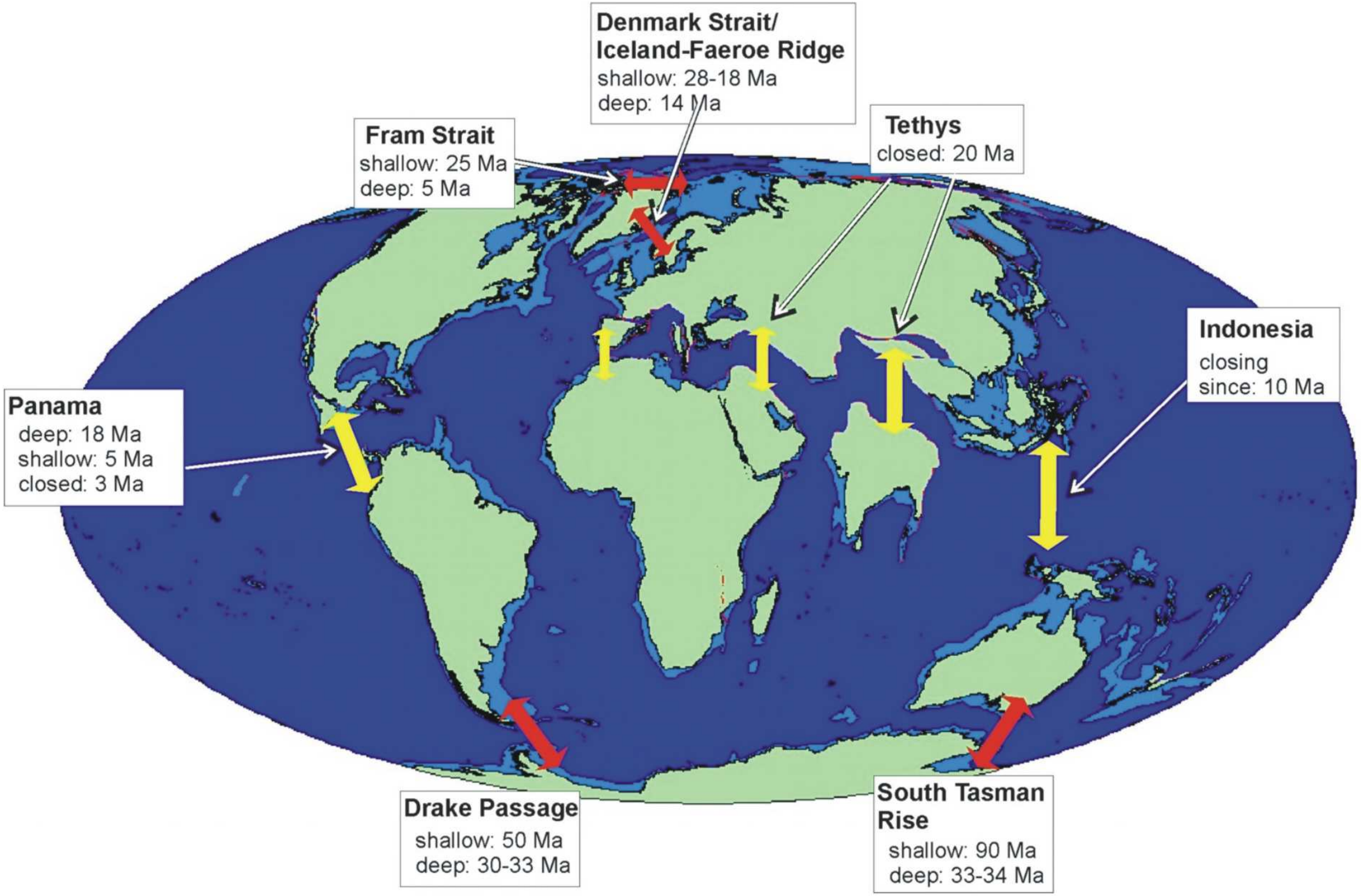
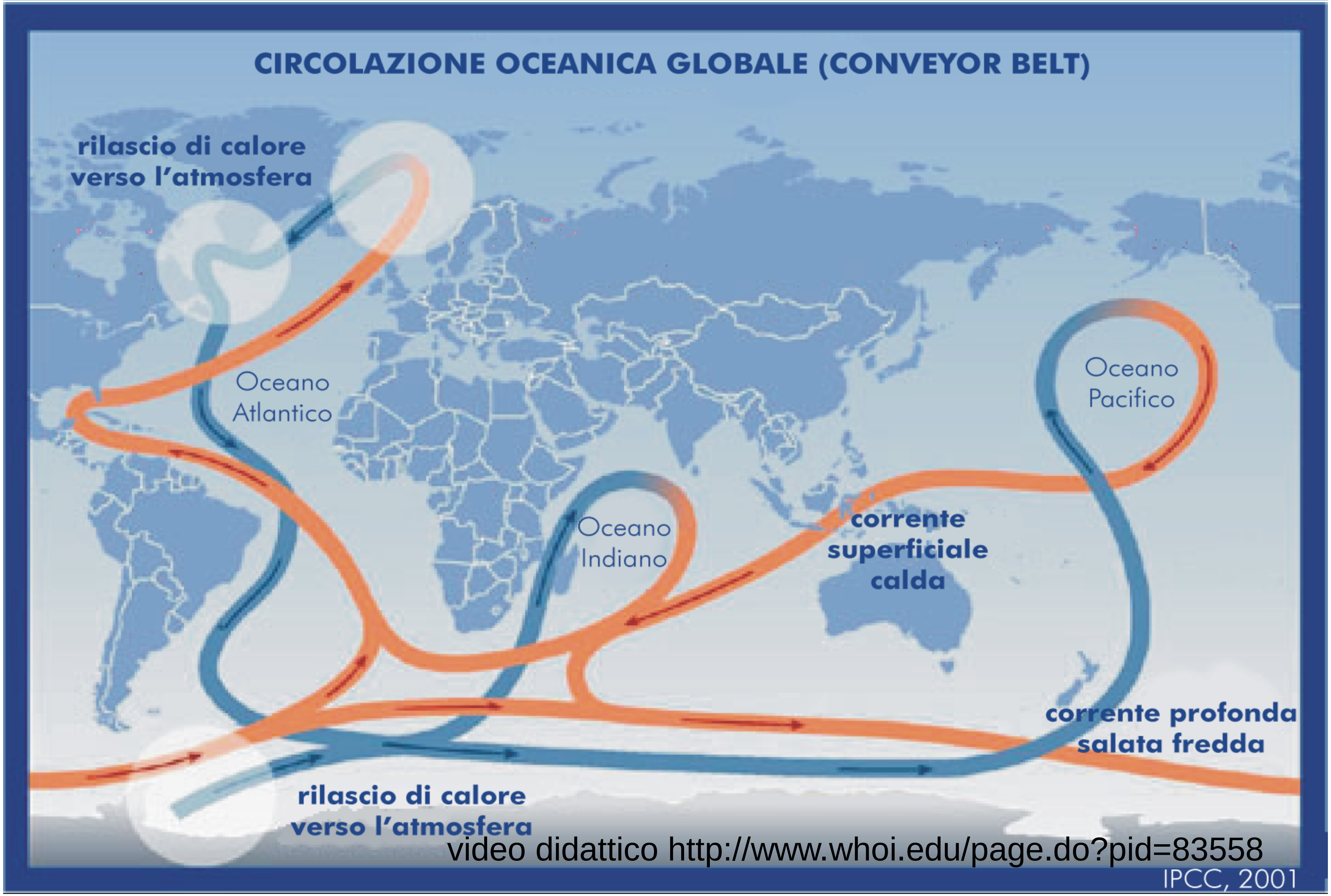
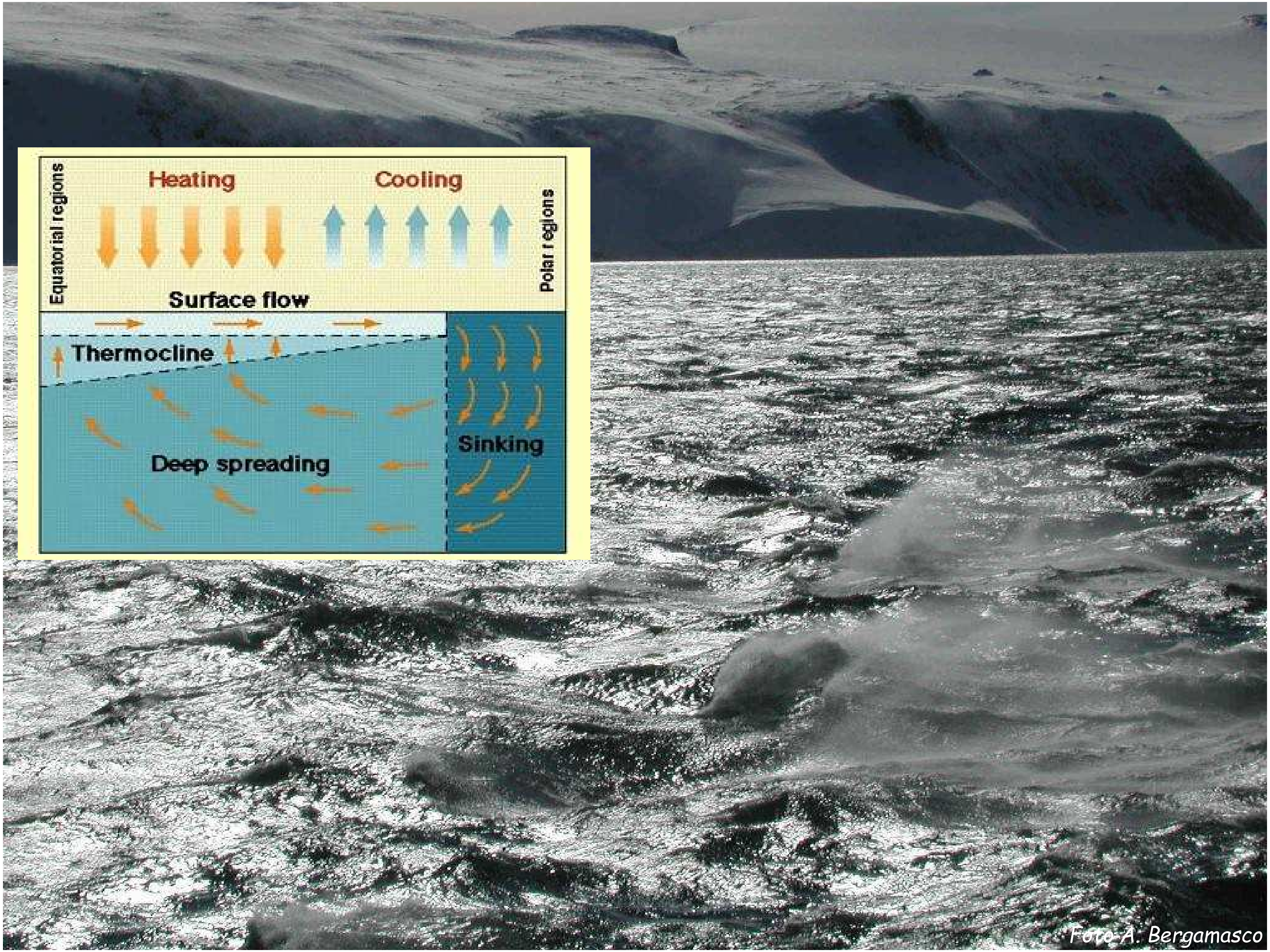
Ocean Gateways

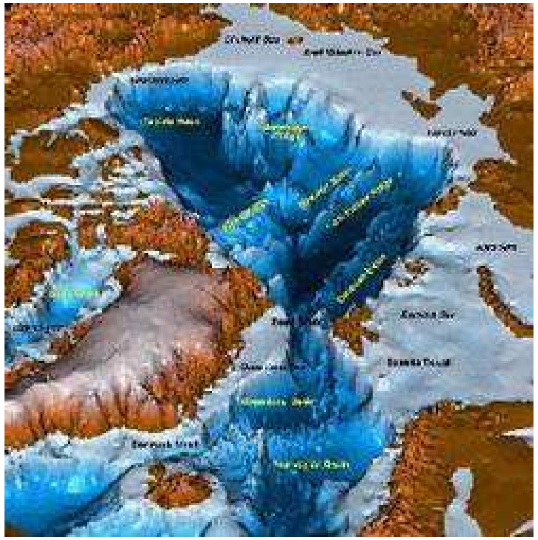




video didattico http://www.whoi.edu/page.do?pid=83558


Equatorial regions
Heating
Cooling
Polar regions
Surface flow
Thermocline
Sinking
Deep spreading
Foto A. Bergamasco

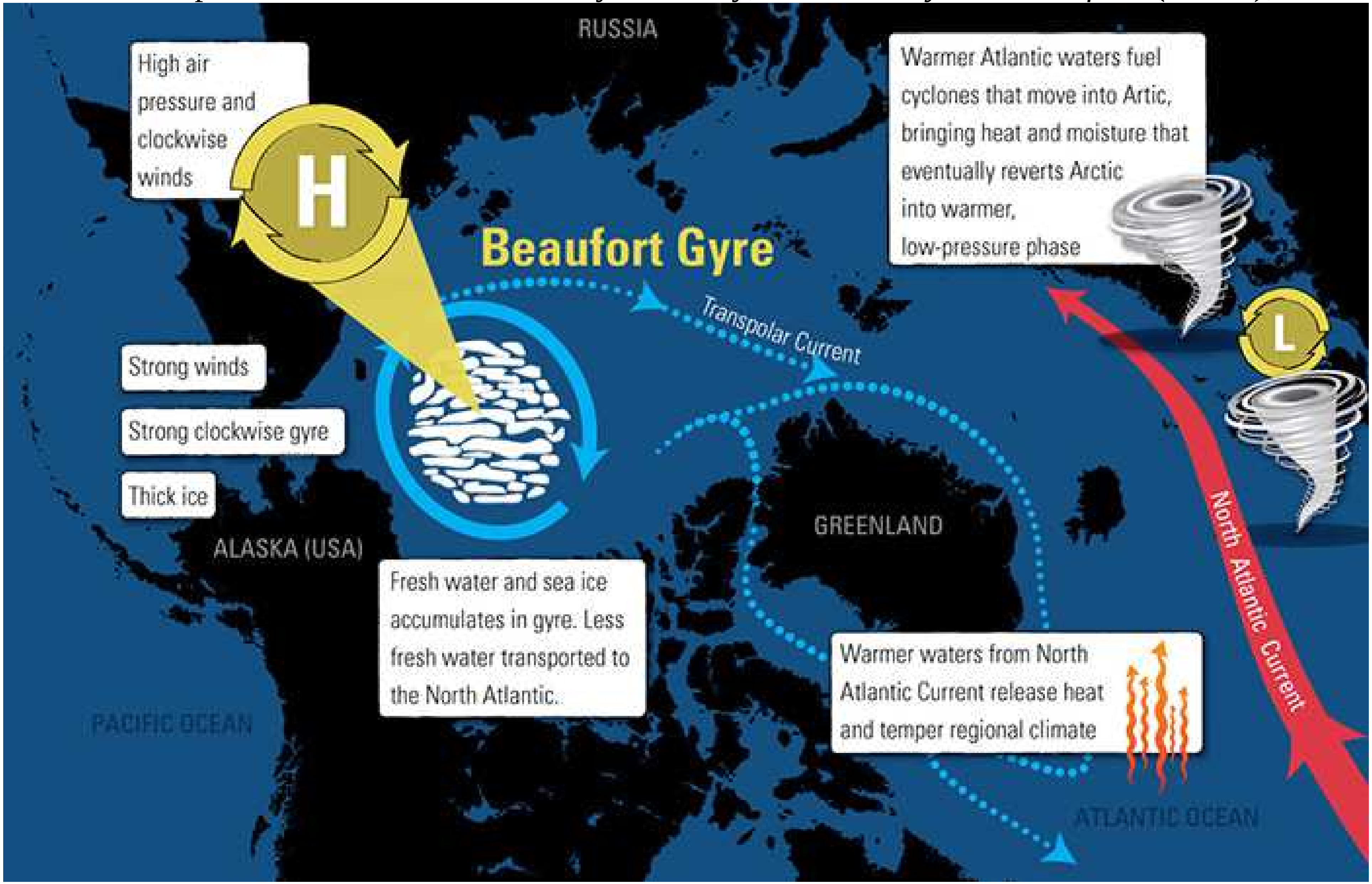
The main currents in the Arctic



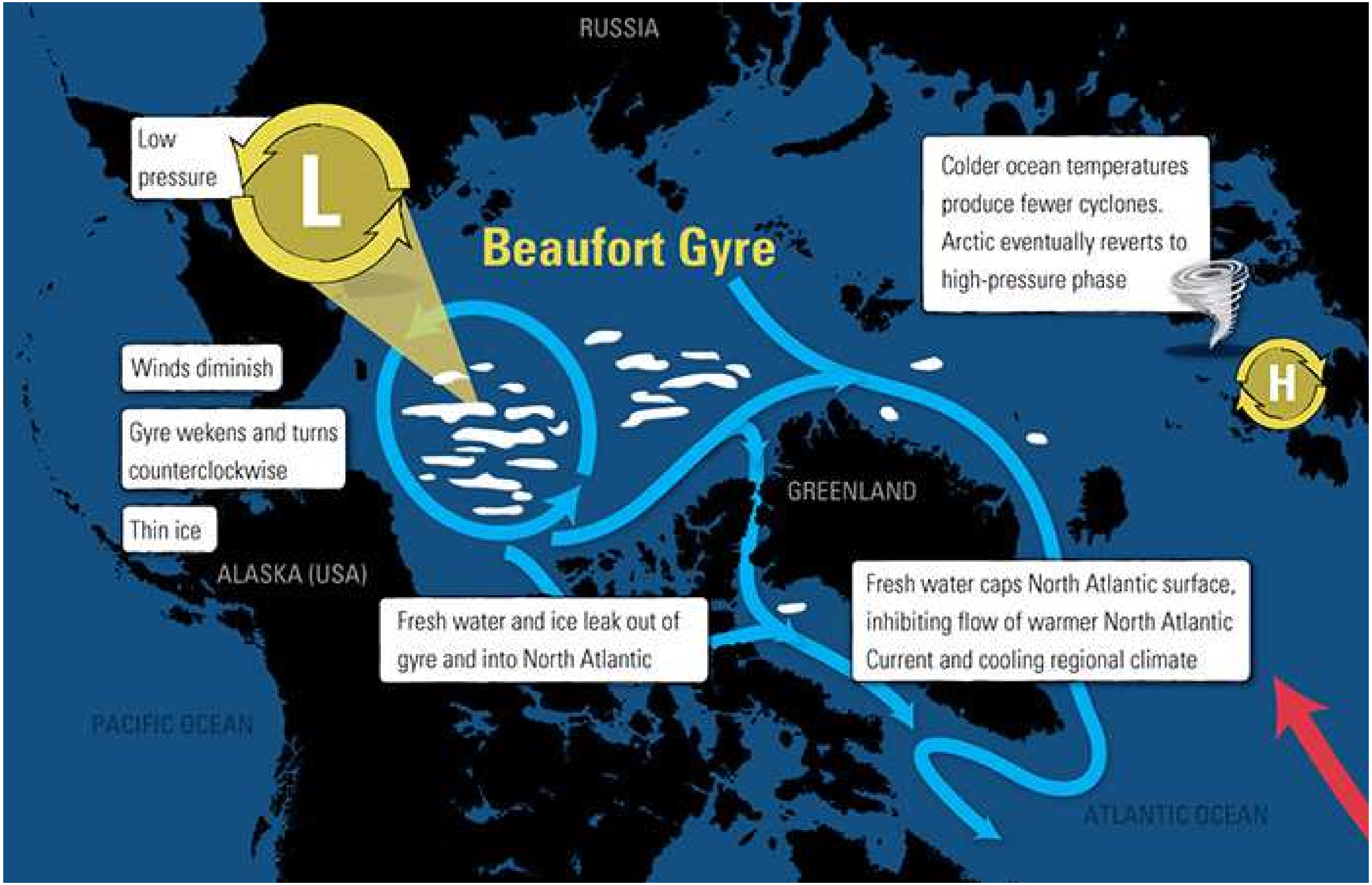
Outflow from the Arctic Ocean

Areas of inflow for the Arctic Ocean

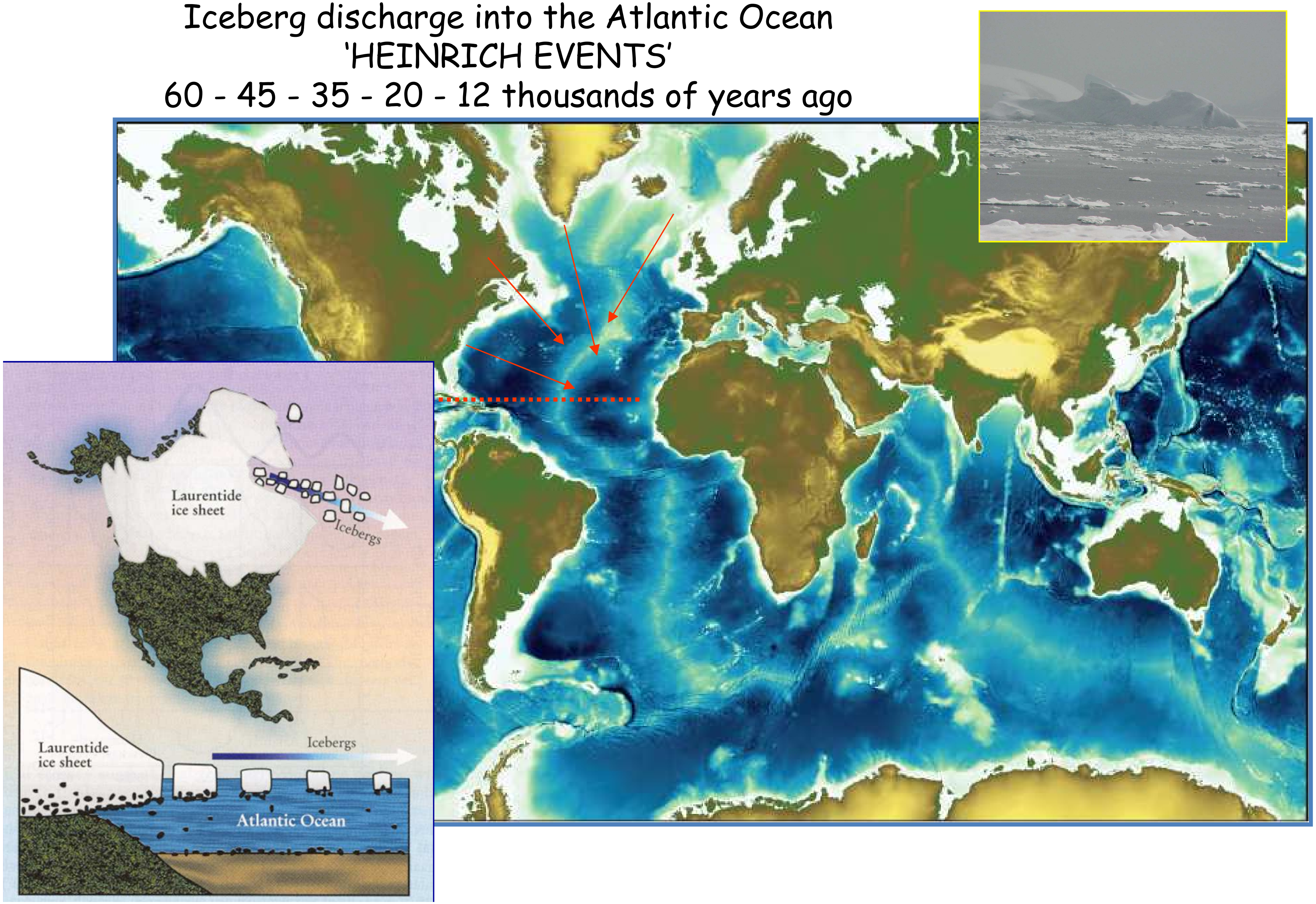
2015 Philosophical Transactions of the Royal Society, *Proshutinsky and Krishfield (WHOI), et al.*



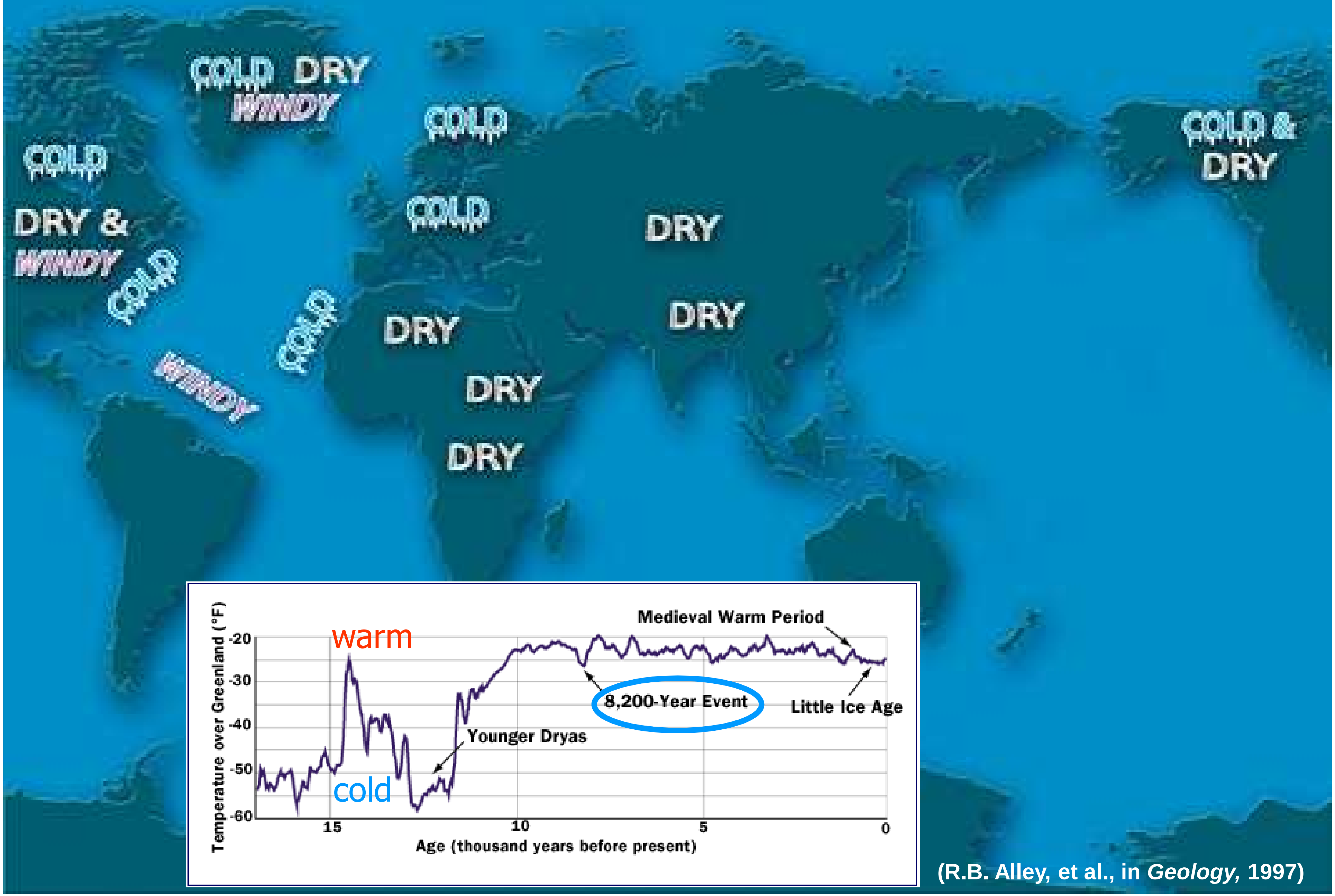
2015 Philosophical Transactions of the Royal Society, *Proshutinsky and Krishfield (WHOI), et al.*



