ANTARCTICA

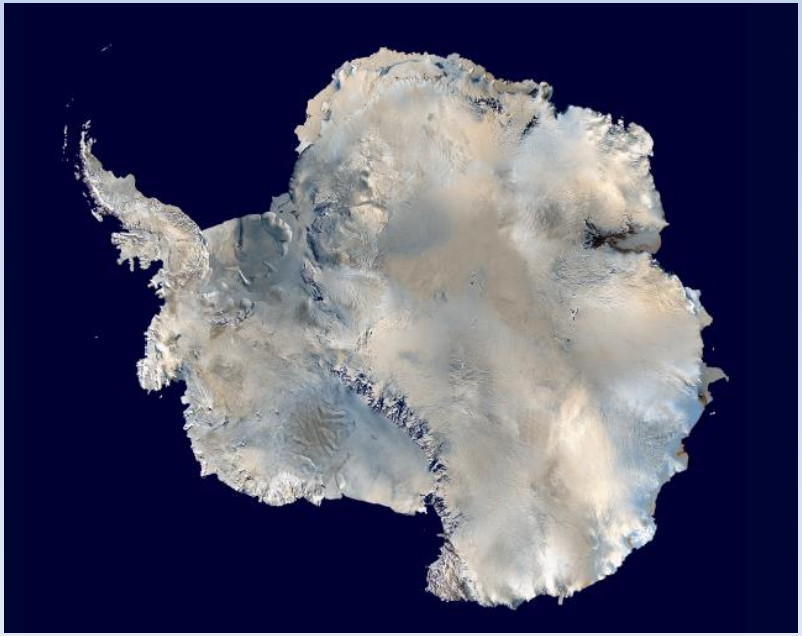
The 7th Continent

John Gunton

Mar 27, 2021

OUTLINE

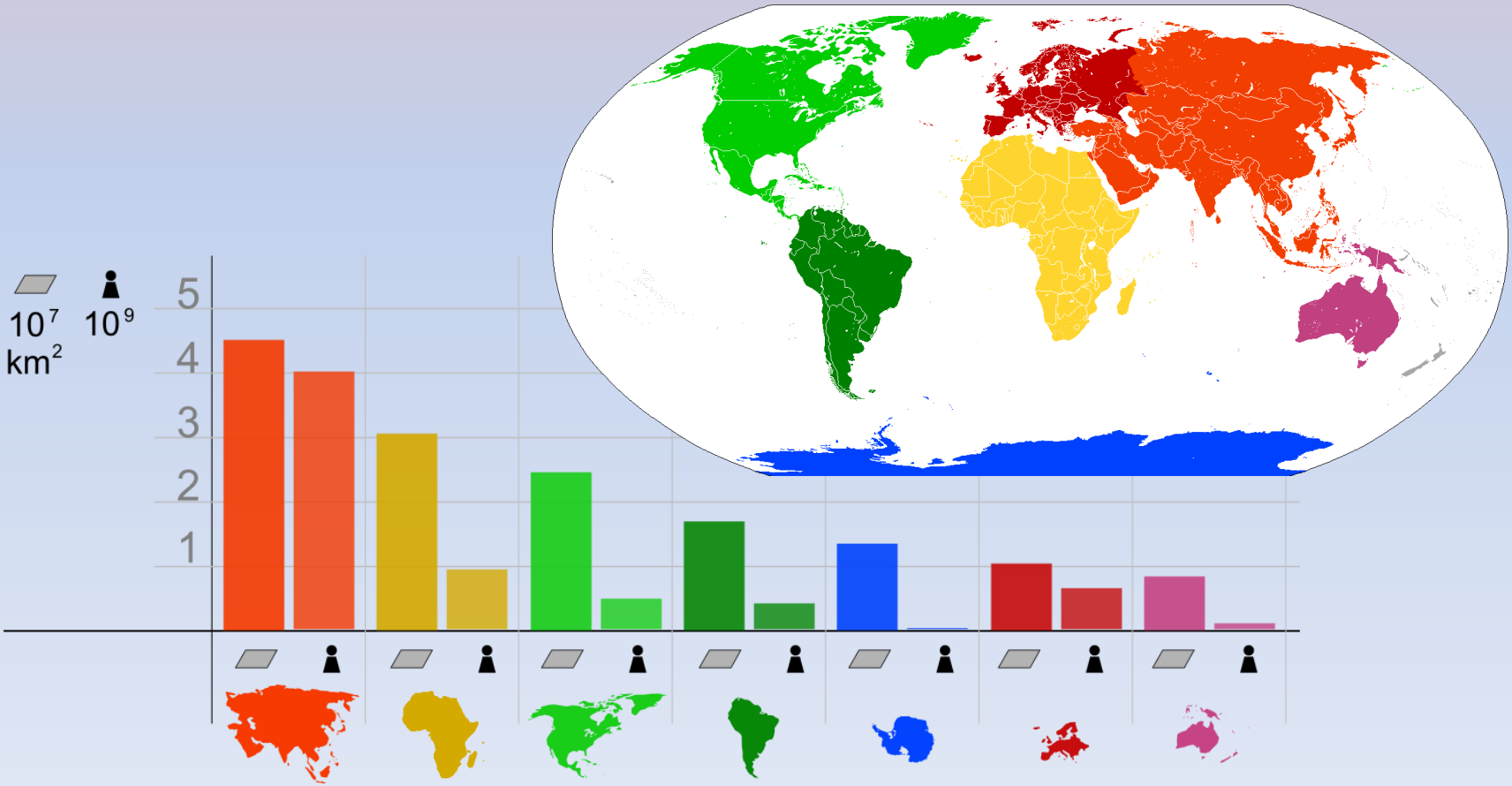
- Why is Antarctica the 7th continent and so different from the Arctic?
- How Antarctica came to be.
- Is Antarctica melting?
- Antarctic Treaty
- Research
- Ice dynamics
- Drilling

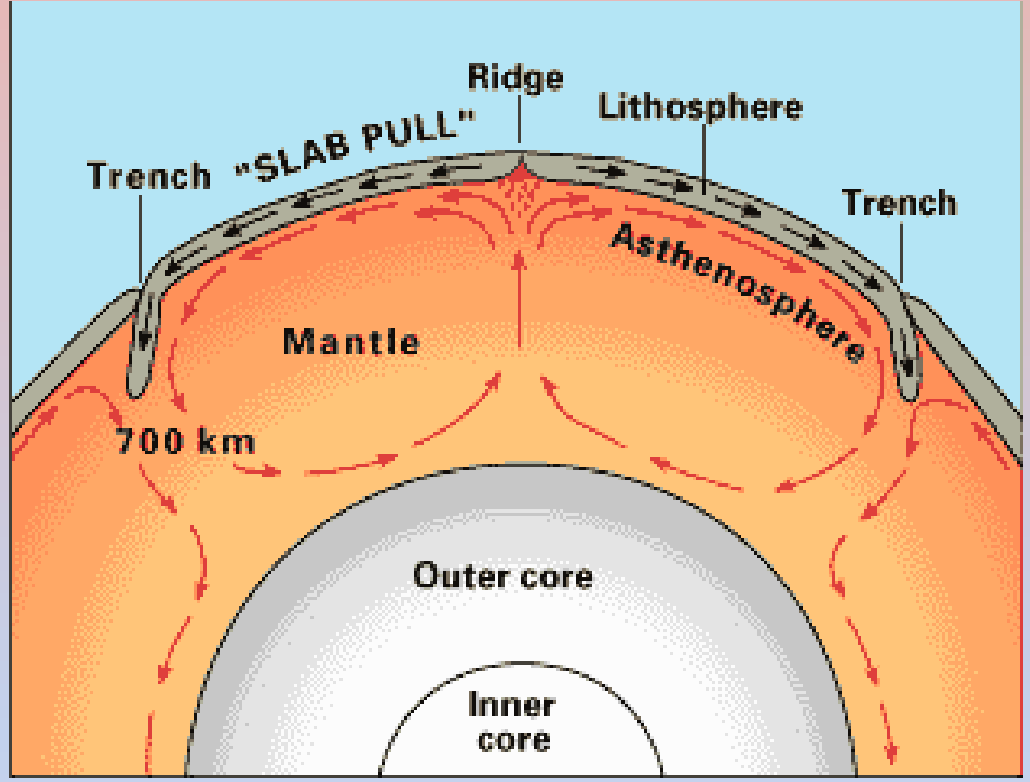


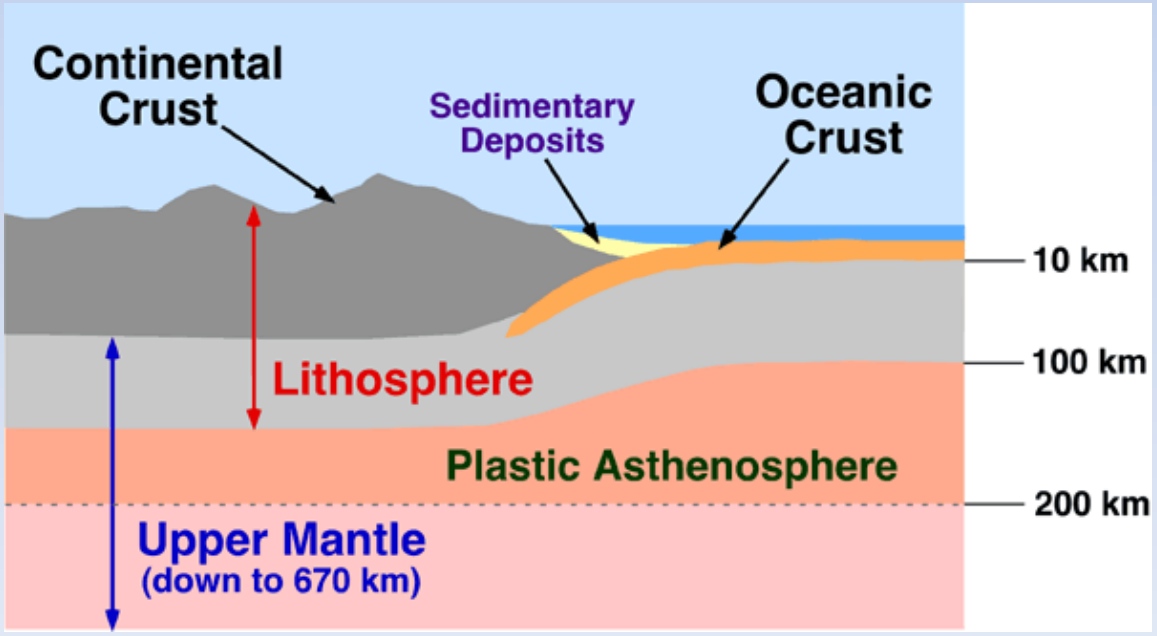
Why the 7th Continent?

What defines a continent?

Convention: World's main continuous expanses of land?
Historical: Last to be discovered
Geological: "Lands accreted to a core of ancient cratonic rock (2.4 Gya)"

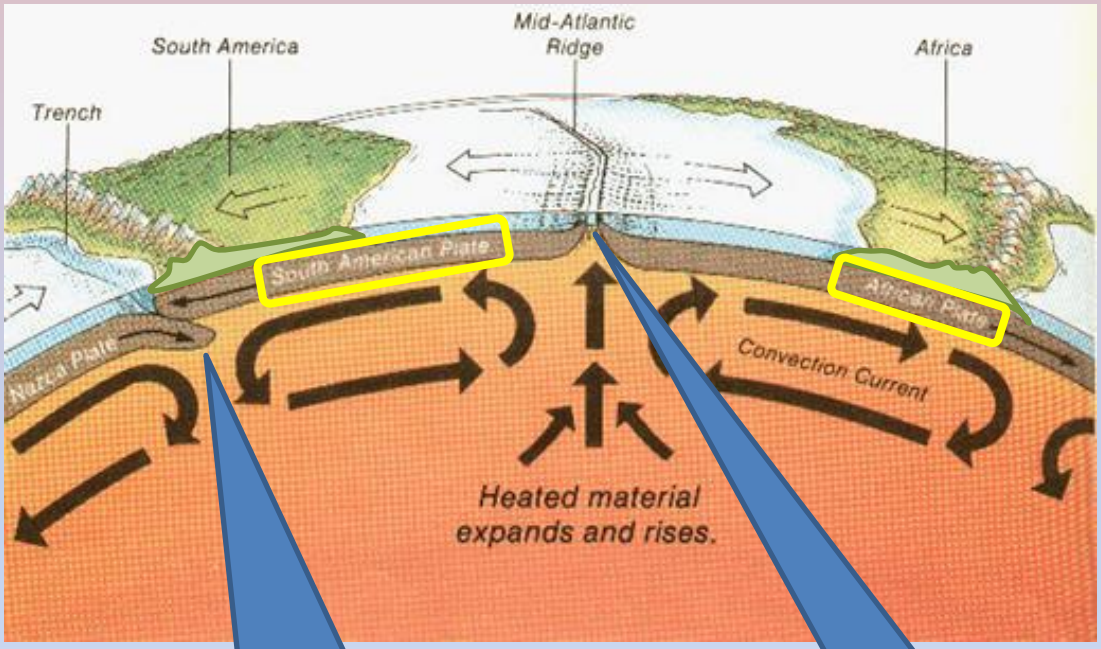



Ridge
Lithosphere
Trench
"SLAB PULL"
Trench
Asthenosphere
Mantle
700 km
Outer core
Inner
core


Continental
Crust
Sedimentary
Deposits
Oceanic
Crust
10 km
Lithosphere
100 km
Plastic Asthenosphere
200 km
Upper Mantle
(down to 670 km)

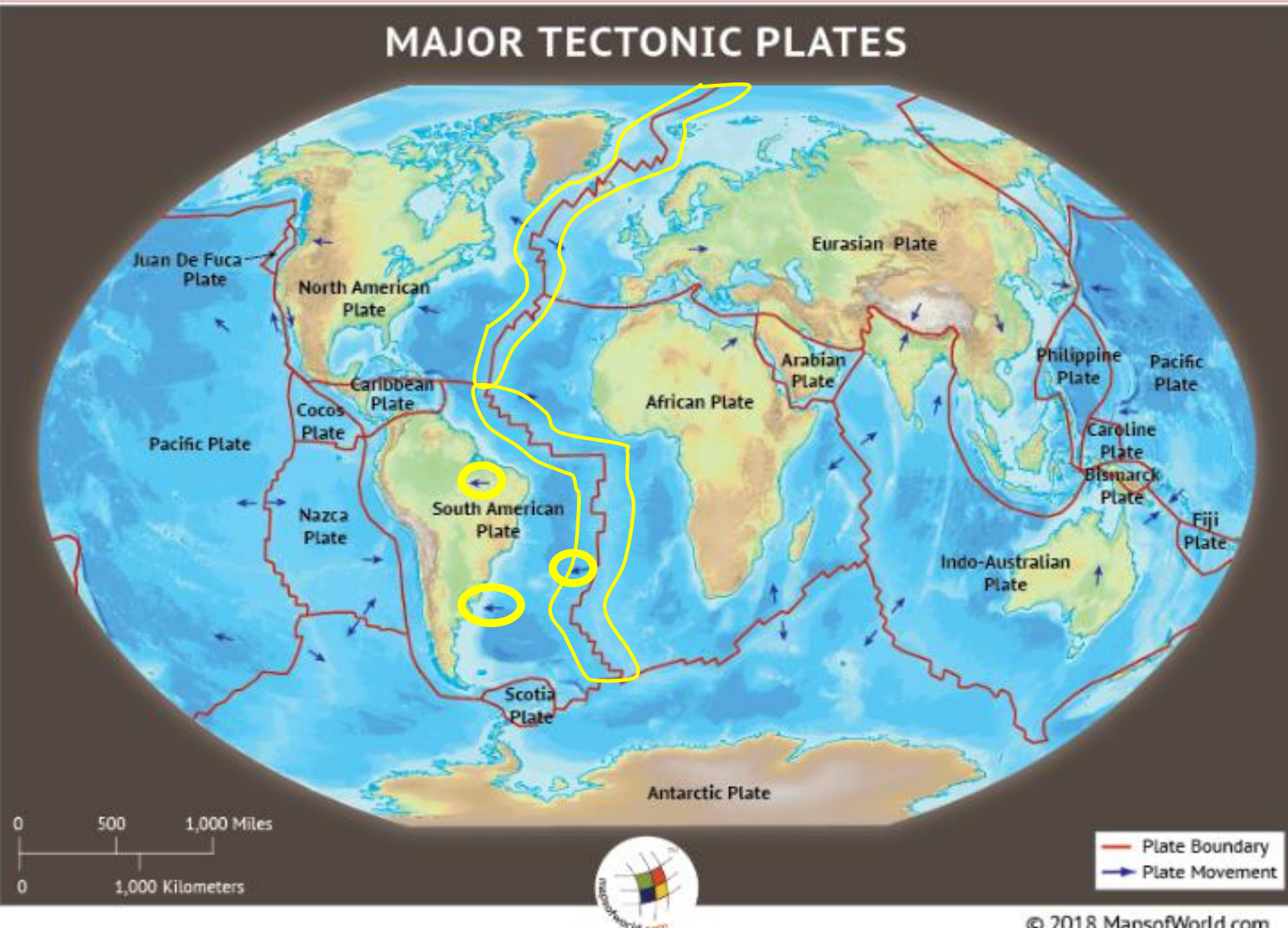

Continent
Oceanic Crust
Oceanic Crust
Continent
Upper
Mantle
Upper
Mantle

Plates and Plate Margins

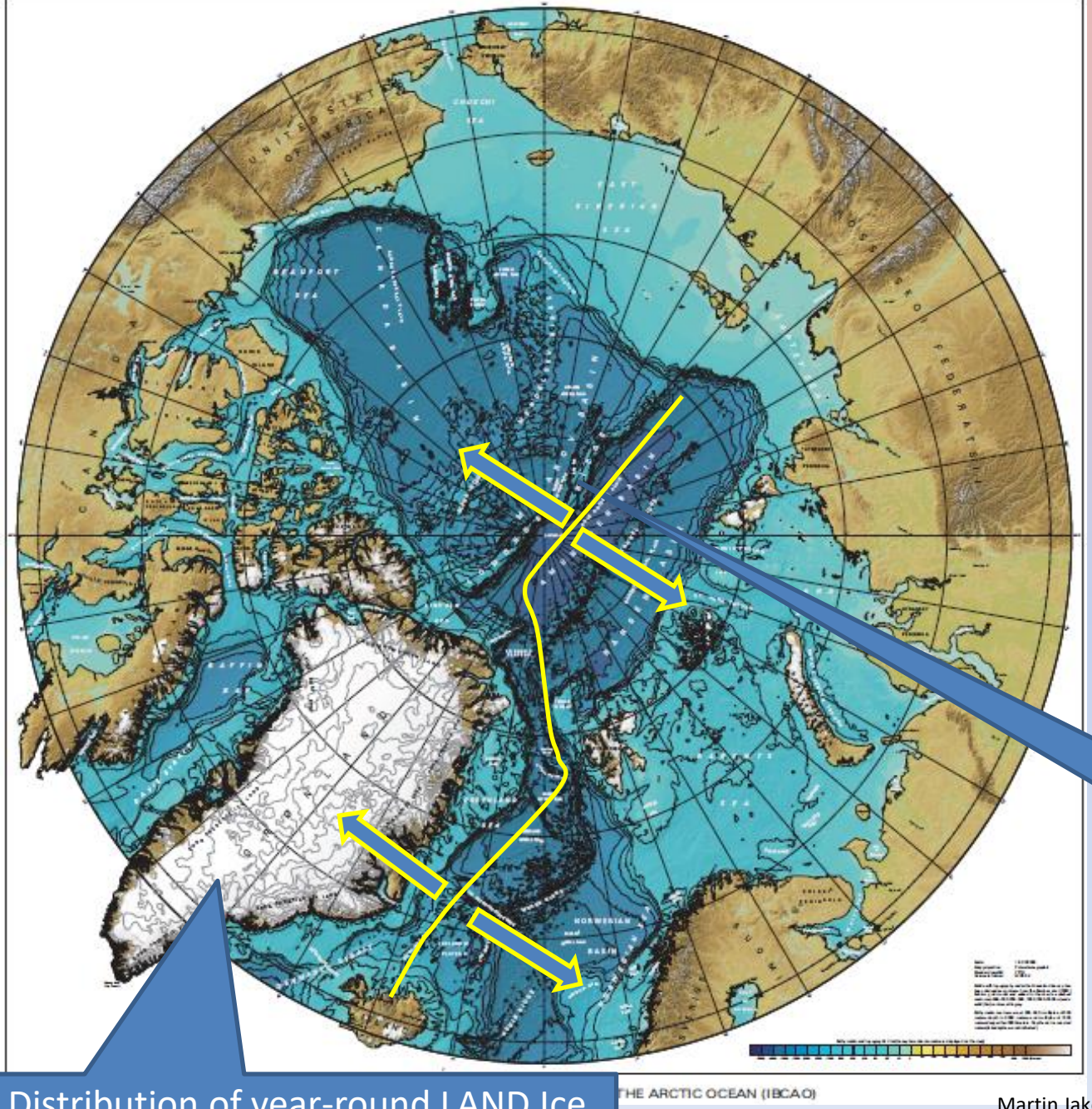


Subducting/collision plate margin

Spreading ridge plate margin


MAJOR TECTONIC PLATES
Juan De Fuca Plate
North American Plate
Eurasian Plate
Arabian Plate
Philippine Plate
Pacific Plate
Caribbean Plate
Cocos Plate
African Plate
Pacific Plate
Caroline Plate
Bismarck Plate
Fiji Plate
Nazca Plate
South American Plate
Indo-Australian Plate
Scotia Plate
Antarctic Plate
0 500 1,000 Miles
0 1,000 Kilometers
Plate Boundary
Plate Movement
© 2018 MapsofWorld.com

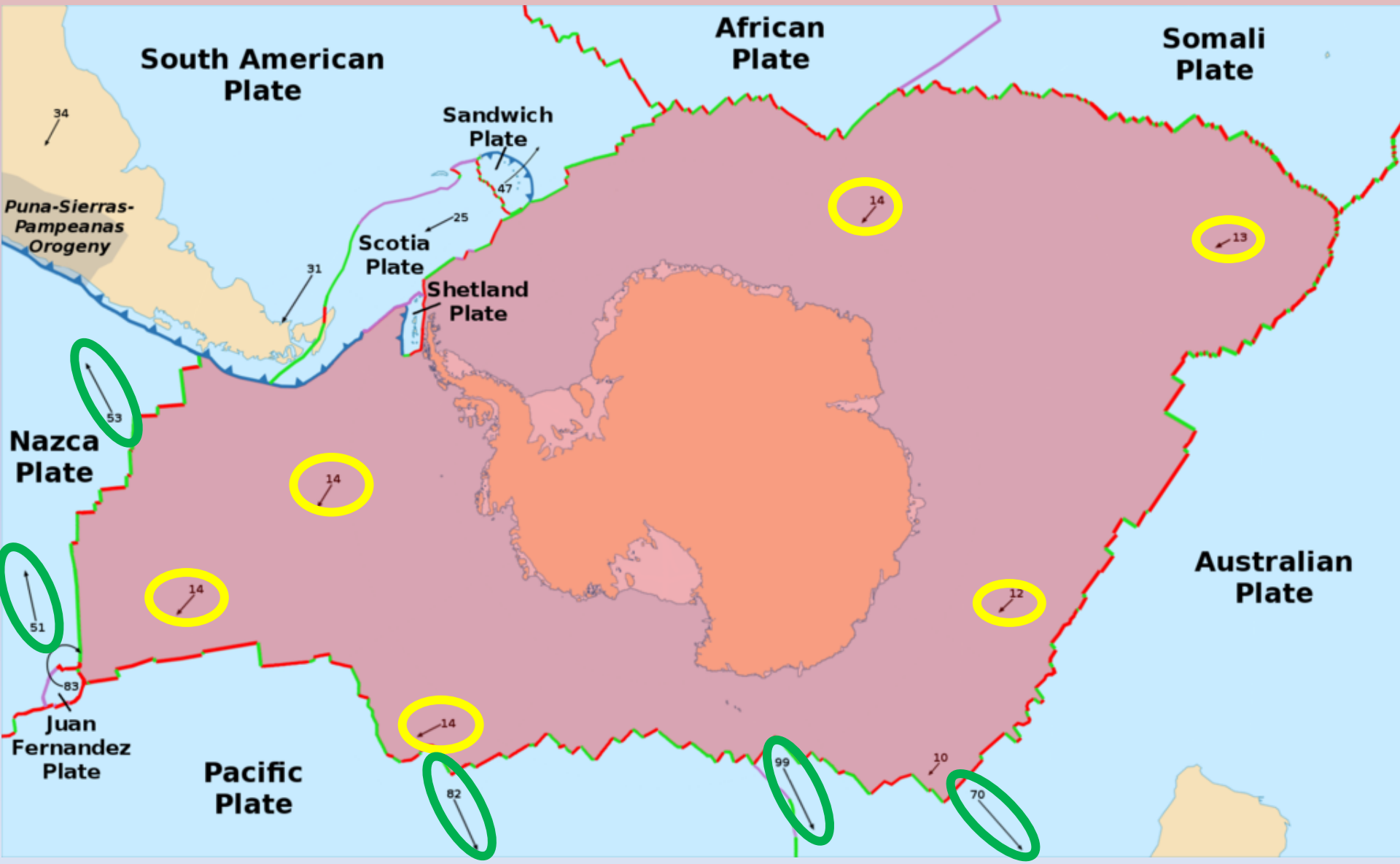
THE INTERNATIONAL BATHYMETRIC CHART OF THE ARCTIC OCEAN (IBCAO)



Lomonov Ridge (spreading centre) Extension of Mid Atlantic Ridge

Distribution of year-round LAND Ice
SEA ICE removed from map

Compiled by
Martin Jakobsson, U of New Hampshire, USA
Ron Macnab, Geological Survey of Canada (Ret)
Norman Cherkis, Five Oceans Consultants, USA

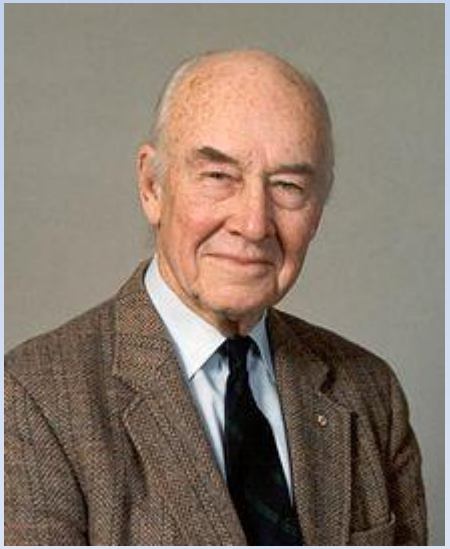

South American Plate
African Plate
Somali Plate
Sandwich Plate
Puna-Sierras-Pampeanas Orogeny
Scotia Plate
Shetland Plate
Nazca Plate
Australian Plate
Juan Fernandez Plate
Pacific Plate
34
47
25
31
14
13
53
14
14
51
12
83
14
99
10
82
70

Continental Drift:
A precursor concept to Plate Tectonics

- 1912 Alfred Wegener proposed “Continental Drift”.
- His drift mechanism was the spinning earth
- The mechanism was rejected by geologists
- He died in 1930.
- His idea was taken up by Wilson and others.
- In 1966 Wilson published a landmark paper.
  John Tuzo Wilson, Nature 1966, v. 211
- This led to Plate Tectonic Theory and the “Wilson Cycle” was introduced in 1974

