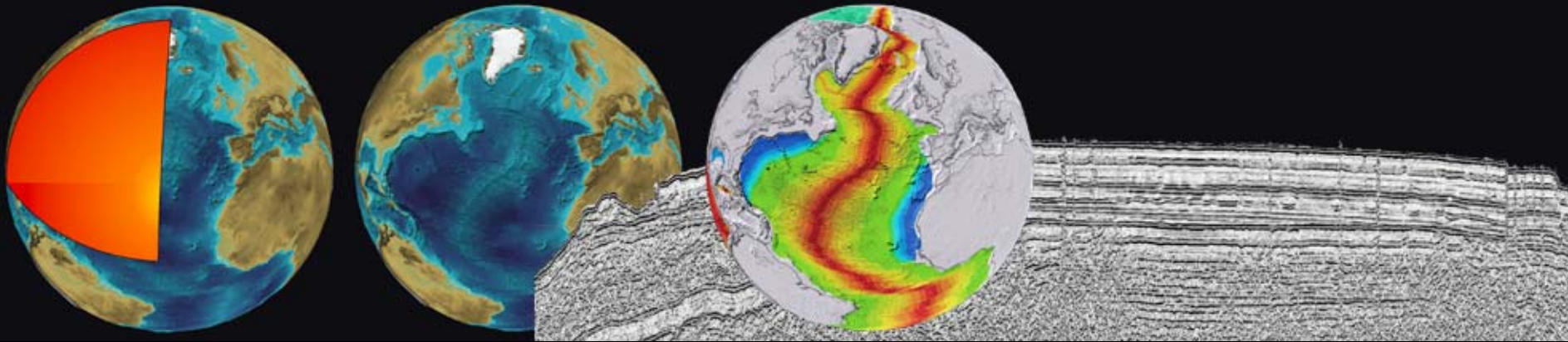




Was the Arctic always cold?



Martin Jakobsson
Dept. of Geology and Geochemistry
Stockholm University





Was the Arctic always cold?

1. *History: The discovery of an ice covered cold deep ocean*
2. *Arctic glacial-interglacial climate variations during the last million years: where are we going?*
3. *The development of the Amerasian and Eurasian basins: from a greenhouse world to an icehouse world*
4. *Arctic Coring EXpedition (ACEX)*

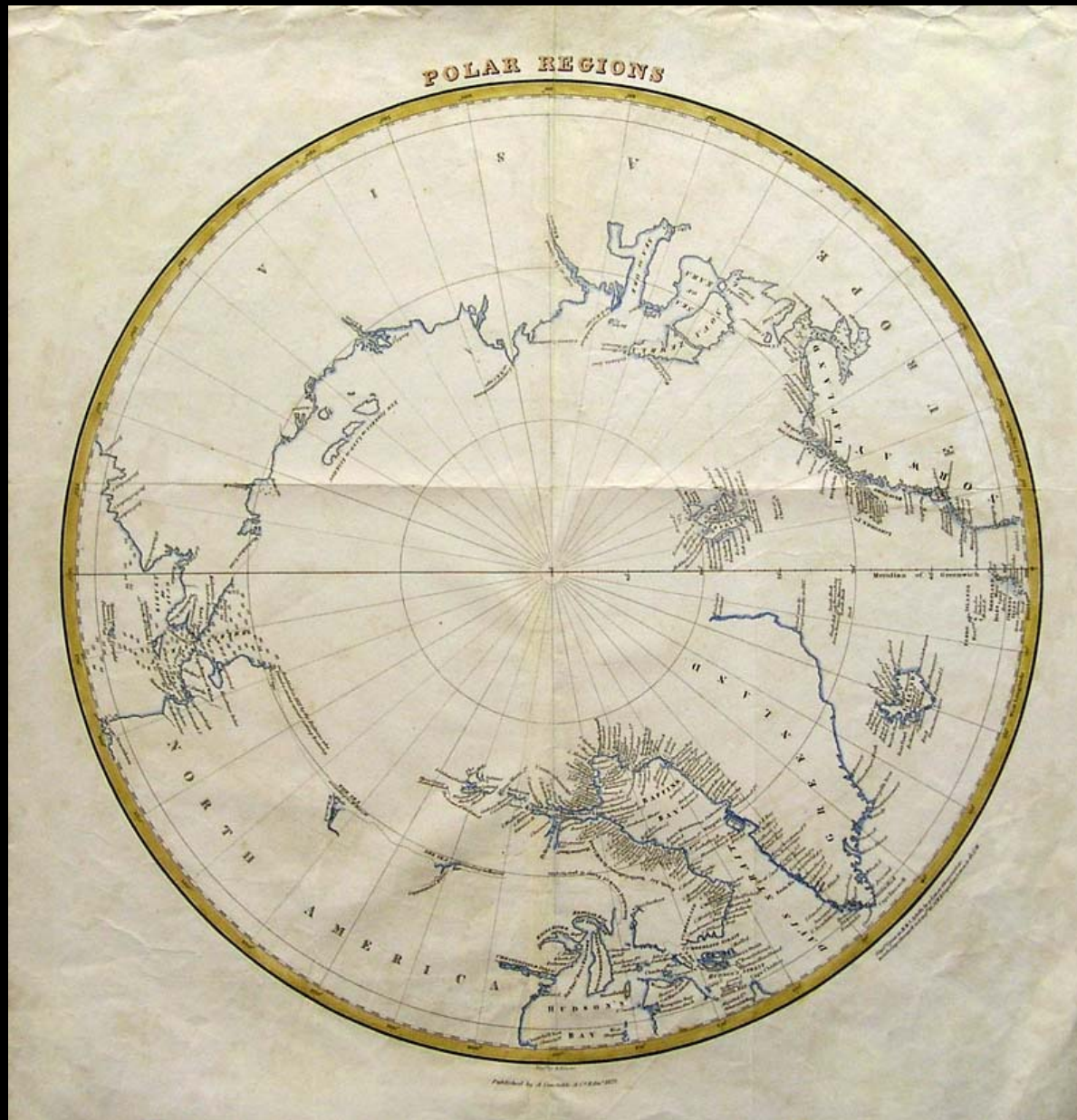


1. The discovery of an ice covered deep ocean

Gerhard Mercator 1595



W.Lizards 1822.





The ship *Jeanette*, under the command of captain De Long, was crushed 12 June 1881 North-West of Wrangell Island.



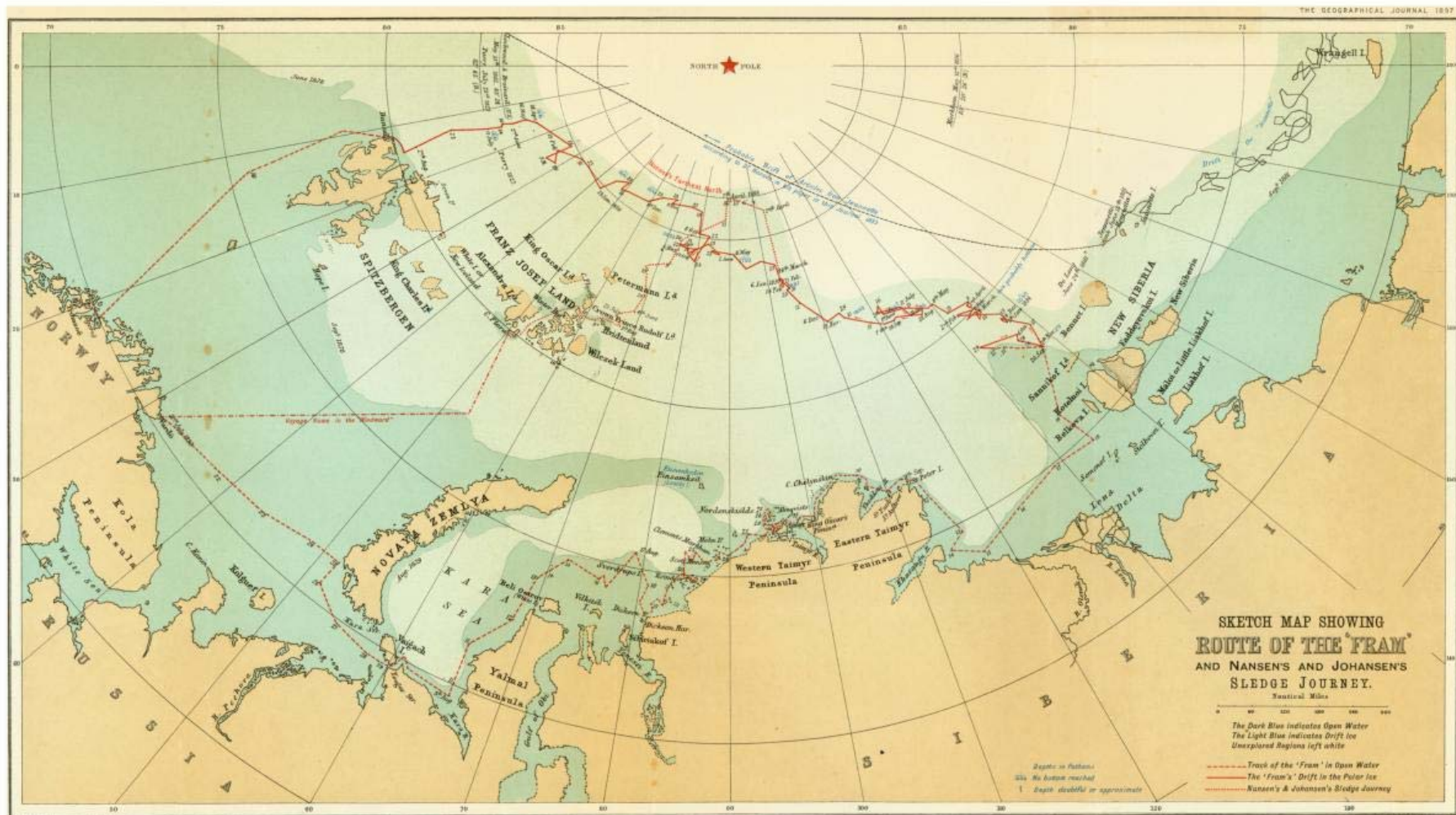
Pieces of the *Jeanette* wreck was found three years later on the coast of Greenland.



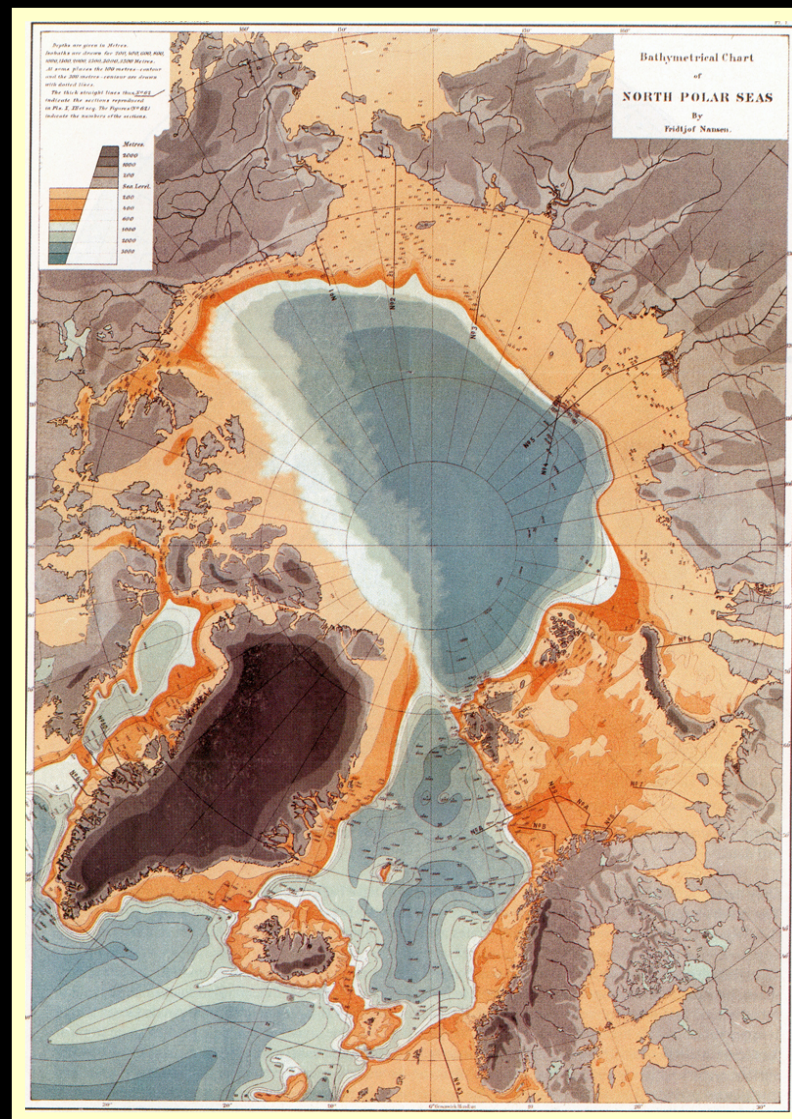
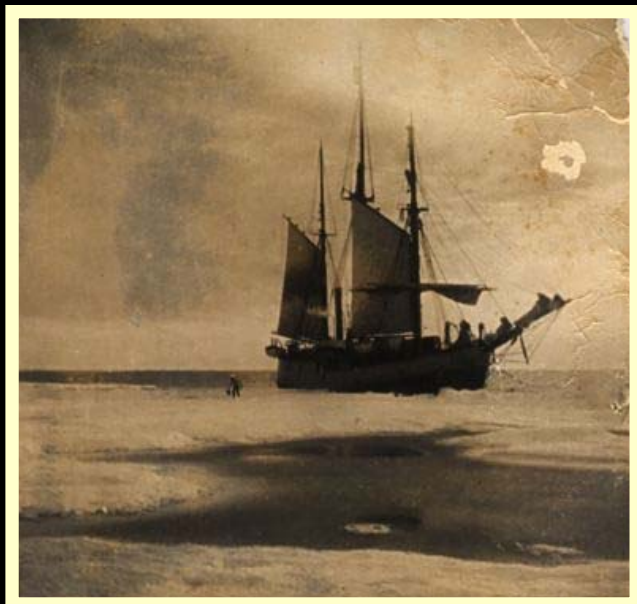
*The wreck parts together with e.g. drift wood, which was discovered to have drifted from Siberia to Svalbard, inspired the **Fram expedition***

