Antarctica: At the heart of it all

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Osher Lifelong Learning Institute

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[Field work in Antarctica in 2017-18]

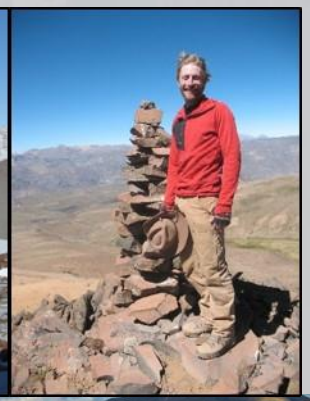
Dr. Dan Morgan, PhD

- Grew up in Portland, OR
- Pomona College in Claremont, California, BA 2002
- University of Washington in Seattle, Washington, PhD 2009
- Vanderbilt since 2009

- What I like to study:
  - Landscapes and how they record how Earth has changed
  - Field work in Antarctica, New Zealand, California, Peru, Nepal, Iceland, Italy



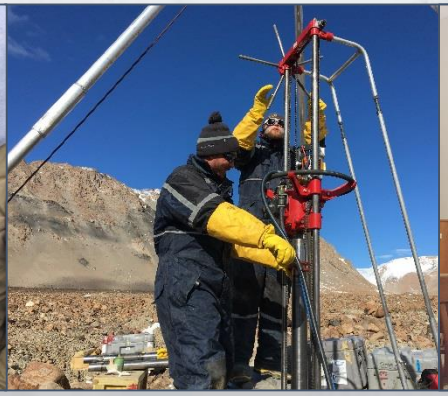




What do I do?

- Associate Dean, College of Arts & Science
- Principal Senior Lecturer, Earth & Environmental Sciences
- Former Faculty Head of Memorial House, Martha Rivers Ingram Commons



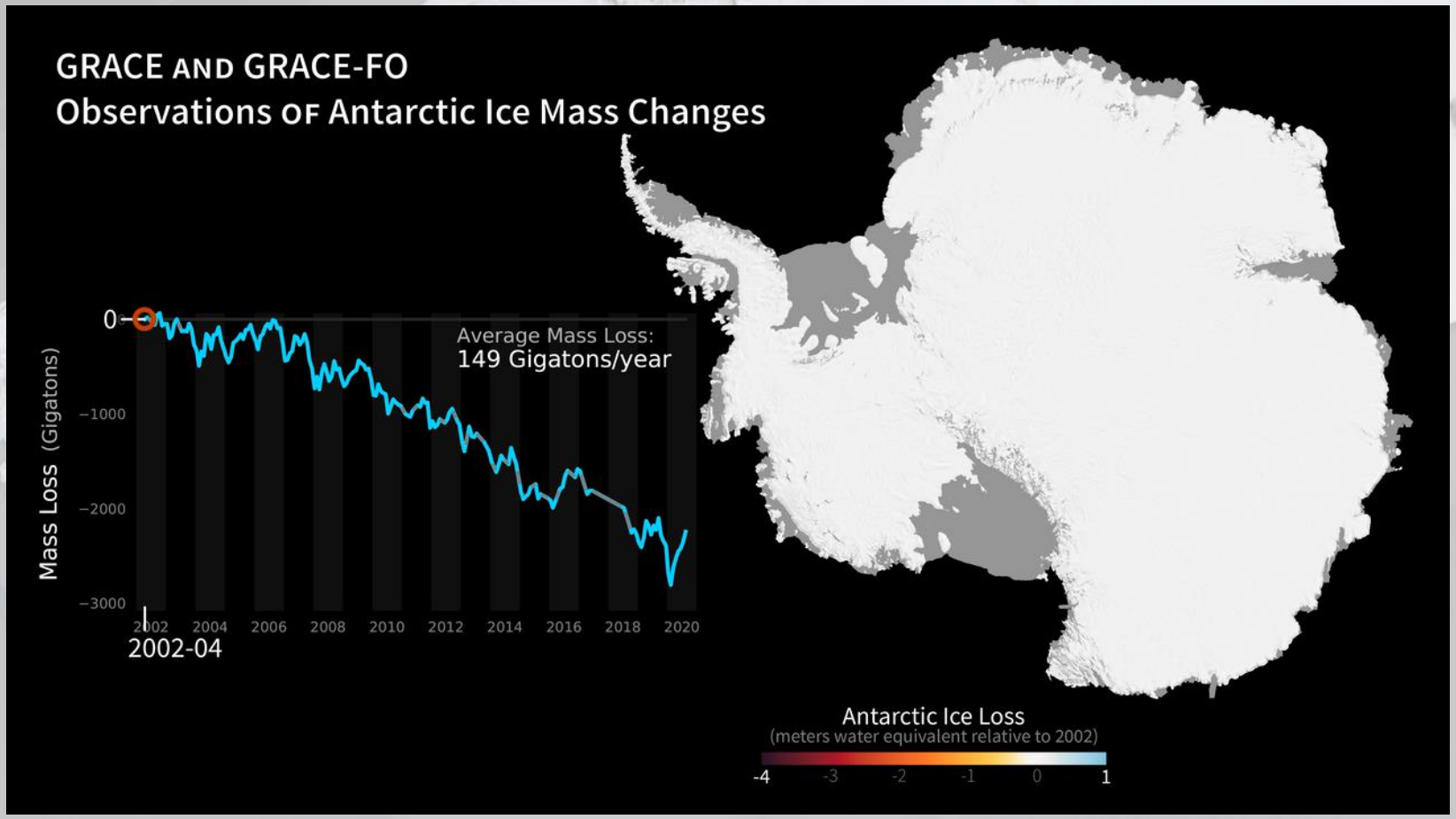



Collaborators

- Collaborators: Jaakko Putkonen (UND), Greg Balco (BGC), Warner Cribb (MTSU), Ted Bibby (UND-UCSB), Mauro Guglielmin (U. Insubria)
- Students: Courtney Megerian (‘22), Ellie Miller (‘22), Sophia Wang (‘22), Andrew Grant (‘19), Lucia Berkey (SSMV ‘20), Ruby Kinkel (SSMV ‘19), Evan Miranda (‘18), Sarah Sams (‘16), Julia Liu (‘16), Katherine Edwards (‘15), Michael Diamond (‘15), Carson Hedberg (‘16), Ashley Ball (‘13), Kyle Ringger (‘13), Mitchell Stocky (‘12), Collin Giusti (UND), Erin Hoeft (UND), Holly Westad (UND), Josh Cox (UTK), Eli Orland (PO), Frank Lyles (PO)
- Funding and support: NSF #1842542, #1445169, PLR-0838968 and PLR-0838757, Vanderbilt University Summer Research Program, Vanderbilt Research Supervision Grant, PRIME Lab, UNAVCO, Polar Geospatial Center

Motivation: Antarctica is changing!

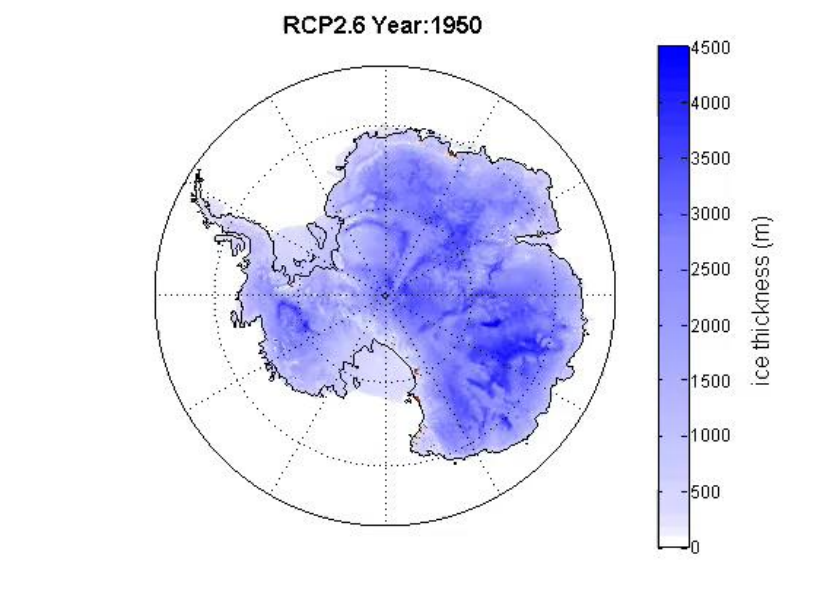
[NASA's GRACE mission]

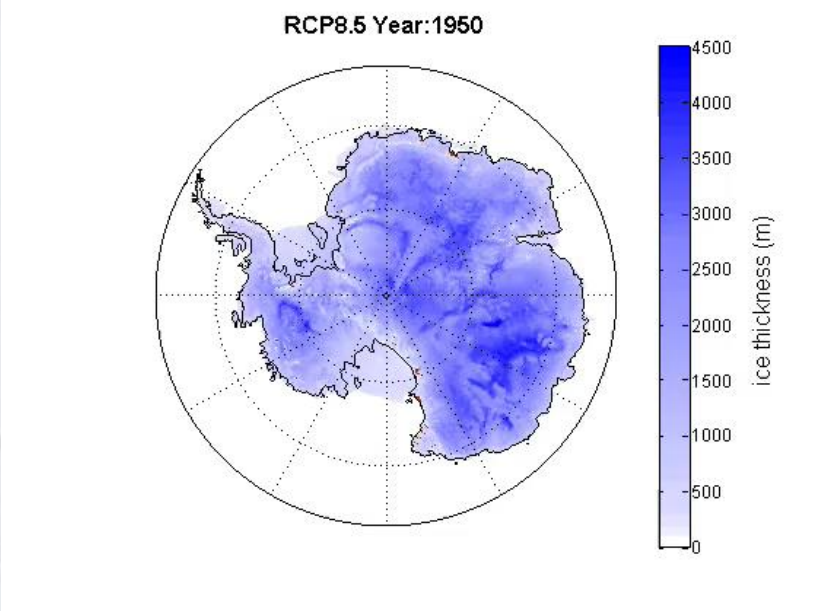


Contribution of Antarctica to past and future sea-level rise

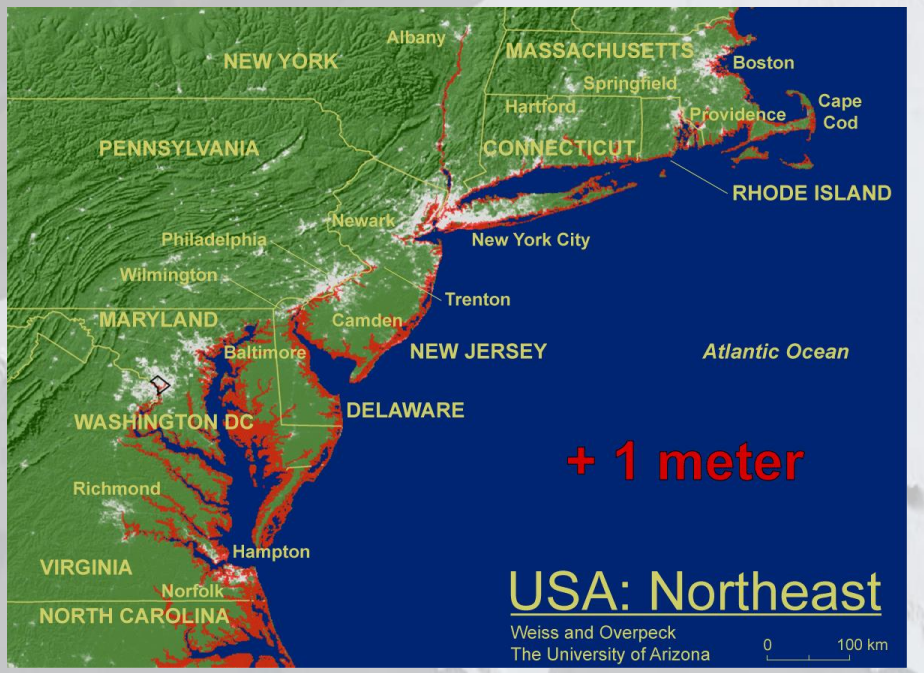
Robert M. DeConto[1] & David Pollard[2]