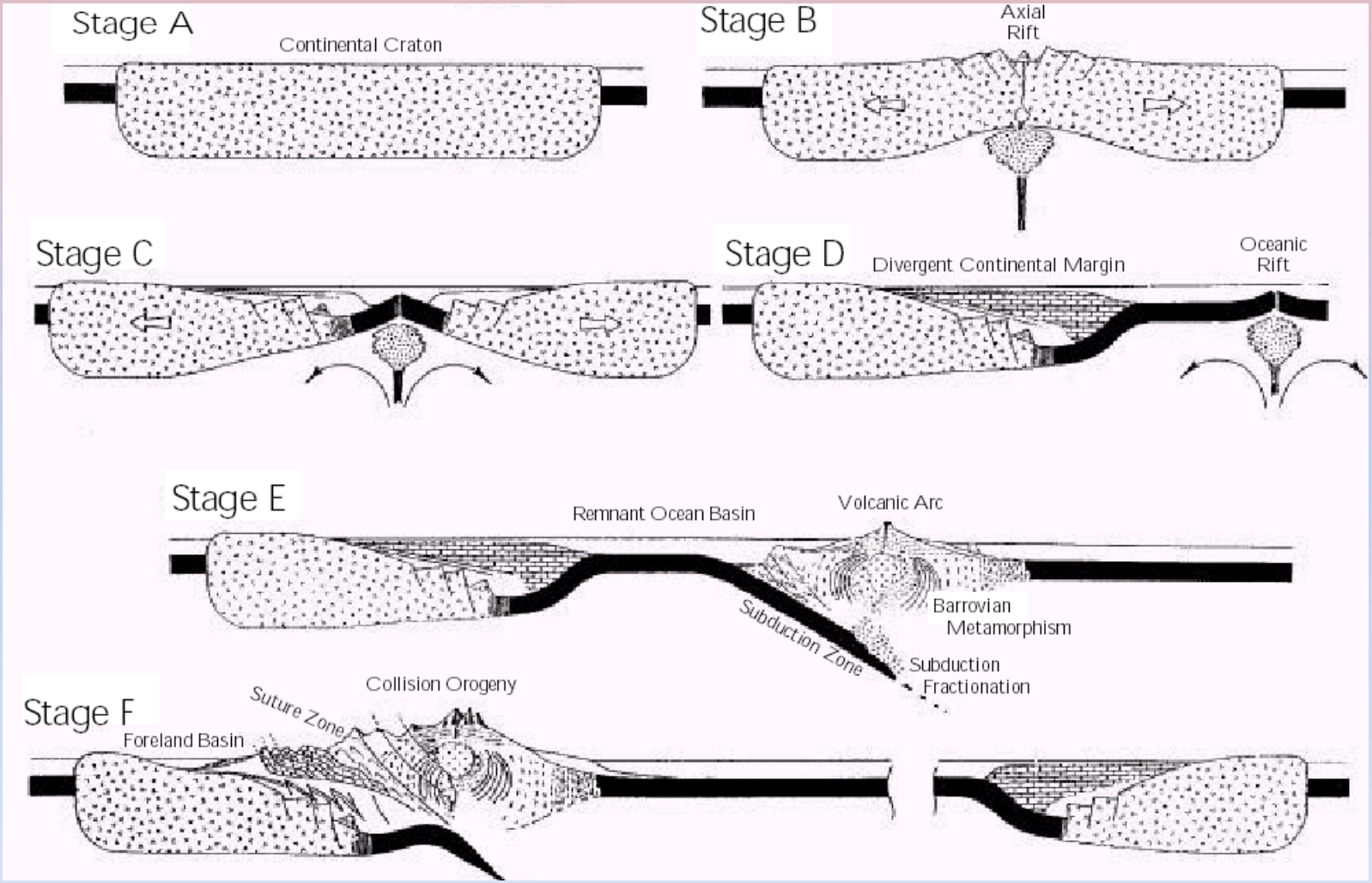
I ENJOY, AND ALWAYS HAVE ENJOYED, DISTURBING SCIENTISTS

JOHN TUZO WILSON

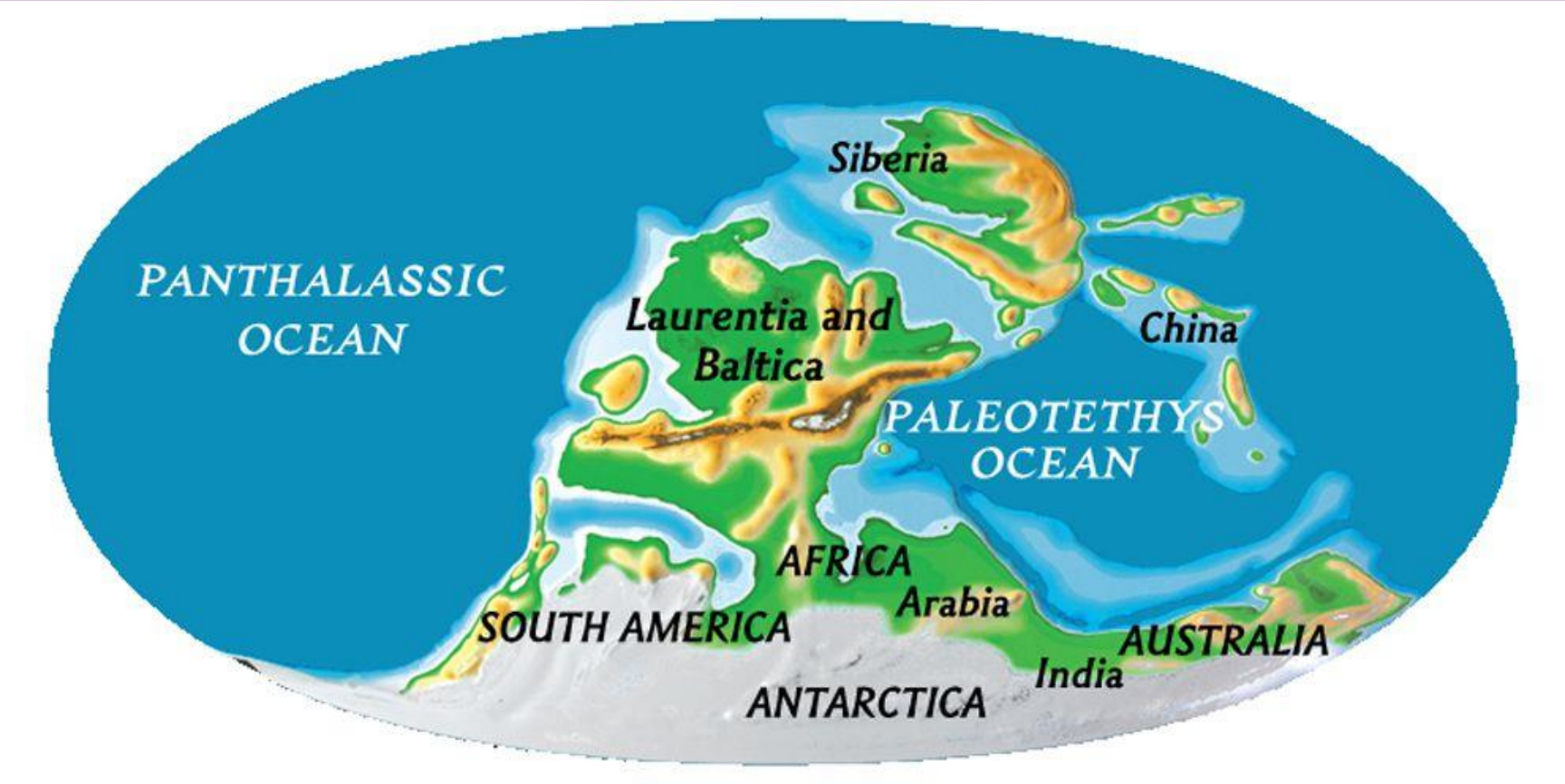


J. Tuzo Wilson CC OBE FRS FRSE FRSC (1908-1993)

Wilson Stages A to F –Tectonic Rock Cycle



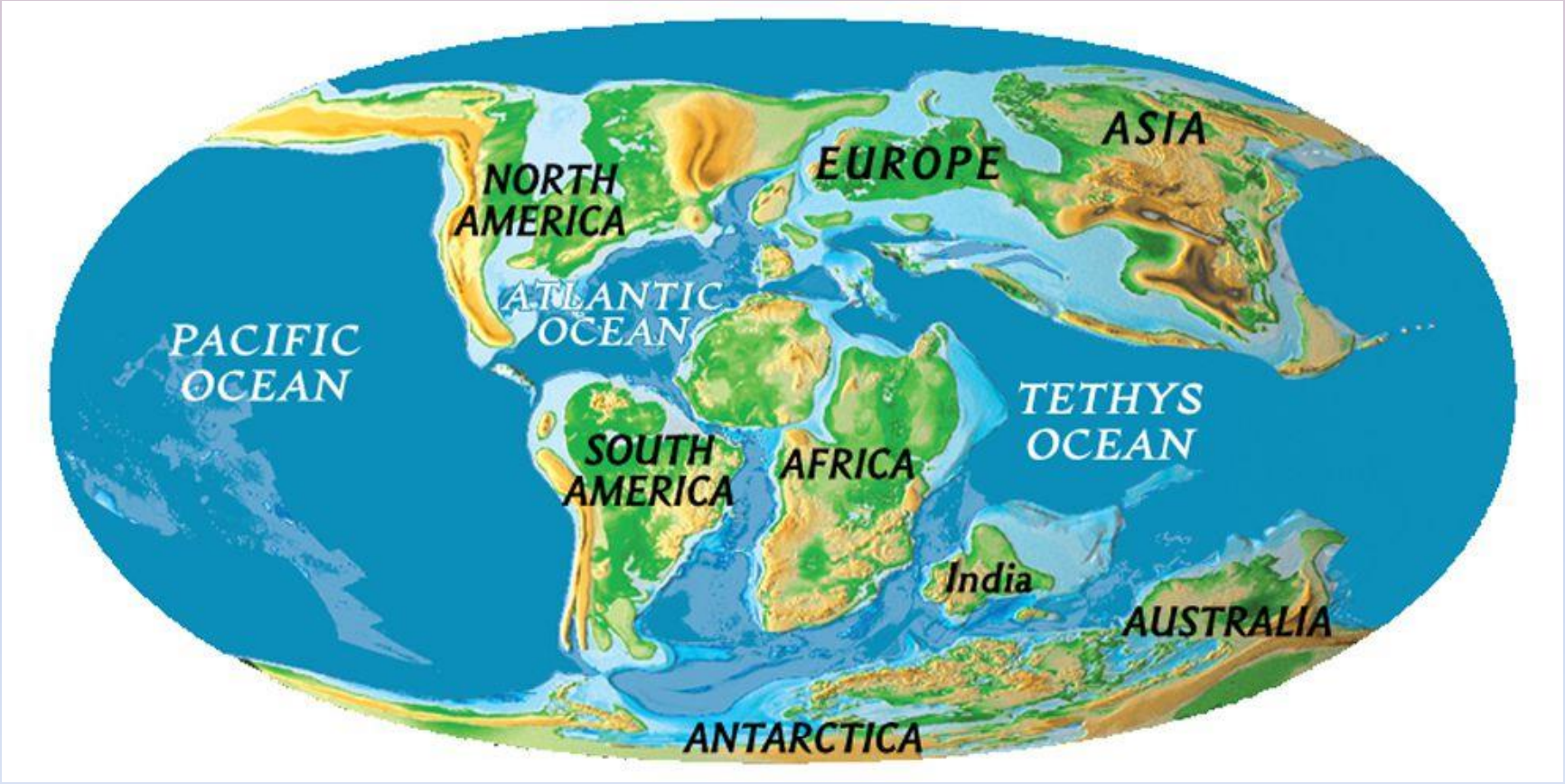
300 Mya
Pangaean Glaciation



200 Mya


EURASIA
China
NORTH AMERICA
Cimmeria
PANTHALASSIC OCEAN
Wrangellia
TETHYS OCEAN
SOUTH AMERICA
AFRICA
India
AUSTRALIA
ANTARCTICA

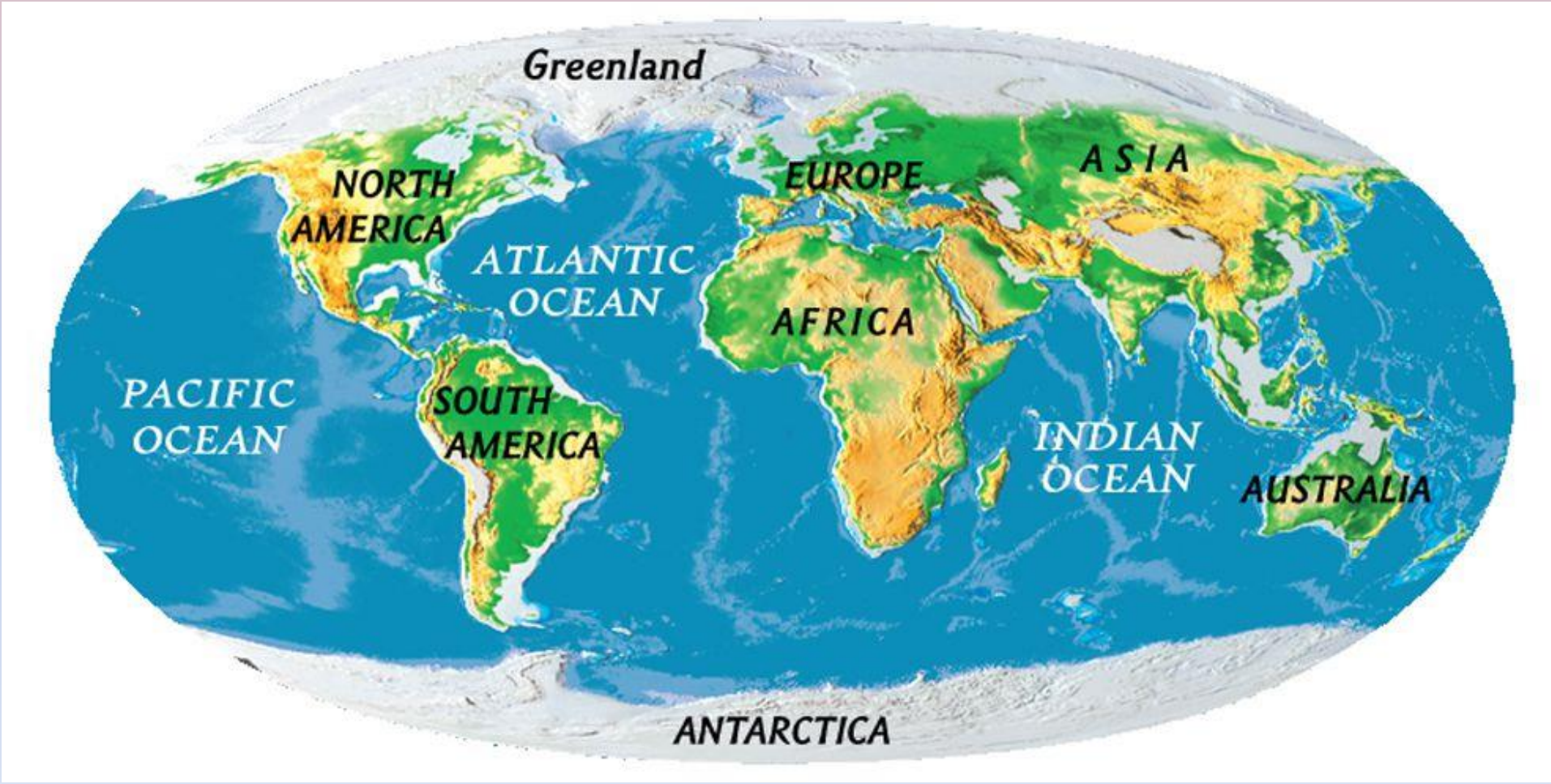
100 Mya


ASIA
EUROPE
NORTH AMERICA
ATLANTIC OCEAN
PACIFIC OCEAN
TETHYS OCEAN
SOUTH AMERICA
AFRICA
India
AUSTRALIA
ANTARCTICA

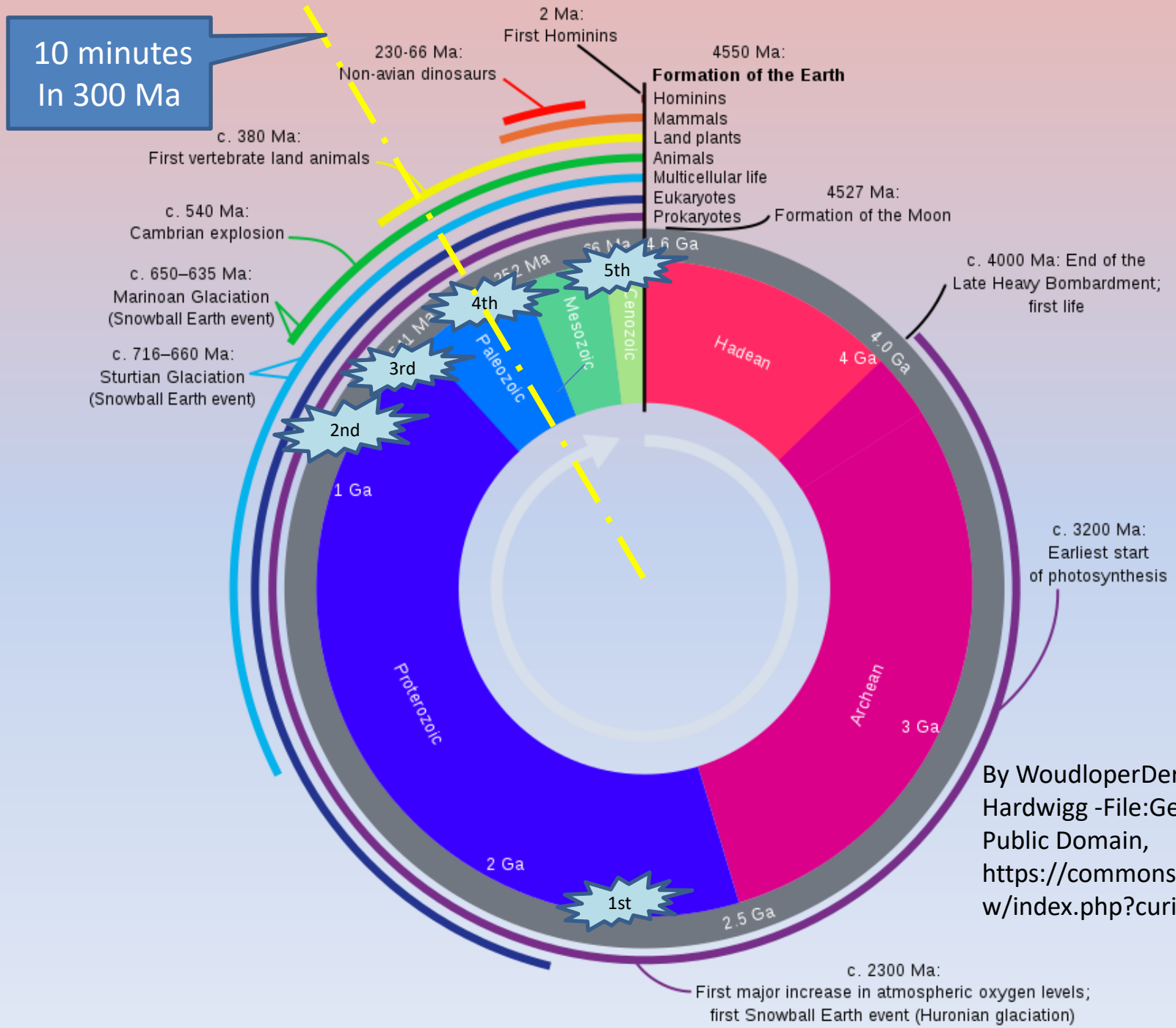
50 Mya

MAP COURTESY OF CR SCOTESE, PALEOMAP PROJECT

Present Day



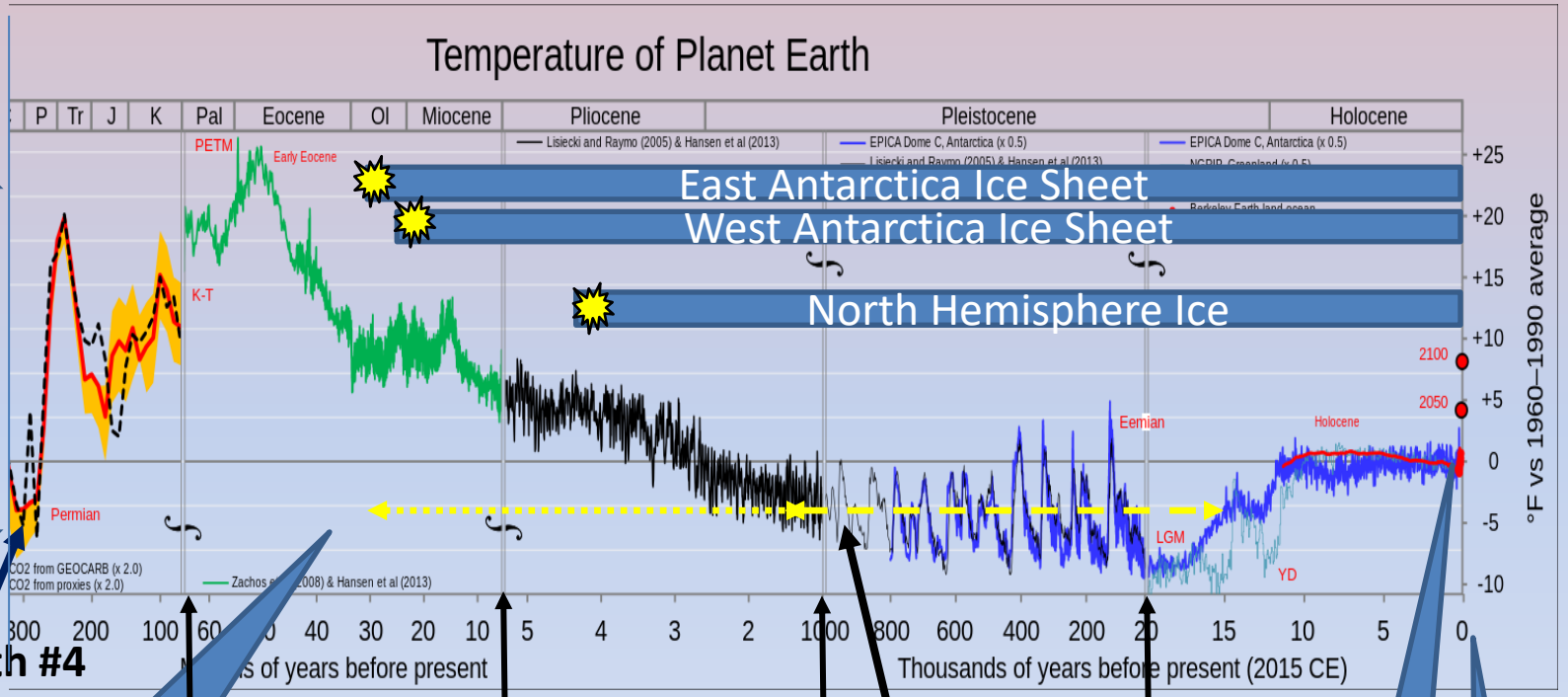
MAP COURTESY OF CR SCOTESE, PALEOMAP PROJECT: NATIONAL GEOGRAPHIC



By WoudloperDerivative work: Hardwigg -File:Geologic_clock.jpg, Public Domain, https://commons.wikimedia.org/w/index.php?curid=11926892