1893-1896

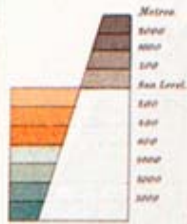




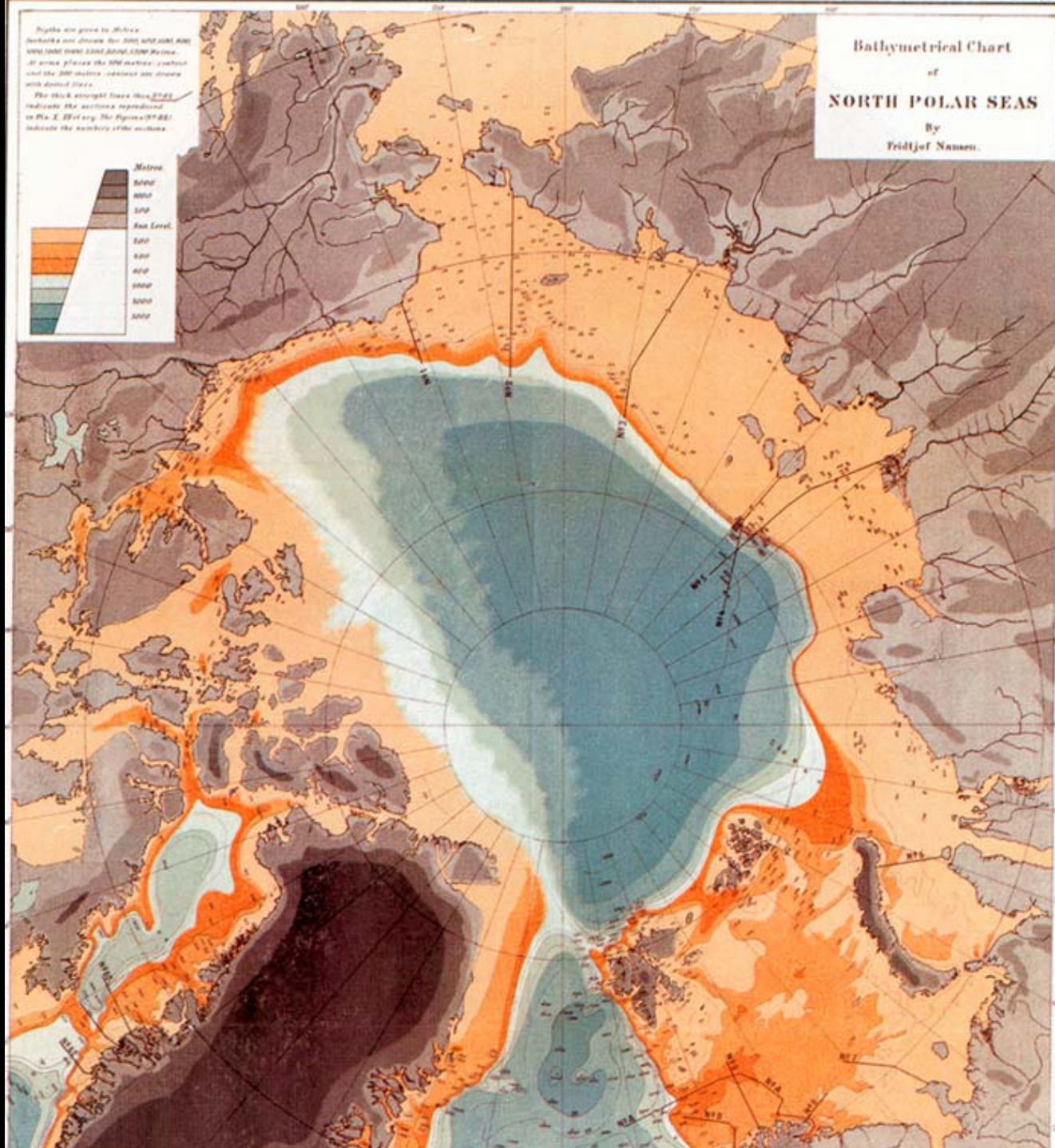
På denne samme is må også en ekspedisjon kunne føres den samme vei
Nansen, 1890

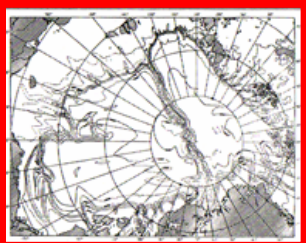


Depths are given in fathoms.
Isobaths are drawn for 500, 1000 and 2000
and the 3000 metres contour line is shown.
At some places the 500 metres contour
and the 3000 metres contour are drawn
with dotted lines.
The thick straight lines show traces
indicate the sections reproduced
in Pls. I, II and III. The figures 0° 00',
indicate the latitude of the sections.



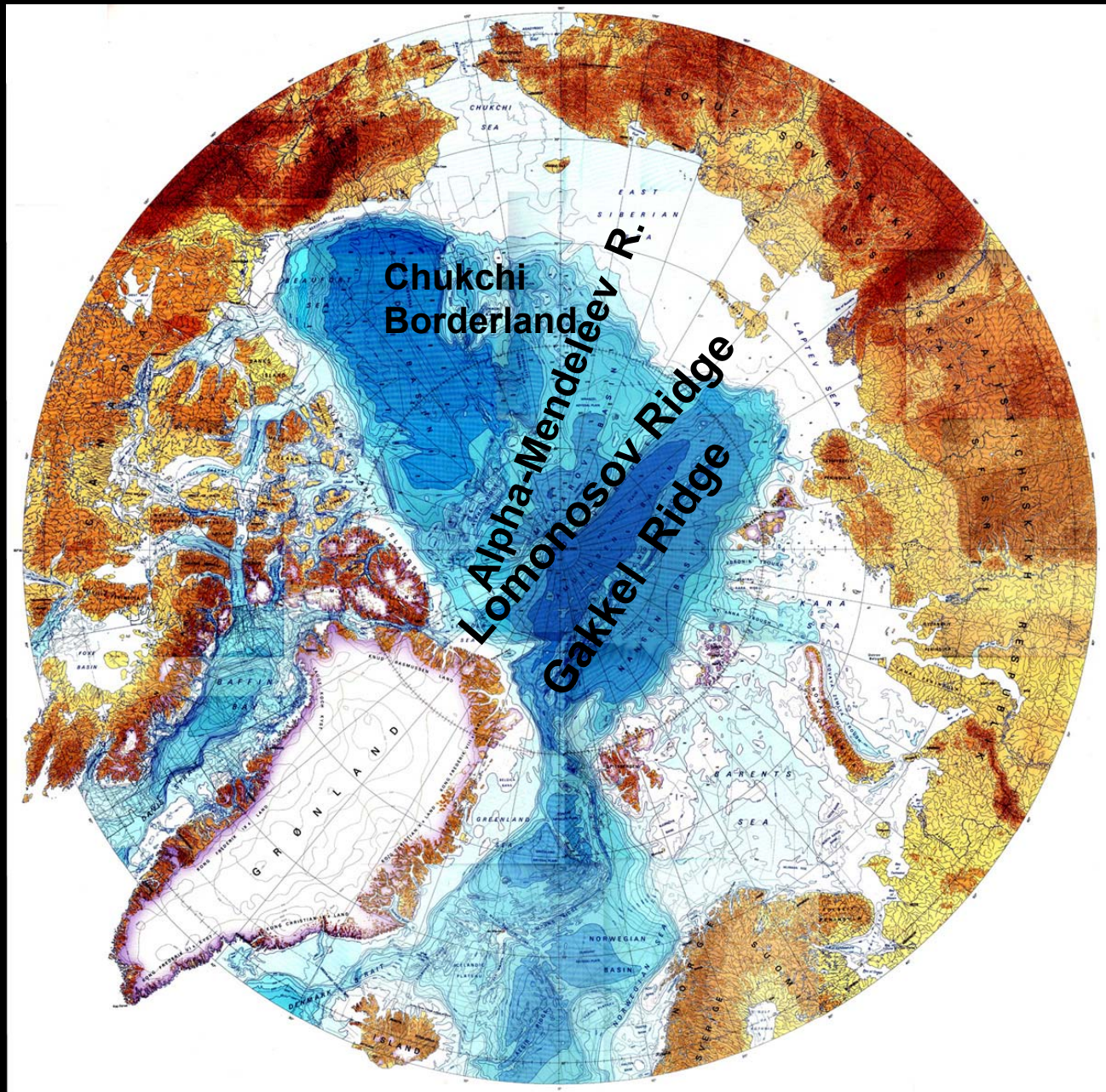
Bathymetrical Chart
of
NORTH POLAR SEAS
By
Fridtjof Nansen.