DeConto and Pollard, 2016: “Antarctica has the potential to contribute more than a metre of sea-level rise by 2100 and more than 15 metres by 2500”





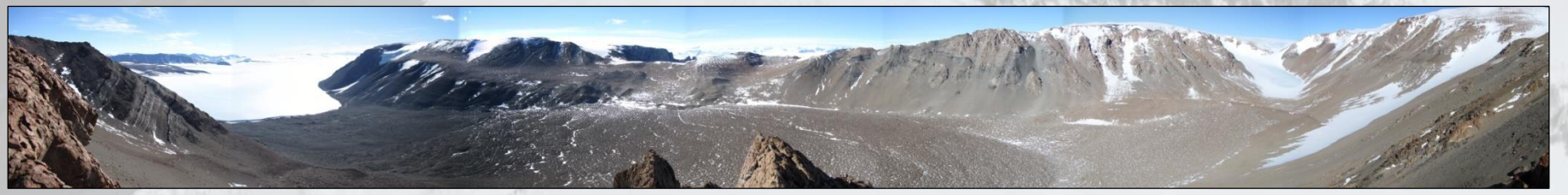
1 meter sea level rise



http://geology.com/sea-level-rise/

Motivating questions for my research

- How old are the glacial deposits in Antarctic Dry Valleys? What was the former extent of past glaciation?



- What geomorphic processes are active in these valleys? How quickly do they alter the landscape?

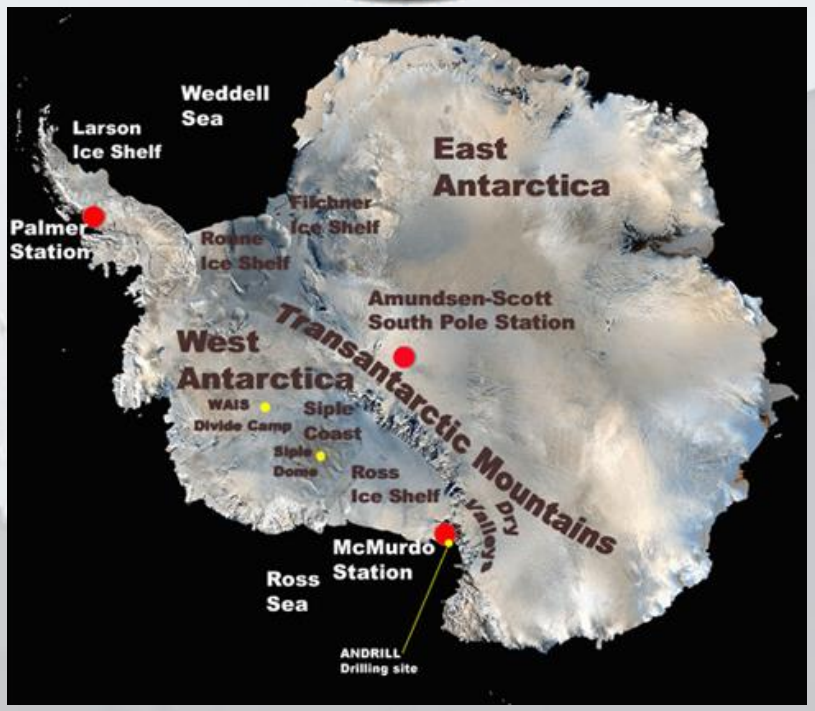
Course Outline

- I. Geography, geology, and biology
- II. Discovery and early expeditions
- III. The “Golden Age” of Antarctic exploration
- IV. 20th century expeditions
- V. Antarctic governance
- VI. Modern science in Antarctica

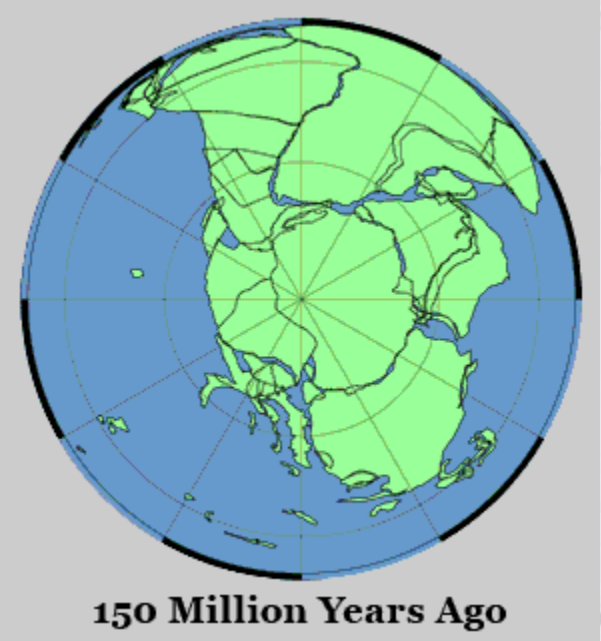
Antarctica

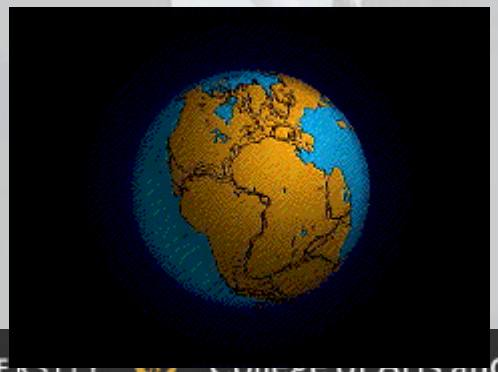
- Coldest, iciest, driest, highest, windiest, brightest, loneliest, most peaceful, & least explored continent

Where is Antarctica?



Geography

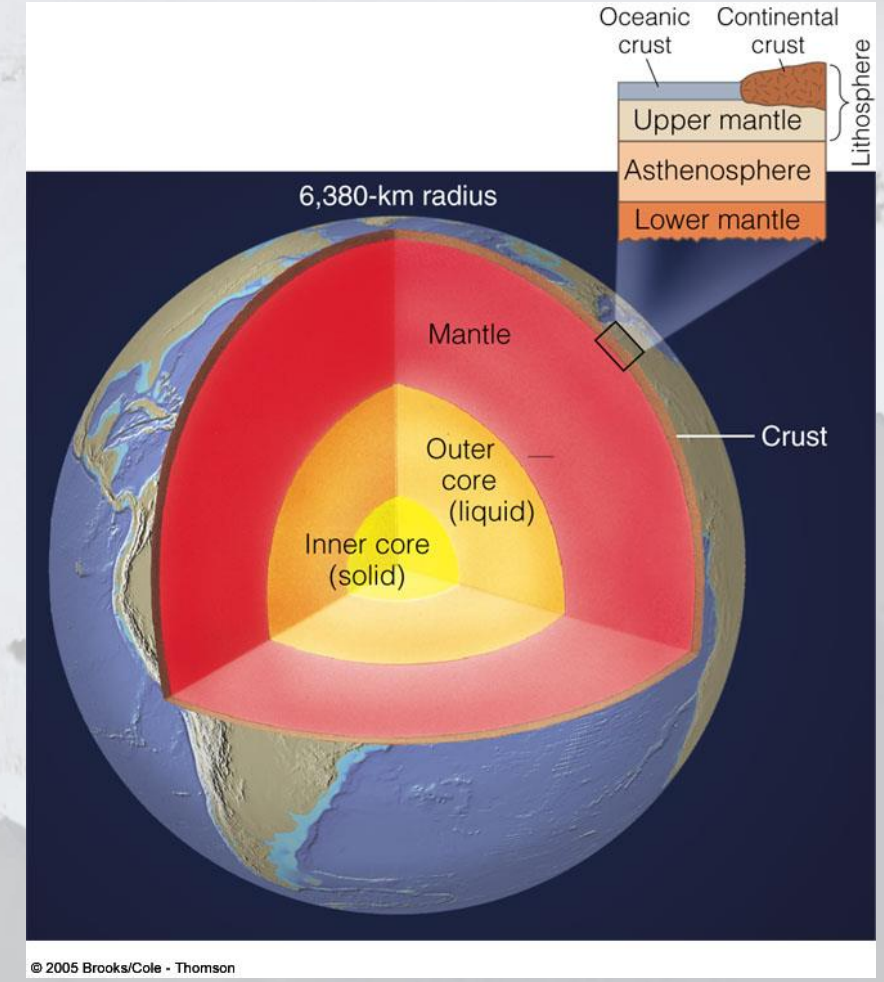




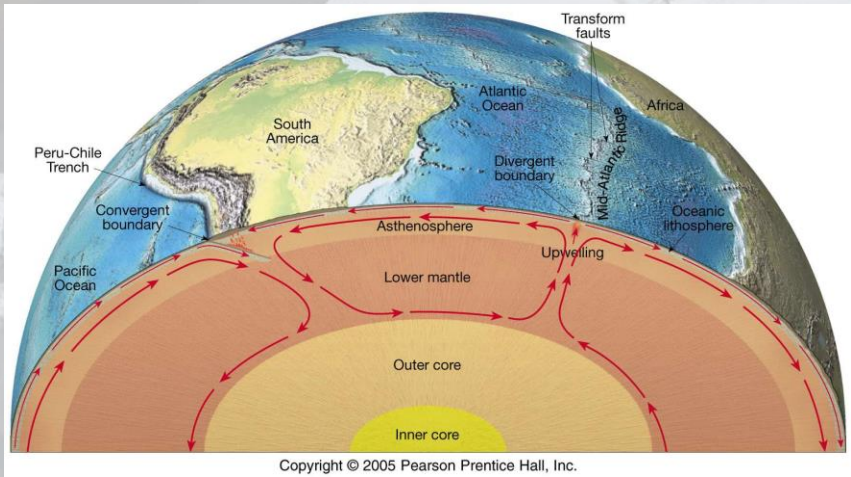
- Antarctica is a continent
- Antarctica is a tectonic plate

Earth's physical structure

- Crust - thin, solid, mostly light elements (e.g., aluminum, silicon), two types: continental and oceanic
- Mantle - viscoelastic (deformable), composition like crust but enriched in heavy elements (e.g., iron, magnesium)
- Outer Core - liquid, mostly iron, other heavy elements
- Inner Core - solid, mostly iron, other heavy elements

