Sub-Ice Shelf and Subglacial Geoscience for Paleoglaciological and Paleoclimatic Histories

Ross Powell et al.

Most geological records currently offshore (sparse isolated outcrops)

Subglacial sedimentary targets - main categories are:

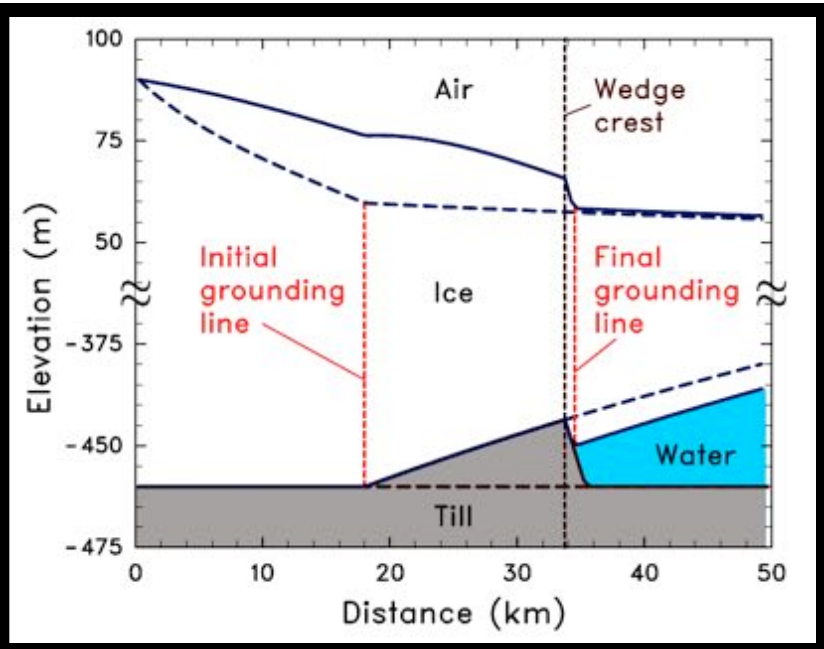
- Sub-ice shelf &
- West Antarctic rift basins
- East Antarctica epeirogenic(?) and rift basins
- Subglacial lakes

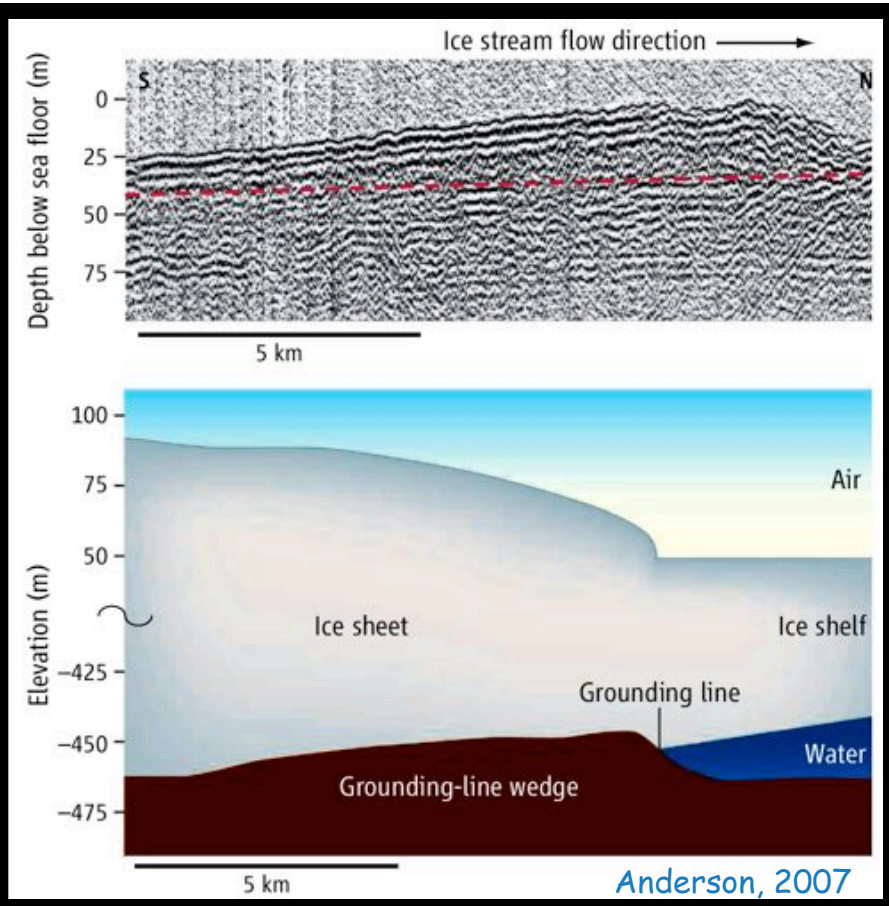
Each has a variety of origins and histories based on location and past ice sheet size and fluctuations

Valuable libraries of past ice sheet and climatic changes

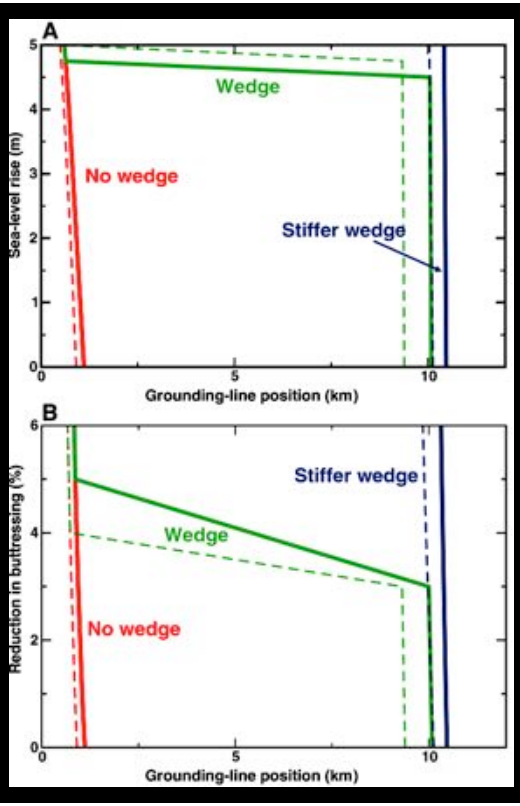
Ice surface paleo-elevations & land surface paleo-topography

past heights of ice sheets to constrain past sizes & volumes
determine by exposure dating of sub-ice bedrock and
reconstructing paleo-topography





Anderson, 2007



Alley et al., 2007

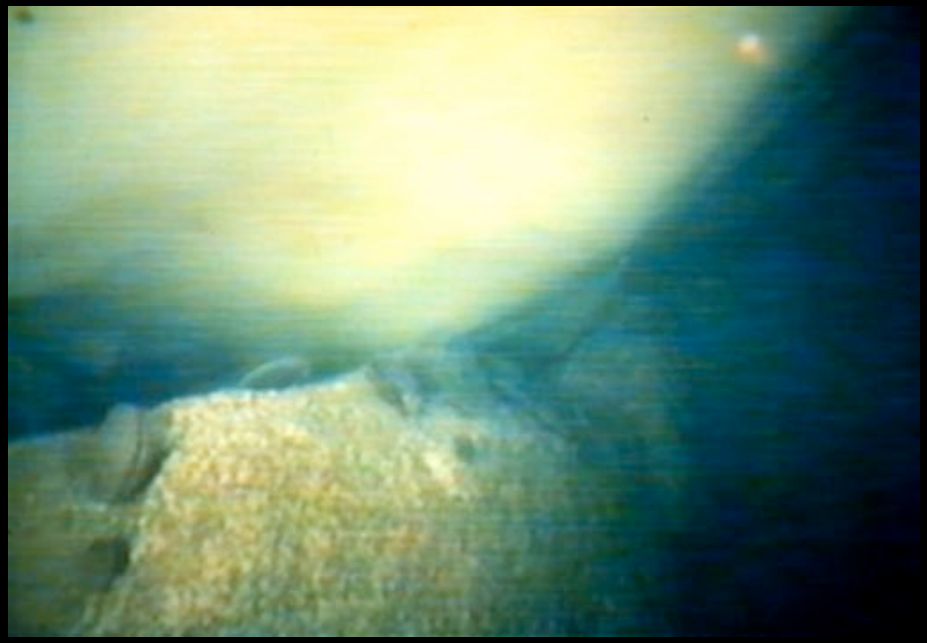
Grounding-zone wedge

Wedge causes ice to thicken,
Grounding-line advance past wedge crest
Stabilizes ice against sea-level rise initially

What are rates of sediment accumulation?
What of ocean melt?

Prior Grounding-line Study

Mackay Glacier
SW Ross Sea



Grounding line: bedrock, rubble, soft till, hard till


Basal crevasse
20m of basal debris

Subglacial melting rate: 1.4 $m.a^{-1}$

Area of subglacial deposition: 6.7km^2

Subglacial till deposition rate: 4.1$mm.a^{-1}$

Rates of Sediment Deposition

Submarine melting rate: 1.7$m.a^{-1}$

Area of glacimarine sedimentation: 5km^2

Glacimarine sediment deposition rate: 5.5$mm.a^{-1}$

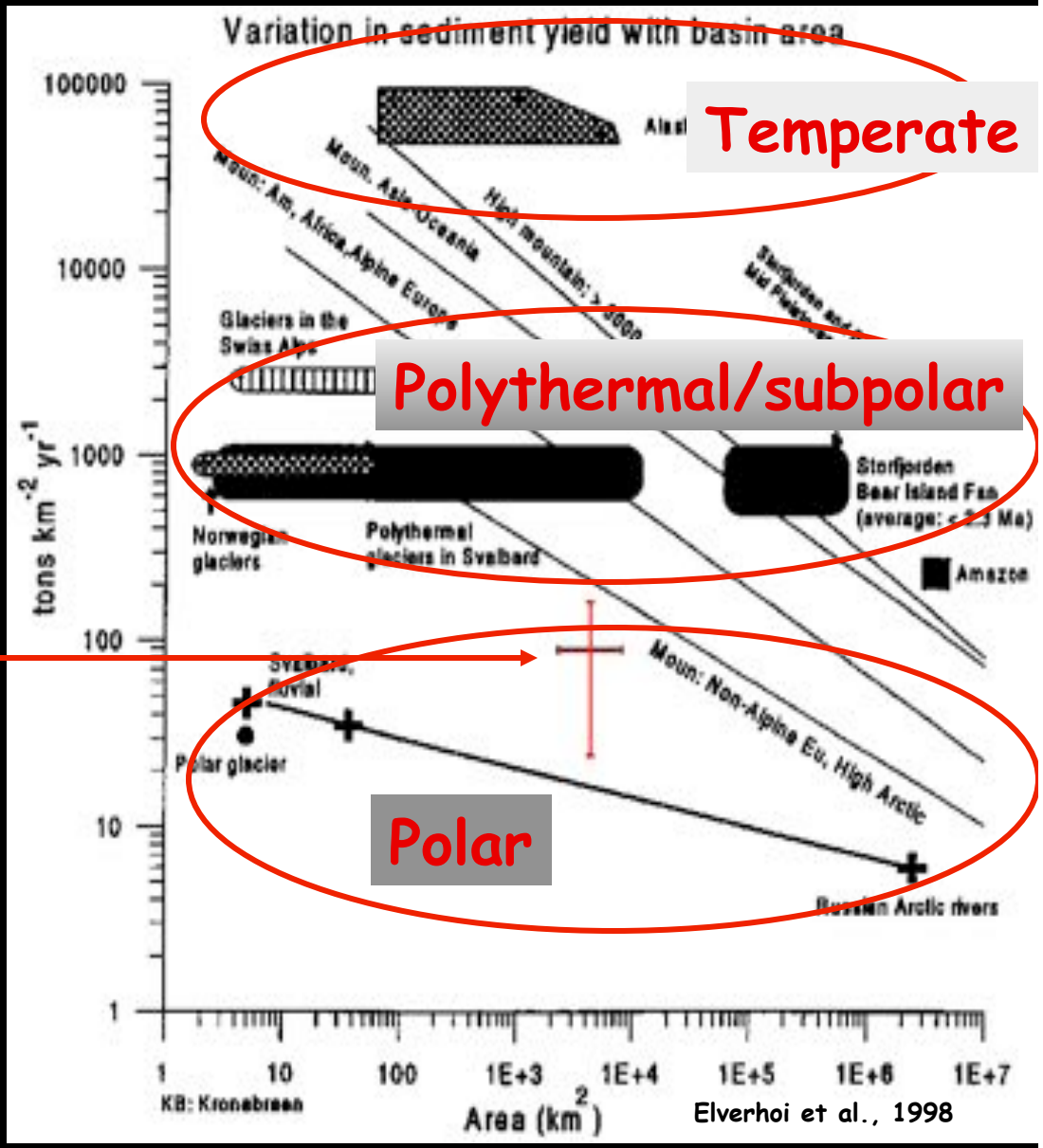
Sediment Yield and Erosion Rates

Basal debris layer thickness:
<20m

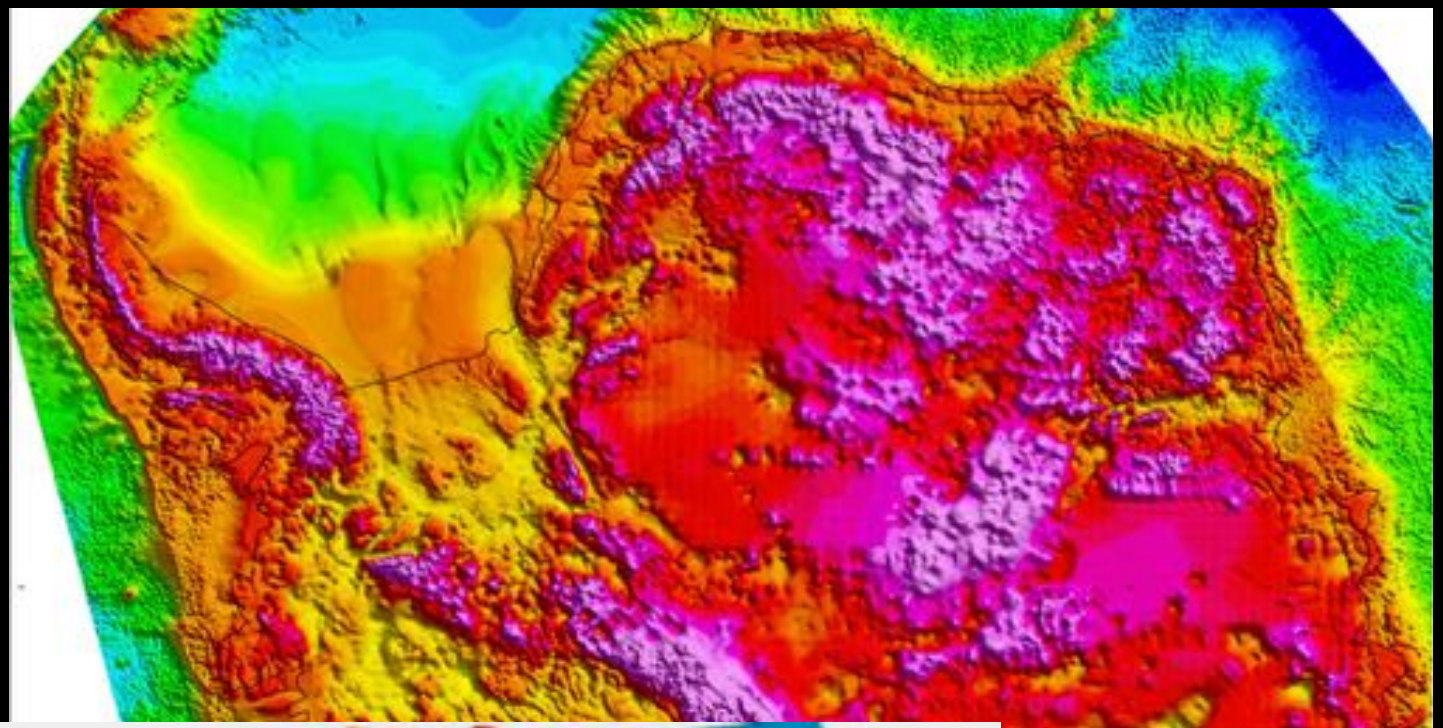
Total debris flux:
$5.5 \times 10^4 m^3 a^{-1}$ ($1.5 \times 10^5 kg.a^{-1}$)

