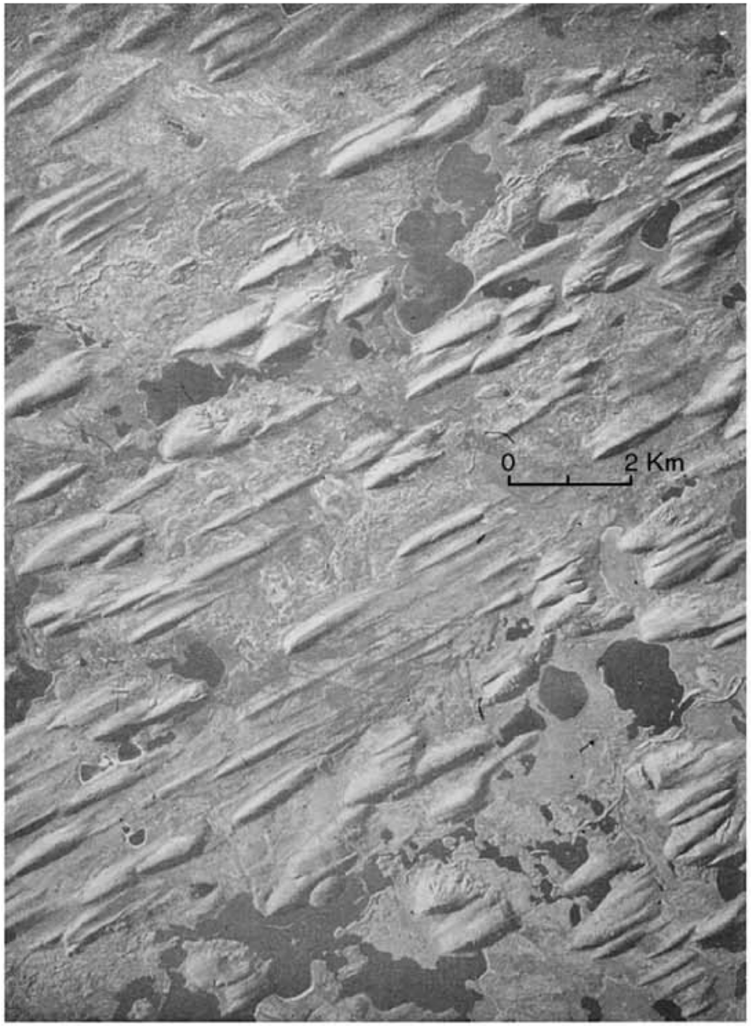


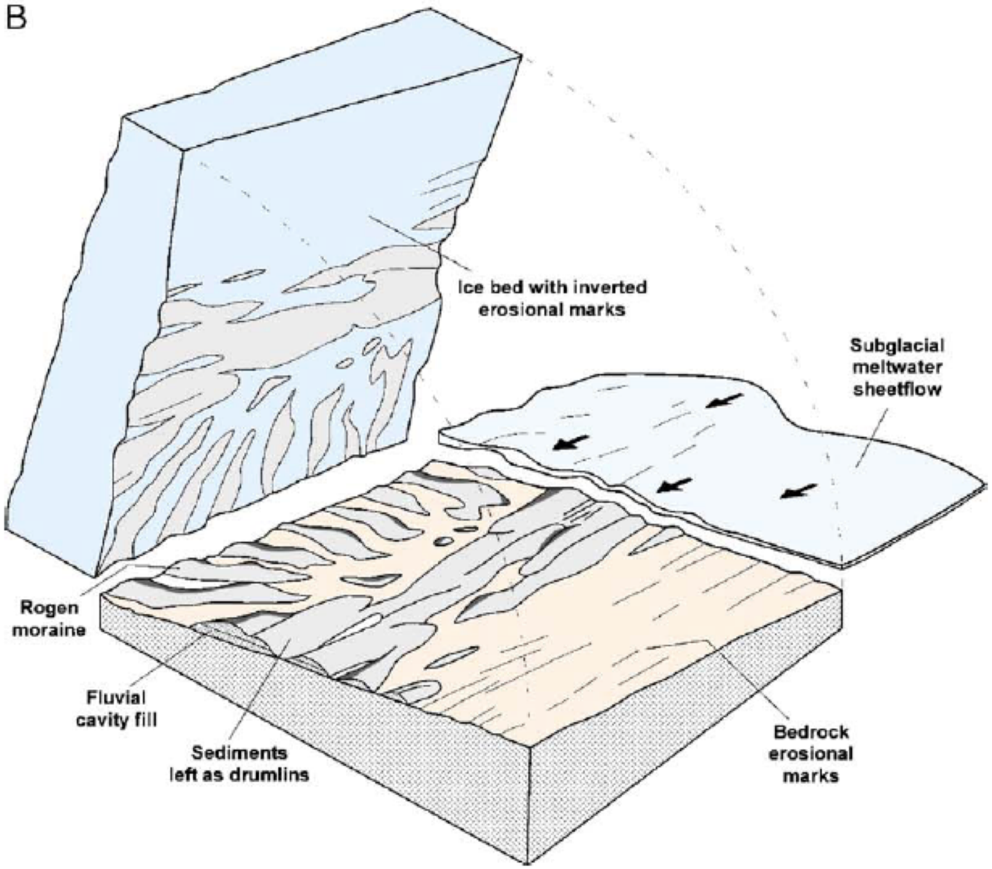
Lucchi et al.,2012

ICE SHEET-DOMINATED SEDIMENTARY SYSTEMS

TWO MAIN SEDIMENTARY AGENTS:

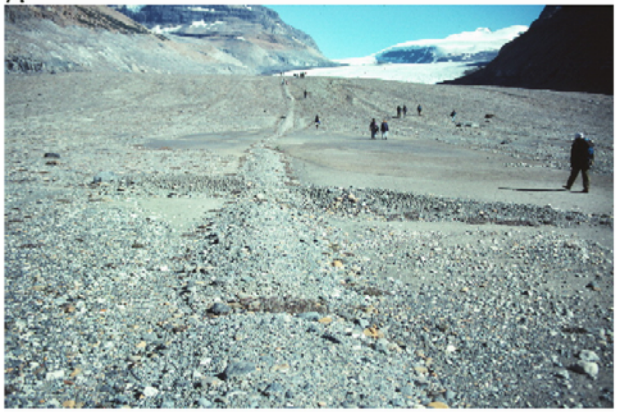
MELTWATER


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

A



B

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

A

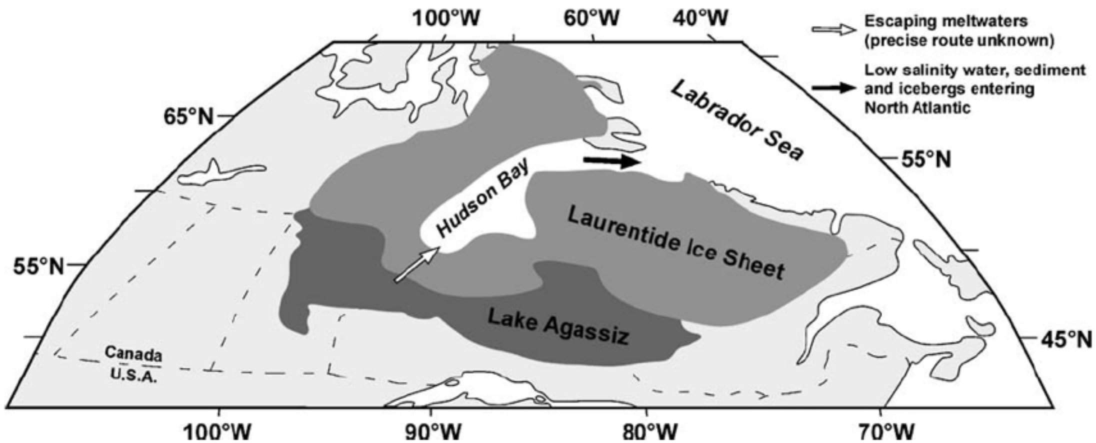
B

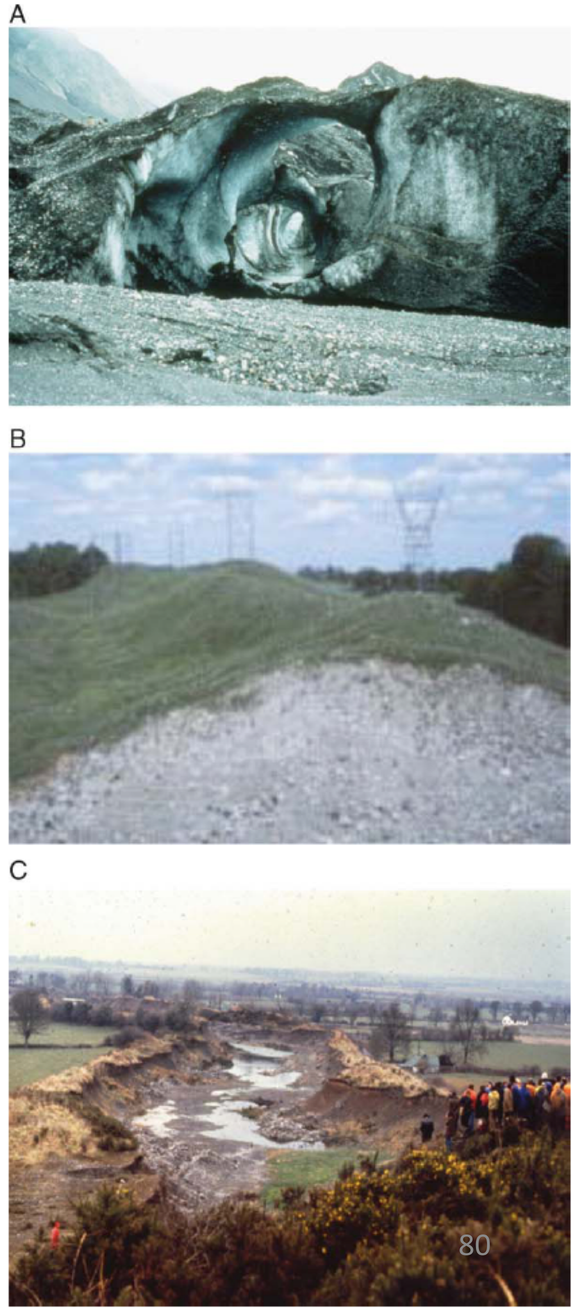
(A) Glacially sculpted bedrock surface at Sudbury, Ontario.

(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

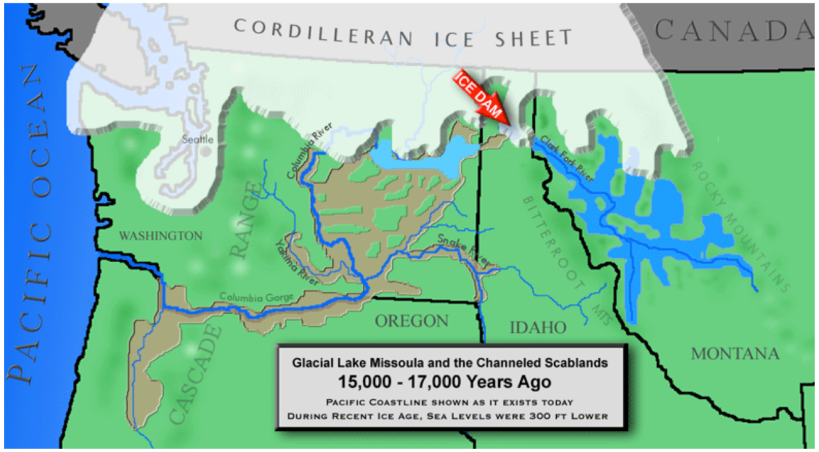




(A) Englacial conduit at Kviarjokull Glacier, Iceland, figure for scale. Eskers are the sediment-plugged remains of conduits (#3, Fig. 2) and form sinuous ridges built of fluvioglacial sands and gravels (B); in C an esker has been completely excavated for aggegate exhuming the lower part of the conduit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

Eyles, 2006

(MEGA-FLOODS EVENTS Missoula glacial lake breakout)



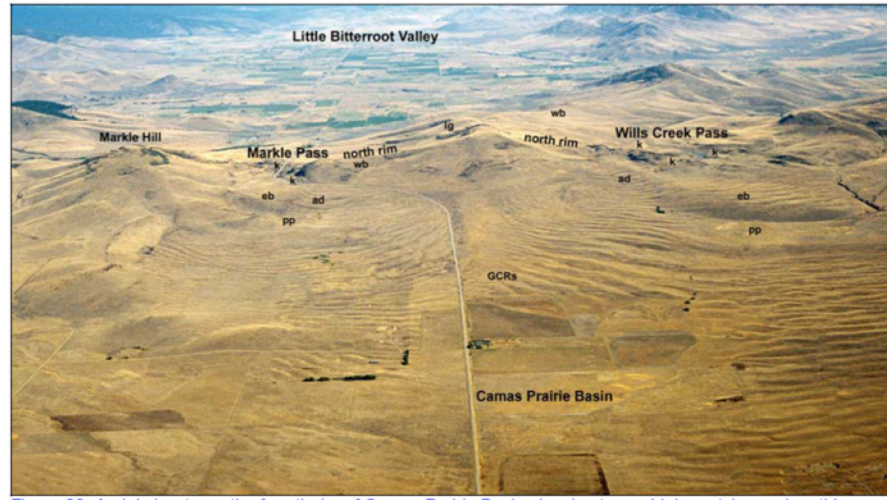


Figure 39–Aerial view to north of north rim of Camas Prairie Basin showing two sublake notches. ad, antidunes;eb, expansion bar; GCRs, giant current ripples; k, kolk pits; lg, lee gravels; pp, 'plunge pool'; wb, washover bar.