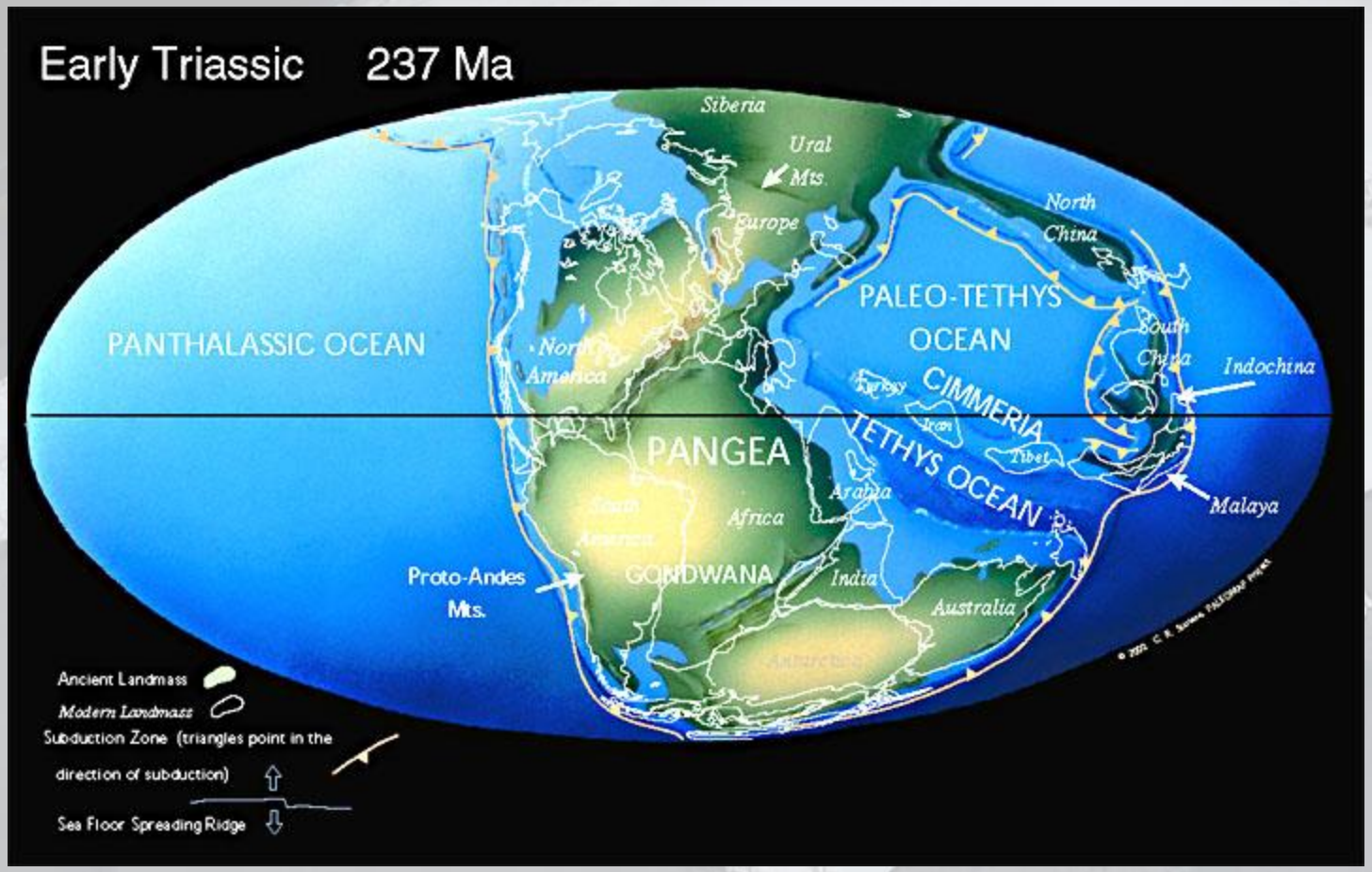


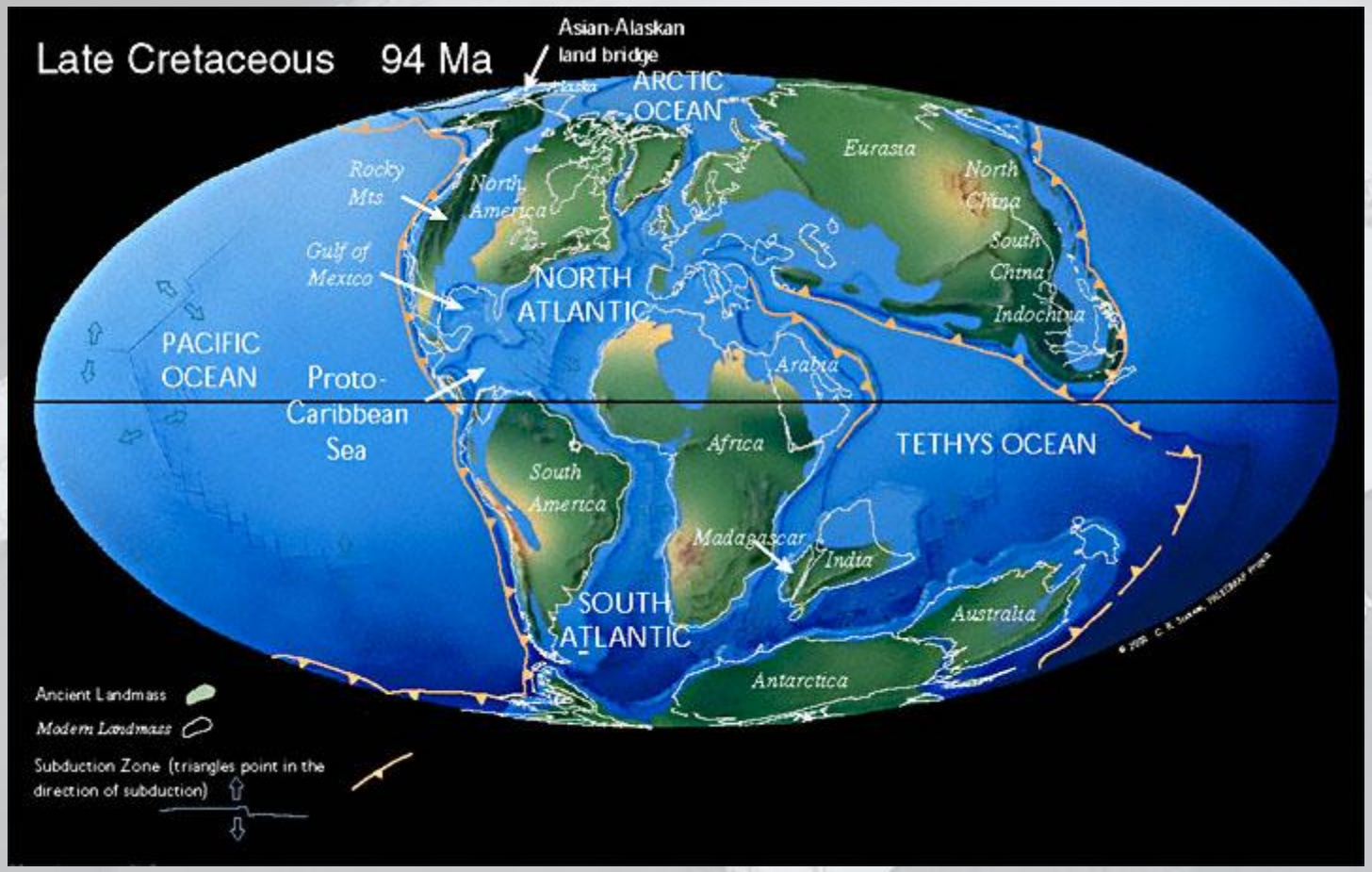
How it works

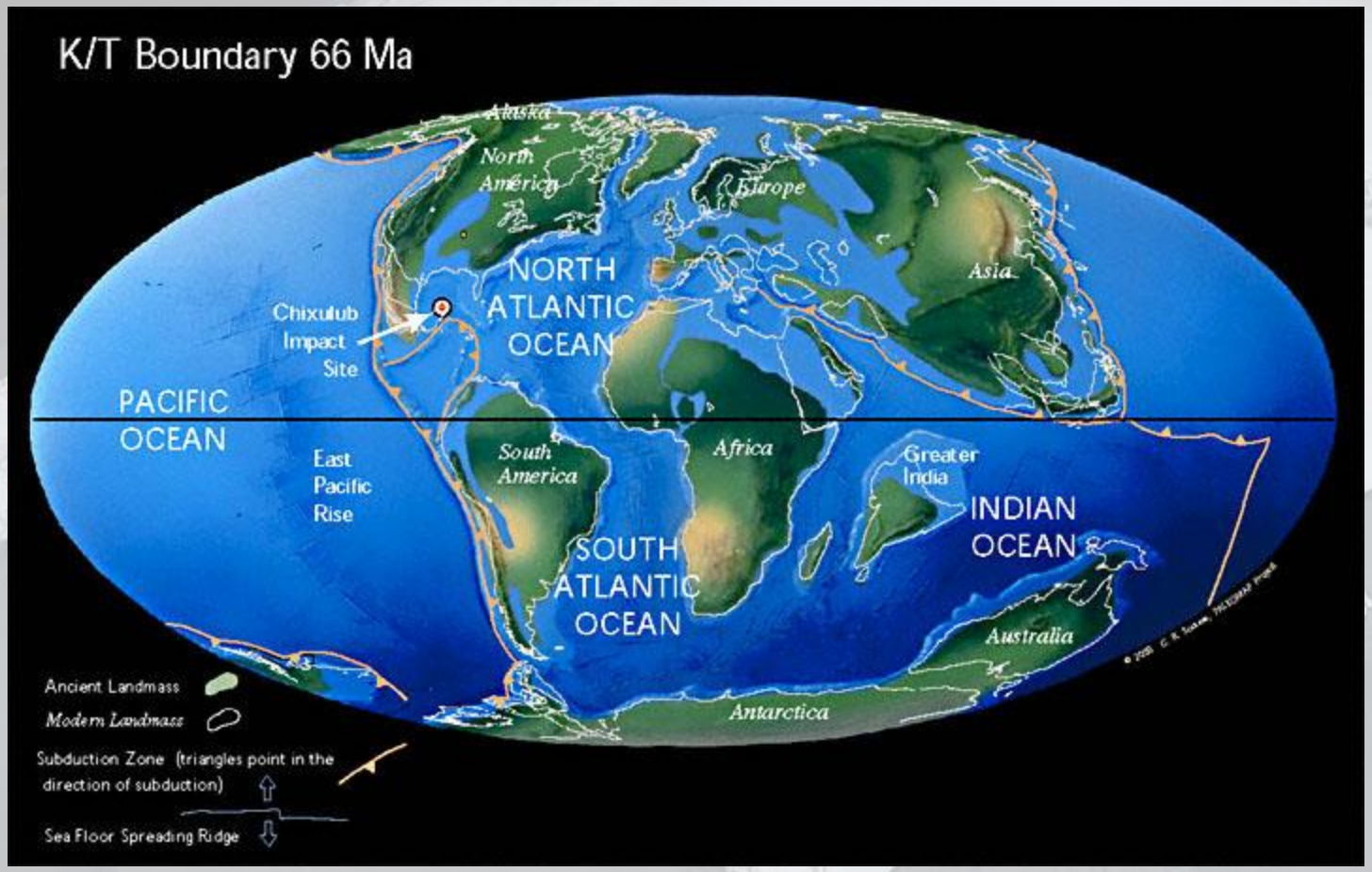


- Heat from the core moves material through the lower mantle and asthenosphere in convection currents
- Lithospheric plates "float" on the asthenosphere and are moved by these currents
- https://www.youtube.com/watch?v=ryrXAGY1dmE