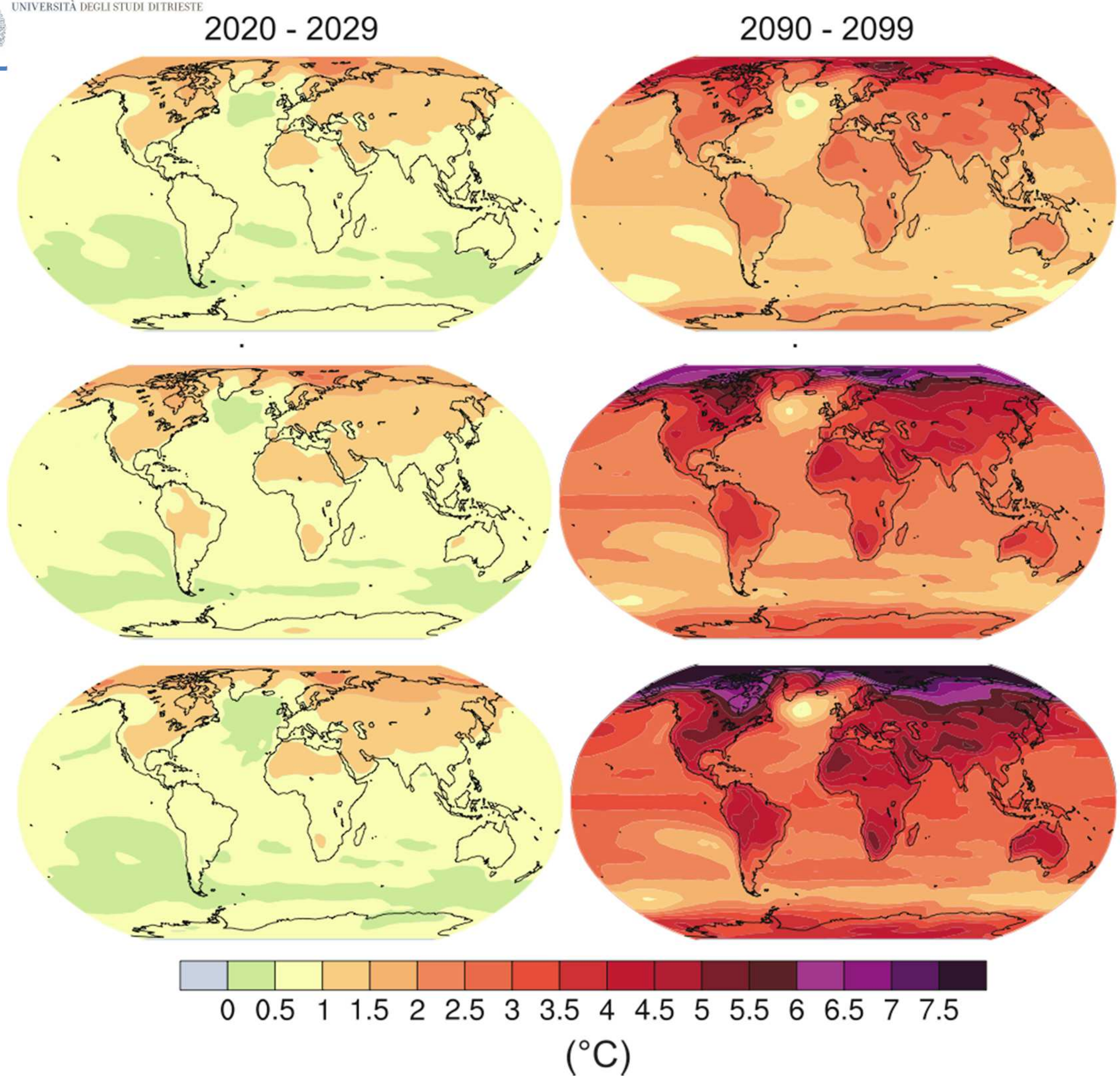
Iceberg discharge into the Atlantic Ocean
'HEINRICH EVENTS'
60 - 45 - 35 - 20 - 12 thousands of years ago

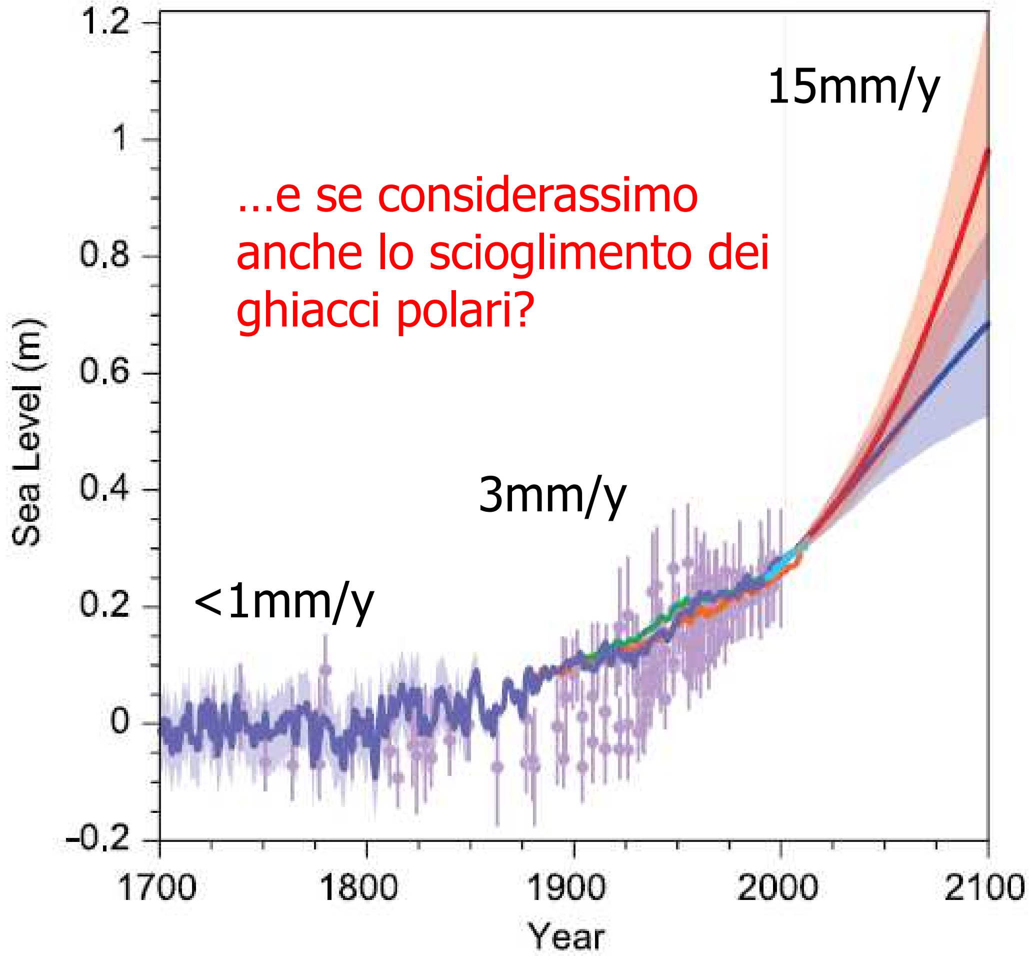


8200 years ago: a rapid global cooling fllowing a warming period, lasted 100 years



(R.B. Alley, et al., in *Geology*, 1997)


2020 - 2029
2090 - 2099
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
(°C)



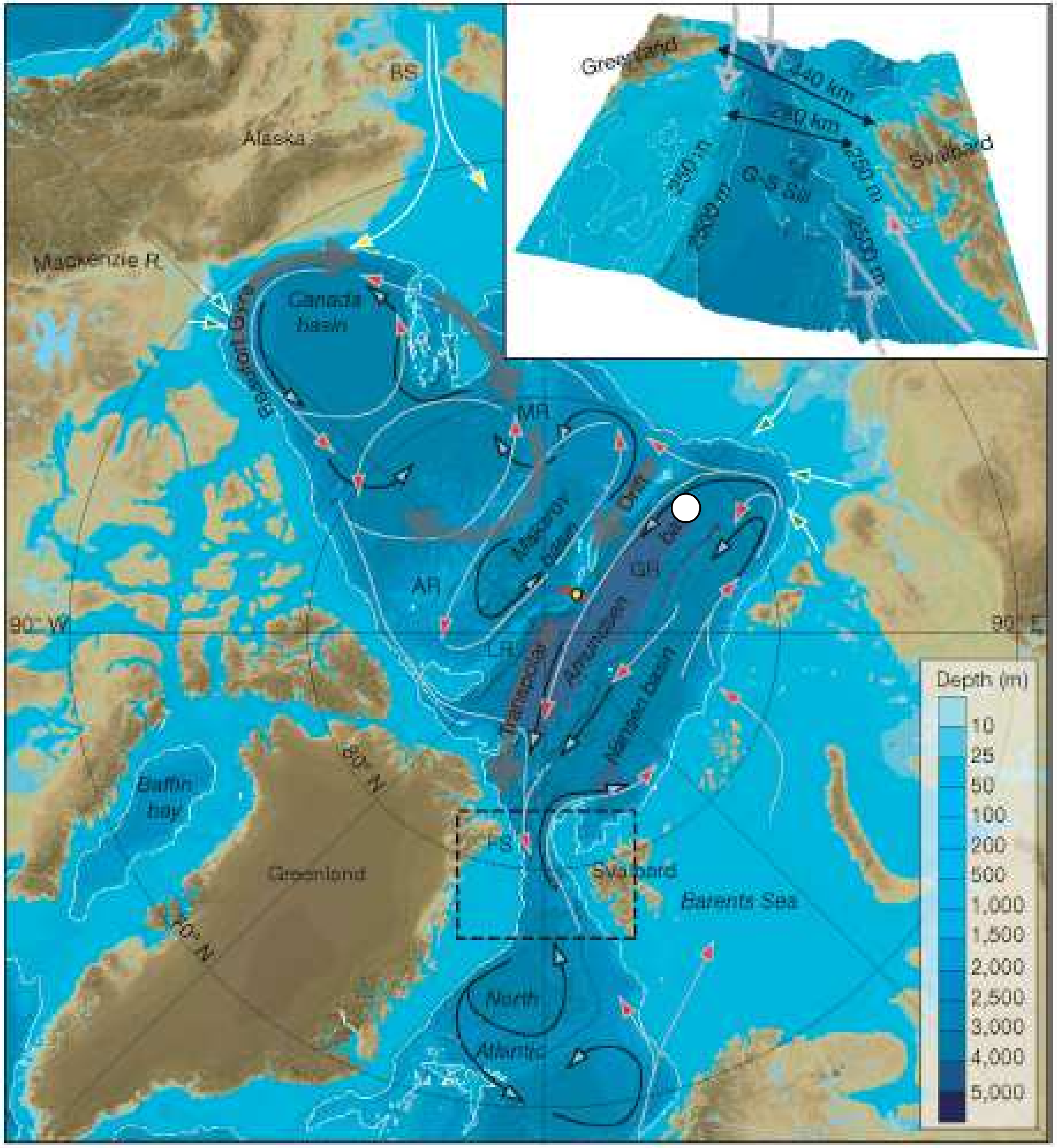
RCP 8.5 (business as usual)

RCP 2.6

Representative (greenhouse gas) Concentration Pathways (RCPs)

Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the likely range during the 21st century….IPCC AR5, 2013

Sources listed in Church et al. IPCC (2013)



Still open questions:

When did the Arctic Ocean begin having its modern configuration?

When did the Fram Strait and bering Strait fully open?

What's the origin of the Arctic Ocean ridges?

Ø. Engen et al. / Tectonophysics 450 (2008) 51–69

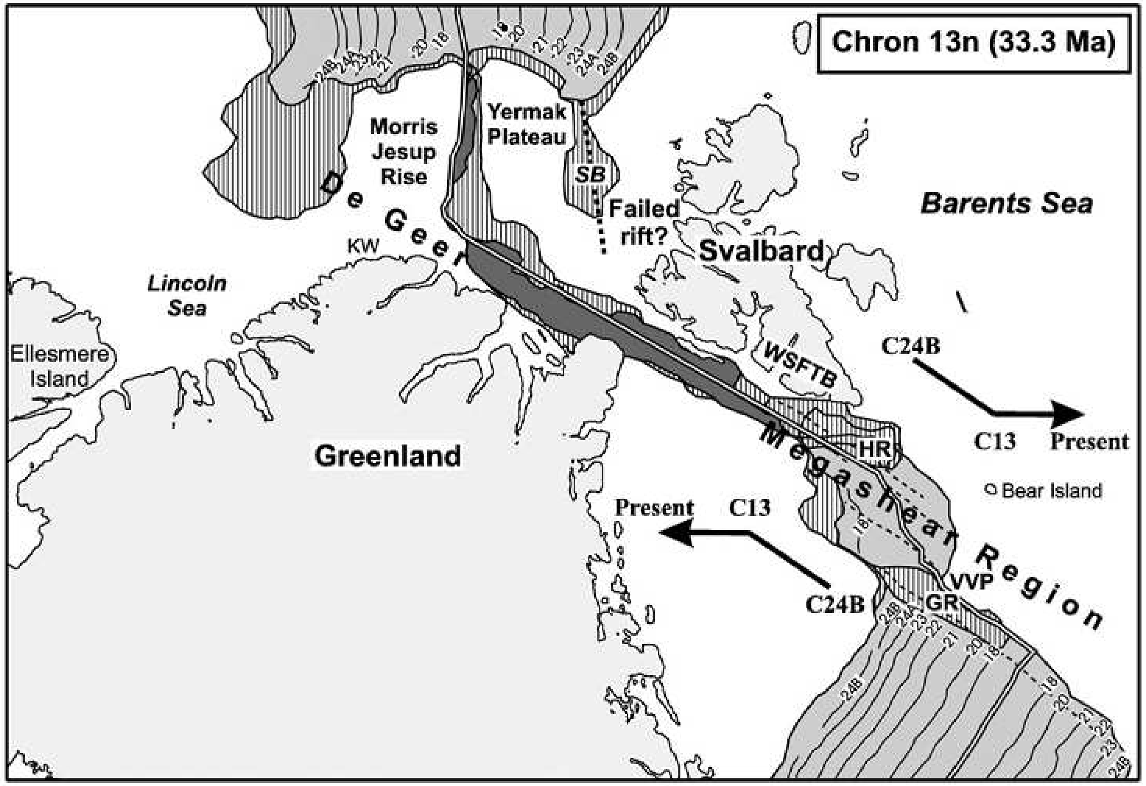


Fig. 4. Plate tectonic reconstruction of the Fram Strait region to Chron 13 times (earliest Oligocene), when relative plate motion between Greenland and Eurasia changed from right-lateral shear to oblique divergence (arrows). Area of crustal overlap (dark grey) indicates crustal stretching and thinning prior to breakup of the Lena Trough. The Sophia Basin (SB) may be a failed Eocene attempt to connect the Eurasia Basin and the Norwegian–Greenland Sea and might have facilitated early water exchange. WSFTB, West Spitsbergen Fold and Thrust Belt; other abbreviations as in Figs. 1 and 2.

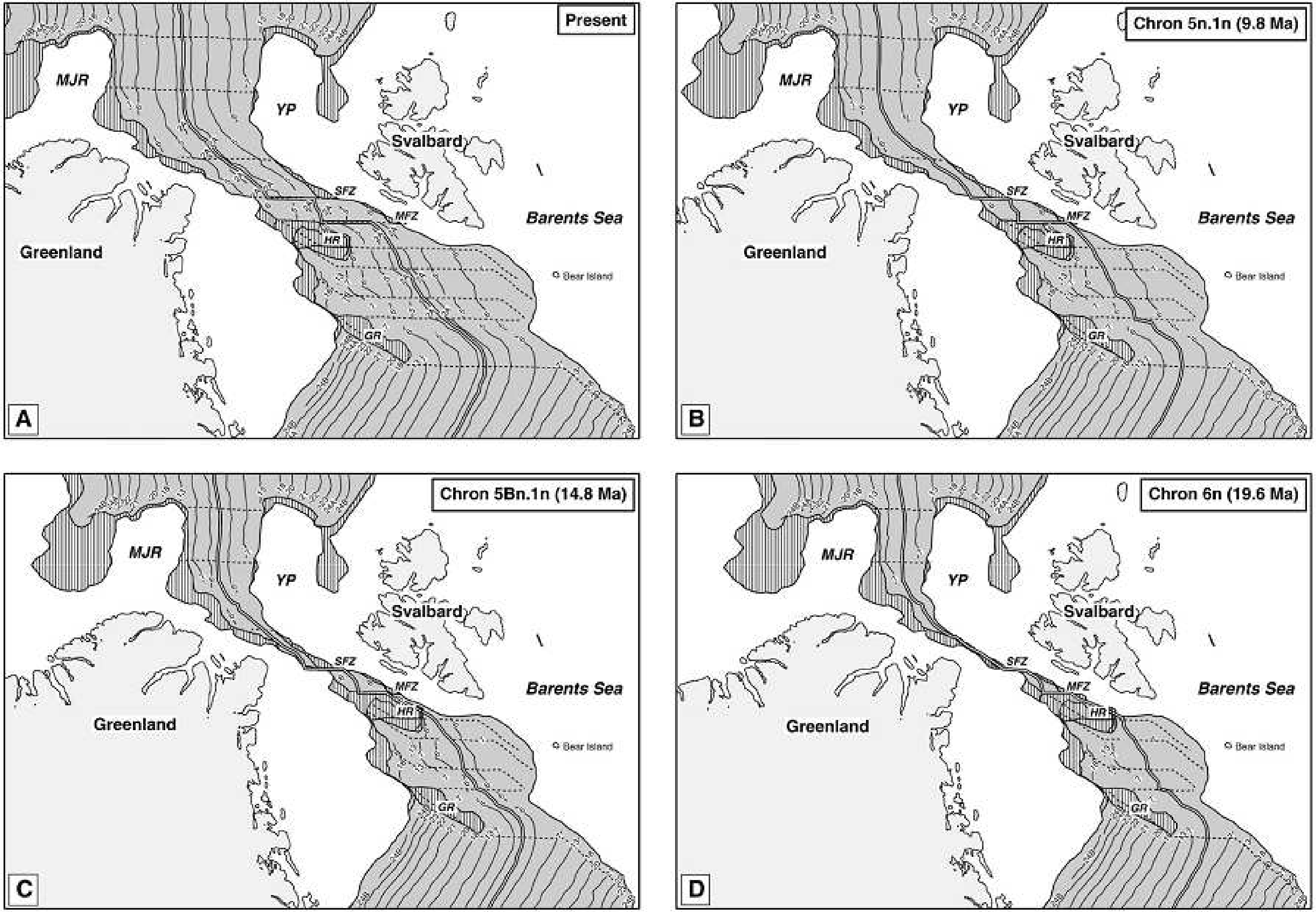


Fig. 12. Plate tectonic reconstruction of the Fram Strait gateway. Eurasia is kept fixed and Greenland and North America rotated using the poles in Table 1. Oceanic crust is shaded and magnetic seafloor spreading anomalies shown as annotated bold lines. COT and uncertain crustal provinces hachured as in Fig. 2. Flowlines of relative plate motion shown by dashed lines. Reconstructions indicate (A) present-day Lena Trough; (B) Development of first well developed seafloor spreading anomalies during late Miocene times (~10 Ma); (C) Formation of an initial, narrow oceanic corridor during early Miocene times (20–15 Ma); and (D) closure between Svalbard and NE Greenland prior to early Miocene times (~20 Ma).

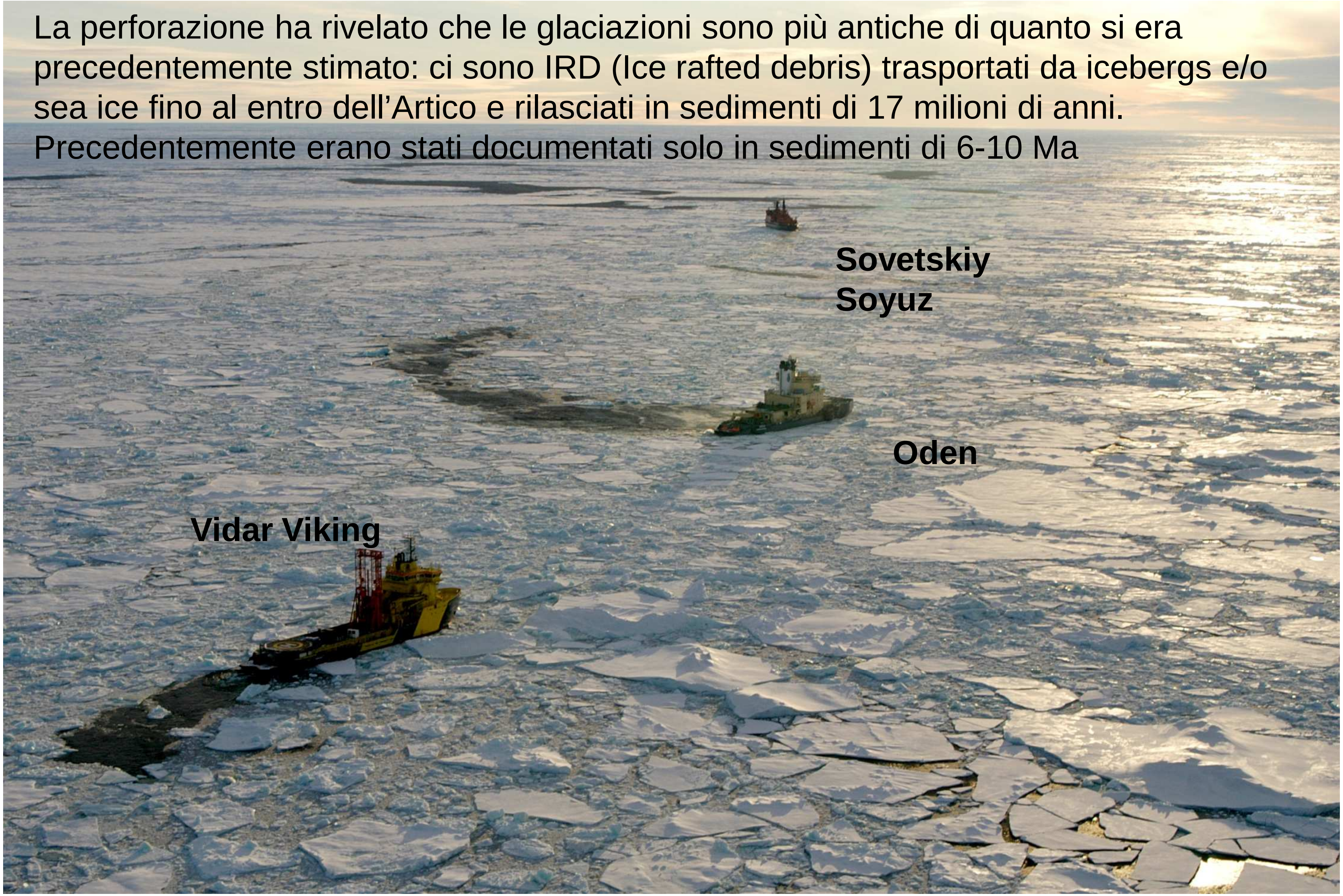
Ø. Engen et al. / Tectonophysics 450 (2008) 51–69

L'Italia (Prof. D. Rio Univ. Padova, micropaleontologo) ha partecipato all'unica perforazione profonda effettuata nell'Oceano Artico dall'Integrated Ocean Drilling Program, il leg 301 IODP ACEX del 2004.

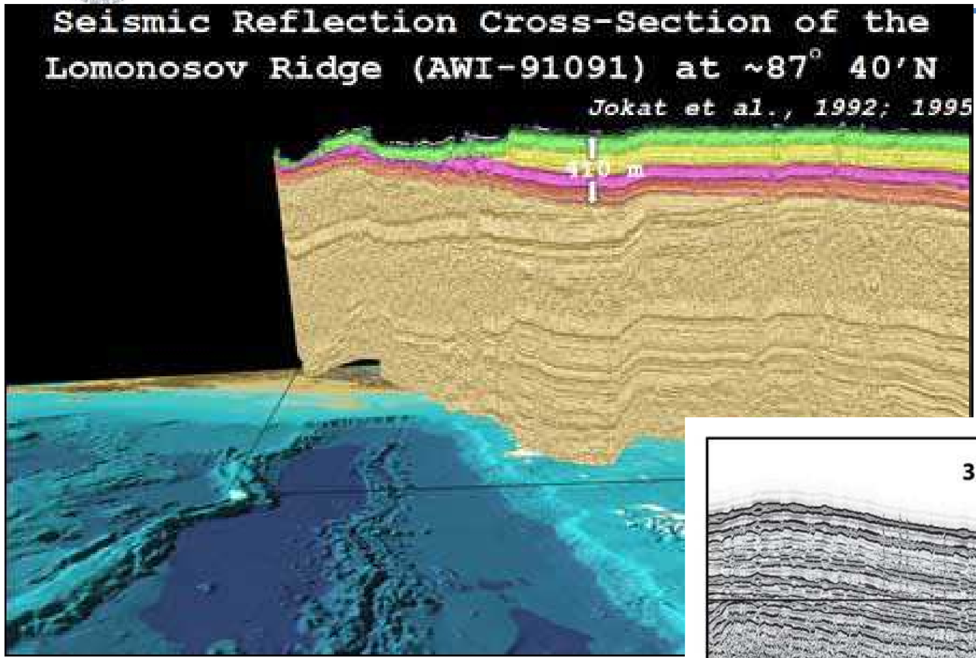
Durante tale leg sono stati prelevati 400 m circa di sedimenti sul Lomosonov ridge

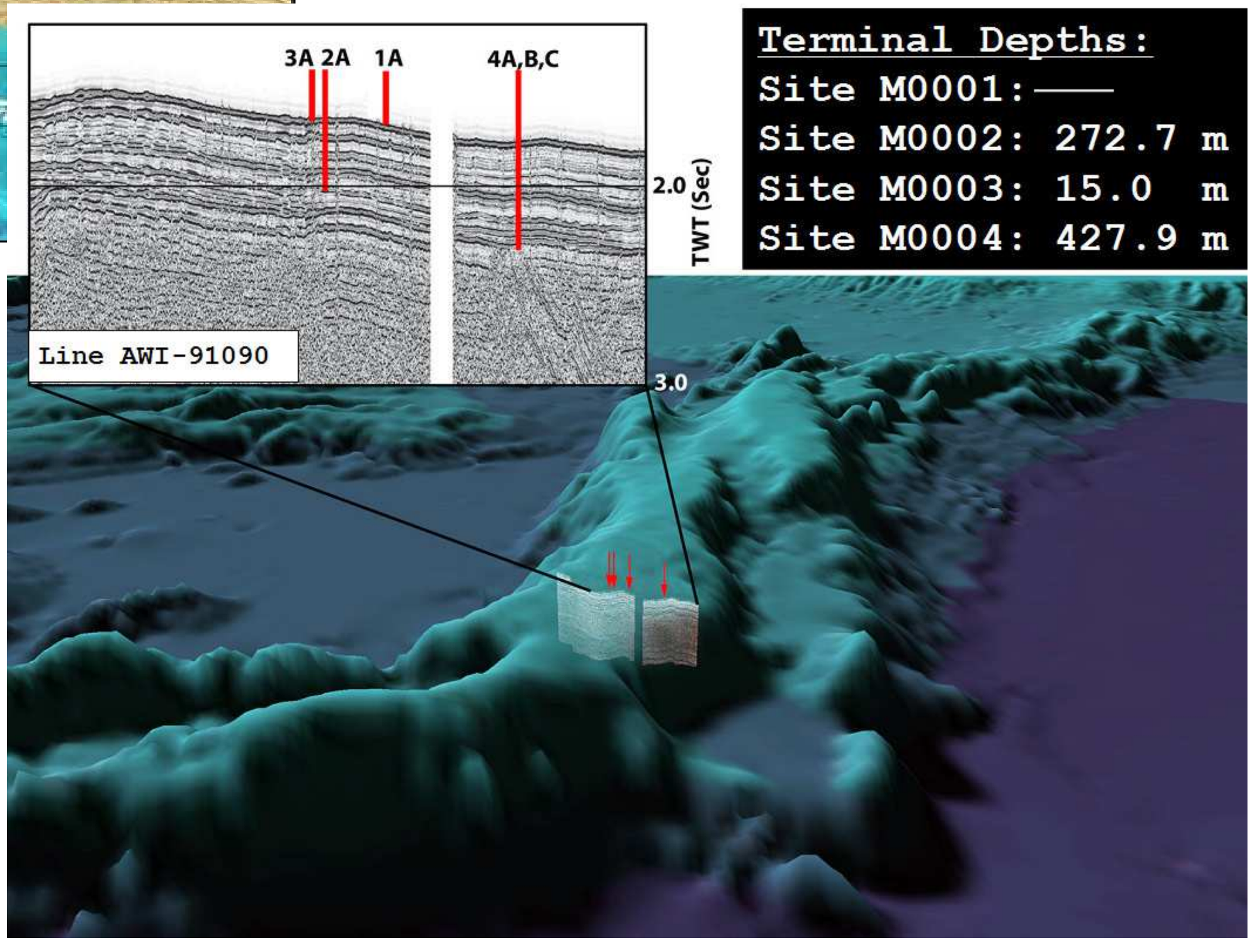

VIDAR VIKING

La perforazione ha rivelato che le glaciazioni sono più antiche di quanto si era precedentemente stimato: ci sono IRD (Ice rafted debris) trasportati da icebergs e/o sea ice fino al entro dell’Artico e rilasciati in sedimenti di 17 milioni di anni. Precedentemente erano stati documentati solo in sedimenti di 6-10 Ma



Vidar Viking could keep its position for max. 9 days


Seismic Reflection Cross-Section of the Lomonosov Ridge (AWI-91091) at ~87° 40'N
Jokat et al., 1992; 1995