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.

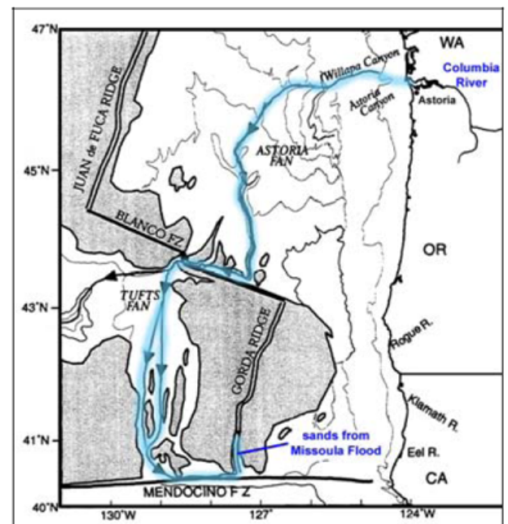


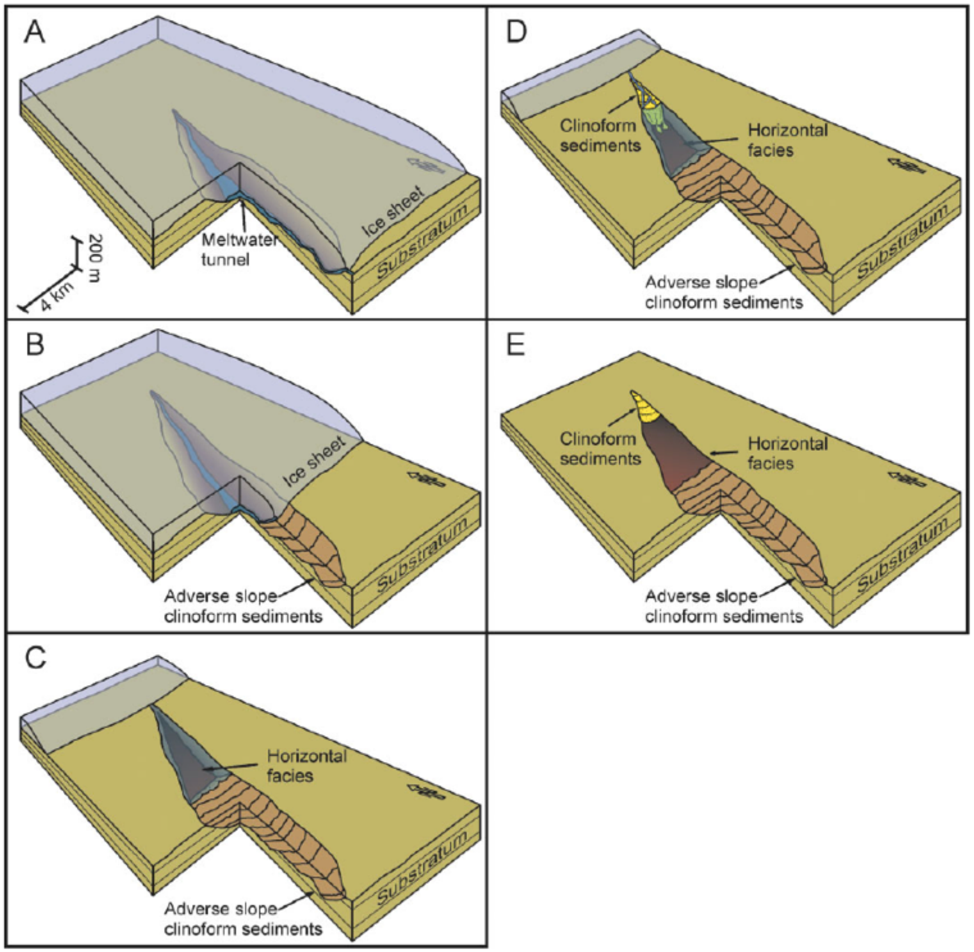
Figure 57—Floodwaters and entrained sediments created turbid currents that swept across the Pacific Ocean floor for 700 miles [1100 km][Zuffa and others, 2000].

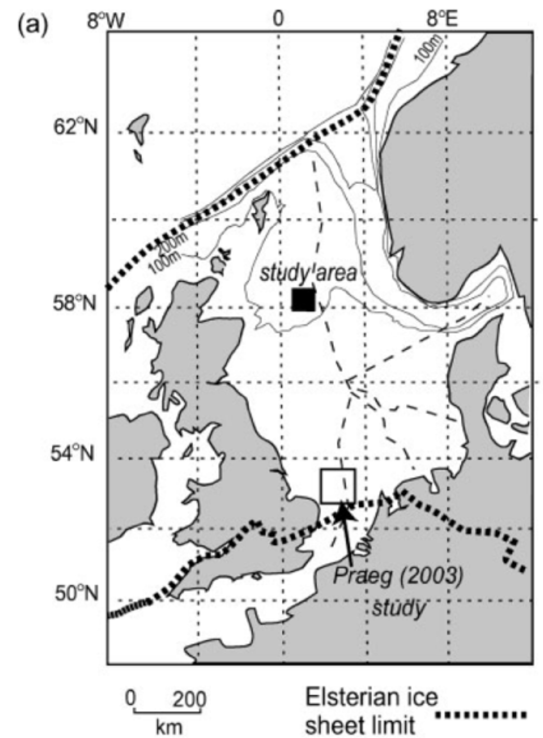
Keenan Lee, Colorado School of Mines, 2009

MELTWATER

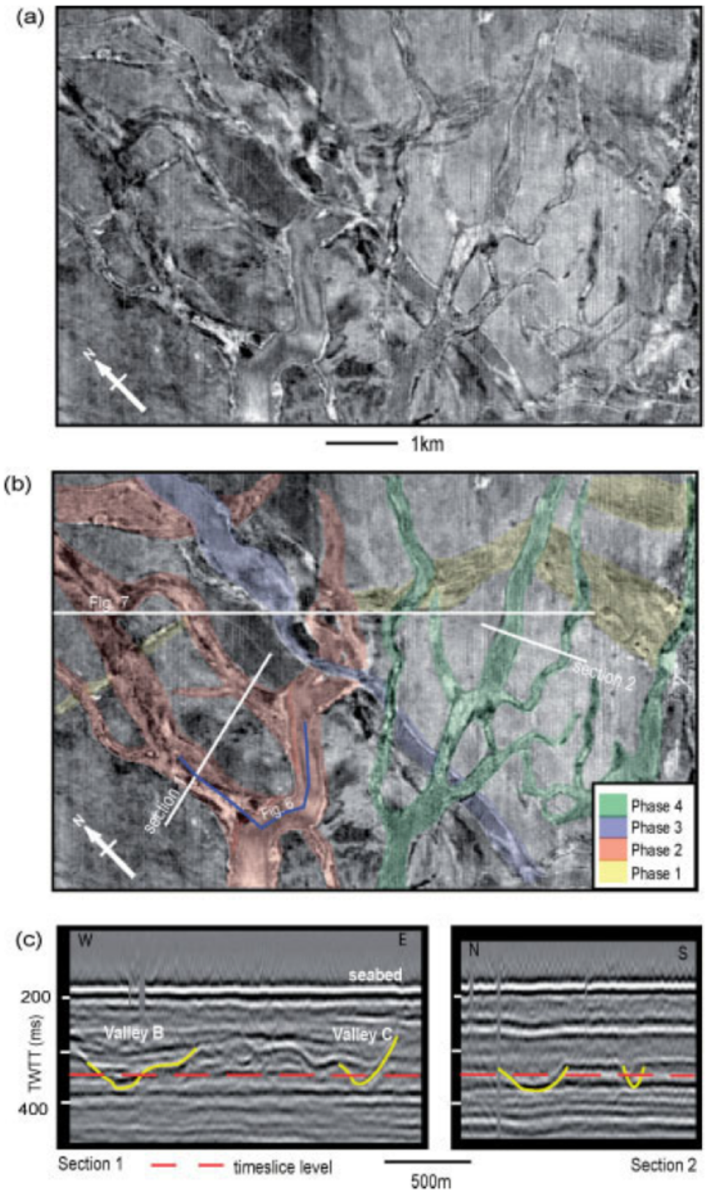
TUNNEL VALLEYS

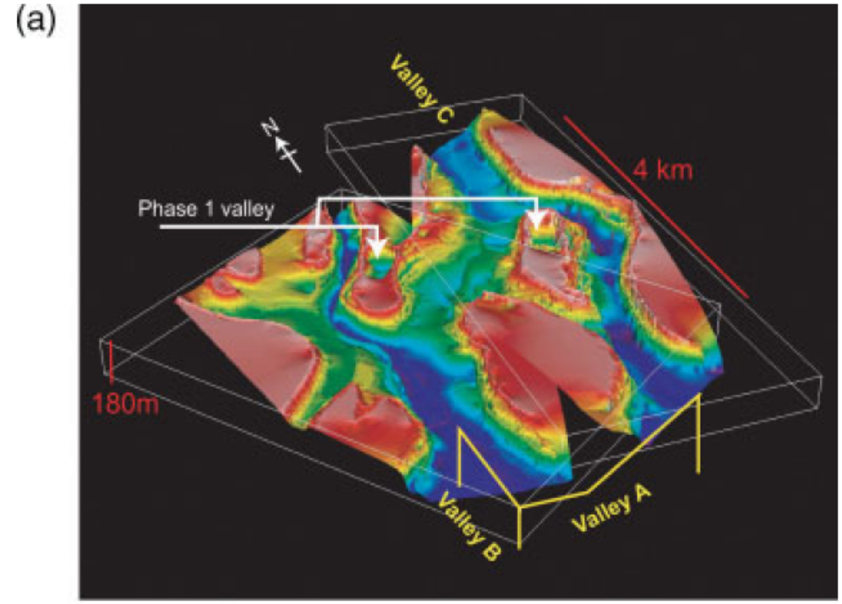
Pleistocene subglacial tunnel valleys in the central North Sea basin: 3-D morphology and evolution

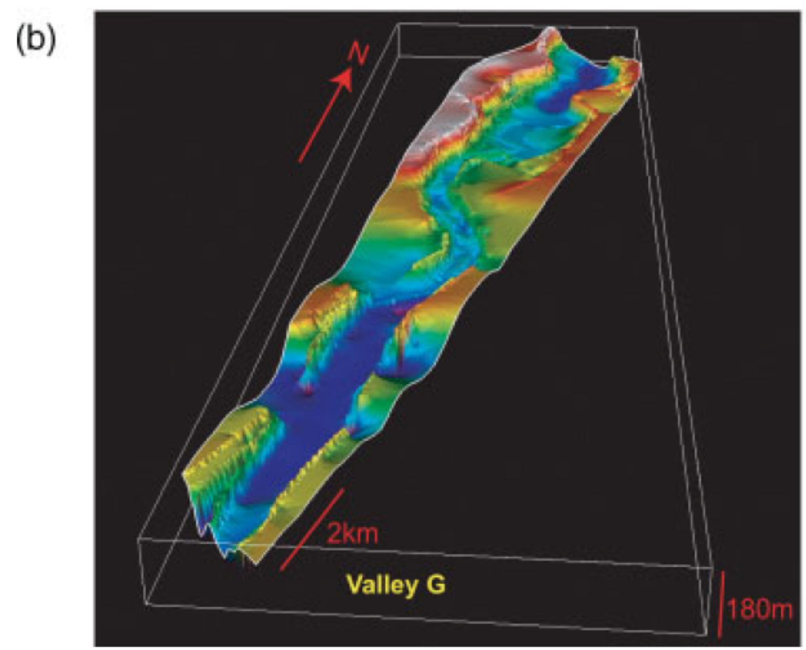




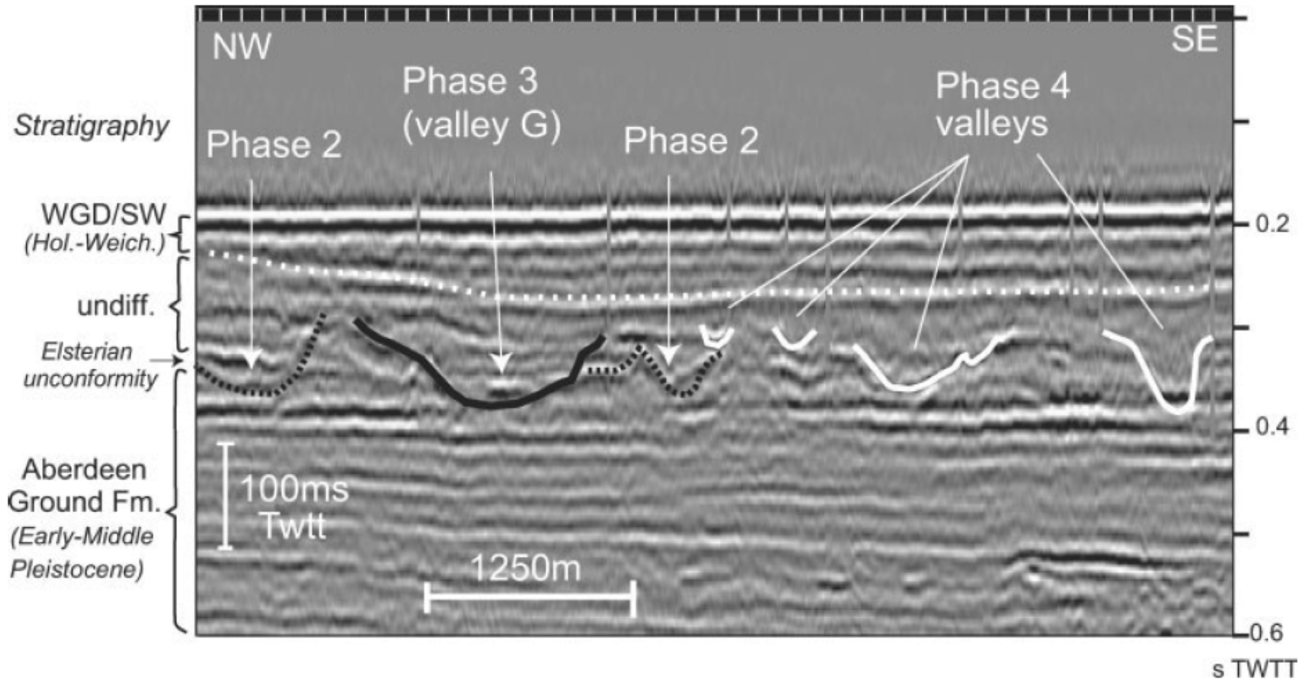
Bojer Kristensen et al., 2008, *Earth Surf. Process. Landforms*