Pangaea (or Pangea)




Late Cretaceous 94 Ma
Asian-Alaskan land bridge
ARCTIC OCEAN
Eurasia
North China
South China
Indochina
Rocky Mts
North America
Gulf of Mexico
NORTH ATLANTIC
PACIFIC OCEAN
Proto-Caribbean Sea
Arabia
Africa
TETHYS OCEAN
South America
Madagascar
India
SOUTH ATLANTIC
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)


K/T Boundary 66 Ma
Alaska
North America
Europe
Asia
NORTH ATLANTIC OCEAN
Chixulub Impact Site
PACIFIC OCEAN
East Pacific Rise
South America
Africa
Greater India
INDIAN OCEAN
SOUTH ATLANTIC OCEAN
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge

Types of plate boundaries

- Plates moving away from each other

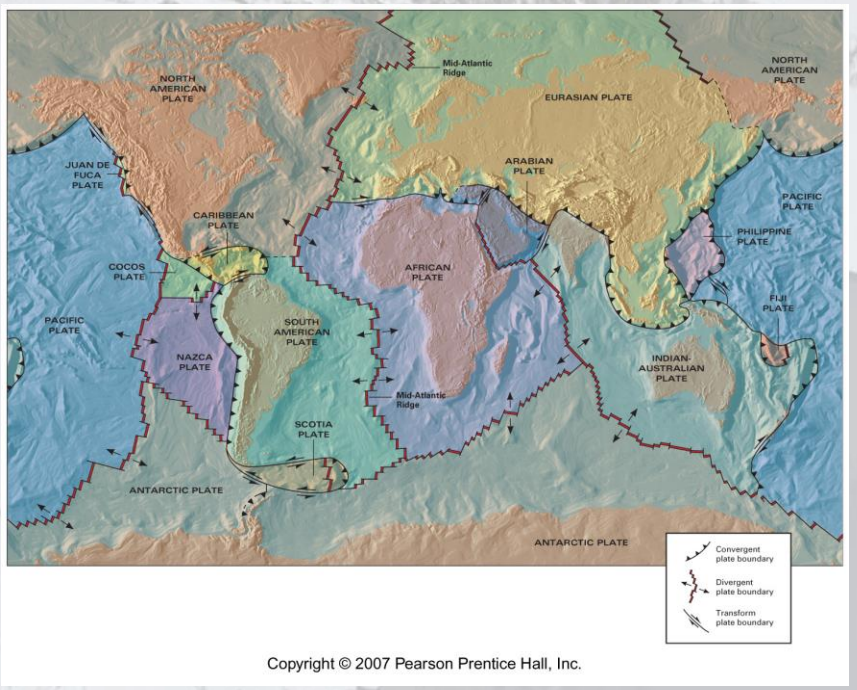
  → Divergent margin

- Plates moving towards each other

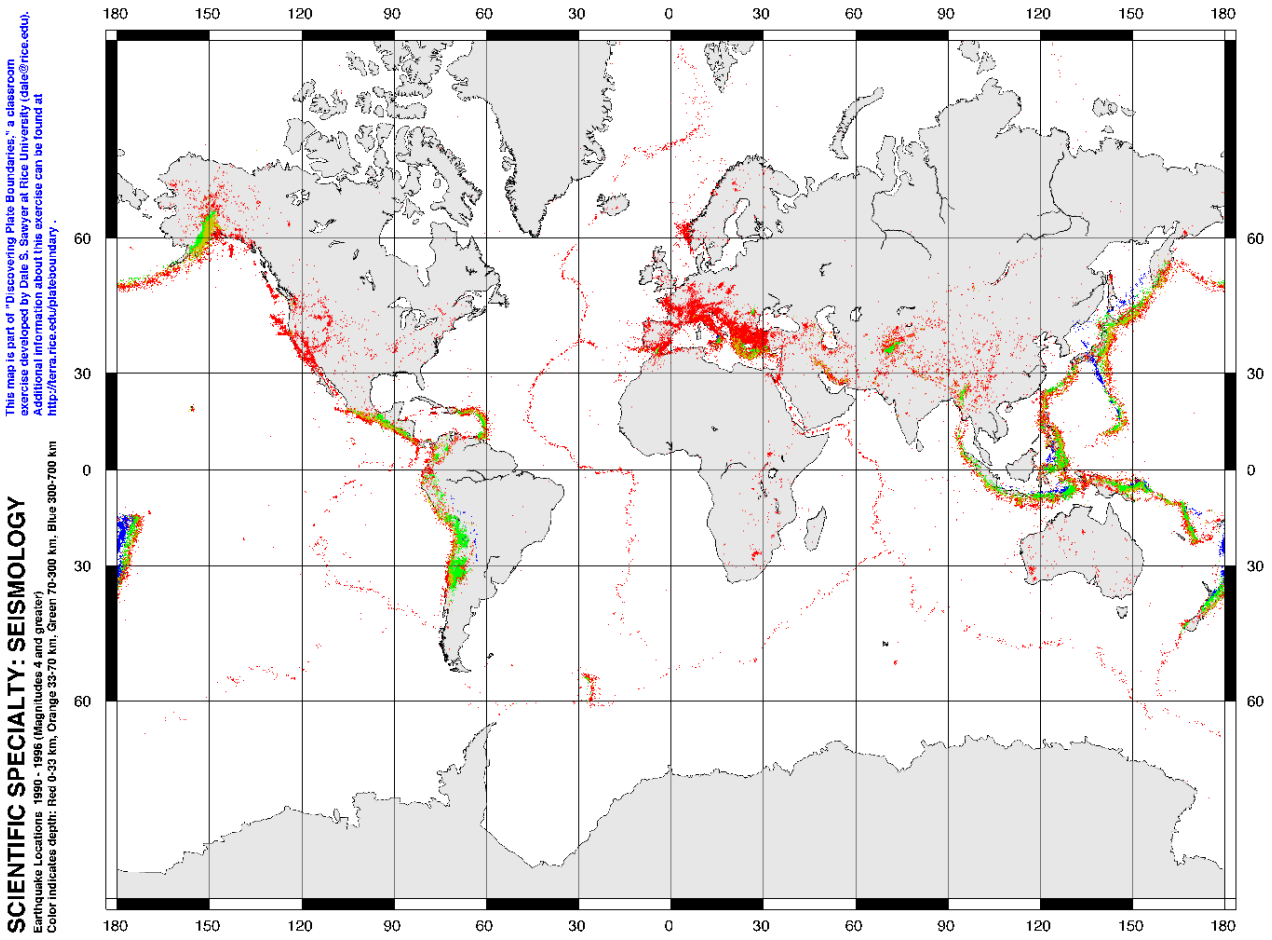