3A 2A 1A
4A,B,C
2.0
3.0
TWT (Sec)
Line AWI-91090
Terminal Depths:
Site M0001: ——
Site M0002: 272.7 m
Site M0003: 15.0 m
Site M0004: 427.9 m

IODP leg 302 in the Arctic Ocean (2004)

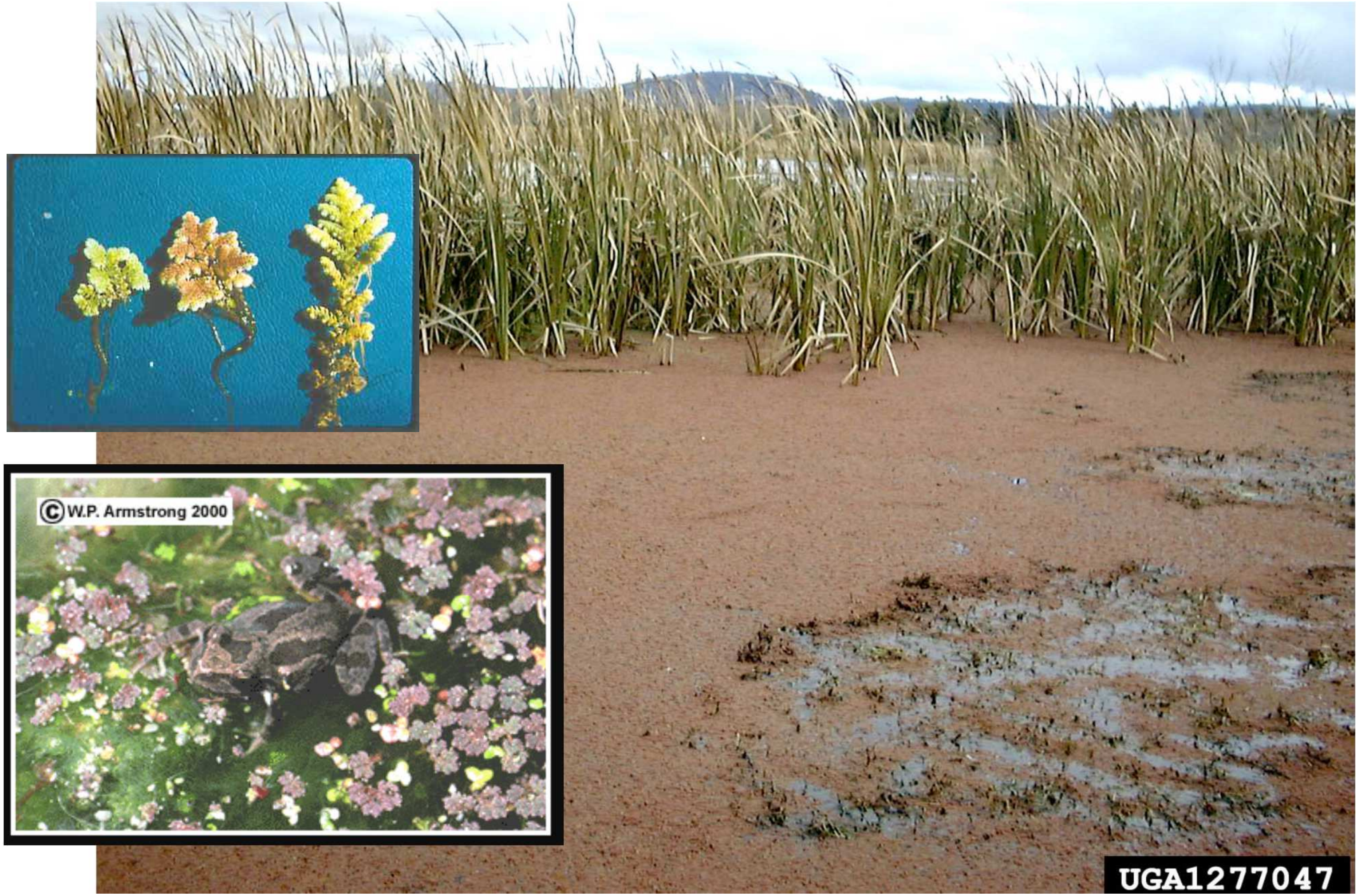
Co-chiefs: Backman, J., Moran, K., Evans, D.,

- Provided the timing of the deep–water connection to the North Atlantic Ocean of the Arctic Ocean: a key driver of the deep–water formation in the North Atlantic and Arctic Oceans, which in turn is a key driver of global climate.

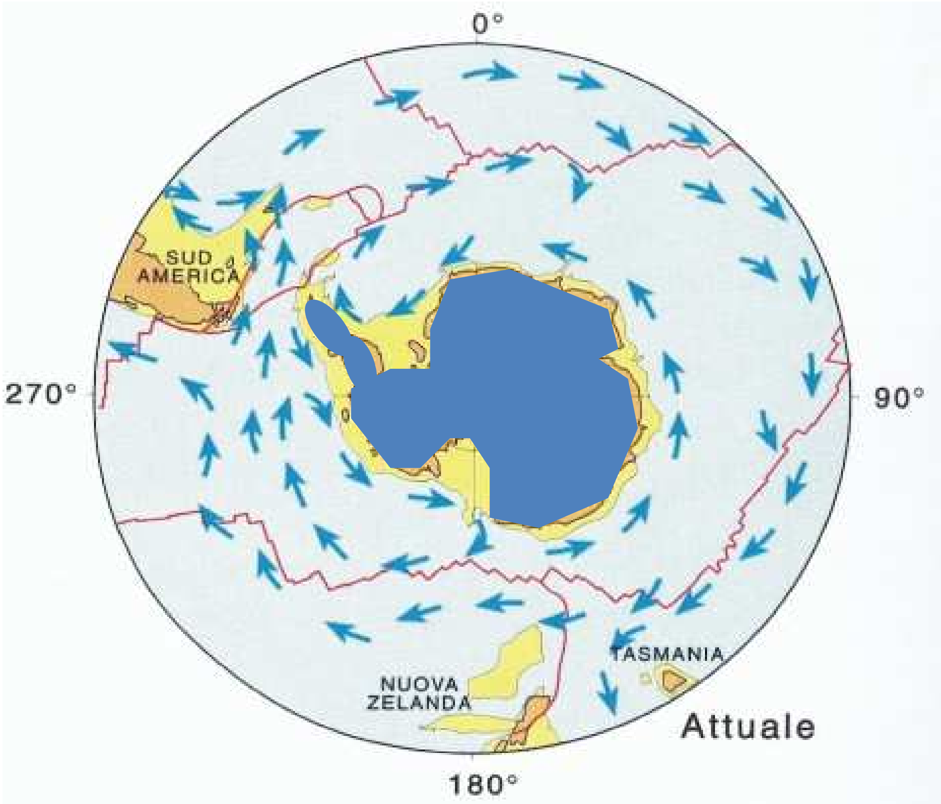
- Confirmed that the Lomonosov Ridge is constructed of continental crust, genetically linked to the Barents Shelf.

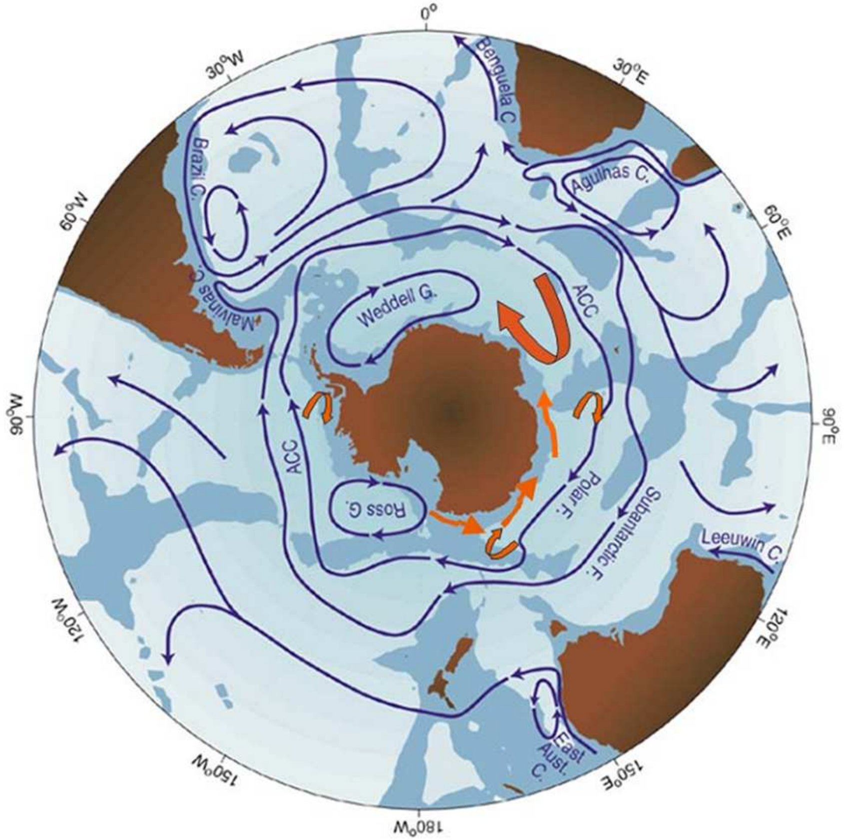
- Revealed that the Cenozoic cooling in the Arctic occurred 17 Ma and possibly of 46 Ma ago, synchronously with that in the Antarctic, contrary to previous hypotheses.

Condizioni ambientali tipiche degli attuali regimi tropicali 55 Milioni di anni fa, con scarsa ventilazione, acqua dolce e condizioni anossiche (Arctic pond) intorno a 48.5 milioni di anni fa (rocce madri di idrocarburi)



ACC transport of 100-150 Sverdrups (1 Sv=10^6 m^3 s^{-1}).
Mean ACC temperature ranges from -1 to 5°C, depending on the time of year and location. The mean surface salinity decreases poleward, in general, from 34.9 at 35°S to 34.7 at 65°S.
he ACC extends from the sea surface to depths of 2000-4000 m and can be as wide as 2000 km. ACC flows eastward at 20 cms^{-1} in regions between the fronts, driven by strong westerly winds. The average wind speed between 40°S and 60°S is 15 to 24 knots with strongest winds typically between 45°S and 55°S.





From Baroni, modified

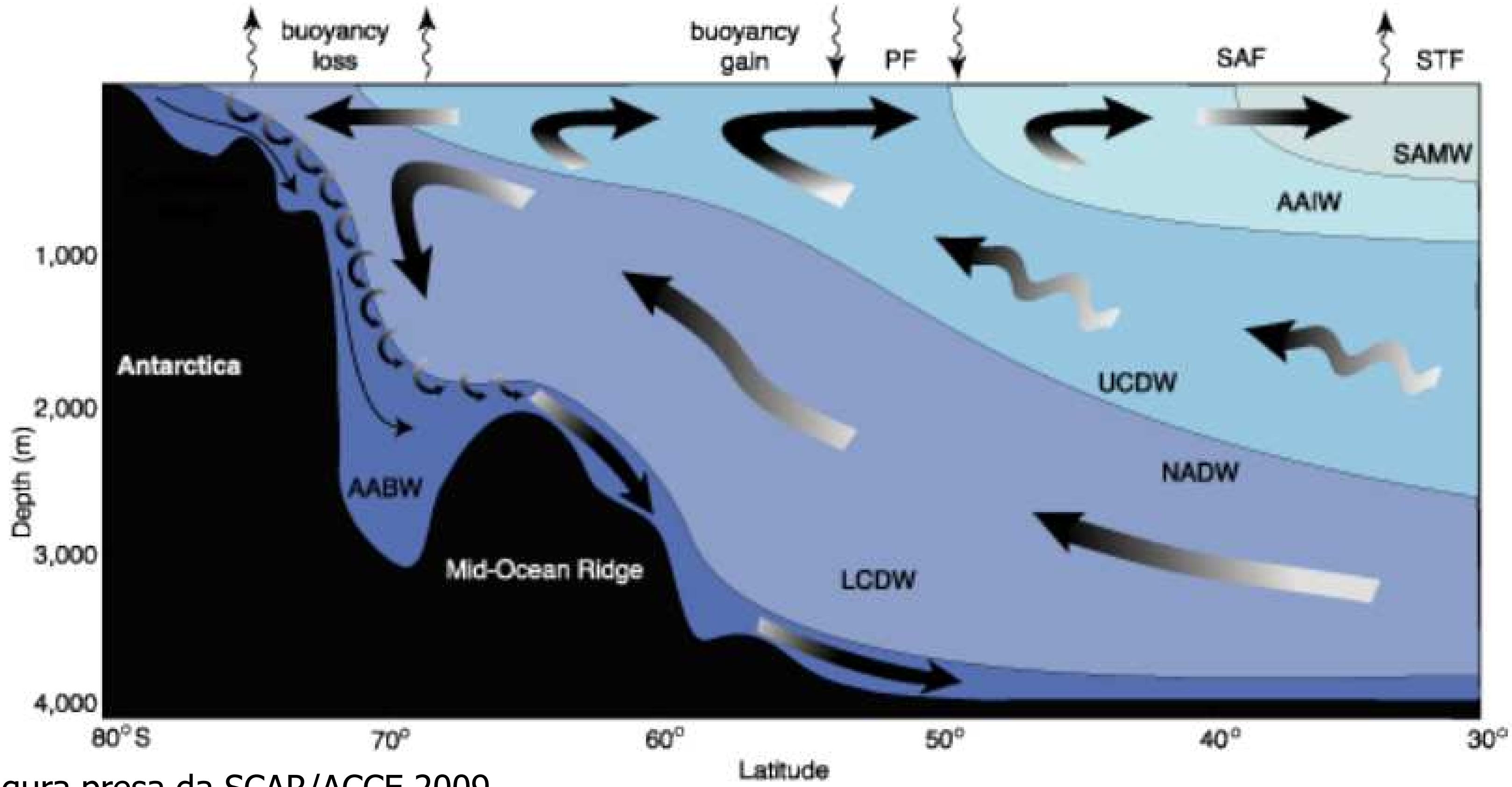
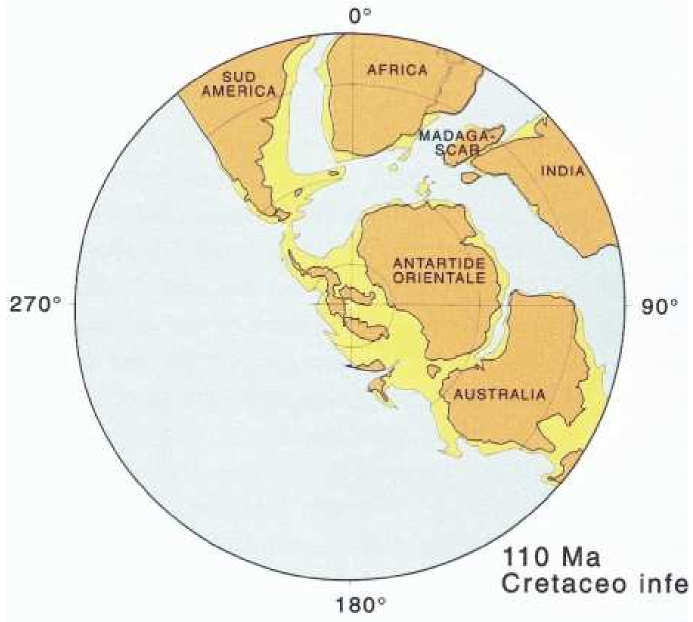
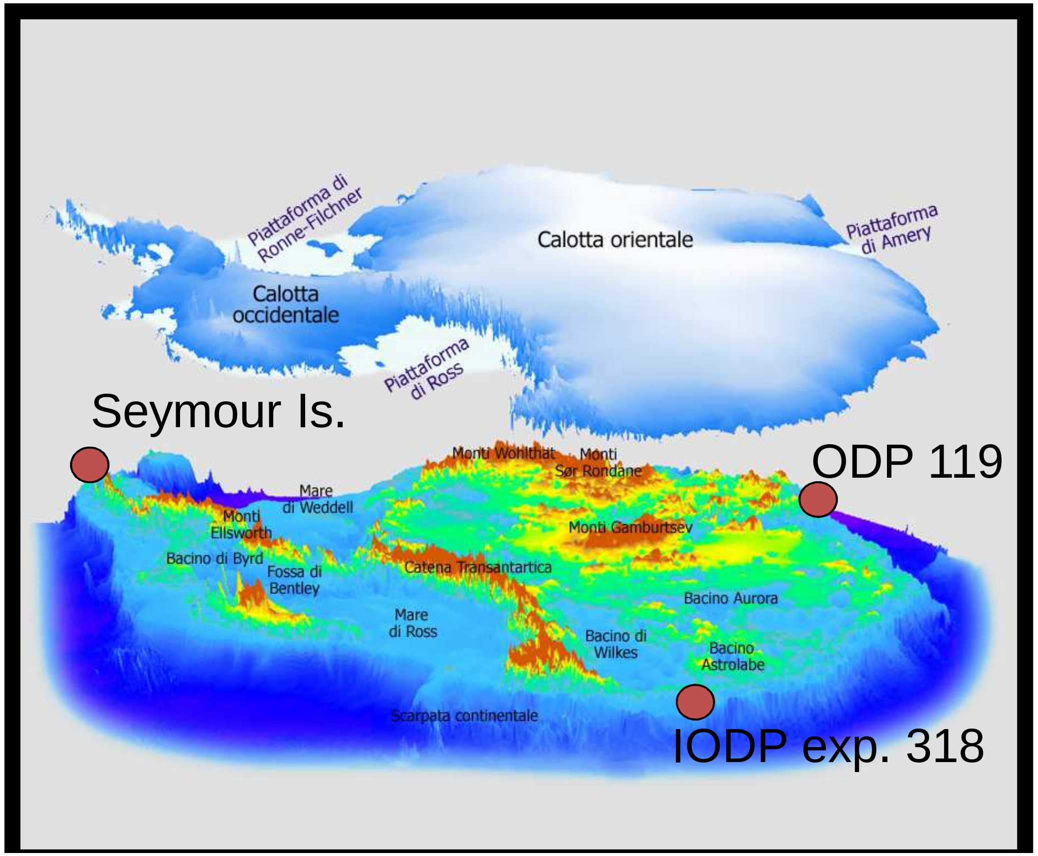


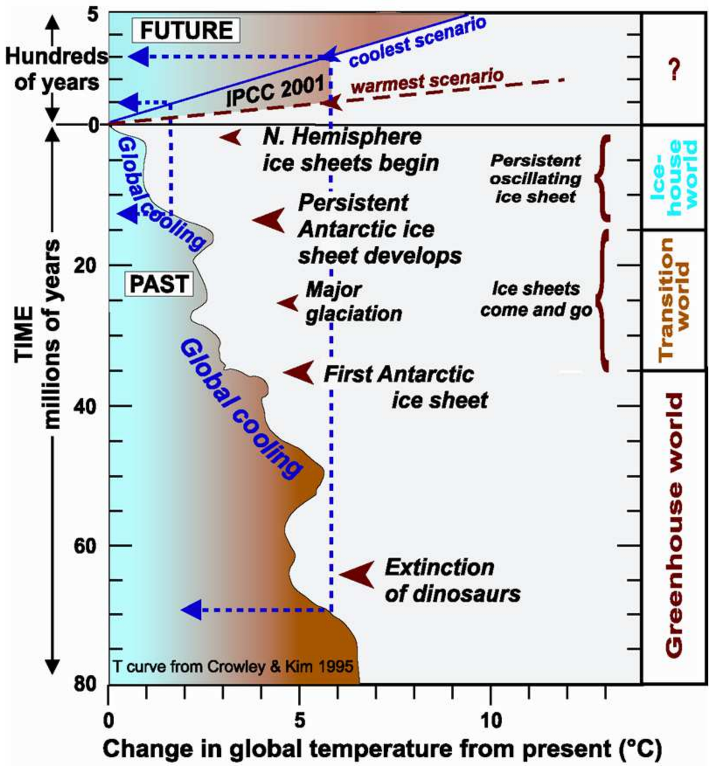
Figura presa da SCAR/ACCE 2009

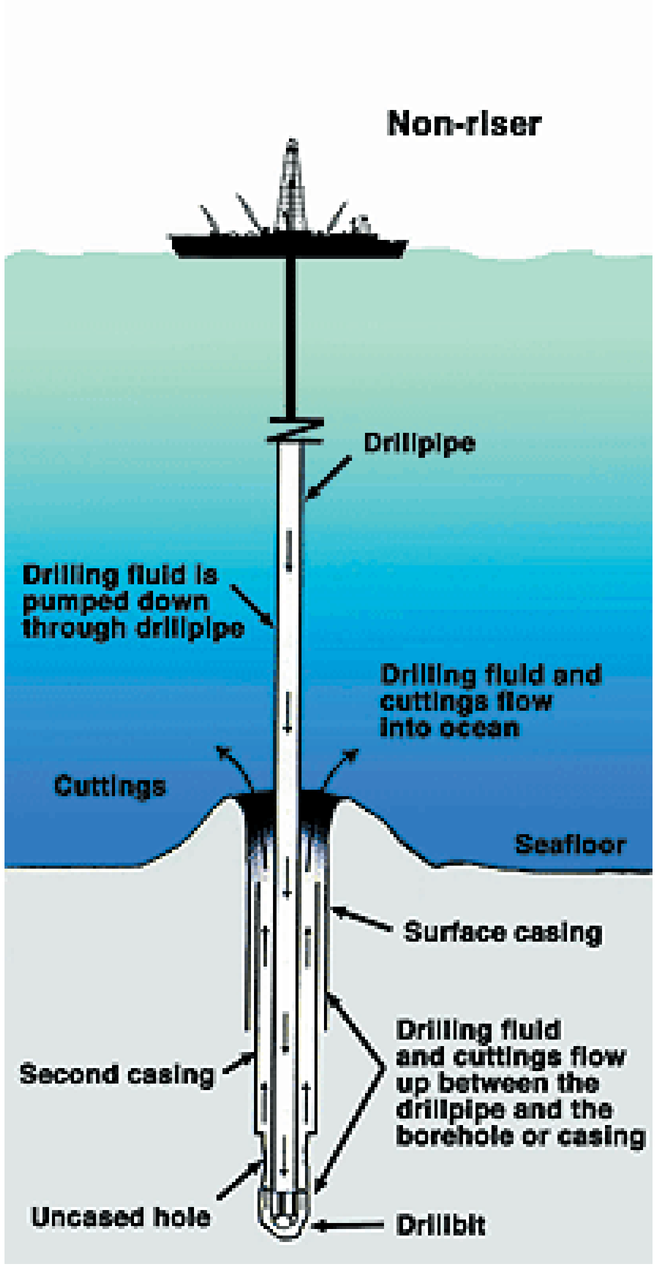
PF – Polar Front; SAF – Sub-Antarctic Front; and STF – Subtropical Front
AABW – Antarctic Bottom Water; LCDW and UCDW, Lower and Upper Circumpolar Deep Waters; NADW – North Atlantic Deep Water; AAIW – Antarctic Intermediate Water and SAMW – Sub-Antarctic Mode Water (from Speer et al., 2000).

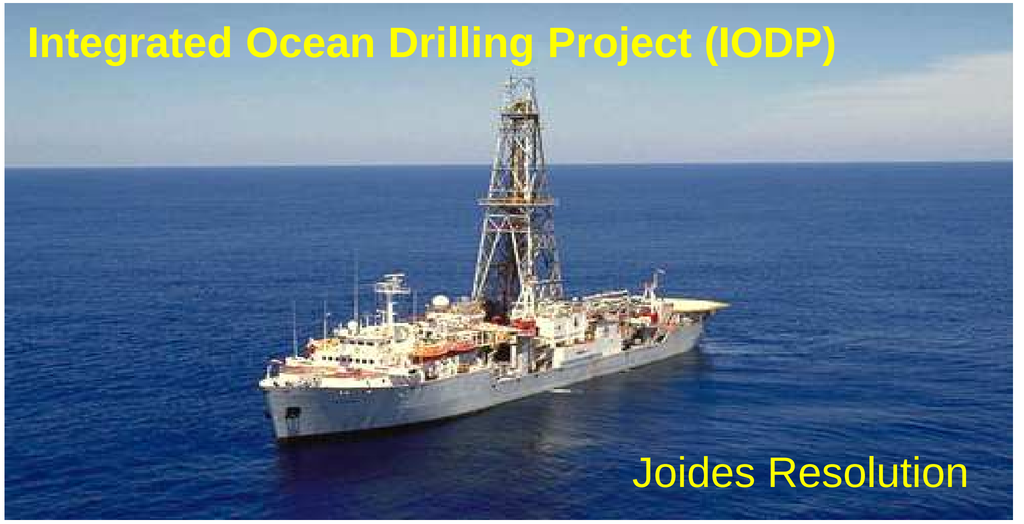

Greenhouse world


0°
SUD AMERICA
AFRICA
MADAGA-SCAR
INDIA
ANTARTIDE ORIENTALE
AUSTRALIA
270°
90°
180°
110 Ma
Cretaceo infe


Piattaforma di Ronne-Filchner
Calotta orientale
Piattaforma di Amery
Calotta occidentale
Piattaforma di Ross
Seymour Is.
ODP 119
Monti Wohlthat
Monti Sør Rondane
Mare di Weddell
Monti Ellsworth
Monti Gamburtsev
Bacino di Byrd
Fossa di Bentley
Catena Transantartica
Bacino Aurora
Mare di Ross
Bacino di Wilkes
Bacino Astrolabe
Scarpata continentale
IODP exp. 318


FUTURE
coolest scenario
IPCC 2001
warmest scenario
Hundreds of years
?
N. Hemisphere ice sheets begin
Persistent oscillating ice sheet
Ice-house world
Global cooling
Persistent Antarctic ice sheet develops
PAST
Major glaciation
Ice sheets come and go
Transition world
TIME millions of years
First Antarctic ice sheet
Global cooling
Greenhouse world
Extinction of dinosaurs
T curve from Crowley & Kim 1995
5
0
20
40
60
80
0
5
10
Change in global temperature from present (°C)


Non-riser
Drillpipe
Drilling fluid is pumped down through drillpipe
Drilling fluid and cuttings flow into ocean
Cuttings
Seafloor
Surface casing
Second casing
Drilling fluid and cuttings flow up between the drillpipe and the borehole or casing
Uncased hole
Drillbit

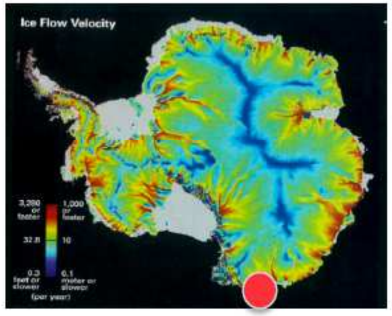

Integrated Ocean Drilling Project (IODP)
Joides Resolution

Pollen from the e. Eocene peak greenhouse conditions
Wilkes Land IODP Site 1356

Pollen of extent palms

Pollen from Wilkes Land

Mean Annual T: >13.3 °C
Cold Month mean T: >5°C + 3°C
Warm Month mean T: >22.8 °C

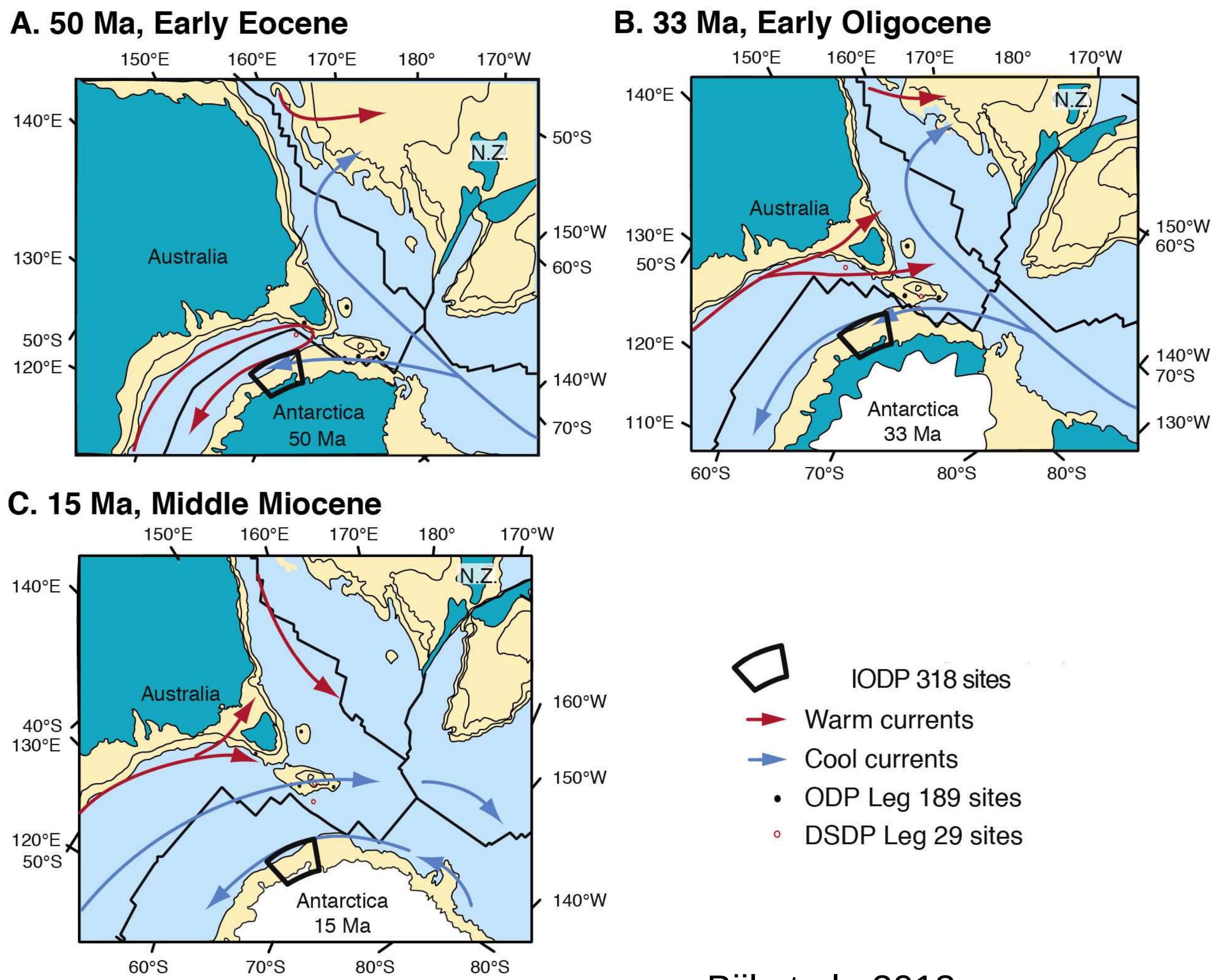


Pollen of extent Bombacaceae plants

Pollen from Wilkes Land

Mean Annual T: >16.8 ºC
Cold Month mean T: >10.6 °C + 3°C
Warm Month mean T: >21.5 °C

Pross et al., Nature, 2012
Contreras et al., 2013



Bjil et al., 2013

Eocene records of Antarctic vegetation and landscape history (e.g. Lewis et al., 2007, Hambrey et al., 2007, Wilson et al., 2011).