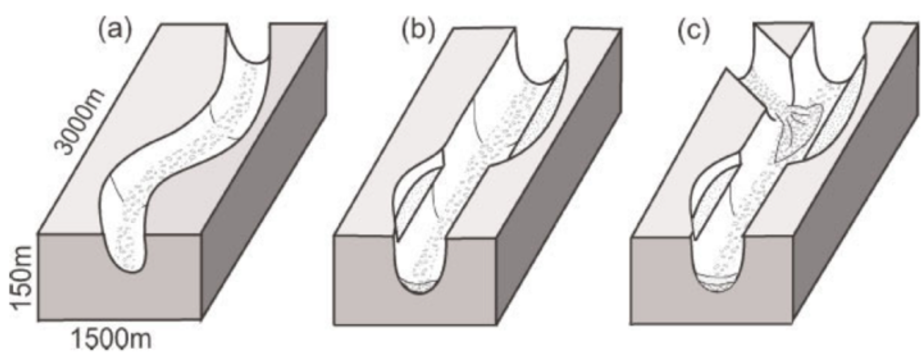




Bojer Kristensen et al., 2008, *Earth Surf. Process. Landforms*

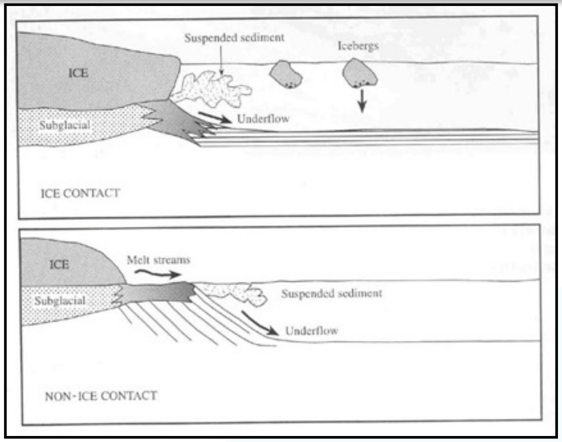


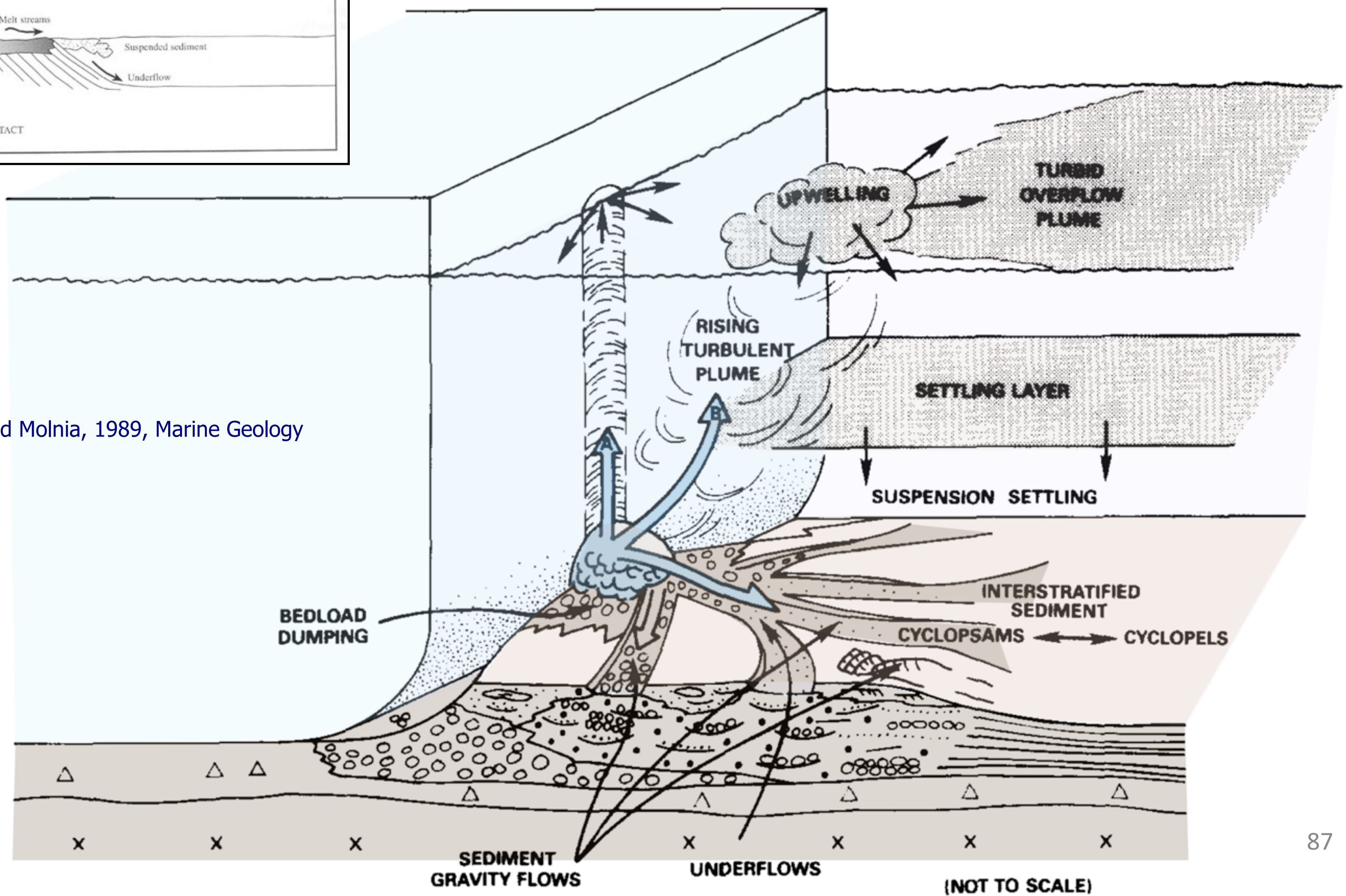
Sand fill



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

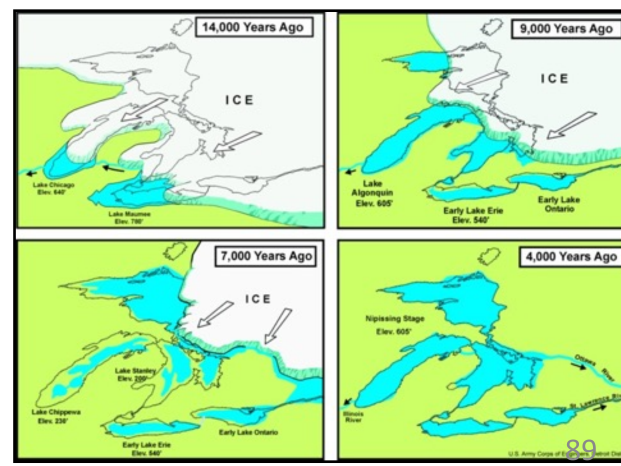
MELTWATER PLUMES and PLUMITES





Powell and Molnia, 1989, Marine Geology

Itú, Brasil - Parque do Varvito


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

SEDIMENT LITHOFACIES

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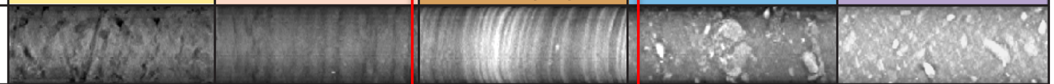
X-radiograph					
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magnetic susceptibility	20-30 SI	30 SI	15-20 SI ⁞ up to 40 SI	15-30 SI	13 SI
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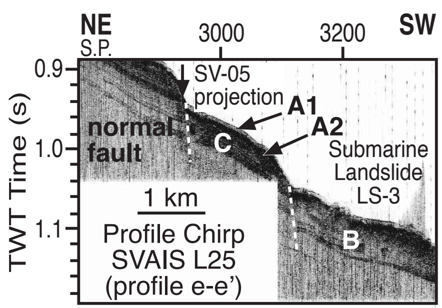
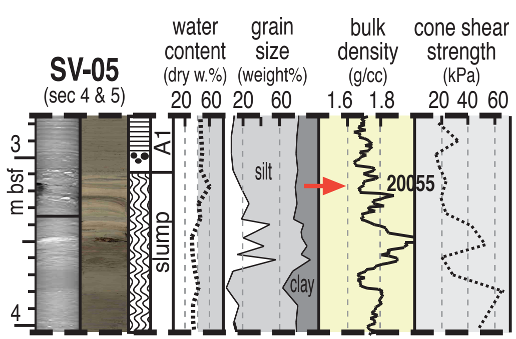
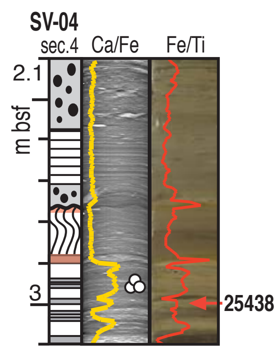
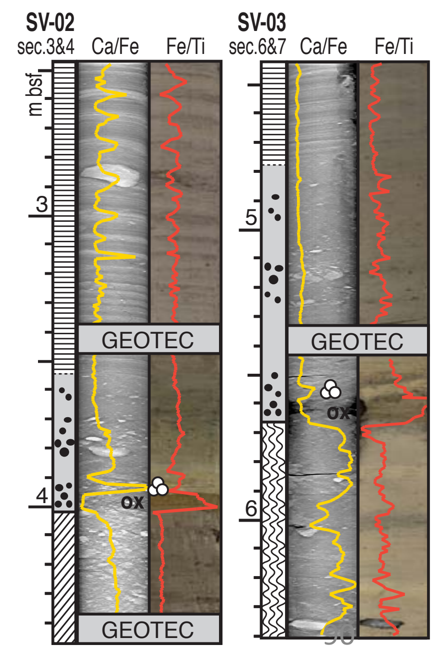
bioclasts	calcareus and siliceus	mainly siliceus	barren	almost barren	rare reworked bioclasts