300 My of Temperature Fluctuation Global Average

Wikimedia



Snowball Earth #4

Scale change

Scale change

Scale change

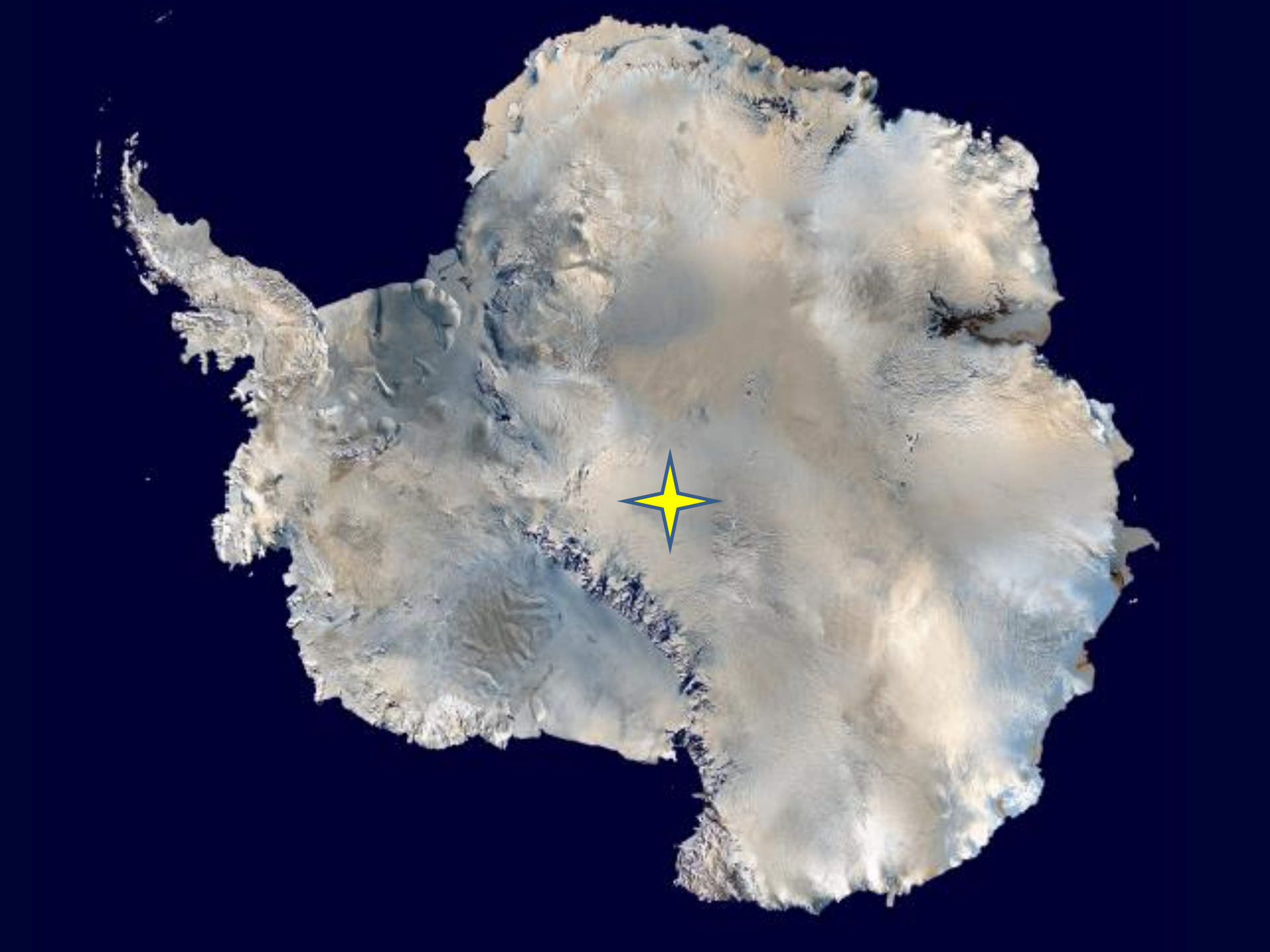
Scale change

Drake Passage Forms & Antarctica is isolated in polar position 40 mya

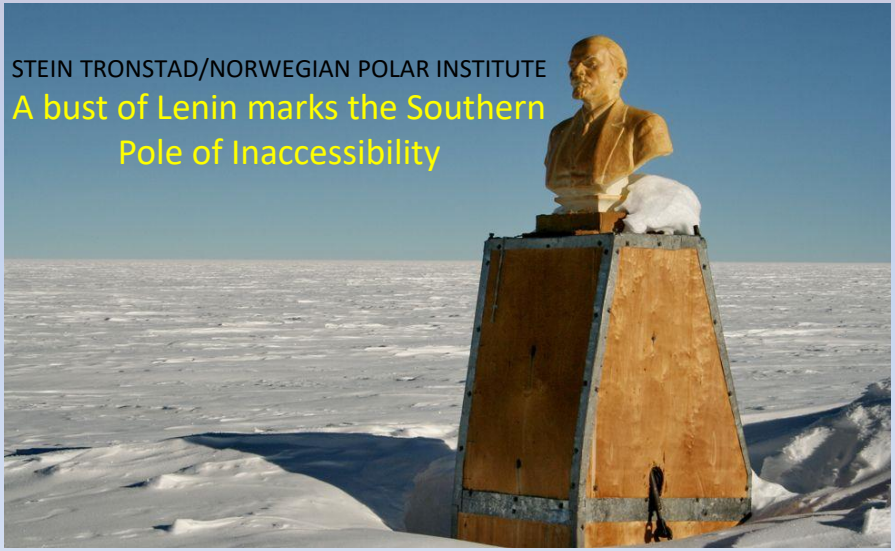
Snowball Earth #5

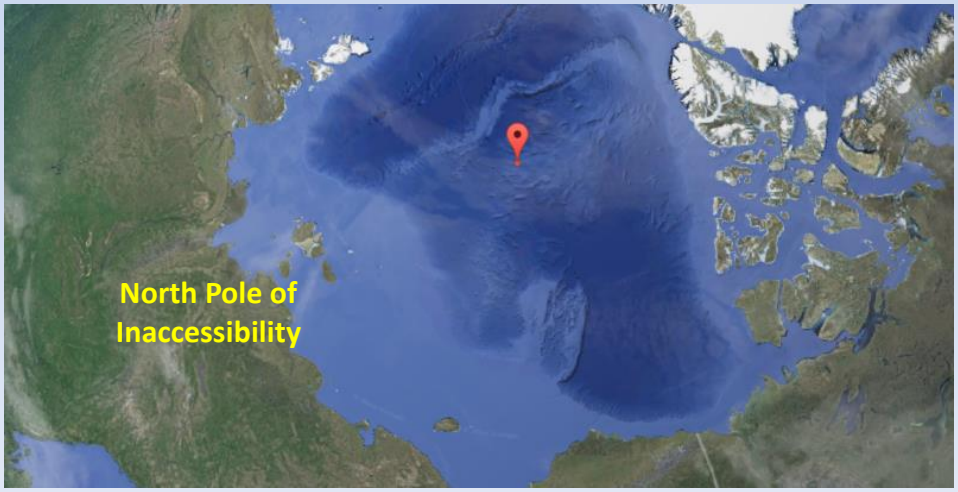
TODAY's Temp

TODAY Time zero



1. Geographic South Pole
2. Geomagnetic Pole 2007
3. Magnetic Pole 2005
4. South Pole of Inaccessibility

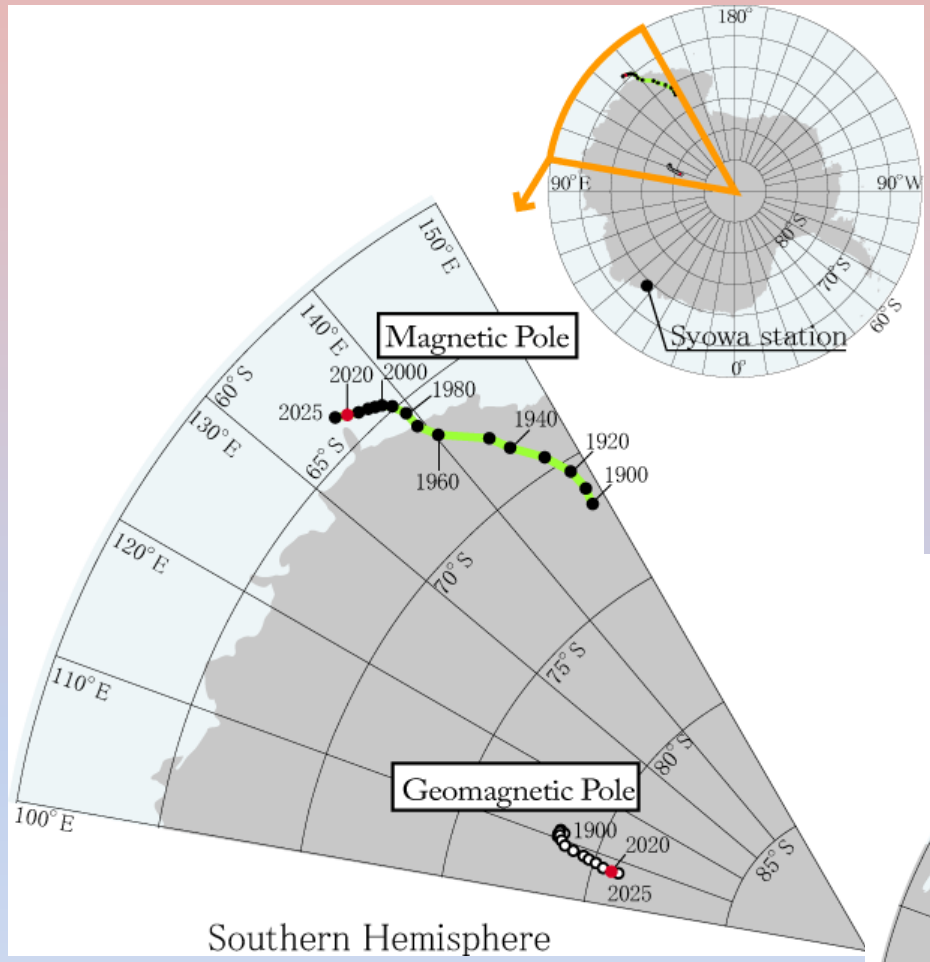


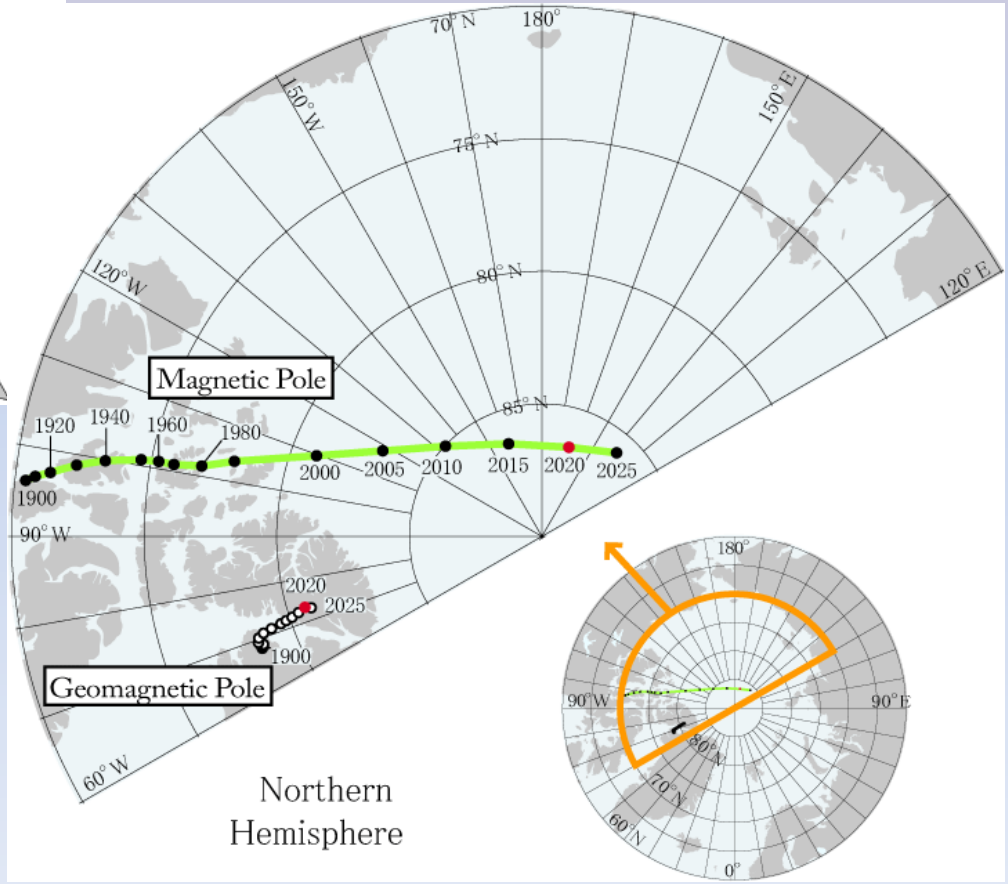


[Geomagnetic and Magnetic Poles (kyoto-u.ac.jp)]

North Magnetic Pole

- Drifting NW @55 - 60 kms per yr





South Magnetic Pole

- Drifting NW @10-15 kms per yr
- Currently located Sth of Antarctic Circle
- 2860 kms from Geographic South Pole

ANTARCTICA

First sighted 1820 (Russians - Lazarev)

First landing 1821 (Americans - Davis)

7th Continent 1839 (Americans – Wilkes)

5th largest continent

Twice size of Australia

Coldest, driest, windiest, highest continent

Highest Point 4,892 m (16,050 ft) Vinson Massif

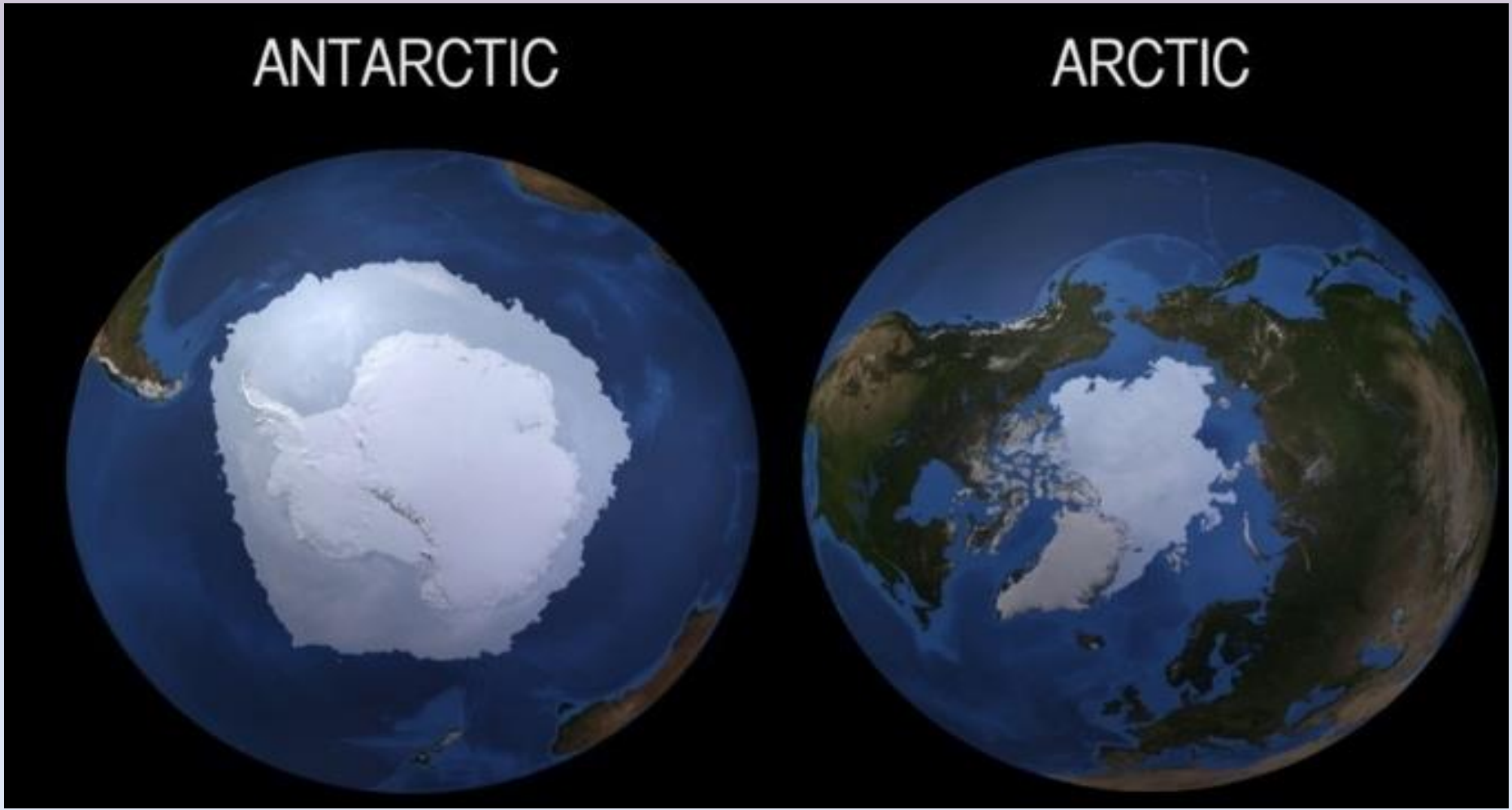
98% covered by a continuous ice sheet called land ice to distinguish it from sea ice

The land ice holds approx. 70% of world`s fresh water

Predicted sea level rise of 60 m if melted

No permanent human residents

Why is “Being a Continent” Relevant to Polar Opposites?



Secretariat of the Antarctic Treaty
Secrétariat du Traité sur l'Antarctique
Секретариат Договора об Антарктике
Secretaría del Tratado Antártico

The Antarctic Treaty

1959

- 1959 - Founding member countries (12)

territorial claimants (7):

Argentina, Australia, UK, Chile,
France, New Zealand, Norway,

non-claimants consulting members (5):

Belgium, Japan, Sth. Africa,
USSR, USA.

Unclaimed (Marie Byrd Land)
Nowhere else in the world is there unclaimed territory

- Now 54 states party to treaty
- 1988 Canada joins by ratifying treaty along with 40 countries & the original 12 claimants

Antarctic Treaty System

International Council of Science (ICSU)

Responsible for Antarctic Research

Scientific Committee on Antarctic Research (SCAR)

Canadian Polar Commission (CPC)

Since 1991 www.polarcom.gc.ca

Canadian Committee on Antarctic Research (CCAR)

14 member body of scientists to review Antarctic research proposals

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The Antarctic Treaty

1959

ONLY TWO REASONS TO VISIT ANTARCTICA

RESEARCH

1000 to 5000 researchers

~60 stations - (28 permanent year-round, 30 summer only)

TOURISM

80,000+ tourists annually governed by IAATO

International Association of Tour Operators

Research

Research Stations

Information & Data Gathering

- Surface mapping
- Drilling
- Telescopes
- Remote surveys (land, sea, airborne & satellites)
  - acoustic (seismic)
  - radioglaciology (Ice penetrating radar)
  - gravity
  - magnetics

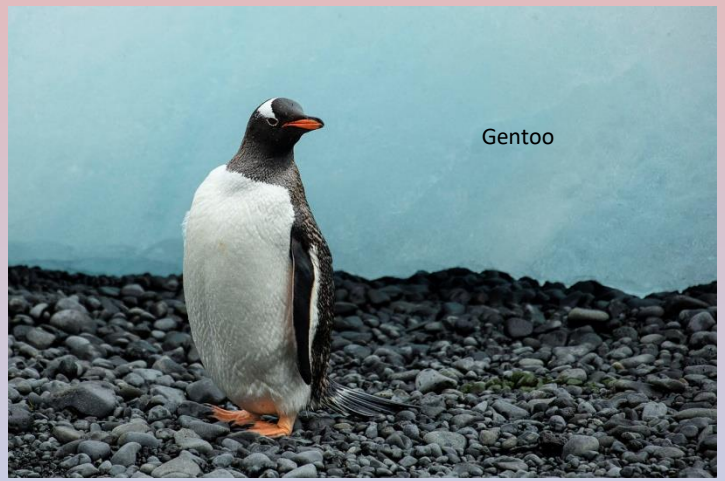

Australia Airbus A319 suppling research station

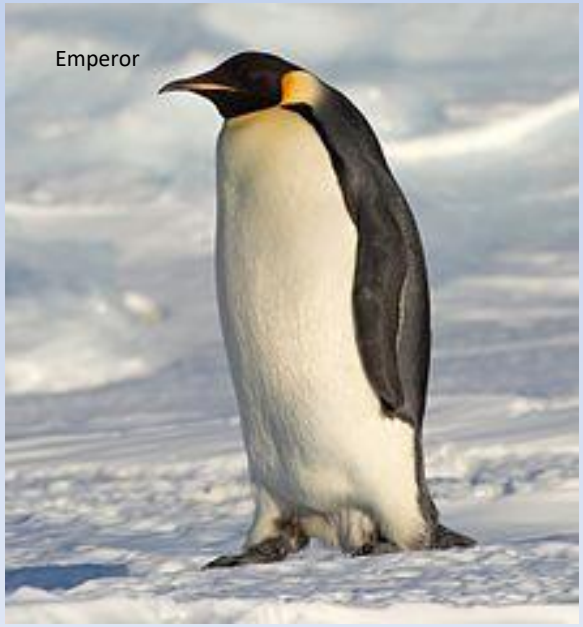

Ken Borek Air Twin otter

Research Topics

- Isostasy and sea level change – ice dynamics
- Microbial life in permafrost environments
- Solar wind – Magnetosphere – Ionosphere (SW-M-I) System
- Bioremediation of pollution (spills)
- Atmosphere – ocean fluxes of climate active gases (CO_2, DMS, CH_4, N_2O, O_3)
- **Effects of UVB radiation**
- Ecology of marine plankton: physical-biological coupling processes and dynamics
- Meteorite & space debris
- Muon & Neutrino Detector Array –IceCube Neutrino observatory

Penguins





Penguin Highways


2015 02 14 04:17


2015 02 12 10:36

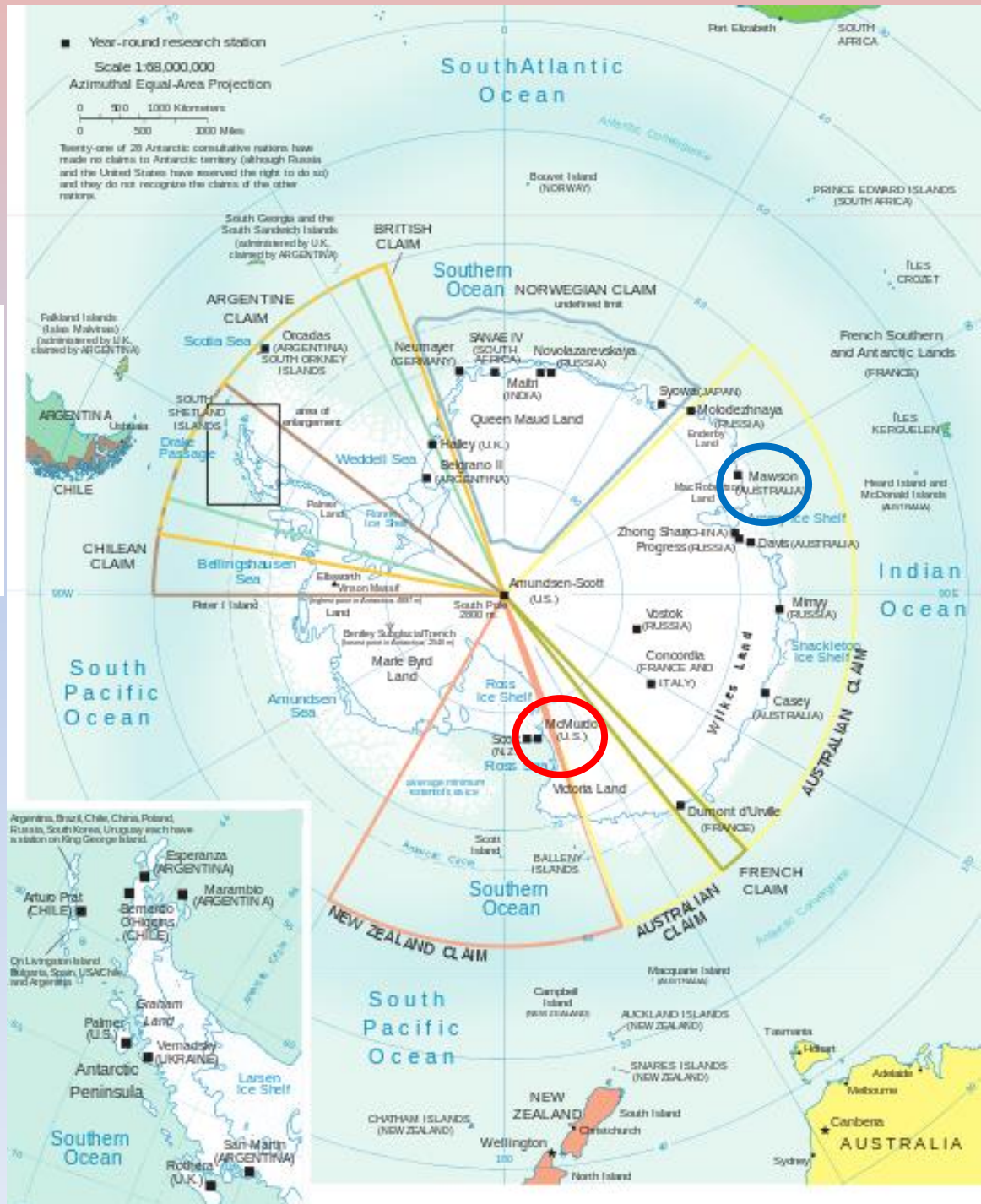

2015 02 12 10:37

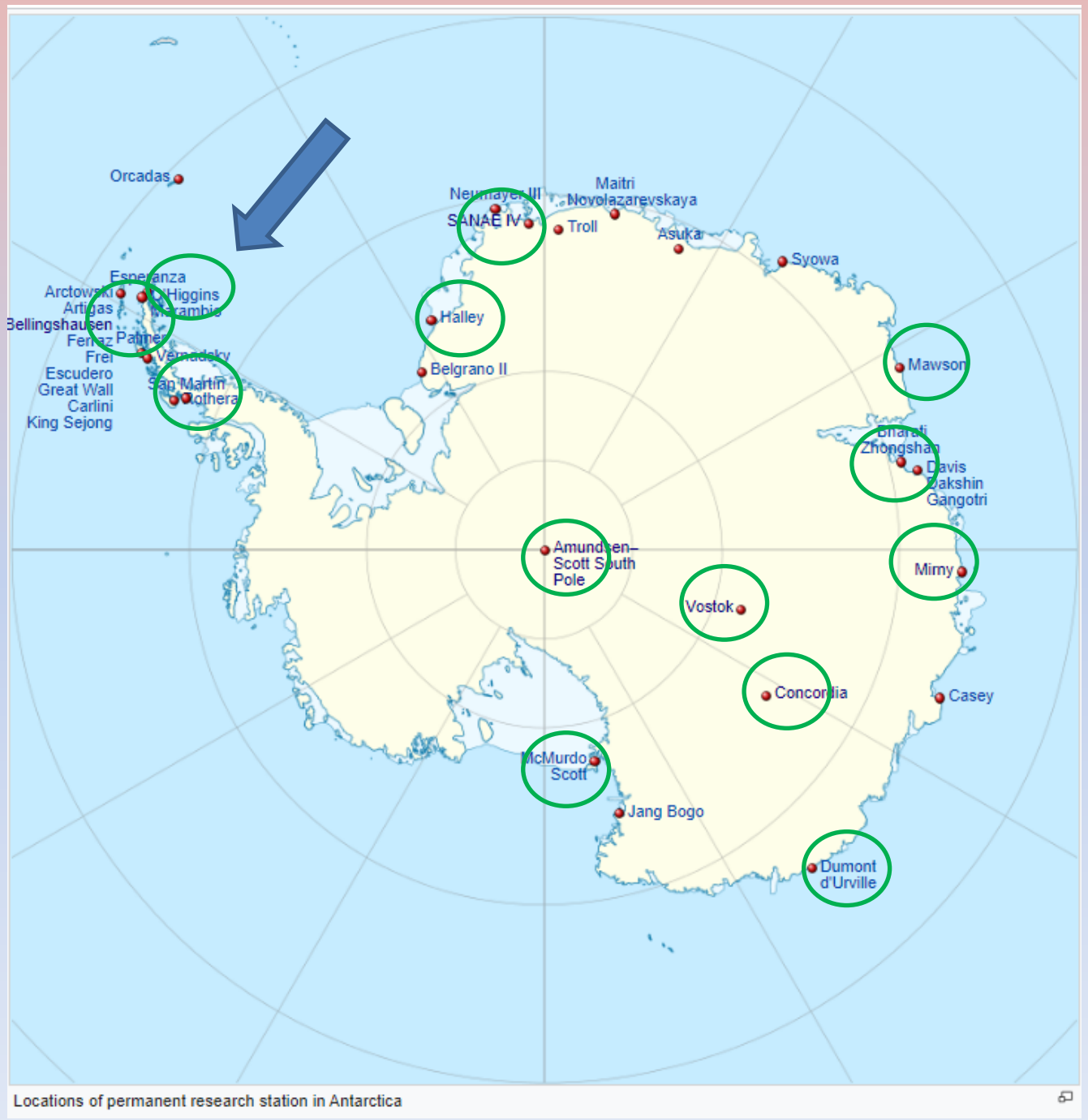

2015.02.13 10:17


2015.02.13 10:17

Research Stations

- 19 countries involved in year round research in permanent stations
- Approx 28 permanent stations
- Staffing grows from 1000 to 5000 (summer)
- Over wintering means no supplies and 24 hour darkness for 6+ months
- Researchers must have appendix and wisdom teeth removed





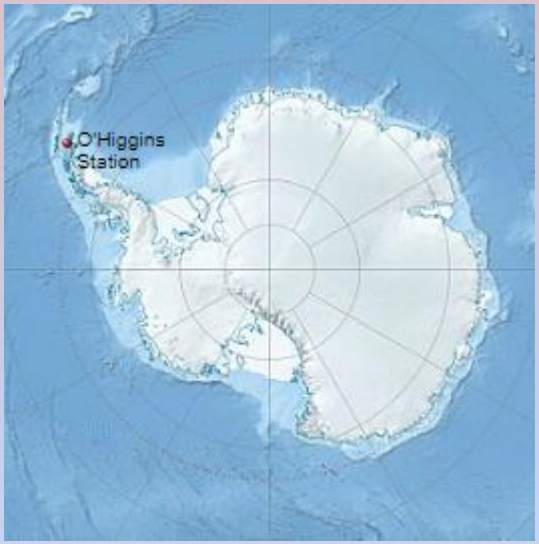
Locations of permanent research station in Antarctica

Permanent Research Stations

Main Research Stations

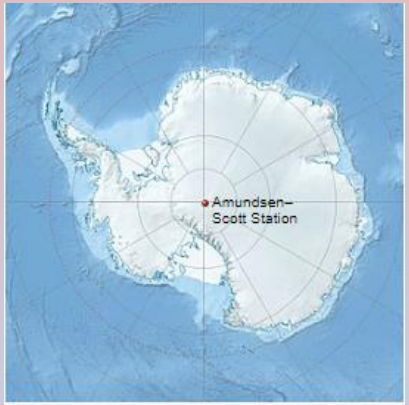
Bernardo O’Higgins - Chile

Oldest station in continuous use: Opened in 1948
Winter 16 staff, summer 60
Operated by Chilean Navy
36 COVID-19 case were reported on December 22, 2020



South Pole – USA
Amundsen Scott

50 Staff winter: 200 staff summer
Keeps moving & is being buried
Geodesic dome decommissioned 2008
And new elevated station opened



Location of Amundsen–Scott Station at the South Pole in Antarctica


@SPTelescope
@NSF
photo taken in July 2020 by Danny Hampton

South Pole Facts:

Elevation 2835 m ASL

Ice thickness Approx 2850 m

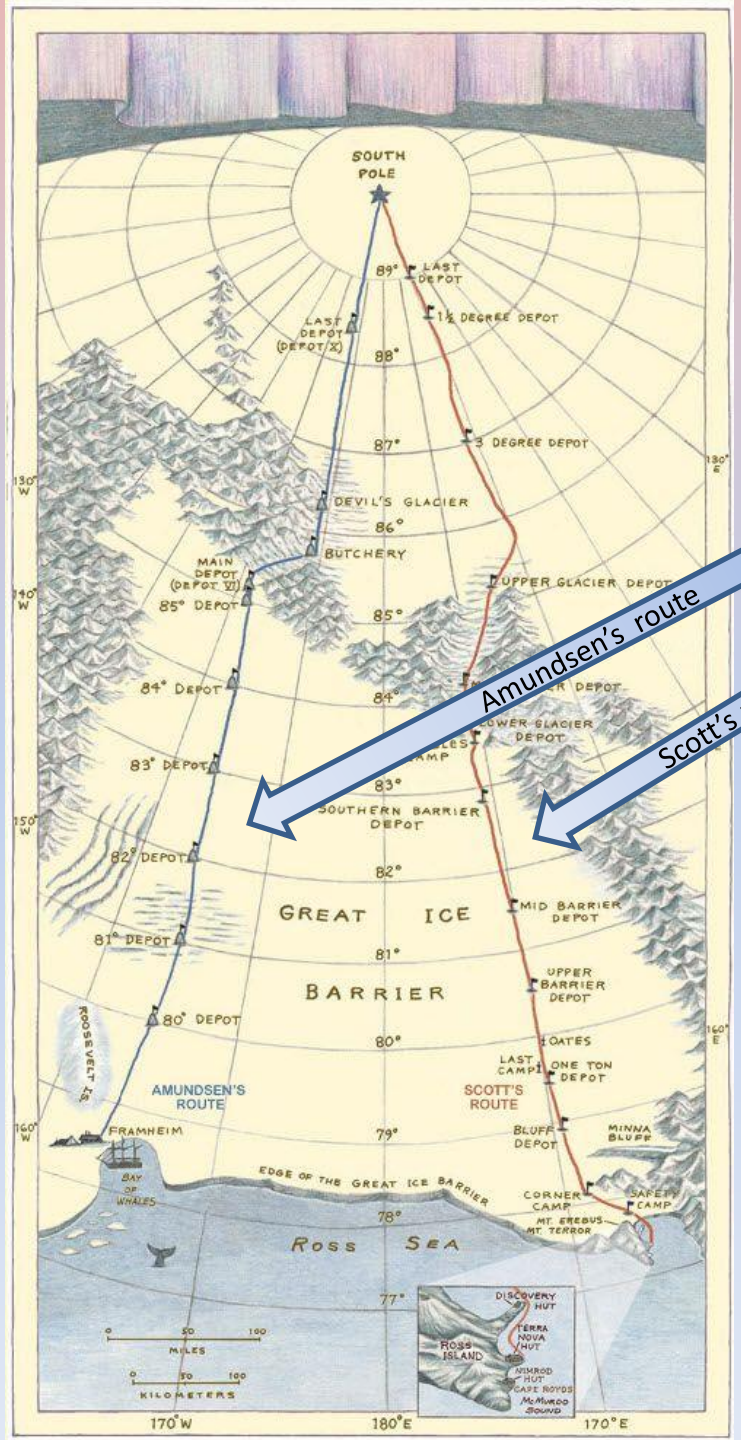
Distance to open sea 1600 kms (Snow rd to McMurdo)

Ice sheet movement 10 m/yr to 37^{o} W of Nth (to Weddell Sea)

1956 Established US South Pole Station –continuously manned

South Pole Attempts

1901-02	Scott, Shackleton, Wilson FAILED (Discovery Expedition)
1909	Shackleton FAILED (Nimrod Expedition)
1911	Amundsen SUCCESSFUL - Norwegian
1912	Scott + 4 companions SUCCESSFUL but died on return
1914	Shackleton Imperial Transantarctic Expedition
1928	Byrd & Balchen First Flight over South Pole



Amundsen's route

Scott's route

AMUNDSEN -1911

The 2021 South Pole marker!