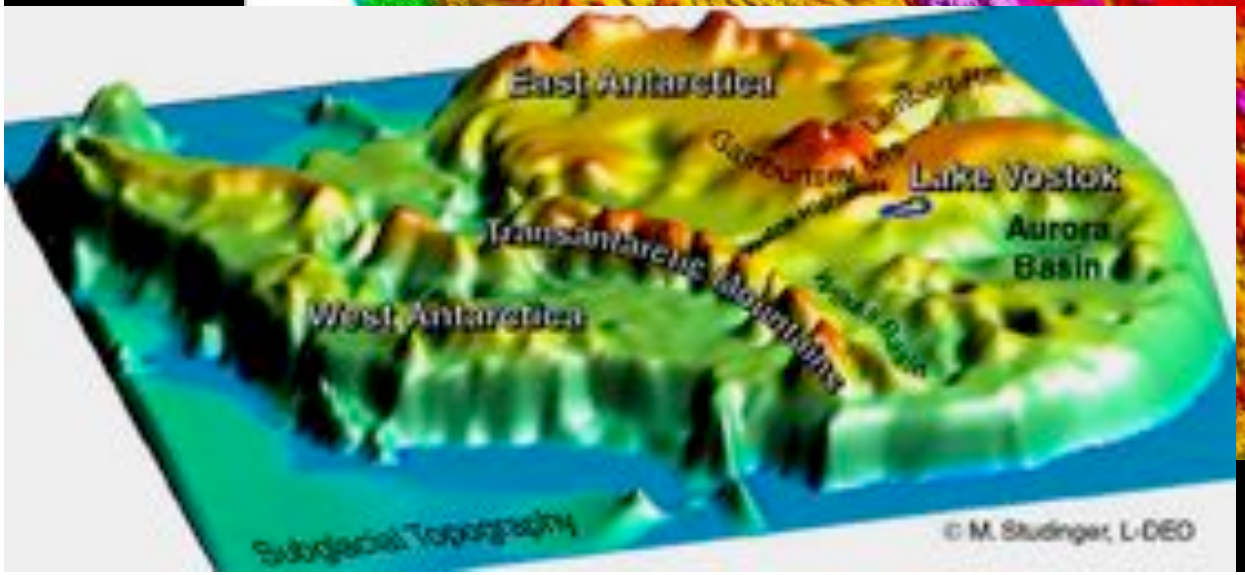
Sediment yield (ρ = 2700kg.m^{-3}):
23-145t.km^{-2}.a^{-1}

Glaciated basin erosion rate:
0.8 – 5.3mm.a^{-1}



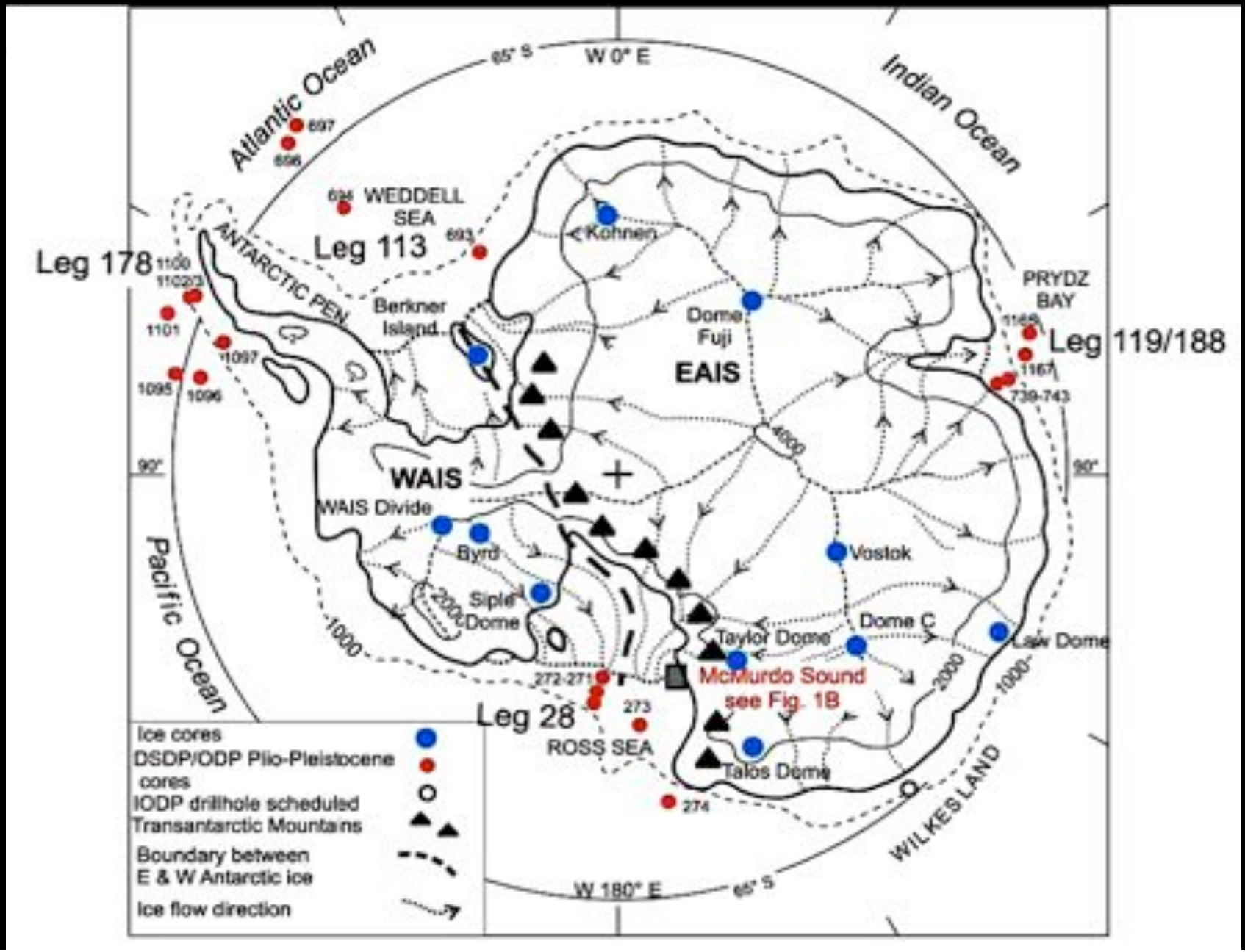
Antarctic subglacial topography

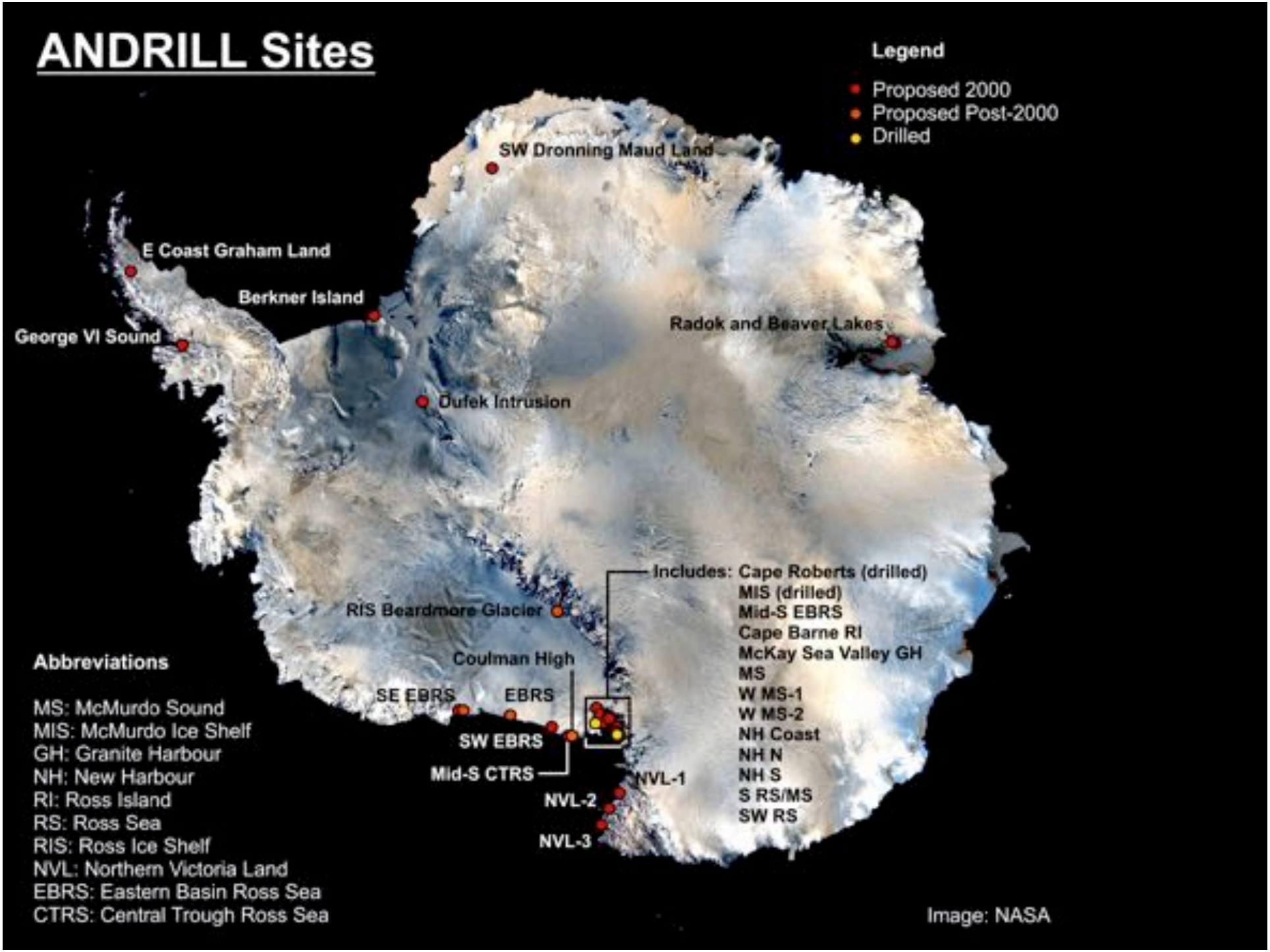




USGS

Most geological records are around margin



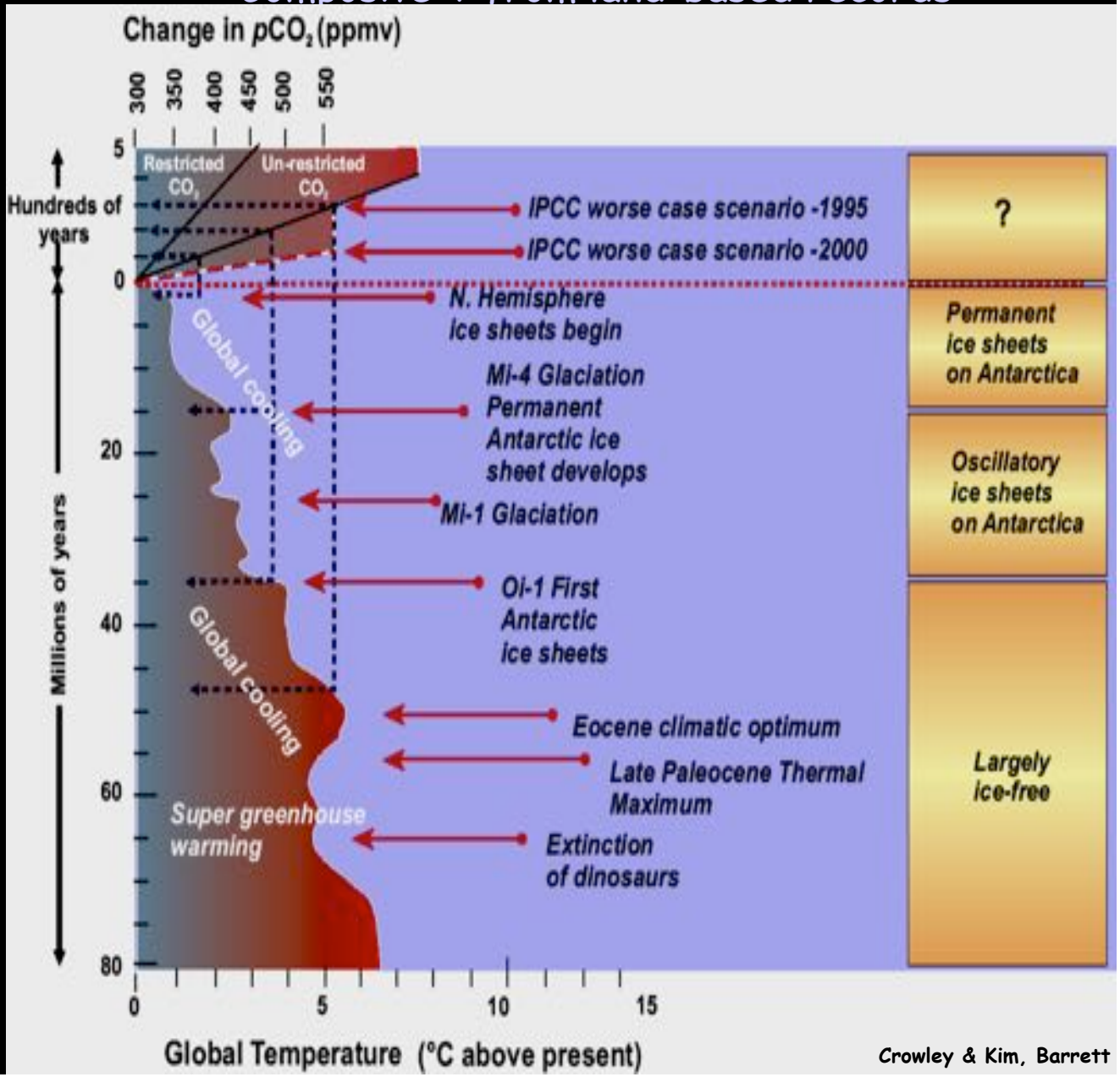

ANDRILL Sites
Legend
Proposed 2000
Proposed Post-2000
Drilled
SW Dronning Maud Land
E Coast Graham Land
Berkner Island
George VI Sound
Radok and Beaver Lakes
Dufek Intrusion
Includes: Cape Roberts (drilled)
MIS (drilled)
Mid-S EBRS
Cape Barne RI
McKay Sea Valley GH
MS
W MS-1
W MS-2
NH Coast
NH N
NH S
S RS/MS
SW RS
RIS Beardmore Glacier
Coulman High
SE EBRS
EBRS
SW EBRS
Mid-S CTRS
NVL-1
NVL-2
NVL-3
Abbreviations
MS: McMurdo Sound
MIS: McMurdo Ice Shelf
GH: Granite Harbour
NH: New Harbour
RI: Ross Island
RS: Ross Sea
RIS: Ross Ice Shelf
NVL: Northern Victoria Land
EBRS: Eastern Basin Ross Sea
CTRS: Central Trough Ross Sea
Image: NASA

Inferences for Antarctica's history

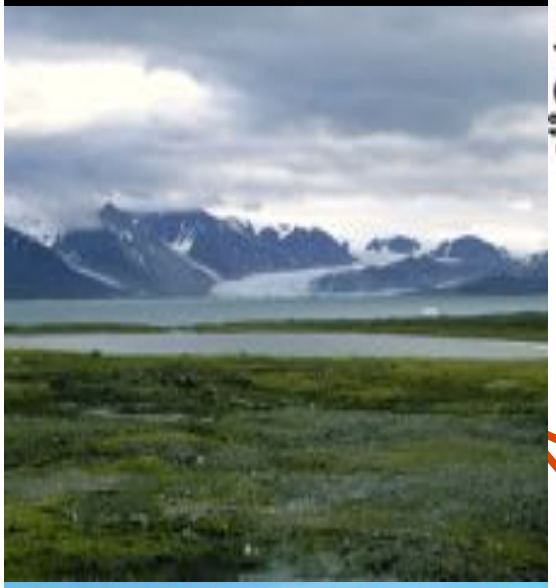
Glimpses of Antarctica's glacial and climatic history through records from deep inside the continent