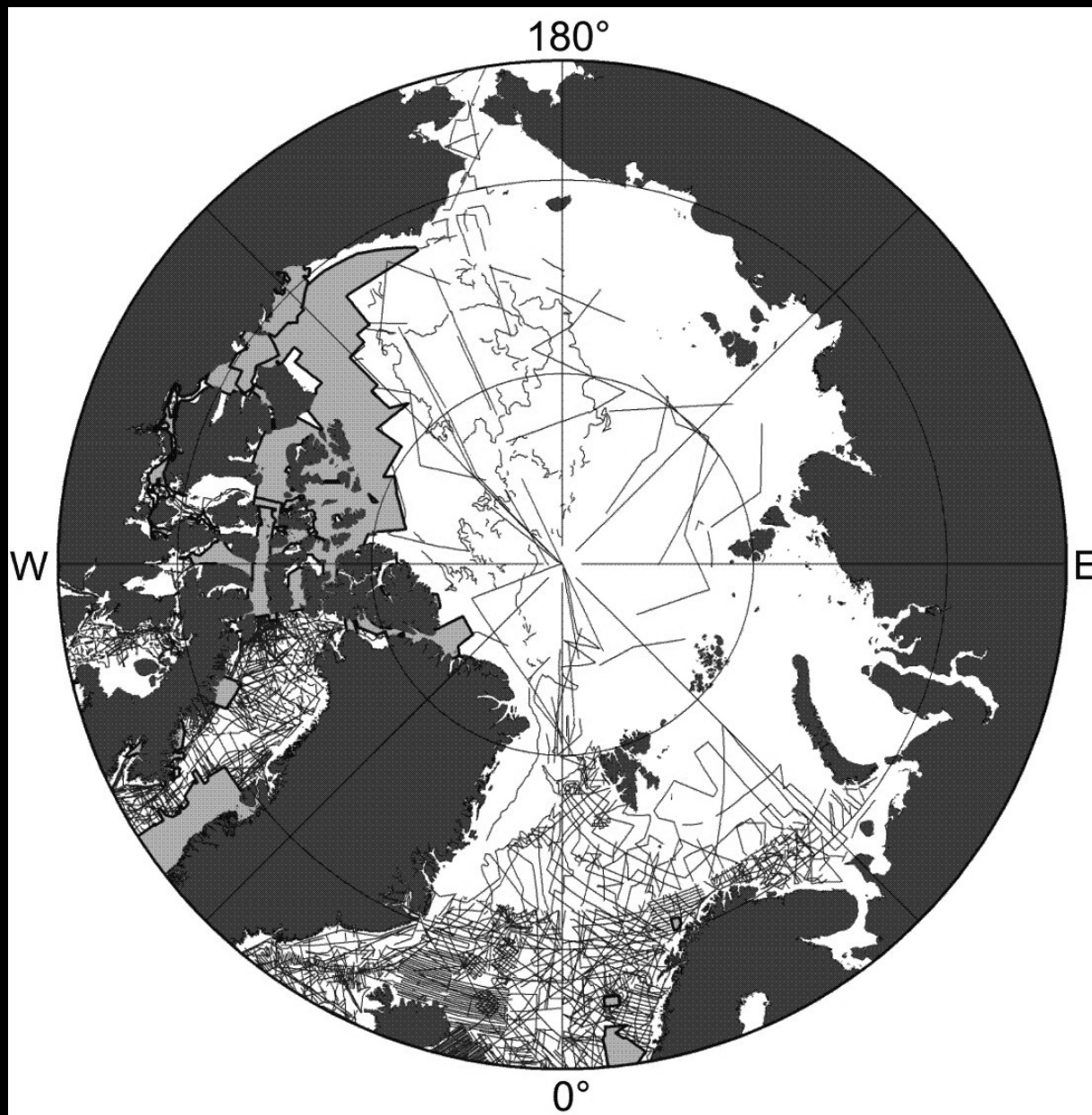


Sovjetisk karta, 1954, Burhanov

GEBCO Sheet 5.17 (Canadian Hydrographic Survey et al., 1979)

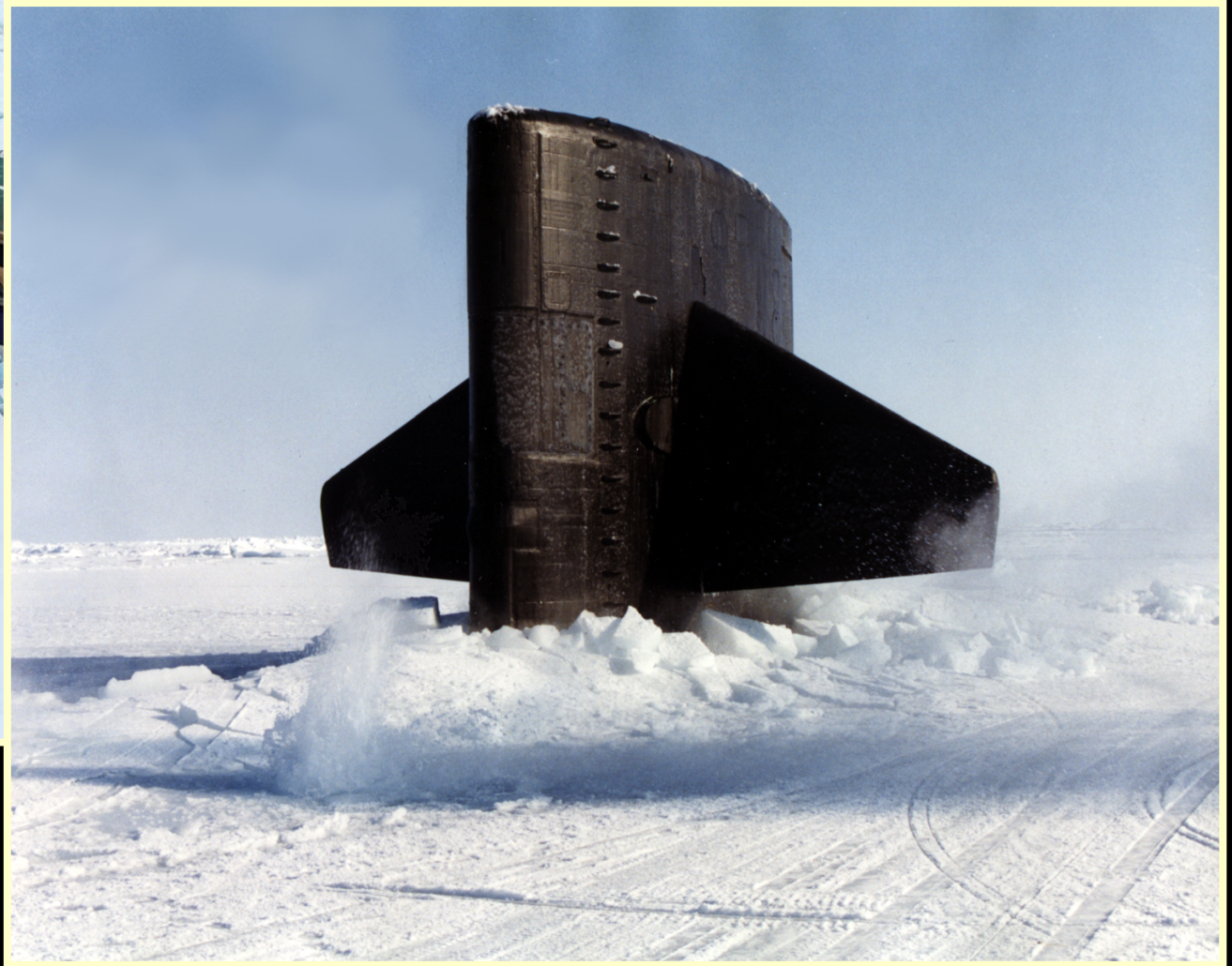


GEBCO Sheet 5.17 source data



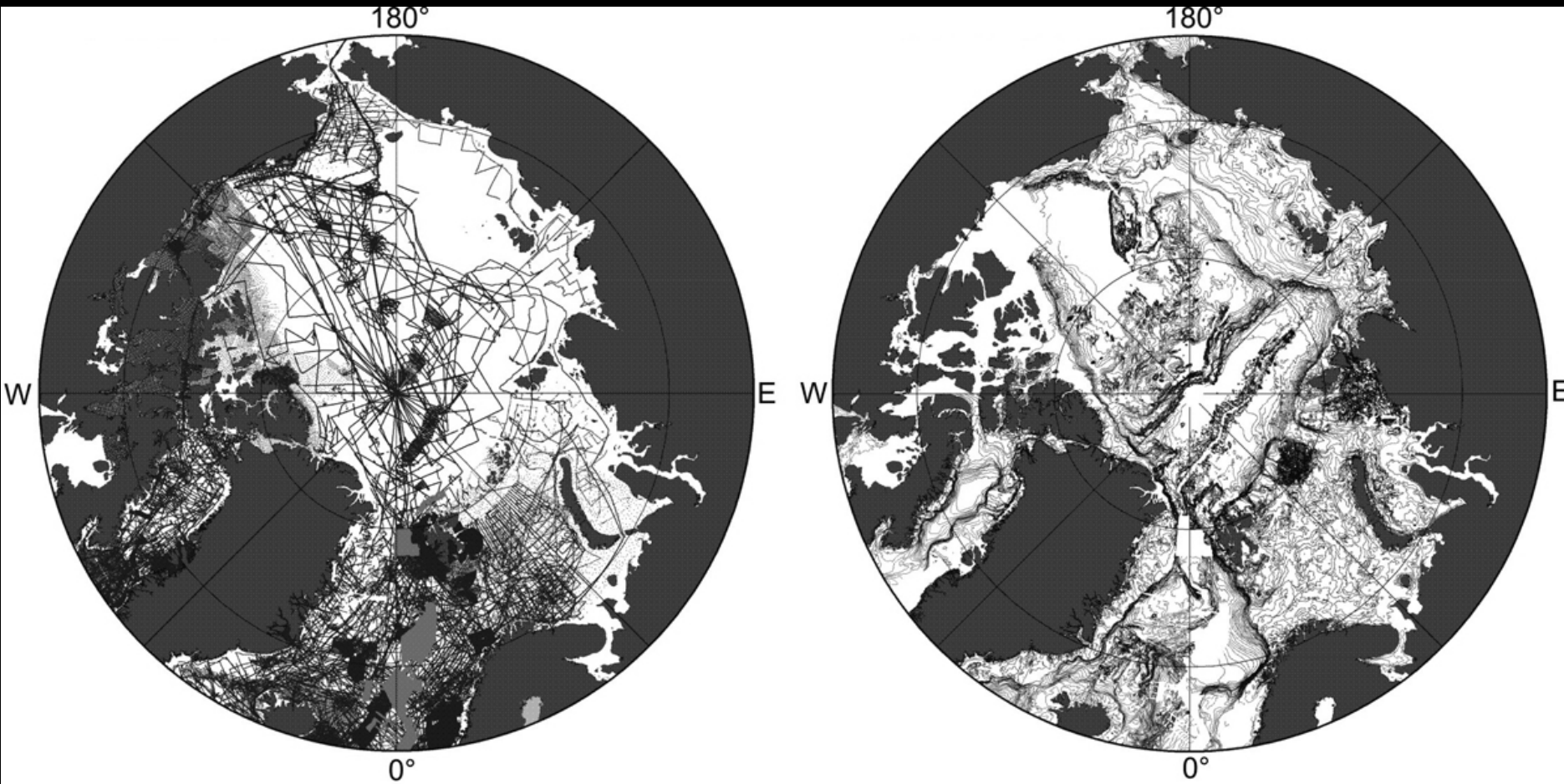
*Icebreaker Oden, first non-nuclear icebreaker
to reach the North Pole (1991)*

USS Hawkbill breaking through the ice in 1999

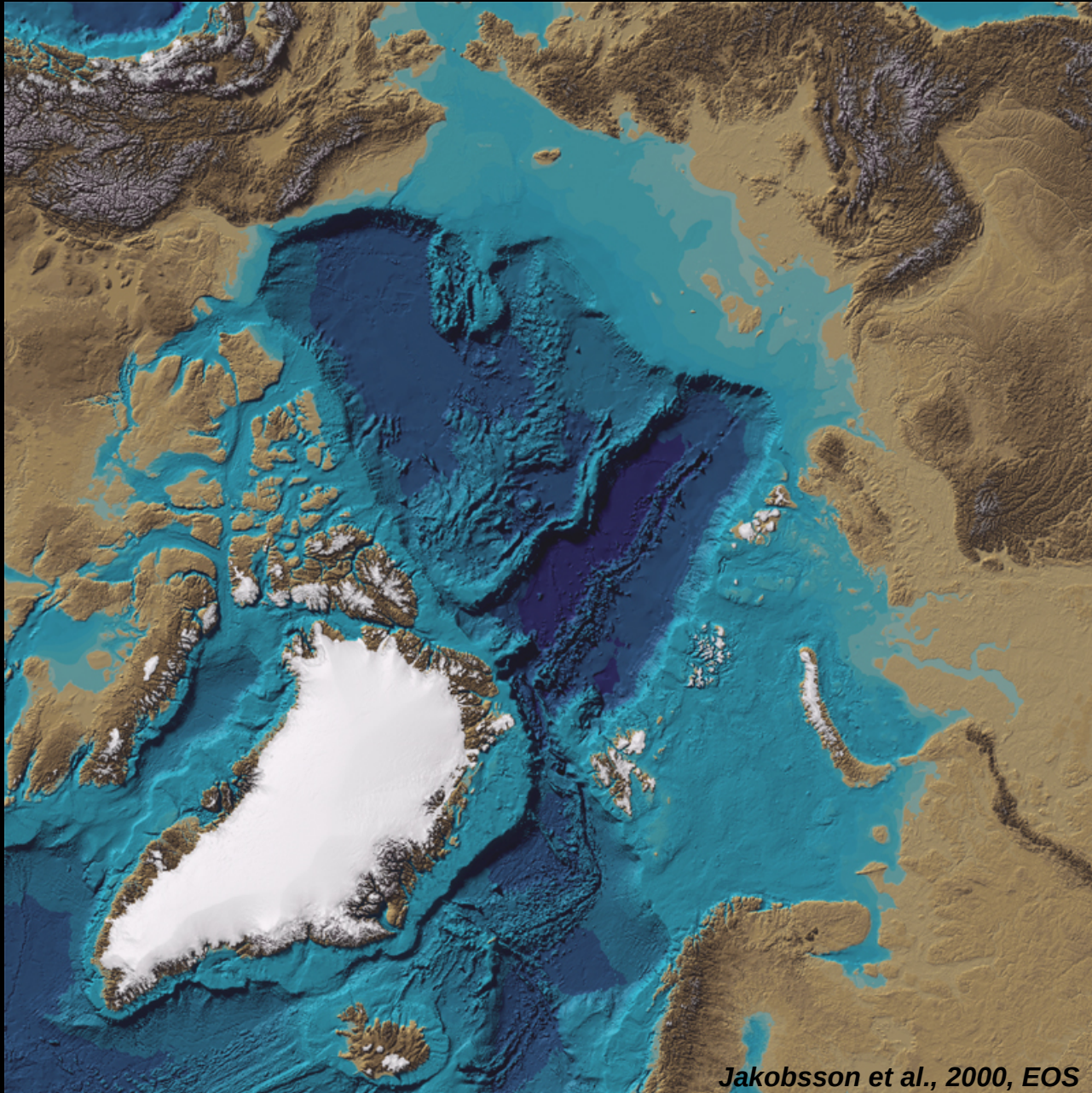


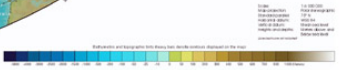
The International Bathymetric Chart of the Arctic Ocean (IBCAO)