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

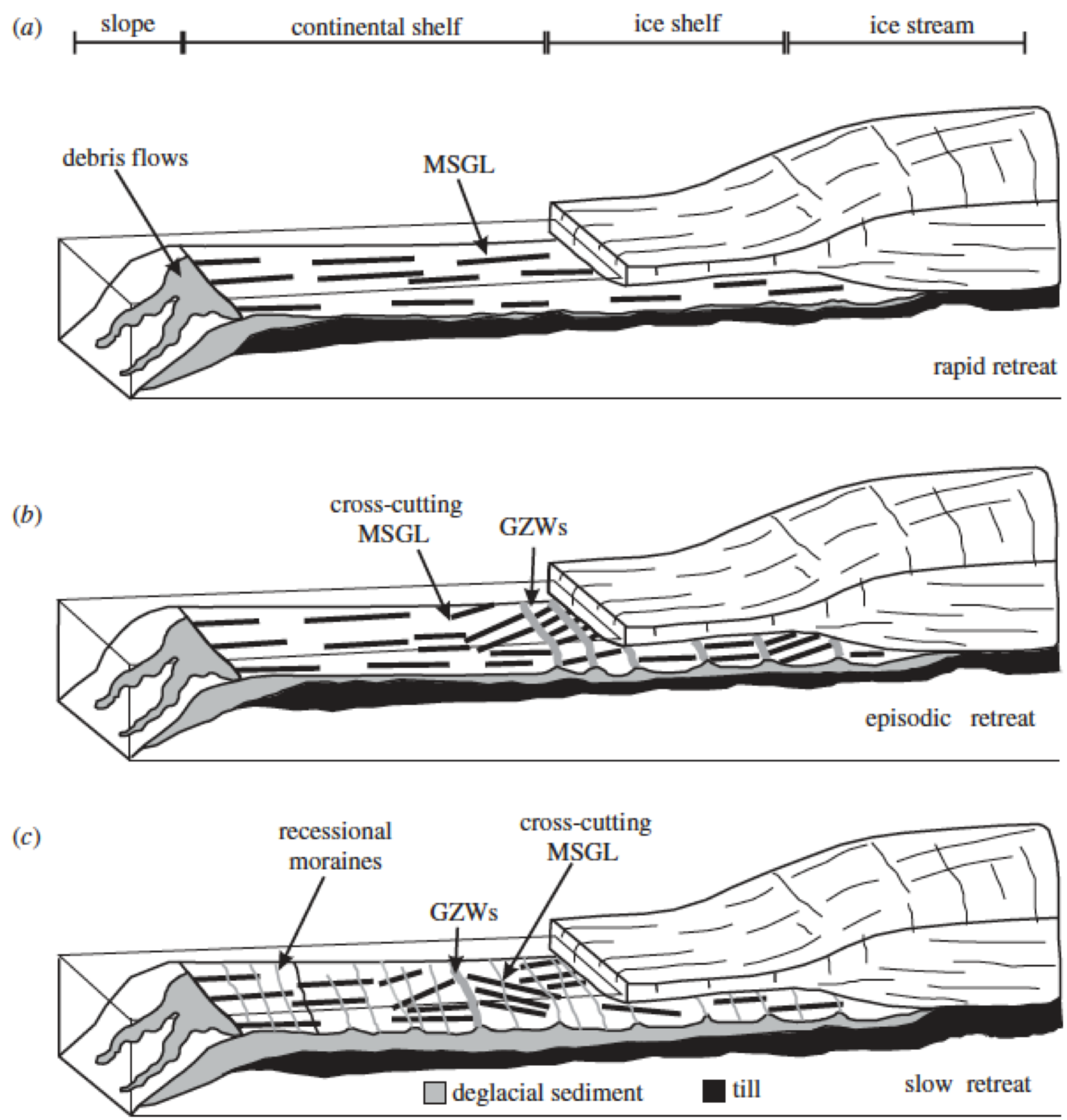




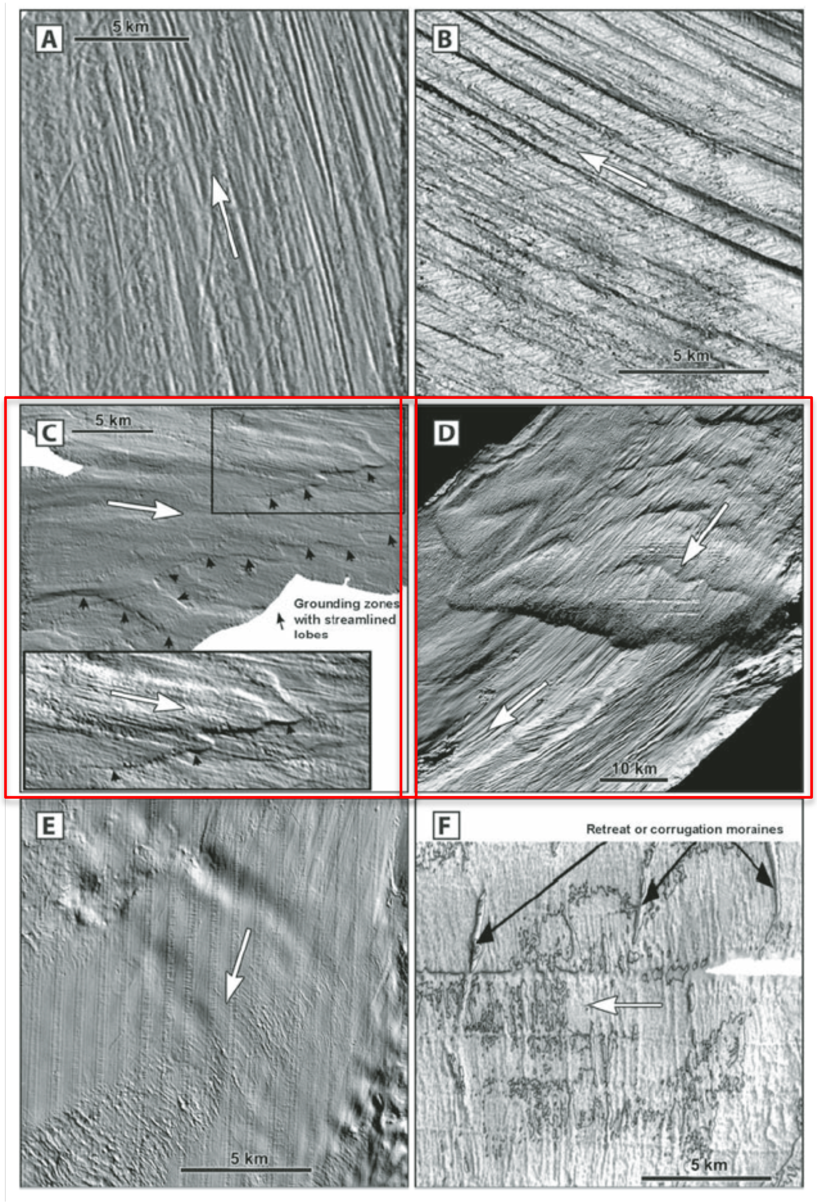




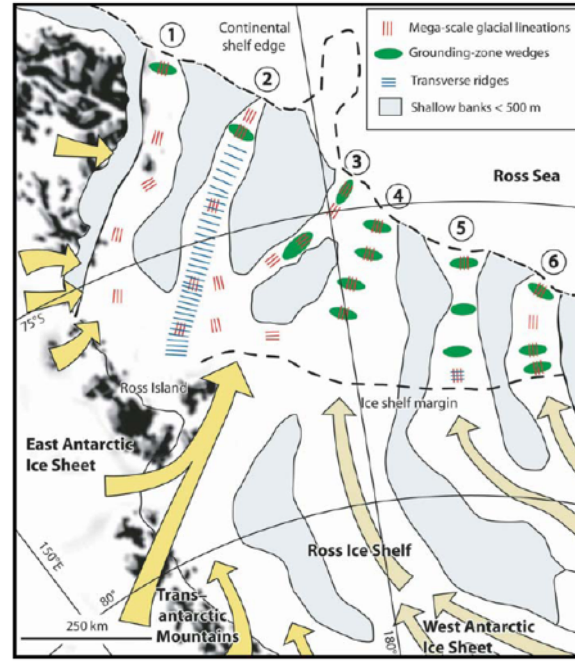
GROUNDING-ZONE WEDGES

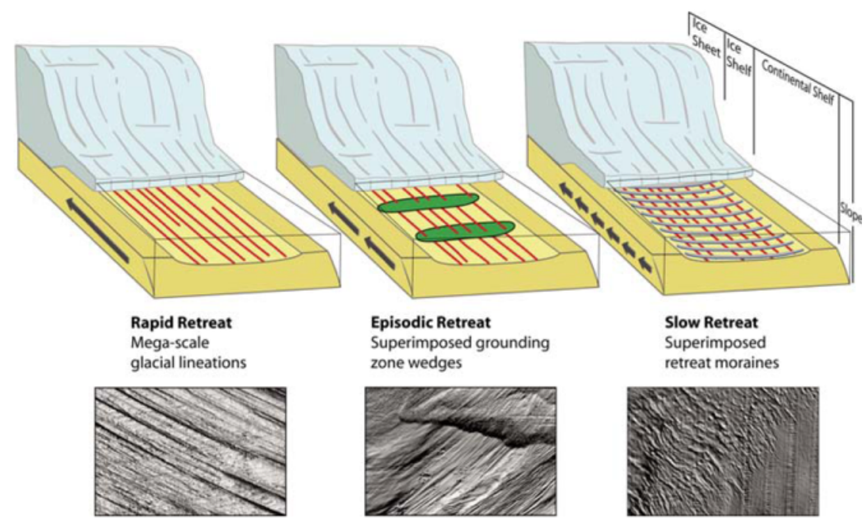


O'Cofaigh, 2012. Phil. Trans. R. Soc. A



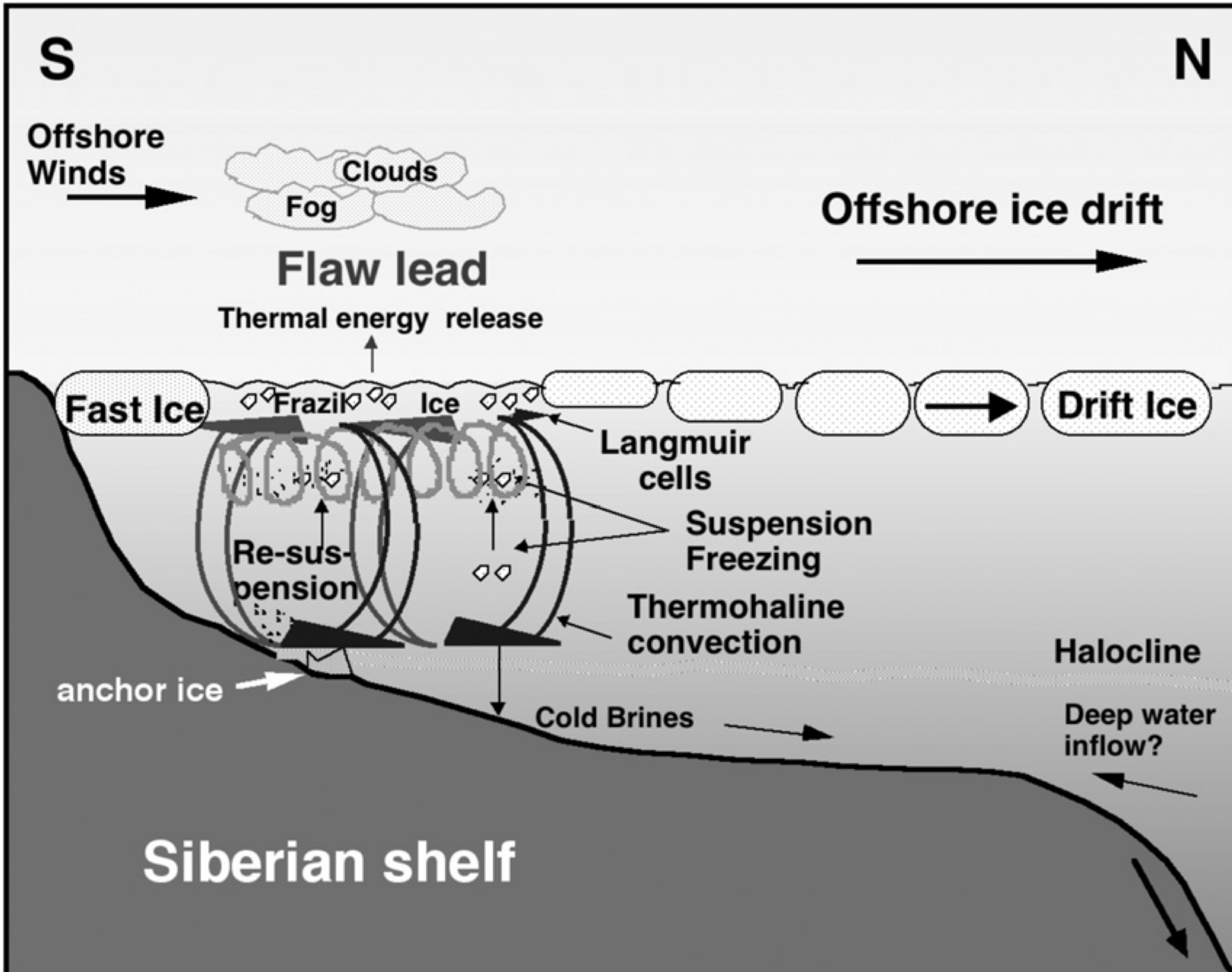
SEE CASE STUDY BY Rebesco)