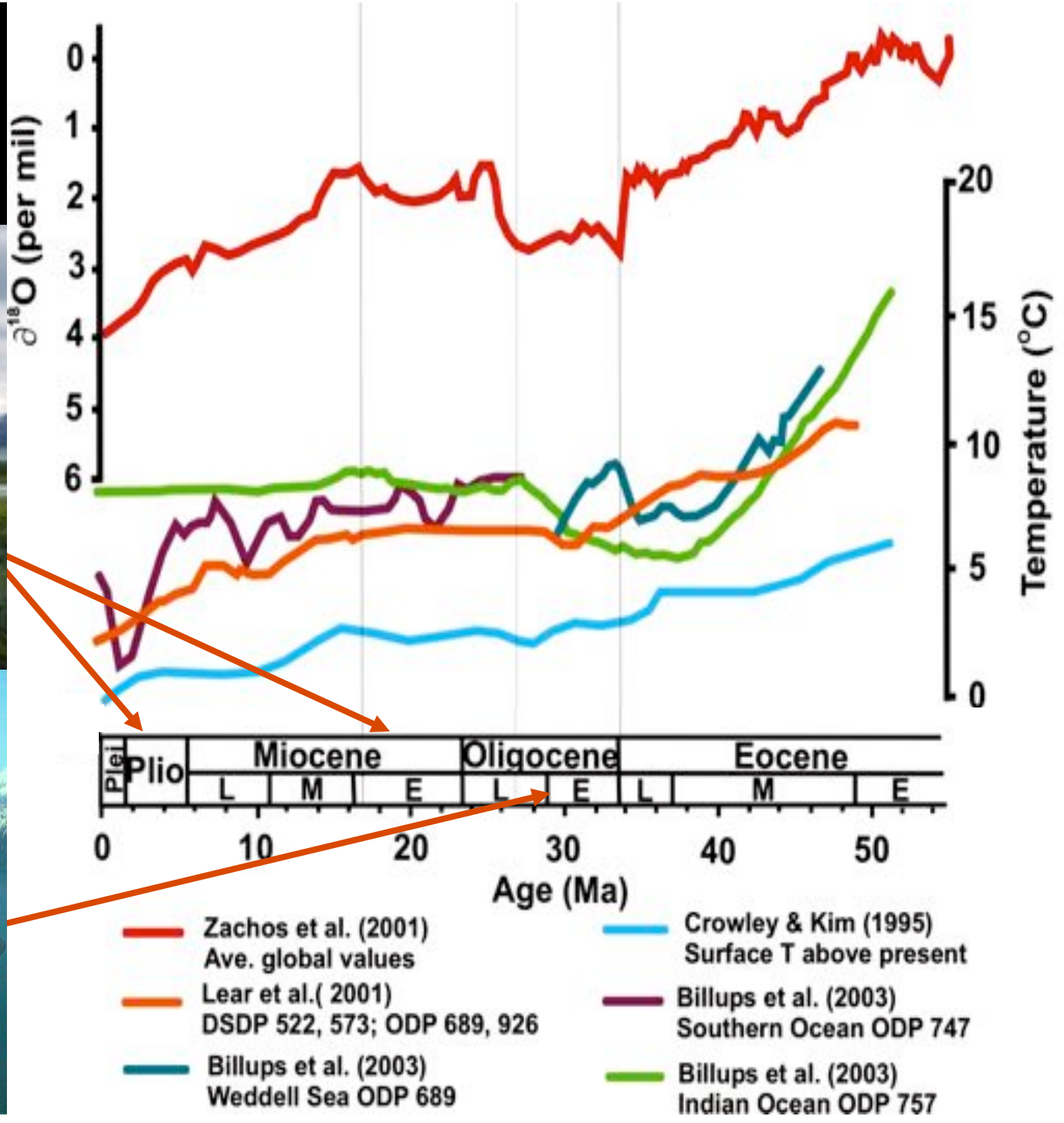
Lakes and basins hold key to interior history

Composite T from land-based records

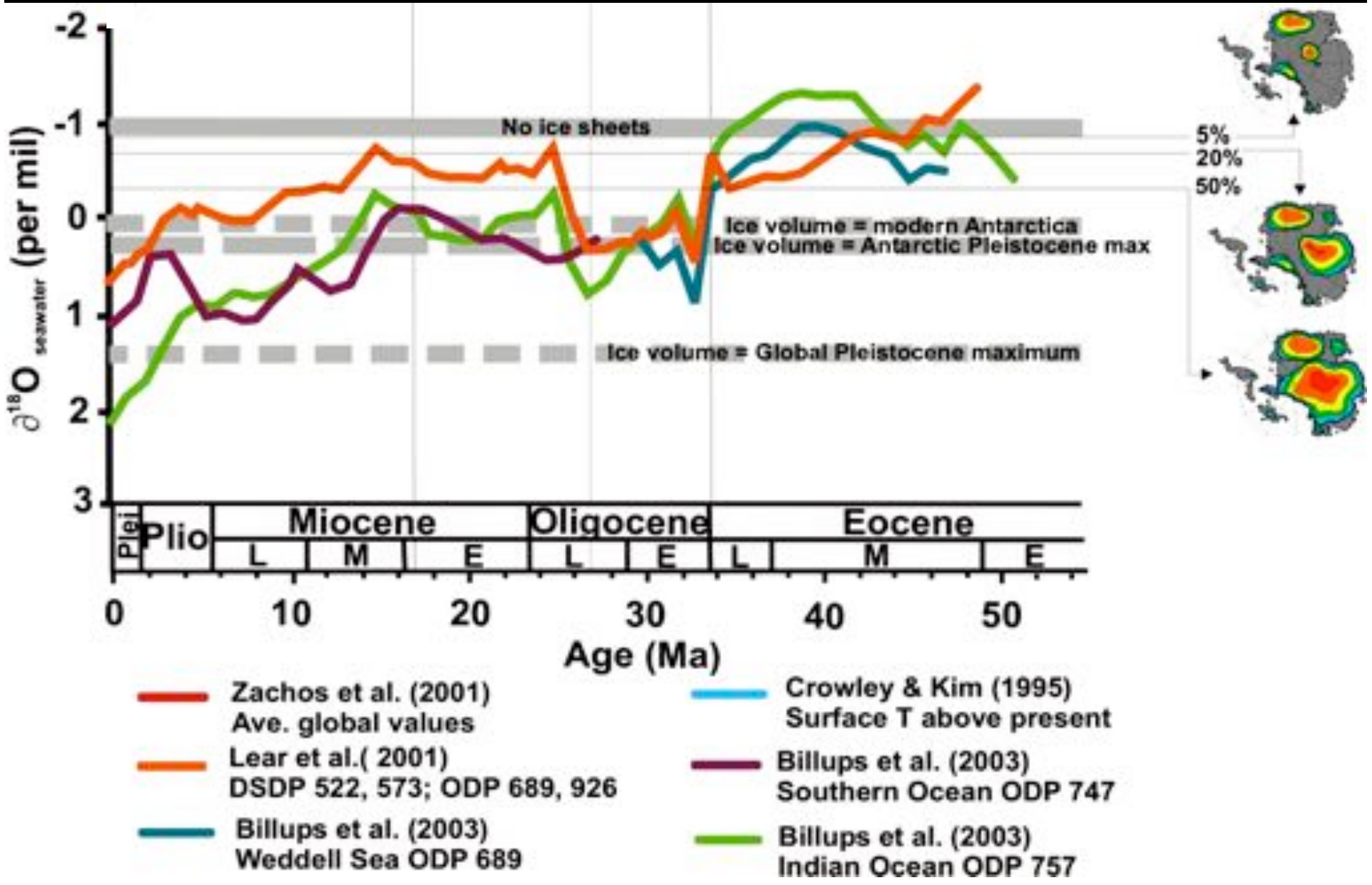


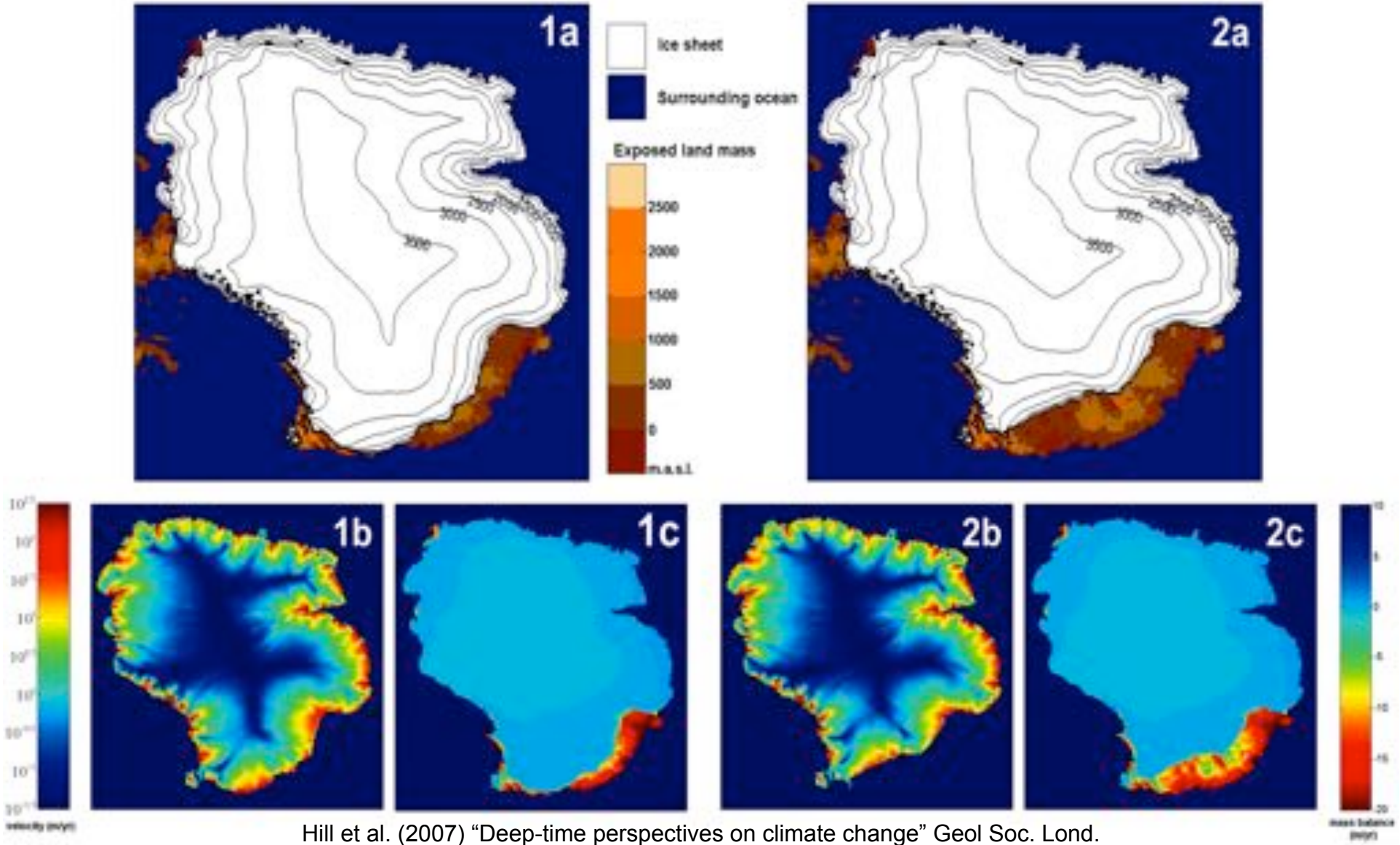
Much warmer in past times





It hasn't been one large ice sheet throughout its 35+ million year history



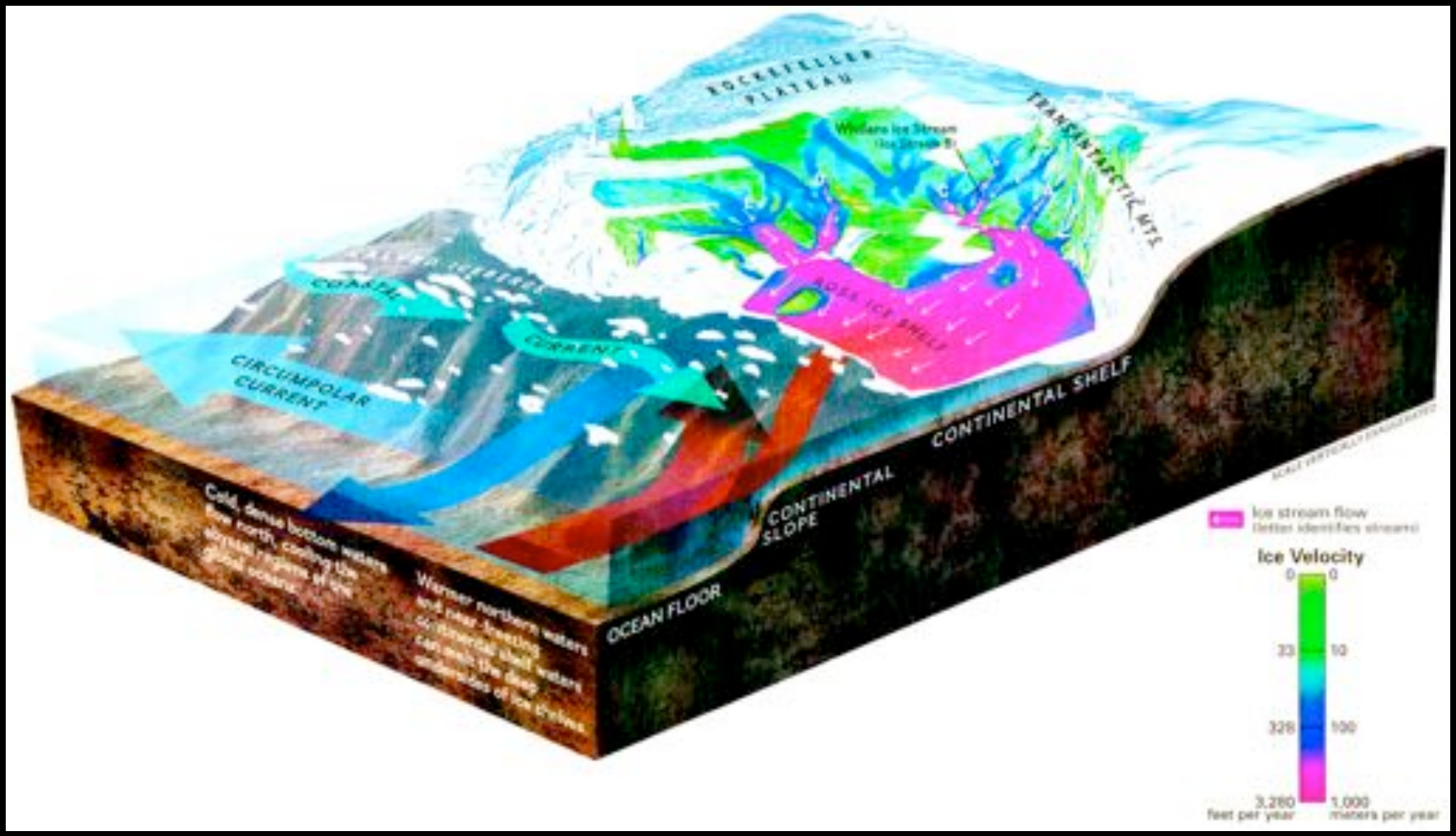


Hill et al. (2007) "Deep-time perspectives on climate change" Geol Soc. Lond.