Sources



Polarstereographic projection, 2.5 x 2.5 km gridmodel





the following information. The information should be provided in the following order: (1) Name of the organization; (2) Address; (3) Telephone number; (4) Fax number; (5) E-mail address; (6) Website; (7) Other contact information; (8) Other relevant information.	the following information. The information should be provided in the following order: (1) Name of the organization; (2) Address; (3) Telephone number; (4) Fax number; (5) E-mail address; (6) Website; (7) Other contact information; (8) Other relevant information.	the following information. The information should be provided in the following order: (1) Name of the organization; (2) Address; (3) Telephone number; (4) Fax number; (5) E-mail address; (6) Website; (7) Other contact information; (8) Other relevant information.	the following information. The information should be provided in the following order: (1) Name of the organization; (2) Address; (3) Telephone number; (4) Fax number; (5) E-mail address; (6) Website; (7) Other contact information; (8) Other relevant information.	the following information. The information should be provided in the following order: (1) Name of the organization; (2) Address; (3) Telephone number; (4) Fax number; (5) E-mail address; (6) Website; (7) Other contact information; (8) Other relevant information.
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2. Arctic glacial-interglacial climate variations during the last million years: where are we going?

Last Glacial Maximum (LGM)
20 ka

Present

??

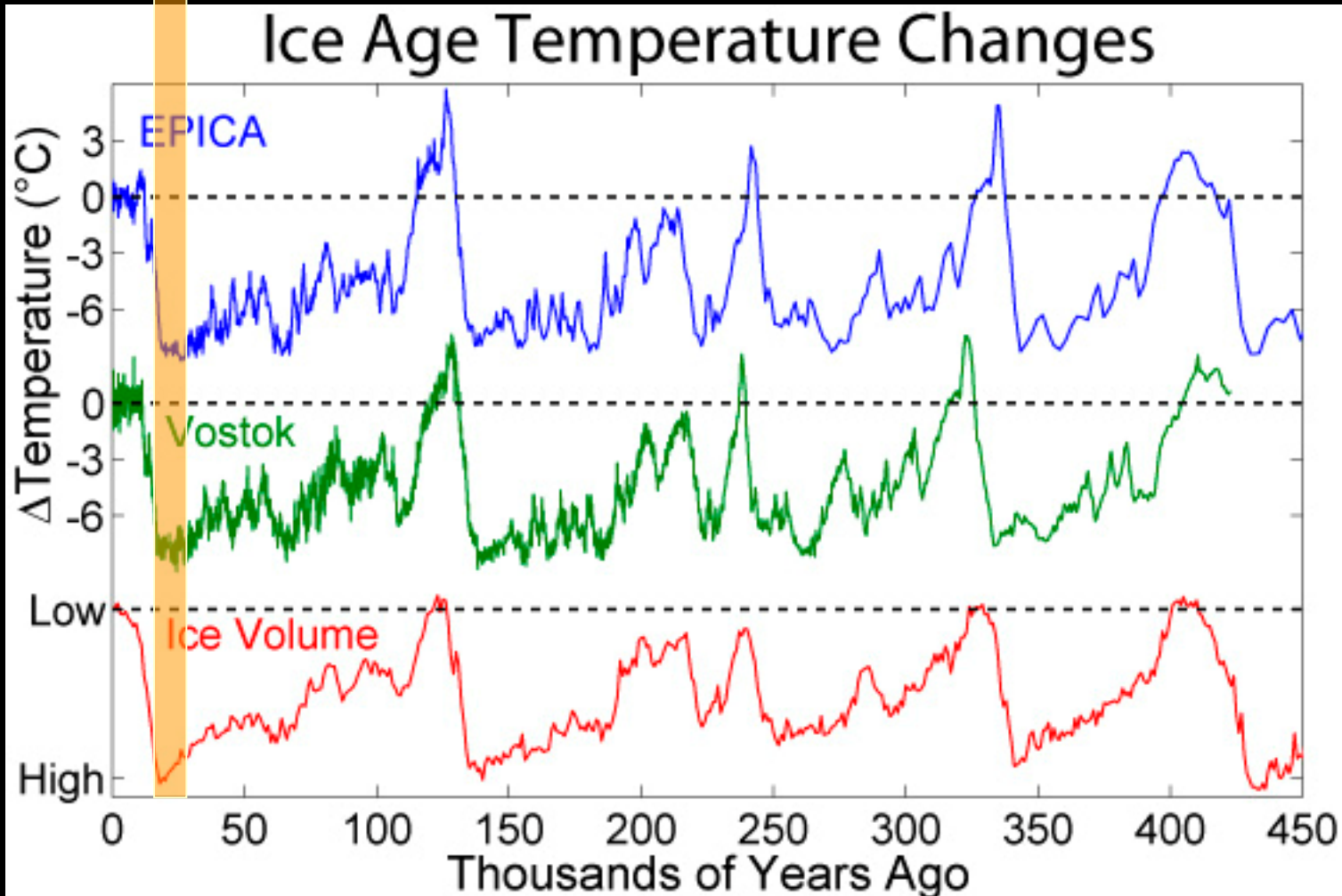


*Images: Martin Jakobsson©
Data sources: ETOPO2, Blue Marble and QUEEN LGM reconstruction*

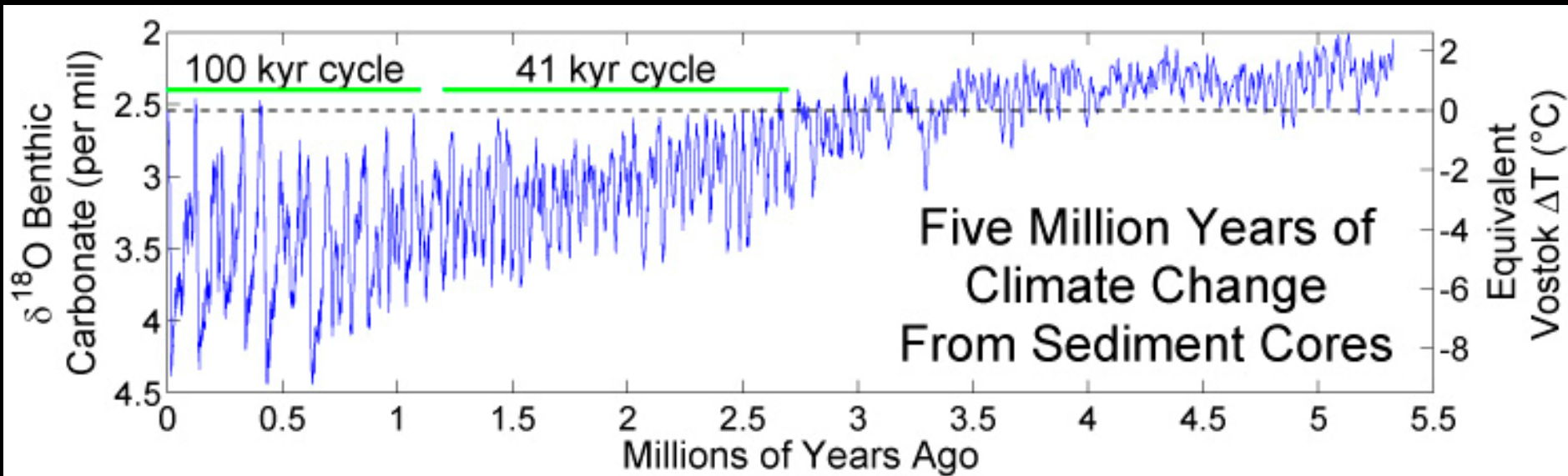


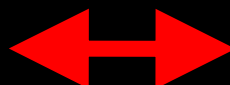
Upper two plots: Changes in temperature derived from deuterium isotopic measurements (δD) on Antarctic ice cores (EPICA Community Members 2004, Petit *et al.* 1999, *Nature*).

Lower plot: Global ice volume based on $\delta^{18}O$ measurements on benthic foraminifera from a composite of sediment cores (Lisiecki and Raymo 2005, *Paleoceanography*).



Benthic foraminifera from a composite of sediment cores (Lisiecki and Raymo 2005, *Paleoceanography*).

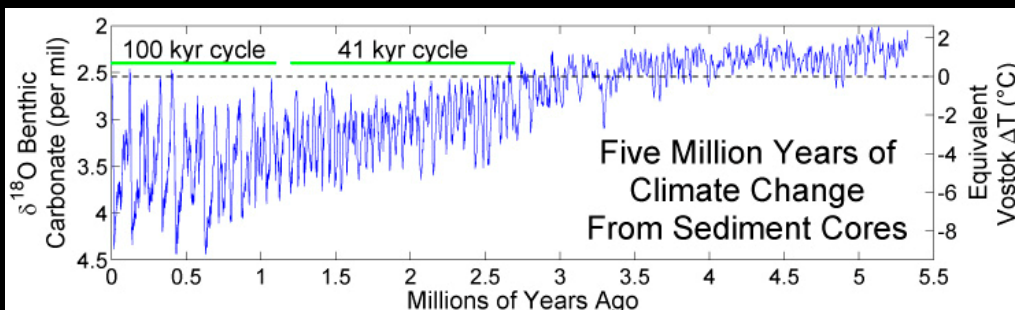



10 cm

Jakobsson et al., 2000, Geology

Milankovitch cycles

1. The Earth's orbit around the sun varies from more elliptic to more circular: eccentricity (c. 100 ka and 400 ka cycles)
2. The tilt of the Earth's axis varies from between 21.5 to 24.5°: obliquity (today c. 23.5°, 41 ka cycles)
3. The Earth is slowly wobbling while spinning: precession (turns one complete turn in relation to the stars in cycles of about 23 ka)

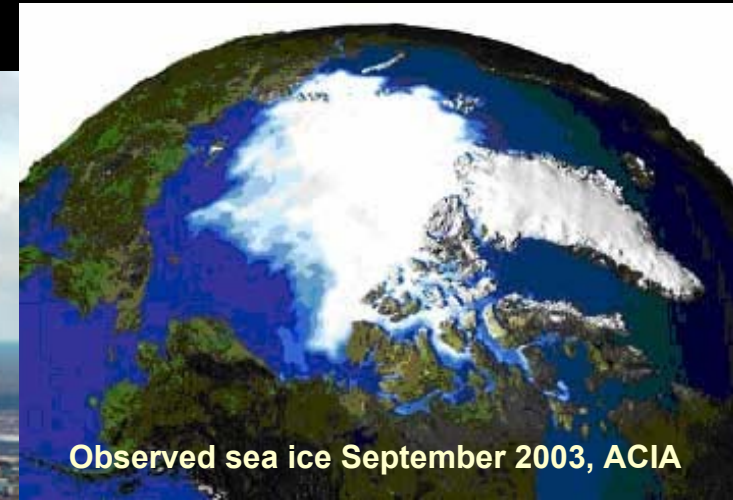


Where are we going?