McMurdo - USA

- Main base and supplier to Amundsen -Scott Sth Pole Station (1600 kms by snow road)
- Access by air from New Zealand through Williams Field: snow-ice runway on 500m of water
- Main supply by ship Operation Deep Freeze
- 1200+ residents

MV American Tern led by Russian icebreaker Operation Deep Freeze.

Rothera & Halley – Britain
BAS (British Antarctic Survey) Research Stations

RRS Sir David Attenborough Research Supply Vessel

Bellingshausen - Russia

Founded in 1968 by Soviets
Year round staffed
Site of first attempted murder in Antarctica October 2018
Eastern Orthodox Church

VOSTOK– Russia

Built 1957 by Soviets
Staffed summer 25 Winter 13
Elevation 3,488 m
Lowest recorded temp on earth -89.2^{O}C July 1983
Site of ice core drilling

Mirny - Russia

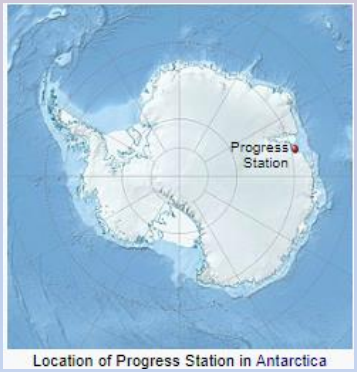
Year round staffed winter 30 – 40: summer 200
Base for Vostok Station 1400 kms away

Location of Mirny Station in Antarctica


Mirny Station in 2007

Progress - Russia

New base for Vostok Station
Completed 2013 following a fire of original
Base for Vostok Station 1400 kms away



Location of Progress Station in Antarctica

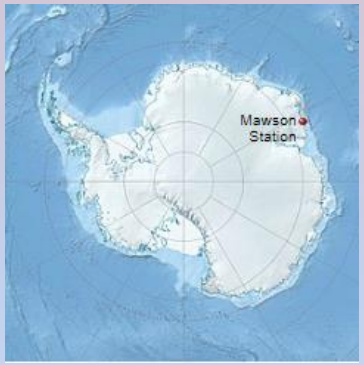

Central building of Progress Station in summer 2007

SANAE IV – Sth Africa

Built 1997
Staffed Summer 100, Winter 10
160 kms from edge of ice shelf
Supplied by S.A. Agulhas II & Over-winters
Class 5 ice hull: heated decks: research labs

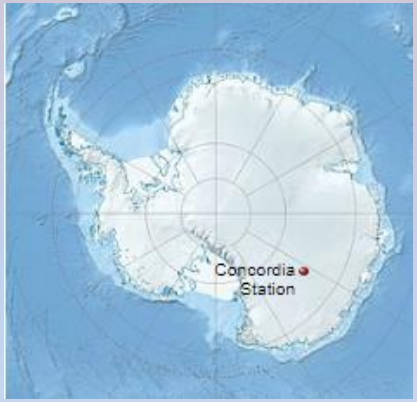
MAWSON – Australia

Built 1954 oldest of 3 permanent Aus stations
One of oldest research stations in Antarctica
Staffed Summer 60, Winter 20
70% of power needs met from wind turbines



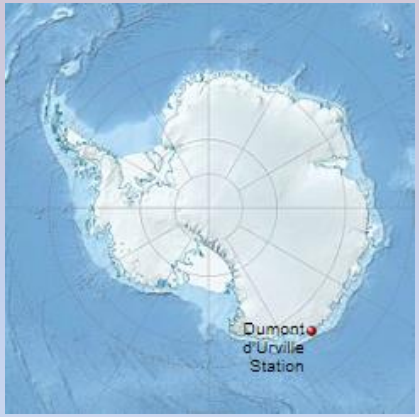
Concordia – French-Italian

Built 2005
3,233 m elevation
Site of Dome C drilling
Winter staff 13 French ; 2 Italian
9 months of darkness



Dumont d'Urville – French

Built 1956
202 m elevation
Supply base for Dome C drilling
Winter staff 30, summer 120
Research includes O_3, cosmic ray detection

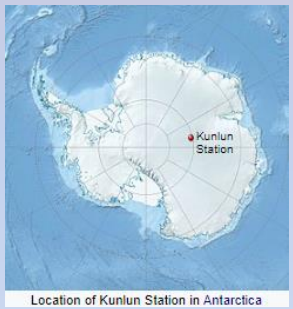


KUNLUN – China

Summer Operations only

4087 m elevation
opened 2009
Several telescopes

3 Antarctica Schmidt telescopes (AST3)
1 Kunlun Dark Universe Survey Telescope (KDUST),



Location of Kunlun Station in Antarctica

Zhongshan - China

60 summer, 25 winter
Opened 1989

Location of Zhongshan Station in Antarctica


Zhongshan Station in 2007

ANTARCTICA

The 7th Continent

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Mar 27, 2021

OUTLINE

- What makes a continent and why is Antarctica the 7th continent and so different from the Arctic?
- How Antarctica came to be.
- Is Antarctica melting?
- Antarctic Treaty
- Research
- Ice dynamics
- Drilling

3 Running Races

Antarctic Marathon King George Island by ship Vavilov or Loffe from Punta Arenas (Buenos Aries) $9 000 10 days

Antarctic Ice Marathon and the Antarctic 100 Km fly – in Punta Arenas to Union Glacier 14,000 euros 4 days

The Geography of Antarctica

Continental Ice Sheet/Shelves vs Bedrock

Antarctic Circle 66.34 ^{0}S

Which way is North?

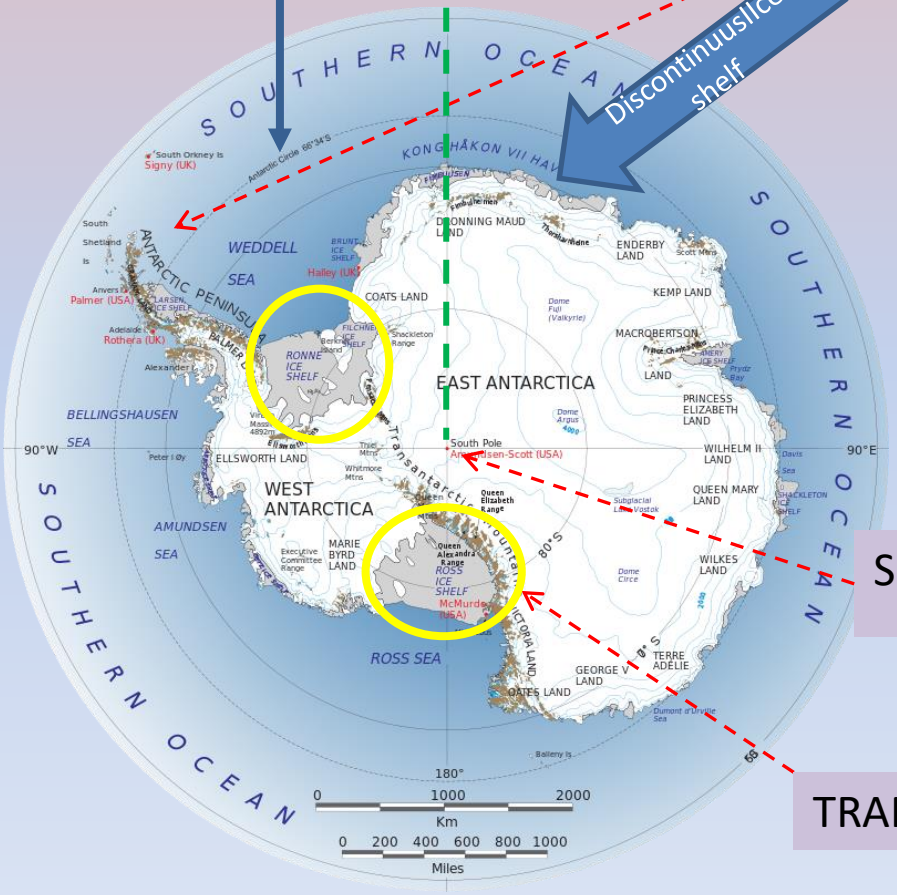
With Snow and Ice Removed

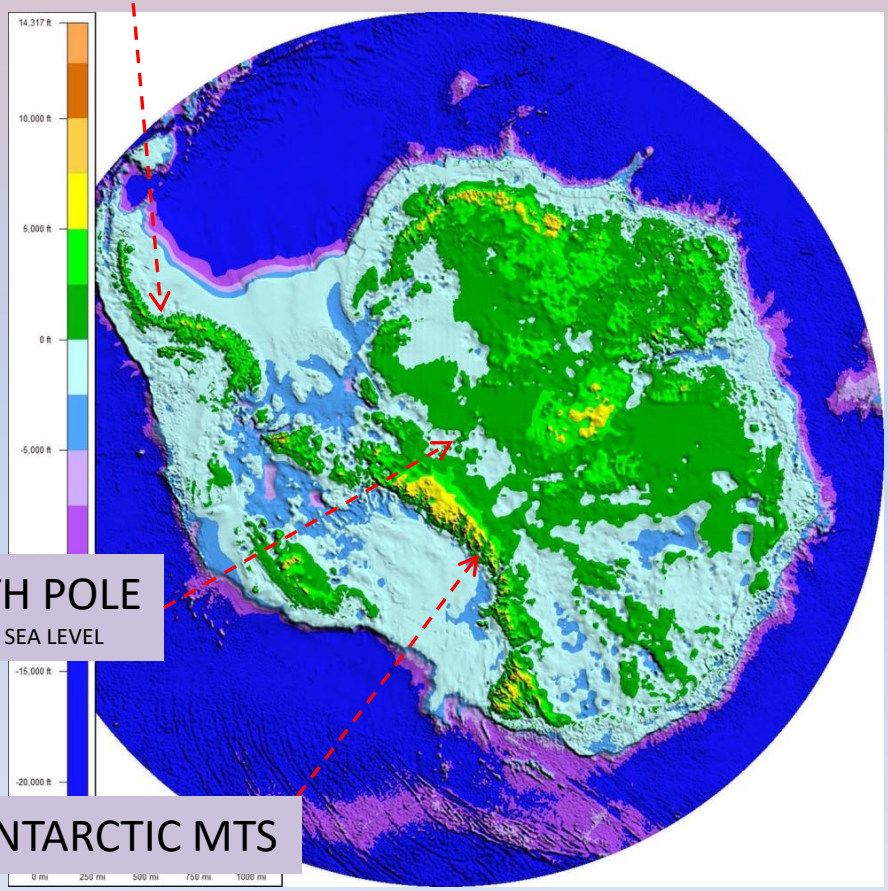
land = green & yellow

continental shelf = pale blue

ANTARCTIC PENINSULA

Discontinuus Ice shelf





SOUTH POLE

Below SEA LEVEL

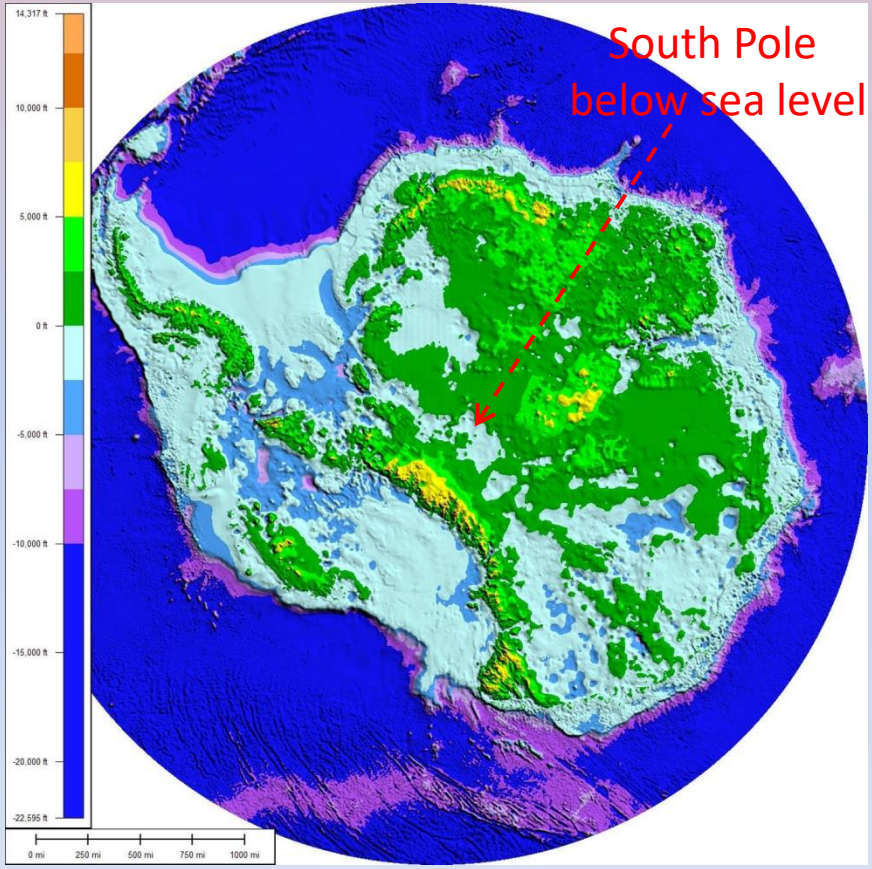
TRANSANTARCTIC MTS

SEA ICE NOT SHOWN

With Snow and Ice Removed

land = green & yellow

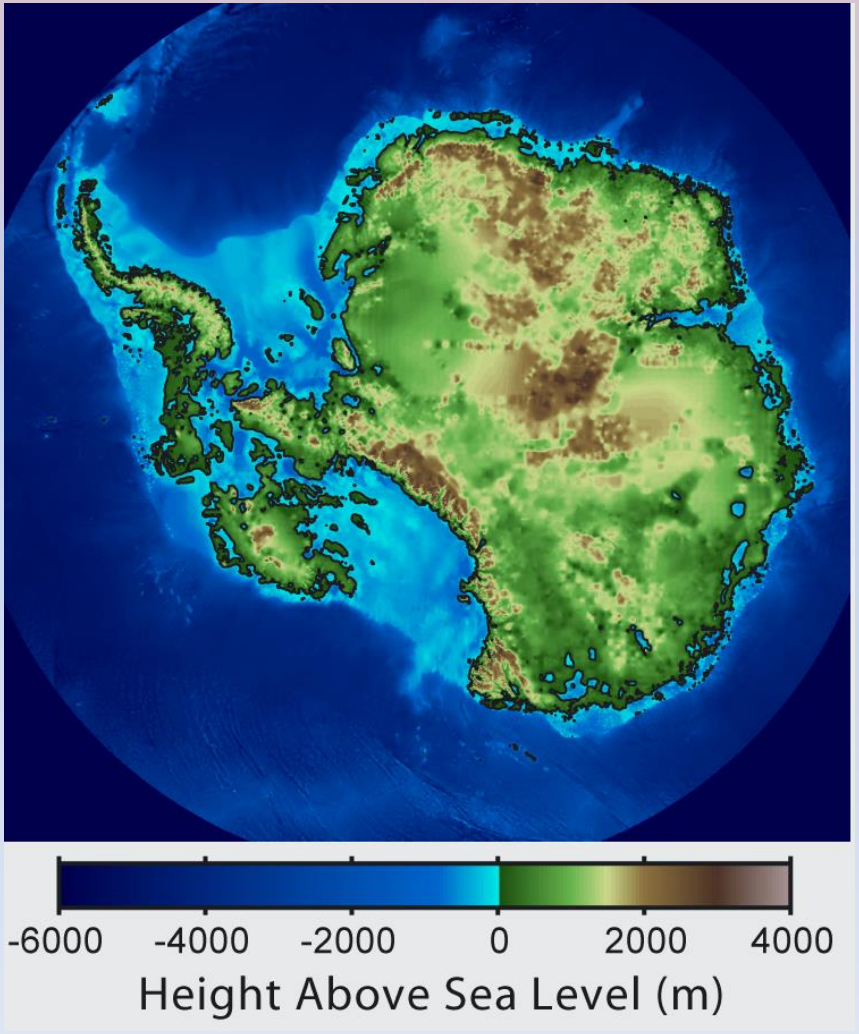
continental shelf = pale blue



With Snow and Ice Removed

Isostatic Rebound

Crust Rises



ANTARCTIC CONTINENTAL PLATE – ICE REMOVED

PLATE MARGIN
EARTHQUAKES
VOLCANOS
HOTSPOT

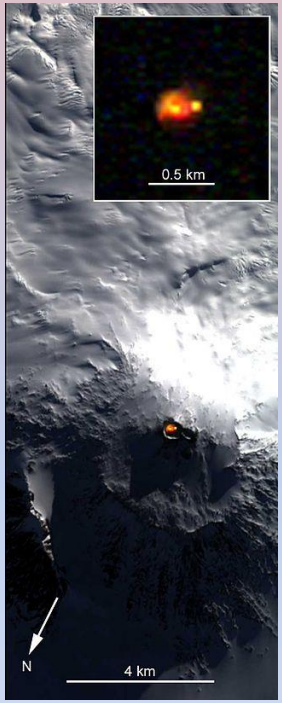
Earthquakes – black
Volcanoes - red

Ice limits-white

ANTARCTICA PLATE

Mt Erebus

Transform-ridge plate margin



Mt Erebus

- 1734 m high
- Active
- Air New Zealand Flight 901
- Nov 1979
- DC 10 Crashed on Mt Erebus – whiteout
- 257 sightseers killed

Ross Island: + Mt. Erebus

Mt Erebus

Mt. Terror

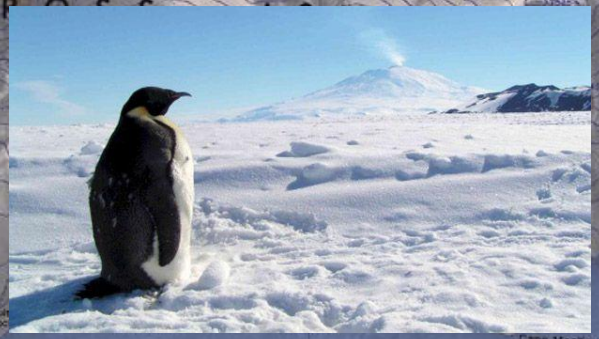
Ice Front Nov 1960

McMurdo Base (US)

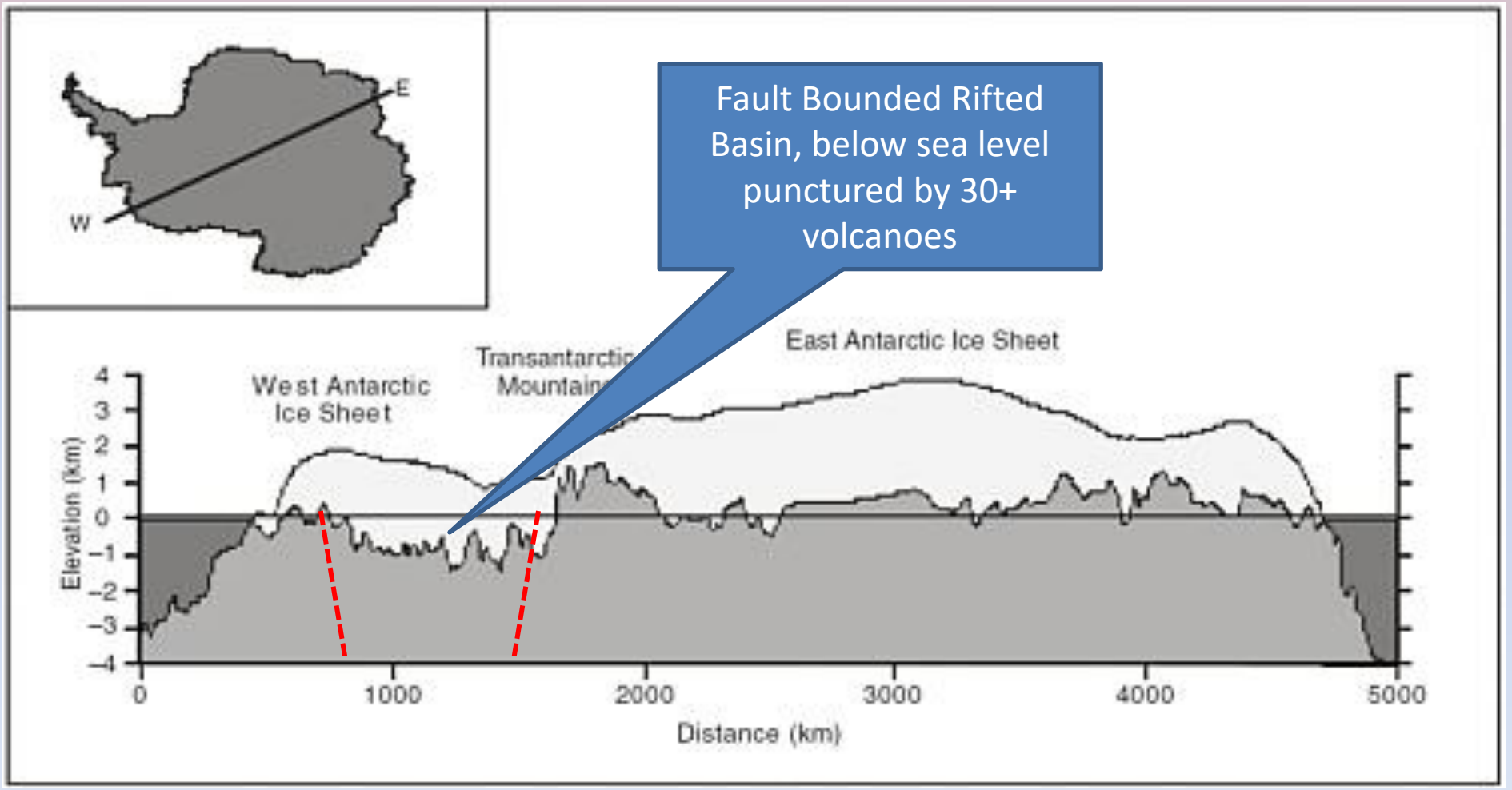
Scott Base (NZ)

Ross Ice Shelf

Ice Front Feb 1965

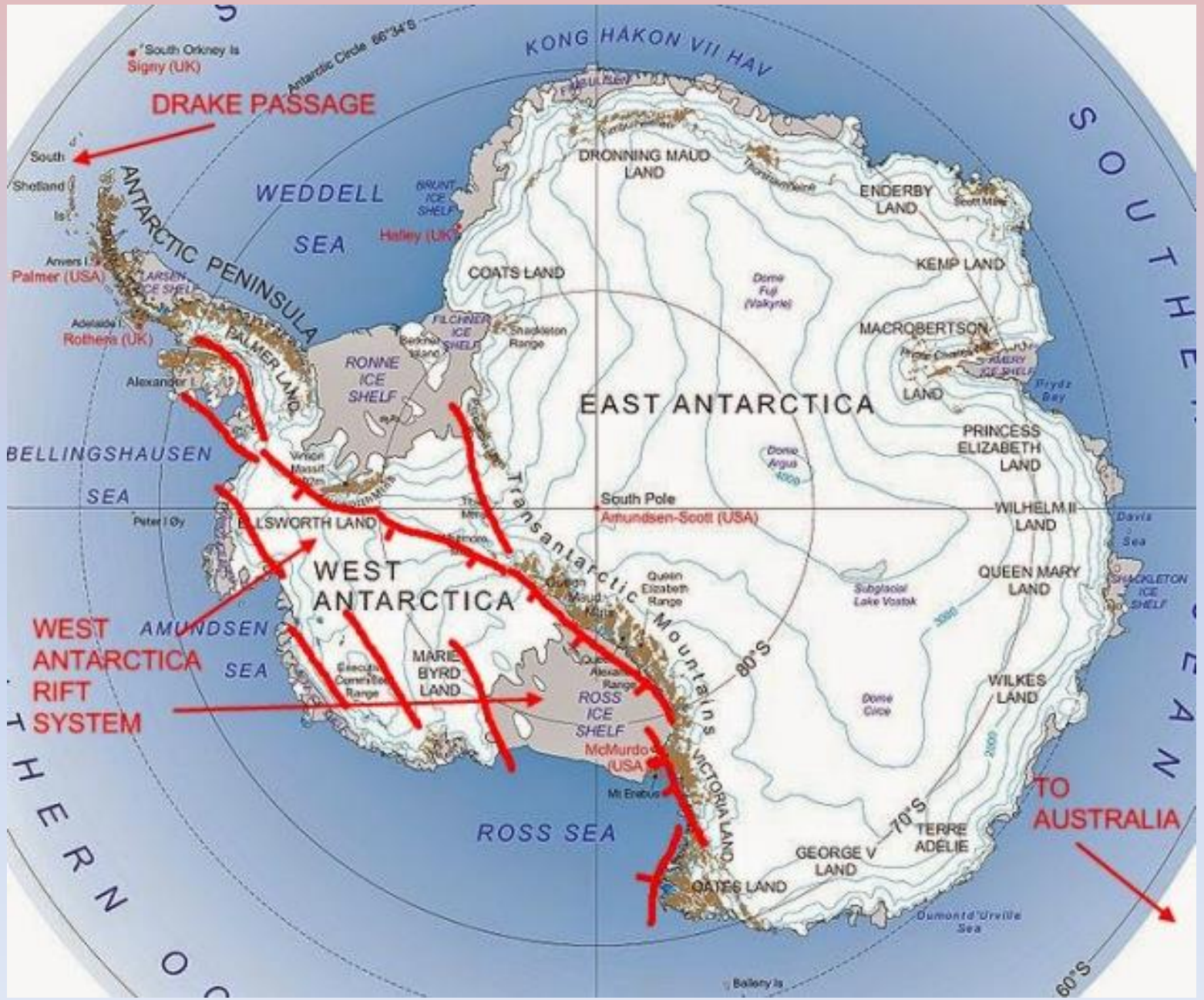


Cross-sectional profile of the Antarctic ice sheet based on BEDMAP bed topography



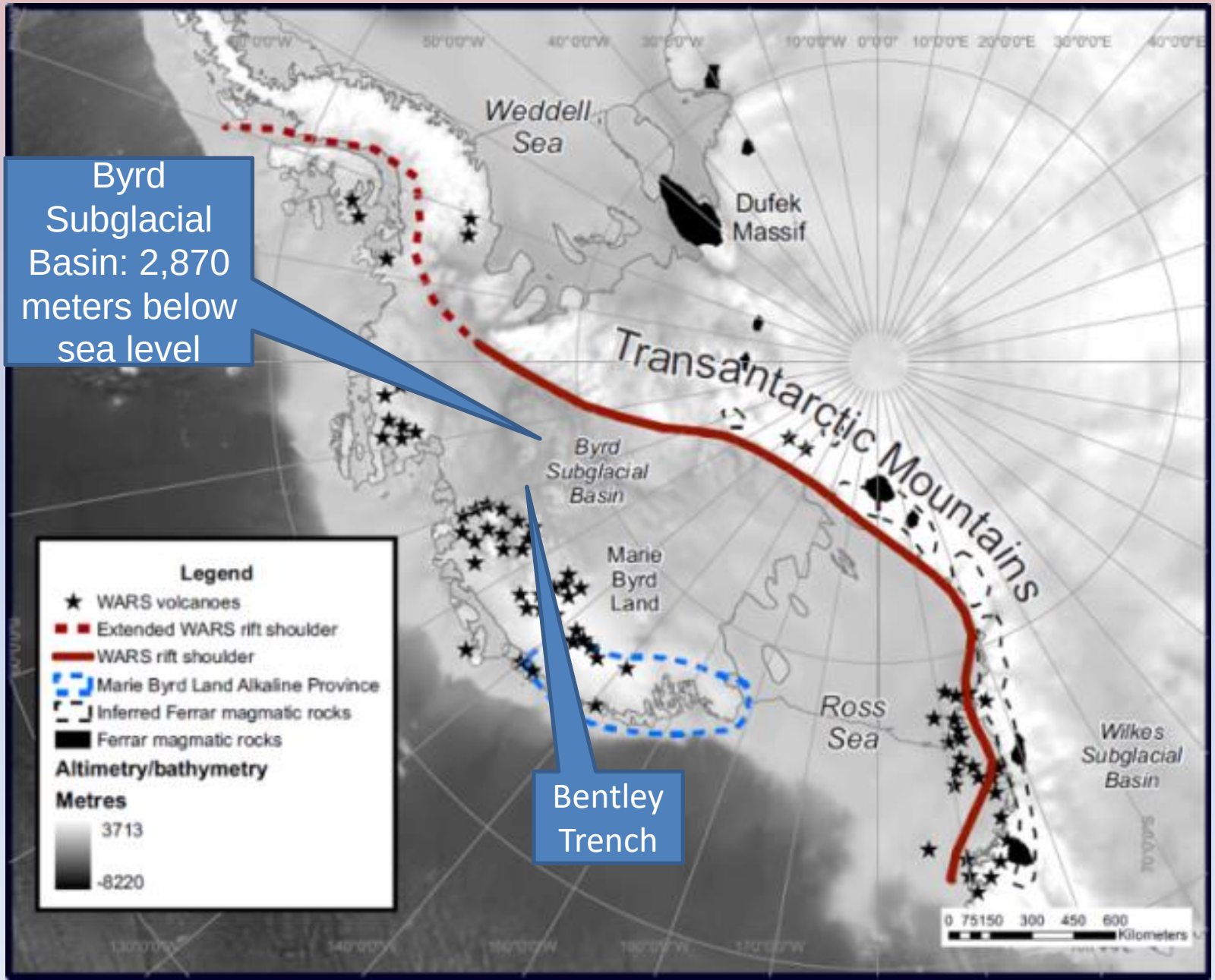
Journal of Geophysical Research B: Solid Earth, 106 (B6): pp. 11335-11351 (2001).