Early Pliocene ice volume modeling

- fully-coupled GCM driving ice sheet model
- ~20m sea-level equivalent ice volume
- 400ppm CO_2

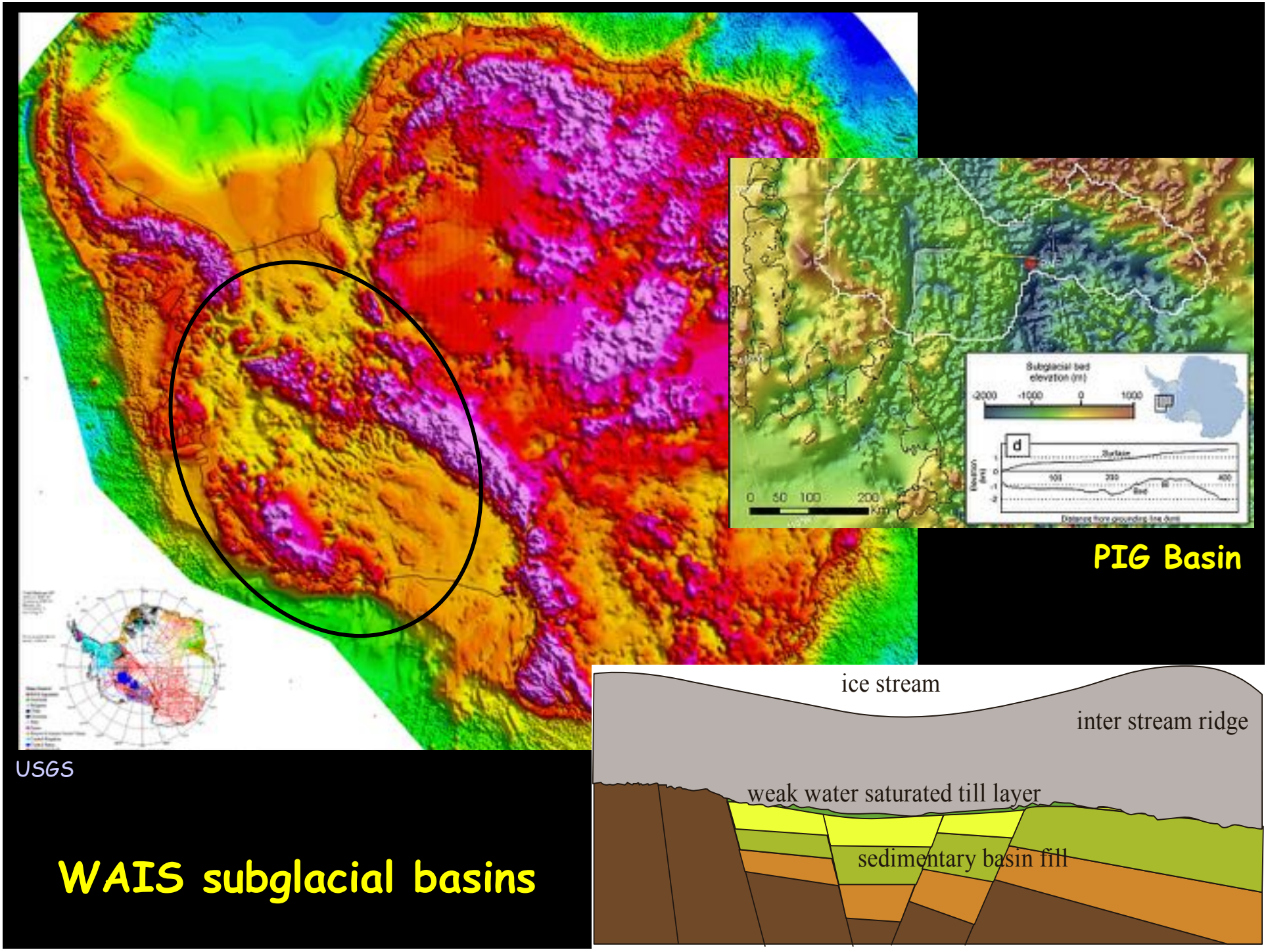
Ross Embayment (WAIS, RIS) basins



NGS

Sub-ice shelf – compliment ANDRILL with:

geophysical surveys, oceanography, geological sampling and traverse style fast access



WAIS subglacial basins

Microfossils from Beneath UpB

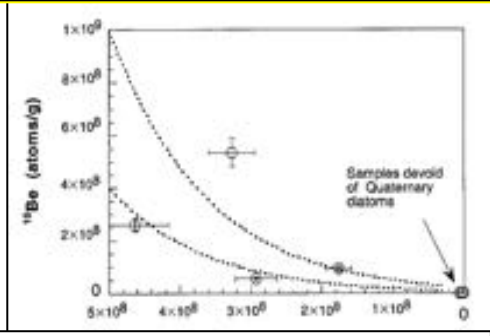
include diatoms and other fossils of mixed ages

The youngest (Pleistocene) diatoms provide direct evidence of the most recent collapse

3 JULY 1998 VOL 281 SCIENCE REPORTS

Pleistocene Collapse of the West Antarctic Ice Sheet

Reed P. Scherer,* Ala Aldahan, Slawek Tulaczyk, Göran Possnert, Hermann Engelhardt, Barclay Kamb



Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Change Section), 90 (1991) 395–412
Elsevier Science Publishers B.V., Amsterdam

Quaternary and Tertiary microfossils from beneath Ice Stream B: Evidence for a dynamic West Antarctic Ice Sheet history

Reed P. Scherer

Byrd Polar Research Center and Department of Geological Sciences, The Ohio State University, Columbus, Ohio 43210, USA

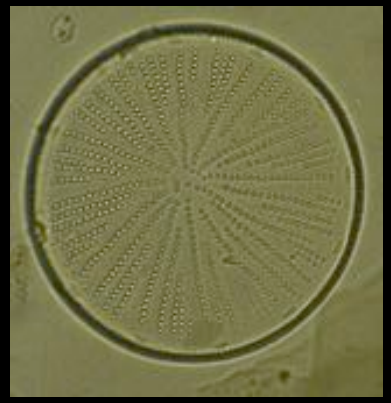
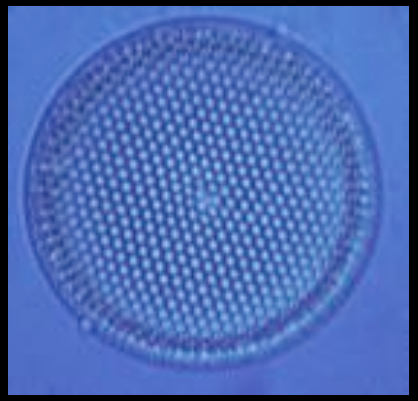
(Received January 2, 1991; revised and accepted March 4, 1991)

Microfossils from Beneath UpB (Kamb)

include diatoms and other fossils of mixed ages

The youngest (Pleistocene) diatoms provide direct evidence of the most recent collapse



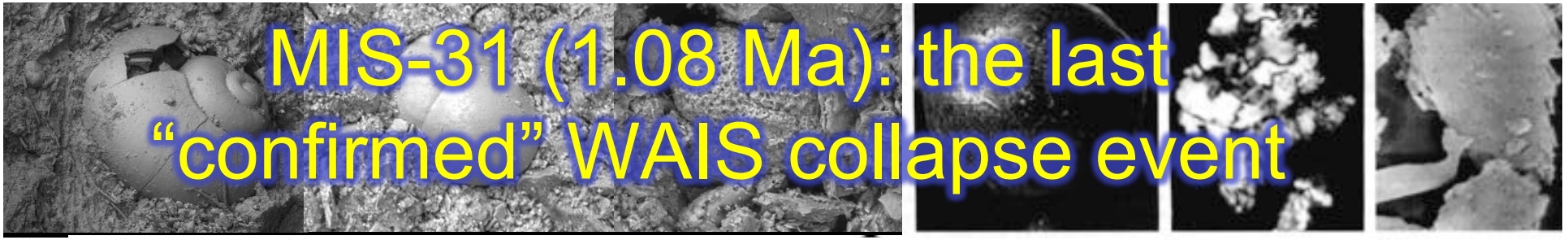
But they don't say with certainty if it was

the last interglacial (MIS-5e) or

an earlier late Pleistocene interglacial

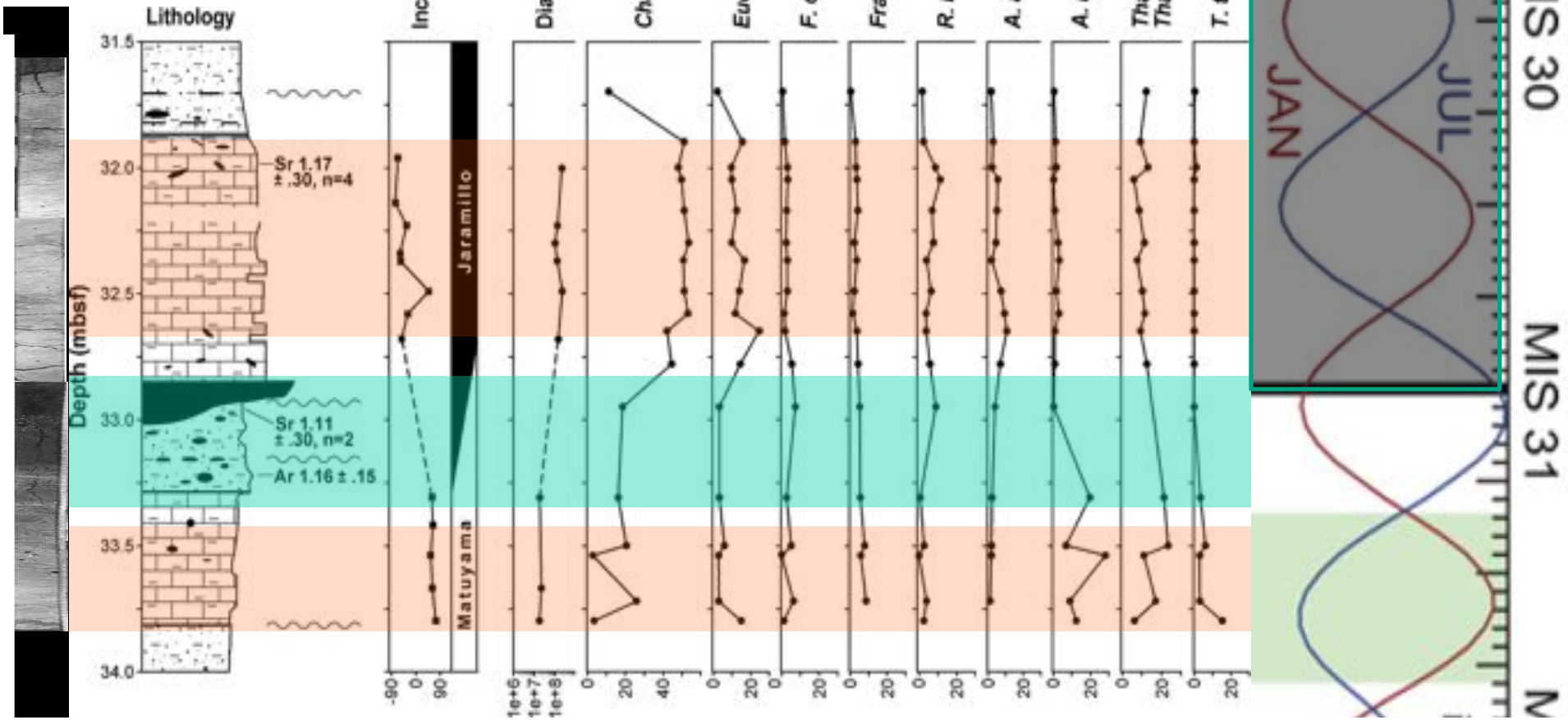
Also can't say how fast it happened

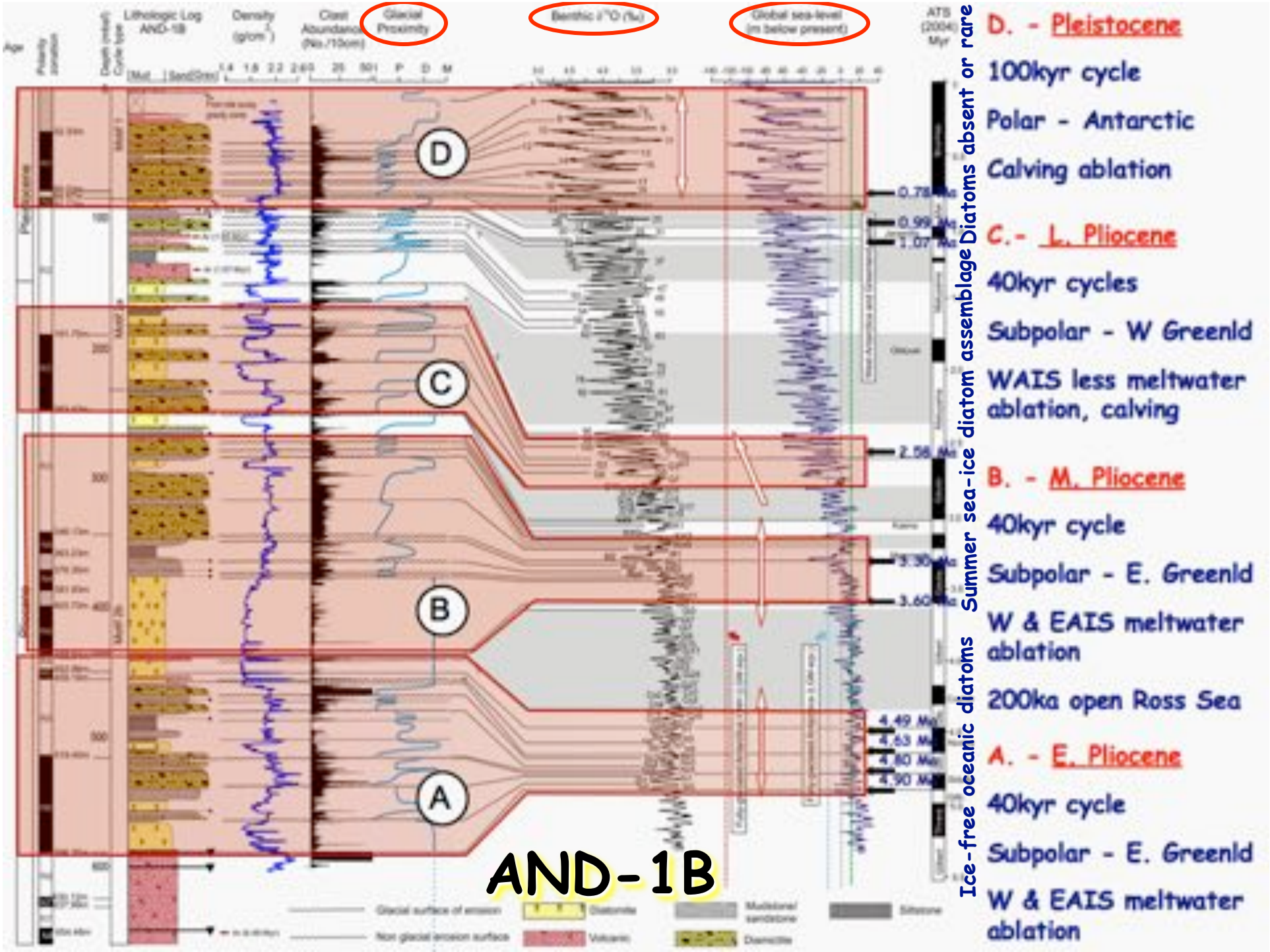
MIS-31 (1.08 Ma): the last "confirmed" WAIS collapse event



Antarctic records of precession-paced insolation-driven warming during early Pleistocene Marine Isotope Stage 31