The Eocene/Oligocene boundary unconformity was crossed by exp. 318, and sub-tropical vegetation was found at 53.6–51.9 Ma in the early Eocene (Pross et al., 2012).

IODP Exp. 318 (2010)

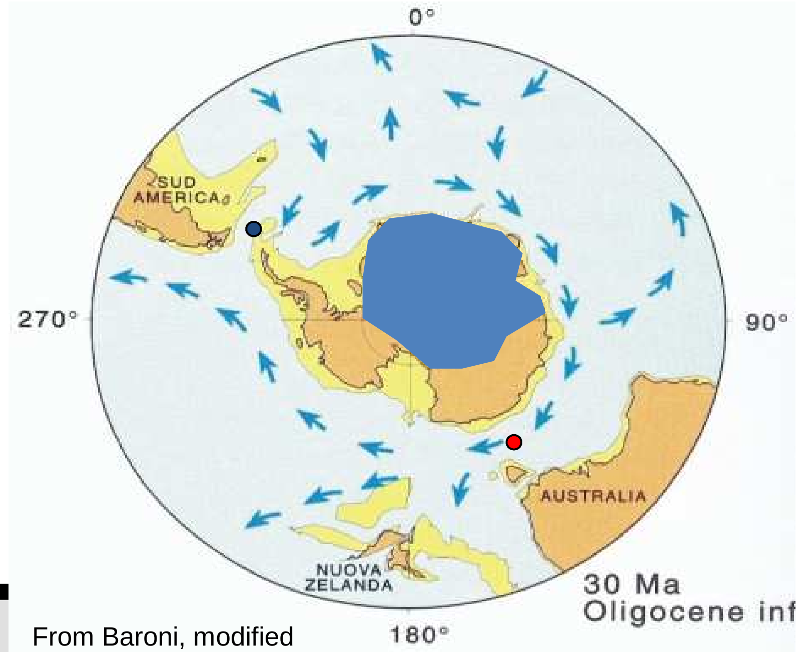
LETTER

doi:10.1038/nature11300

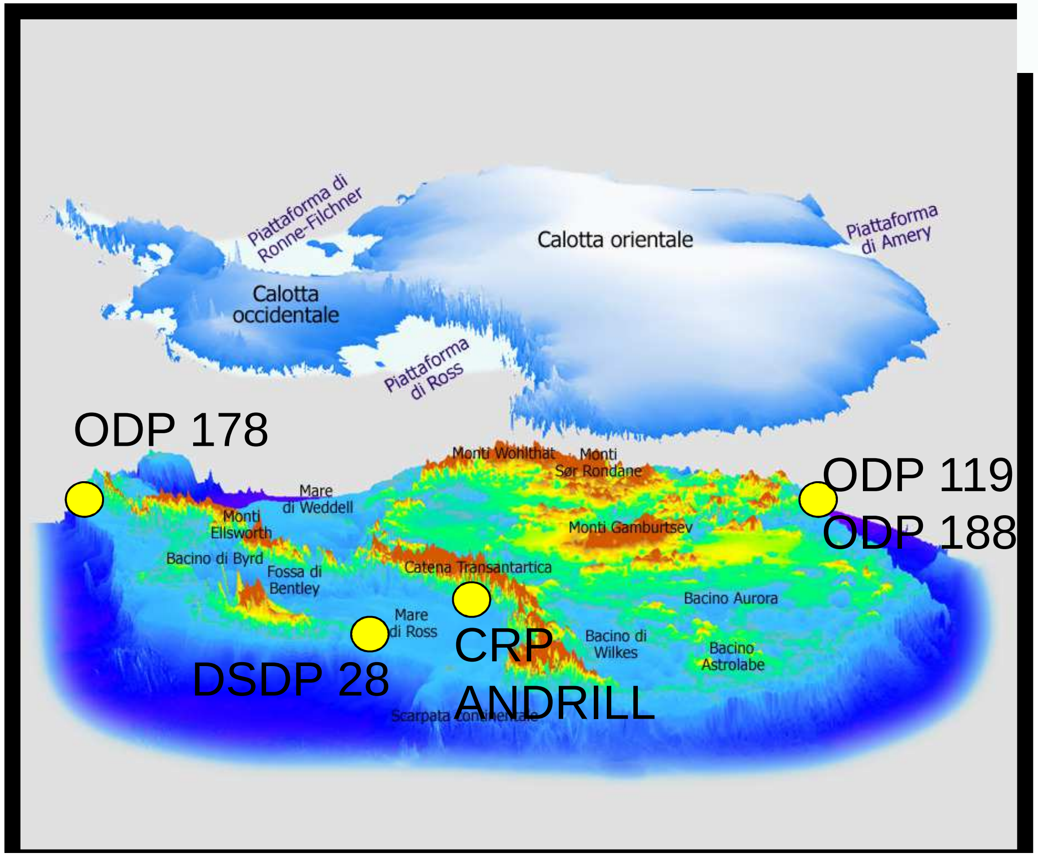
Persistent near-tropical warmth on the Antarctic continent during the early Eocene epoch

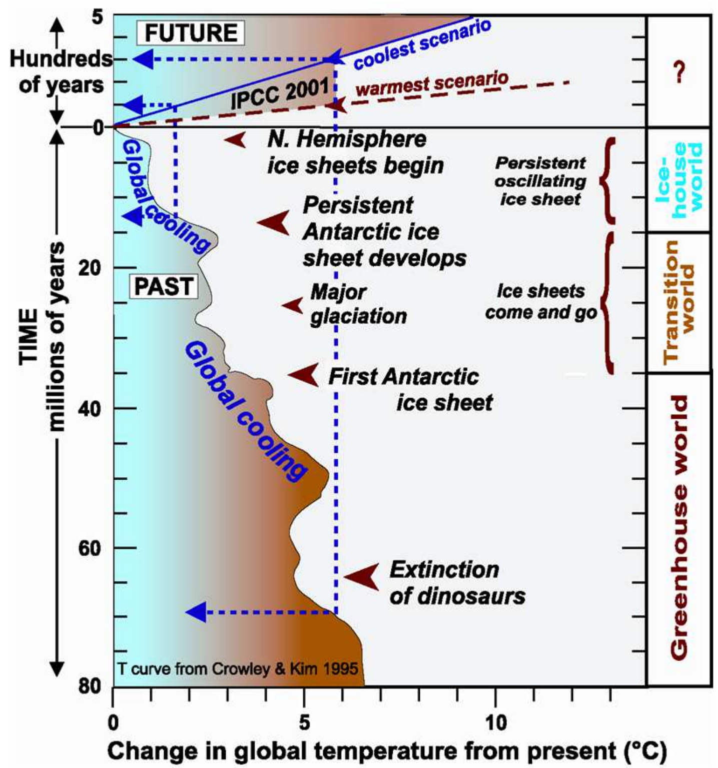
Jörg Pross[1,2], Lineth Contreras[1], Peter K. Bijl[3], David R. Greenwood[4], Steven M. Bohaty[5], Stefan Schouten[6], James A. Bendle[7], Ursula Röhl[8], Lisa Tauxe[9], J. Ian Raine[10], Claire E. Huck[11], Tina van de Flierdt[11], Stewart S. R. Jamieson[12], Catherine E. Stickley[13], Bas van de Schootbrugge[1], Carlota Escutia[14], Henk Brinkhuis[3] & Integrated Ocean Drilling Program Expedition 318 Scientists*

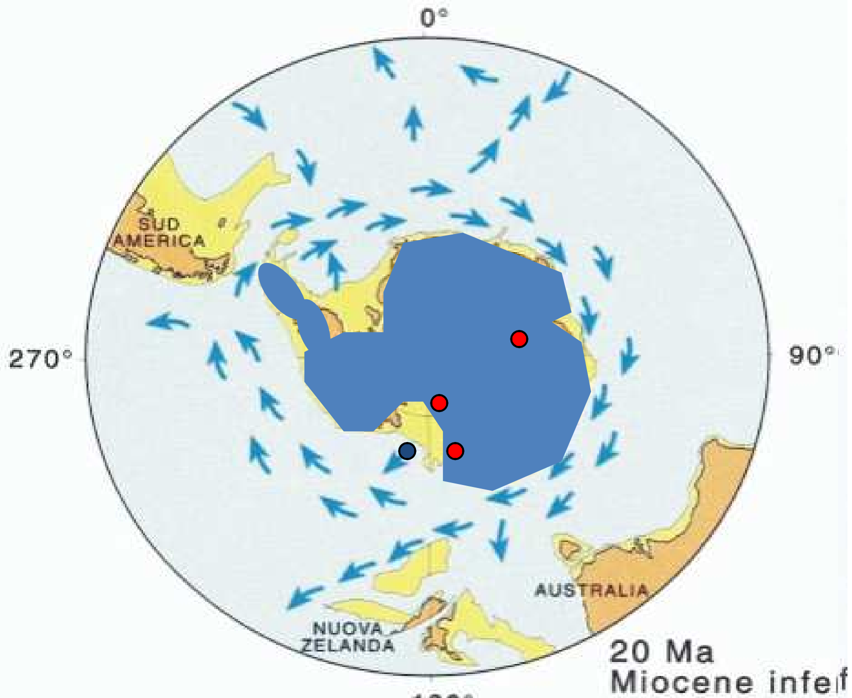
2 AUGUST 2012 | VOL 488 | NATURE | 73



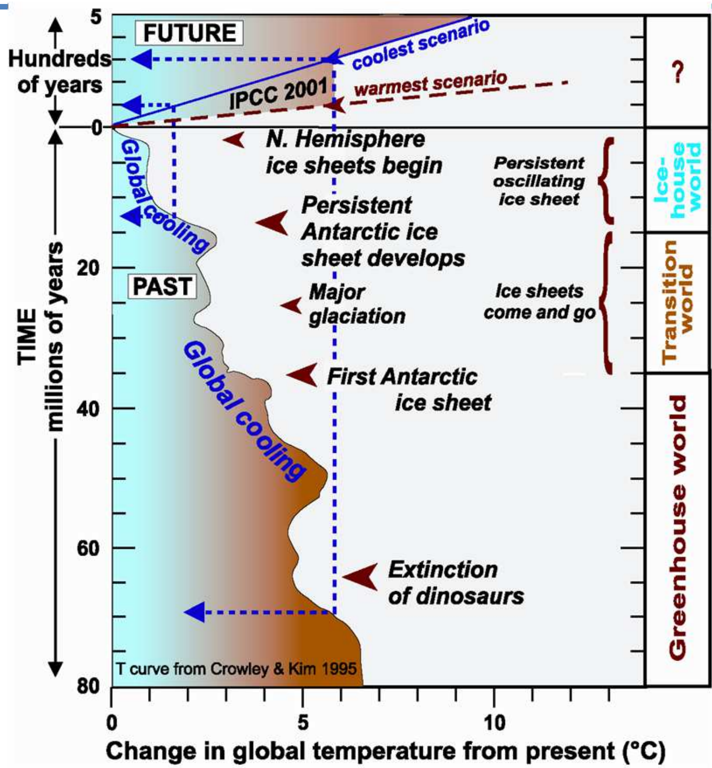
From Baroni, modified





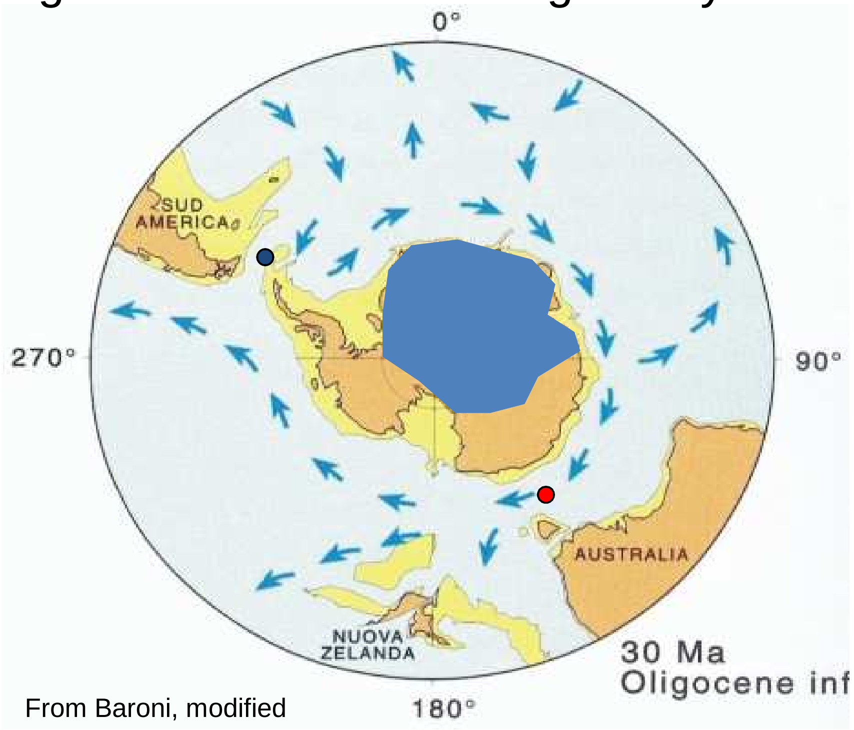


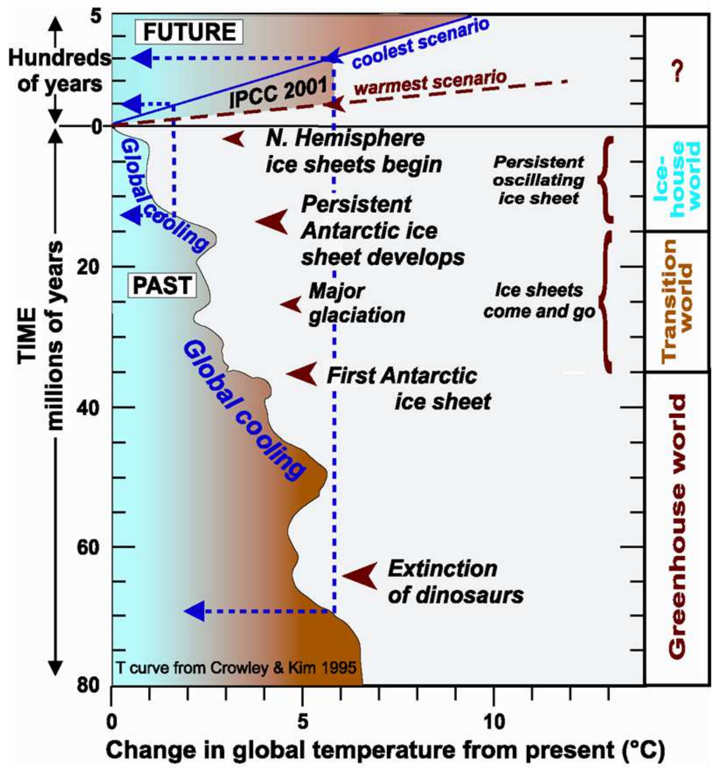
From Baroni, modified



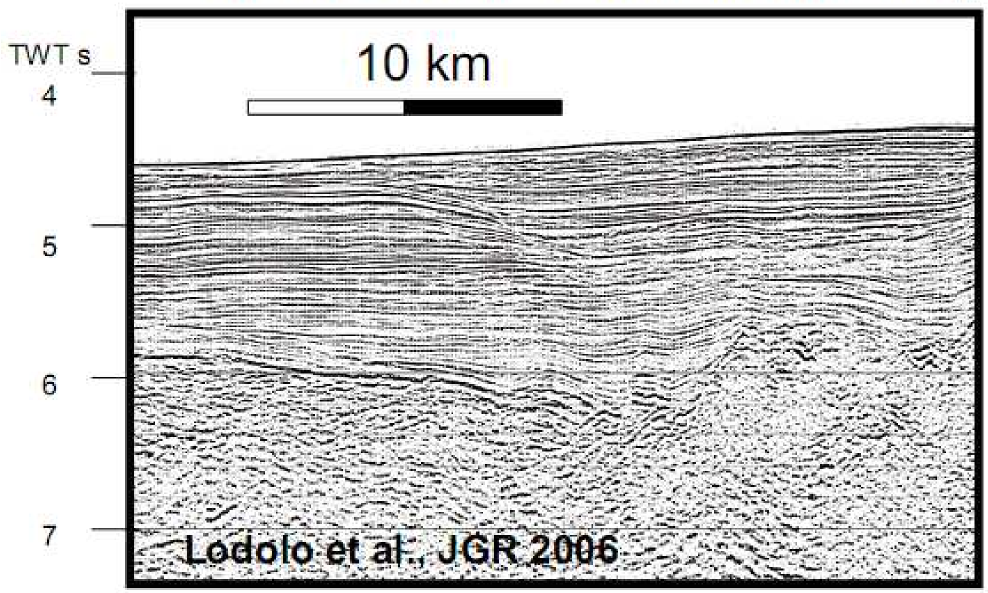
Sirius Formation - Foto by D. Harwood

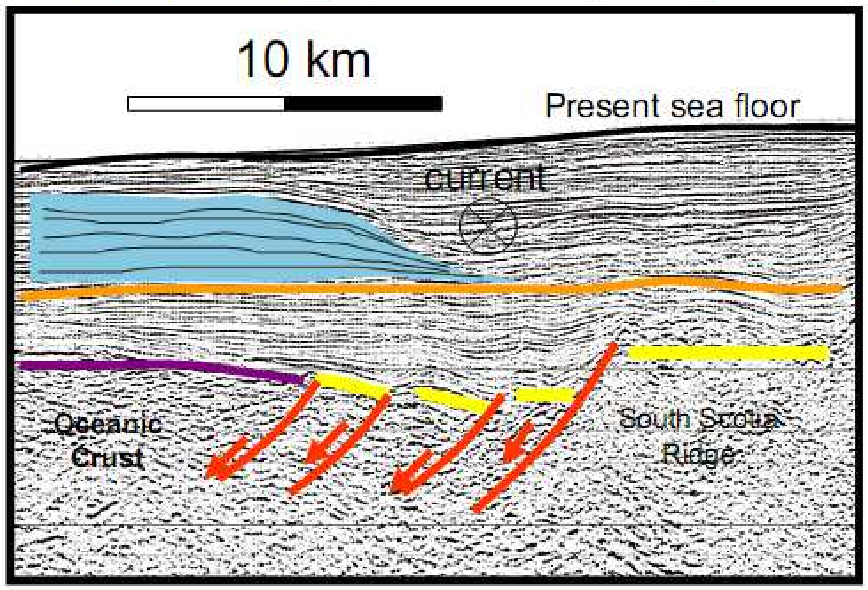
Opening of Tasman and Drake gateways

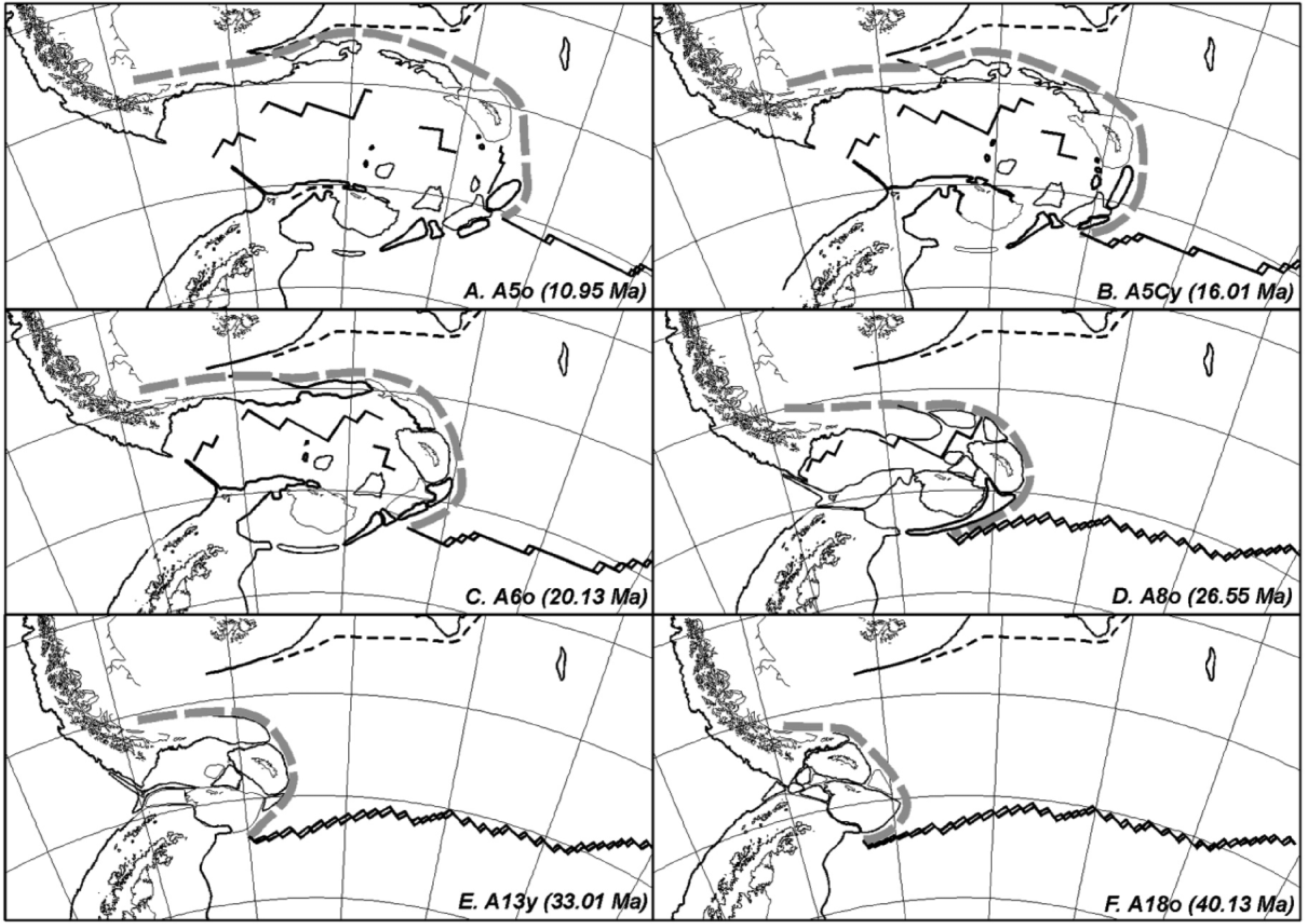




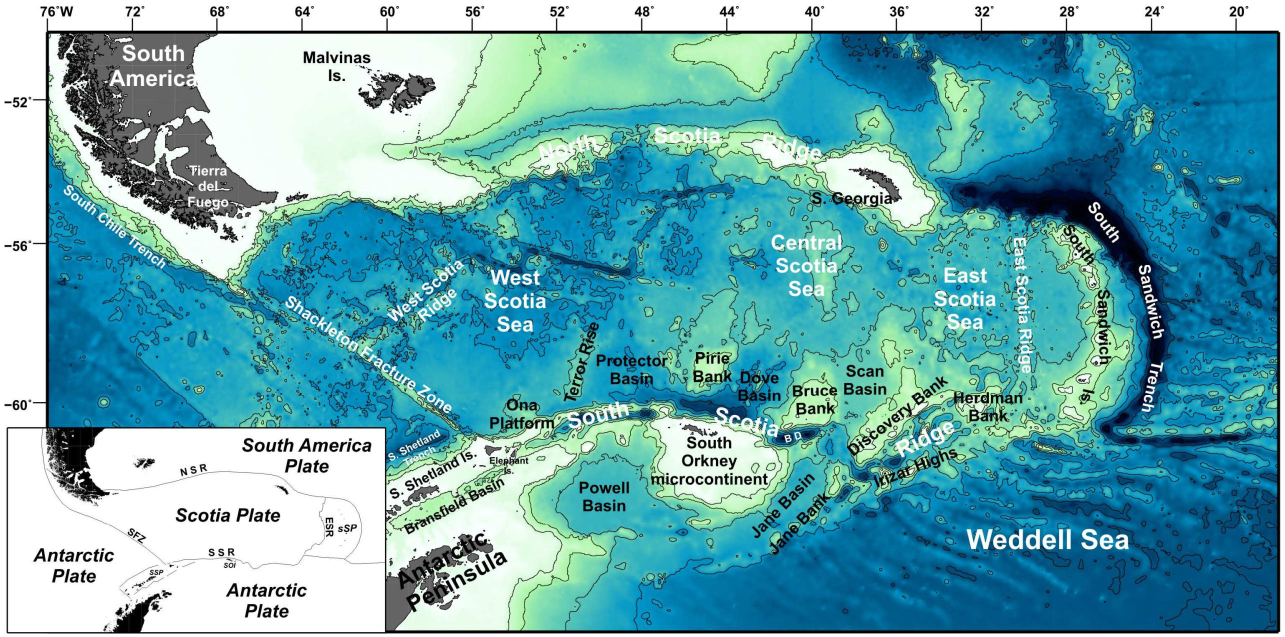
Current-controlled sediment drift forming after the opening of the Drake passage