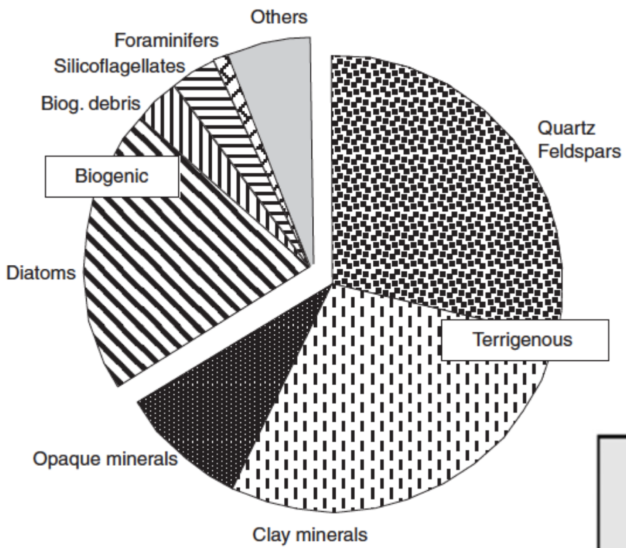


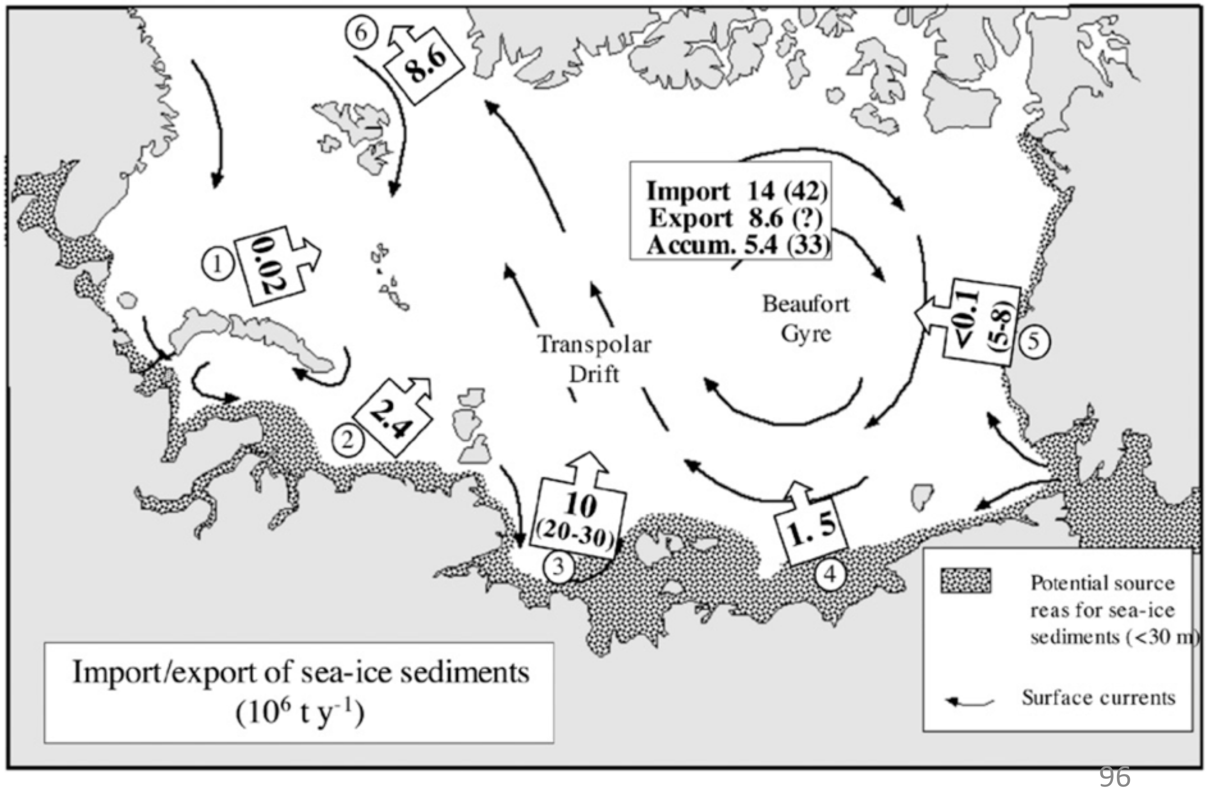
Dowdeswell et al. , 2009.Geology

SEA ICE SEDIMENT TRANSPORT


S
N
Offshore Winds
Clouds
Fog
Flaw lead
Thermal energy release
Offshore ice drift
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

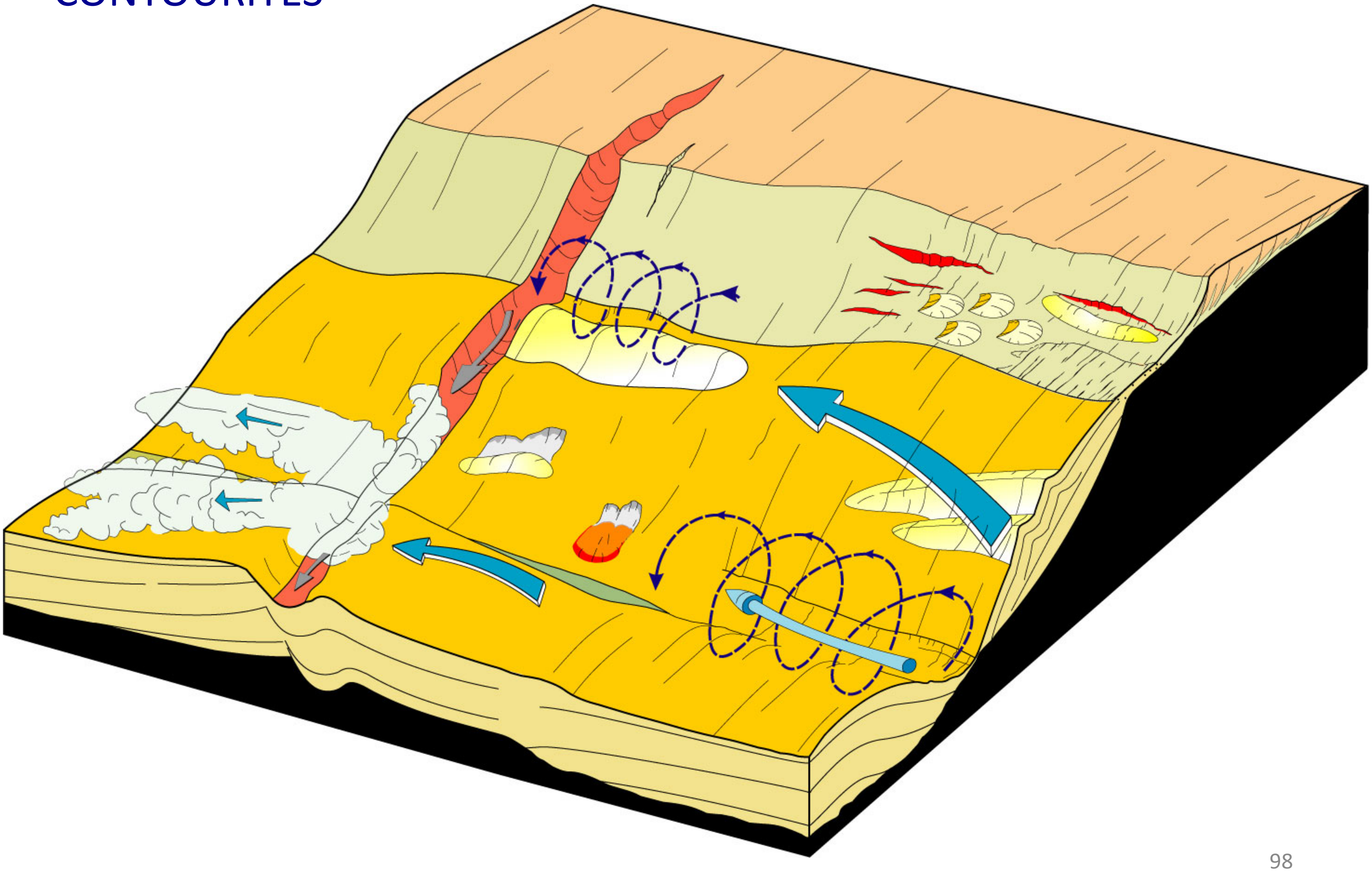

Others
Foraminifers
Silicoflagellates
Biog. debris
Biogenic
Diatoms
Quartz
Feldspars
Terrigenous
Opaque minerals
Clay minerals


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

Stein, 2008

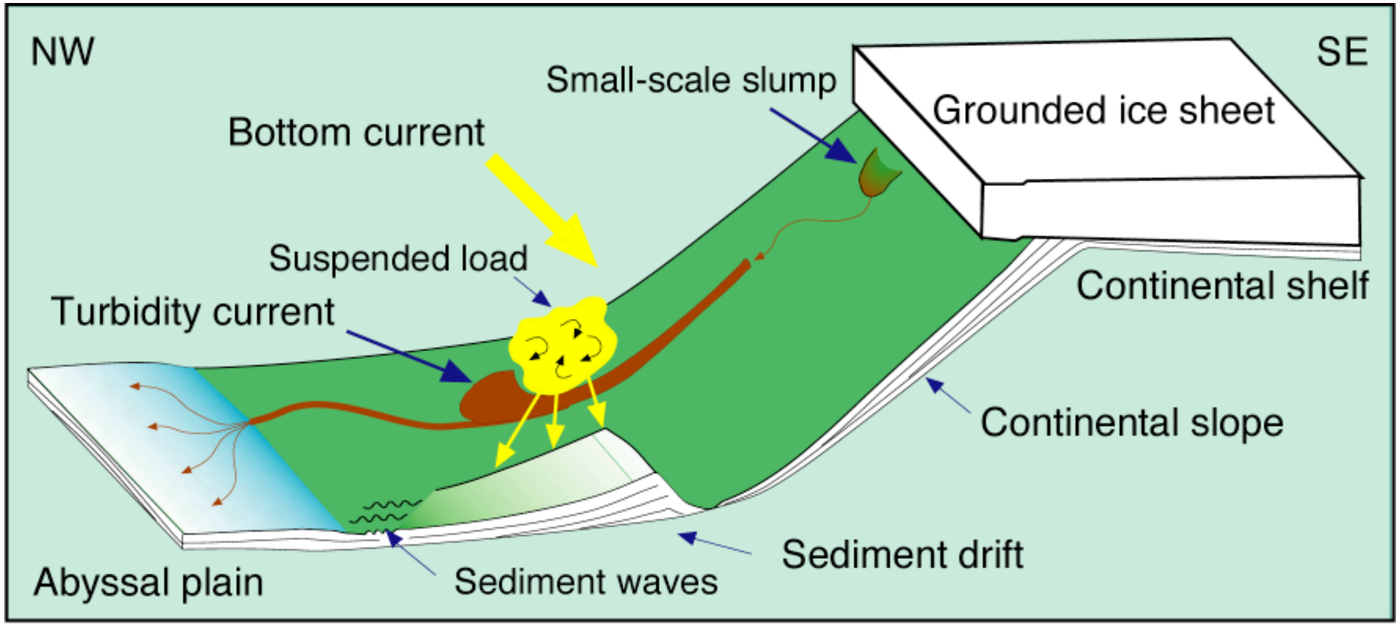
CONTOURITES

CONTOURITES

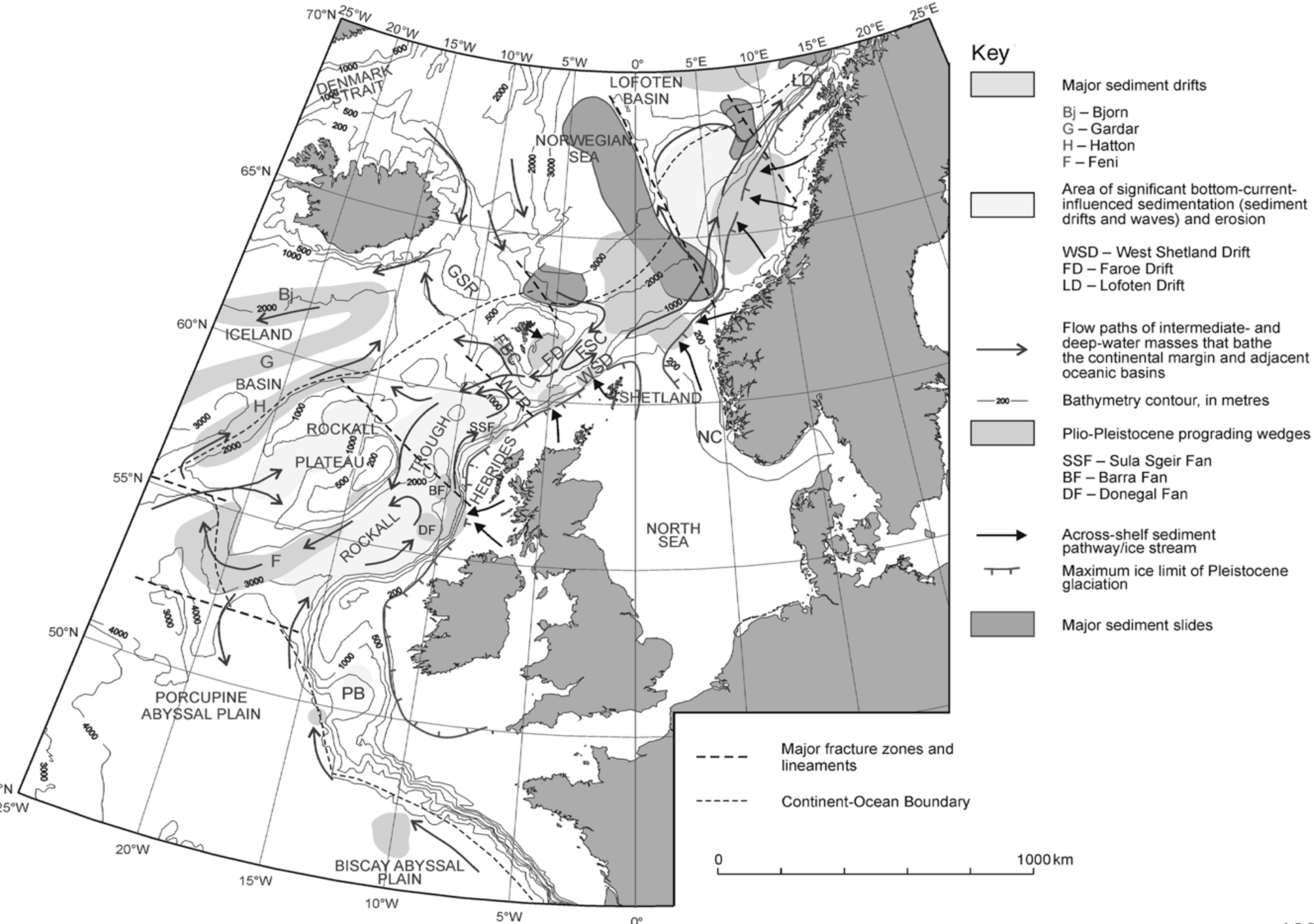


Cover image: Contourites, 2009. Edited by M. Rebesco and A. Camerlenghi, Elsevier