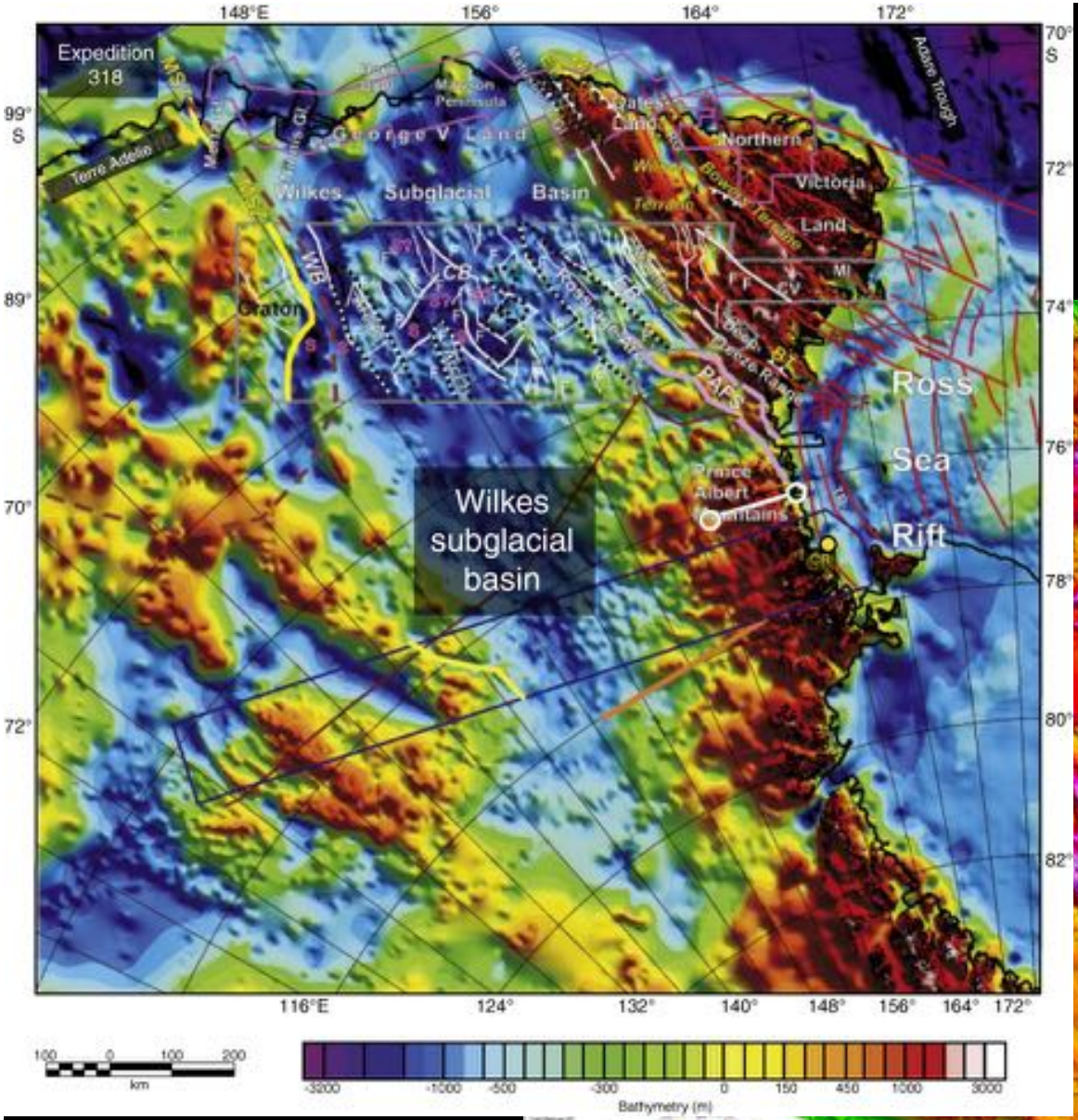
Scherer et al. 2008, GRL

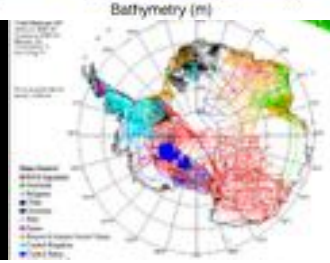



Lithologic Log AND-1B
Glacial Proximity
Benthic δ18O (‰)
Global sea-level (m below present)
D
C
B
A
0.78 Ma
0.99 Ma
1.07 Ma
2.58 Ma
3.30 Ma
3.60 Ma
4.49 Ma
4.63 Ma
4.80 Ma
4.90 Ma
AND-1B
D. - Pleistocene
100kyr cycle
Polar - Antarctic
Calving ablation
C.- L. Pliocene
40kyr cycles
Subpolar - W Greenld
WAIS less meltwater ablation, calving
B. - M. Pliocene
40kyr cycle
Subpolar - E. Greenld
W & EAIS meltwater ablation
200ka open Ross Sea
A. - E. Pliocene
40kyr cycle
Subpolar - E. Greenld
W & EAIS meltwater ablation
Ice-free oceanic diatoms
Summer sea-ice diatom assemblage
Diatoms absent or rare