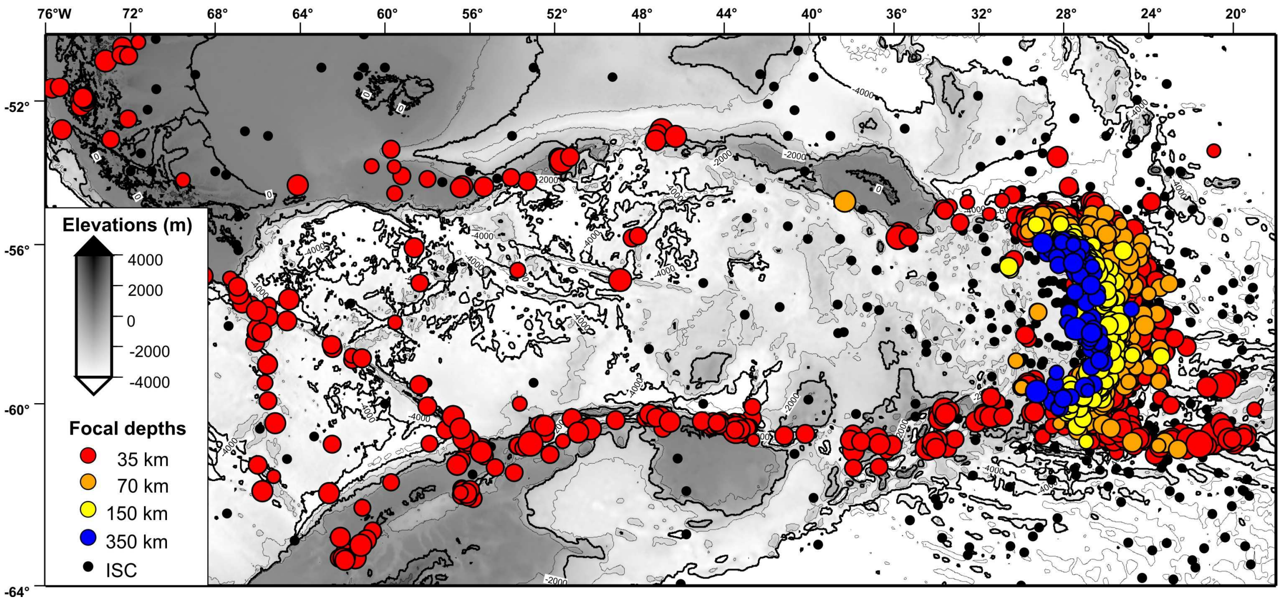




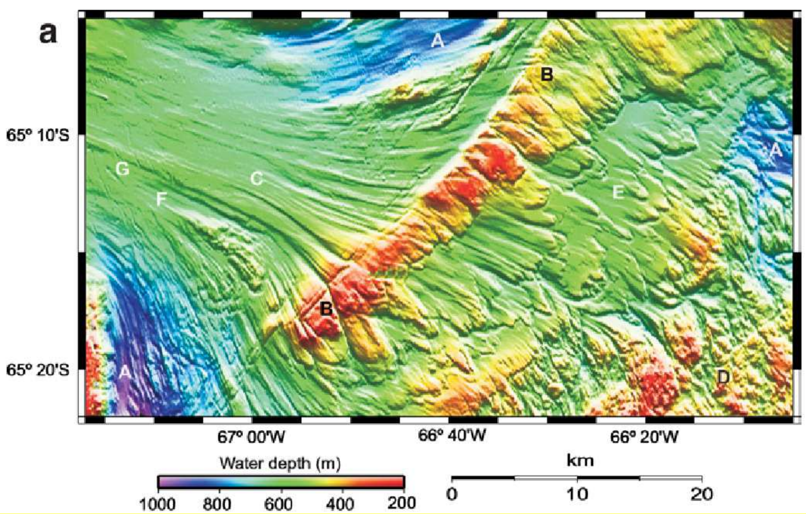
Barker, 2001, Earth Sciences Review



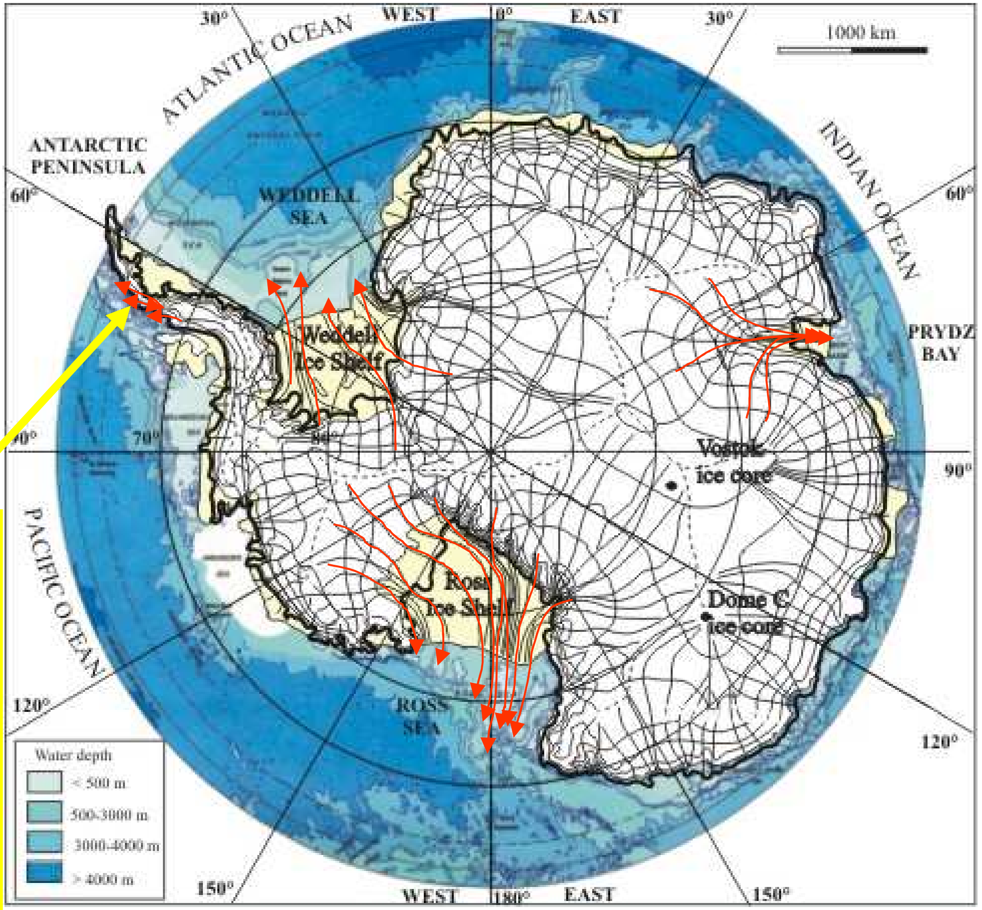
Principali elementi morfo-strutturali della placca di Scozia (sopra) e distribuzione degli eventi sismici (sotto)

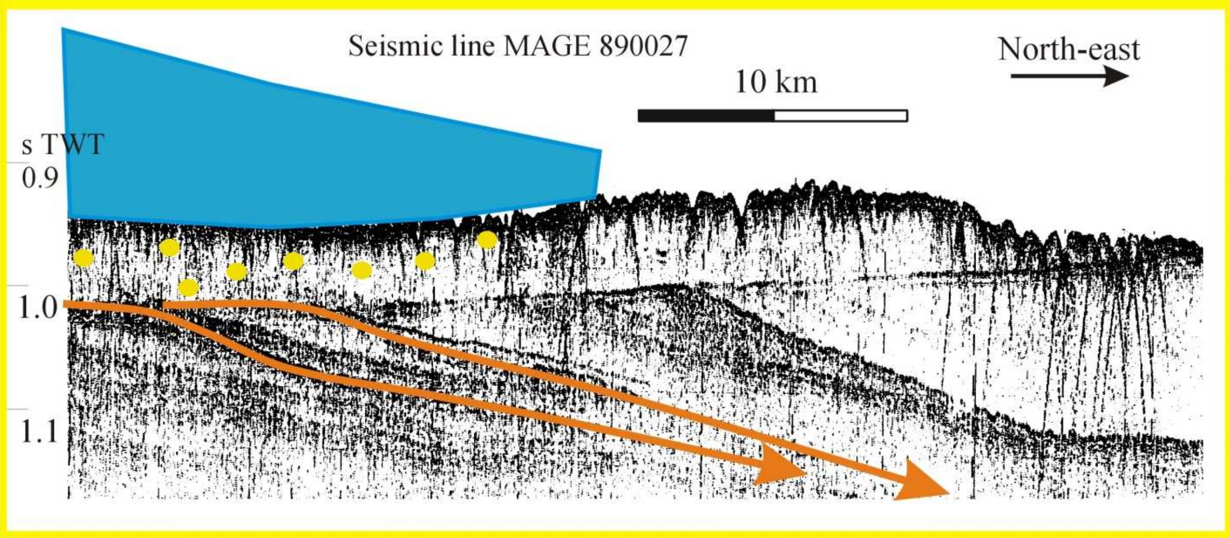


QUATERNARIO

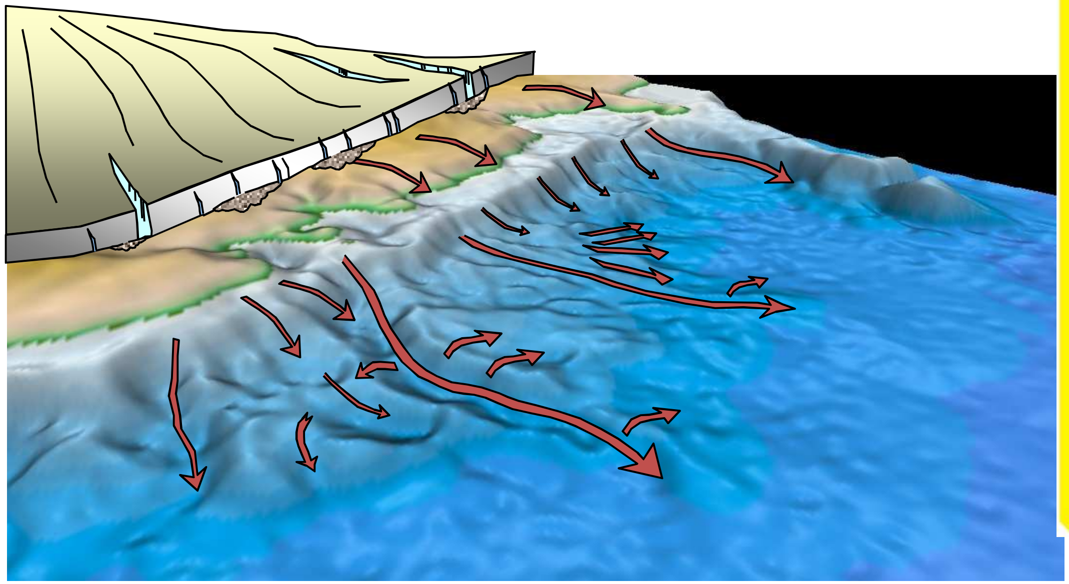


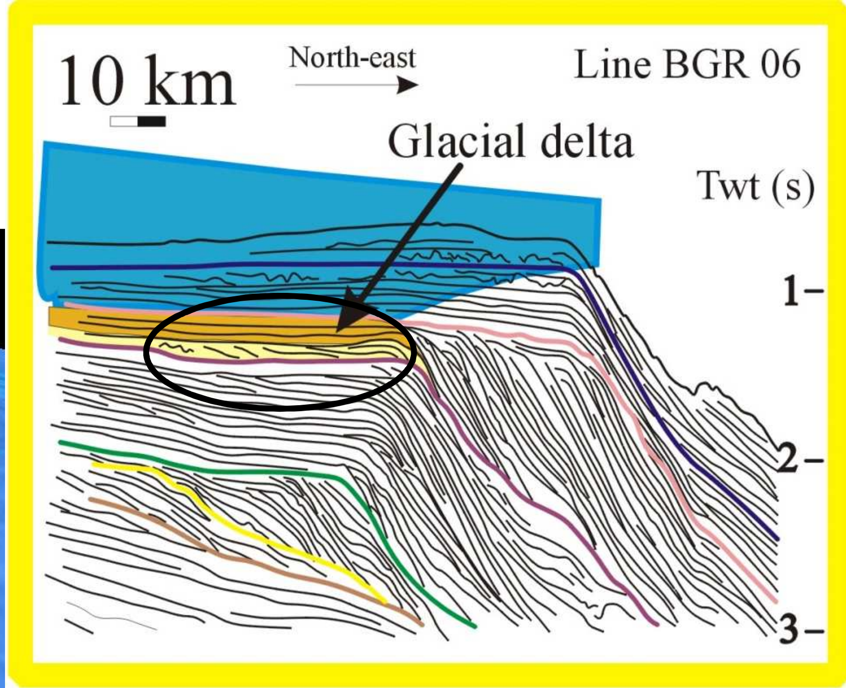
Eos, vol. 84, 11, March 2003

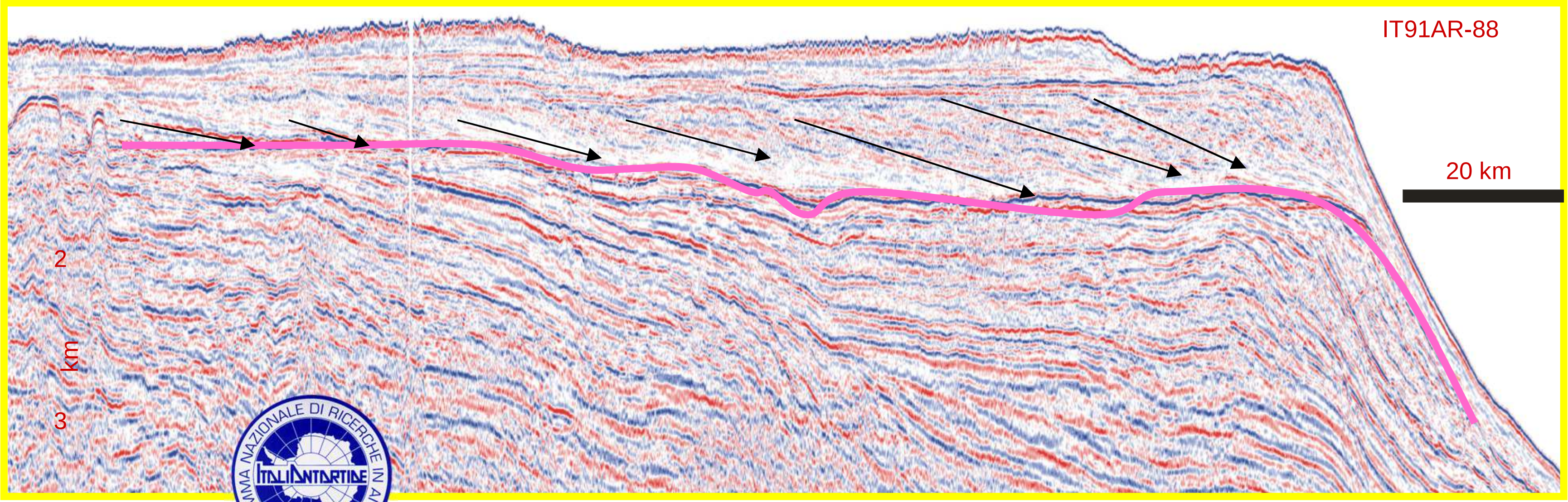




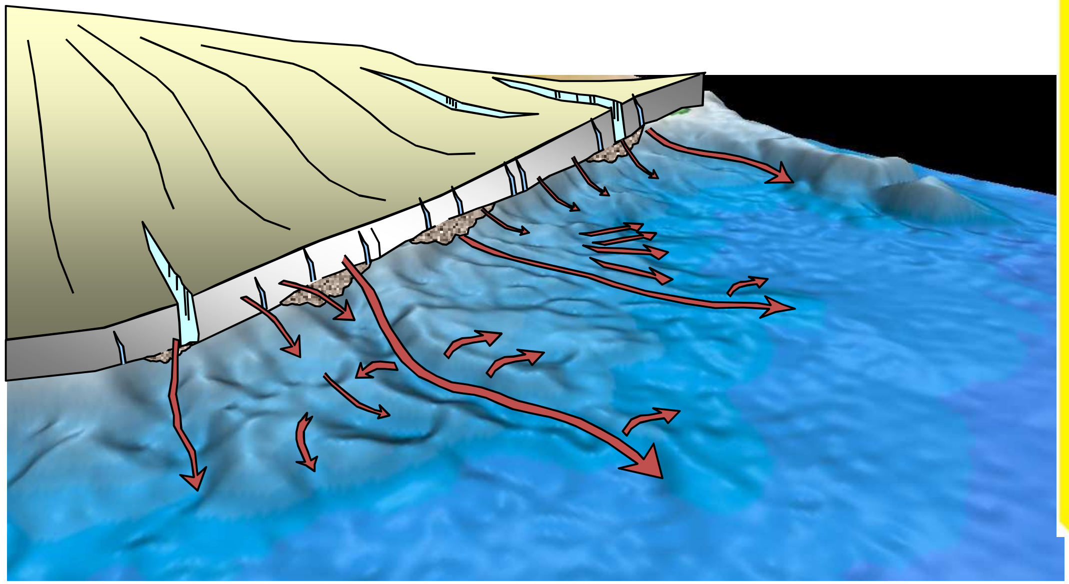
Nelle fasi di massima espansione i sedimenti alla base del ghiaccio sono deposti sul ciglio del margine continentale.

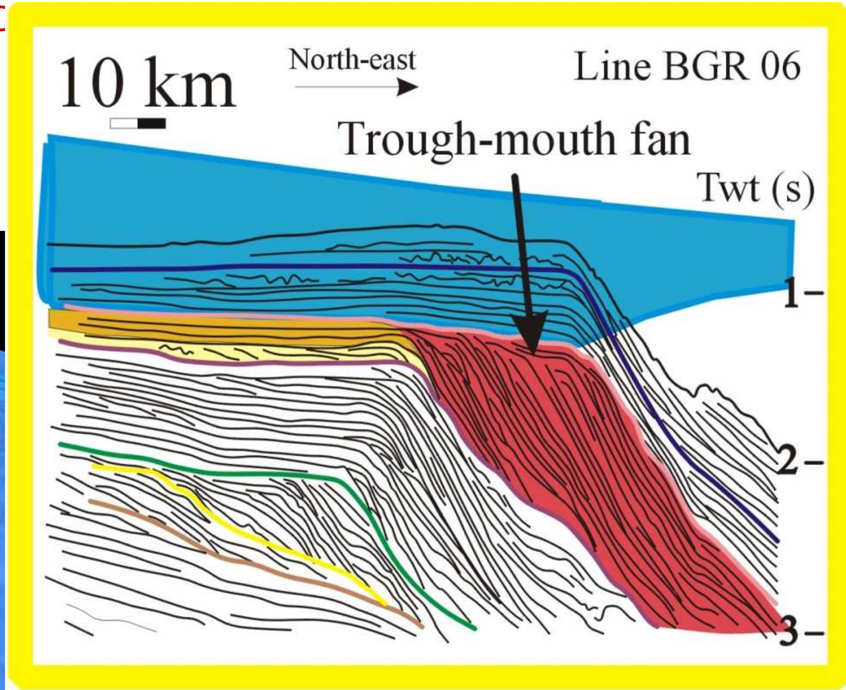


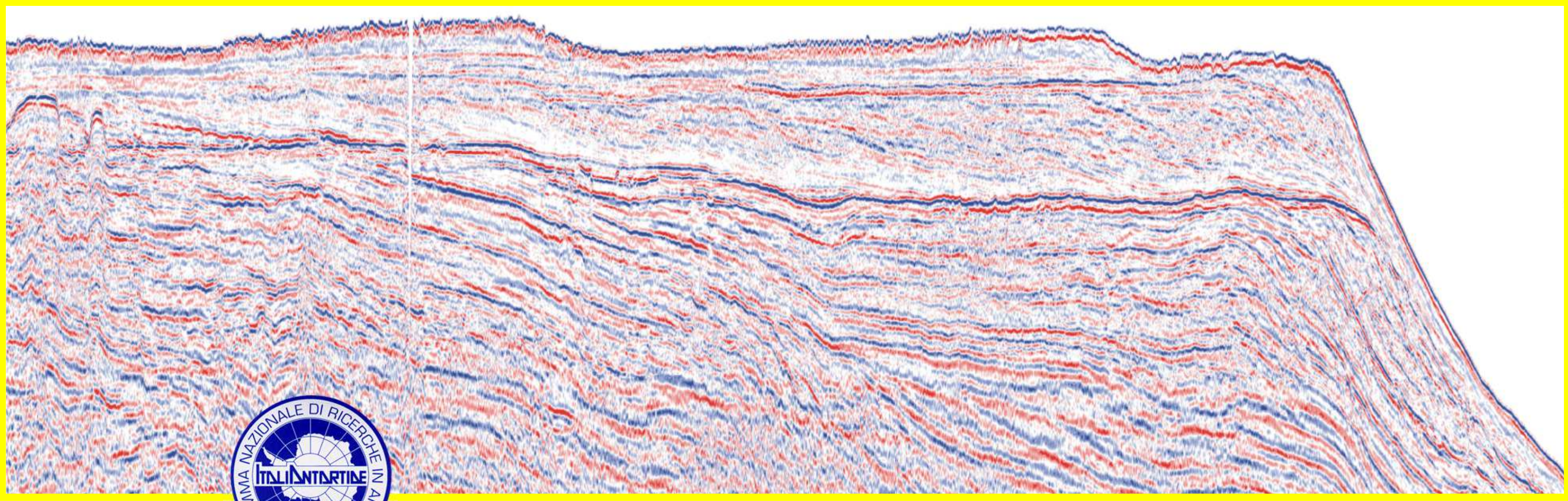




Sauli, Busetti, D

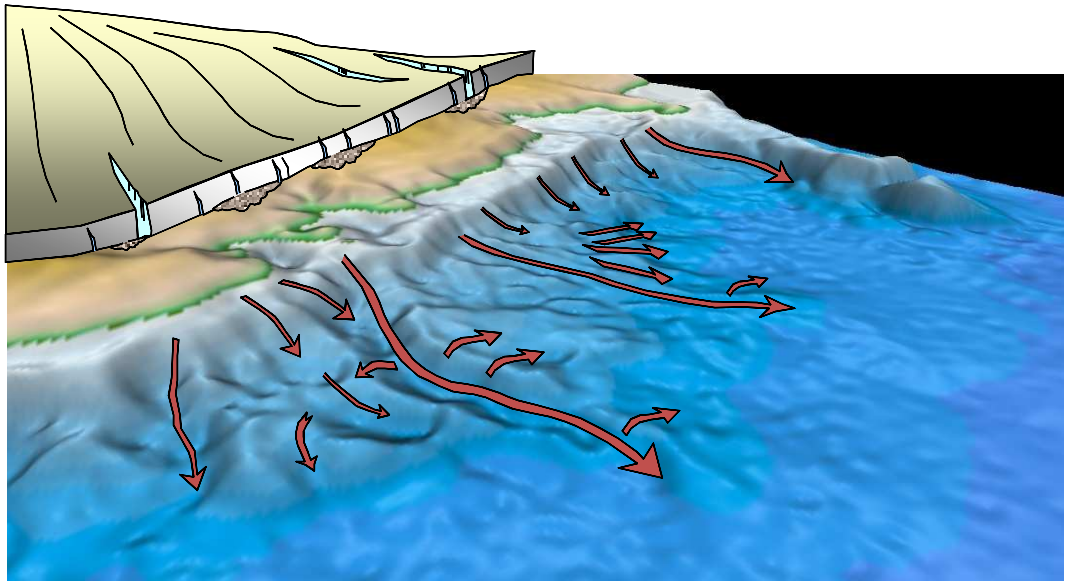


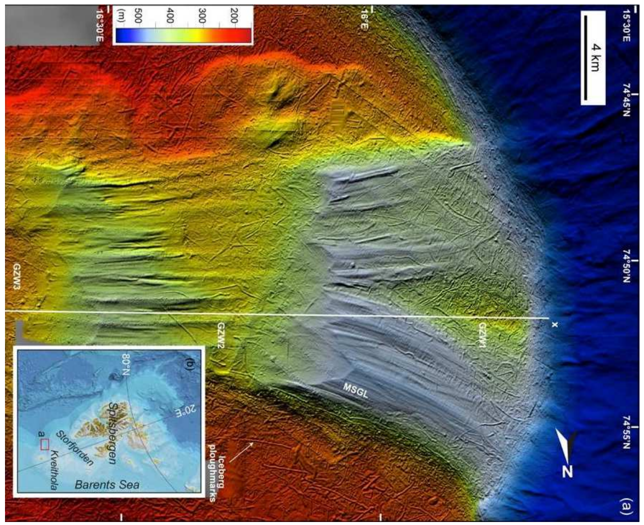


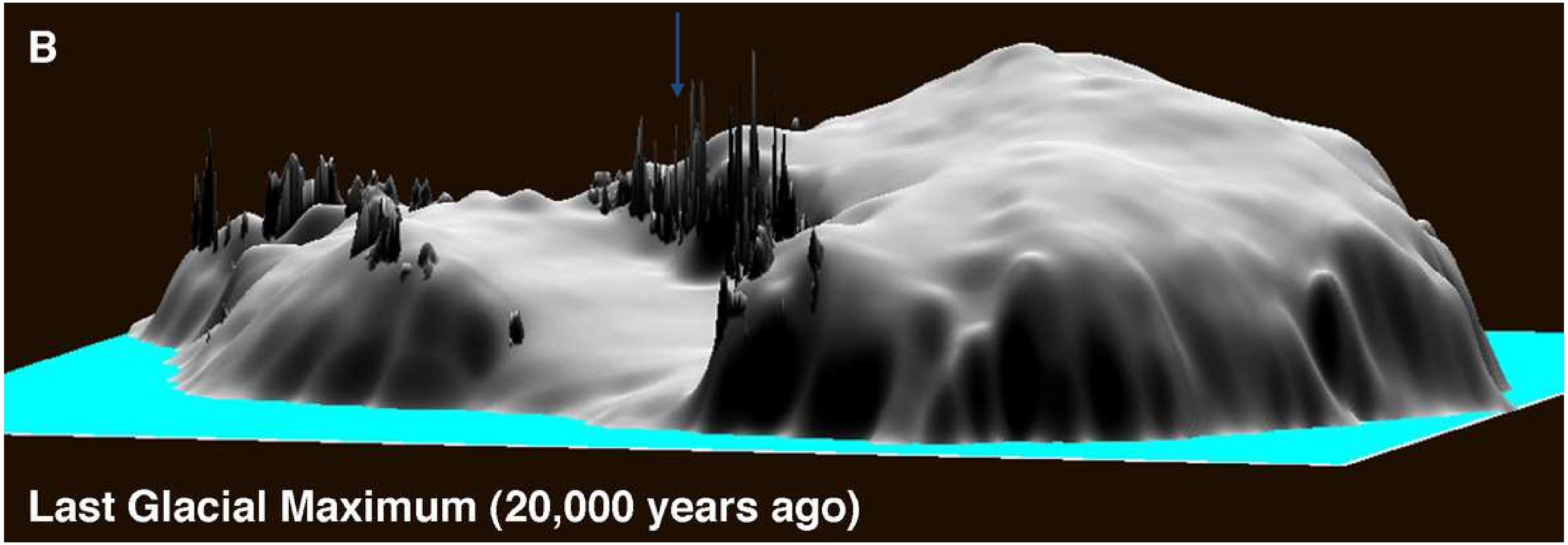


Sauli, Busetti, De Santis, Wardell (Marine Geology 2014)

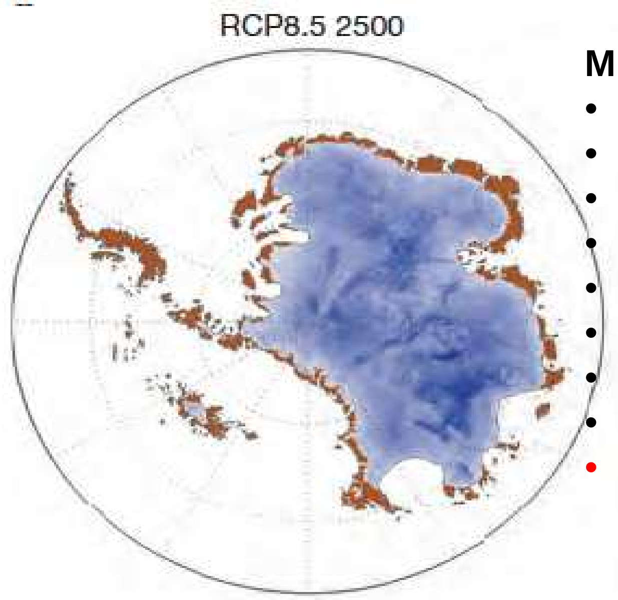
Rebesco M., Urgeles R., Özmaral A., Coribar Scientific Party, in press in: Dowdeswell J.A., eta., (Eds.) *Atlas of Submarine Glacial Landforms.* Geological Society of London Memoir.