  → Convergent margin

- Plates sliding past one another

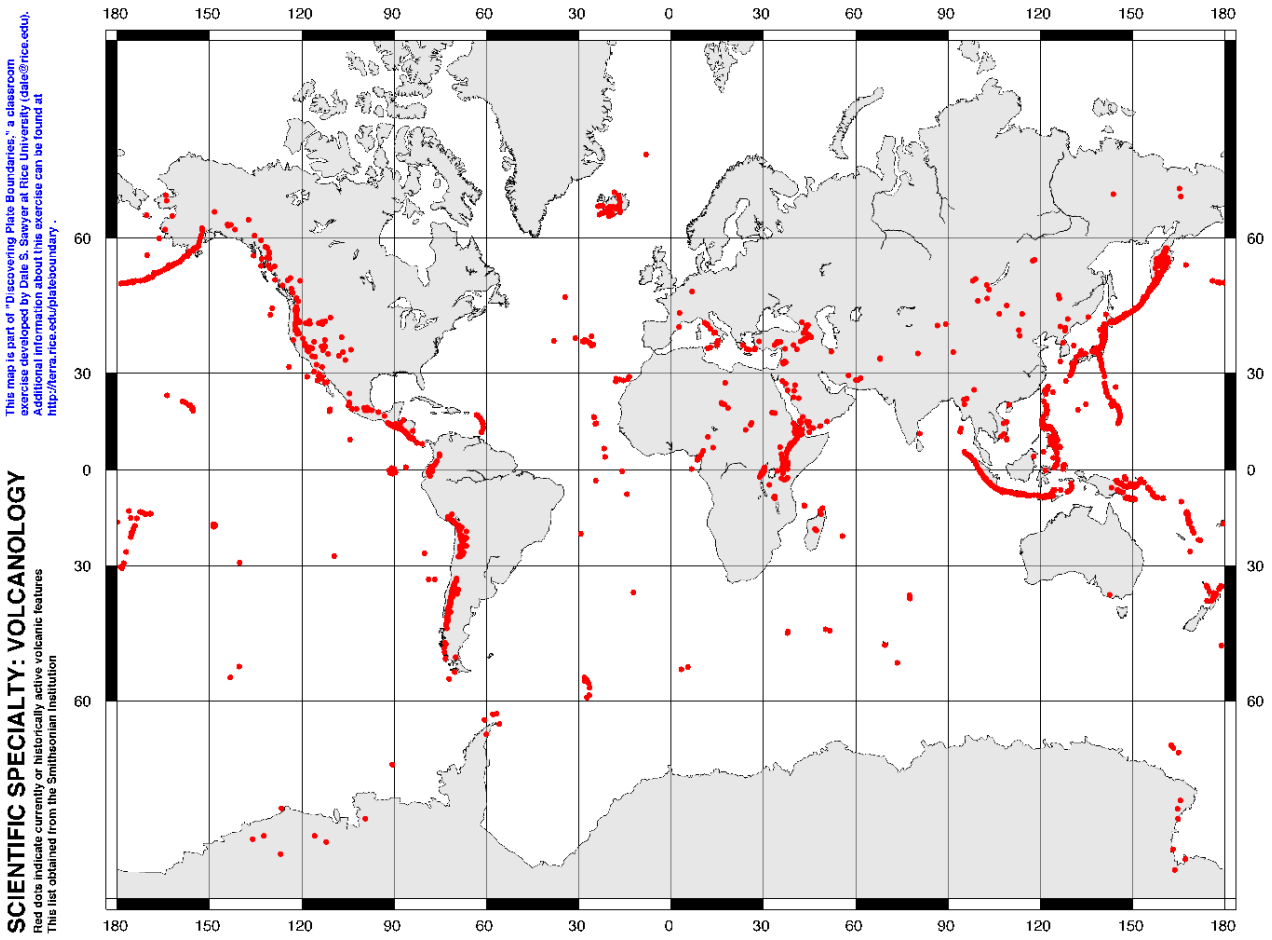
  → Transform margin



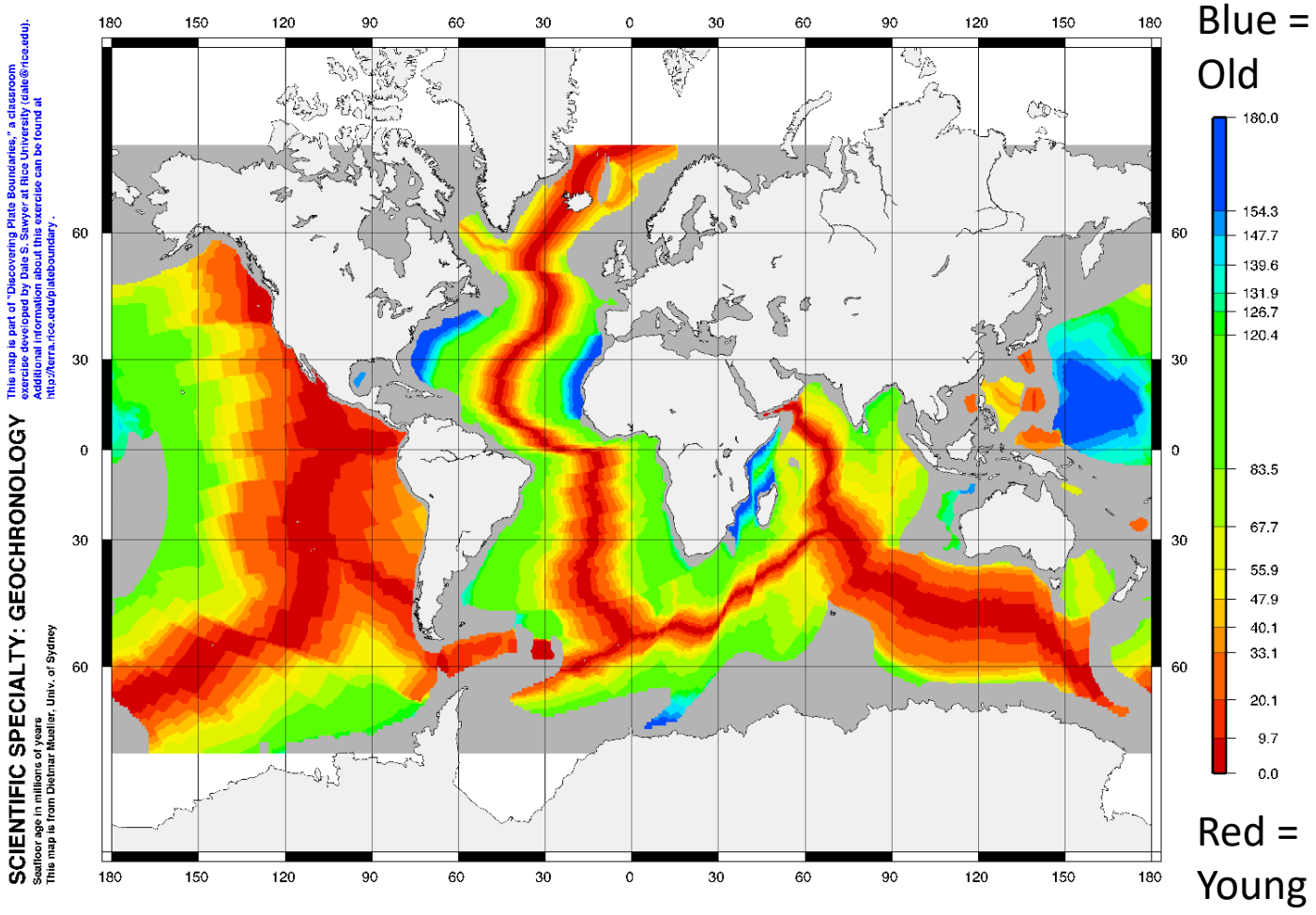
Distribution of earthquakes



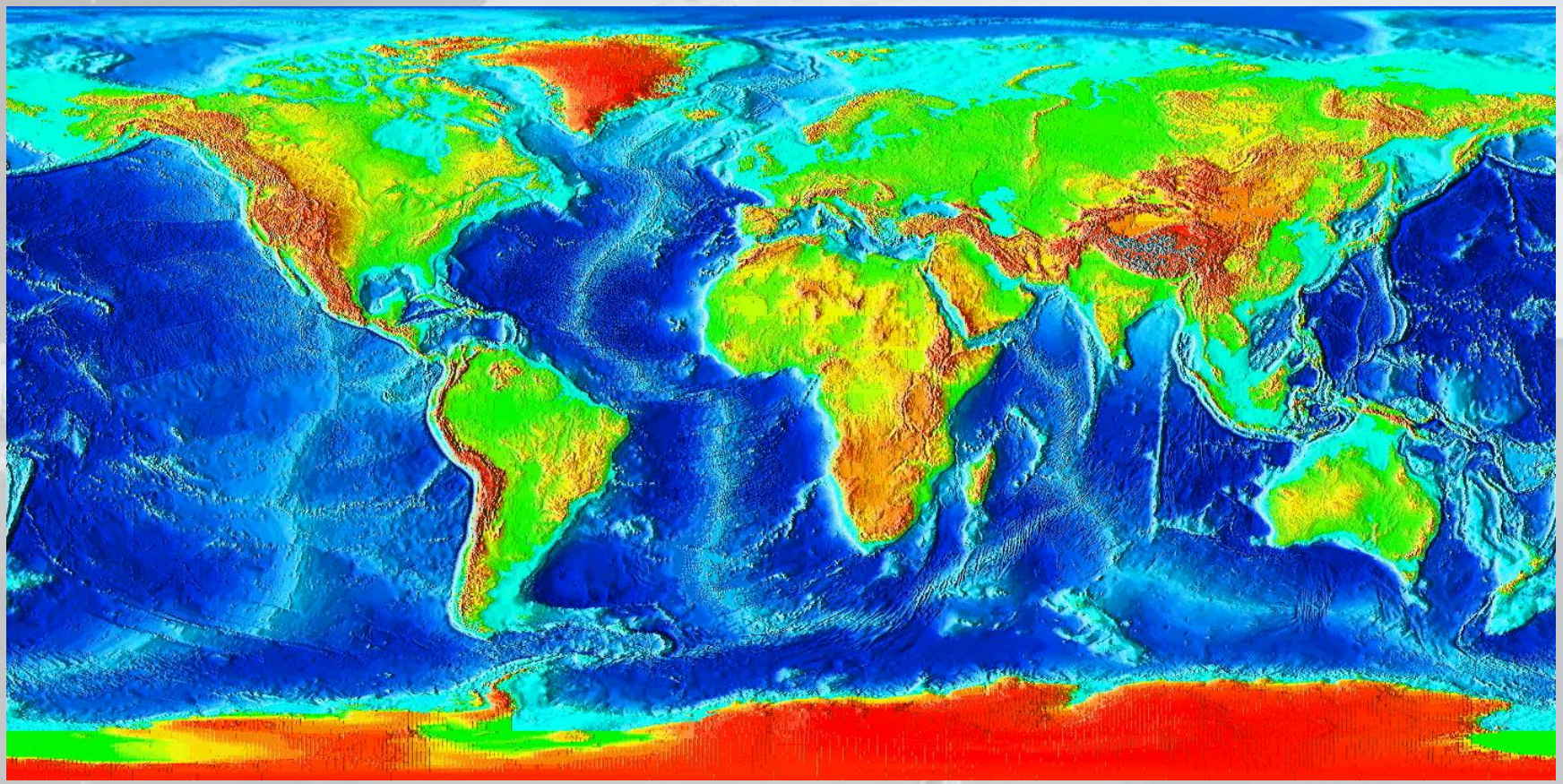
Distribution of volcanoes



Age of the seafloor



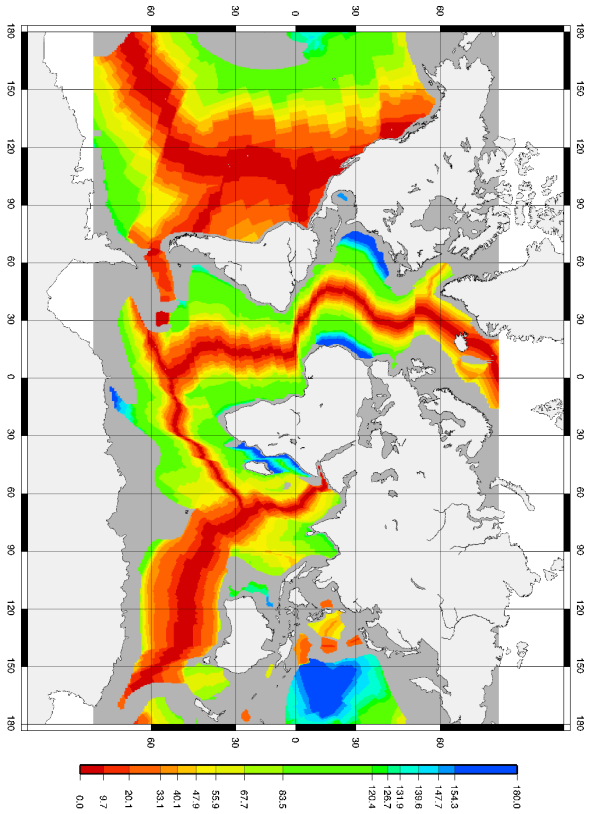
Topographic map – colored for elevation (red = high, blue = low)



SCIENTIFIC SPECIALTY: GEOCHRONOLOGY

Seafloor age in millions of years
This map is from Dietmar Mueller, Univ. of Sydney

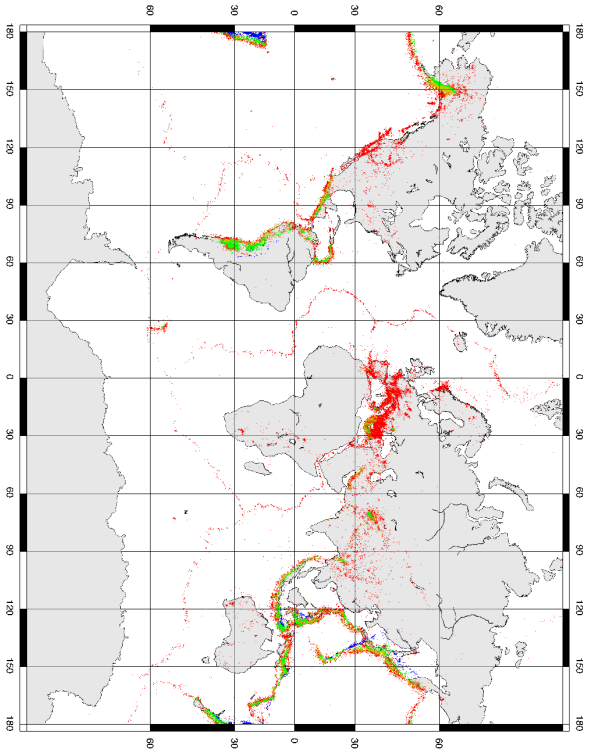
This map is part of "Discovering Plate Boundaries," a classroom exercise developed by Dale S. Sawyer at Rice University (dale@rice.edu). Additional information about this exercise can be found at http://terra.rice.edu/plateboundary .