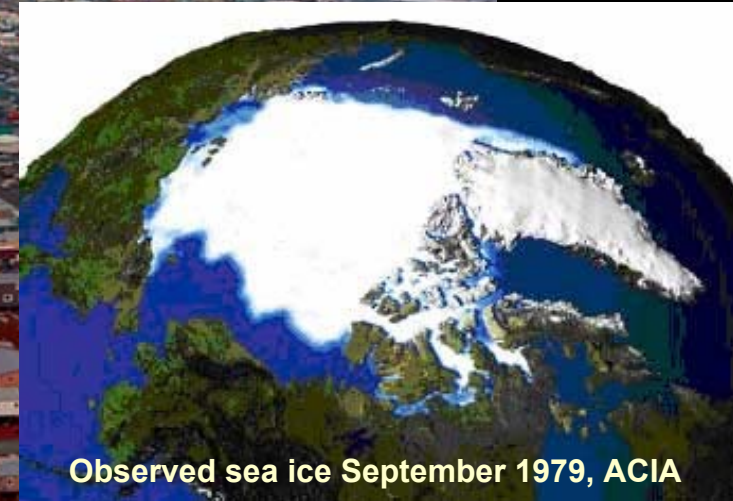
Where are we going?



Barrow, Alaska, August 11, 2003



Observed sea ice September 2003, ACIA



Observed sea ice September 1979, ACIA

Where are we going?



Ward Hunt Ice Shelf breaking up in August 2002
(Radarsat Image courtesy of Canadian Space Agency and Alaska Satellite Facility)



Imbrie and Imbrie: Ice ages: solving the mystery: 1979

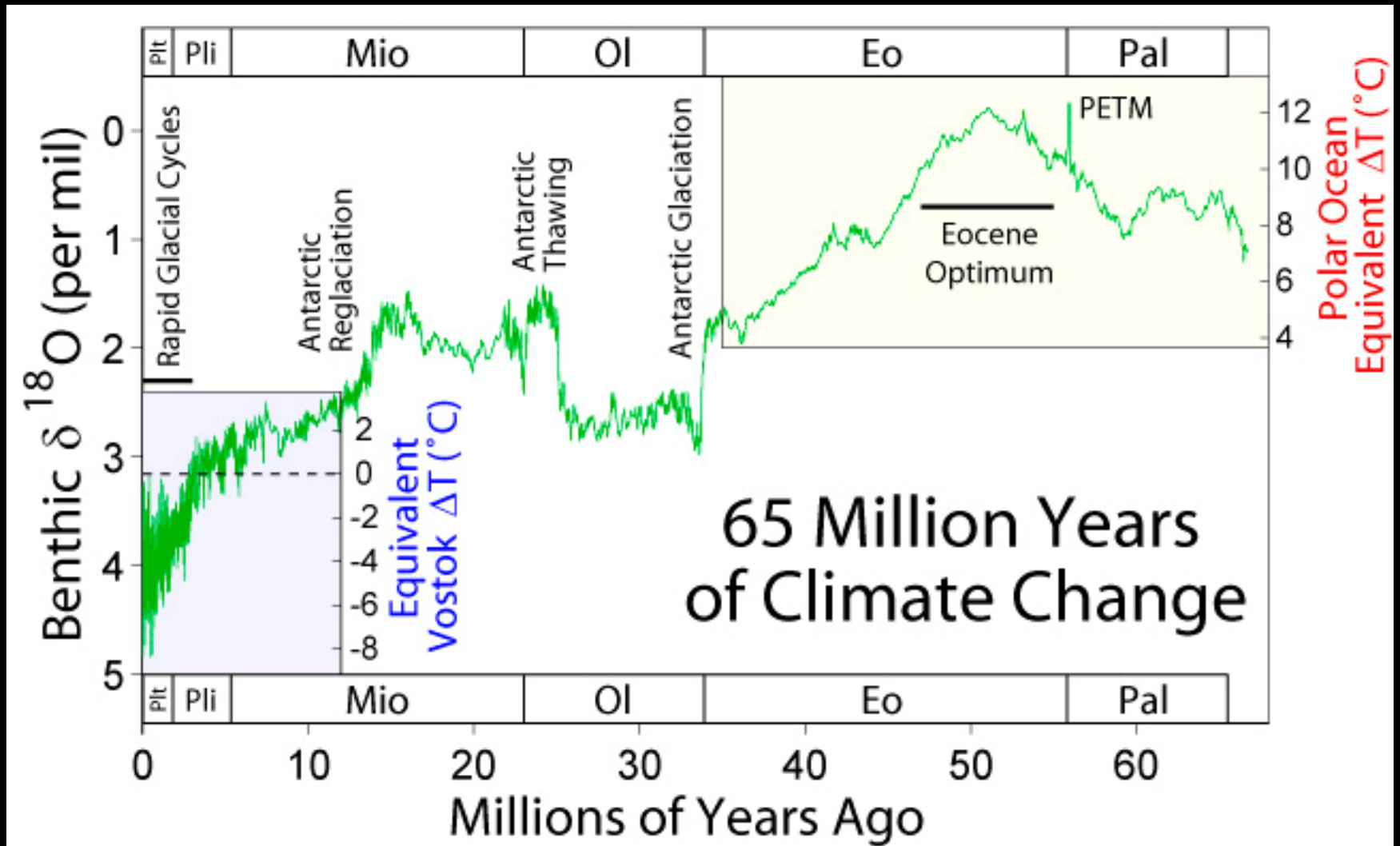
“Unless there is some fundamental and unforeseen change in the climate system, most scientists who have examined the evidence agree that the world will experience another age of ice. But when? On this question, geologists disagree. Some predict that the present interglacial age will last another 50,000 years. Others, finding that the earth has been cooling for some time, believe that an ice age is already on its way - due within the next few centuries, according to one extreme view.”

Based on the astronomical theory

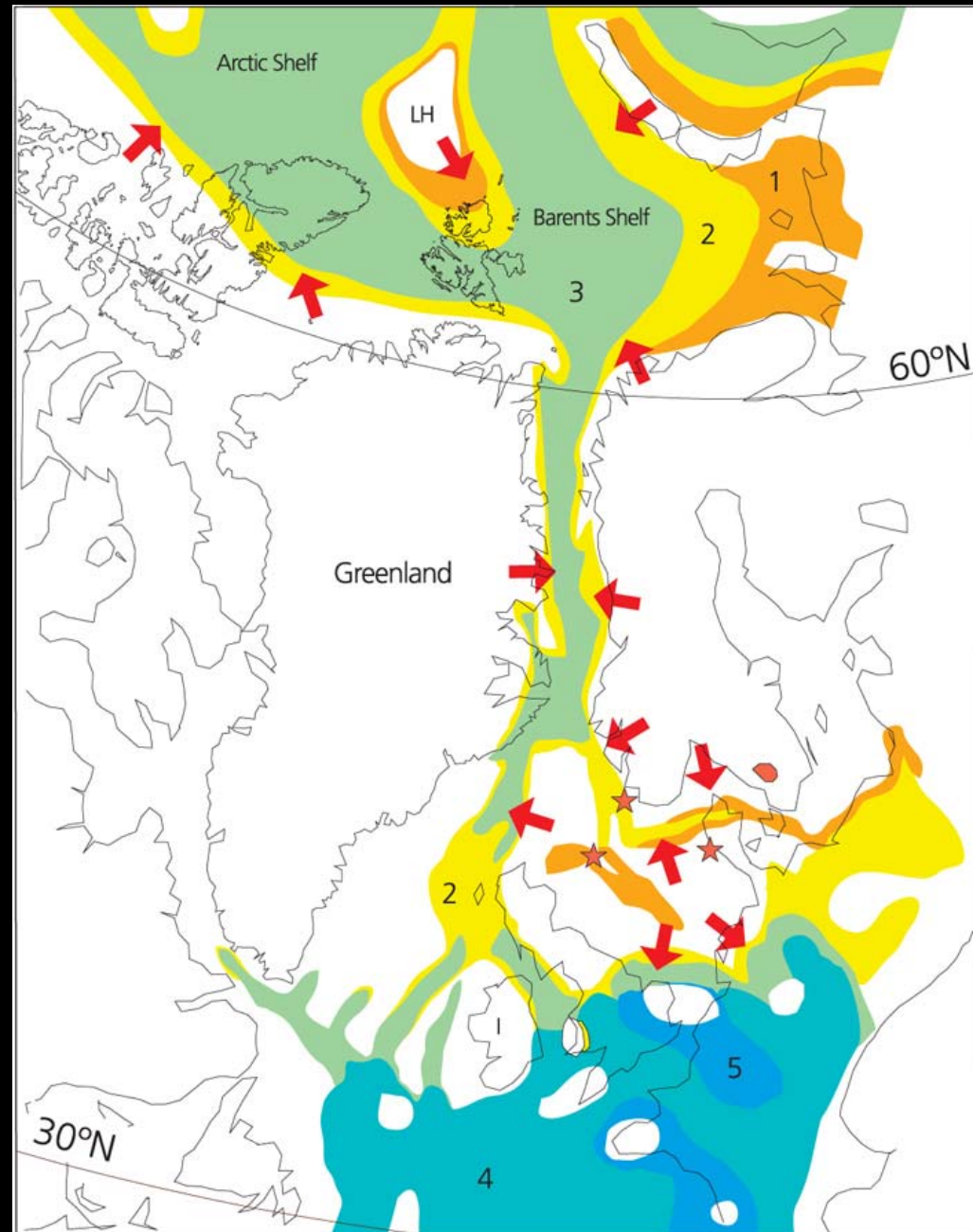
...the cooling trend that began 7000 years ago will continue into the future, and lead to a maximum advance of the glaciers 23,000 years from now.....

But what about the present global warming trend??

3. The development of the Amerasian and Eurasian basins: from a greenhouse world to an icehouse world



Middle Jurassic 170 MA



Shallow marine to lacustrine environments, none of the Arctic Ocean basins yet developed

Torsvik et al., 2002

“Dinosaur fossils found on Svalbard

Norway's only dinosaur researcher, Jørn Hurum, has found 160 million year old fossils of ichthyosaurs and plesiosaurs in polar Svalbard. Hurum characterized the find as extremely good and enthused about the untouched area that appeared chock-full of paleontological treasure.”

Aftenposten, 2 September 2004



PHOTO: TORBJØRN PEDERSEN/SCANPIX
Aftenposten, 2 September 2004

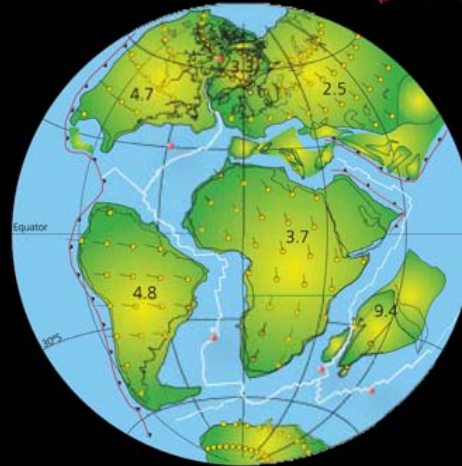
Exposed strata on Svalbard



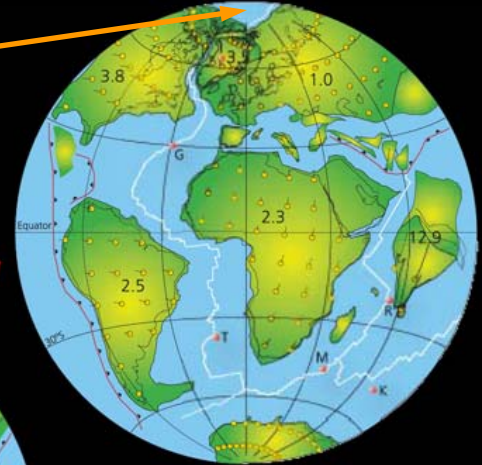
Rifting propagated into the Arctic Ocean first from the Labrador Sea through Nares Strait at about 58 MA (anomaly 26). The Lomonosov Ridge was subsequently rifted off as a sliver from the Barents-Kara sea shelf as the opening of the Eurasian Basin continued.