Antarctic octopus (Paraledone turqueti).
Credit: E. Jorgensen, NOAA 2007



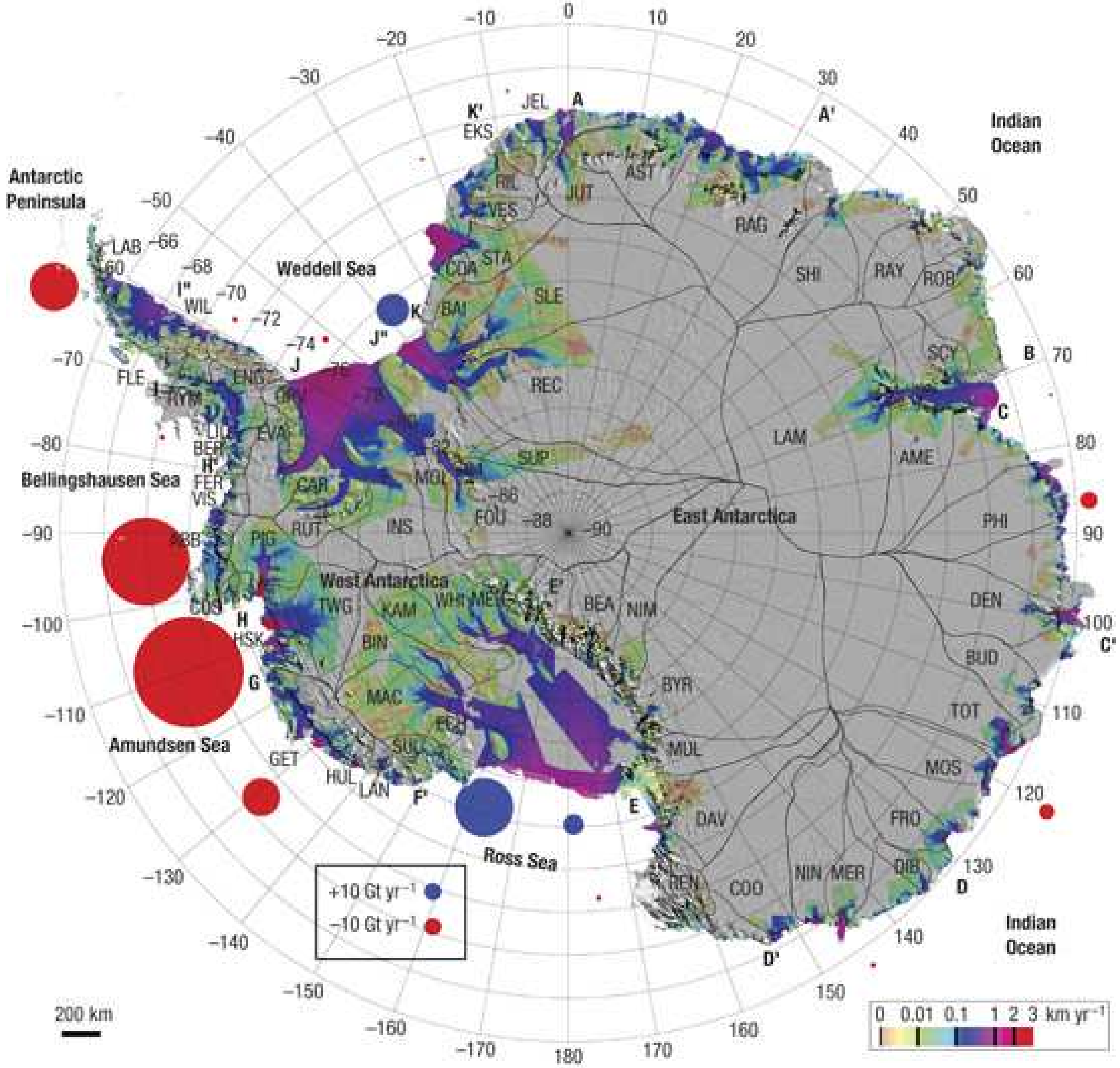
DeConto and Pollard 2016 (Nature)

Mid Pliocene

- 350-400ppm CO_2
- +3°C global average air,
- +3-5°C Antarctic SST (Ross)
- +8°C Arctic SAT (Lake E)
- GMSL ~ +20m
- Up to 7m from GIS
- Up to +4m WAIS
- Up to +13m EAIS
- AIS contribution ???

Ice velocity and ice mass loss/gain

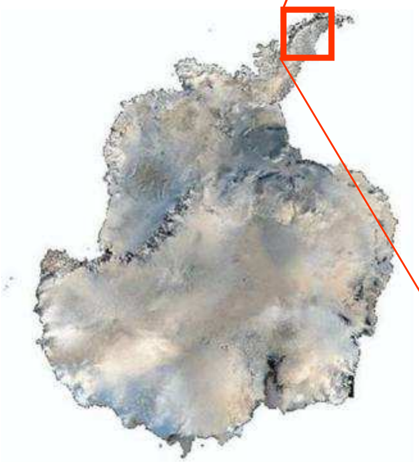
Rignot et al. (2007)



3 major types of changes to ice flow rate:

1. Faster ice flow in summer in Greenland
2. Rapidly disintegrating ice shelves
3. Rapid retreat, thinning and acceleration of outlet glaciers

Dramatic decade of ice sheet behavior



Requires >10,000 years to form

Disintegrate in weeks

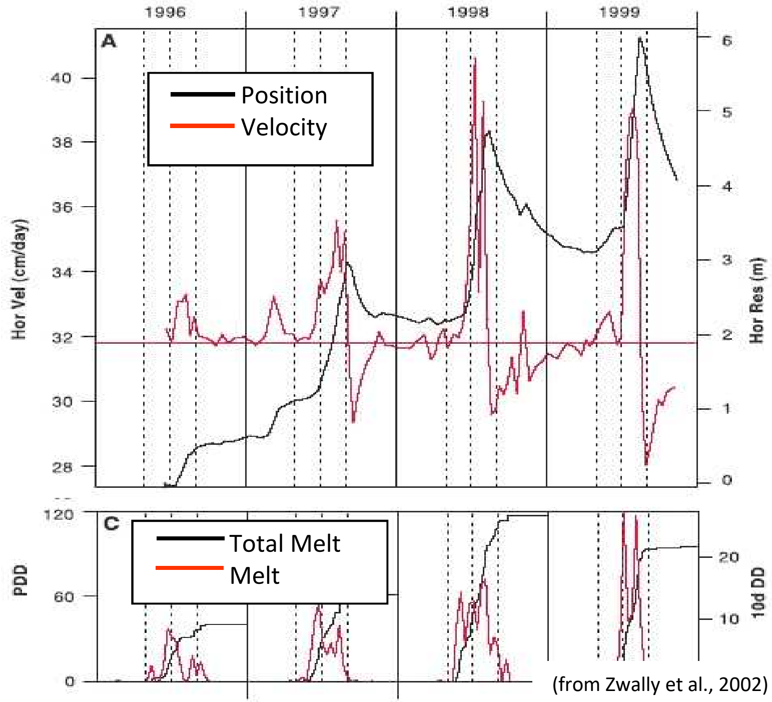
150 miles: Portland, to Seattle

Water as a Lubricant

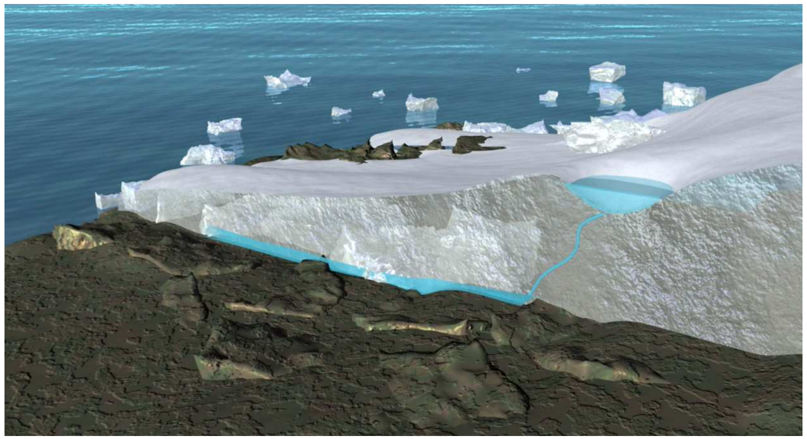
(photo credit: R. Braithwaite)

Glacier flow increases 10-15%
Slower ice increases up to 70%

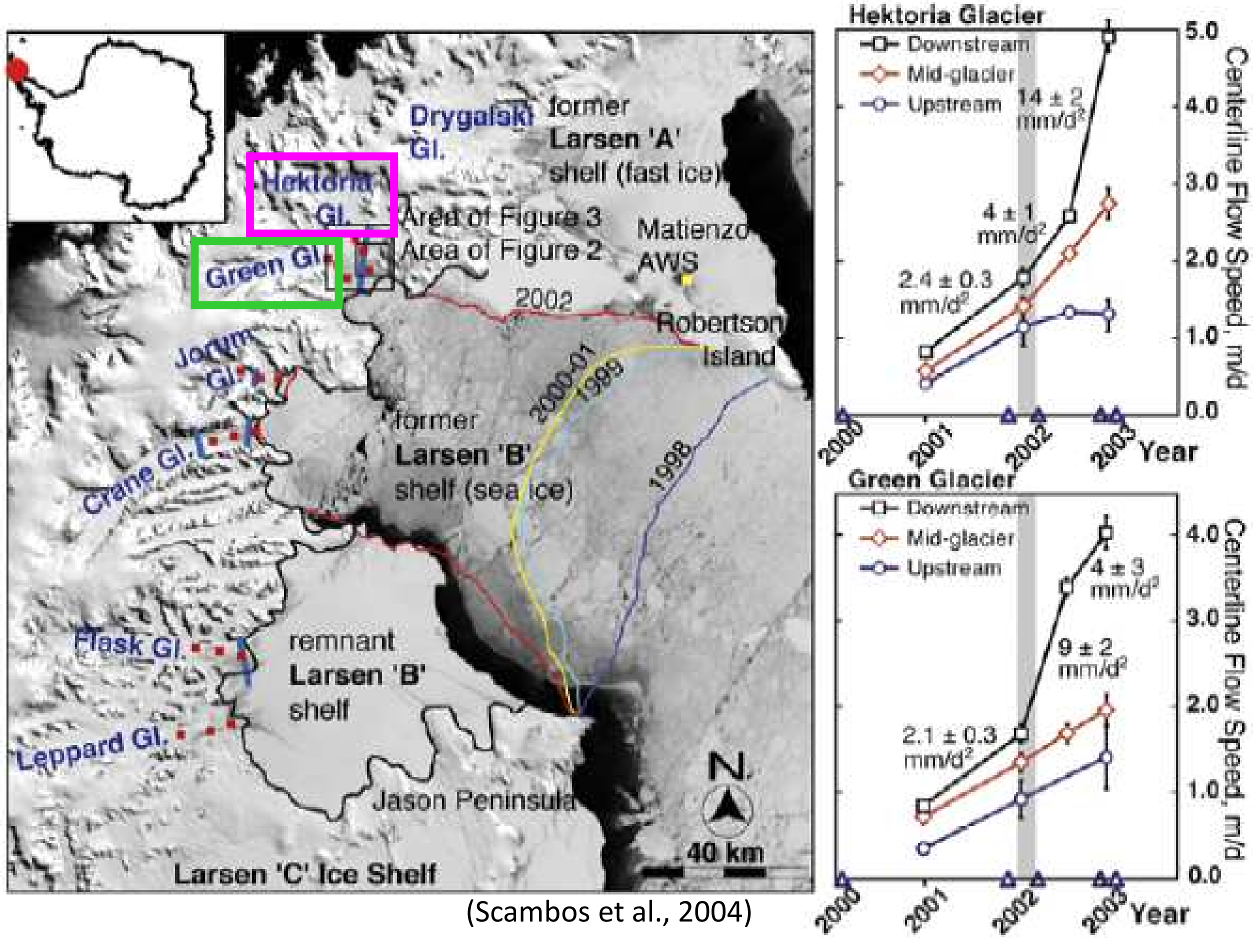
(from Joughin et al., 2008)



(from Zwally et al., 2002)



Consequence of Ice Shelf Loss



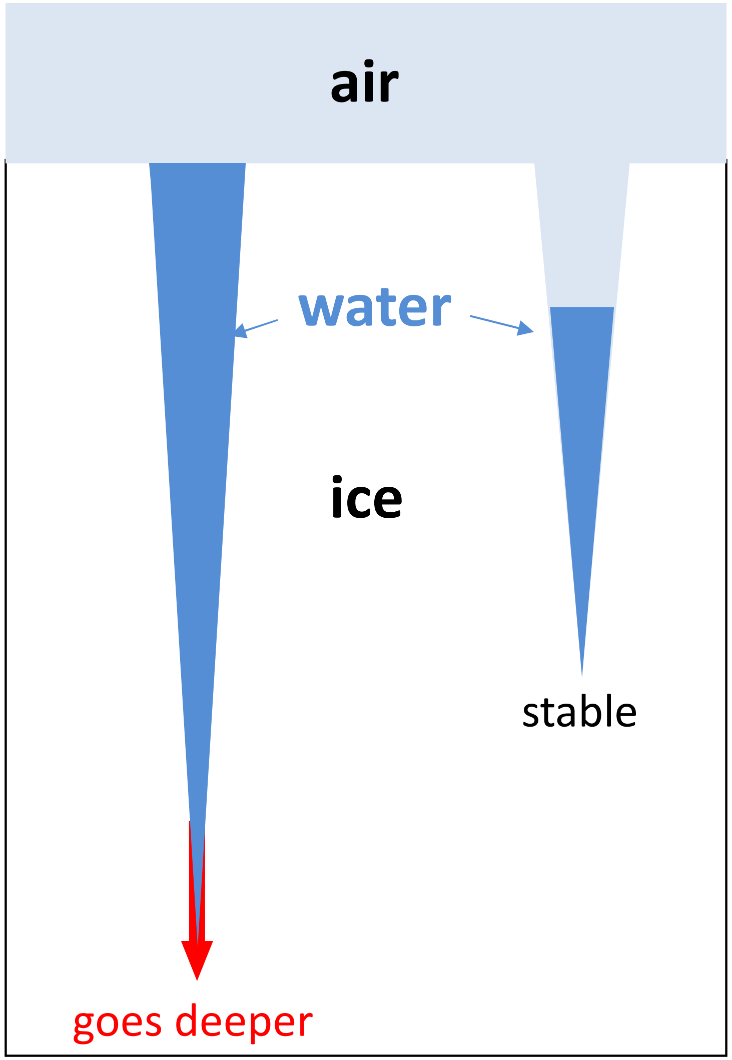
(Scambos et al., 2004)

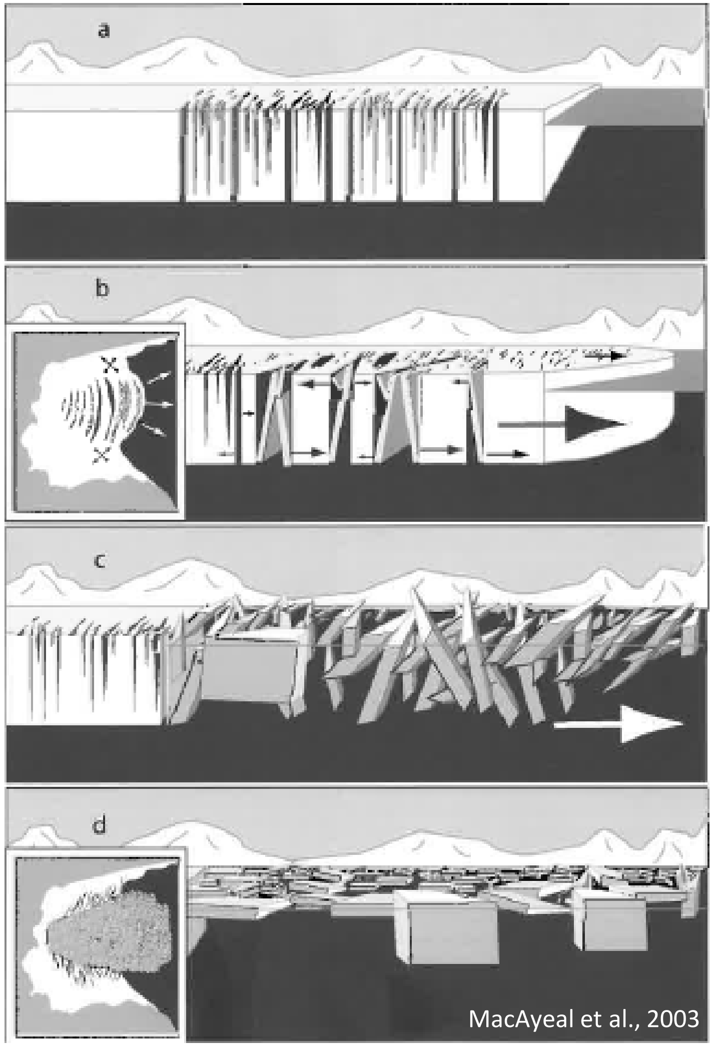
up to 510% faster in 2 years

up to 400% faster in 2 years

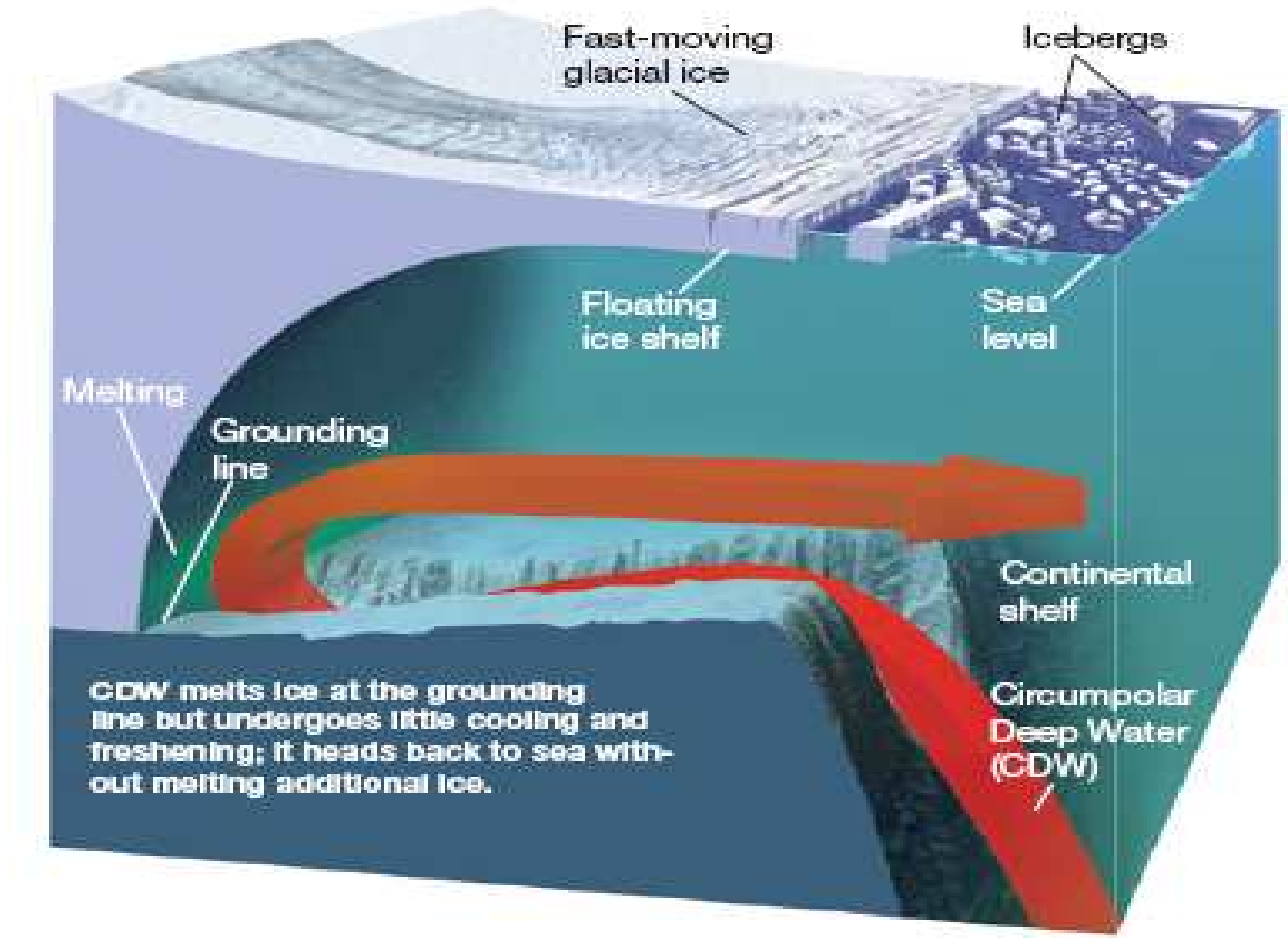
Formerly buttressed glaciers accelerate

Water as a Wedge



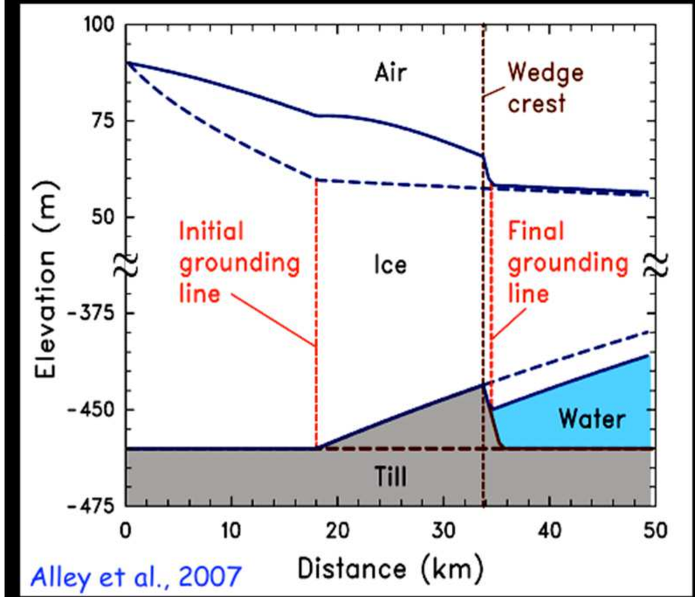


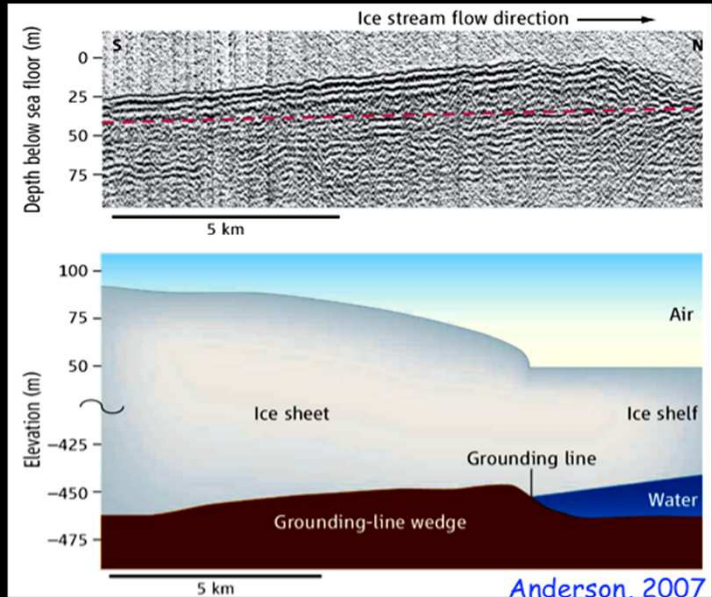
Water as a Heater

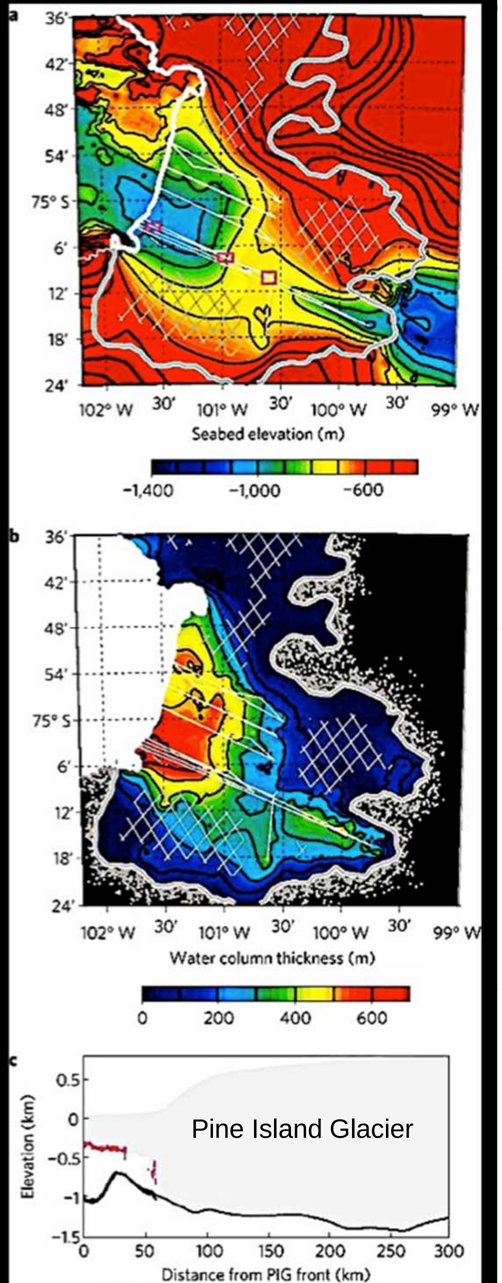


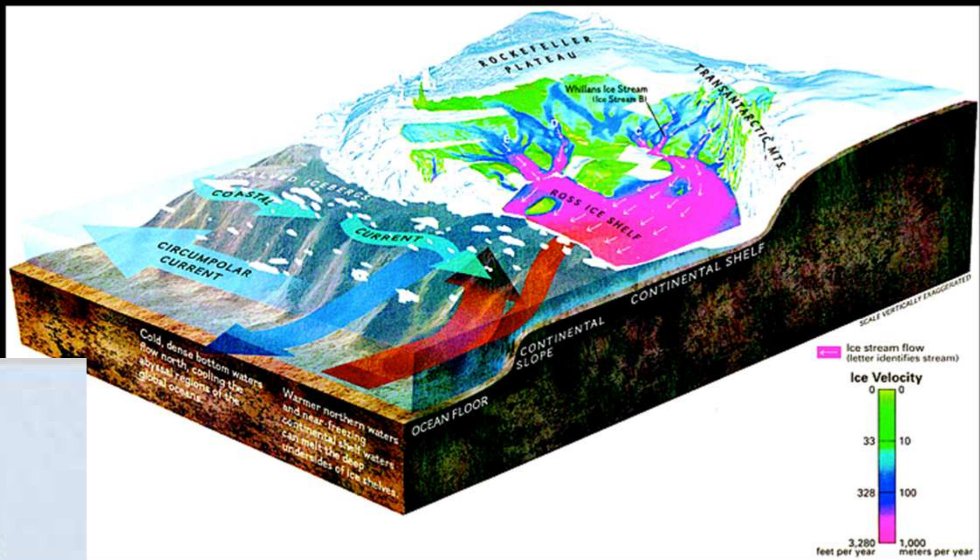
(illustration (c) Frank Ippolito)

Grounding-zones and ice shelf ocean cavities



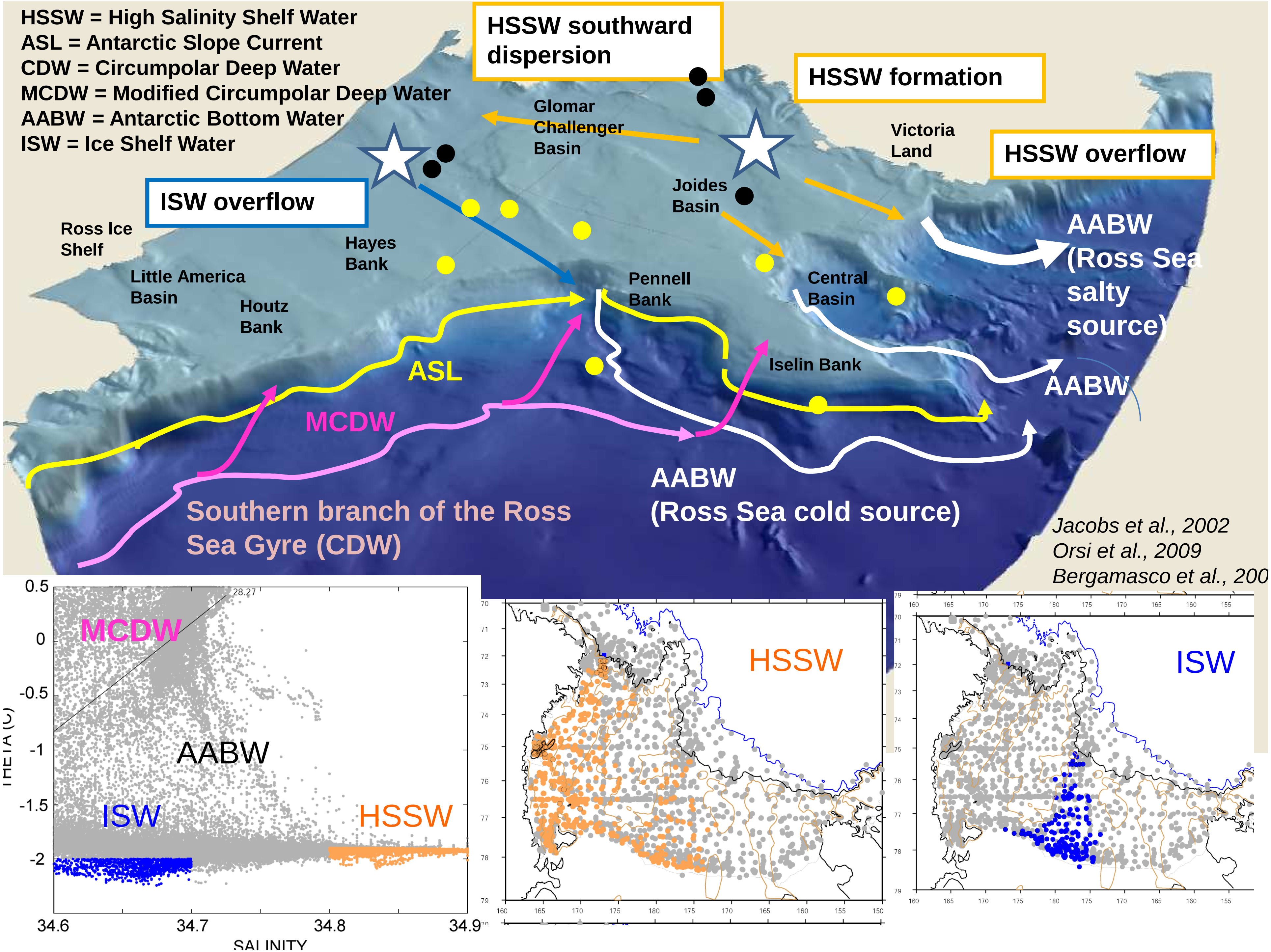




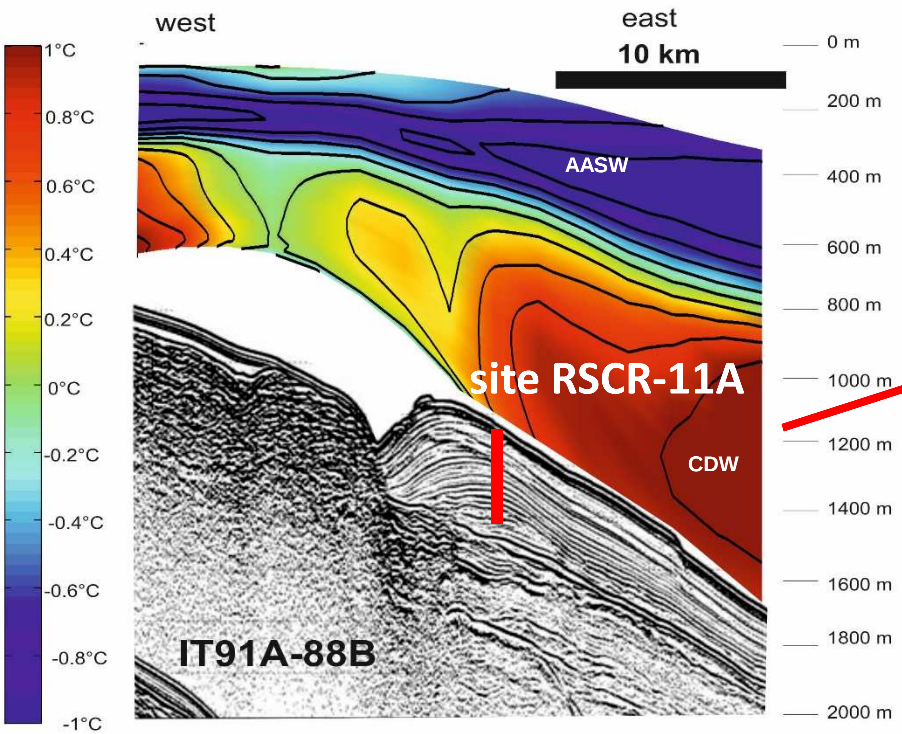


Siple Coast & RIS - Nat. Geog.