SCIENTIFIC SPECIALTY: SEISMOLOGY

Earthquake Locations 1990 - 1996 (Magnitudes 4 and greater)
Color indicates depth: Red 0-33 km, Orange 33-70 km, Green 70-300 km, Blue 300-700 km

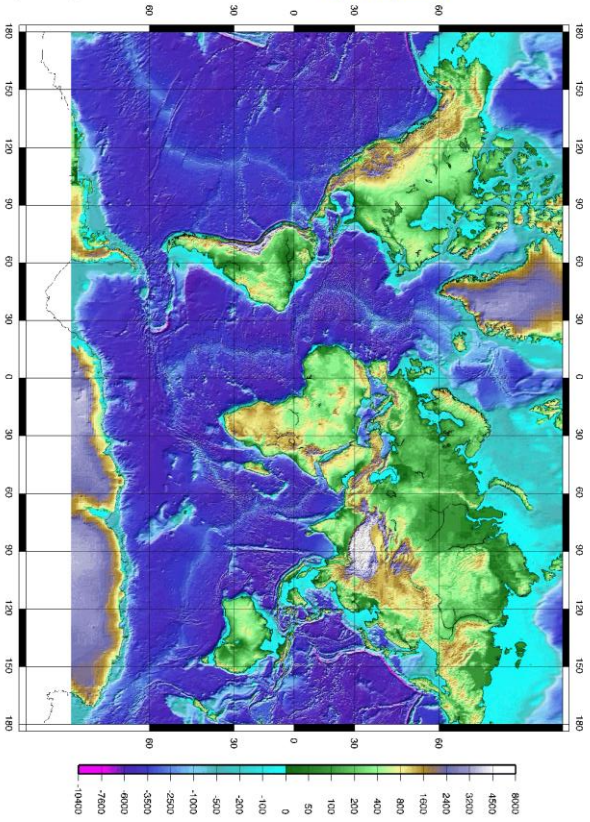
This map is part of "Discovering Plate Boundaries," a classroom exercise developed by Dale S. Sawyer at Rice University (dale@rice.edu). Additional information about this exercise can be found at http://terra.rice.edu/plateboundary .



SCIENTIFIC SPECIALTY: GEOGRAPHY

Elevation in meters above sea level
Map based on widely available dataset ETOPO5

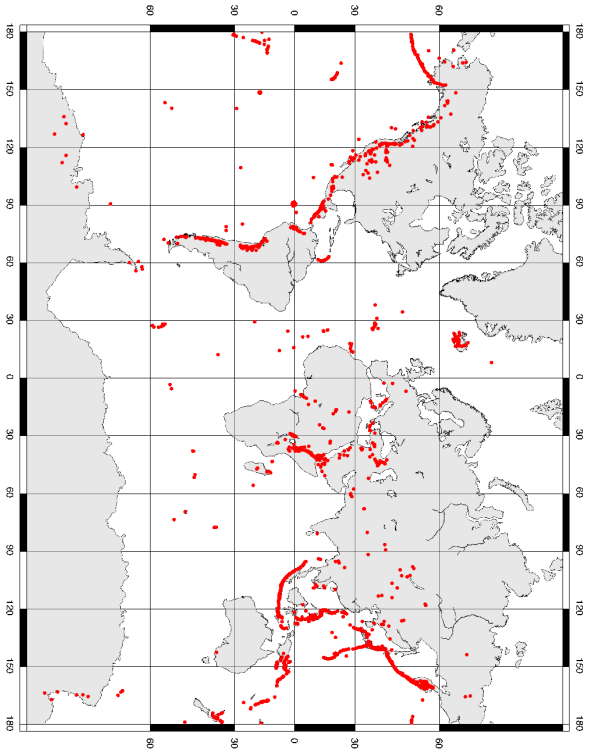
This map is part of "Discovering Plate Boundaries," a classroom exercise developed by Dale S. Sawyer at Rice University (dale@rice.edu). Additional information about this exercise can be found at http://terra.rice.edu/plateboundary .

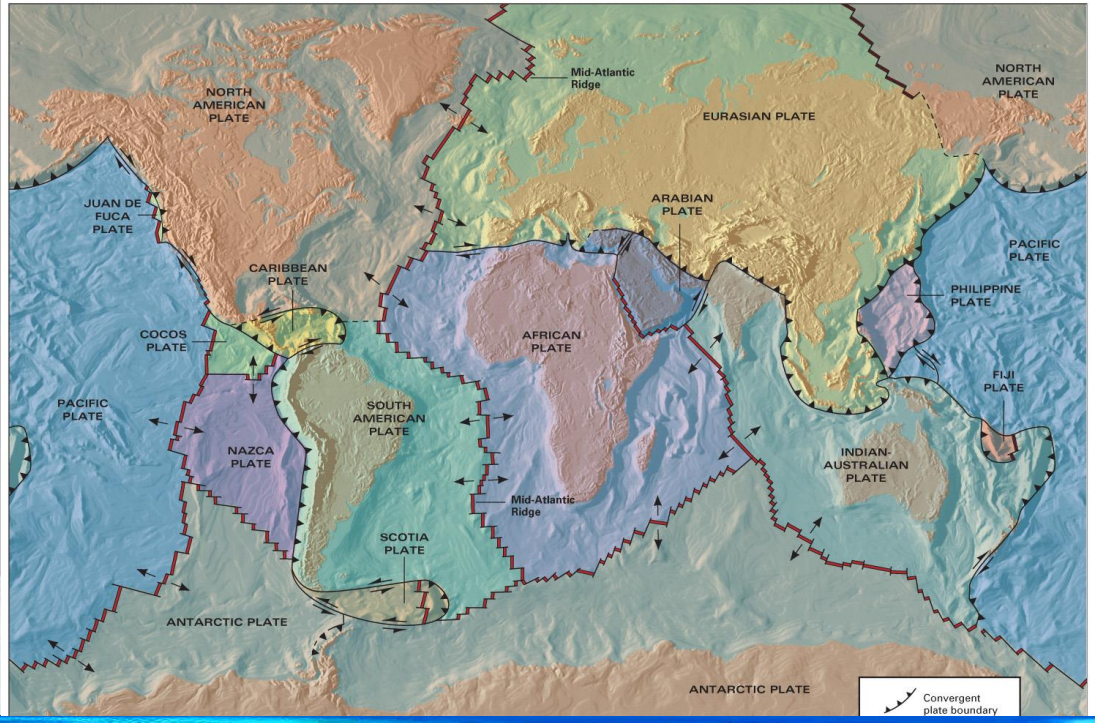


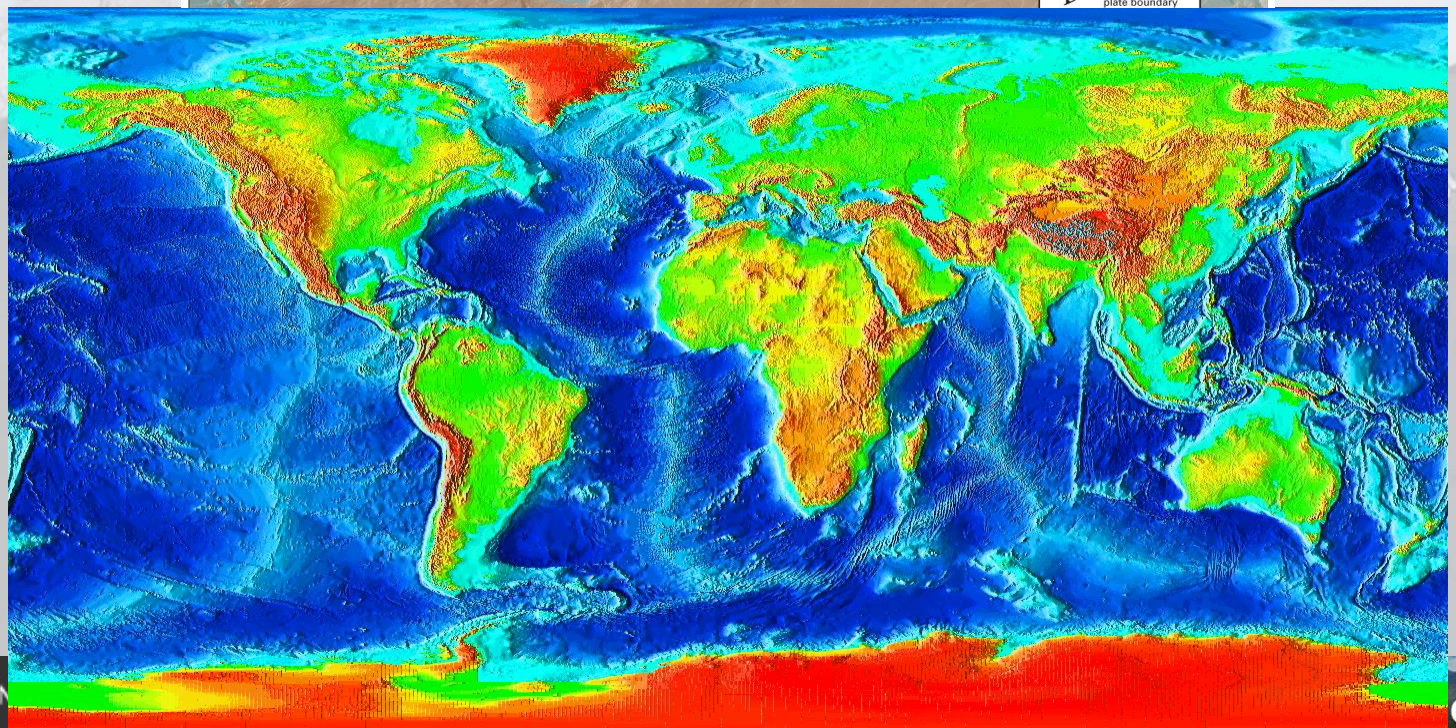
SCIENTIFIC SPECIALTY: VOLCANOLOGY

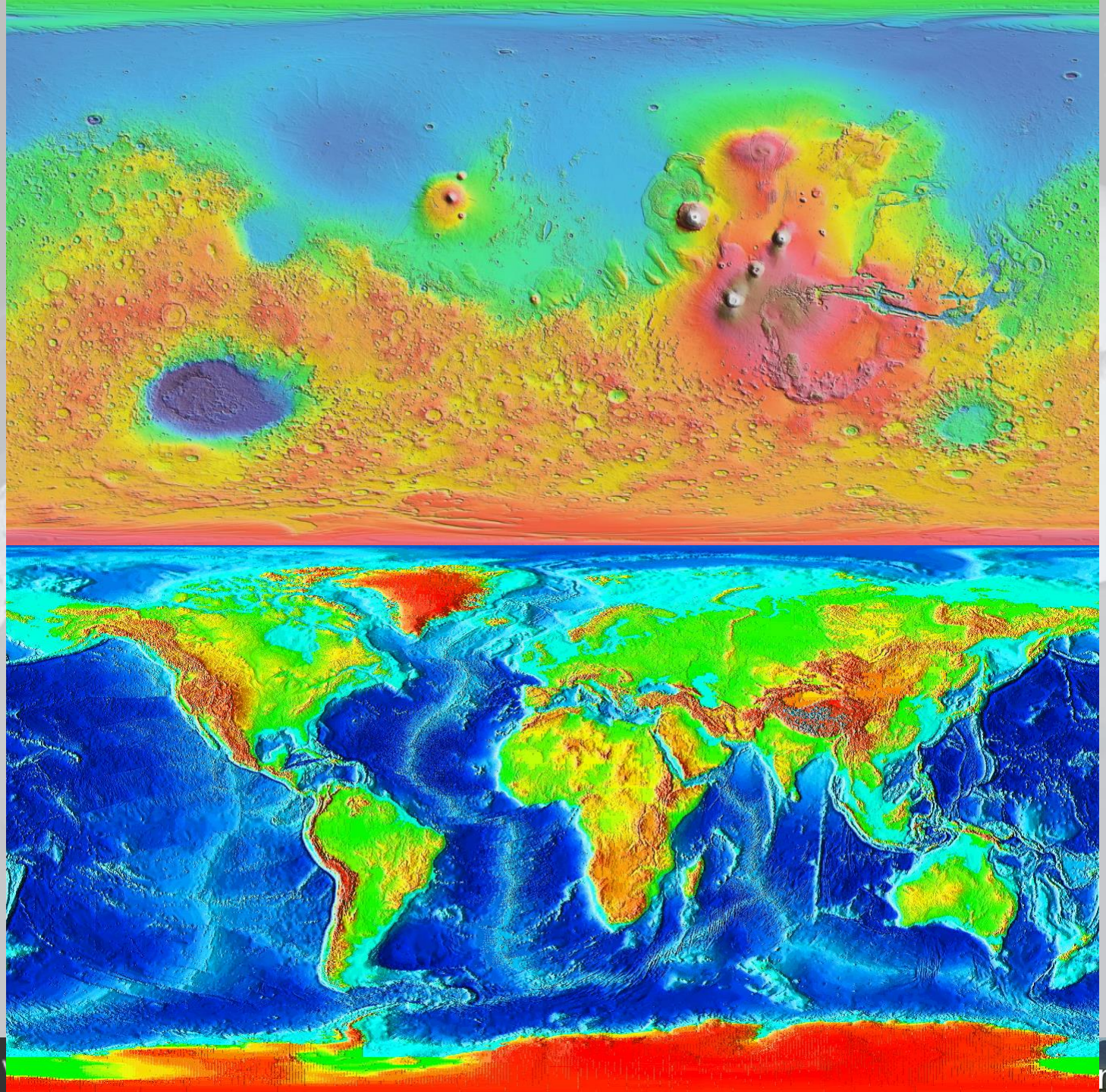
Red dots indicate currently or historically active volcanic features
This list obtained from the Smithsonian Institution