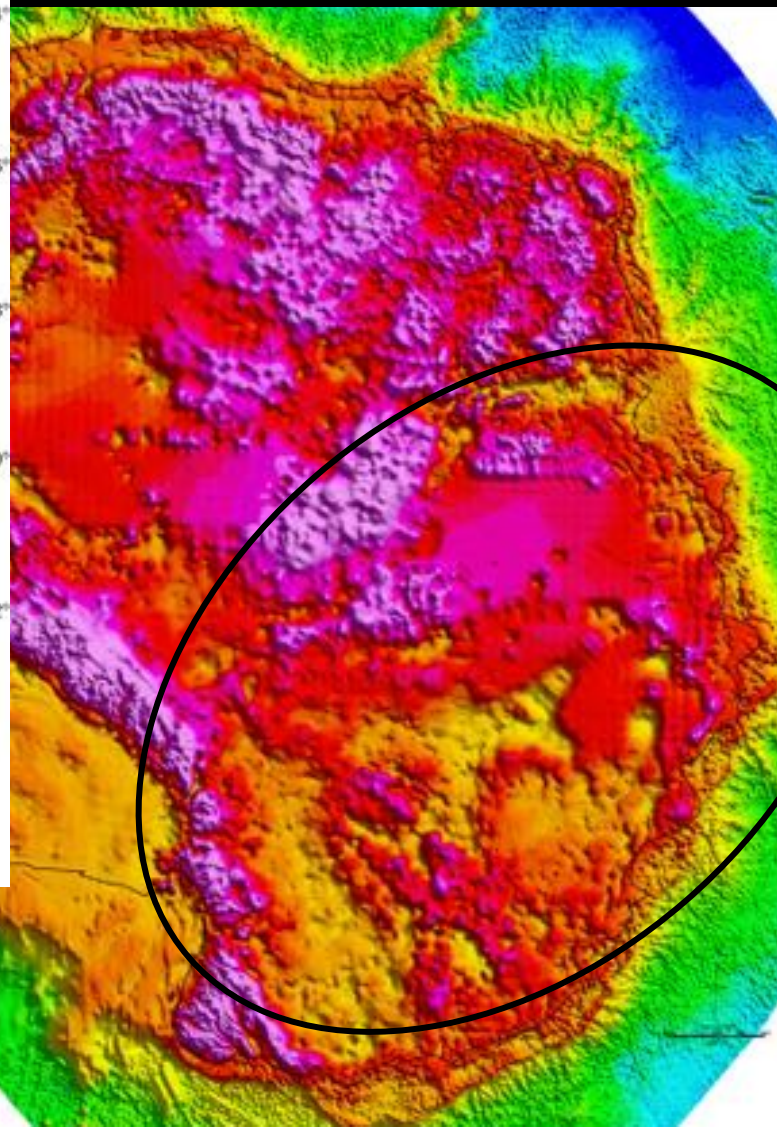
EAIS subglacial basins

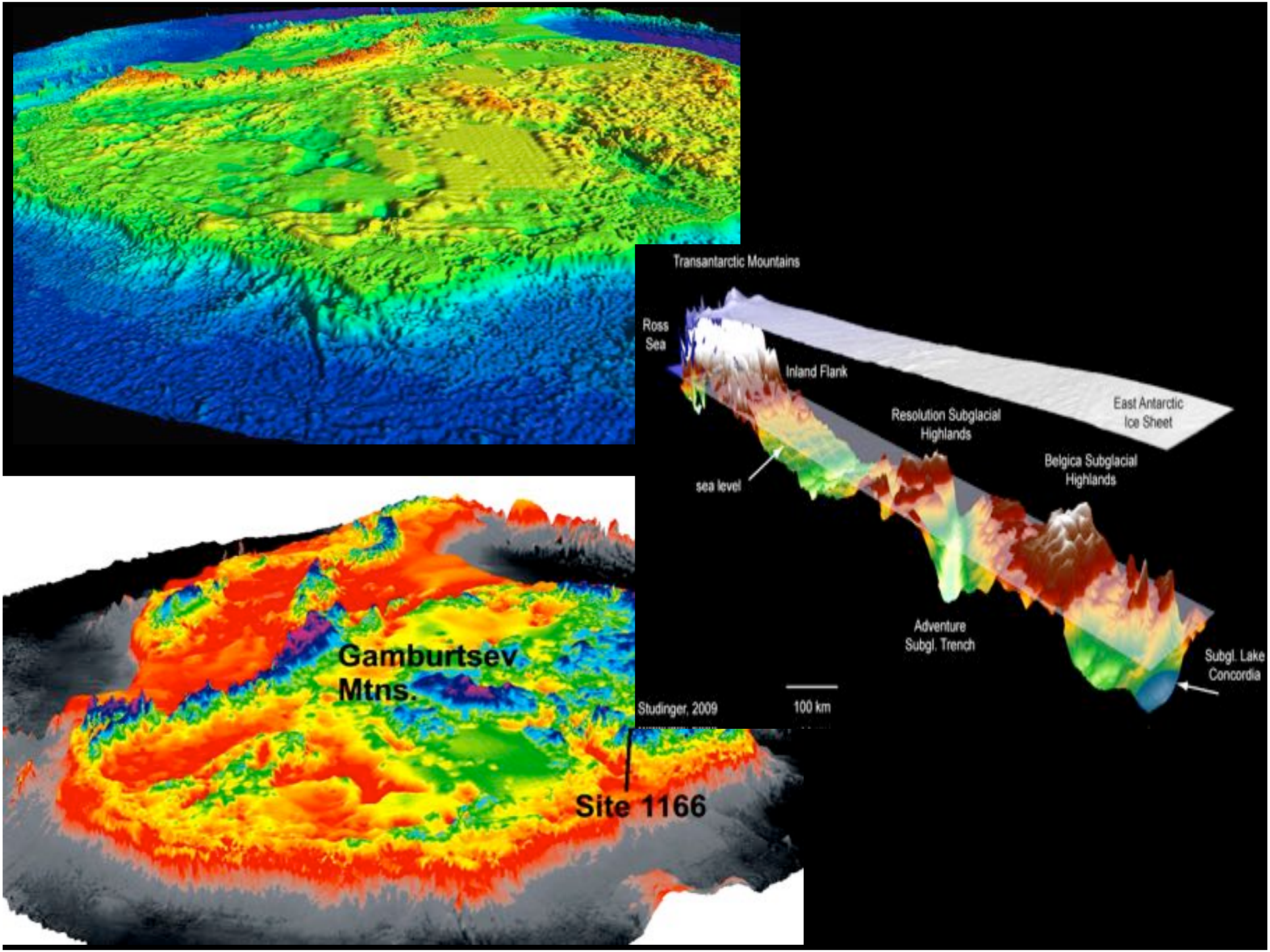
USGS



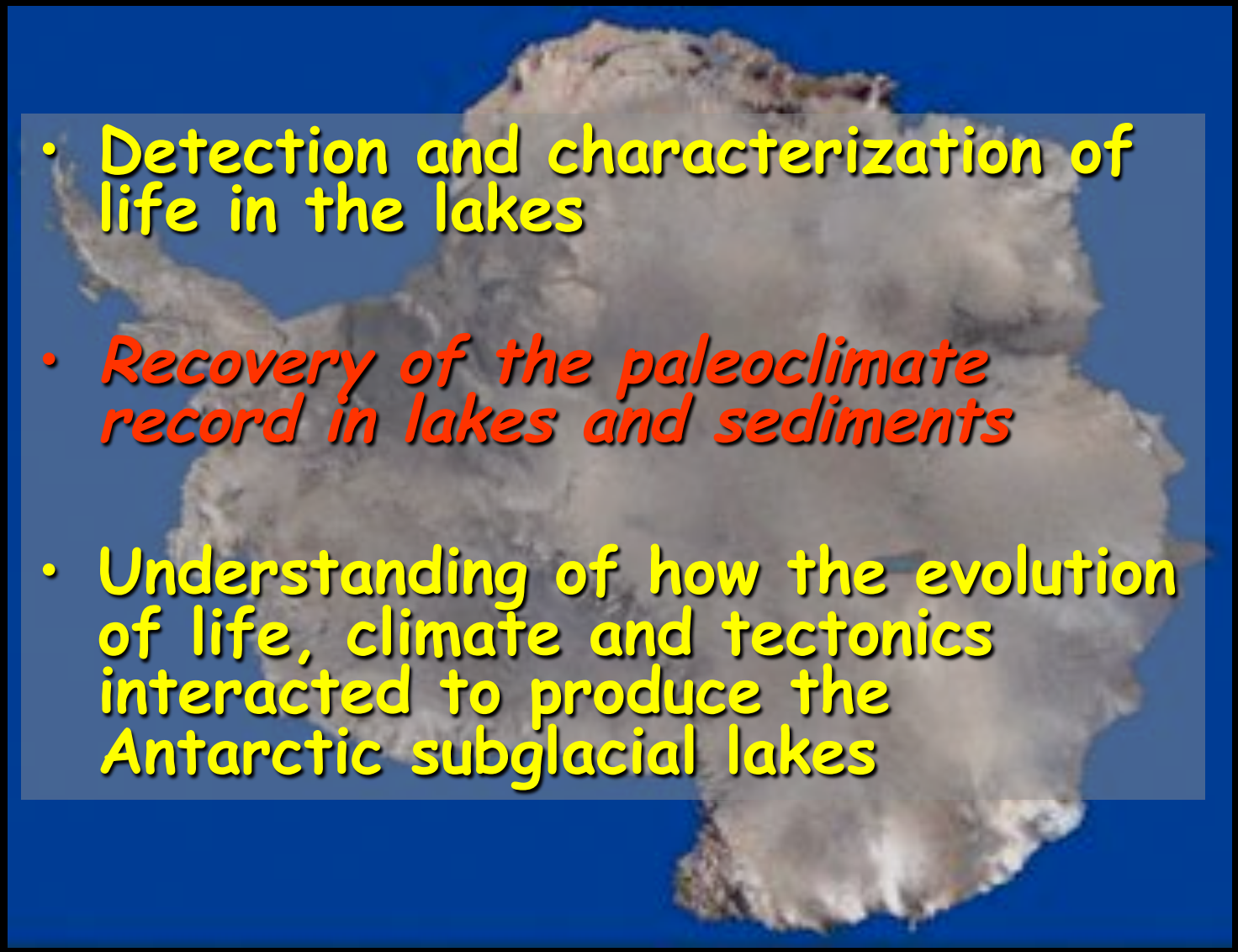


Wilkes subglacial basin



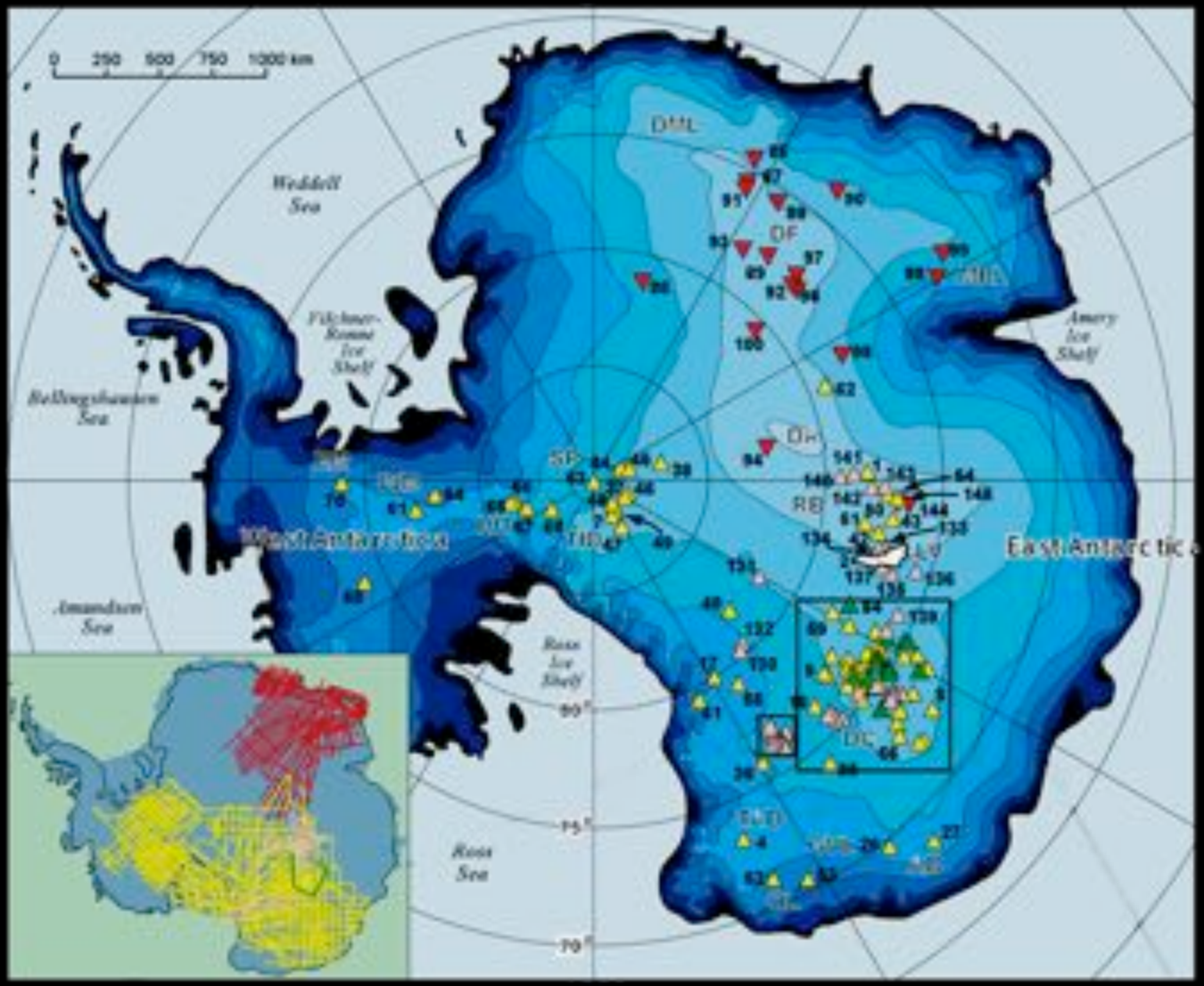

Transantarctic Mountains
Ross Sea
Inland Flank
East Antarctic Ice Sheet
Resolution Subglacial Highlands
Belgica Subglacial Highlands
sea level
Adventure Subgl. Trench
Subgl. Lake Concordia
Studinger, 2009
100 km
Gamburtsev Mtns.
Site 1166

Subglacial Antarctic Lake Environments Scientific Objectives



- Detection and characterization of life in the lakes
- *Recovery of the paleoclimate record in lakes and sediments*
- Understanding of how the evolution of life, climate and tectonics interacted to produce the Antarctic subglacial lakes

Lake locations on ice surface elevation

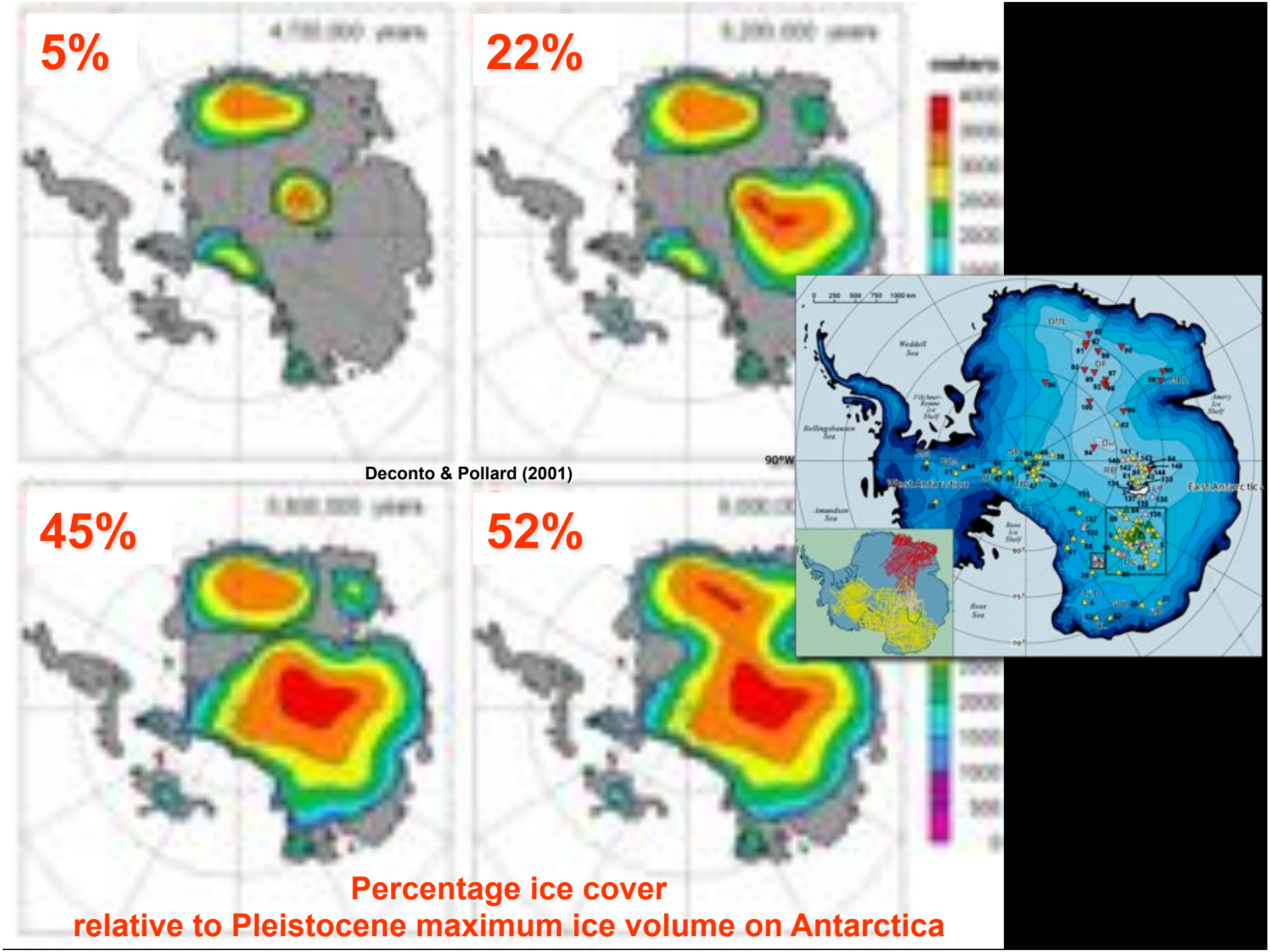


Key to subglacial lake identification

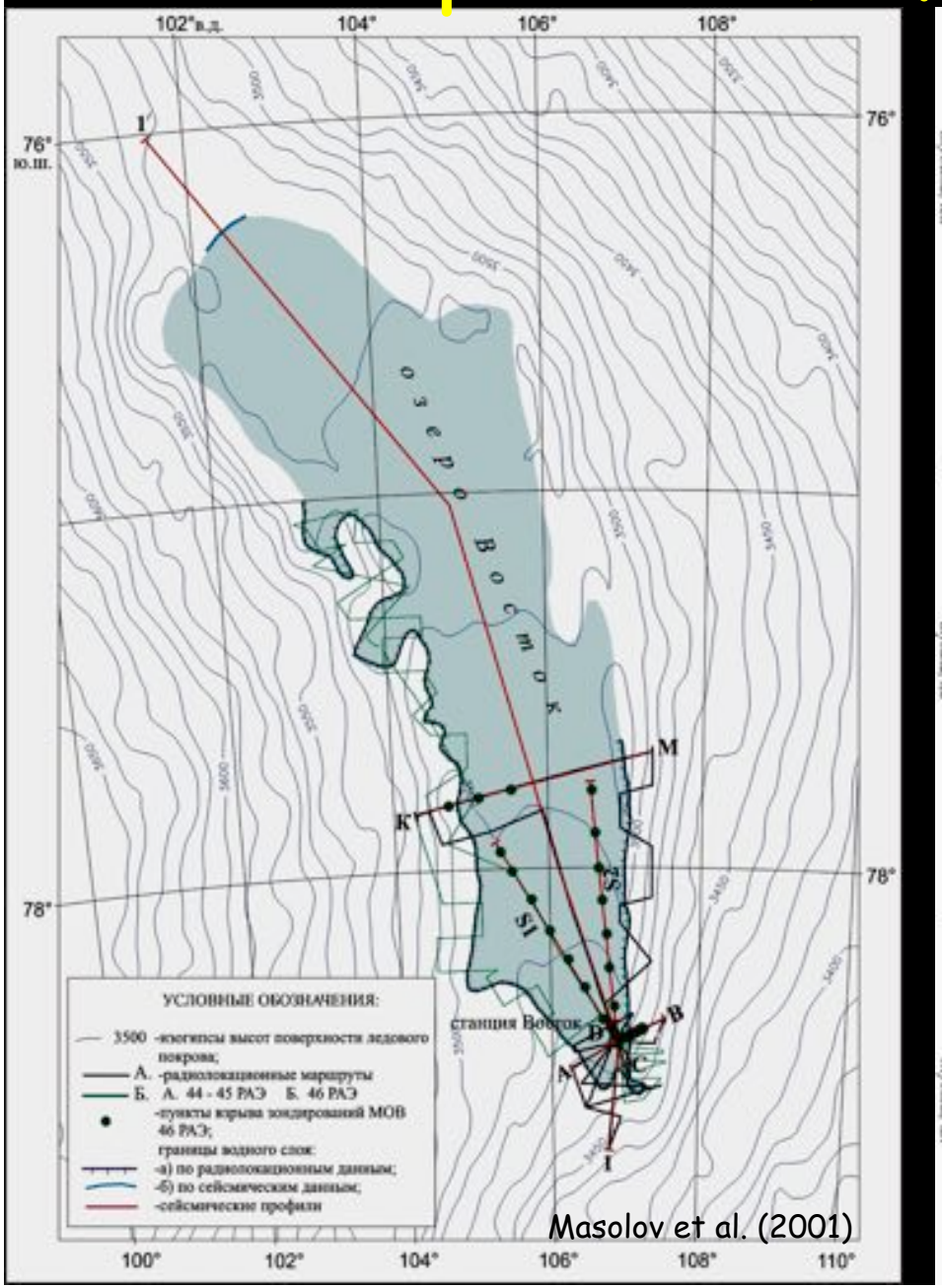
- US
- Russian
- Italian
- UK-US-Danish

More than 150 subglacial lakes in Antarctica

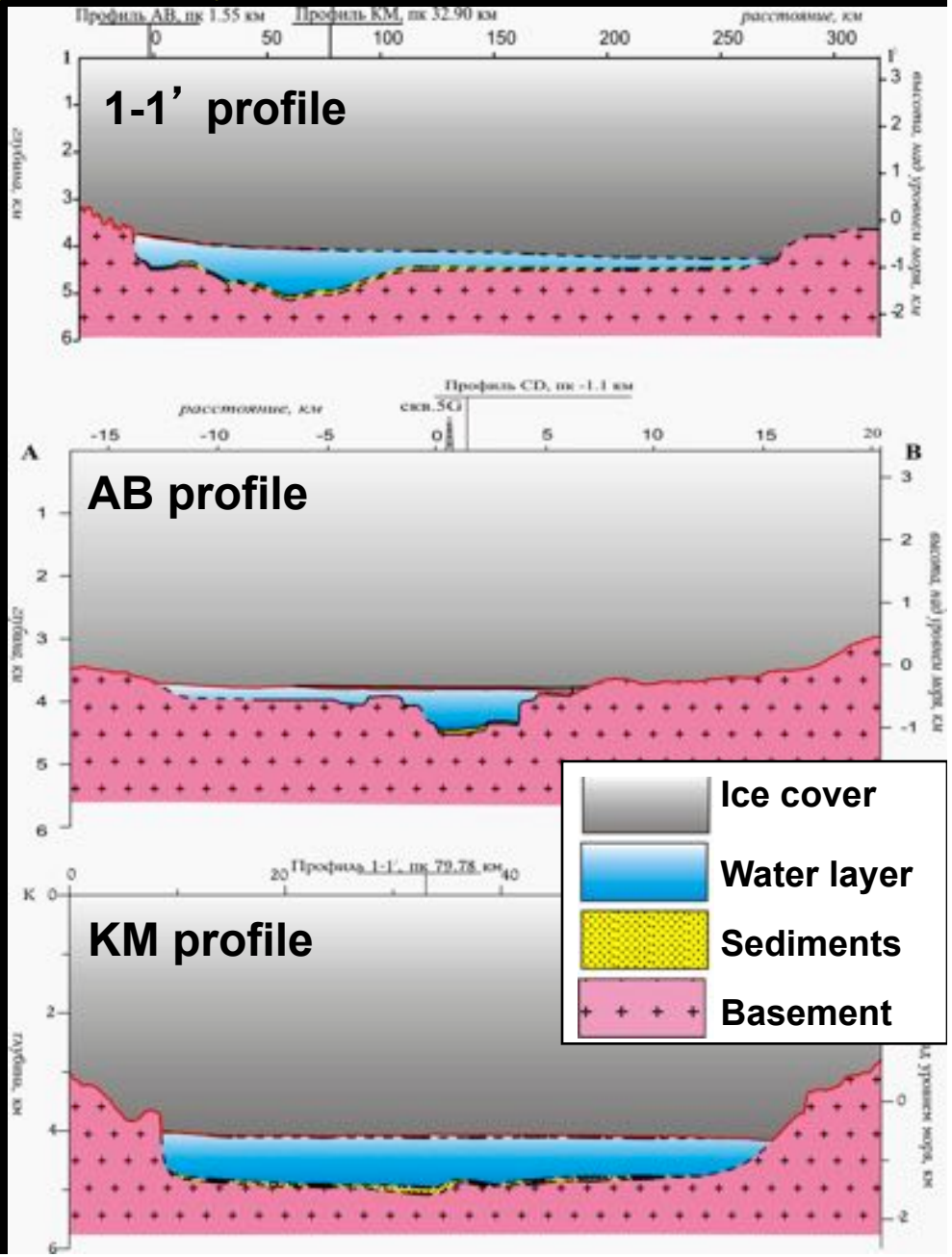
Siegert, et al 2006


5%
22%
45%
52%
Deconto & Pollard (2001)
Percentage ice cover
relative to Pleistocene maximum ice volume on Antarctica