West Antarctica Rift System 3000 km X 700 km



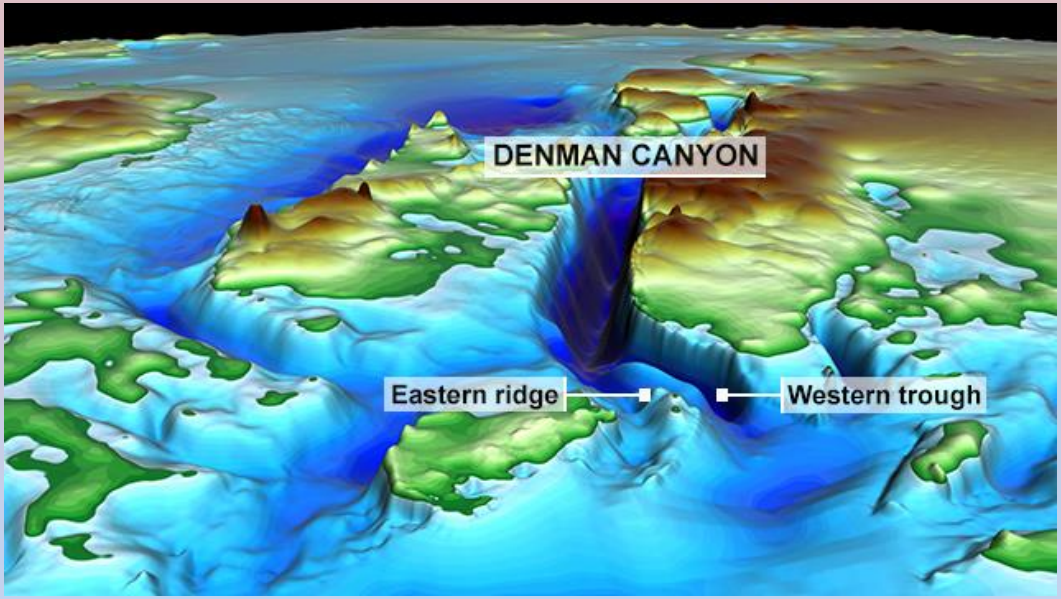
West Antarctic Rift System – Byrd Subglacial Basin.

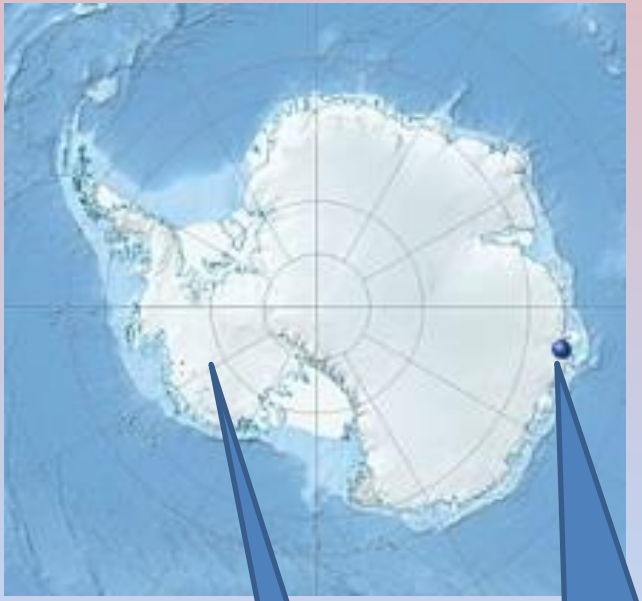
http://www.largeigneousprovinces.org/13apr



Denman Canyon - Lowest point on land

Amos, Jonathan (2020-03-23). "Climate change: Earth's deepest ice canyon vulnerable to melting"

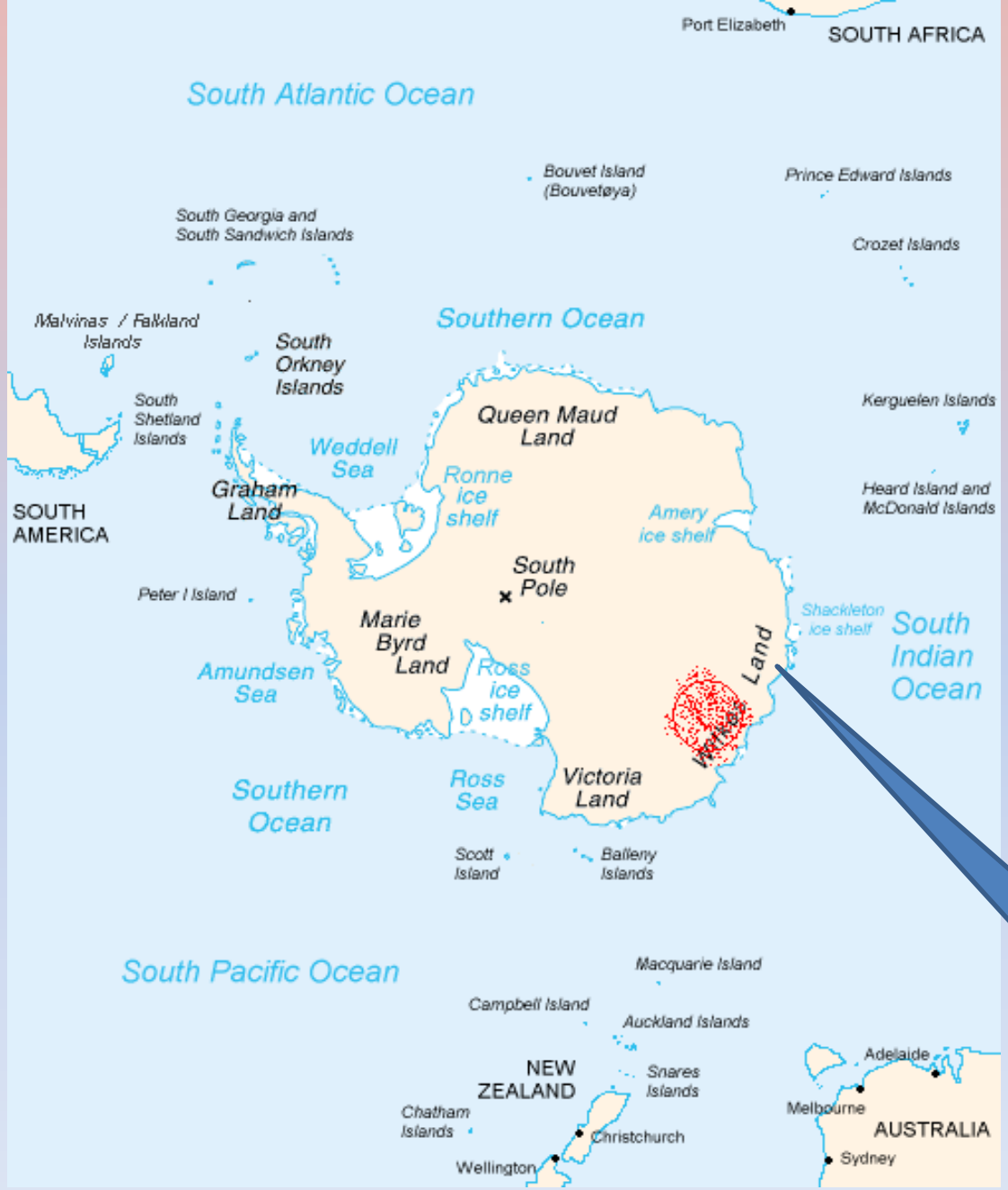




Denman Glacier and Canyon

West Antarctic Rift System

Map of Antarctica showing Wilkes Land, with the asteroid impact crater conjectured by von Frese and team marked in red

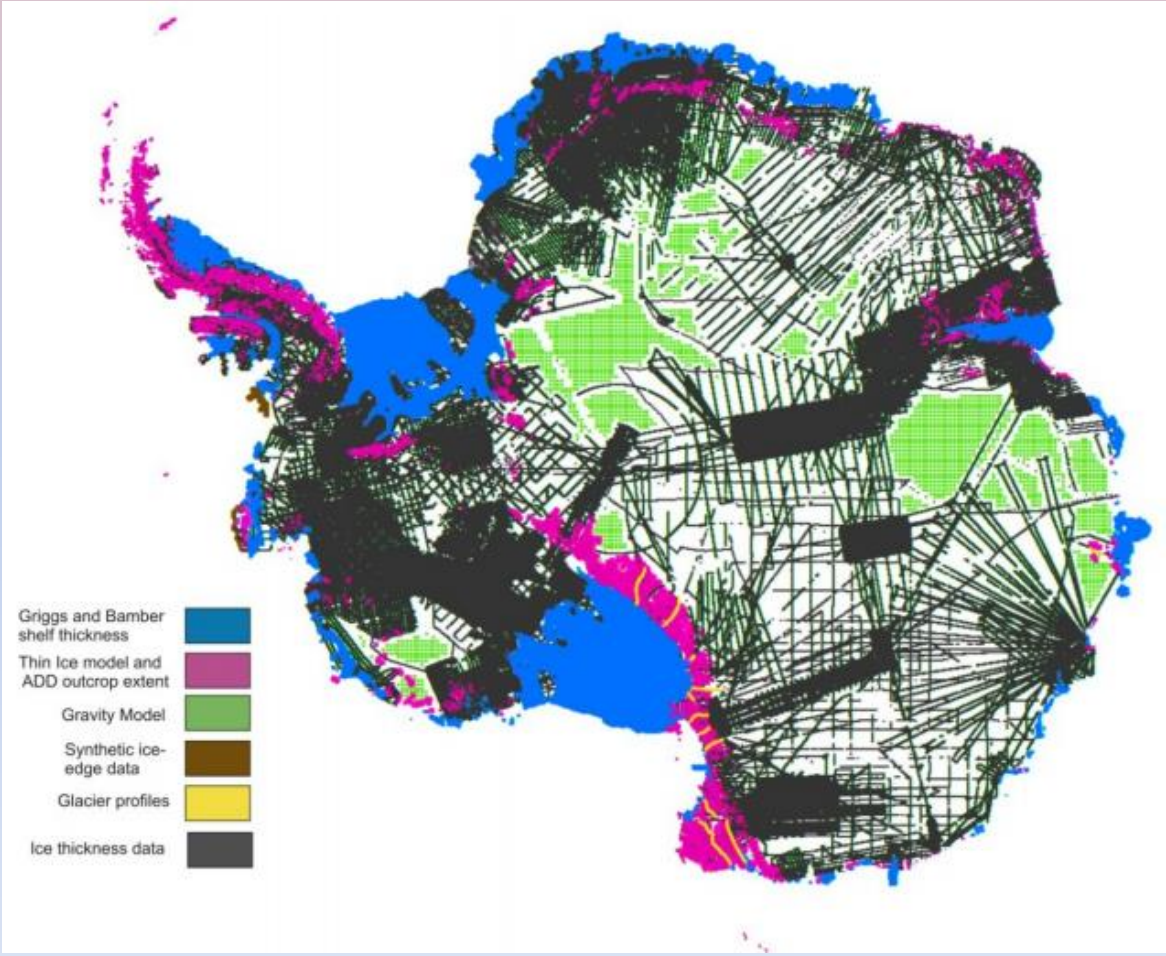


- Ring structure detected by radar under 2km of ice
- Probable asteroid impact crater 480 km diameter
- 2.5 X Chicxulub Crater
- Speculative date P-T Boundary & Extinction

Denman Glacier - -3500 m trench

*Weihaupt, JG (1976). "The Wilkes Land anomaly: Evidence for a possible hypervelocity impact crater". Journal of Geophysical Research. **81** (B32): 5651–5663.*

Bedmap2: improved ice bed, surface and thickness datasets for Antarctica



Coverage of datasets used in the construction of the ice thickness grids

- Satellite gravity
- Outcrop
- Drilling
- Seismic
- Airborne Radar
- Aeromagnetics

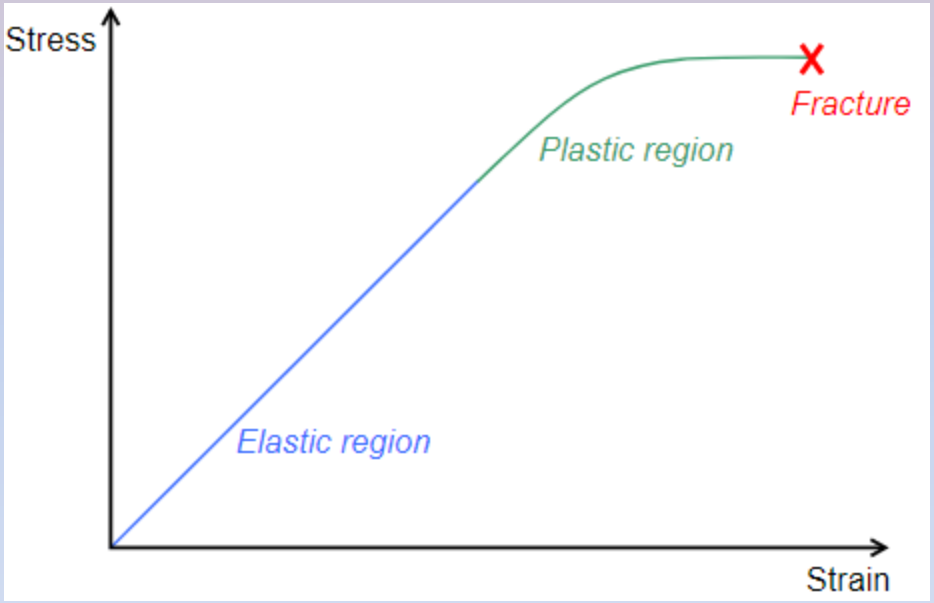
Fretwell et al , 2013
The Cryosphere, 7, 375–393, 2013
https://doi.org/10.5194/tc-7-375-2013

Ice Sheets, Ice Streams, Ice Shelves, Sea Ice

(Hannes Grobe, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany)

Churchill Peninsula NUNATUK
Credit: British Antarctic Survey

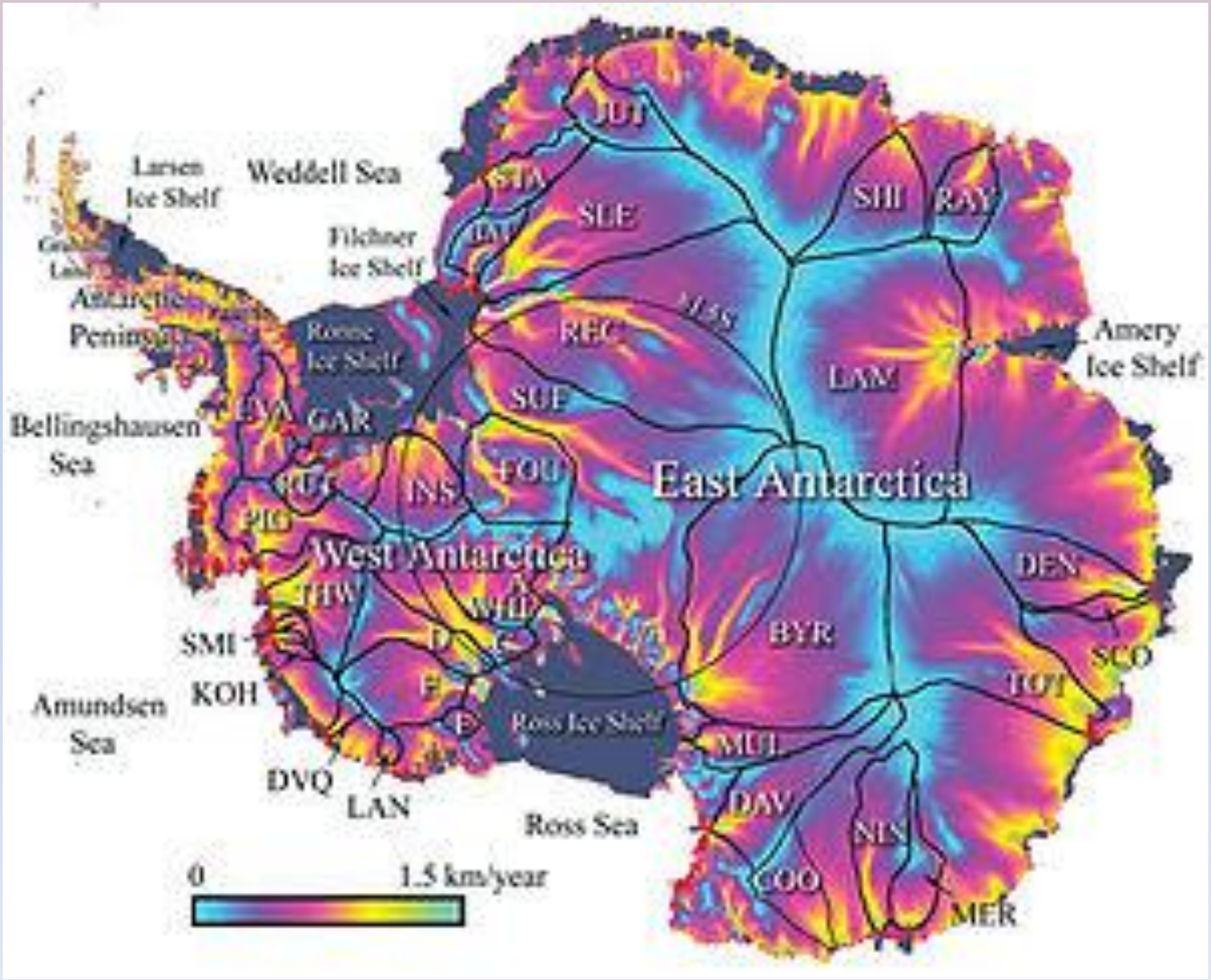
ICE FLOW

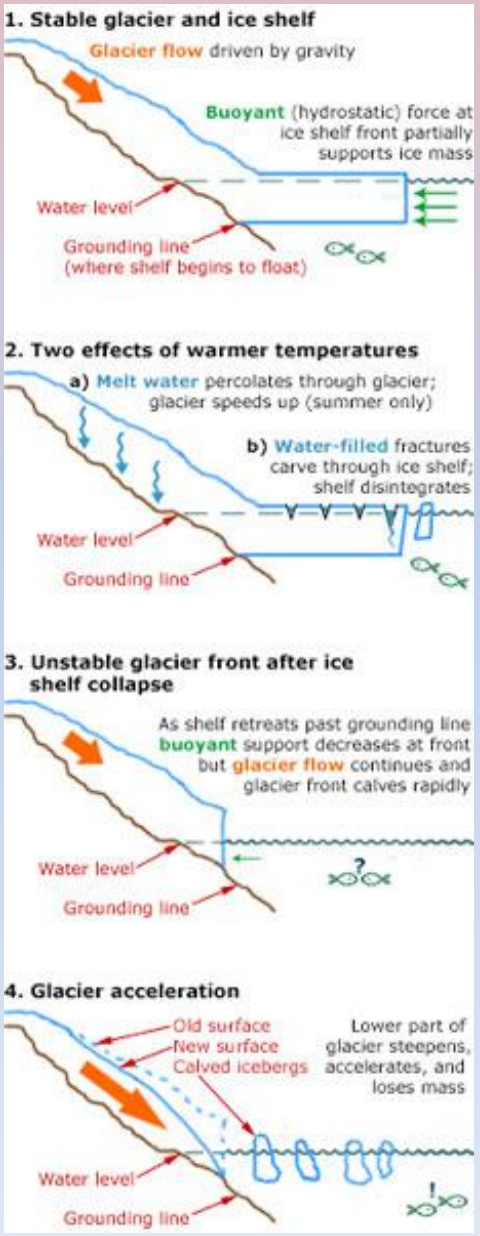


Ice sheet Dynamics –Rate of Flow

Up to 1.5 Kms/year

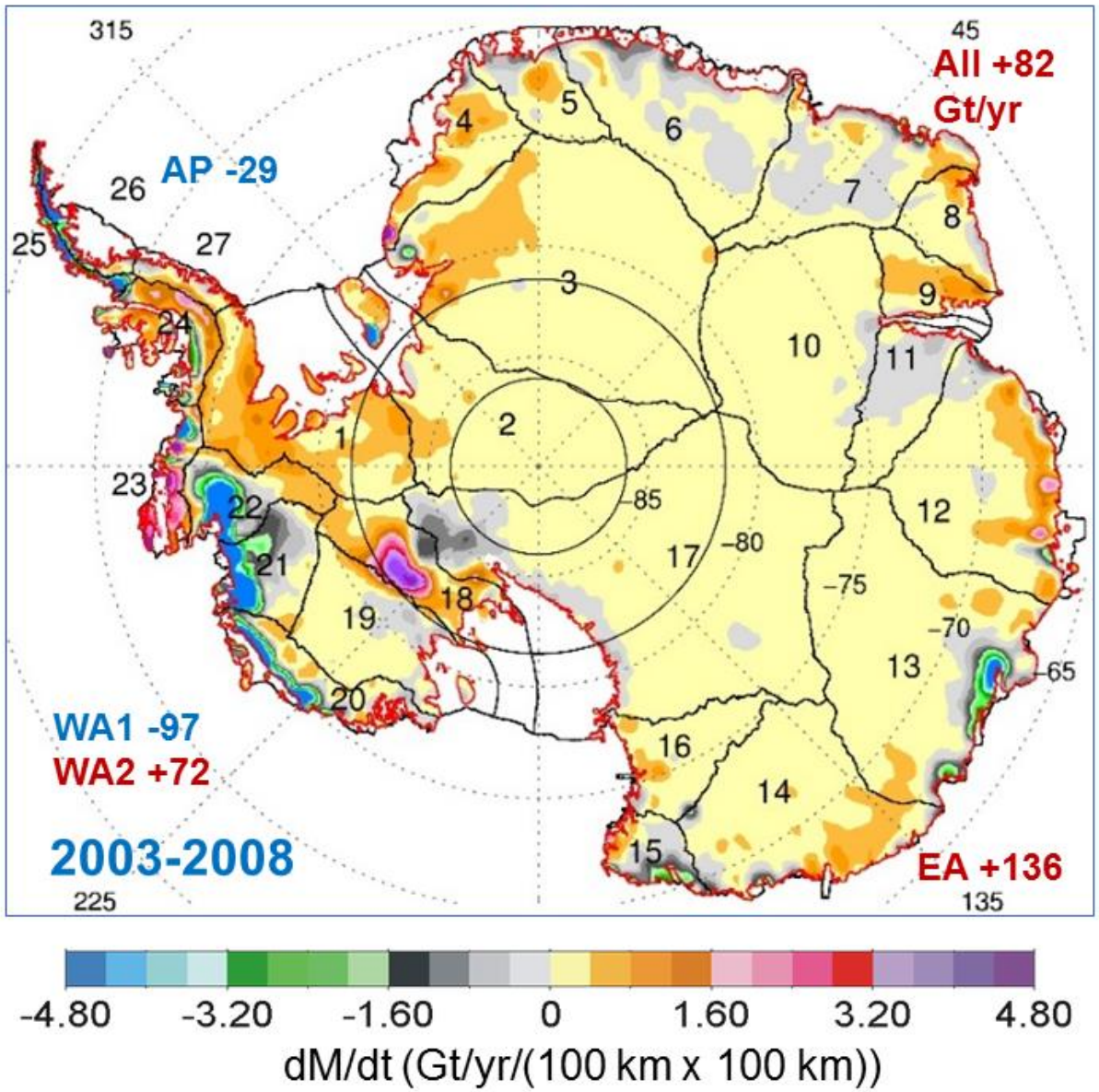
Wikipedia





Map showing the rates of mass changes

From ICESat 2003-2008 over Antarctica. Credits: Jay Zwally/ Journal of Glaciology