This map is part of "Discovering Plate Boundaries," a classroom exercise developed by Dale S. Sawyer at Rice University (dale@rice.edu). Additional information about this exercise can be found at http://terra.rice.edu/plateboundary .

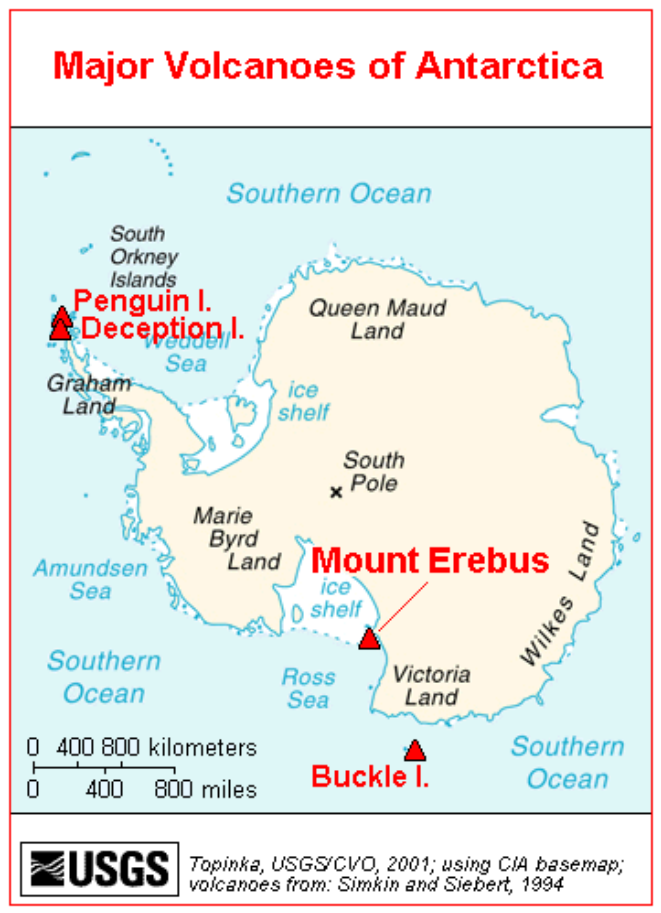



NORTH AMERICAN PLATE
Mid-Atlantic Ridge
EURASIAN PLATE
NORTH AMERICAN PLATE
JUAN DE FUCA PLATE
ARABIAN PLATE
PACIFIC PLATE
CARIBBEAN PLATE
PHILIPPINE PLATE
COCOS PLATE
AFRICAN PLATE
FIJI PLATE
PACIFIC PLATE
SOUTH AMERICAN PLATE
NAZCA PLATE
INDIAN-AUSTRALIAN PLATE
Mid-Atlantic Ridge
SCOTIA PLATE
ANTARCTIC PLATE
ANTARCTIC PLATE
Convergent plate boundary

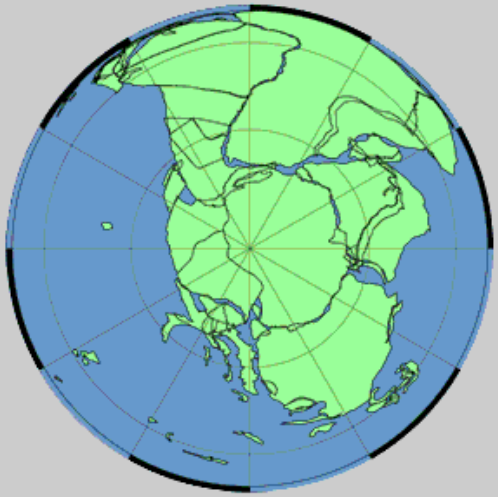




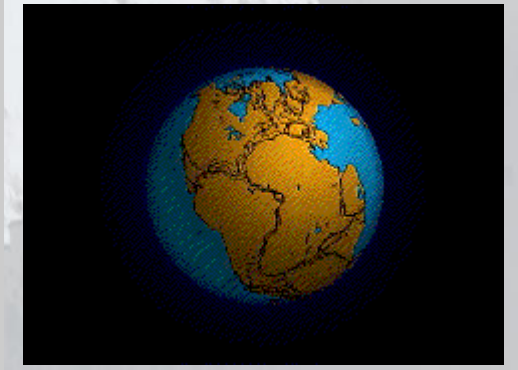
Geology



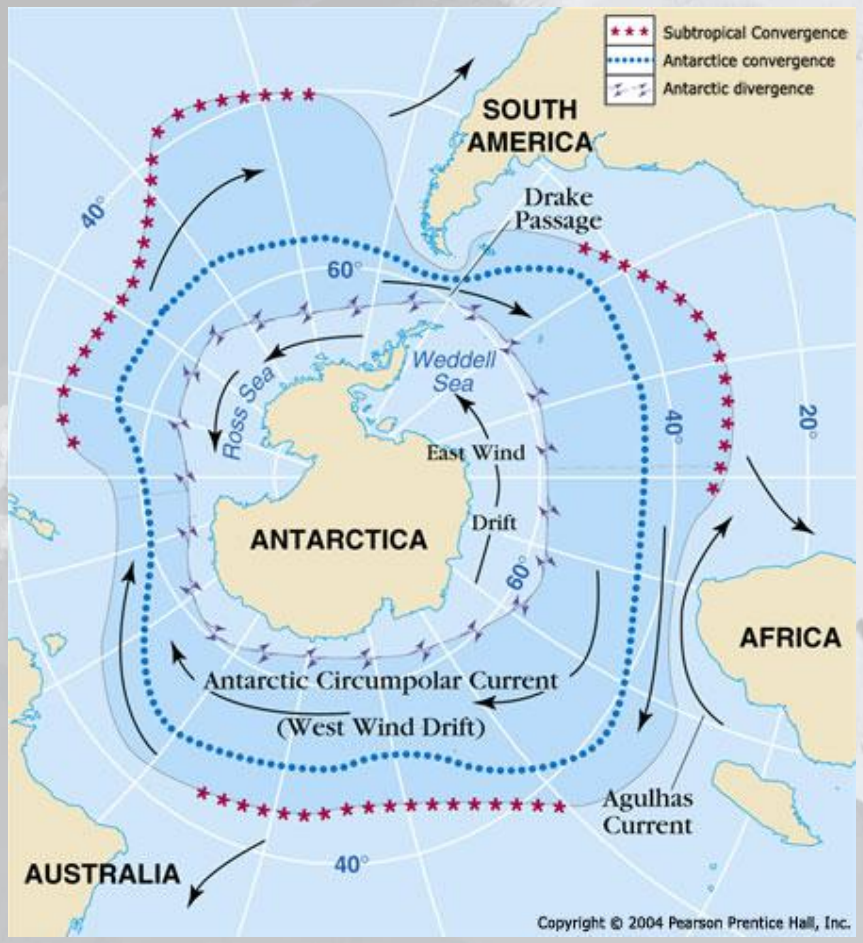
- Tectonically isolated
- Few volcanoes, earthquakes, or young mountains
- Central to recreating former supercontinents