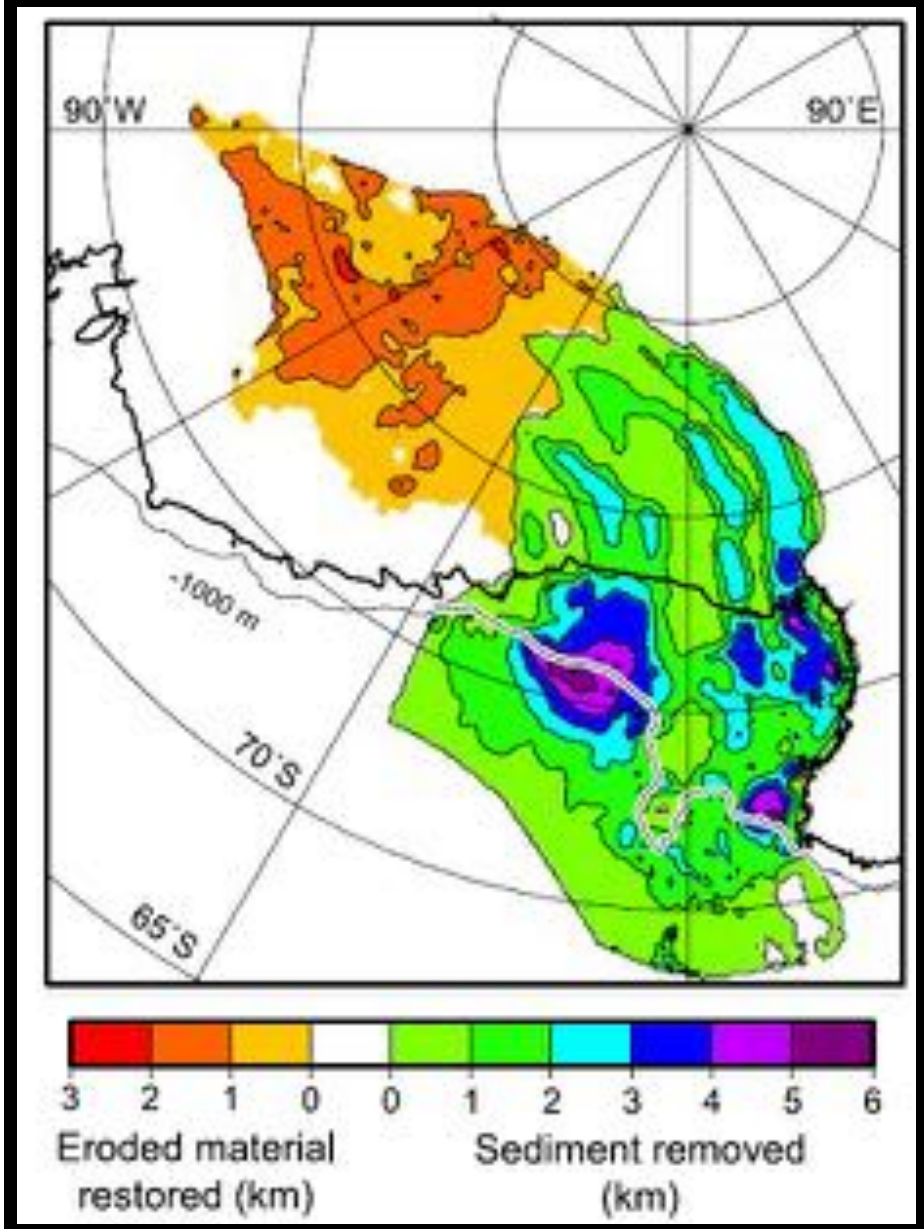
e.g. seismic reflection in Subglacial Lake Vostok shows up to 300 m of sediment on lake bed



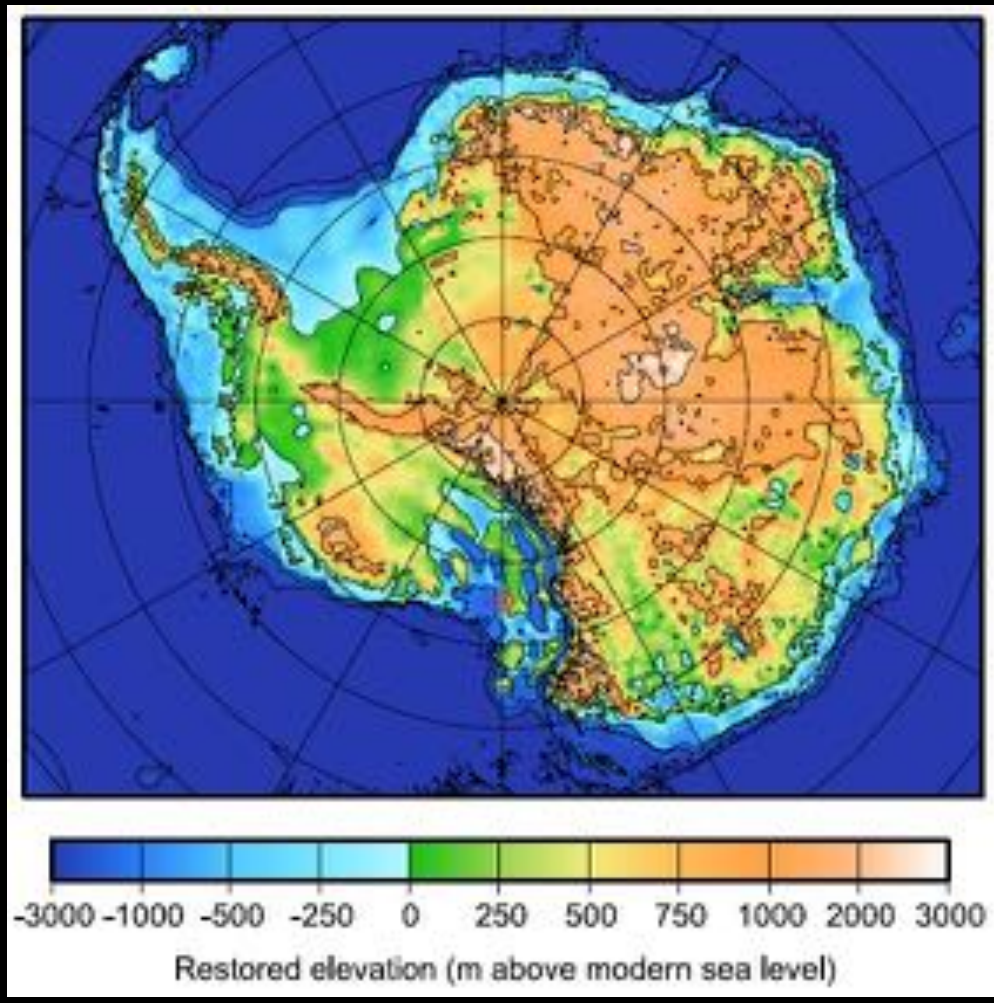
Masolov et al. (2001)



Reconstructed topography for West Antarctica



Eocene ~34Ma



Wilson & Luyendyke 2009

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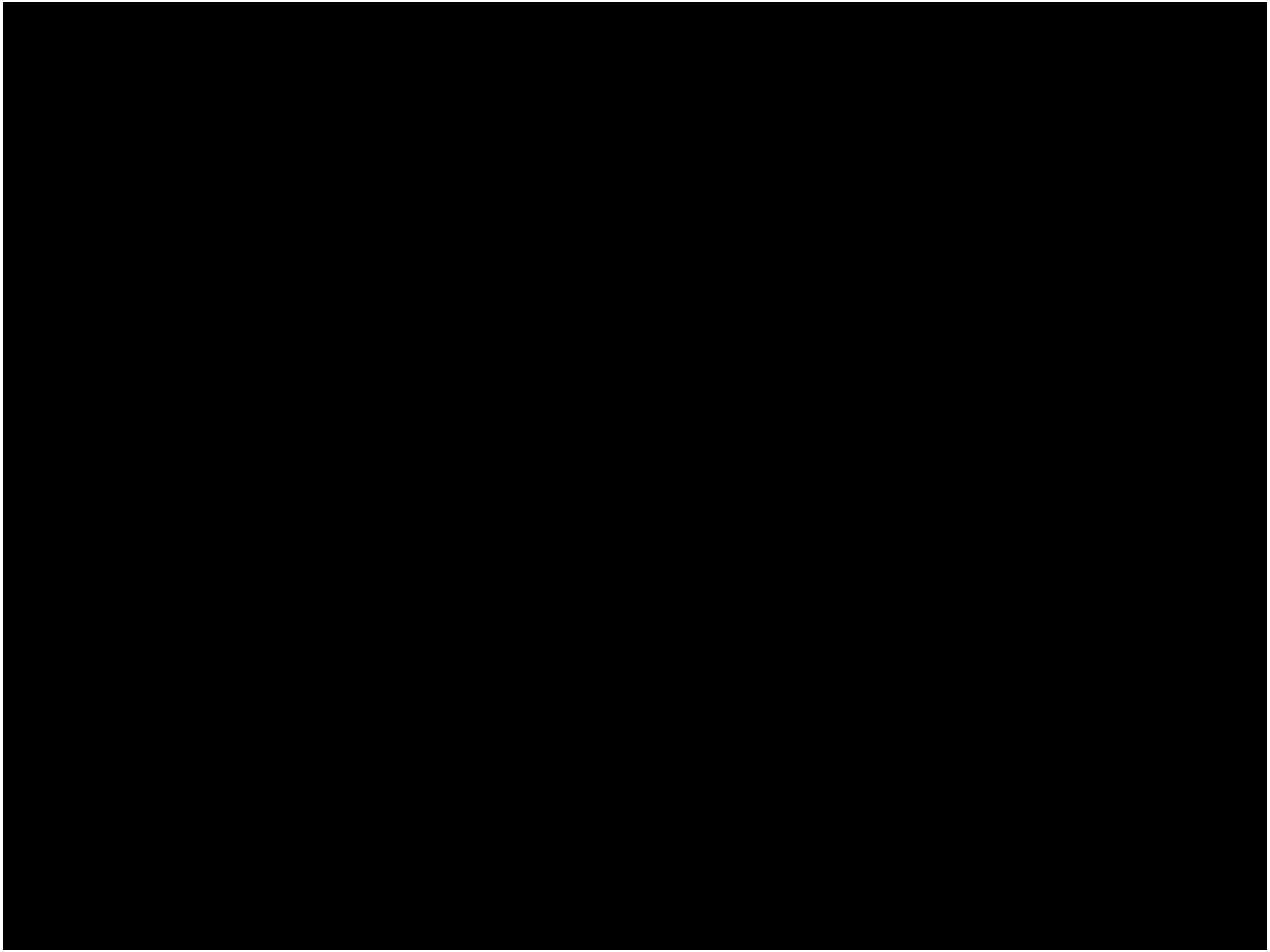
past heights of ice sheets to constrain past sizes & volumes
determine by exposure dating of sub-ice bedrock and
reconstructing paleo-topography

Greenland ice free
for the last time?

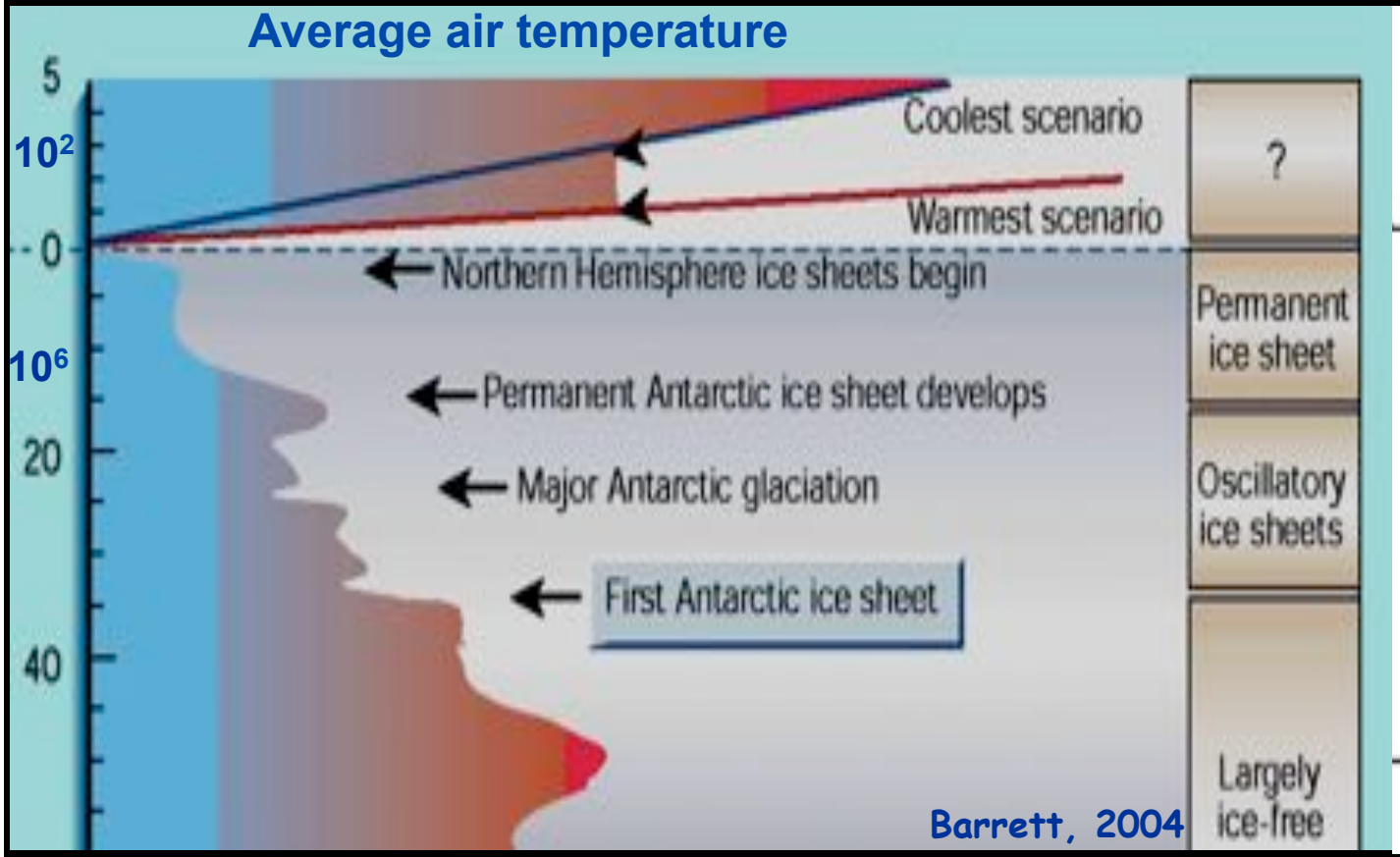
Svend Funder

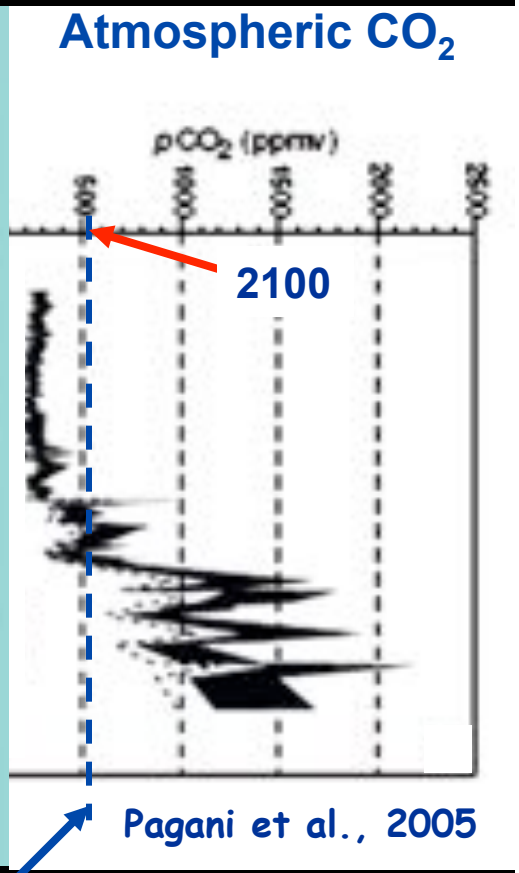
Also important questions and targets in Greenland