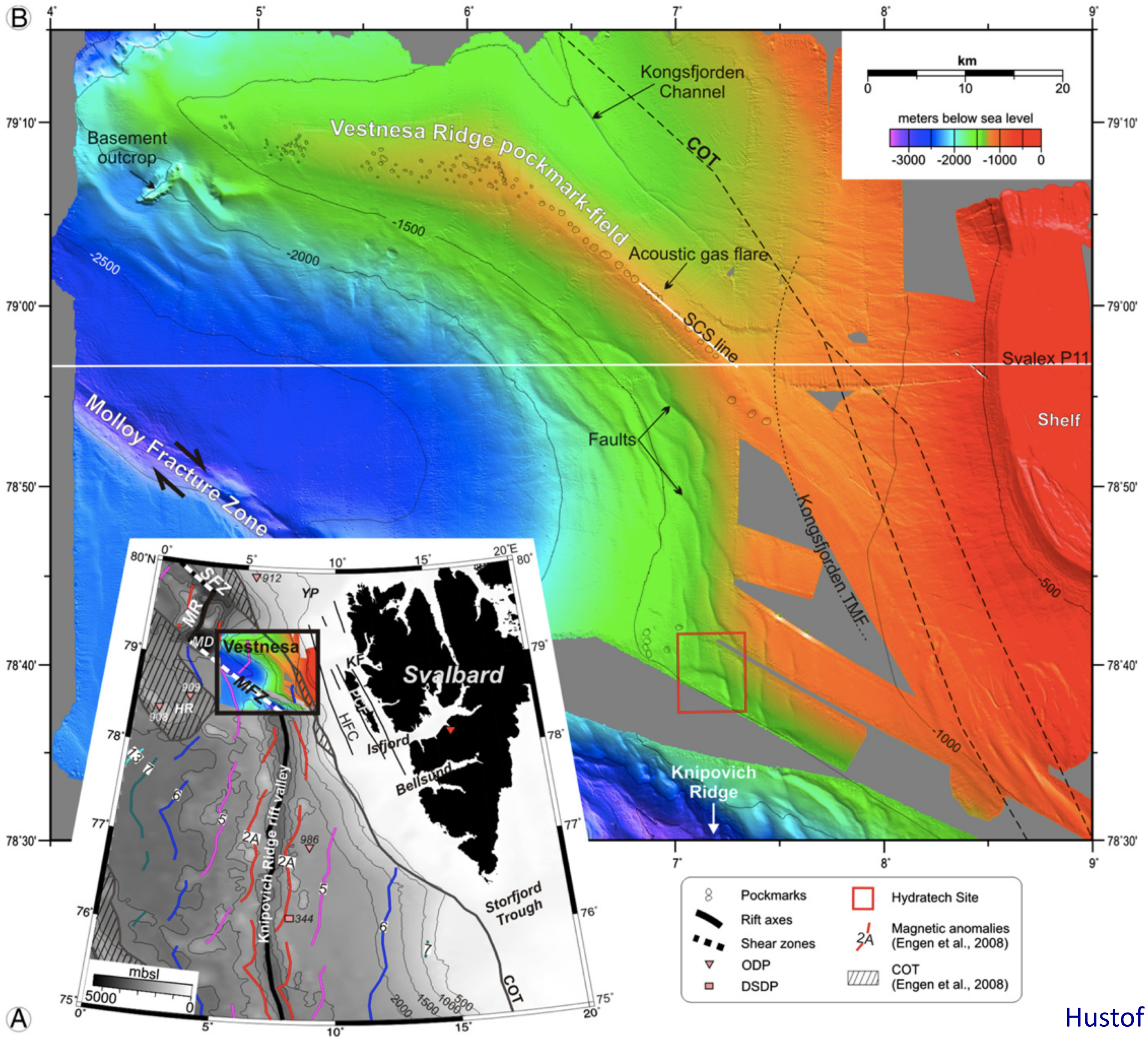
Model of glacial sedimentation on continental slope and rise on the Antarctic Margin



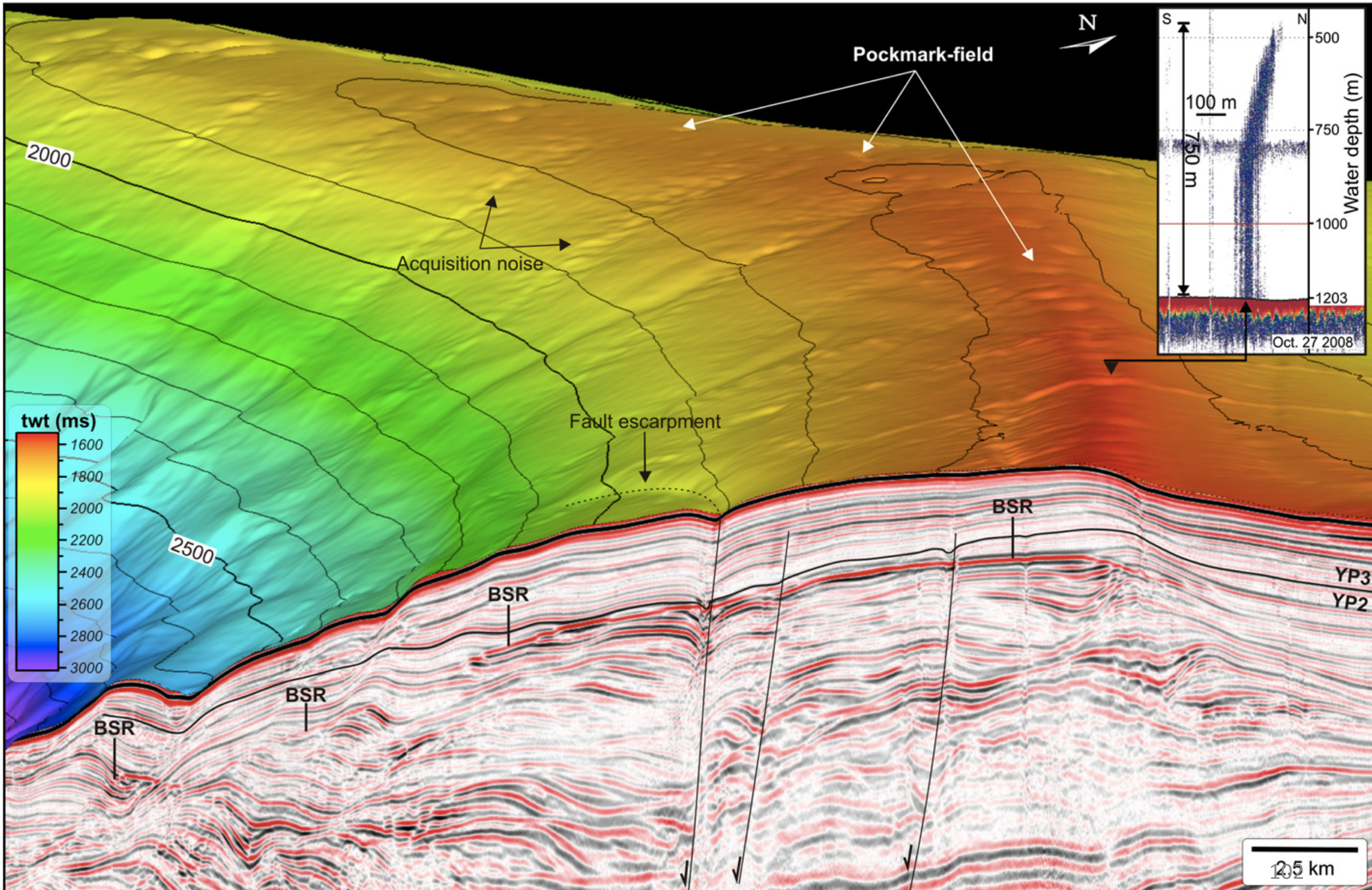
Rebesco et al., 1997



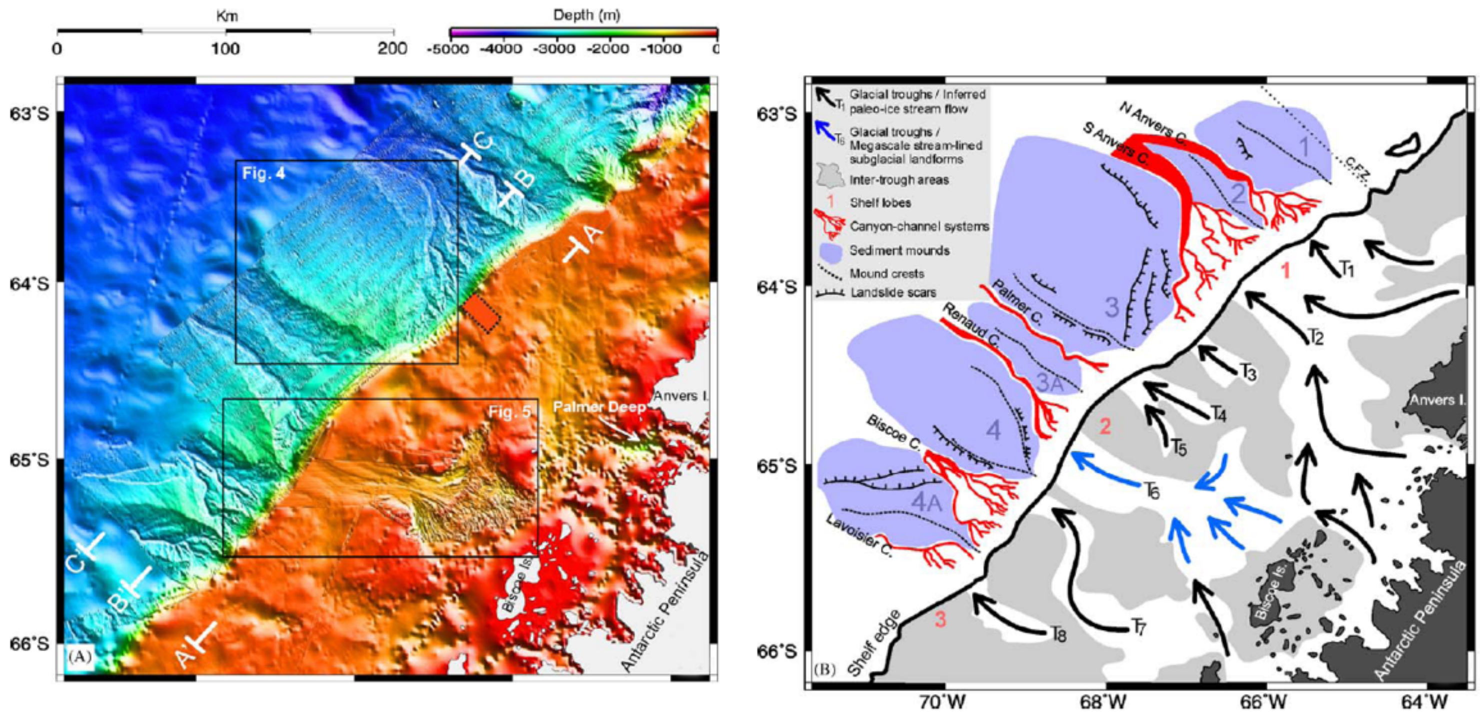
Van Weering et al., 2009.