Initiation of seafloor spreading at about 130 MA in the area which later will develop into the Amerasian Basin

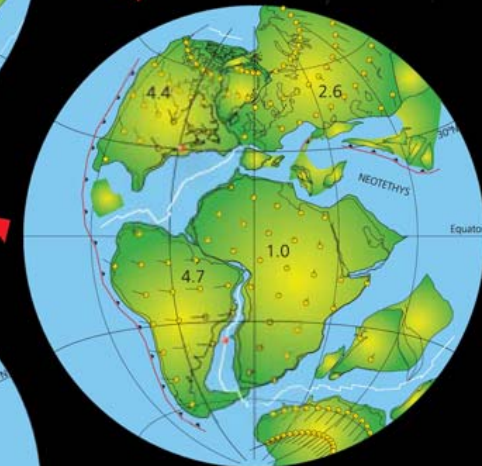
Late Cretaceous, 80 MA



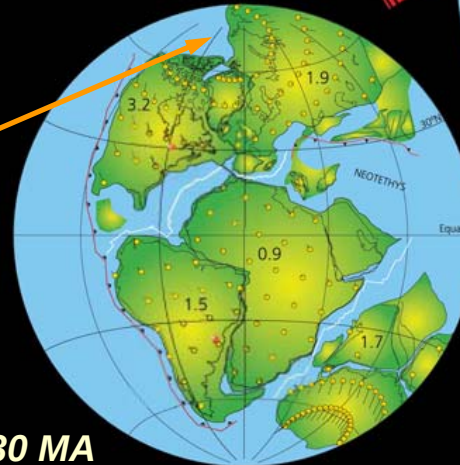
Early Tertiary, 60 MA



Early Cretaceous, 110 MA



Early Cretaceous, 130 MA



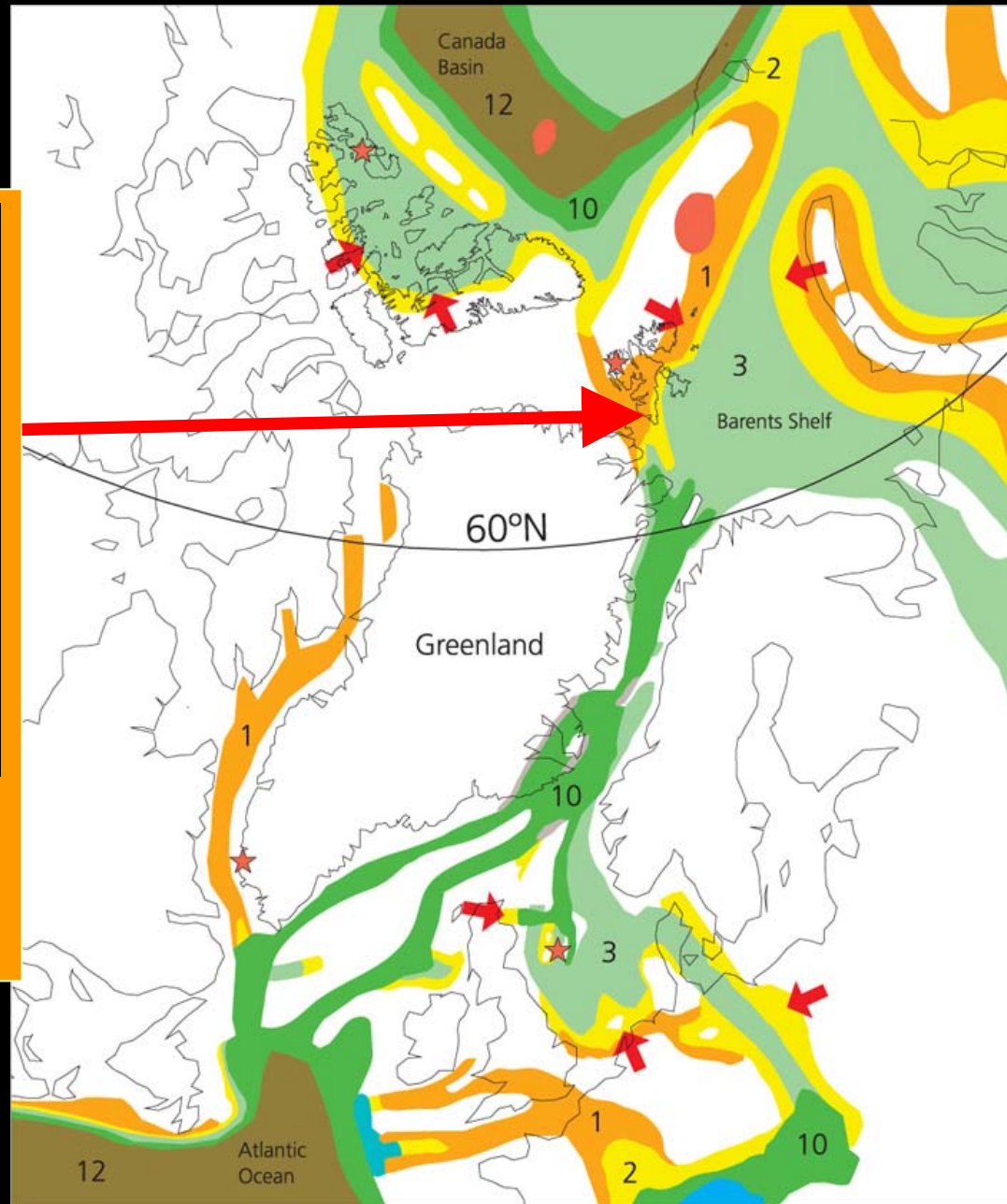
Early Cretaceous 130 MA

- 1  mainly continental clastics
- 2  deltaic-shallow marine, mainly sands
- 3  shallow marine, mainly shales



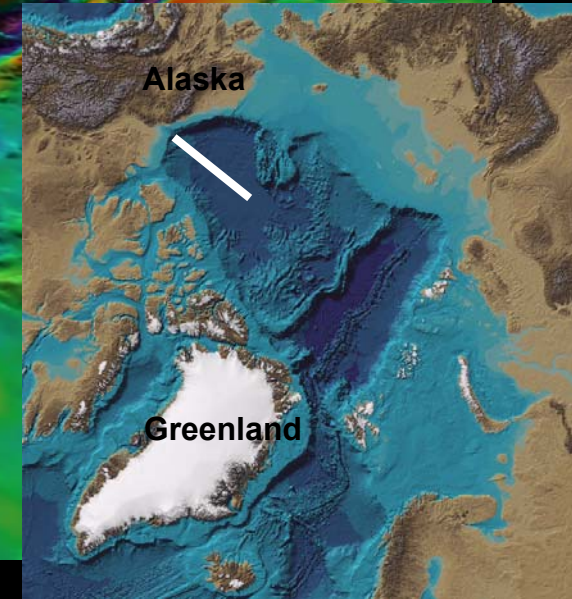
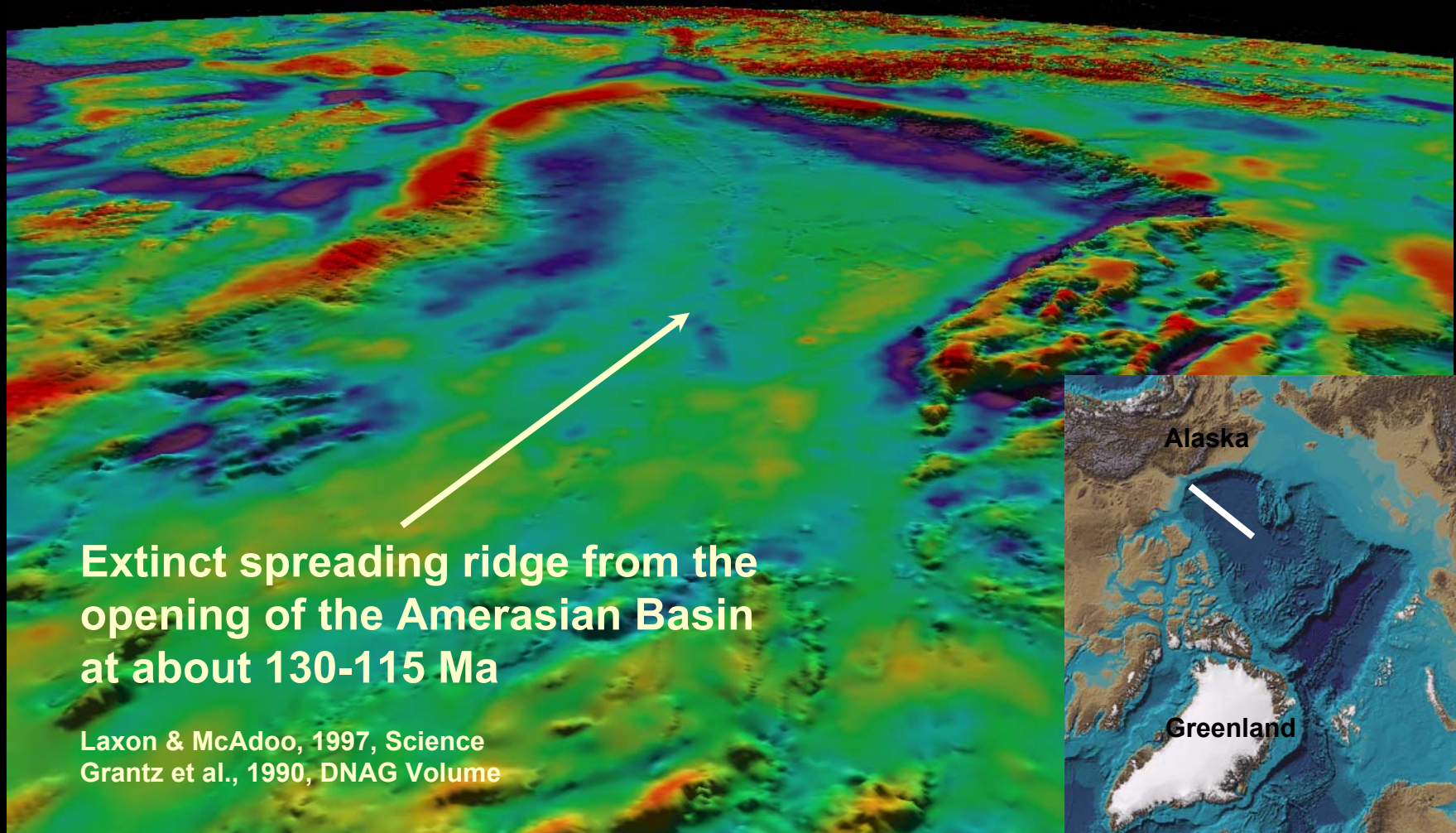
**Cretaceous Iguanodontid
dinosaur footprint,
Sprintsbergen, Svalbard**