All Antarctica;
+82 GT/yr

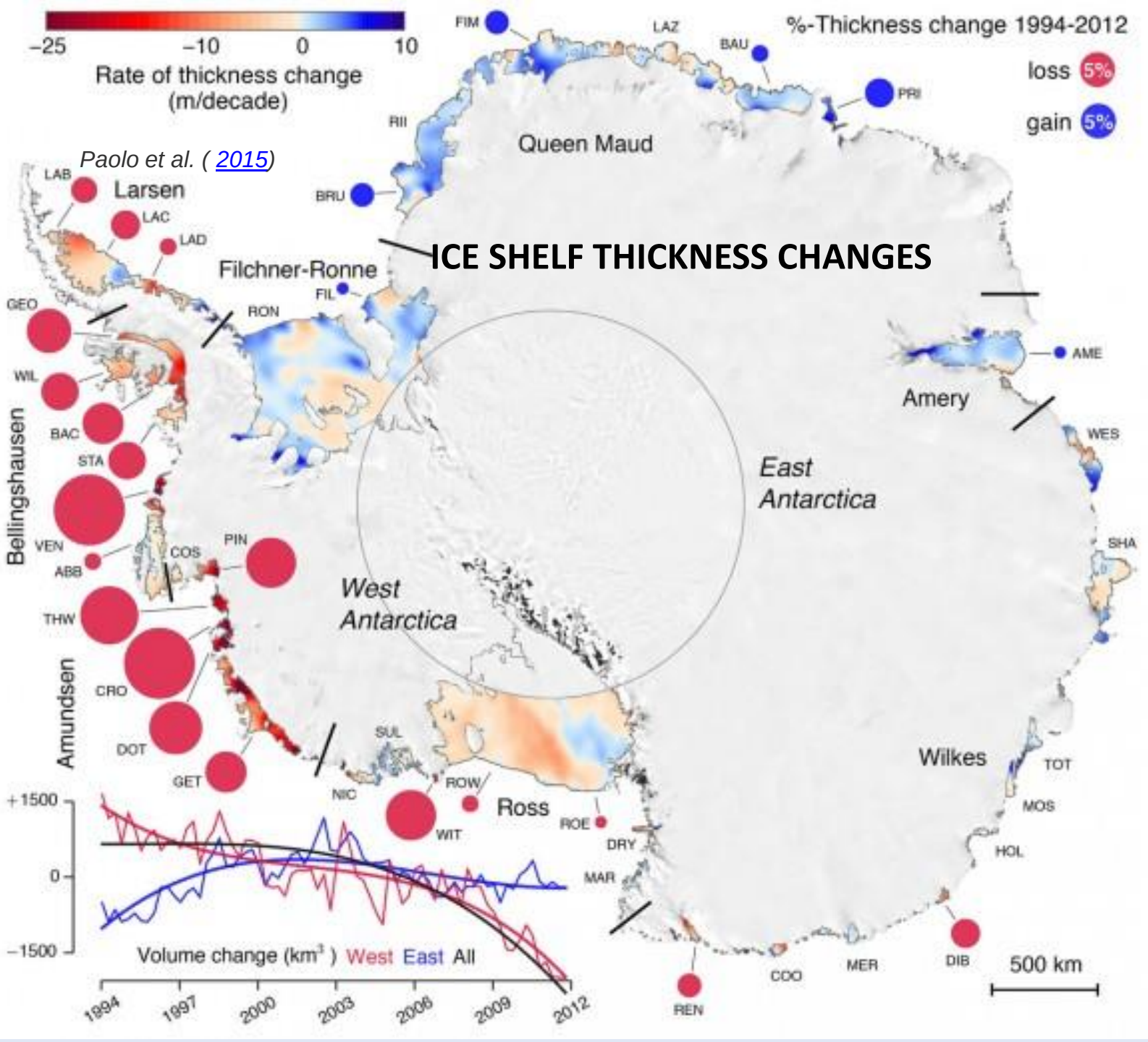
East Antarctica (EA, 2-17);
+136 GT/yr

Interior West Antarctica
(WA2, 1, 18, 19, and 23);
+72 GT/yr

Coastal West Antarctica
(WA1, 20-21);
-97 GT/yr

Antarctic Peninsula (24-27).
-29 GT/yr

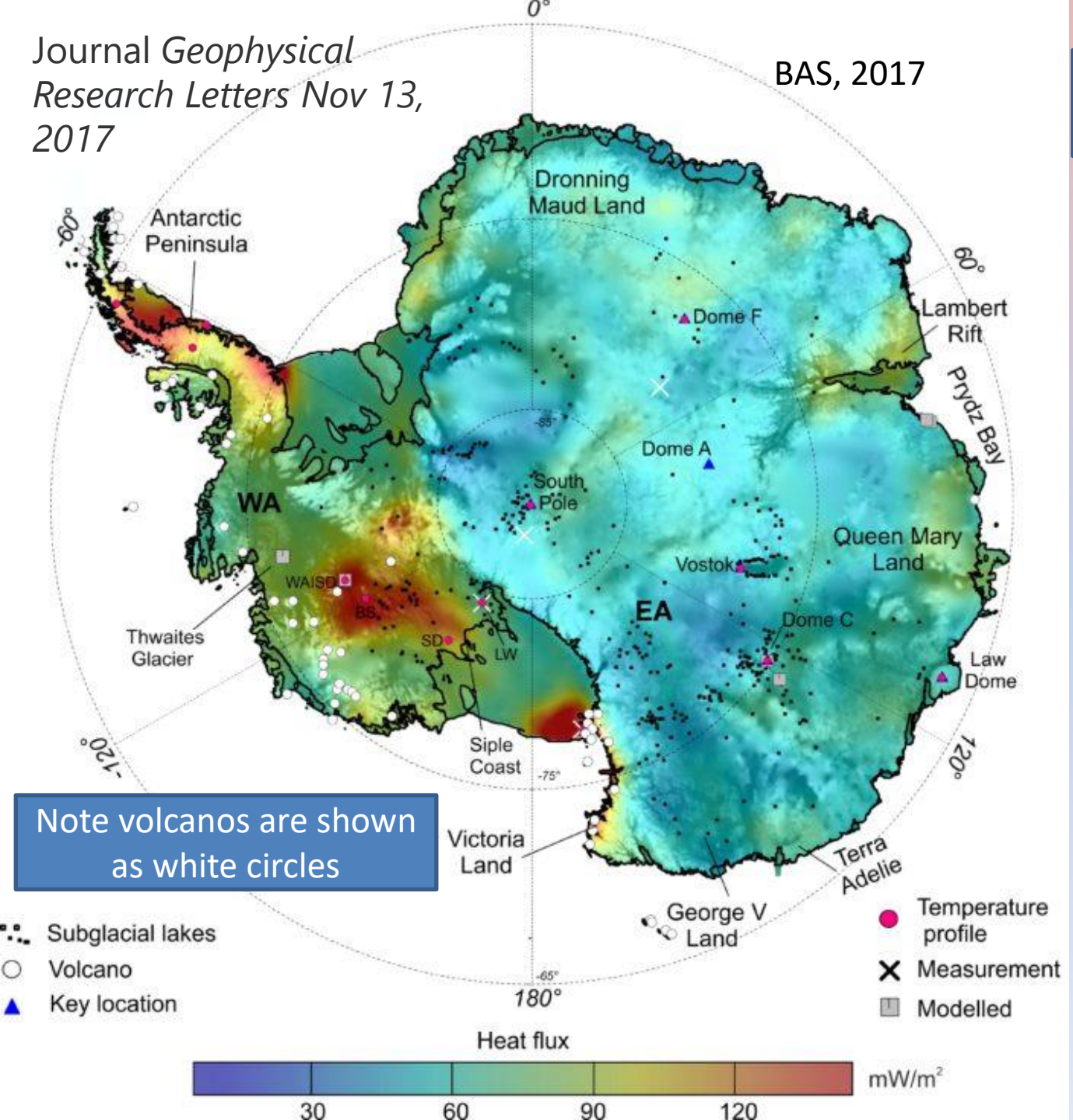
1gigaton (Gt) = 1 billion metric tons


−25
−10
0
10
Rate of thickness change (m/decade)
%-Thickness change 1994-2012
loss 5%
gain 5%
Paolo et al. (2015)
ICE SHELF THICKNESS CHANGES
Queen Maud
Larsen
Filchner-Ronne
Amery
Bellingshausen
Amundsen
Ross
Wilkes
East Antarctica
West Antarctica
FIM
LAZ
BAU
PRI
RII
BRU
LAB
LAC
LAD
FIL
RON
GEO
WIL
BAC
STA
VEN
ABB
COS
PIN
THW
CRO
DOT
GET
SUL
NIC
ROW
WIT
ROE
DRY
MAR
REN
COO
MER
DIB
TOT
MOS
HOL
WES
SHA
AME
+1500
0
−1500
Volume change (km³) West East All
1994
1997
2000
2003
2006
2009
2012
500 km

Geothermal Heat Flux

Journal *Geophysical Research Letters Nov 13, 2017*

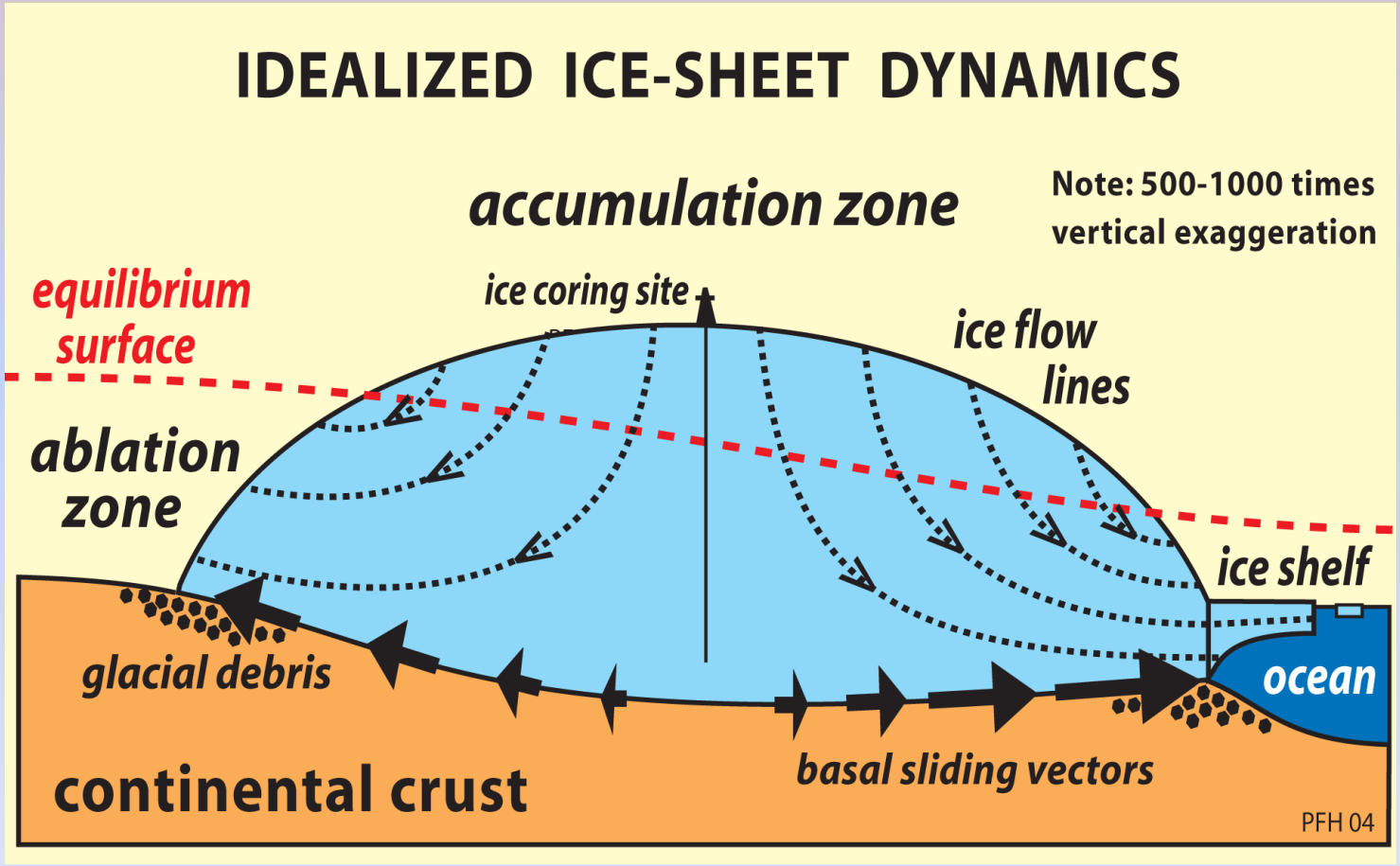
BAS, 2017



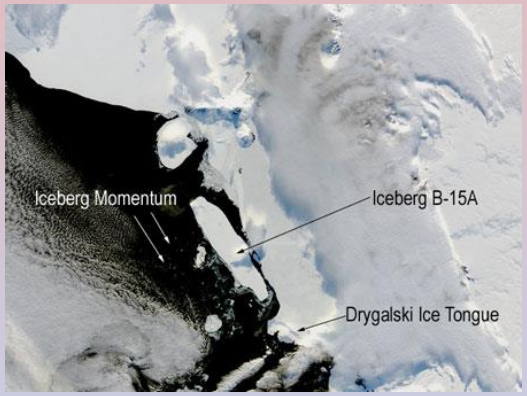
Ablation in action: polished hard blue ice, glazed by persistent katabatic winds, which remove (ablate) and vaporize (sublimate) snow. A wind scour at Mt Henderson;, East Antarctica

(photo by Matt Williams in May @AusAntarctic)

ICE SHEET Dynamics
Schematic Summary



Iceberg Monitoring



Worldwide by (NIC) US National Ice Center

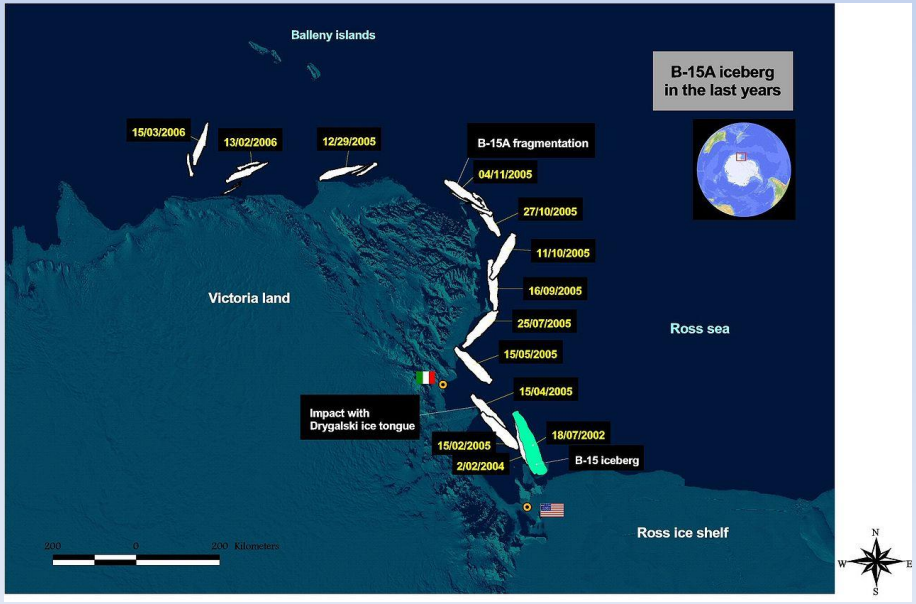
Names and tracks Antarctic icebergs

Larger than 10 Nm long

A, B, C, D according to Longitude quadrant + running number

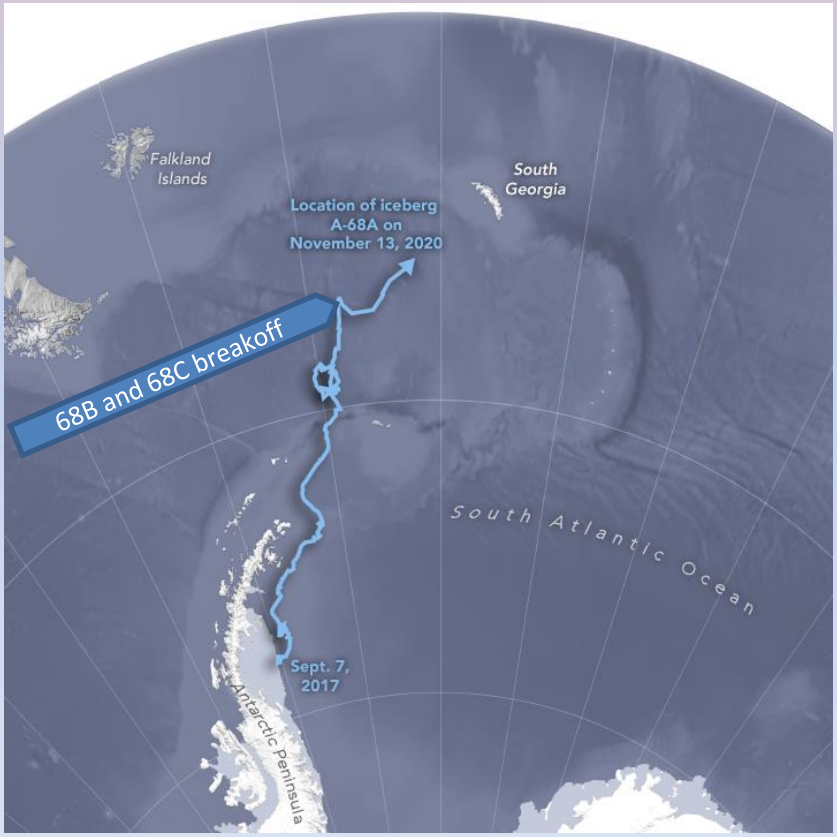
Largest recorded B15 – Calved 2000 – Ross Ice Shelf – 295 kms long

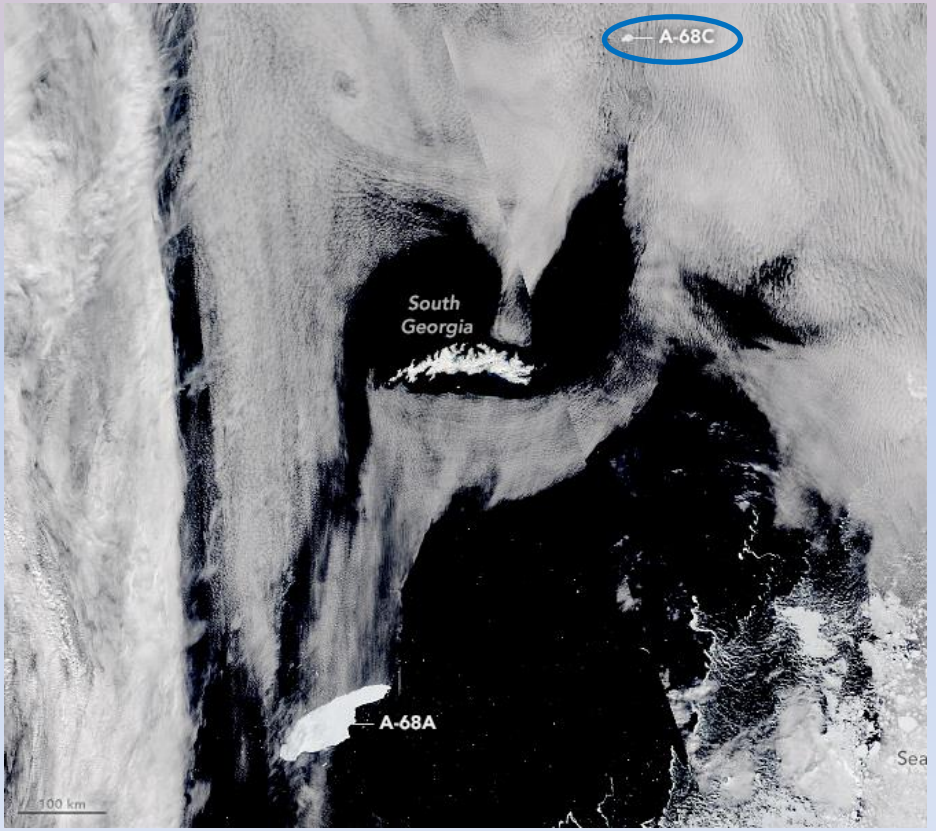
Ross Ice Shelf is 330 m thick and twice the area of Spain



Iceberg A-68A

- July 2017 broke from Larsen Ice Shelf
- Broke off (spawned) A 68B and A 68C
- Skirted by Sth Georgia Island (Dec 2020)
- Half the size of B 15





Drinking Water from Tabular Icebergs

[Towing an Iceberg: One Captain's Plan to Bring Drinking Water to 4 Million People - Bloomberg]

Towing a Berg

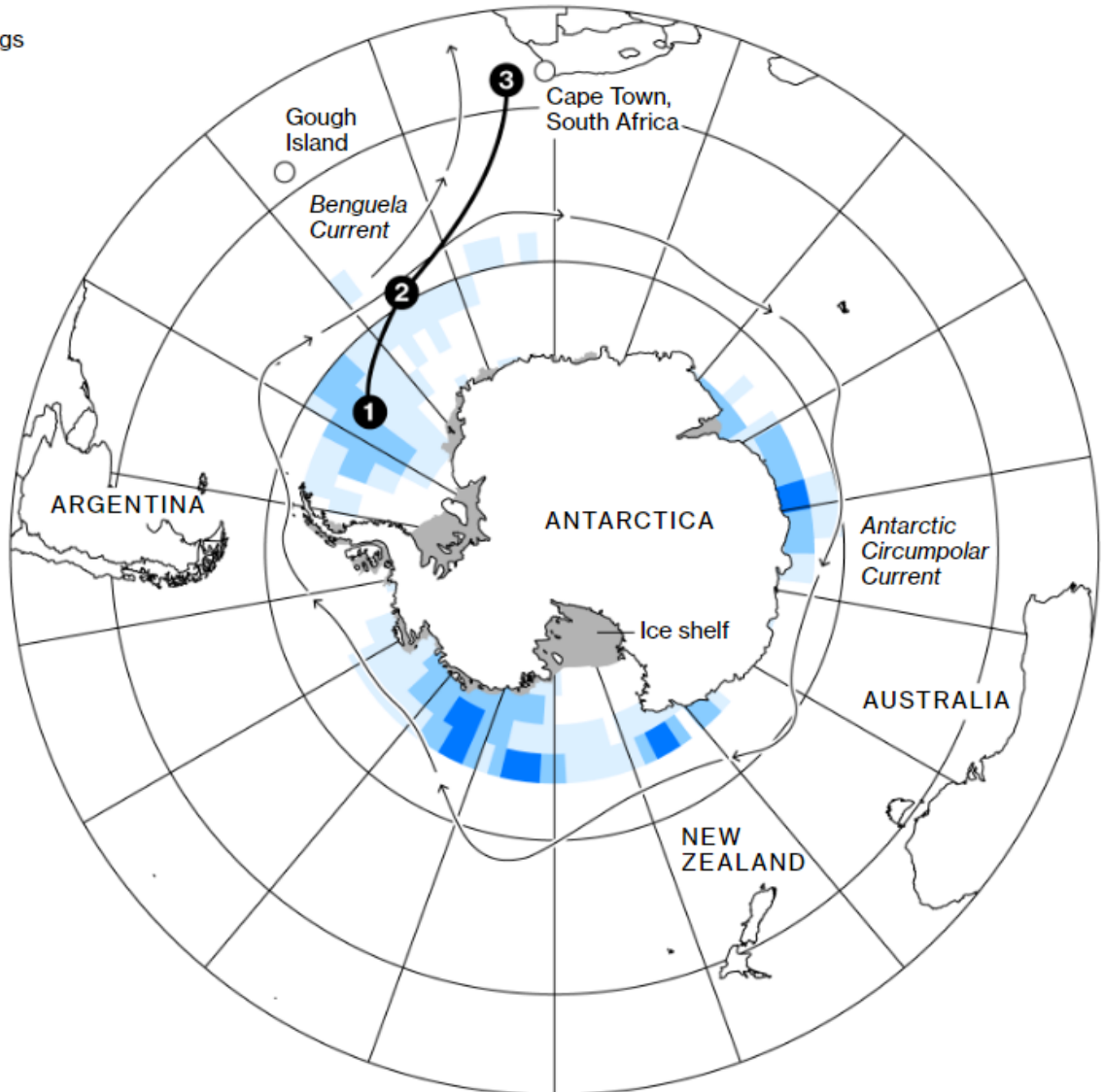
Iceberg density per 20,000 square miles in 2017: Most Antarctic icebergs are 1,300 feet to 4,000 feet long

□ 25 to 100 □ 100 to 300 ■ 300+

❶ Encircle an iceberg in a giant plastic net.

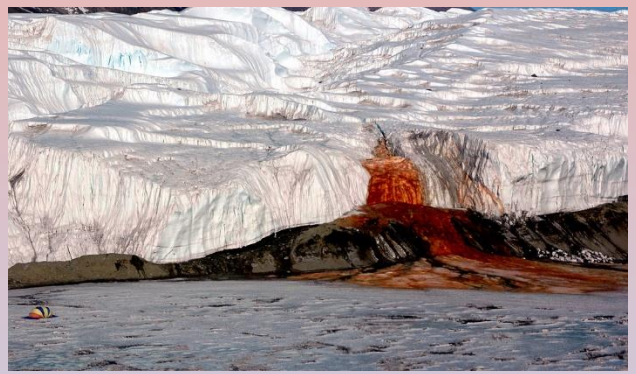
❷ Use tankers and tugboats to maneuver the skyscraper-size iceberg into a helpful current...

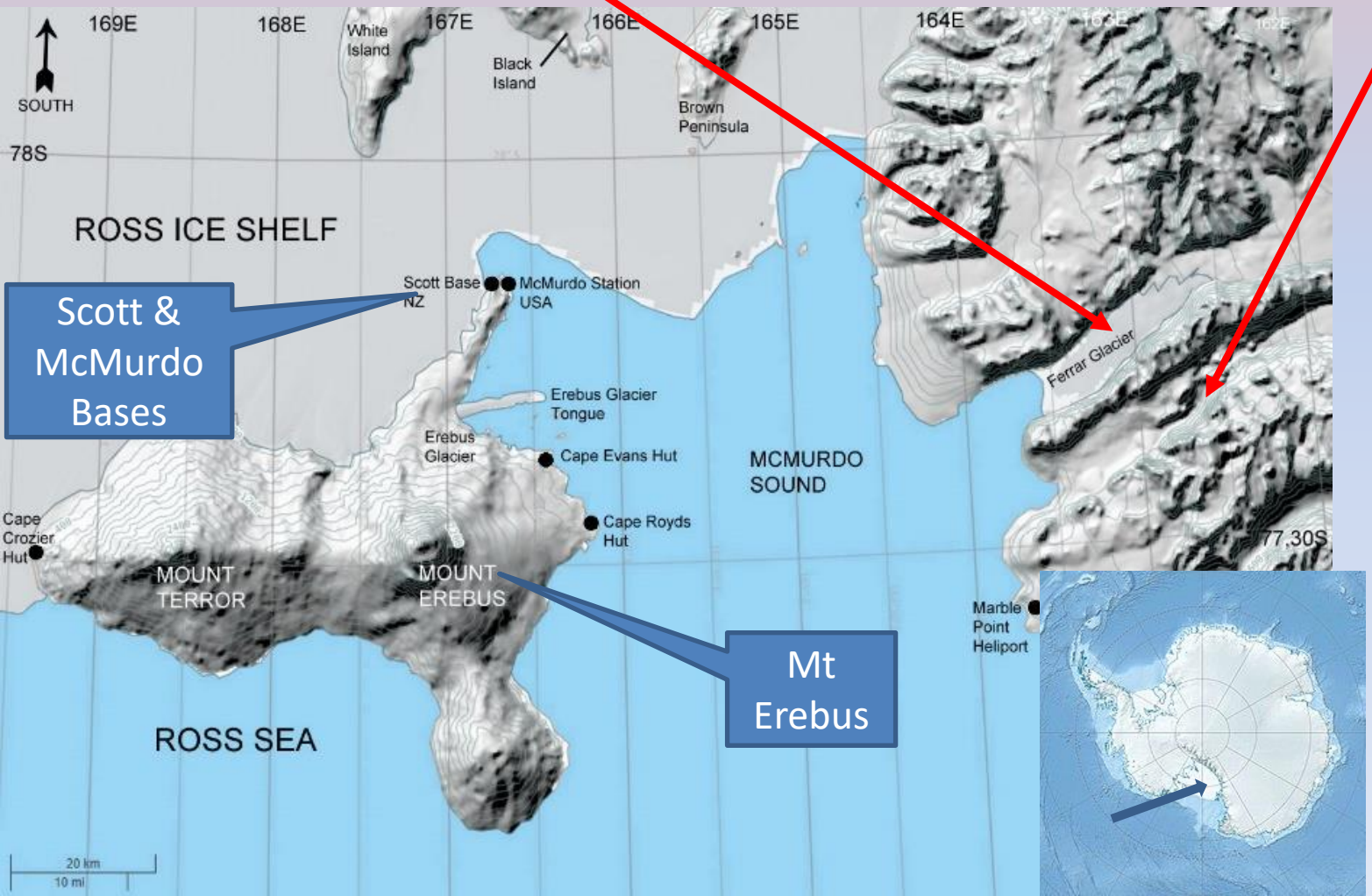
❸ ...and park it off the coast of South Africa three months later. Container ships take the water ashore.