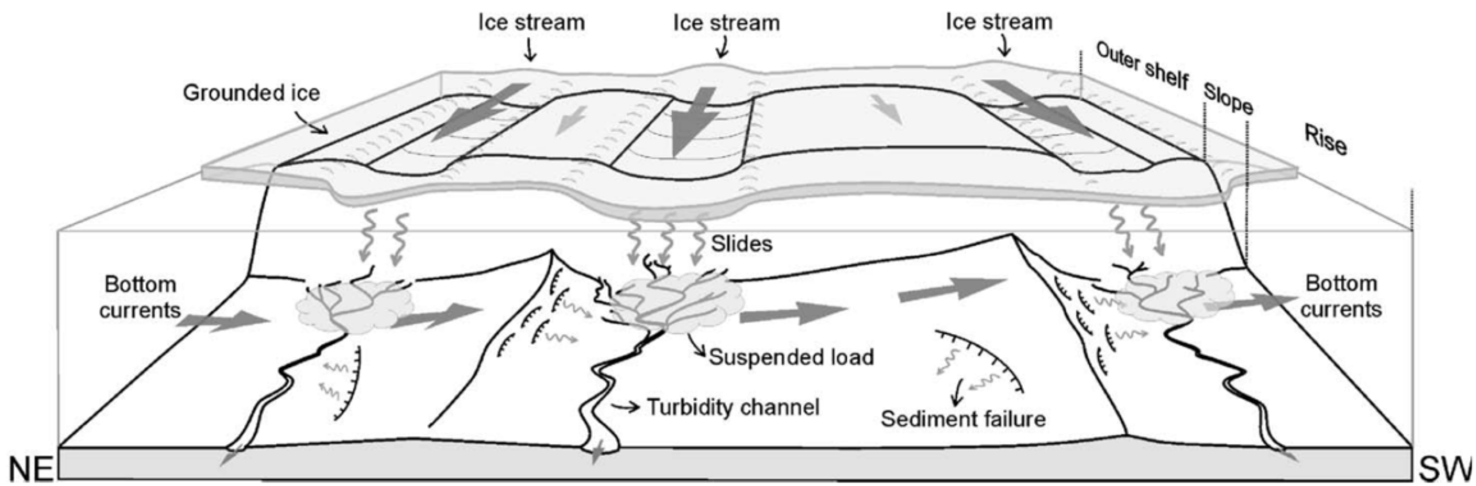


Hustof et al., 2009

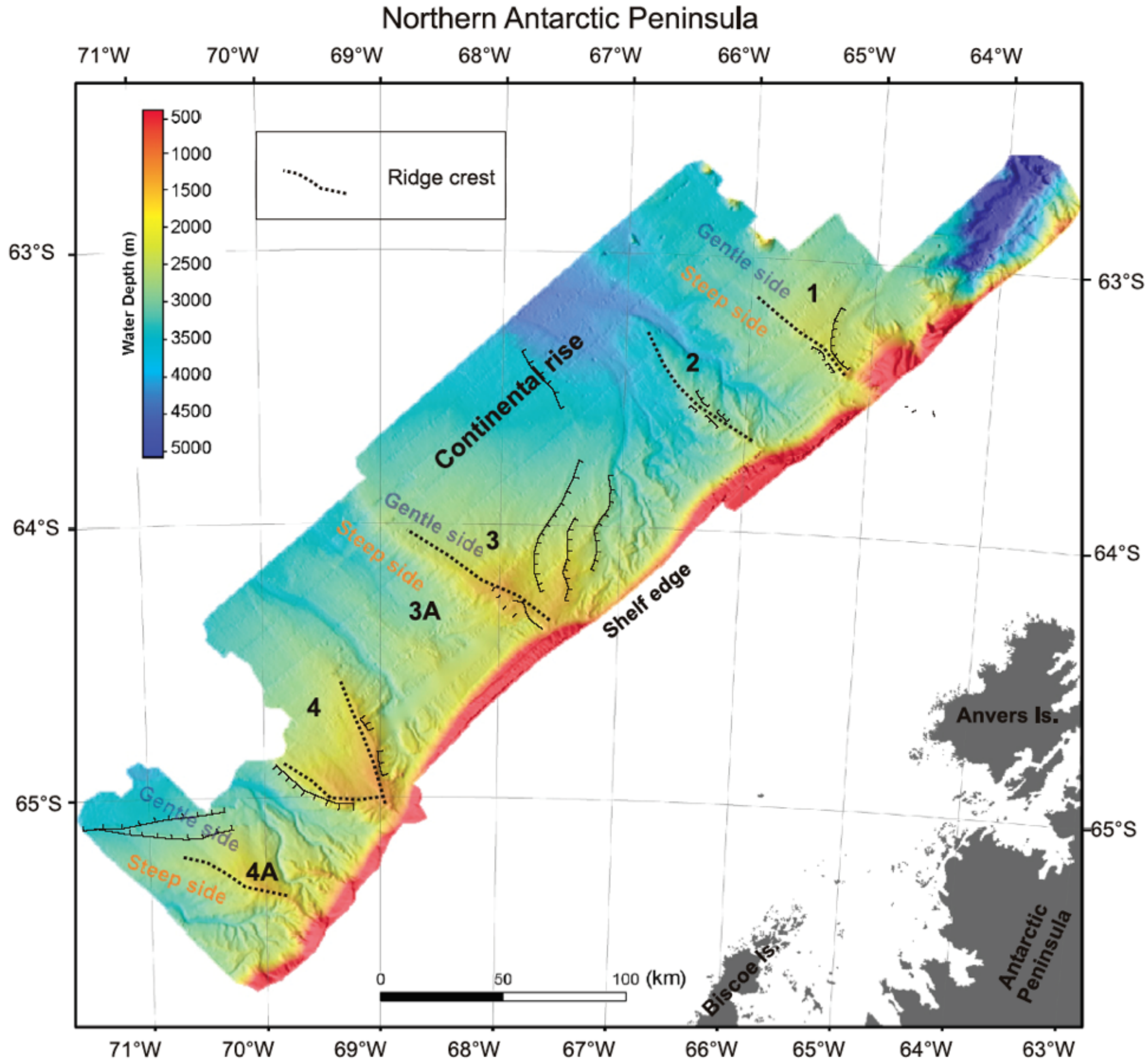

N
Pockmark-field
2000
Acquisition noise
Fault escarpment
2500
twt (ms)
1600
1800
2000
2200
2400
2600
2800
3000
BSR
BSR
BSR
BSR
YP3
YP2
S
N
500
750
1000
1203
Water depth (m)
100 m
750 m
Oct. 27 2008
2.5 km

TURBIDITES

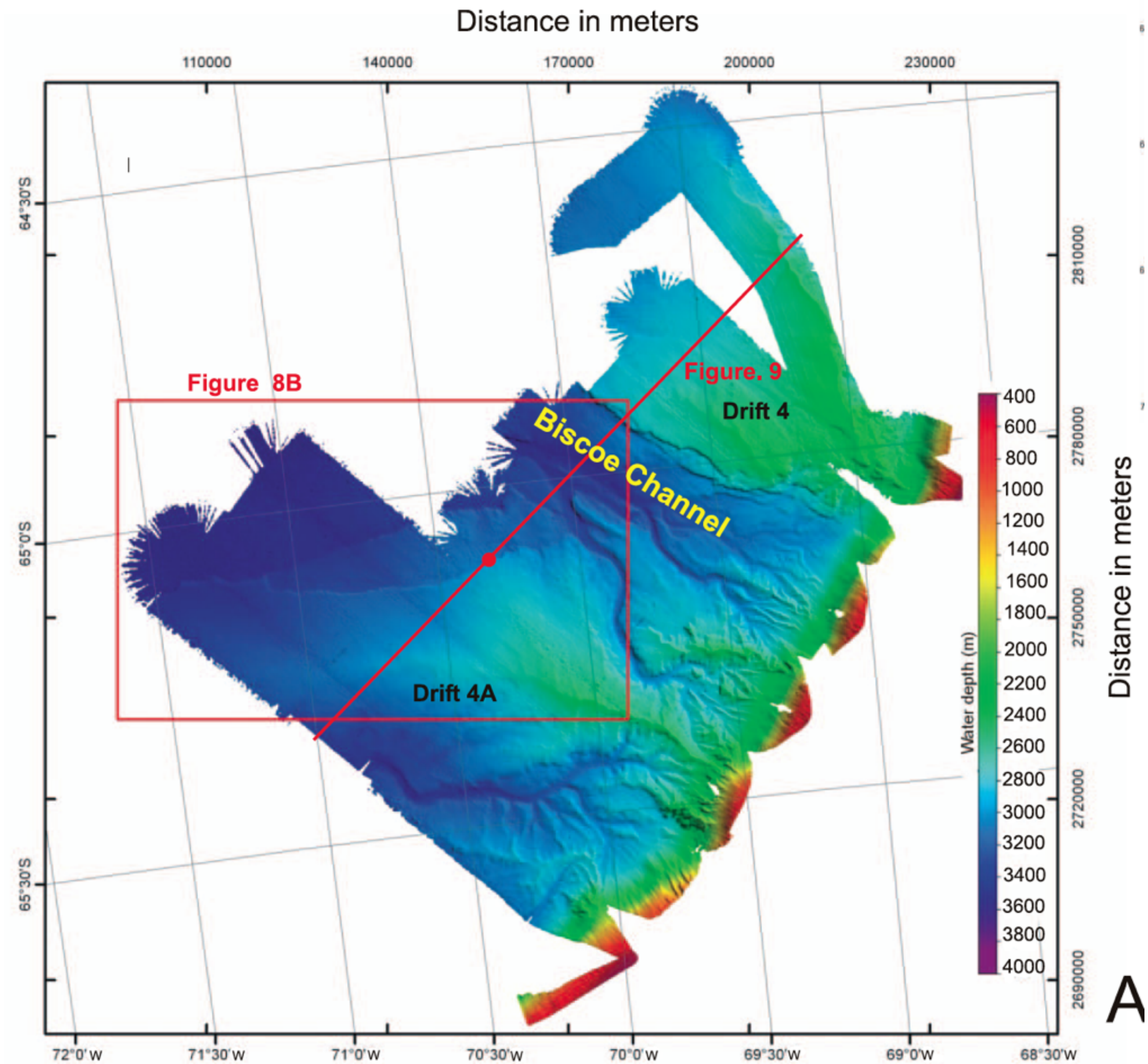




Amblas et al., QSR, 2006

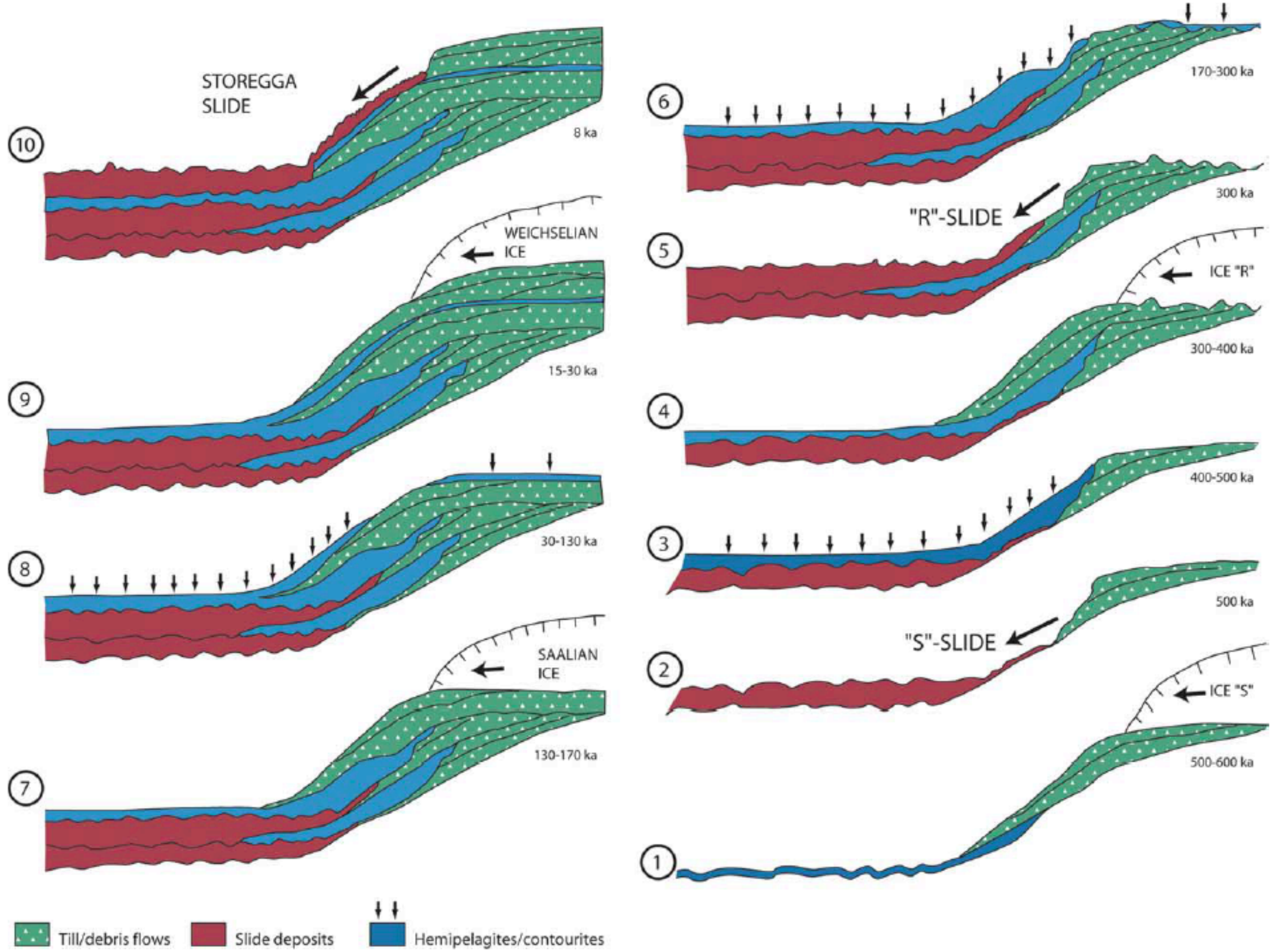


Volpi et al., 2011 SEPM Special Publication No. 96,


Distance in meters
110000
140000
170000
200000
230000
64°30'S
65°0'S
65°30'S
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
2810000
2780000
2750000
2720000
2690000
Distance in meters
A
72°0'W
71°30'W
71°0'W
70°30'W
70°0'W
69°30'W
69°0'W
68°30'W