 inactive/abandoned sea-floor spreading axis



Gravity anomalies draped on top of the bathymetry

Data: ArcGrav and IBCAO

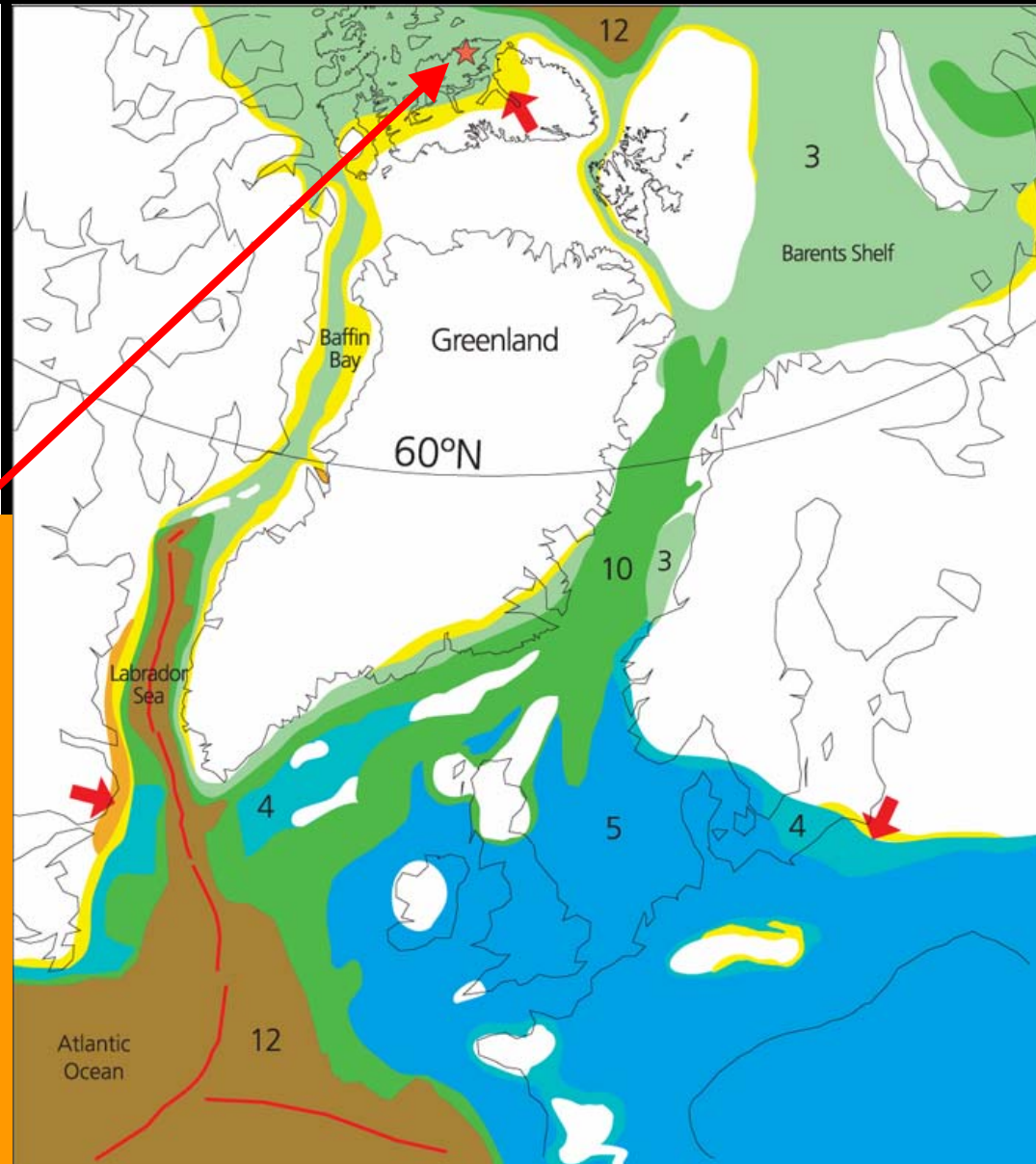


- 1  mainly continental clastics
- 2  deltaic-shallow marine, mainly sands
- 3  shallow marine, mainly shales
- 4  shallow marine, carbonates and clastics
- 5  shallow marine, mainly carbonates
- 6  evaporites and clastics
- 7  mainly evaporites
- 8  evaporites, clastics and carbonates

Axel Heiberg Island

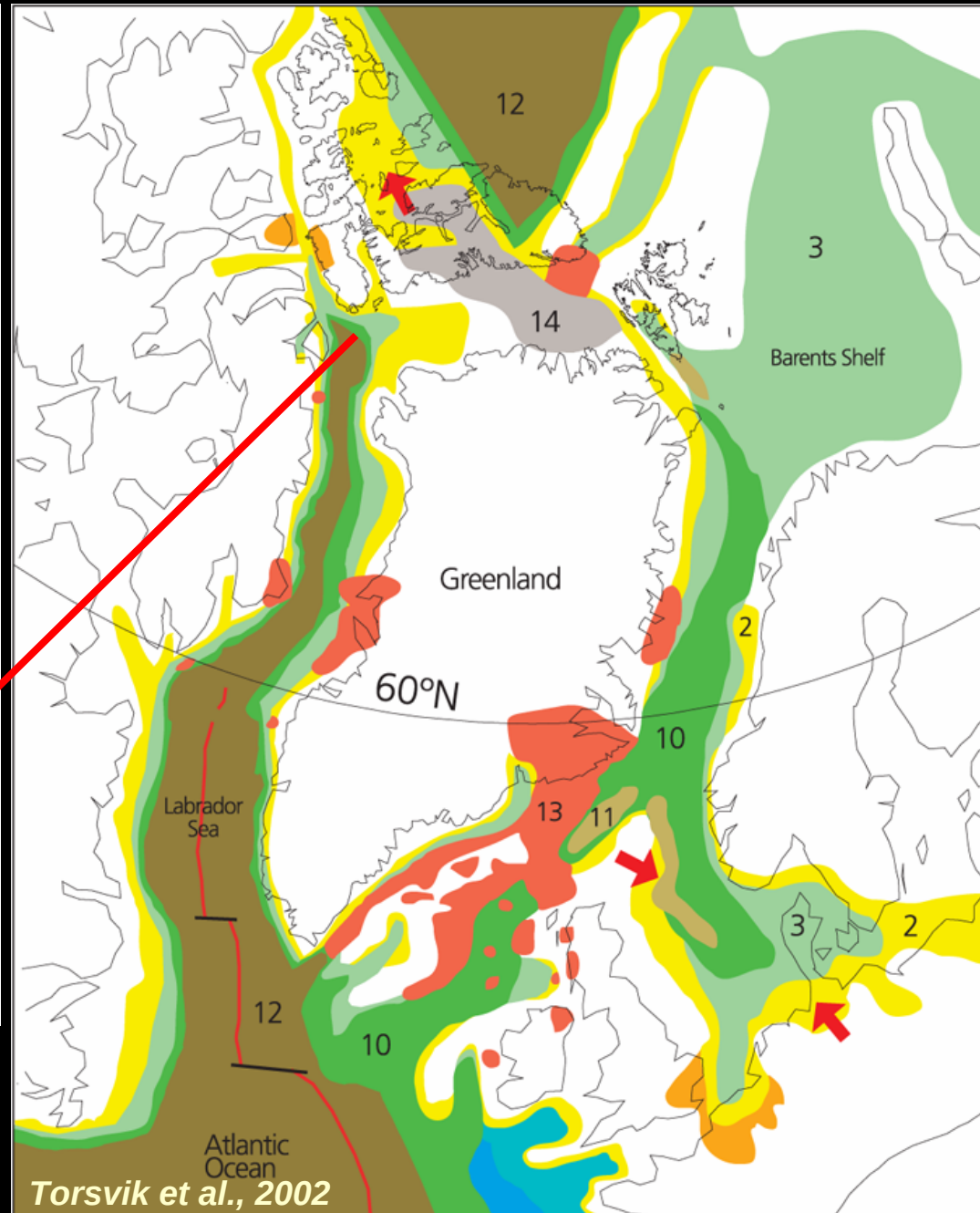
**92-86 Ma old
champsosaurs finds
(extinct crocodile-like
reptiles). Indicates a
warm Arctic Ocean**

Tarduno et al., 1998, Science



Torsvik et al., 2002

Early Tertiary 60 Ma



**Propagating seafloor
spreading in Baffin Bay**

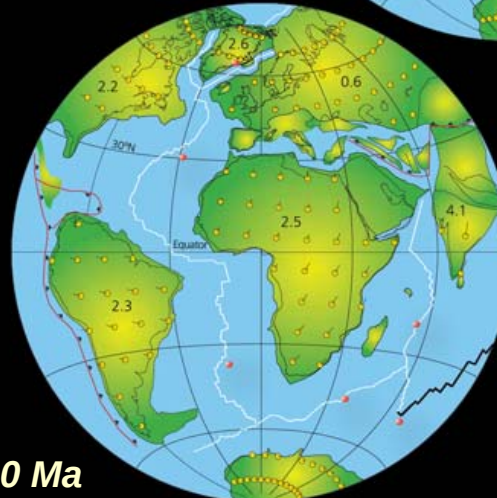
Torsvik et al., 2002

Opening of the Fram Strait? (Between Greenland and Svalbard)

Today



Miocene 20 Ma



Eocene 40 Ma

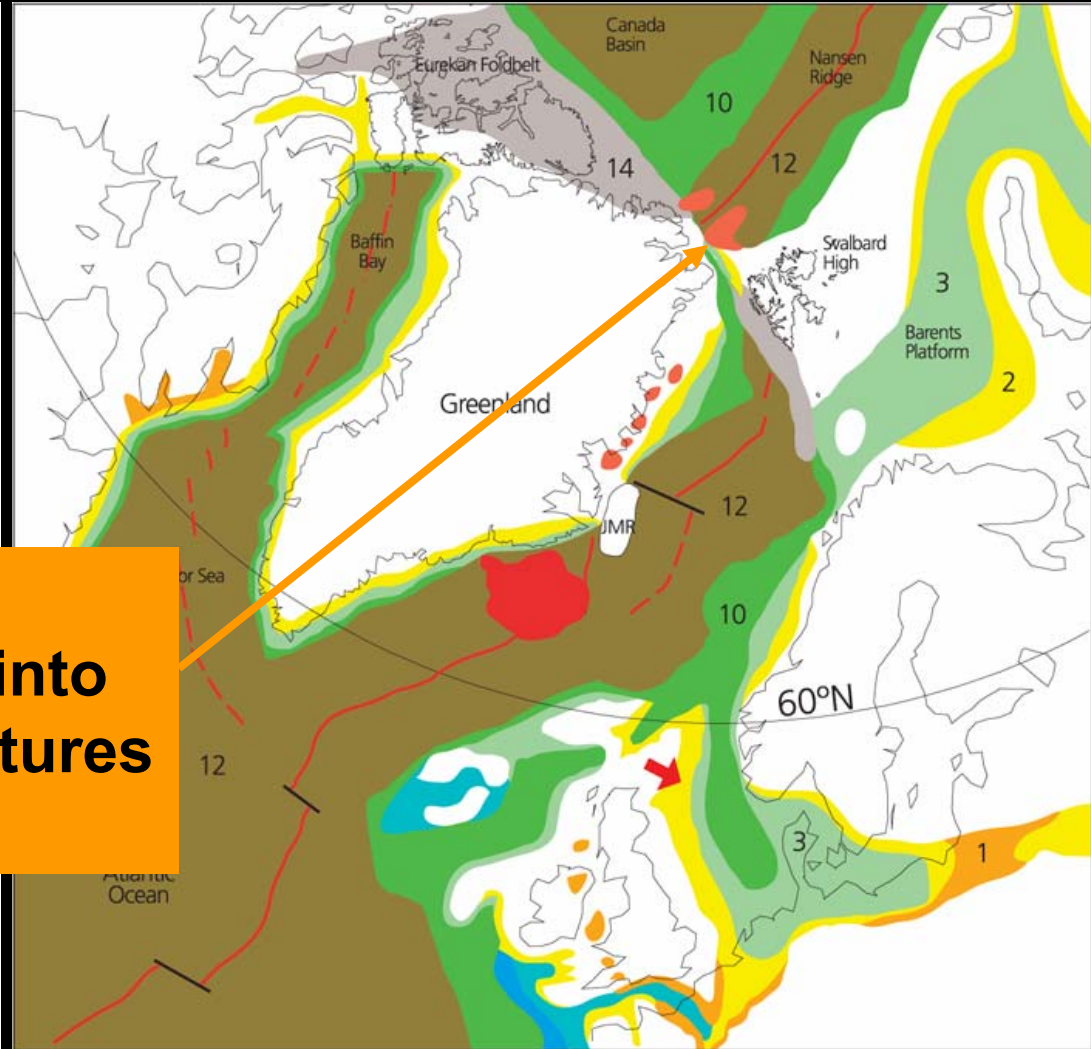
Torsvik et al., 2002

Late Oligocene 25 Ma

- 1 mainly continental clastics
- 2 deltaic-shallow marine, mainly sands
- 3 shallow marine, mainly shales
- 4 shallow marine, carbonates and clastics
- 5 shallow marine, mainly carbonates
- 6 evaporites and clastics
- 7 mainly evaporites
- 8 evaporites, clastics and carbonates
- 9 evaporites and carbonates

Morris Jesup and Yermak break up into two conjugate features at about 33 Ma

- 15 inactive fold belt
-  direction of clastic influx
-  active sea-floor spreading axis
-  inactive/abandoned sea-floor spreading axis