Tabular Iceberg in Bransfield Straits; 2015

McMurdo Dry Valleys
Ferrar & Taylor Glaciers

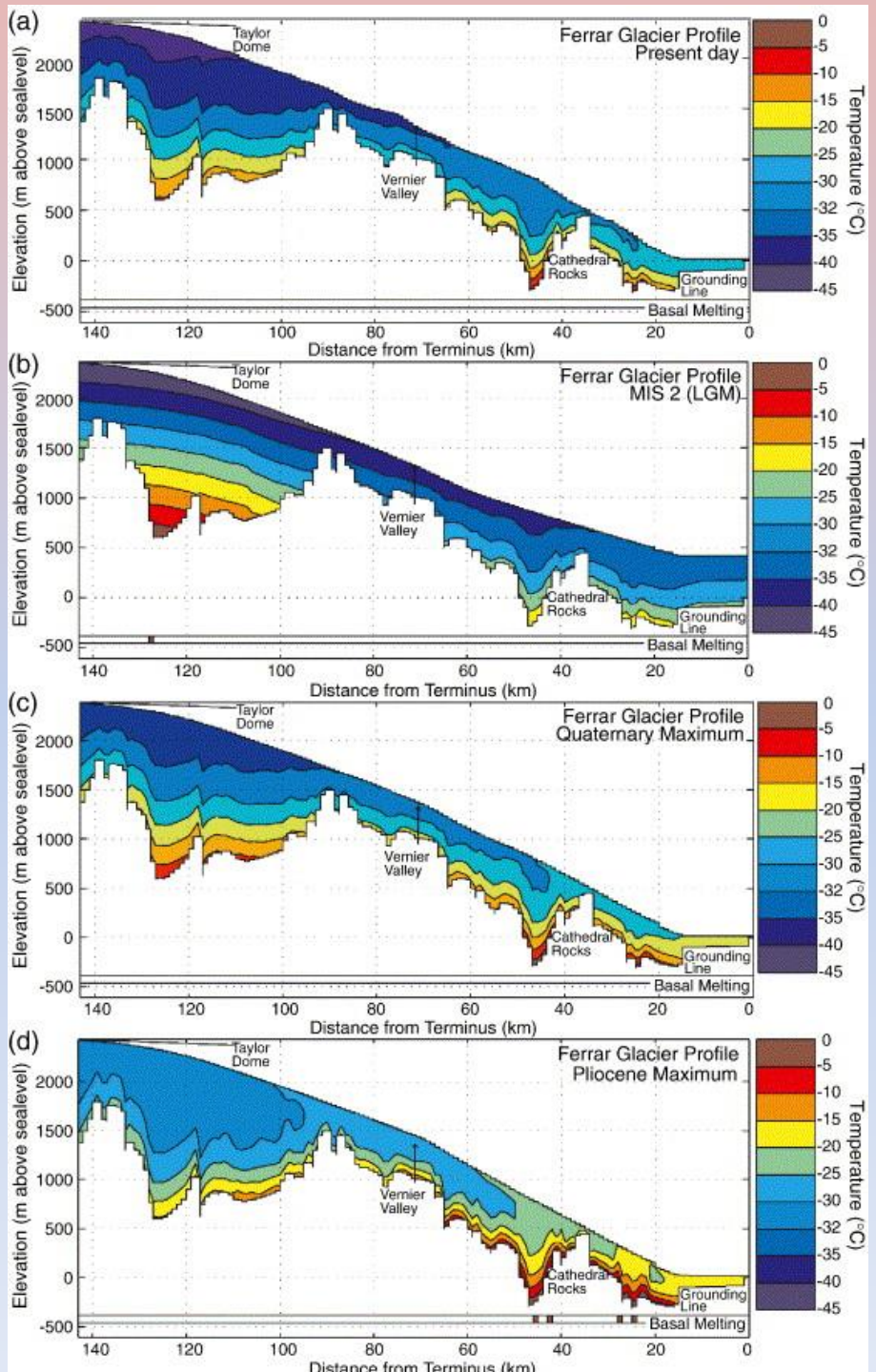


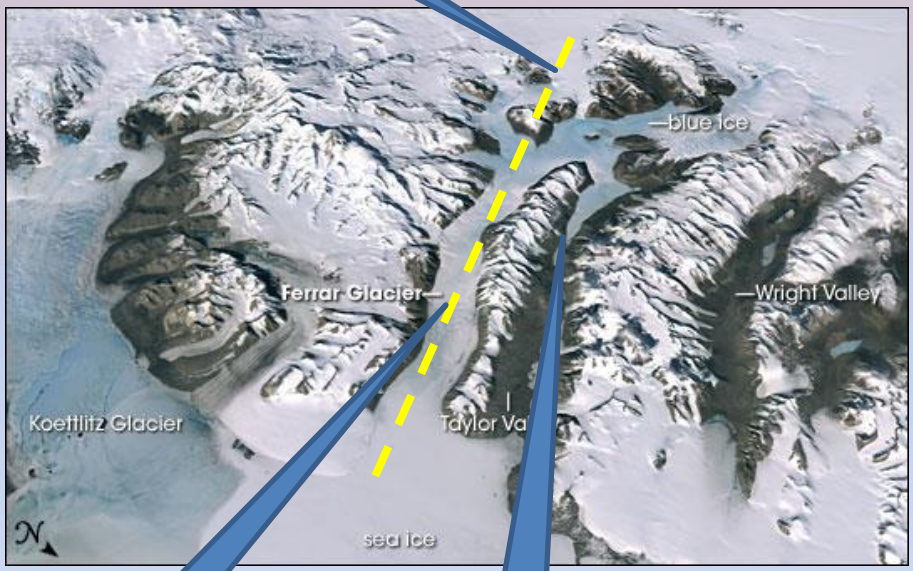


Scott & McMurdo Bases

Mt Erebus

Ferrar Glacier

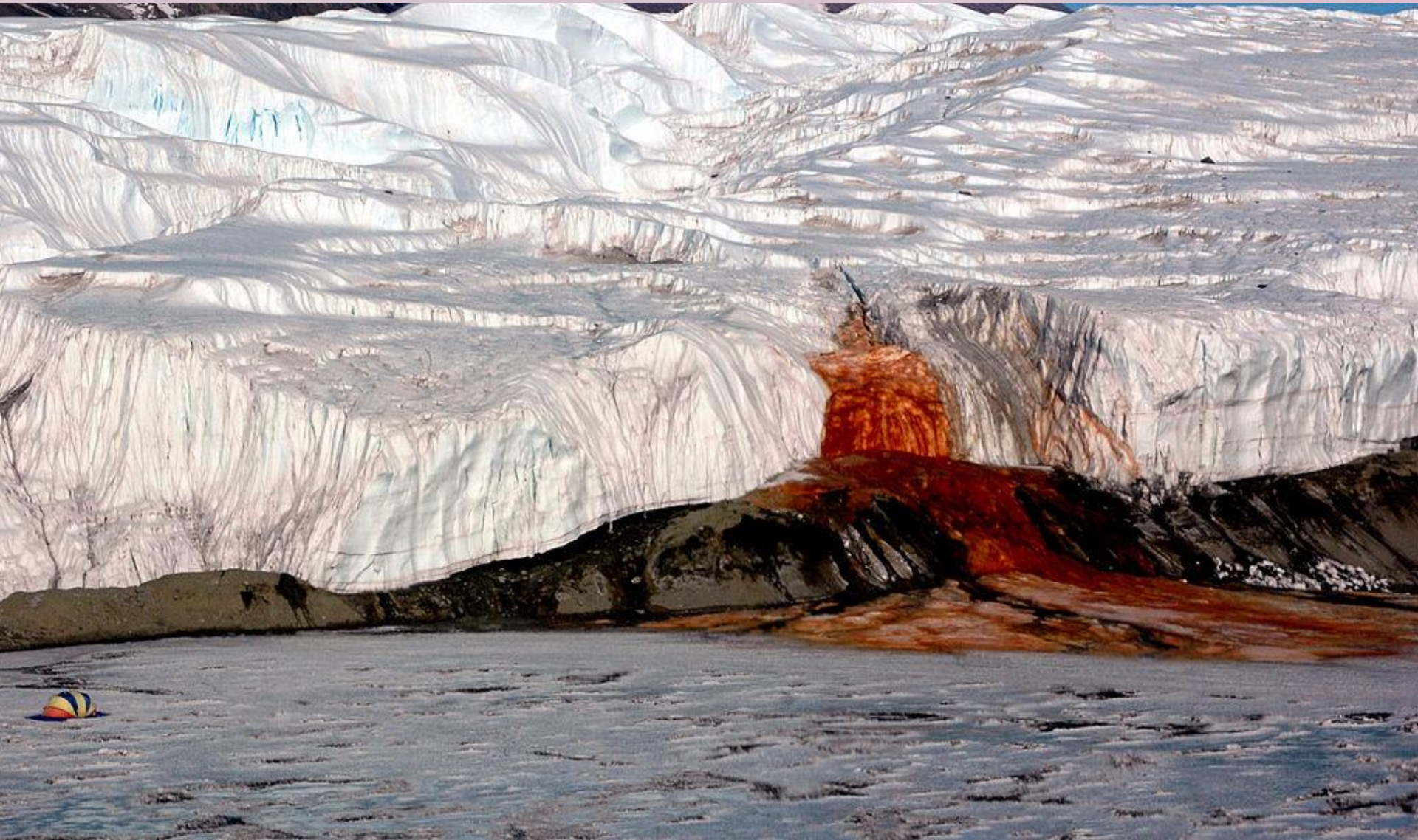


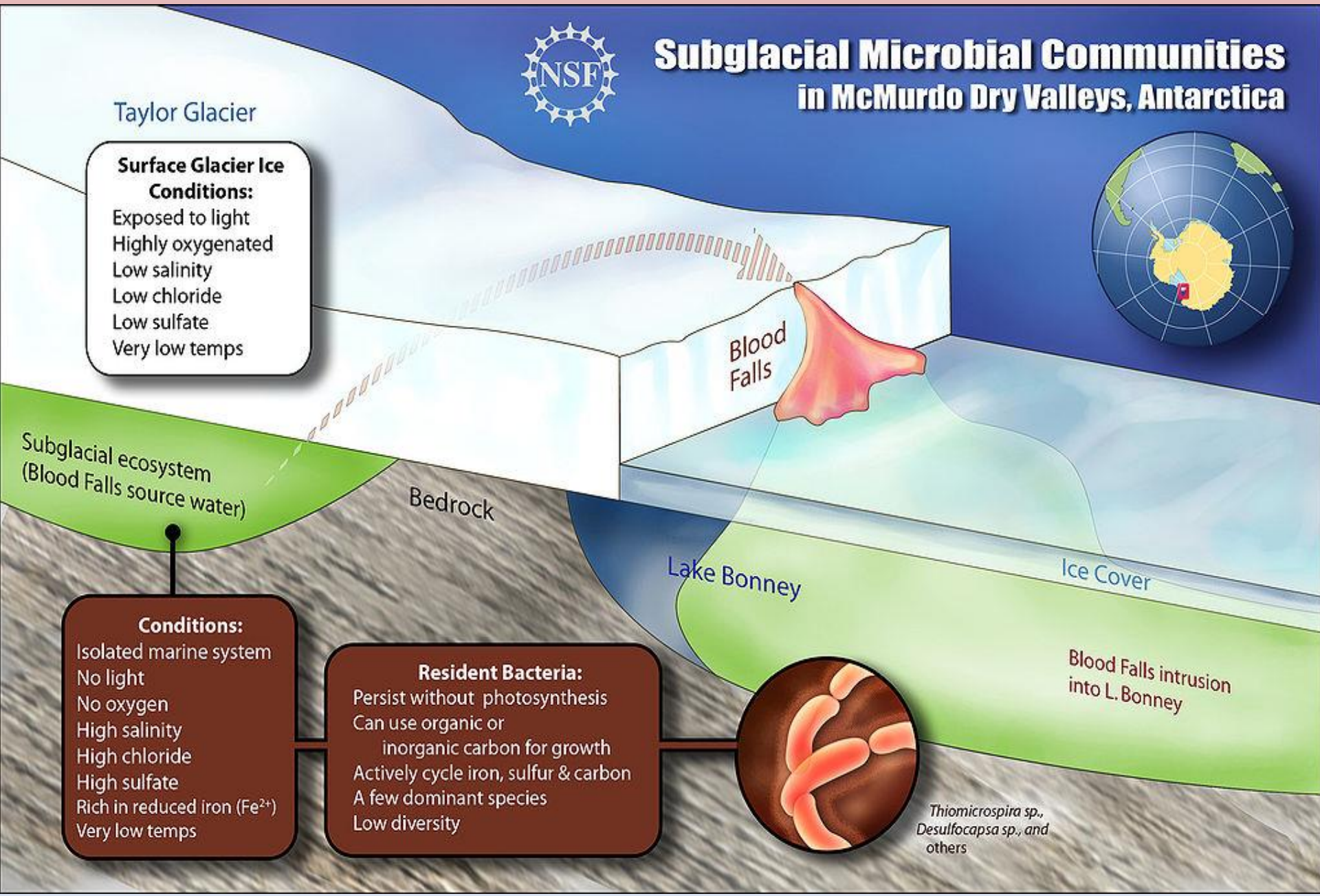


Earth and Planetary Science Letters
Volume 243, Issues 3–4, 30 March 2006, Pages 489-503

Taylor Glacier – Blood Falls: McMurdo Dry Valleys

Taylor Glacier – Blood Falls: McMurdo Dry Valleys





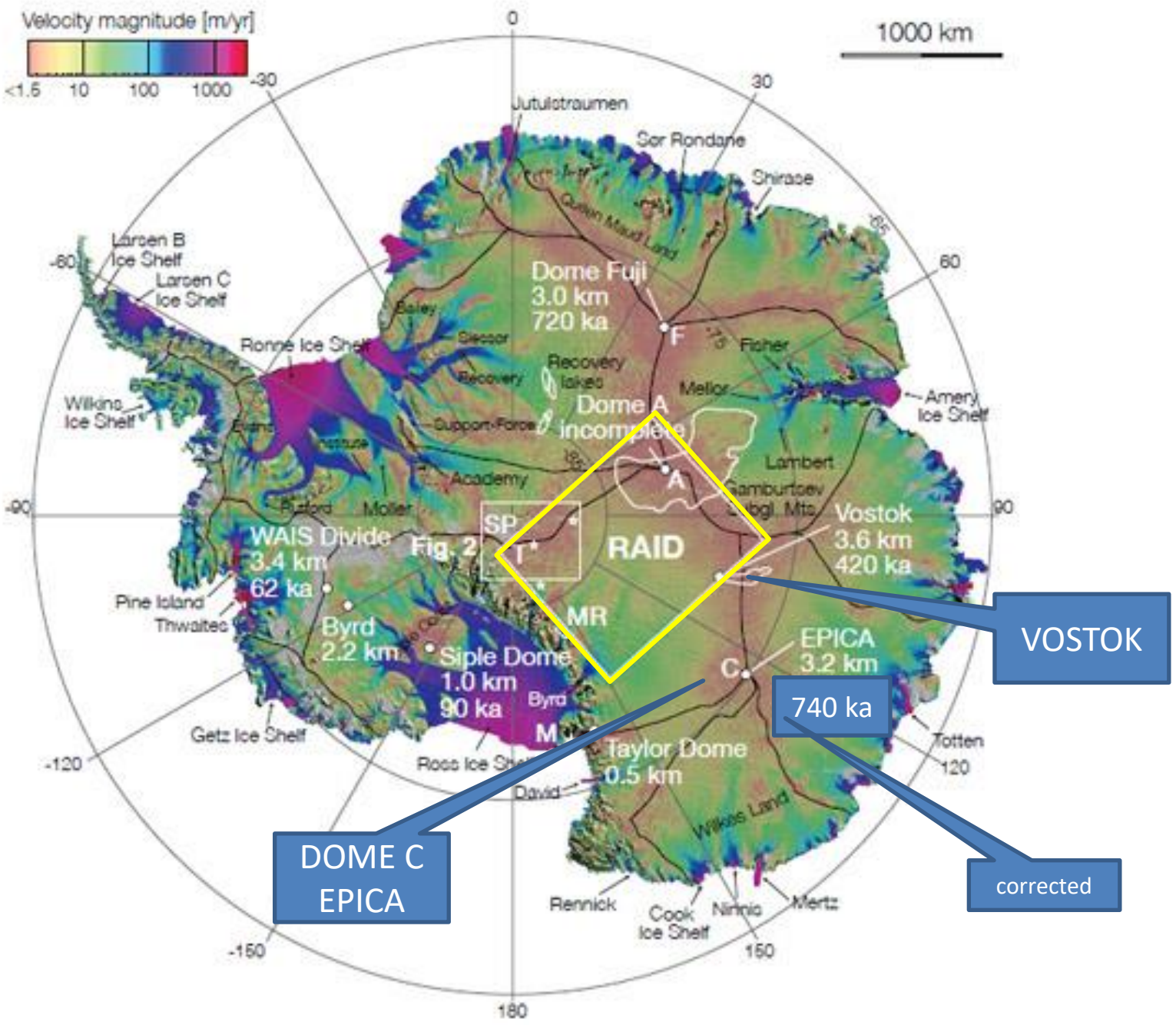
Zina Deretsky / US National Science foundation (NSF) - http://www.nsf.gov/news/news_summ.jsp?cntn_id=114488

DRILLING

- Historical record of temperatures (proxy) and chemistry
- Thickest ice selected (oldest and slow moving)
- Measurement of ice flow behavior
- Capable of sampling bedrock for geological purposes
- Investigate subglacial meltwater system
- Downhole imaging to observe ice properties
- Time consuming and expensive
- 2 Projects have been developed over the last 10 years:

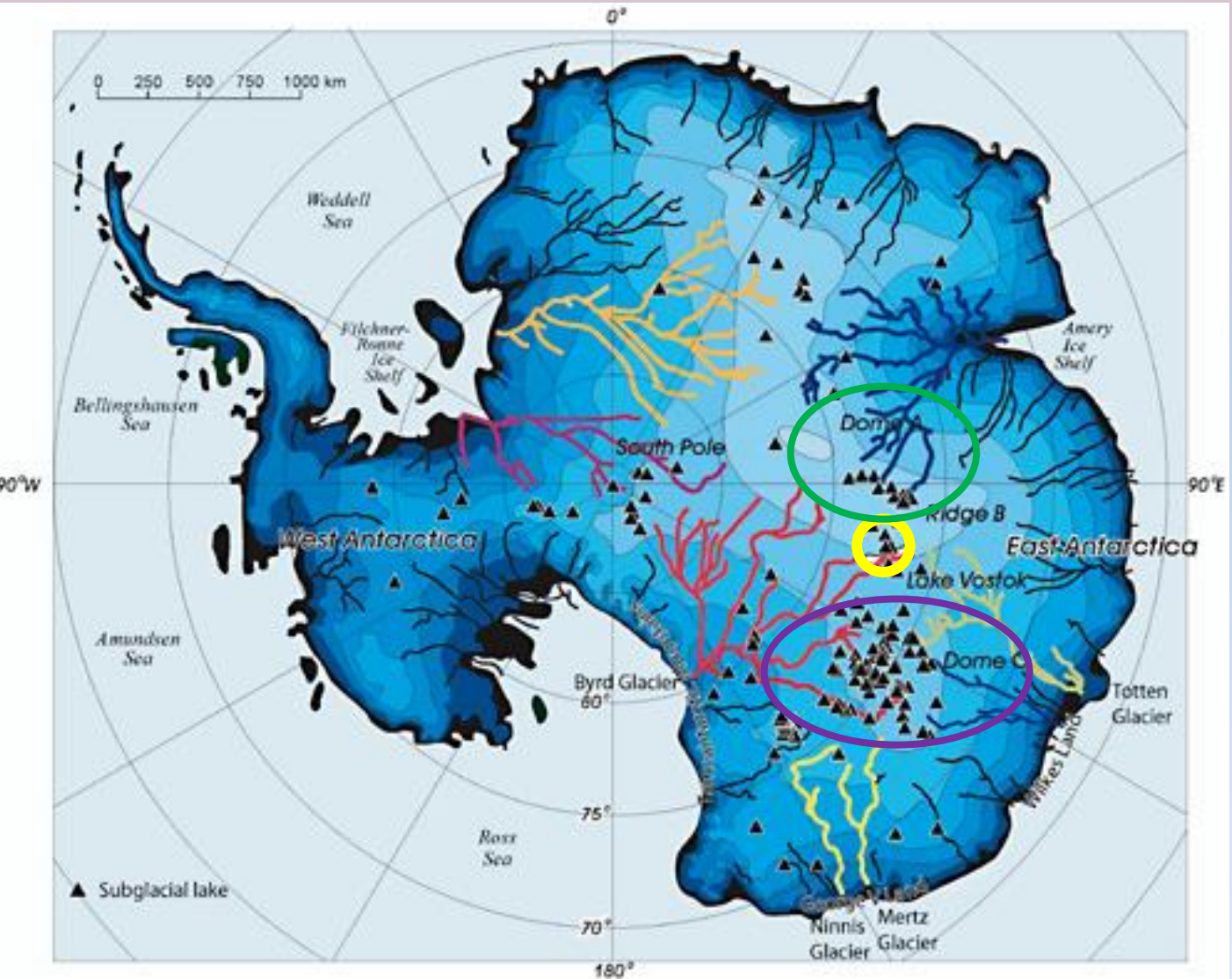
  The Goal: Drilling to bedrock in one season (2-3 months)

  - RAID (USA & UK)…Rapid Antarctic Ice Drilling
  - Subglacior (French)…uses combination cutter & meltprobe


Velocity magnitude [m/yr]
<1.5
10
100
1000
1000 km
Jutulstraumen
Sor Rondane
Shirase
Queen Maud Land
Dome Fuji
3.0 km
720 ka
F
Fisher
Recovery
Recovery lakes
Slessor
Bailey
Ronne Ice Shelf
Larsen B
Ice Shelf
Larsen C
Ice Shelf
Wilkins
Ice Shelf
Evans
Support Force
Dome A
incomplete
A
Mellor
Amery
Ice Shelf
Lambert
Academy
Ruppert
Moller
SP
Fig. 2
RAID
Vostok
3.6 km
420 ka
WAIS Divide
3.4 km
62 ka
Pine Island
Thwaites
MR
Byrd
2.2 km
Siple Dome
1.0 km
90 ka
Byrd
M
EPICA
3.2 km
C
Getz Ice Shelf
Ross Ice Shelf
Taylor Dome
0.5 km
David
Totten
Wilkes Land
Rennick
Cook
Ice Shelf
Ninnis
Mertz
0
30
60
90
120
150
180
-30
-60
-90
-120
-150
VOSTOK
740 ka
DOME C
EPICA
corrected

Locations of known Antarctic subglacial lakes and predicted major drainage routings.

SOURCE: Siegert et al. 2007.

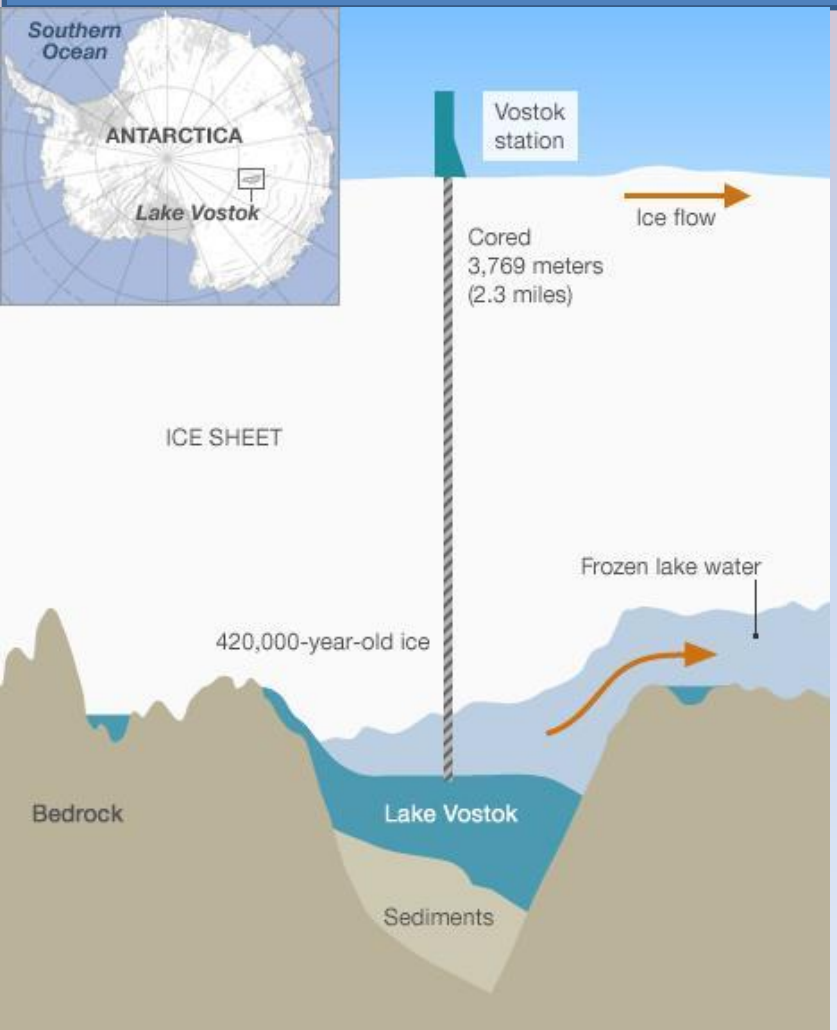


- Major clusters of subglacial lakes are located in Dome C and Ridge B areas.
- The majority of these environments are small (<20 km in length) with an average depth of 100 m.
- A few larger lakes may be up to 1000 m deep.
- Discovered by radio-echo sounding airborne surveys.

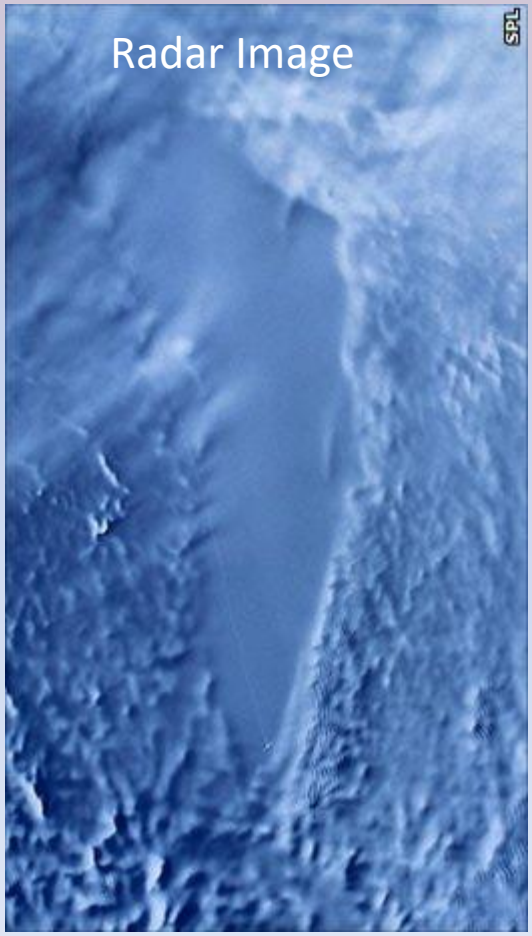
Vostok Drilling

First drilling by Soviets took place in 1970's with several holes
Hole 3G 1984 2202 m
Hole 4G 1990 2546 m
Hole 5G 1993 2755 m
1996 3623 m usable data to 3310 m (414,000 yrs)
2003 3640 m
2012 3770 m reached lake

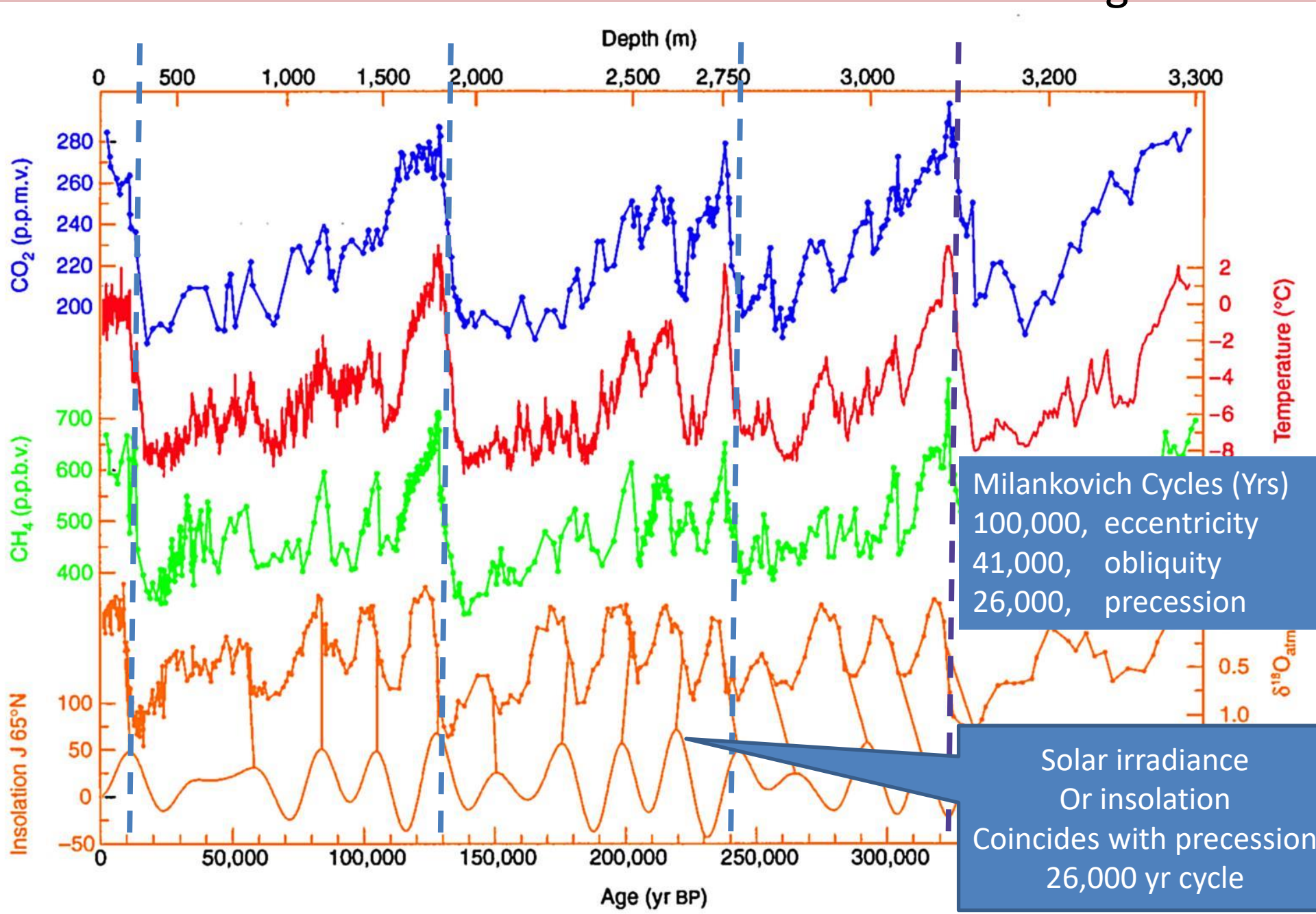
Barnola et al. (1987, 1991), Lorius et al. (1985), and Petit et al. (1999).