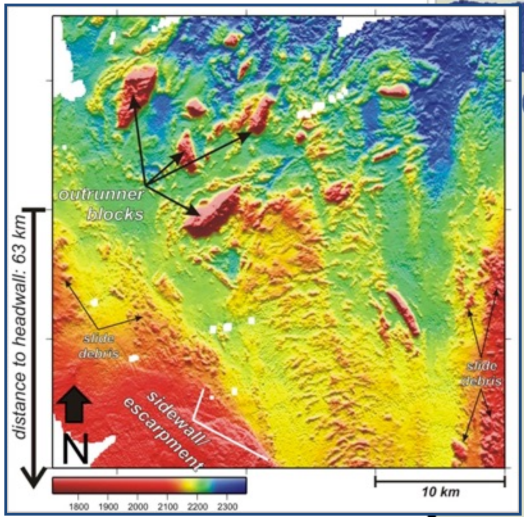
MASS TRANSPORT DEPOSITS

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

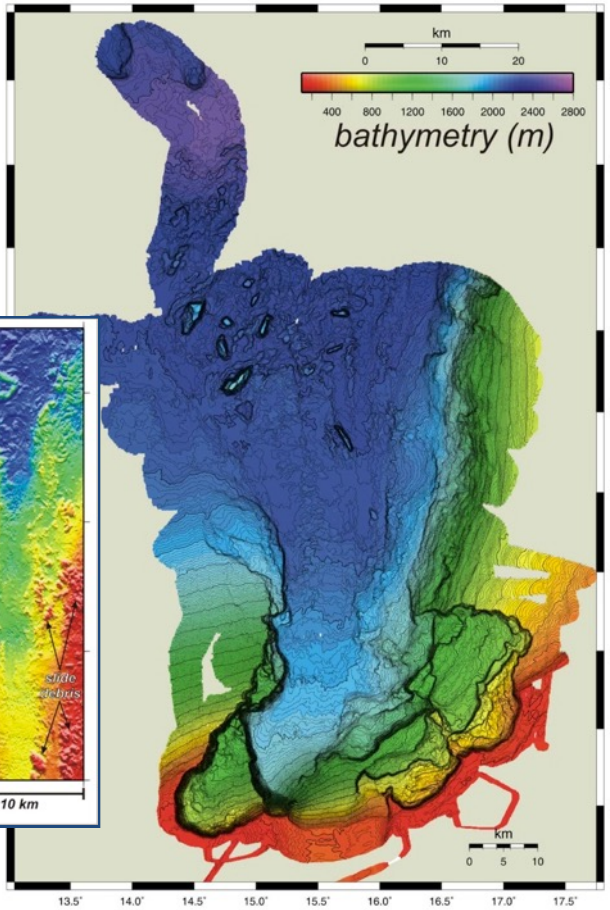


Rise et al., 2005

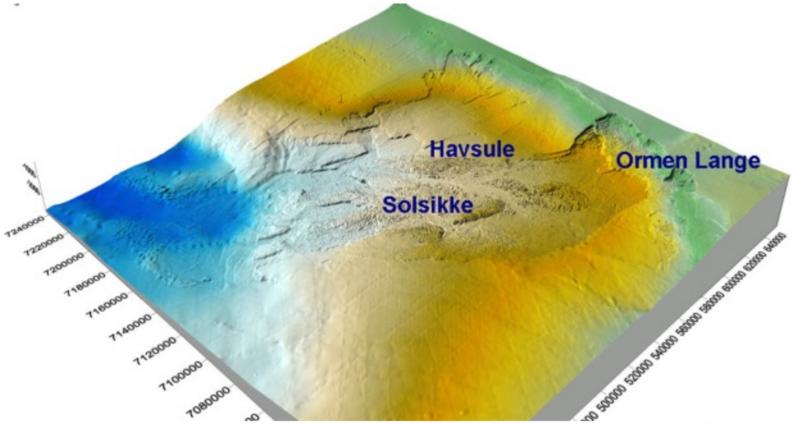
HINLOPEN/ YERMAK SLIDE
North of Svalbard

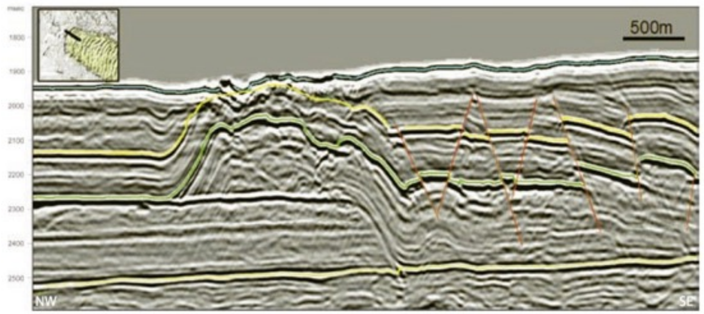


Vanneste et al., 2006, *EPSL*
Winkelmann et al., 2006, G^3

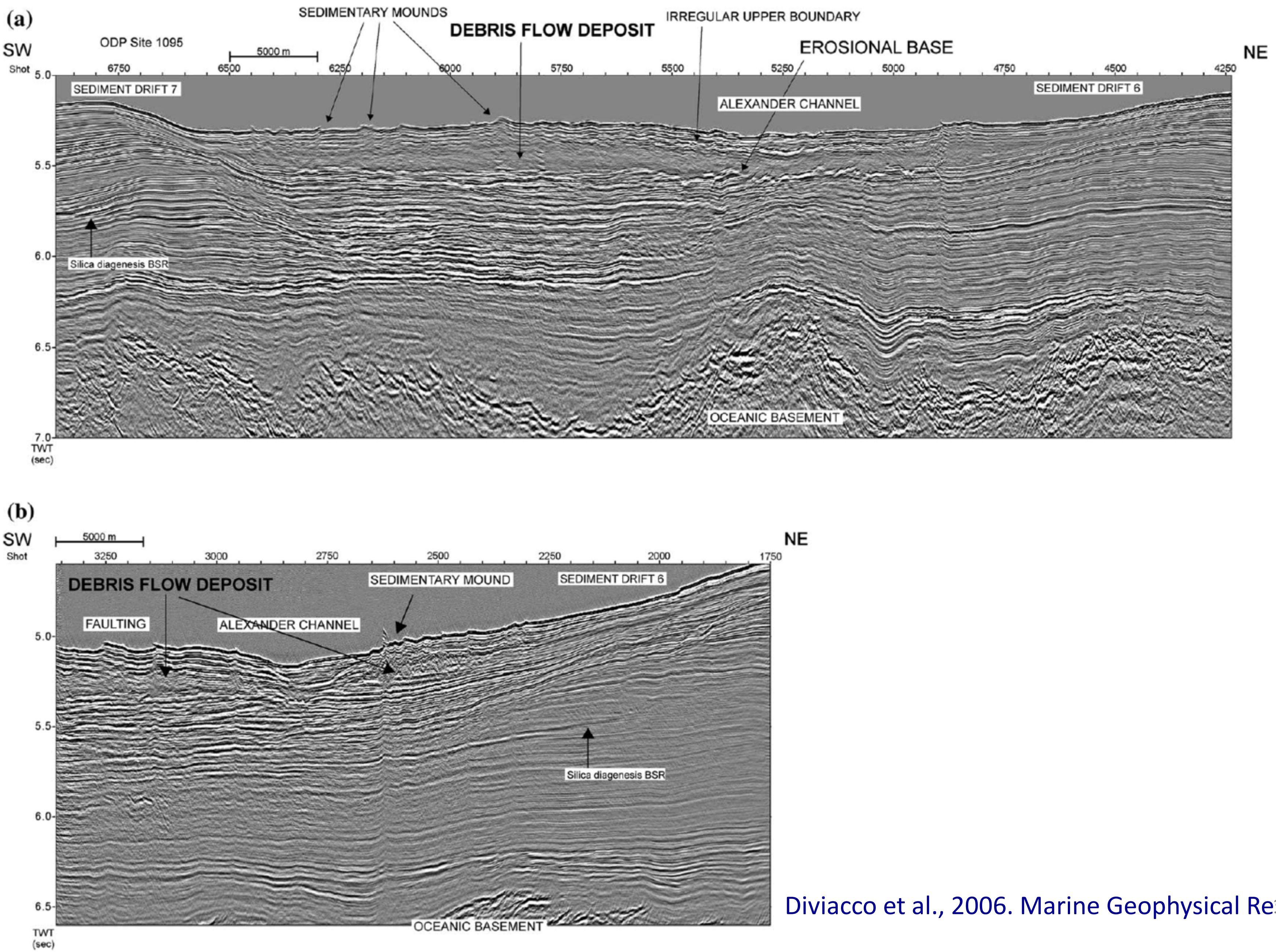


STOREGGA SLIDE
Norwegian margin

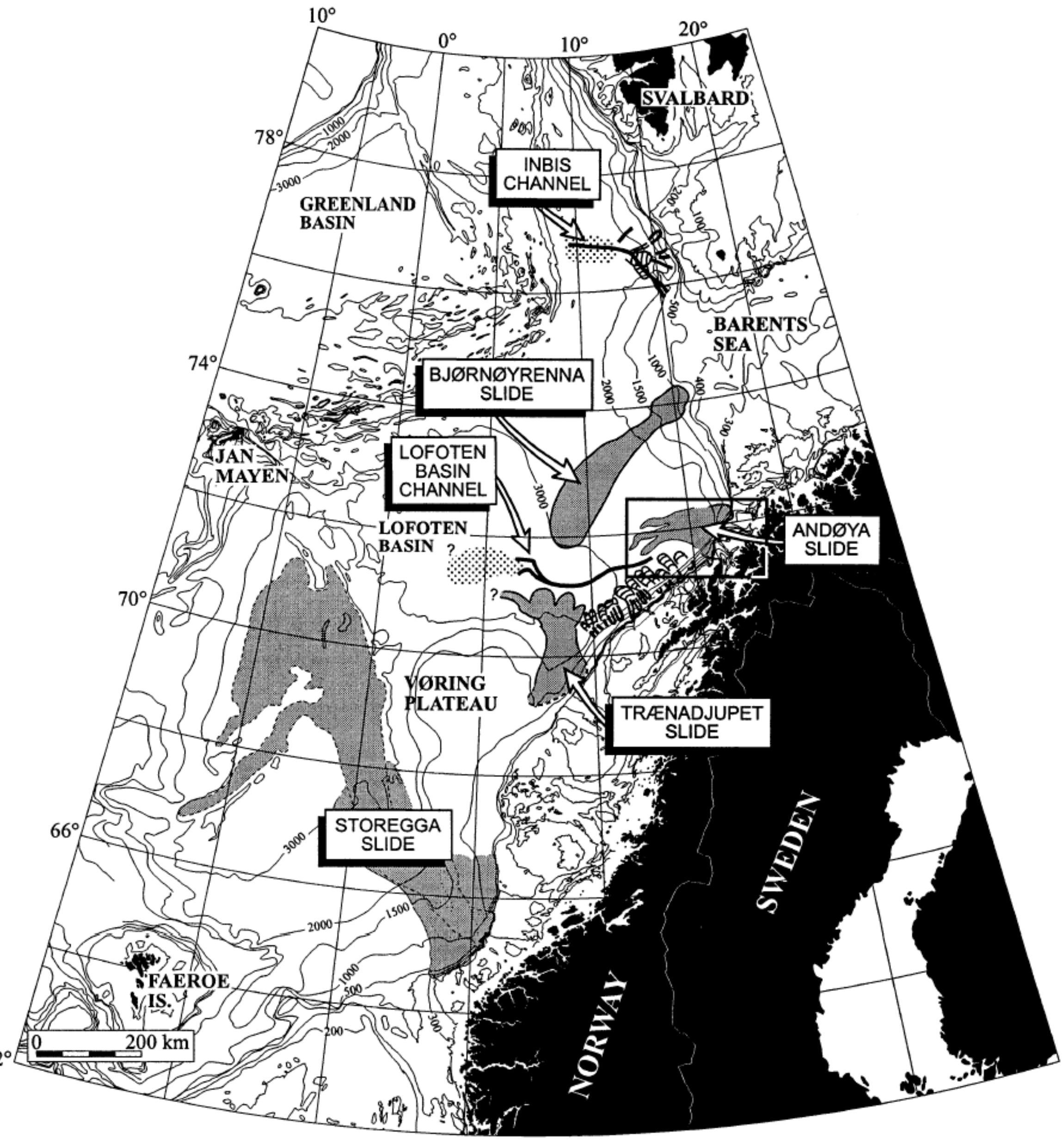




Færseth & Bjørn Helge Sætersmoen, 2008, *Norwegian J. of Geology*



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
78°
74°
70°
66°
62°
10°
0°
10°
20°

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