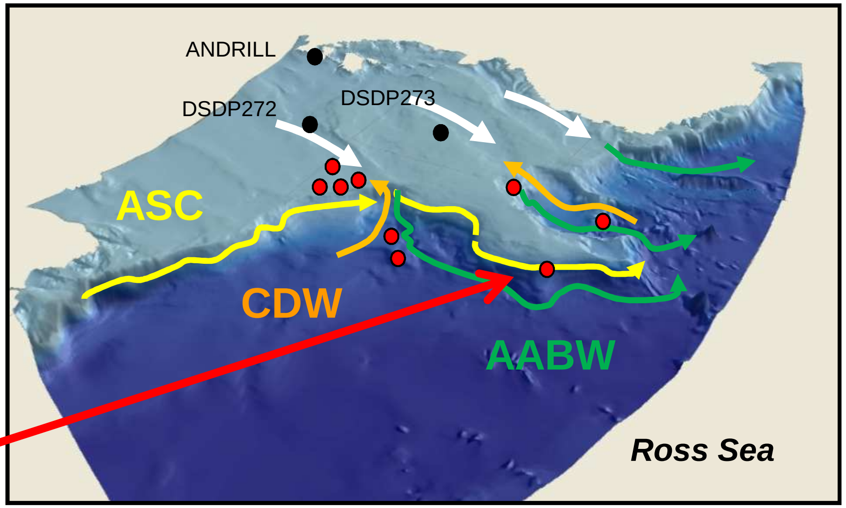
PIG - Jenkins et al. 2010


HSSW = High Salinity Shelf Water
ASL = Antarctic Slope Current
CDW = Circumpolar Deep Water
MCDW = Modified Circumpolar Deep Water
AABW = Antarctic Bottom Water
ISW = Ice Shelf Water
HSSW southward dispersion
HSSW formation
HSSW overflow
ISW overflow
Glomar Challenger Basin
Victoria Land
Joides Basin
Ross Ice Shelf
Hayes Bank
Little America Basin
Houtz Bank
Pennell Bank
Central Basin
Iselin Bank
AABW (Ross Sea salty source)
AABW
ASL
MCDW
AABW (Ross Sea cold source)
Southern branch of the Ross Sea Gyre (CDW)
Jacobs et al., 2002
Orsi et al., 2009
Bergamasco et al., 200
MCDW
AABW
ISW
HSSW
28.27
0.5
0
-0.5
-1
-1.5
-2
34.6
34.7
34.8
34.9
SALINITY
HSSW
ISW

IODP Expedition 374 (2018) Hypothesis to test: The vigor of the Antarctic Slope Current (ASC), and surface/bottom water variance is the main control on oceanic heat flux onto the Ross Sea Continental Shelf



AlongSlope Current - moat/drift



Smith et al., 2012 (oceanography)

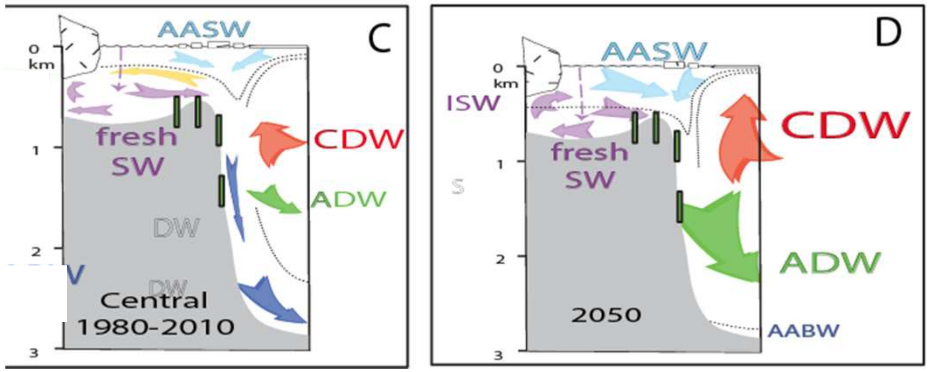
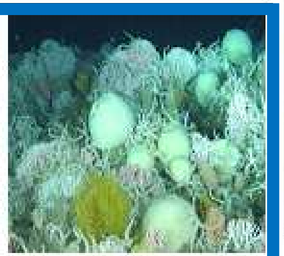
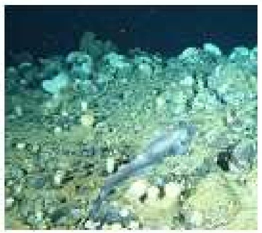


Table 1: Summary of slope transects sampled on the George V continental shelf.

Station	Depth range	Occurrence of *Errina sp.*	Dominant community	Seafloor image
82to83	400-1200 m	Sparse: 600-920 m Dense: 900 m	Medium density soft corals and bryozoans	
79to88	435-1395 m	Sparse: 440-570 m; Dense: 570-950 m	Dense *Errina* sp. and demosponge	
65	650-950 m	Dense: 650-950 m	Dense *Errina* sp. and demosponge	
63	420-430 m	Sparse: 430 m	Medium density soft corals and gorgonian whips	
33	740-770 m	None	Sparse demosponge	

Antarctic Science page 1 of 8 (2010) © Antarctic Science Ltd 2010 doi:10.1017/S0954102010000180

Physical controls on deep water coral communities on the George V Land slope, East Antarctica

ALEXANDRA L. POST[1], PHILIP E. O'BRIEN[1], ROBIN J. BEAMAN[2], MARTIN J. RIDDLE[3] and LAURA DE SANTIS[4]

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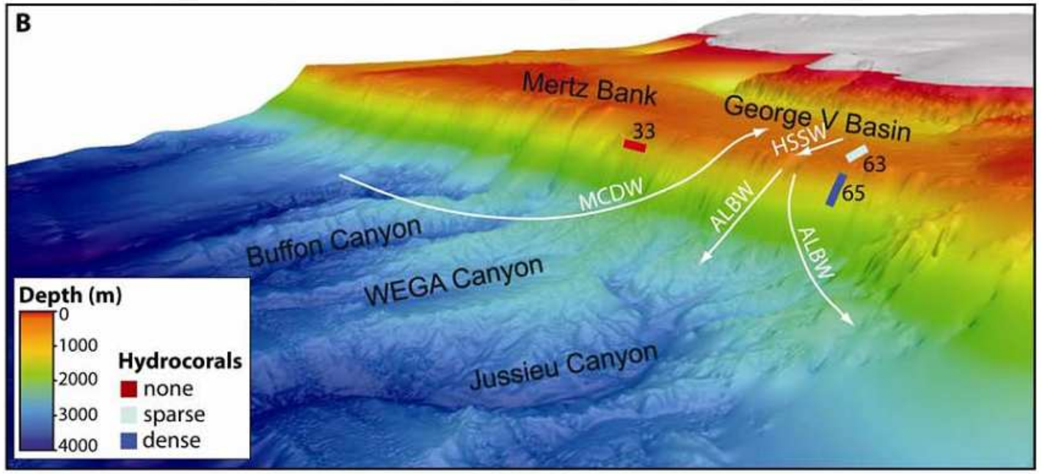
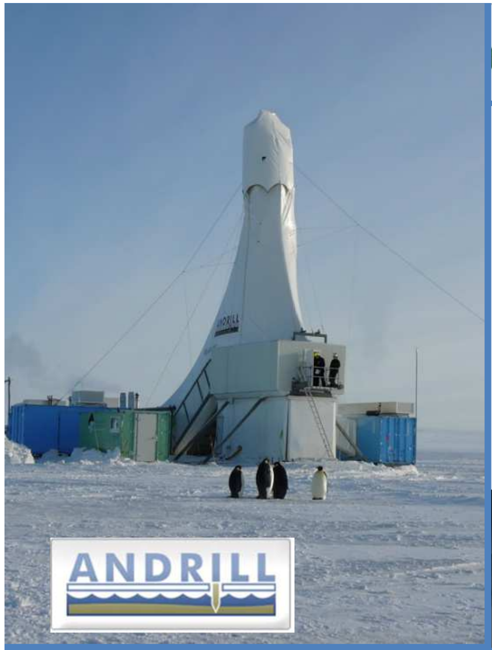
[4]Instituto Nazionale di Oceanografia e Geofisica Sperimentale, Borgo Grotta Gigante 42/c, Sgonico, Trieste 34010, Italy
Alix.Post@ga.gov.au



In profondità, dove gli iceberg non possono arare il fondo del mare, sulla testata dei canyon che convogliano le correnti fredde antartiche, ricche di nutrienti, esistono colonie di coralli e spugne

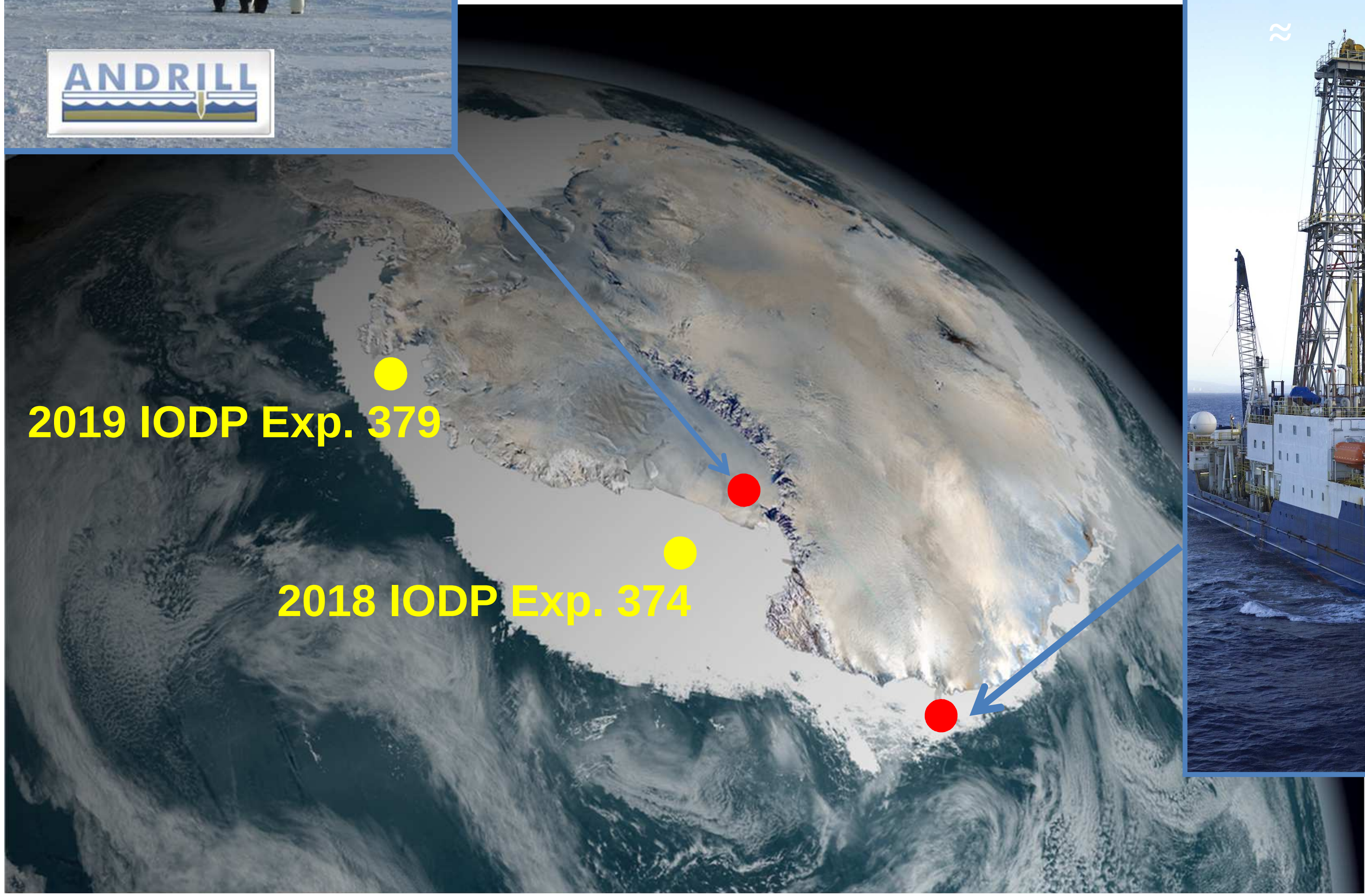


ANDRILL

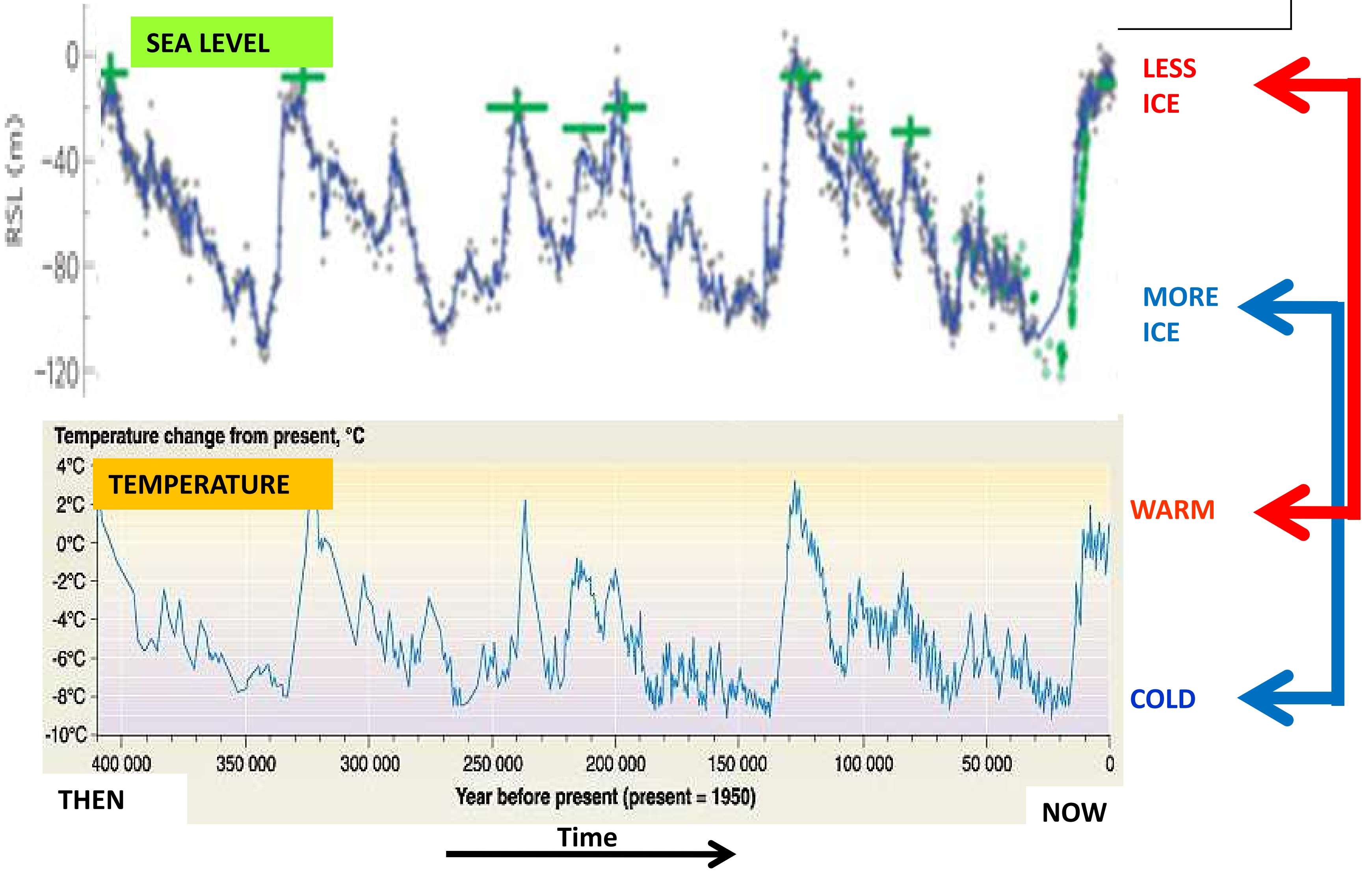
Direct evidence of West
Antarctic Ice Sheet collapse

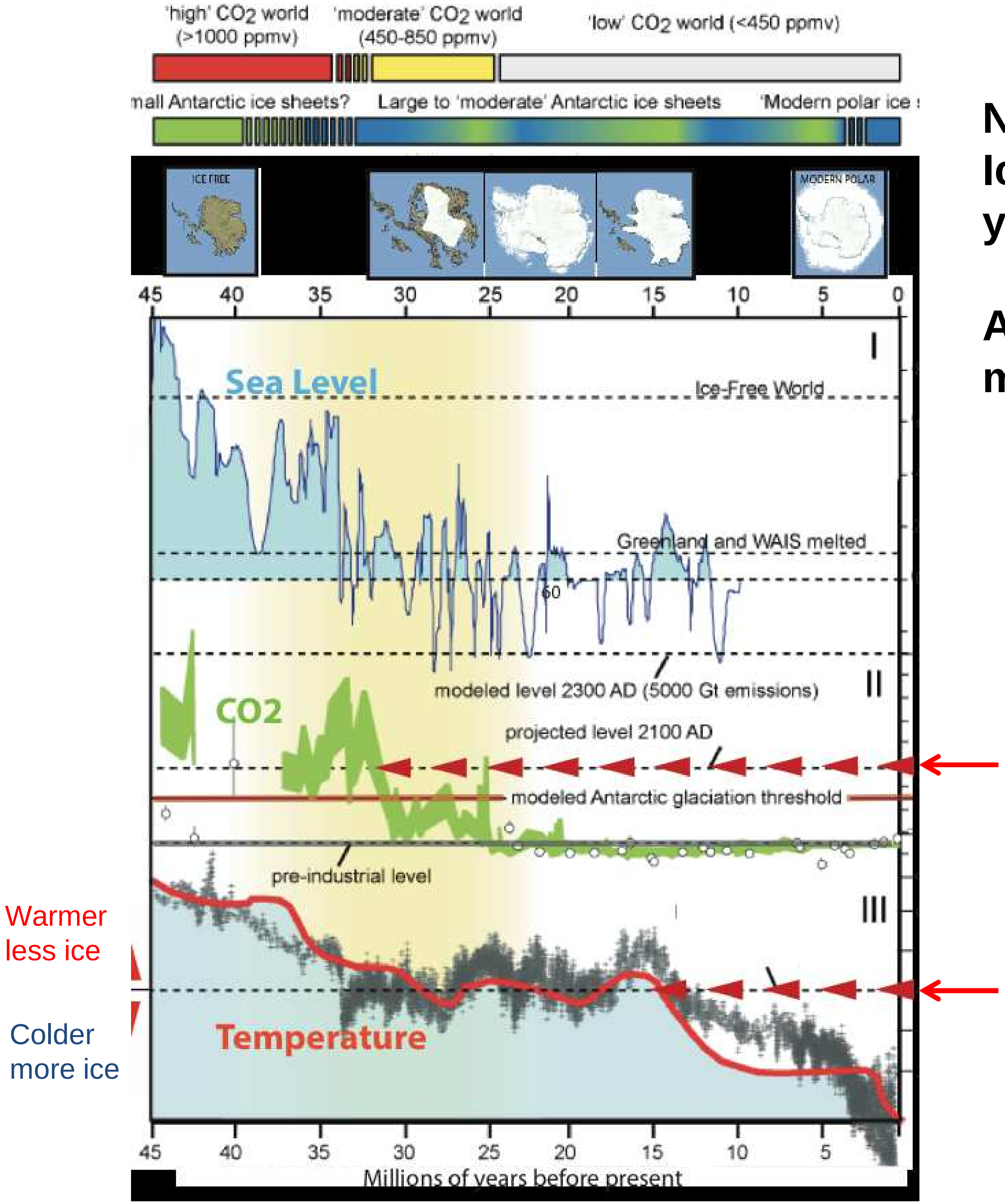
IODP – Leg 318

Direct evidence of East
Antarctic Ice Sheet retreat



History Lesson:
Less ice in warmer climates



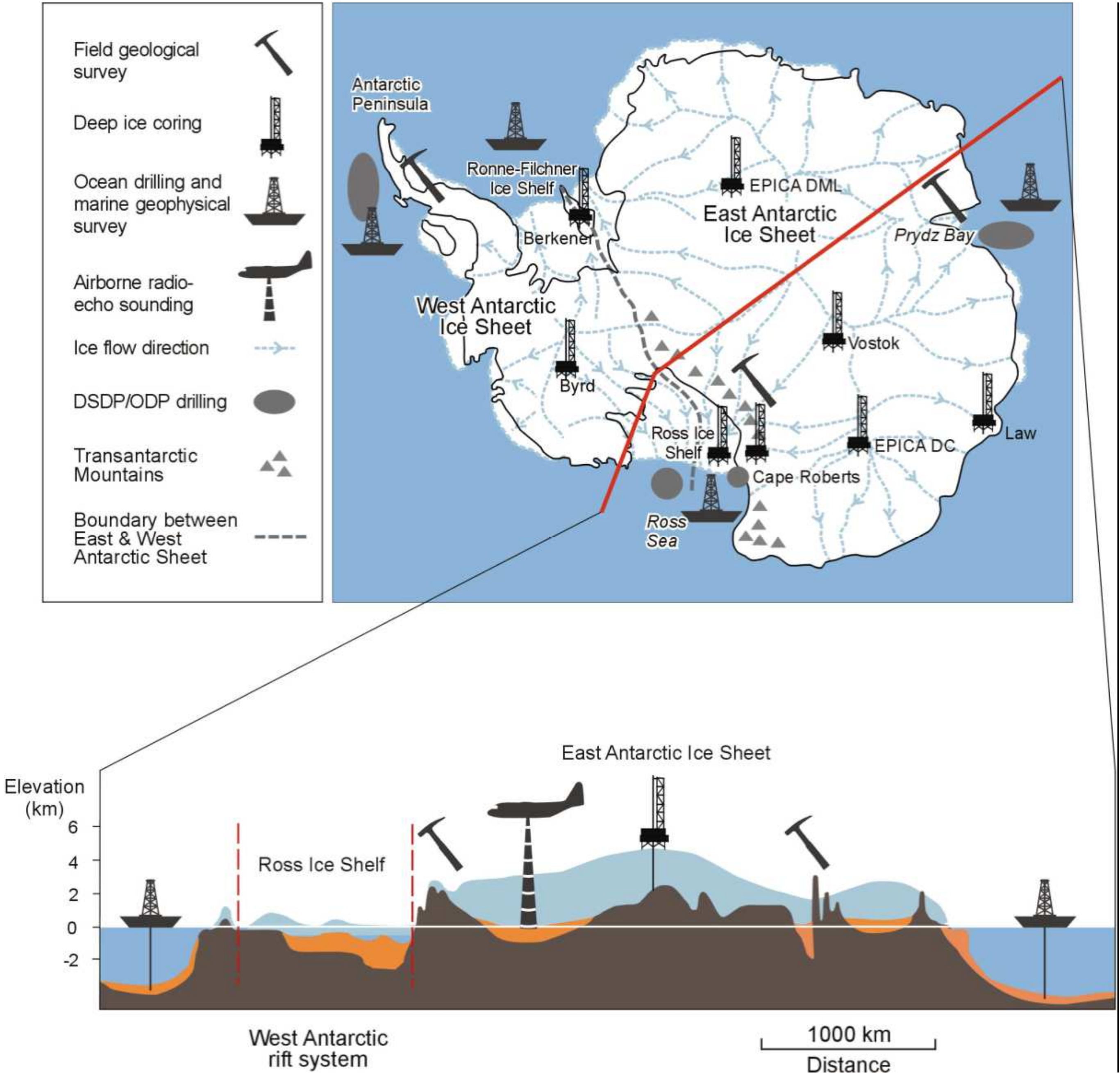


Northern Hemisphere permanent Ice sheets start around 3 million years ago

Antarctic ice sheet start around 34 million years ago

Projected 2100 CO2 concentrations, IPCC AR5 RCP8.5 TAKE US BACK TO WHEN ANTARCTICA DID NOT SUPPORT ICE SHEETS