Lake Vostok
Biggest lake 250 kms x 50 kms
432 m deep
500 m subsea



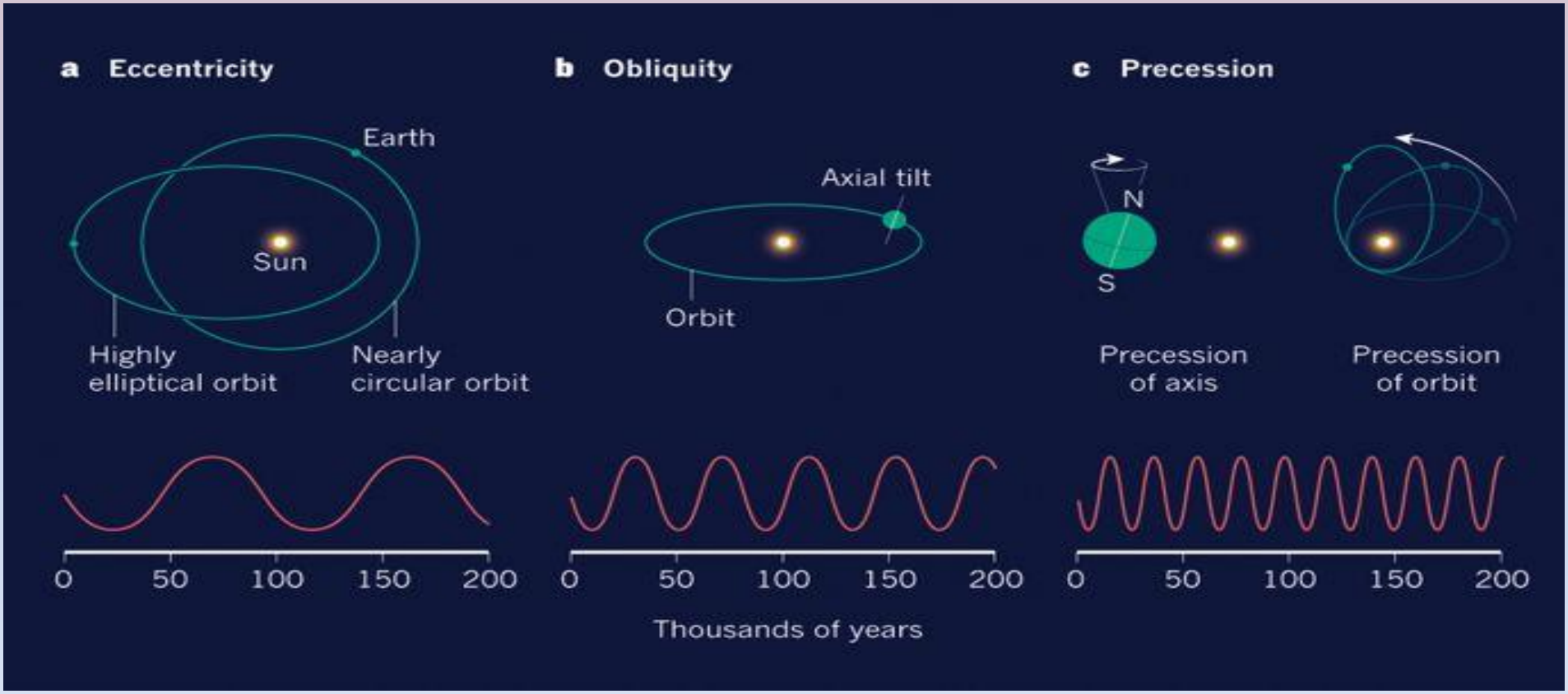
Vostok Drilling



Milankovich Cycles (Yrs)
100,000, eccentricity
41,000, obliquity
26,000, precession

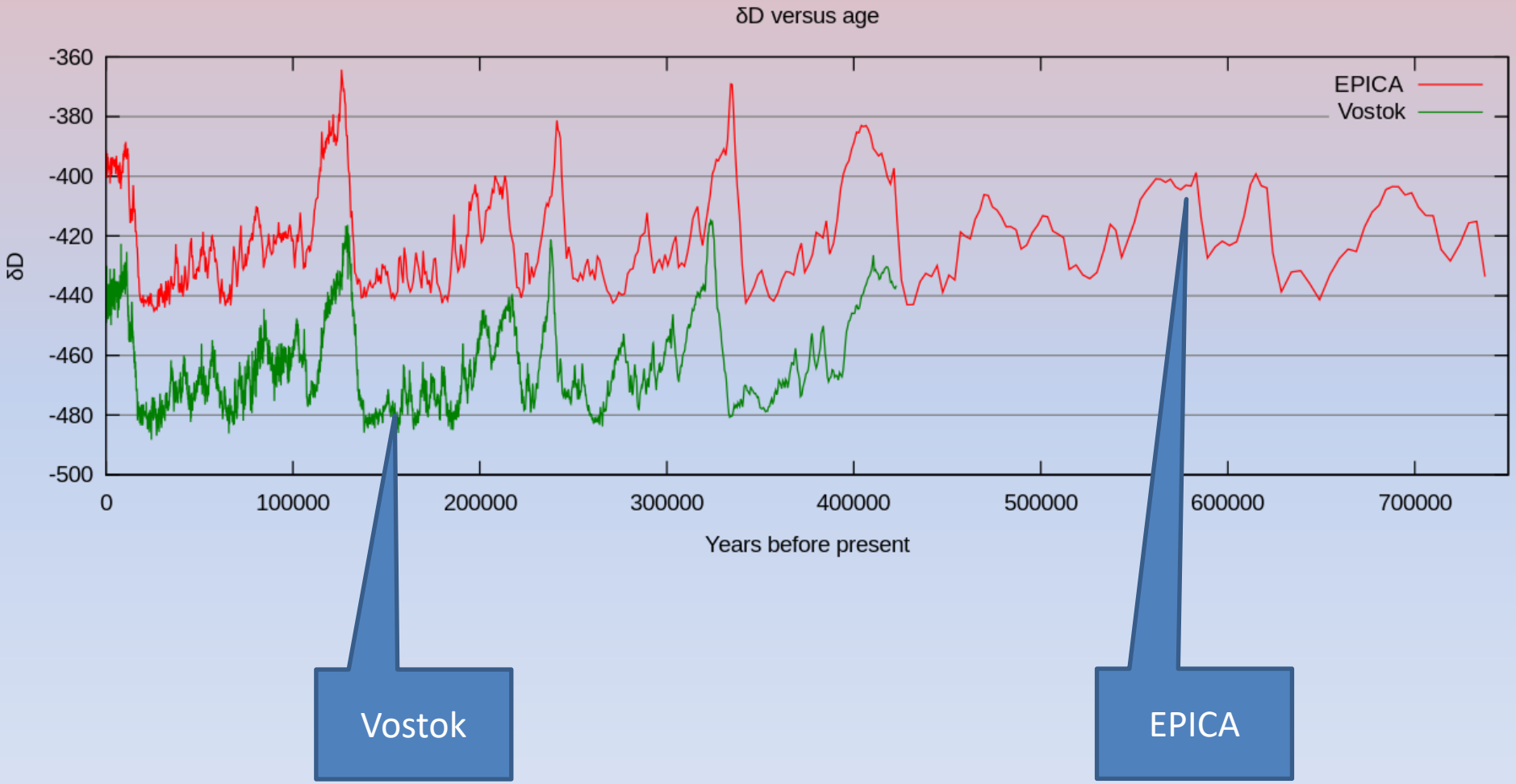
Solar irradiance
Or insolation
Coincides with precession
26,000 yr cycle

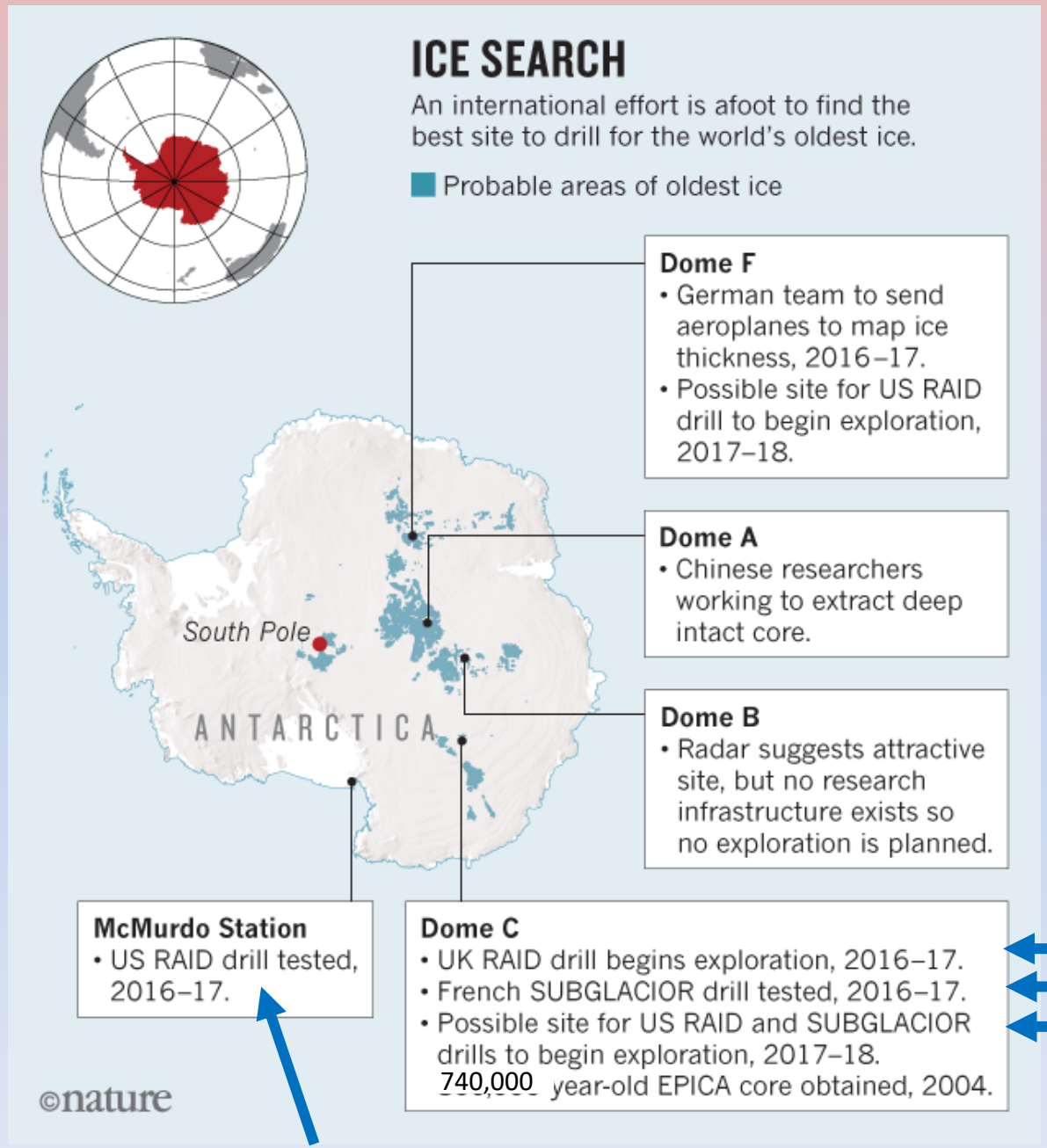
Milankovitch Cycles
100,000, 41,000 & 26,000 yrs duration



EnvironmentCounts.org

Dome C Core (EPICA) 3260 m depth data to 740,000 yrs
Vostok V Core (drilled to 3770 m in 2012) 420,000 yrs



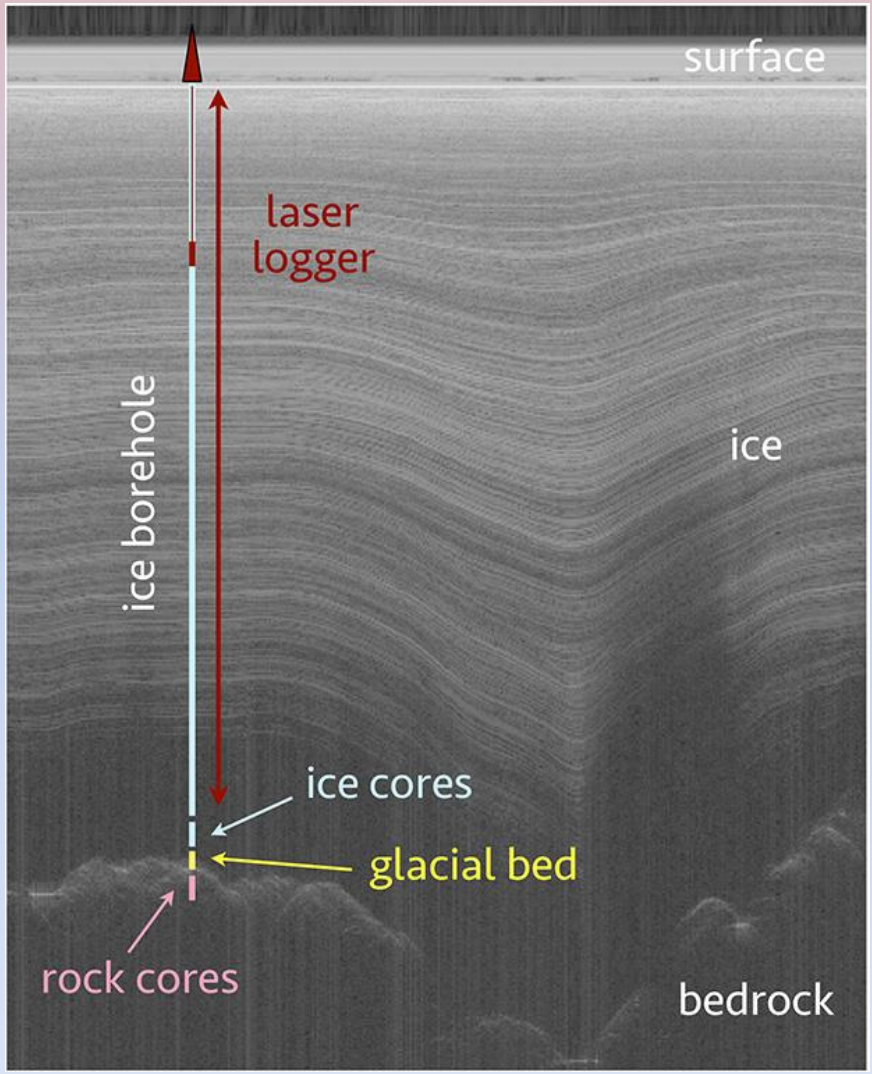


Nature
540,
18–19
(01 December 2016)

RAID (Rapid Access Ice Drill) Plan

The US team is a consortium of Scripps Institute, National Science Foundation and U of Minnesota

- Drill a 2500 to 3300 m borehole to the base of the Antarctic ice sheet as rapidly as possible. 2 to 3 months, 24/7, at high altitude (4000 m) and temperatures of -40C
- Drill through dry, frozen-bed conditions in the absence of liquid water at the basal glacial bed (ice- rock interface).
- Retrieve short ice cores (~50 cm long) of approximately 1.5 inches diameter at up to 2500 m depths.
- Retrieve 25-50 m of bedrock cores of approximately 1.5 inches diameter at up to 2500 m depths.
- Design a drilling rig that will fit on a skid-mounted mobile platform and be deployed as part of a stand-alone, traverse-capable system.
- Construct boreholes that will remain open for down-hole logging for up to 5 years



RAID Drill Testing facility
Salt Lake City
Rapid Access Ice Drilling

March 2013 and November 2015.
Consortium begins design, fabrication, construction, integration, and testing

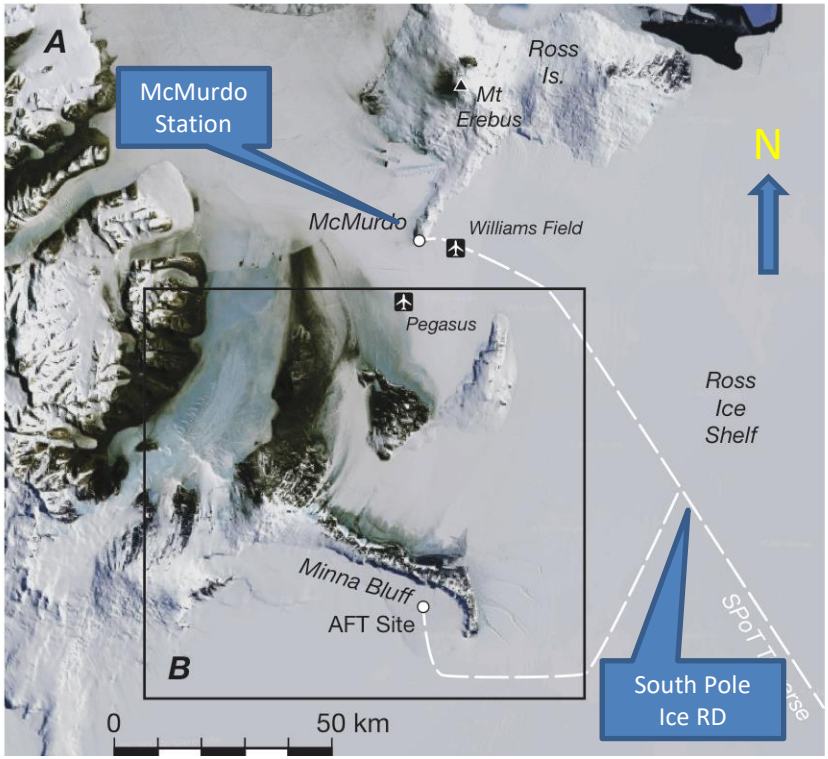
November 5, 2015.
Verified and accepted by the University of Minnesota.

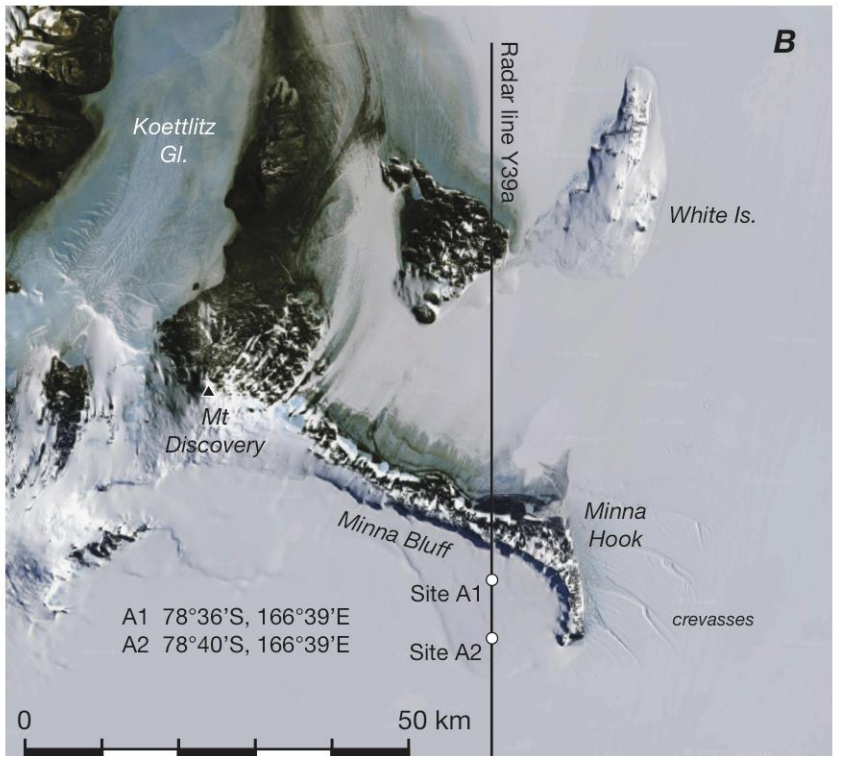
November 2015
shipped by truck to vessel facility at Port Hueneme, California

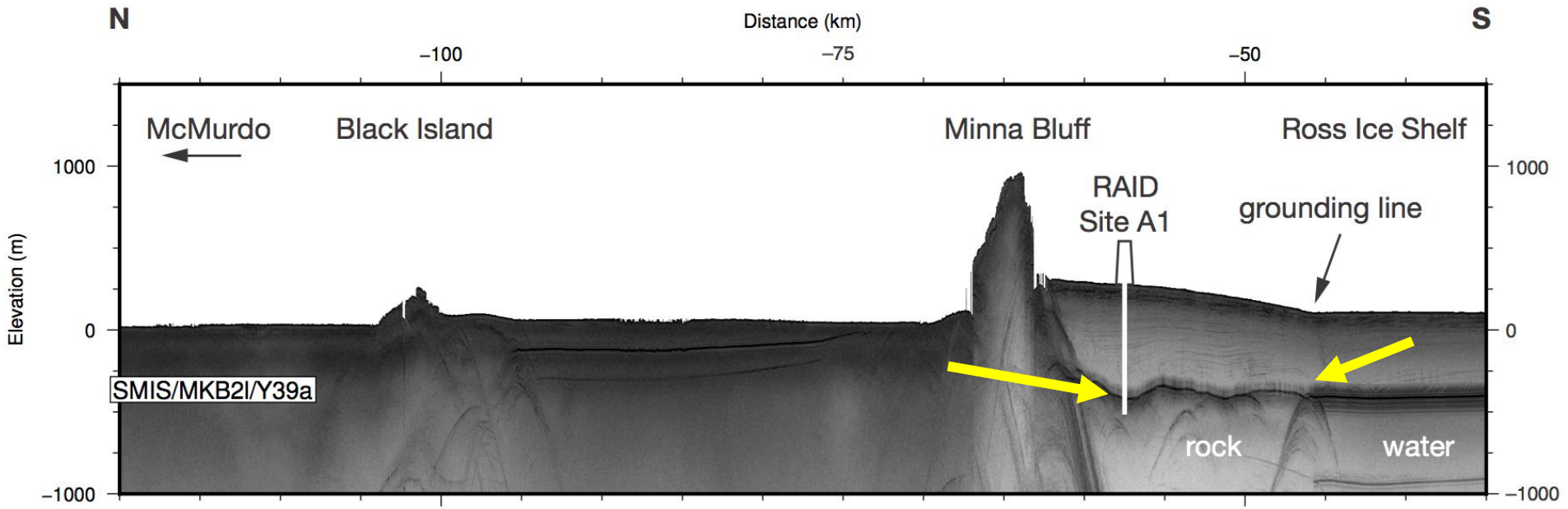
January 28, 2016
RAID arrived at McMurdo Station in Antarctica

2016-17, 2017-18 and 2018-19.
Antarctic field trials and technical development completed

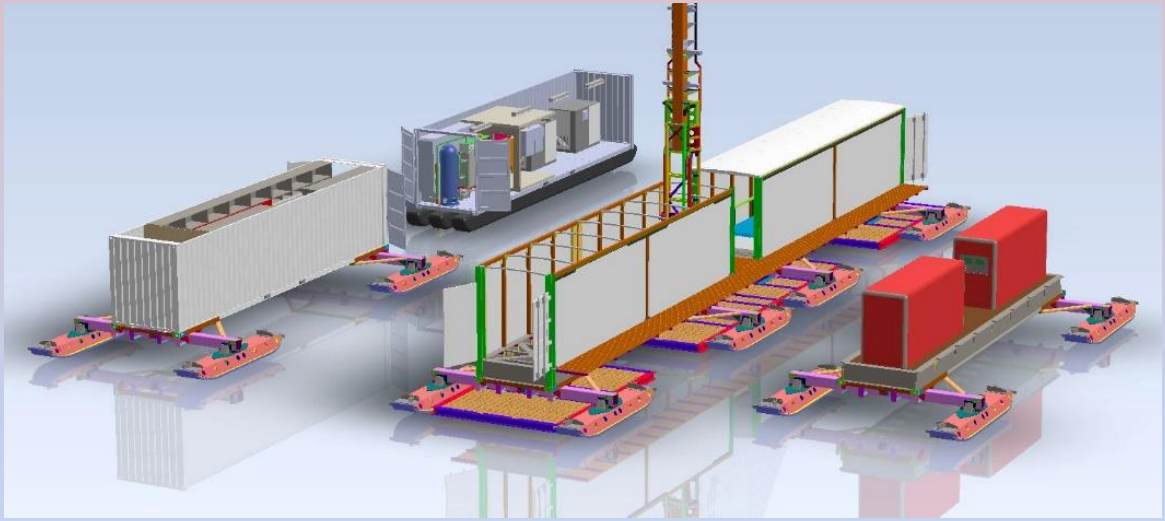
2019-20
RAID will undergo further technical trials

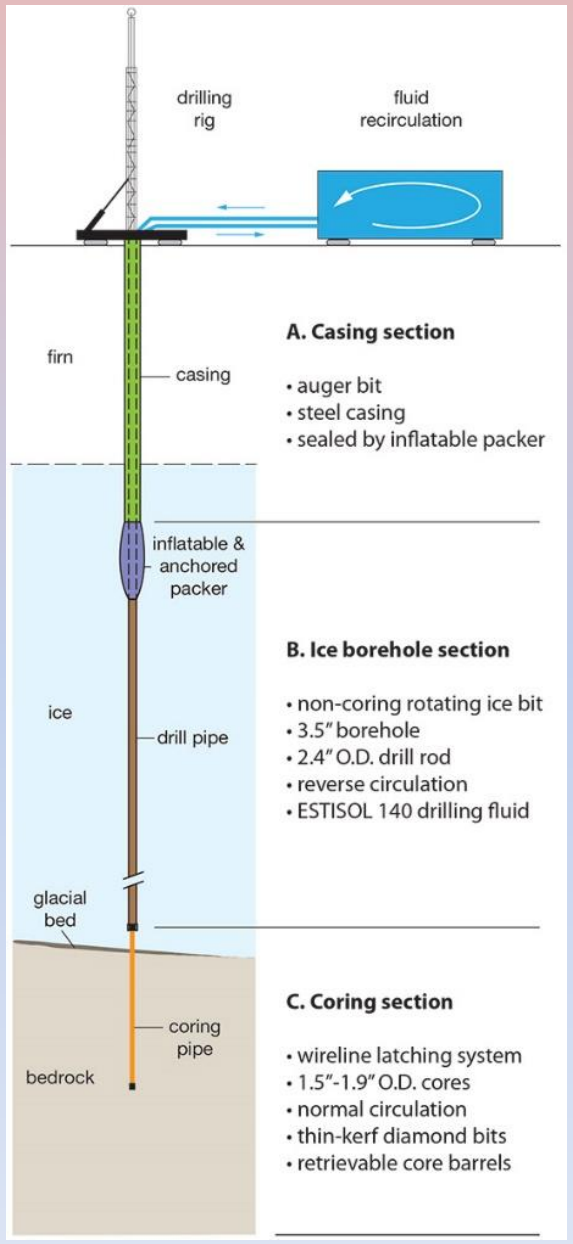

A
McMurdo Station
Ross Is.
Mt Erebus
N
McMurdo
Williams Field
Pegasus
Ross Ice Shelf
Minna Bluff
AFT Site
B
South Pole Ice RD
0
50 km


B
Radar line Y39a
Koettlitz Gl.
White Is.
Mt Discovery
Minna Bluff
Minna Hook
Site A1
A1 78°36'S, 166°39'E
A2 78°40'S, 166°39'E
Site A2
crevasses
0
50 km


N
Distance (km)
S
−100
−75
−50
McMurdo
Black Island
Minna Bluff
Ross Ice Shelf
1000
0
−1000
Elevation (m)
RAID Site A1
grounding line
SMIS/MKB2I/Y39a
rock
water

RAID System




drilling rig
fluid recirculation
firn
casing
A. Casing section
• auger bit
• steel casing
• sealed by inflatable packer
inflatable & anchored packer
B. Ice borehole section
ice
drill pipe
• non-coring rotating ice bit
• 3.5" borehole
• 2.4" O.D. drill rod
• reverse circulation
• ESTISOL 140 drilling fluid
glacial bed
coring pipe
C. Coring section
bedrock
• wireline latching system
• 1.5"-1.9" O.D. cores
• normal circulation
• thin-kerf diamond bits
• retrievable core barrels

RAID Test Site McMurdo 2017

Full Circle – 120 years earlier

The ship Discovery and Scott approaching McMurdo Sound with Mt Erebus in the background in 1901

https://www.coolantarctica.com

The End