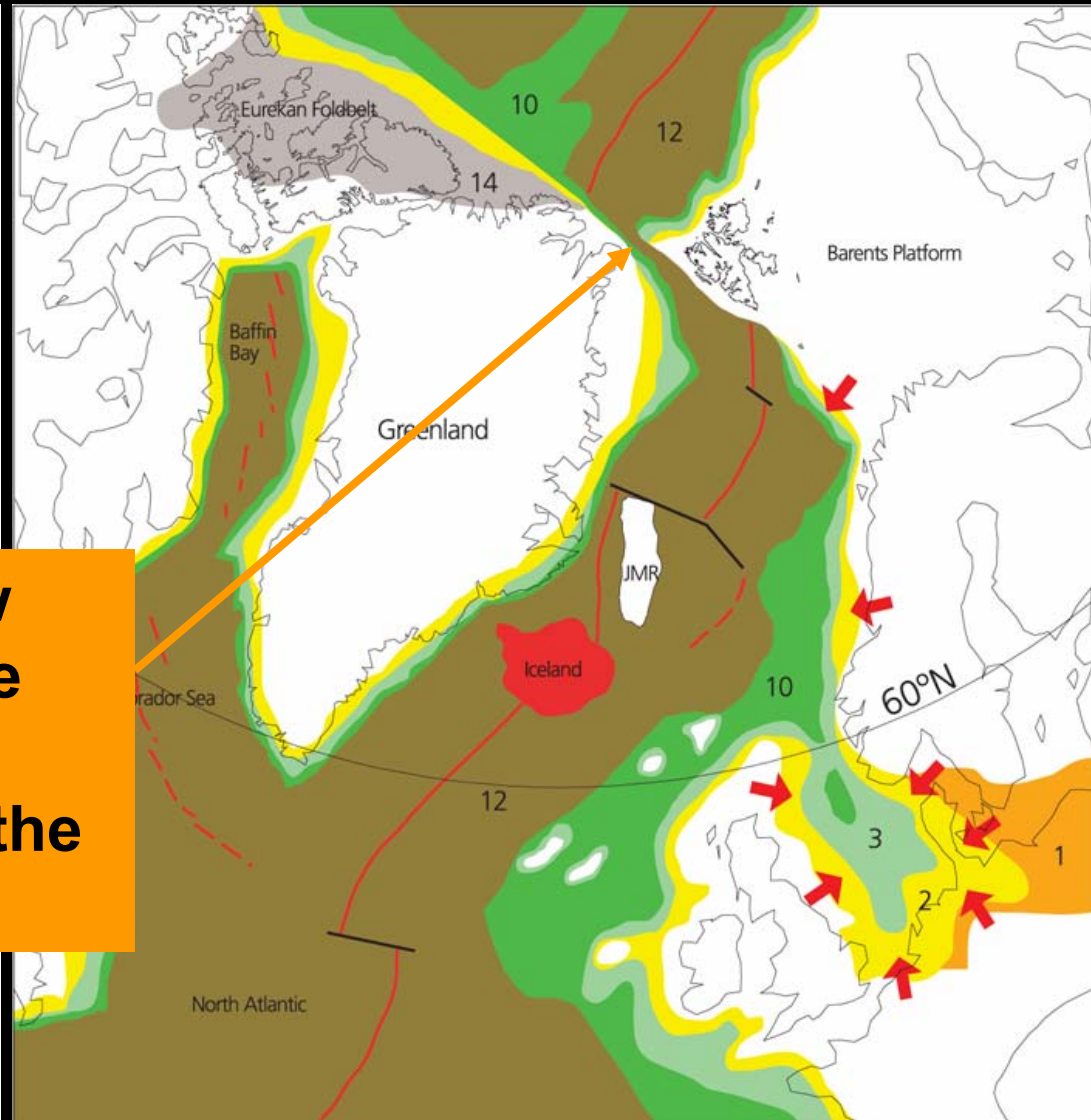
Torsvik et al., 2002

Middle Miocene 15 Ma

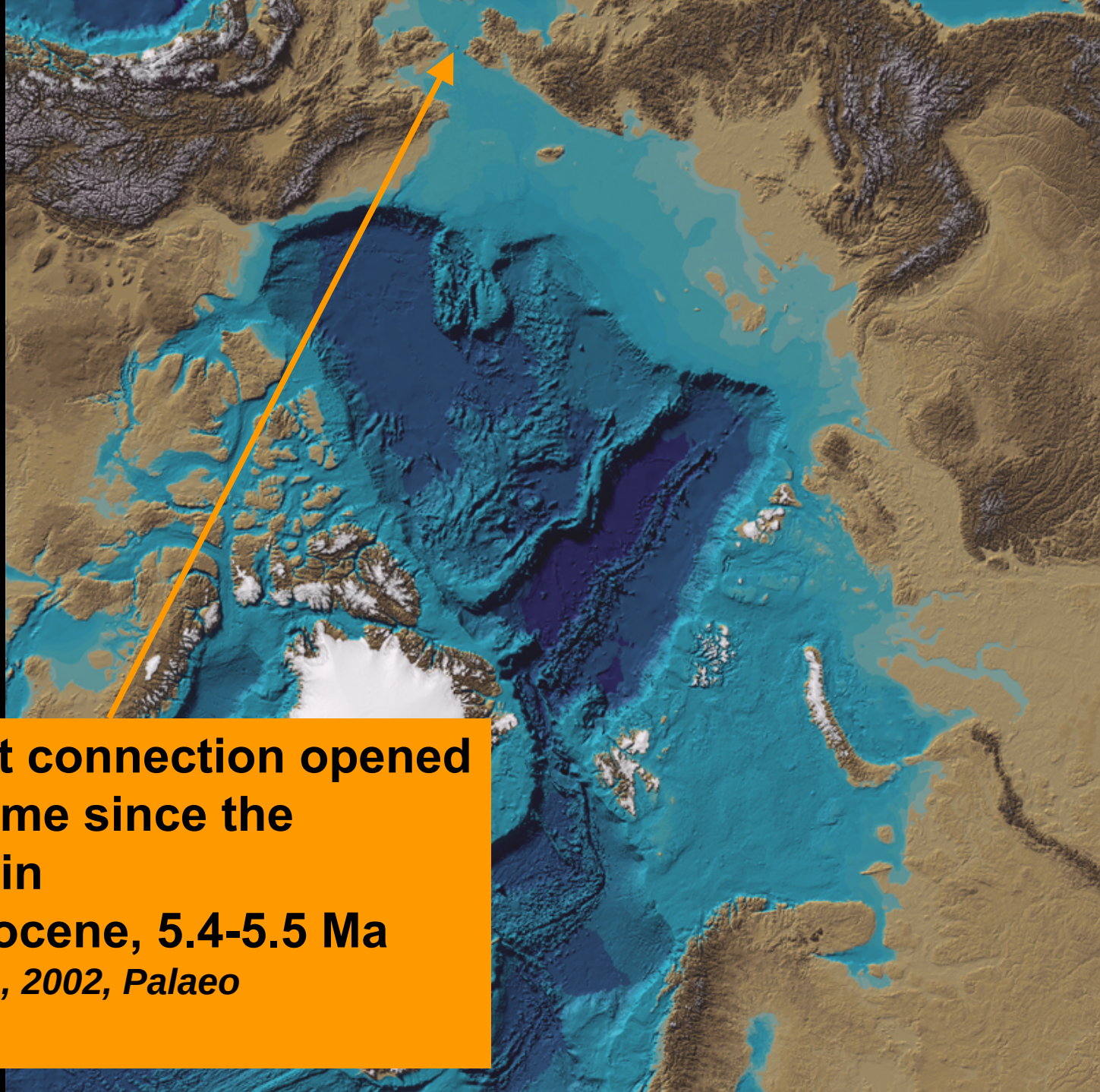
- 1 mainly continental clastics
- 2 deltaic-shallow marine, mainly sands
- 3 shallow marine, mainly shales
- 4 shallow marine, carbonates and clastics
- 5 shallow marine, mainly carbonates
- 6 evaporites and clastics
- 7 mainly evaporites
- 8 evaporites, clastics and carbonates
- 9 evaporites and carbonates

Fram Strait is now open, a key for the present day oceanography in the Arctic Ocean

-  direction of clastic influx
-  active sea-floor spreading axis
-  inactive/abandoned sea-floor spreading axis



Torsvik et al., 2002



**Bering Strait connection opened
at the first time since the
Cretaceous in
Miocene/Pliocene, 5.4-5.5 Ma**
Gladenkov et al., 2002, Palaeo



Arctic Ocean Coring Expedition 2004

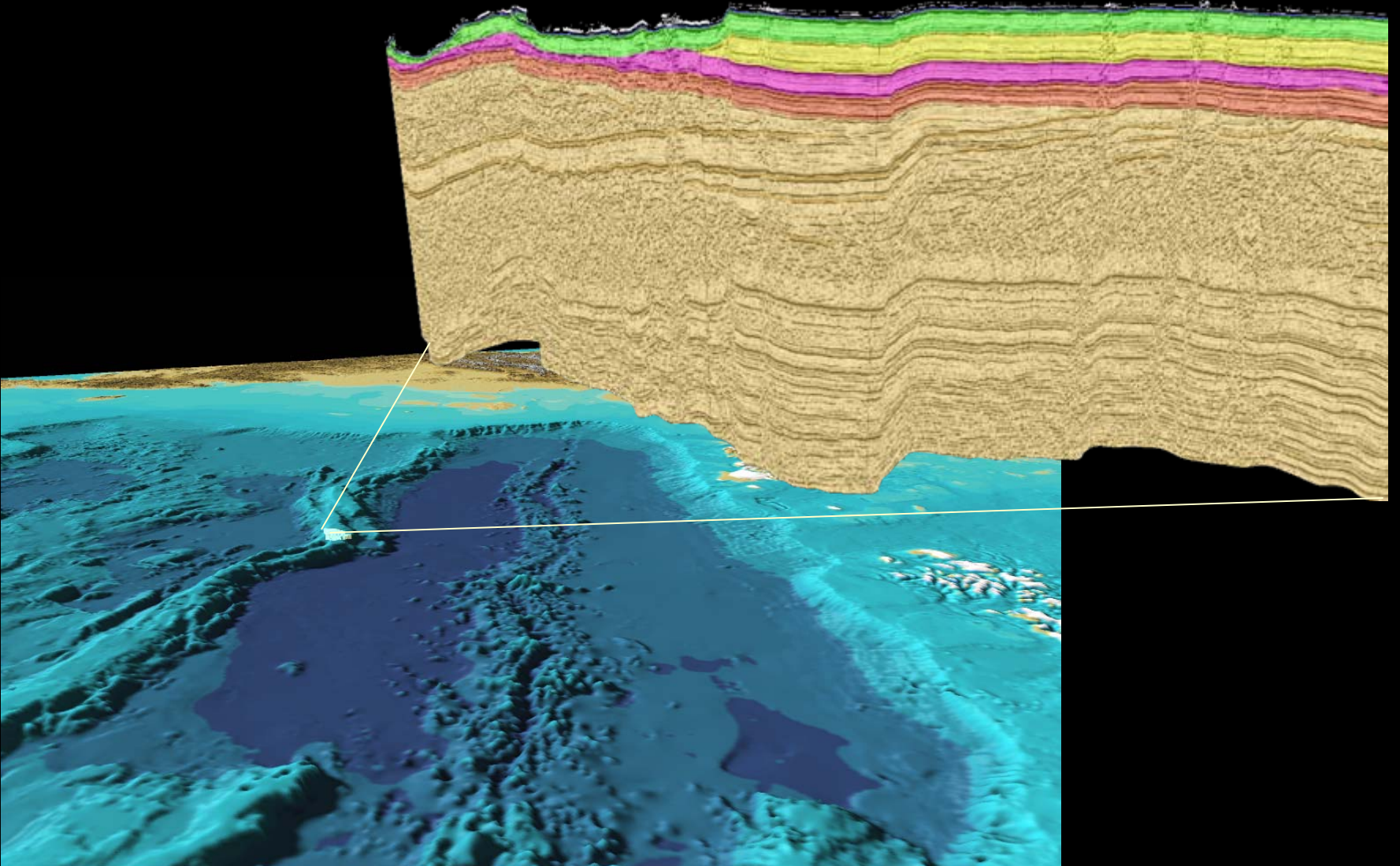
Jan Backman and Martin Jakobsson

Department of Geology and Geochemistry
Stockholm University
Sweden



Seismic line from the Lomonosov Ridge

91091 (Jokat, Kristoffersen et al, 1991, 1995)



Tromsö-Lomonosov Ridge-North Pole-Tromsö

7 August – 14 September, 2004







1996



2004







ACEX results

- **428 m of sediment stratigraphy was drilled from five holes** (M0002A, M0003A, M0004A-C)
- **Recovery was 68.4 %, below 270 m recovery dropped to 43.1 %**
- **The regional unconformity was sampled with a small sample. Fossils indicate age between 80 and 56 million years. *Confirms the continental sliver theory***
- **Subtropical surface waters were present during the Palaeocene Eocene Thermal Maximum (PETM; ~55 million years ago)**



- **Massive presence of Azolla spores (a fern) indicated at least fresh surface water at about 49 millions years ago**
- **Pepples were found down to 239 mbsf suggesting at least seasonal sea ice throughout most of middle Eocene (46-45 million years ago)**