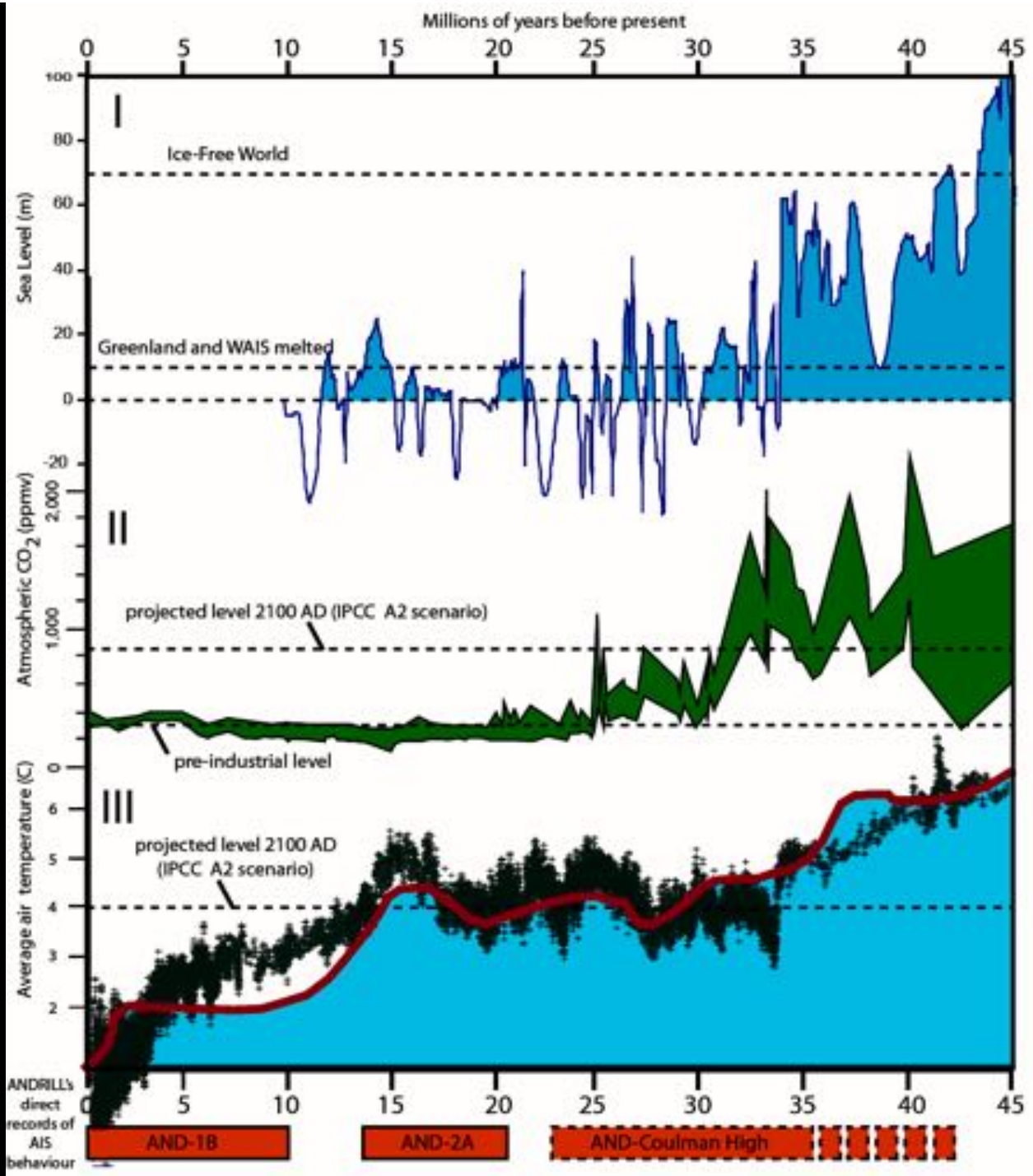
The Antarctic Ice Sheet is old (more than 35 Myr)

It formed as Earth's climate was cooling





Future CO_2 at 550ppm by 2100? - IPCC



after
Kominz et al 2008

after
Pagani et al 2008

after
Crowley and Kim 1995

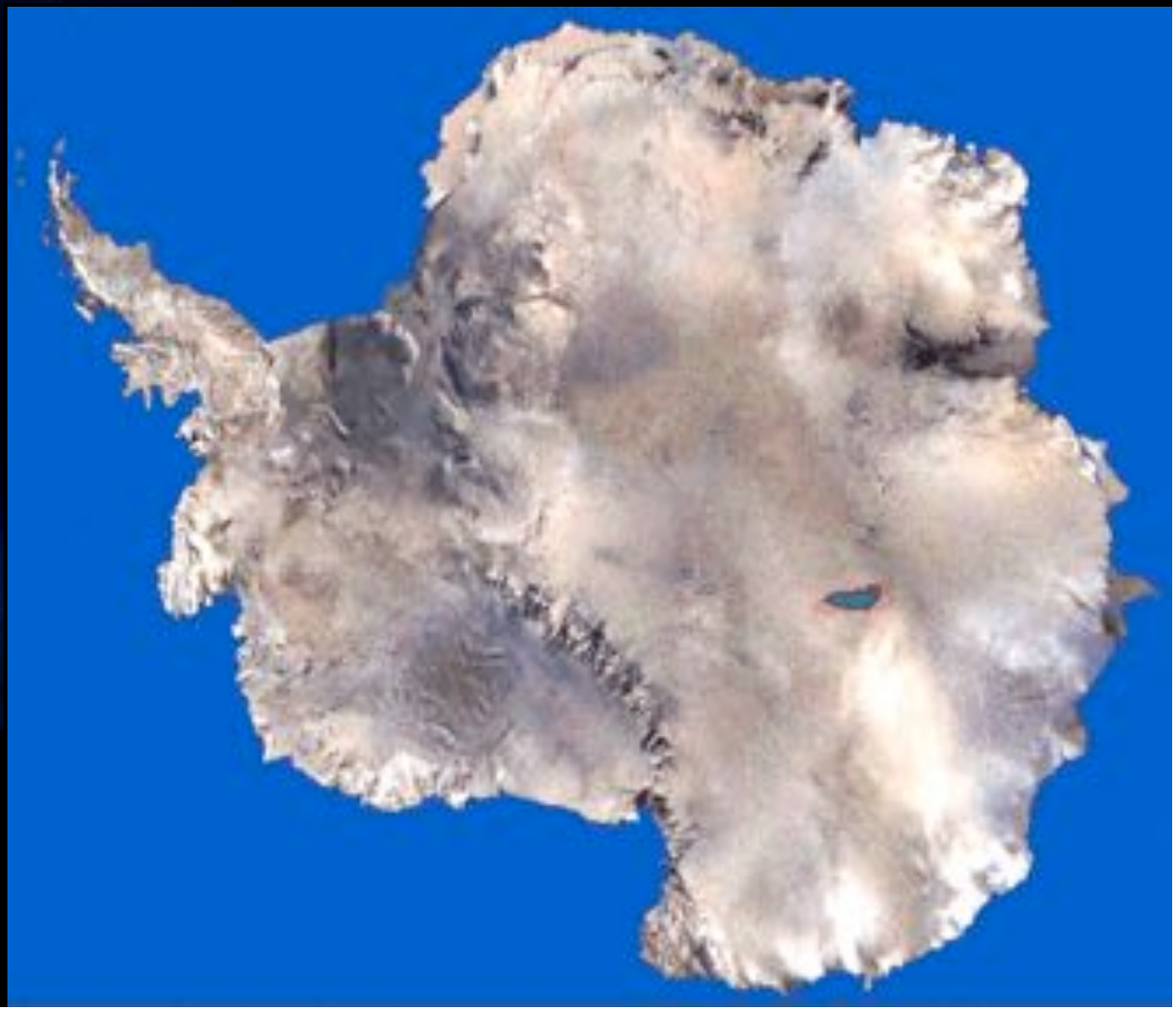
after
Zachos et al 2008

Levy 2009
pers. comm.

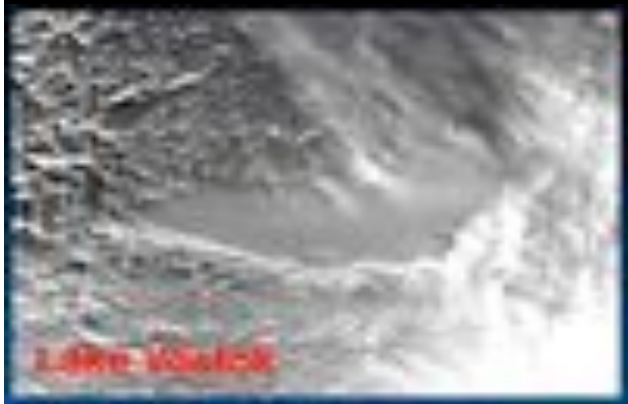
Program in Subglacial Antarctic Lake Environments - SALE

J. C. Priscu, USA, Convener (limnology)	
R. Bell, USA (geology, geophysics)	S. Bulat, Russia (molecular biology)
J.C. Ellis-Evans, UK (limnology, biology)	M.C. Kennicutt, USA, Secretary (geochemistry)
V. Lukin, Russia (glaciology)	R.D. Powell, USA (paleoclimatology, sedimentology)
J.R. Petit, France (glaciology)	
M. Siegert, UK (glaciology)	I. Tabacco, Italy (glaciology, geophysics)

ANTARCTIC SUBGLACIAL LAKES

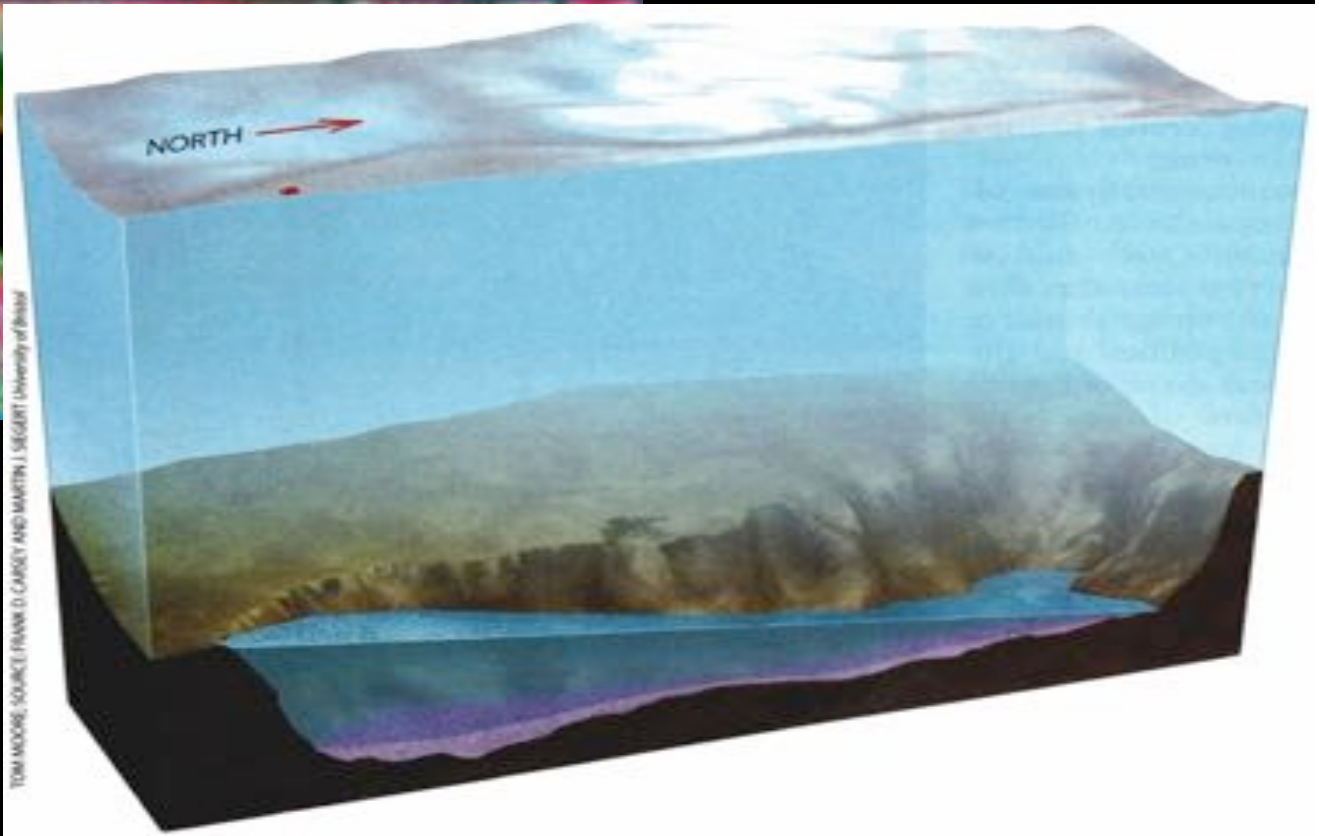


Subglacial Lake Vostok – largest of the subglacial lakes



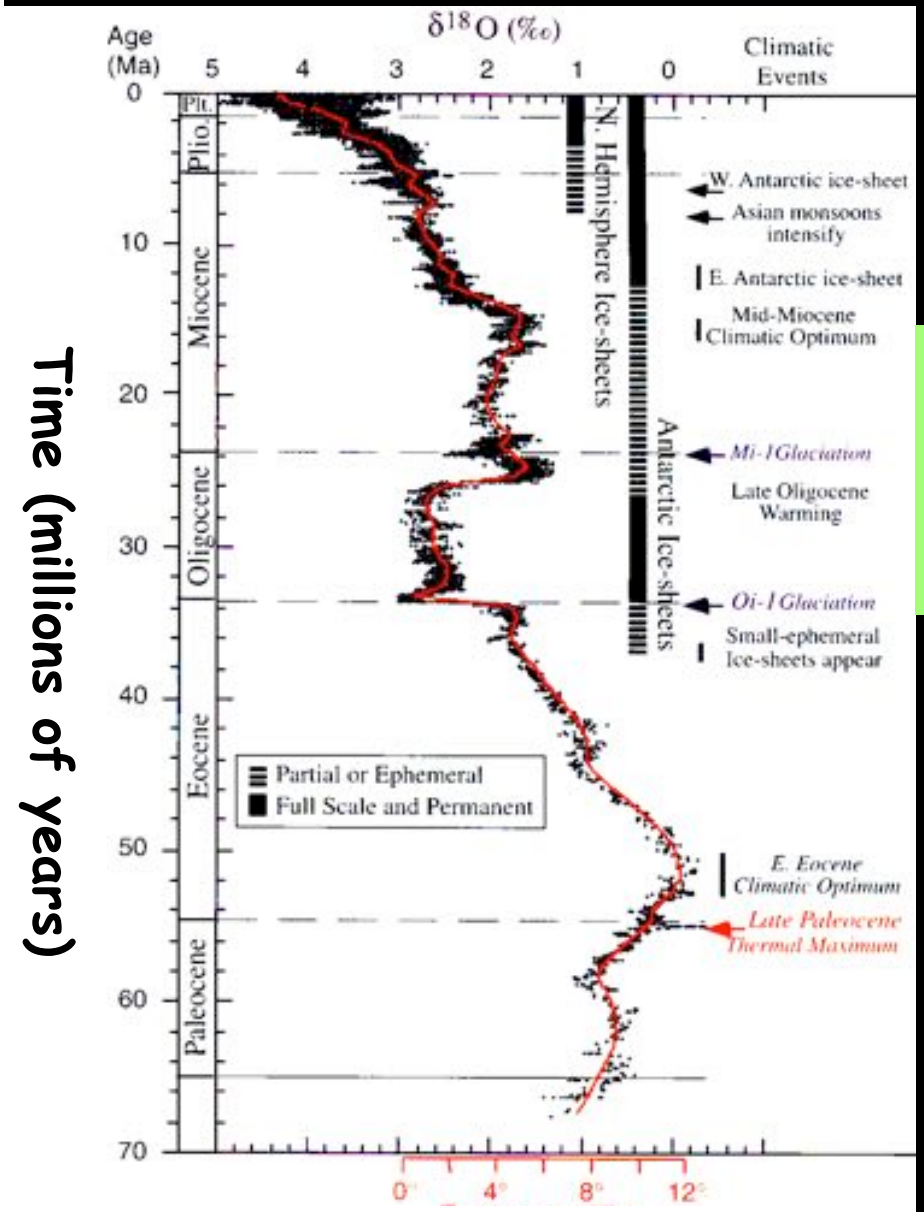
Equal in area to Lake Ontario (230 km x 50 km)

but twice as deep (about 670 m deep)



Cool-temperate through subpolar to polar climates

Oceanic Record



Zachos et al.

CRP

Ross Sea Record

Cape Roberts and ANDRILL

Miocene-Pliocene, sub-polar glaciers, herb-moss tundra

Oligocene, temperate glaciers, beech and woody vegetation