Projected 2100 T (ºC), IPCC AR5 RCP8.5 NOT EXPERIENCED IN OUR PLANET SINCE AROUND 15 Ma



Sedimentary Records in Antarctica

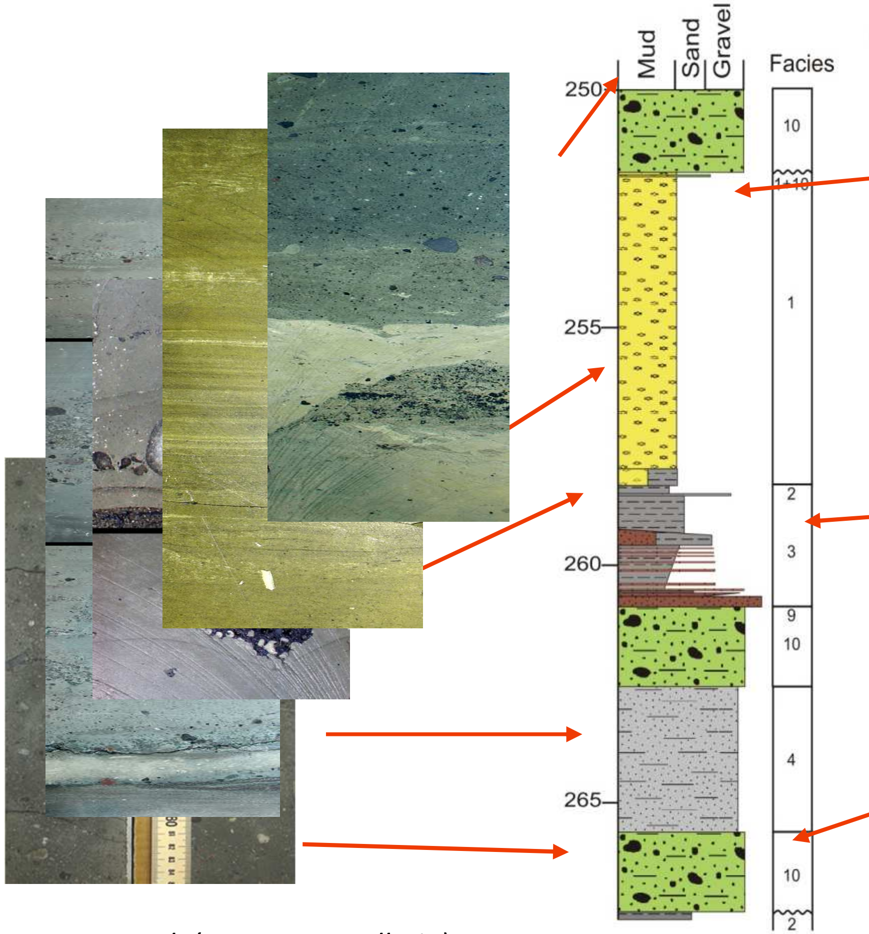
Outcrops:
99.7% of Antarctica is ice covered

Subglacial records

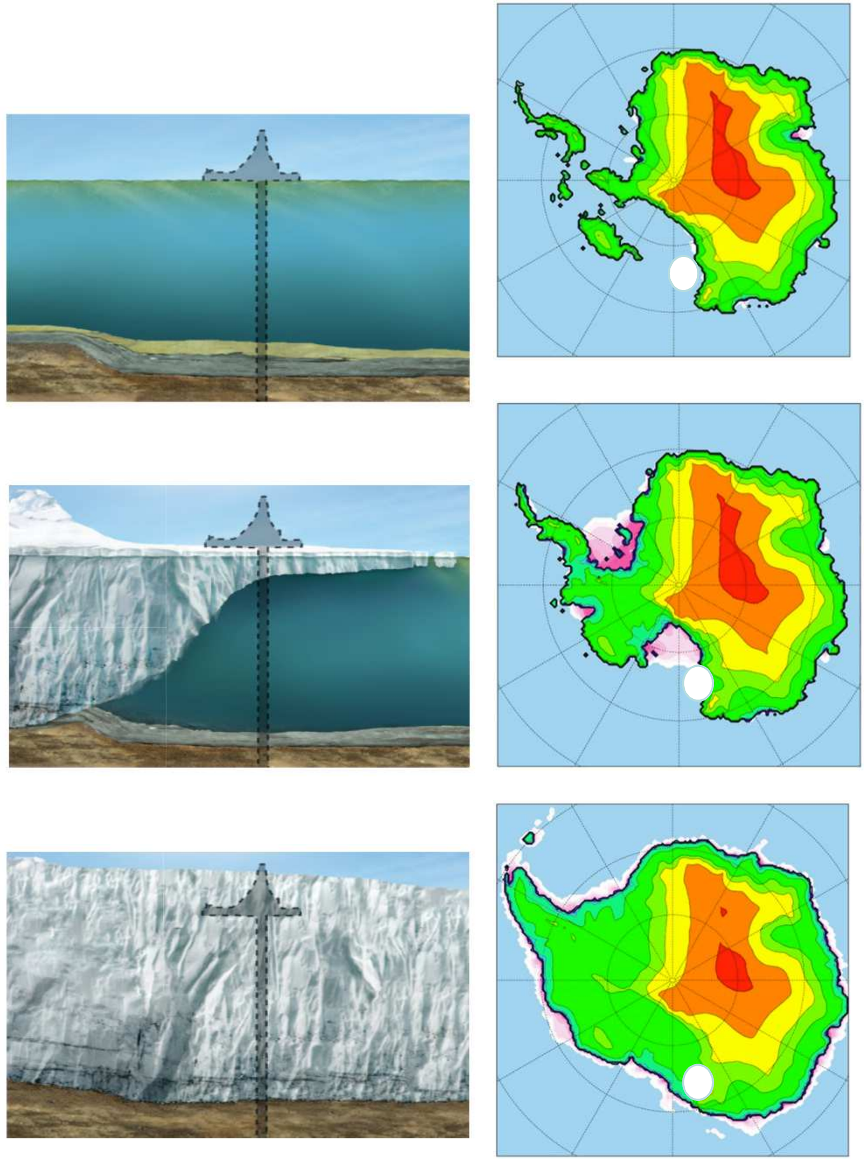
Marine records

Drill core evidence of past West Antarctic Ice Sheet collapse

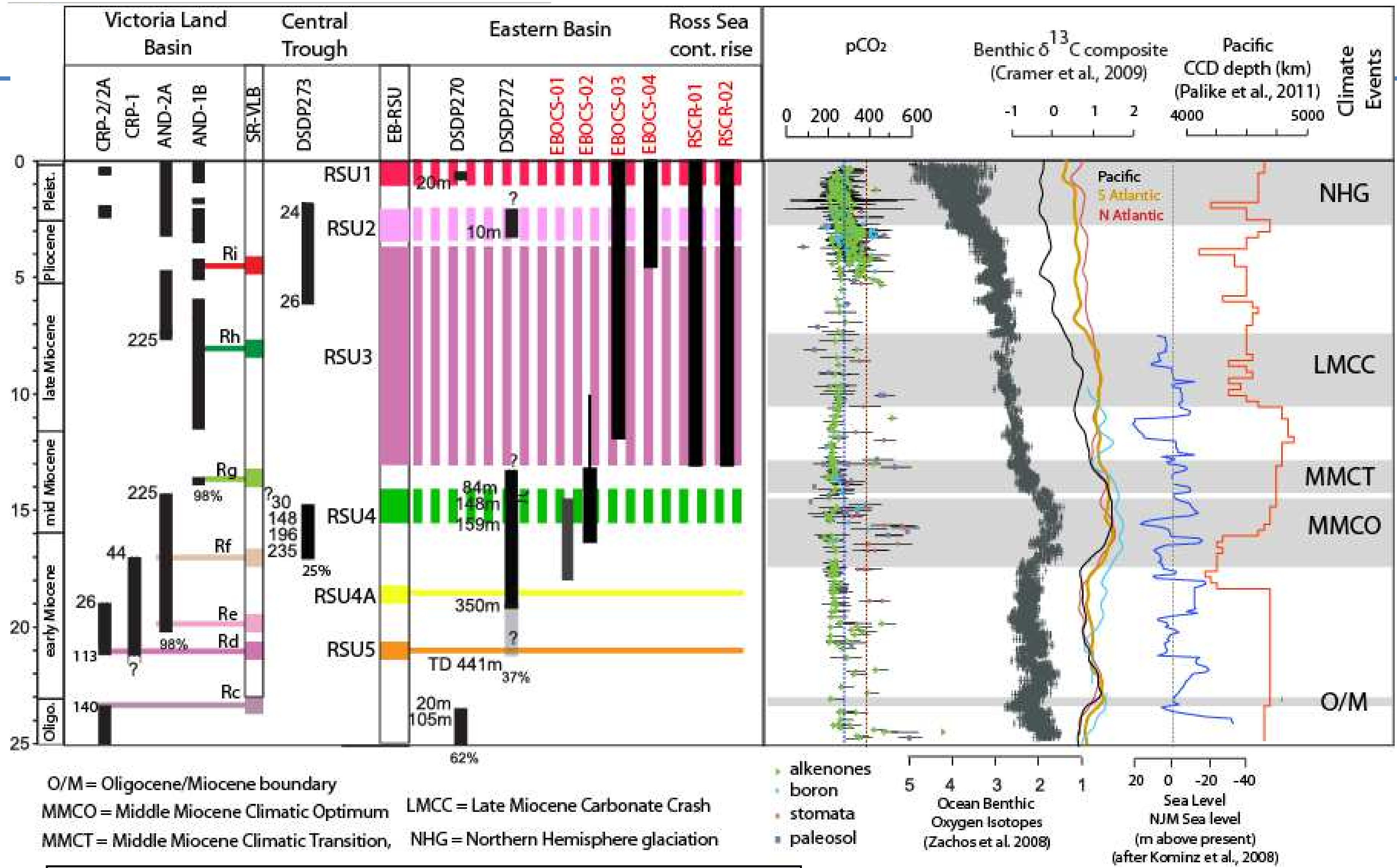
Glacial-Interglacial glacimarine cycles

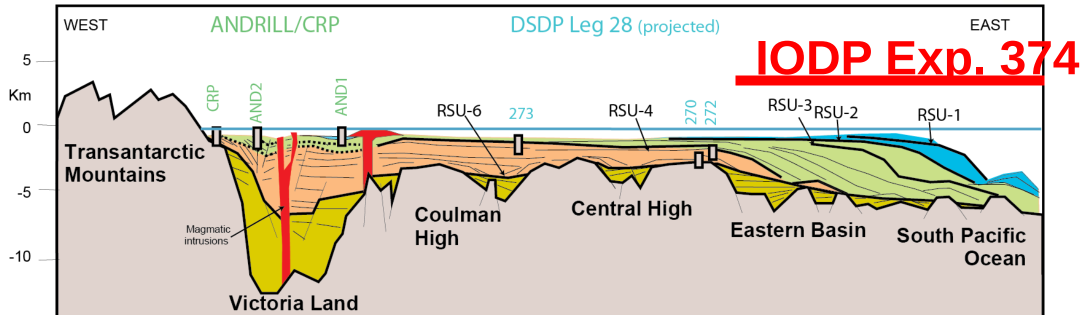


McKay et al. (2009, GSA Bulletin)



Naish et al., 2009; Nature; Pollard and DeConto, 2009 (Nature)

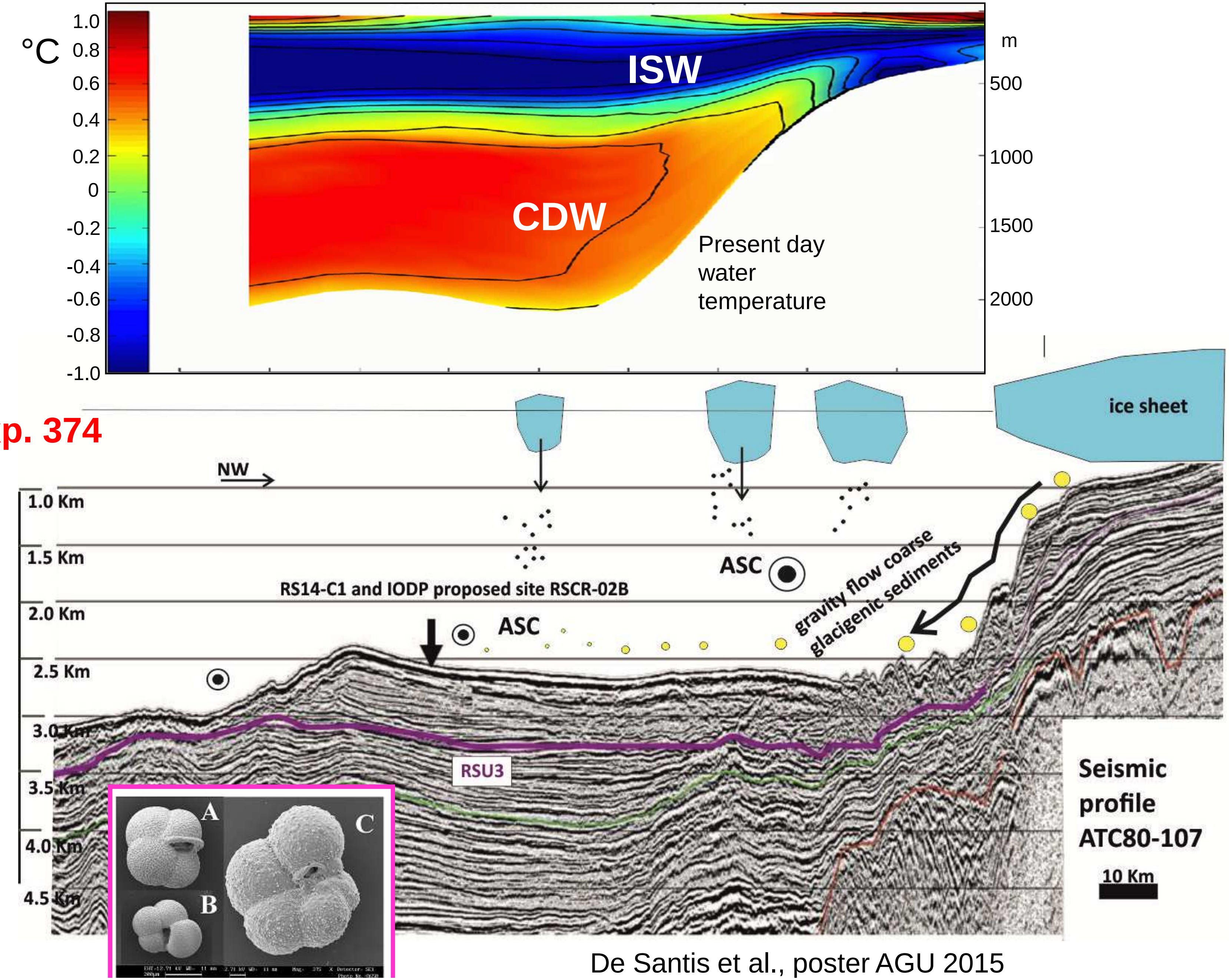




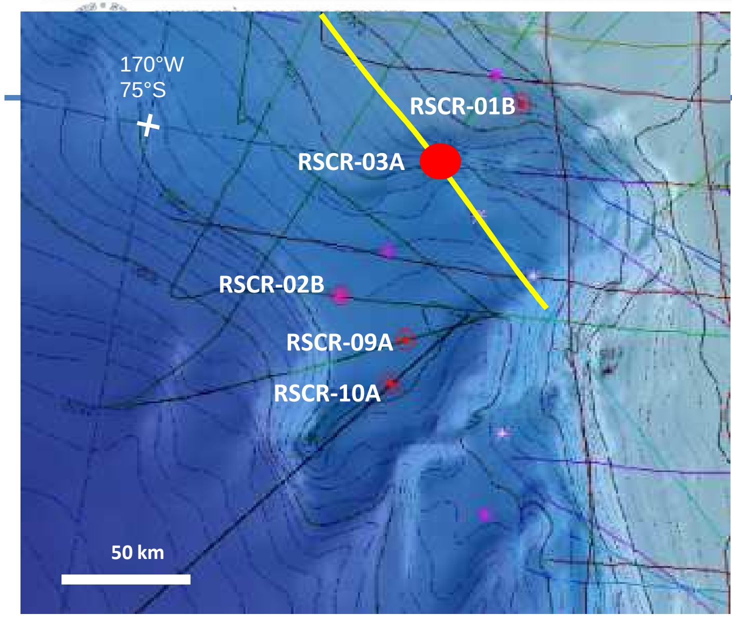
- Pliocene-today (polar environment)
- Miocene-Pliocene (temperate-polar environment)
- Oligocene-Miocene (glaciation onset)
- Cretaceous-Oligocene (no ice?)

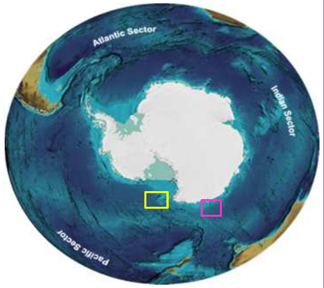
McKay et al., 2013 (IODP prop. 751)

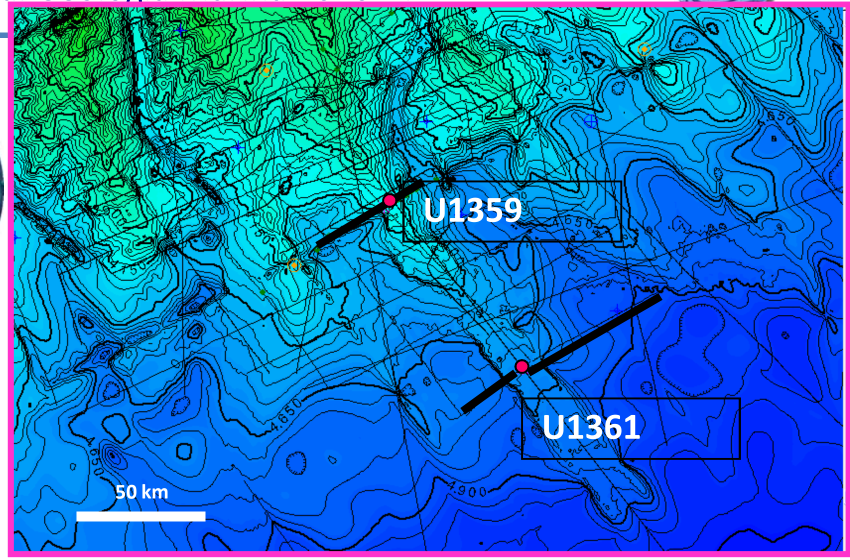
IODP Exp. 374

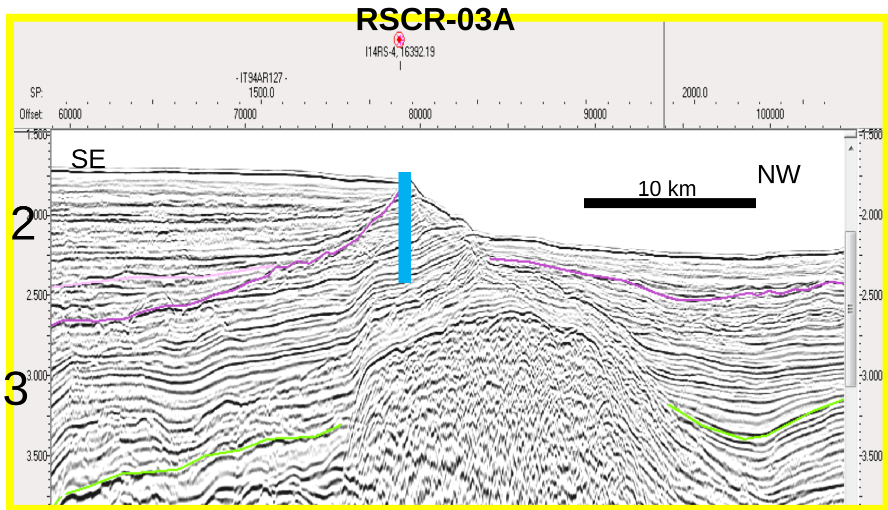


De Santis et al., poster AGU 2015

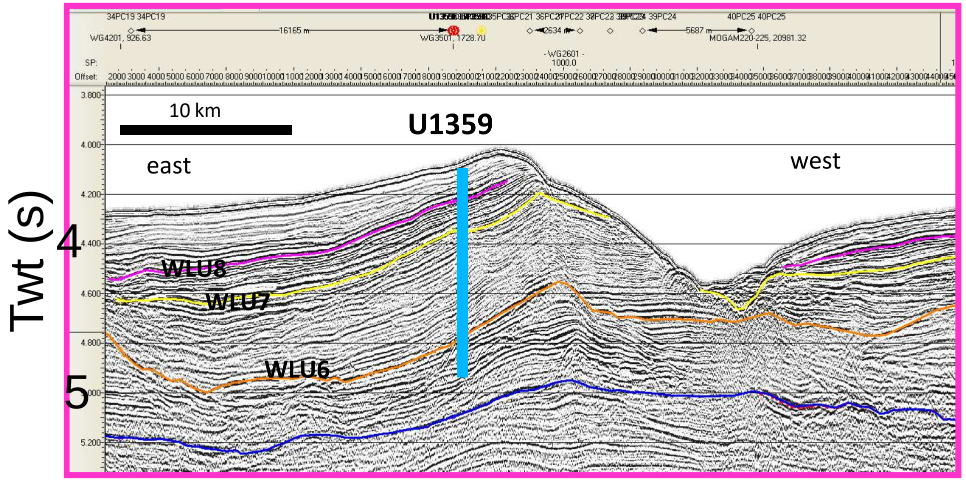








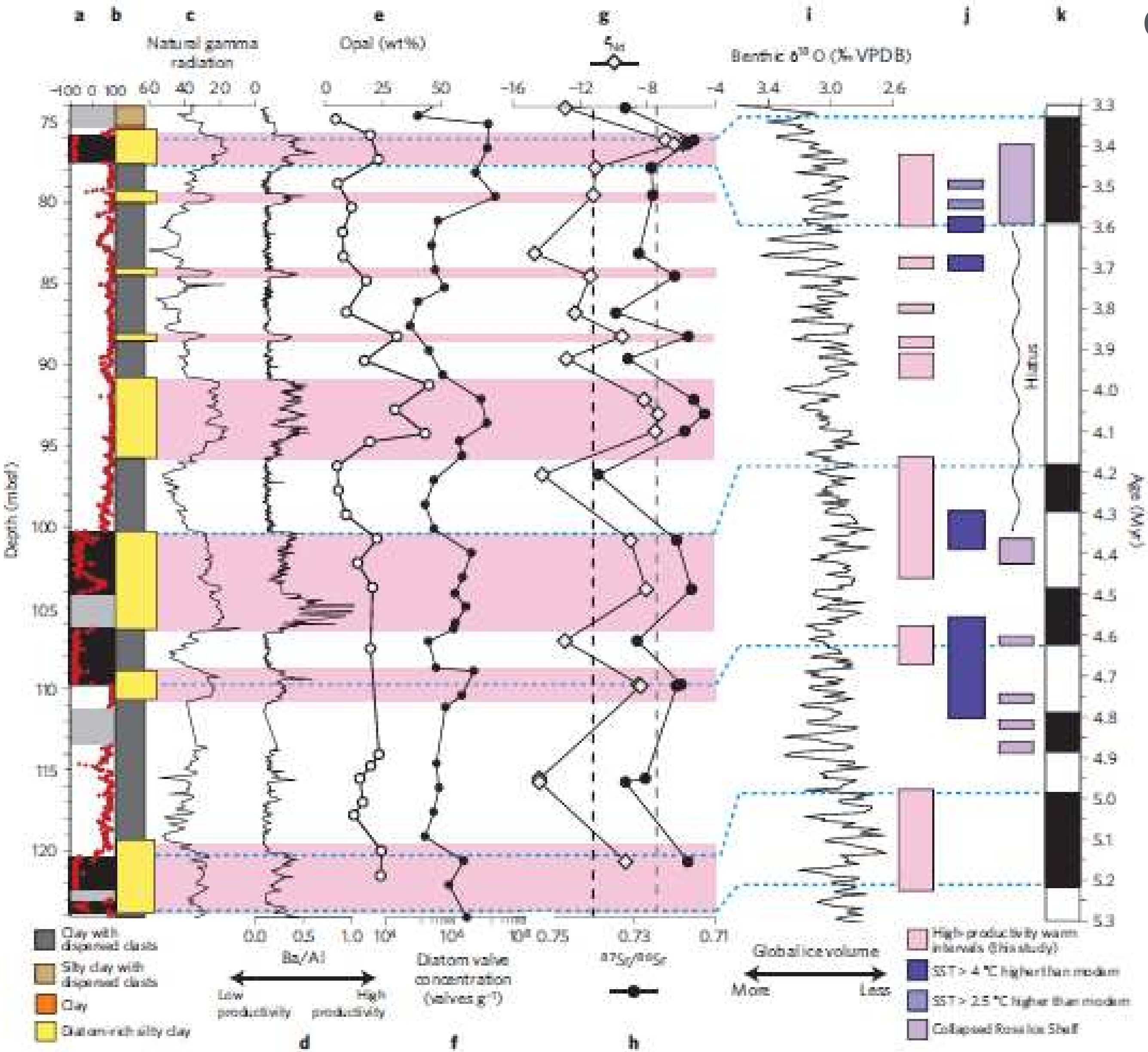
IT94AR-127 (Ross Sea)



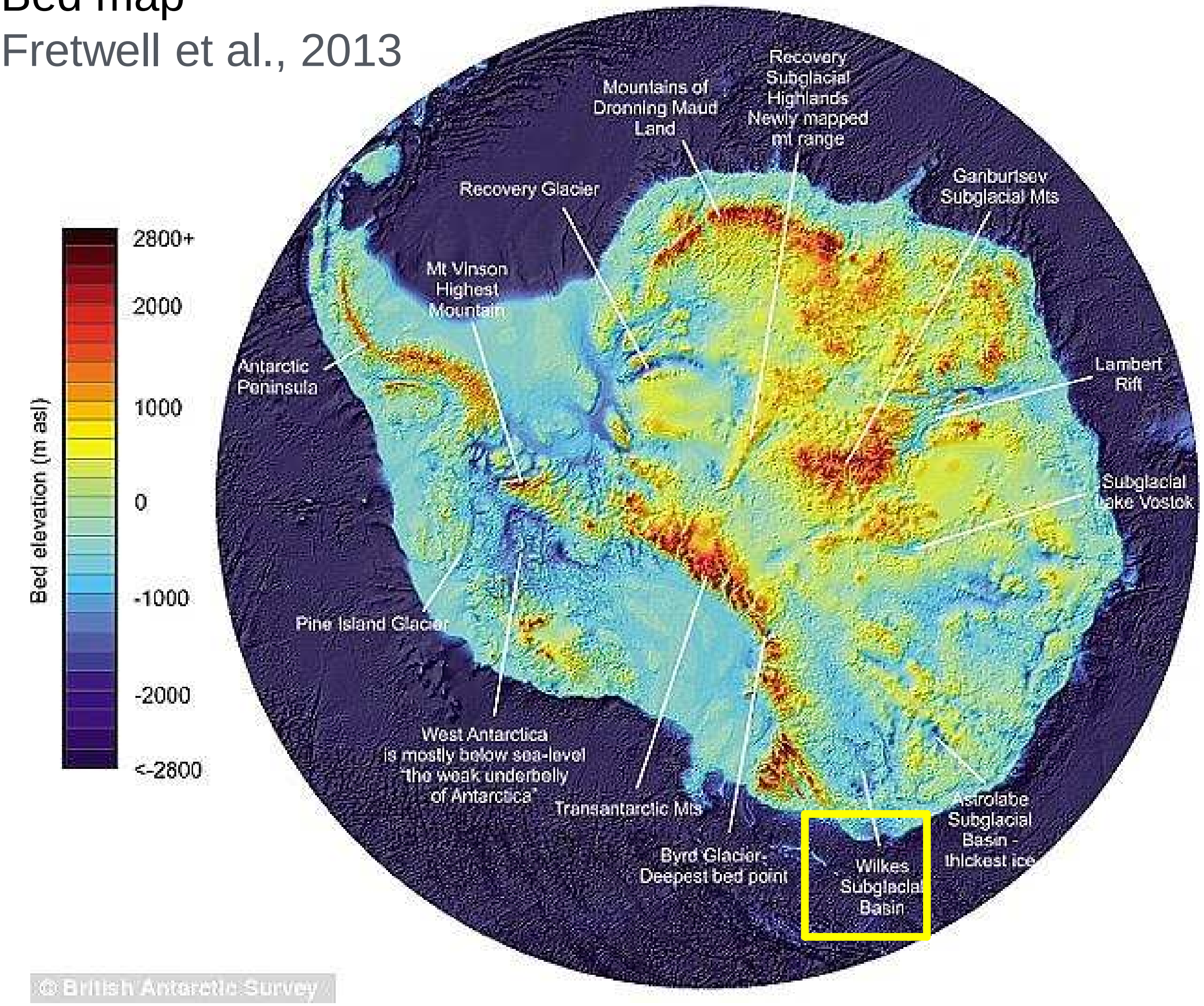
WEGA 2601 (Wilkes Land)

NATURE GEOSCIENCE DOI: 10.1038/NGEO1889 LETTERS

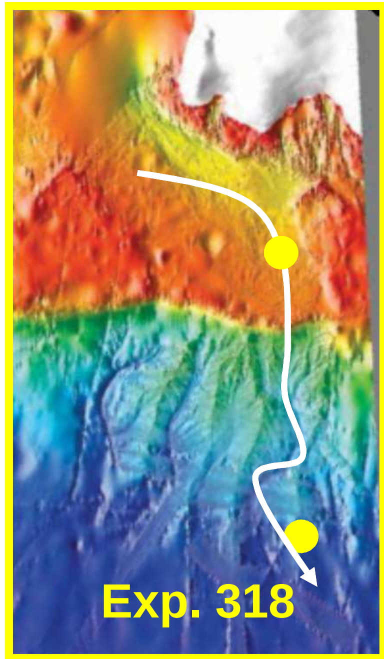
Cook et al., 2013



Bed map
Fretwell et al., 2013



Antarctic bottom water pathway



Escutia et al., 2010;
Patterson et al., 2014