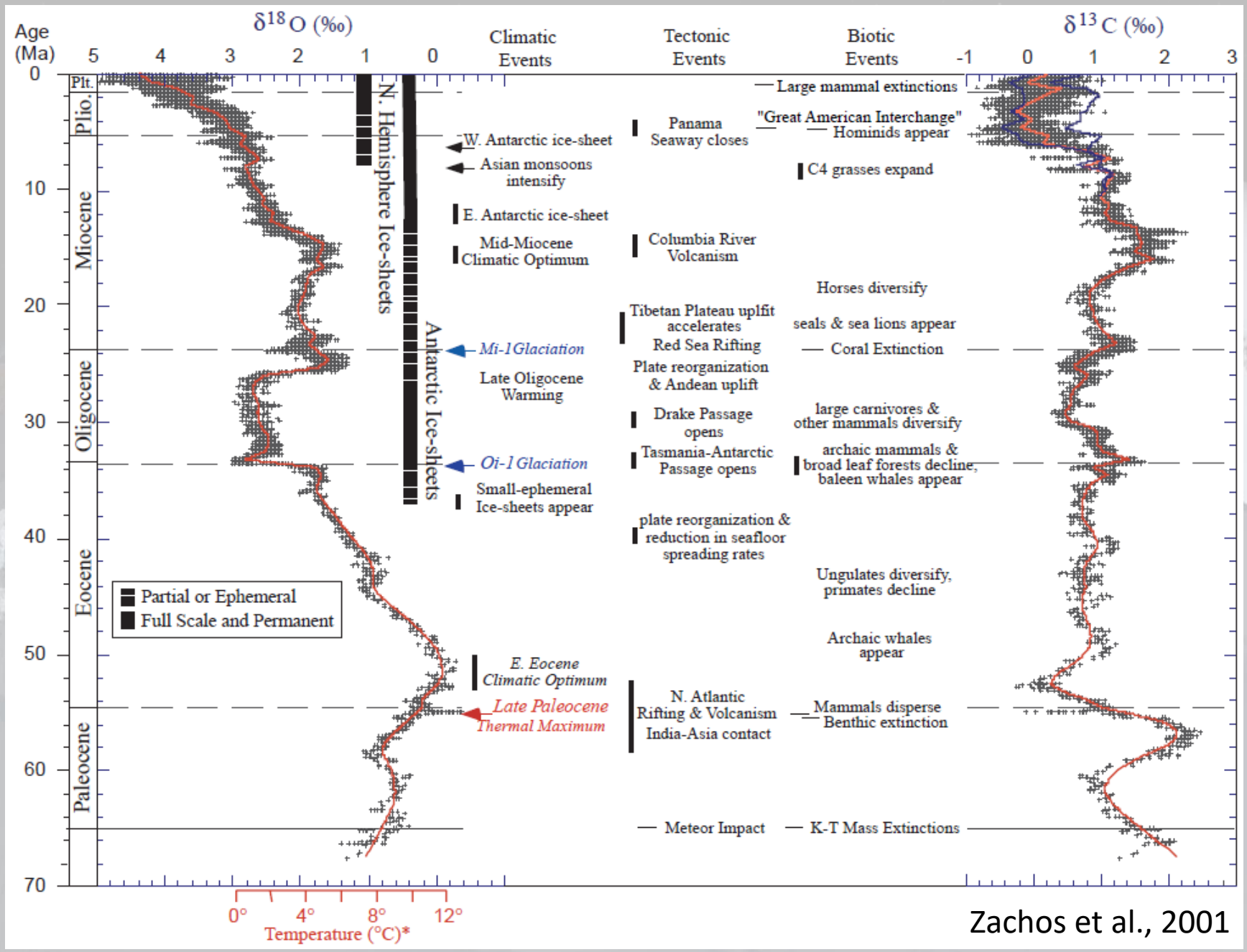
150 Million Years Ago



Geology and climate



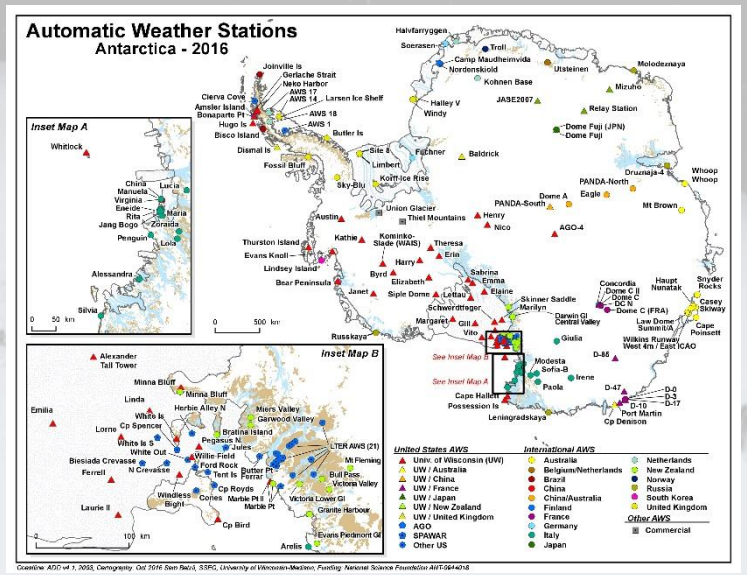
- Antarctica separated from South America ~34 Million years ago
- Antarctic Circumpolar Current largest wind-driven current in world!
- Heat has a hard time making it to the interior → Antarctica is cold and icy



Zachos et al., 2001

Modern Climate

- Average snowfall 17 cm/year of water equivalent
- Persistent surface winds
- Surface reflects ~80% of light



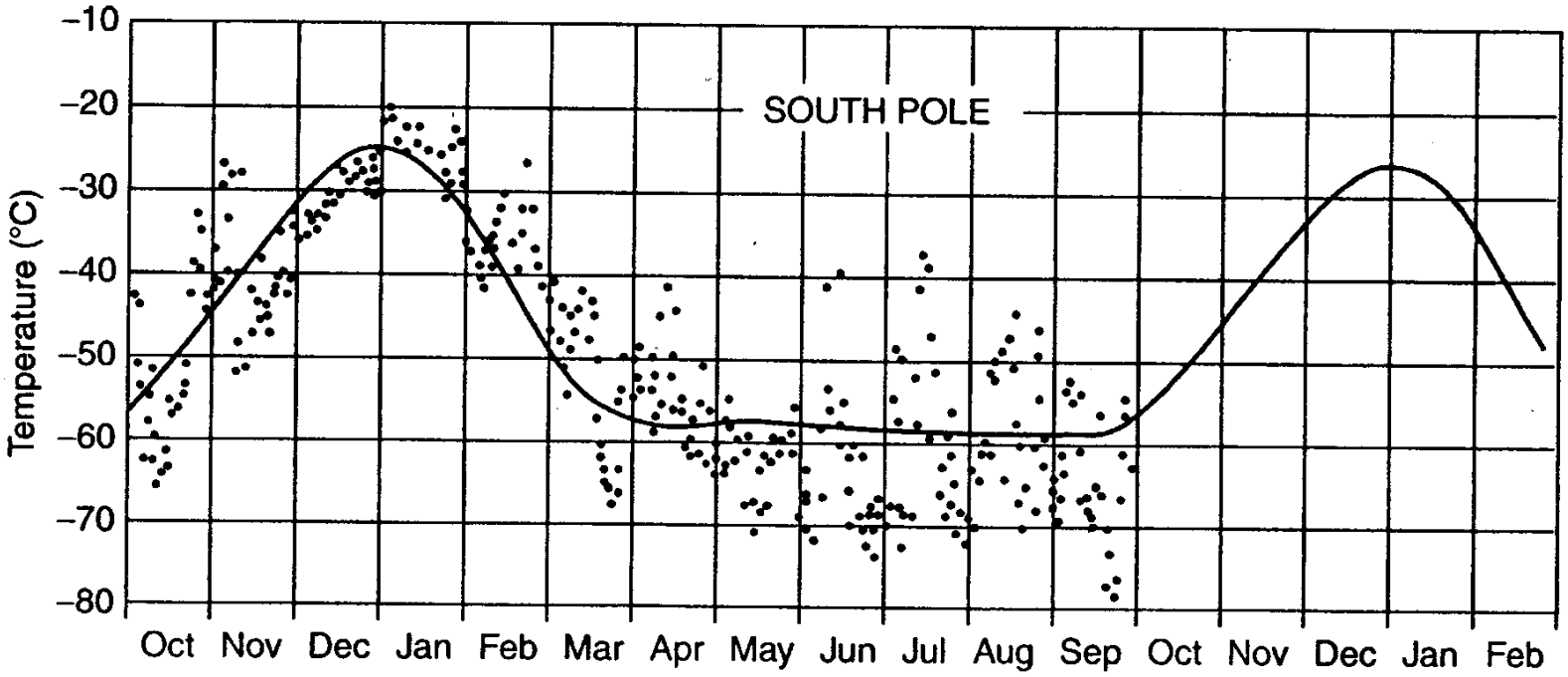
ANTARCTICA. Table 1. *Surface air temperatures at representative Antarctic stations*

Region	*Low-latitude coast*	*High-latitude coast*	*West Antarctica*	*East Antarctica*	
Station	*Mirnyy*	*Little America (Framheim)*	*Byrd*	*South Pole*	*Vostok*
Latitude (°S)	66	78	80	90	78
Elevation (meters)	30	40	1500	2800	3500
Station pressure (millibars)	980	980	800	680	620
Mean summer temperature (°C)	−2	−7	−15	−28	−33
Mean winter temperature (°C)	−16	−33	−34	−58	−66
Extreme maximum temperature (°C)	+8	+6	−1	−14	−21
Extreme minimum temperature (°C)	−40	−61	−63	−81	−89

Warren and Town, 2011

Annual temperature cycle at the south pole

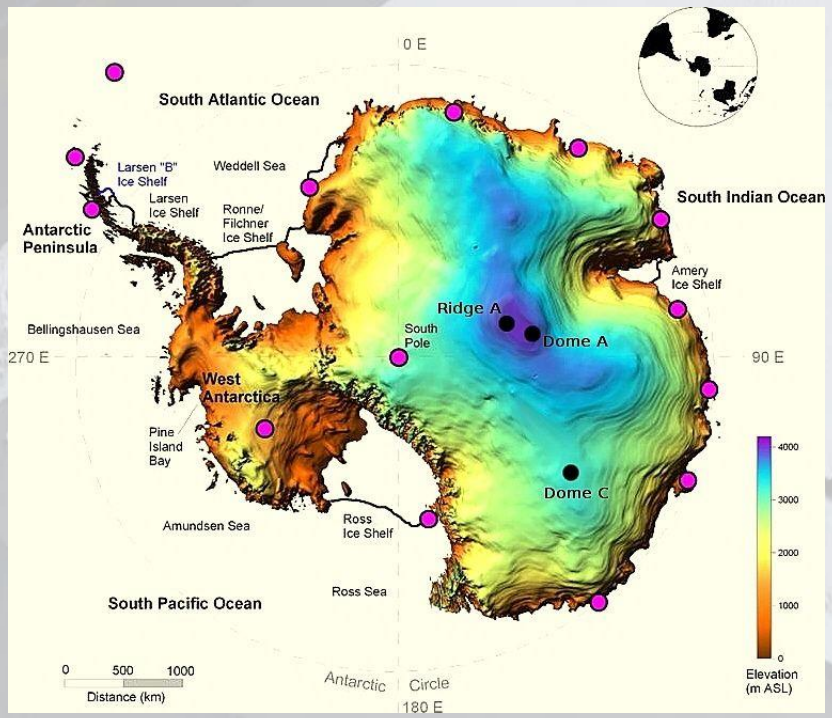
http://www.usap.gov/videoclipsandmaps/mcmwebcam.cfm

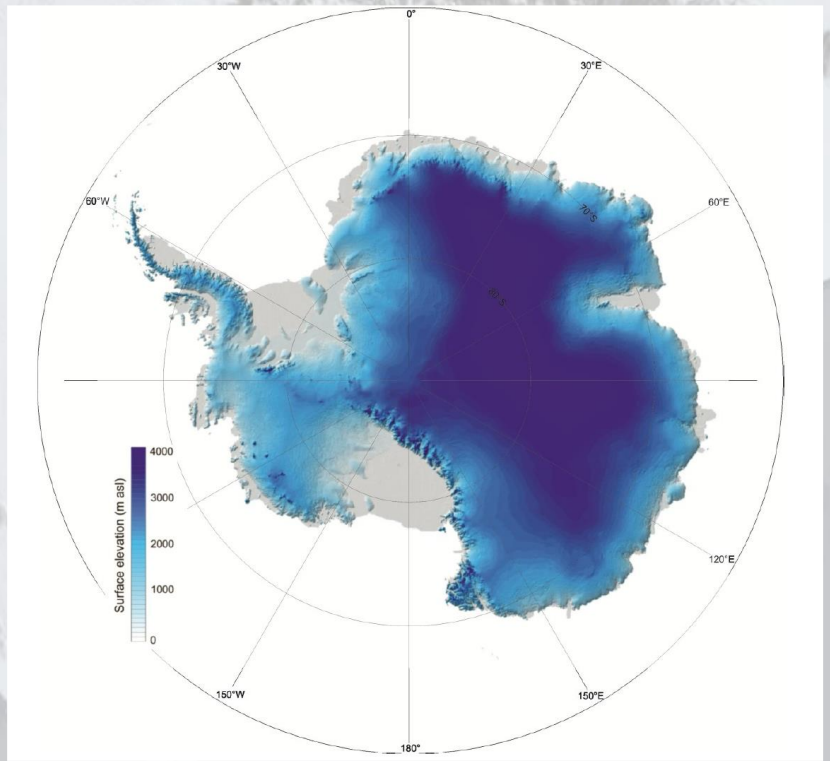


ANTARCTICA. Figure 2. *Surface air temperatures at South Pole Station.* Solid line: 20-year mean for each day. Dots: daily mean temperatures for the year October 1985 to September 1986.

Warren and Town, 2011

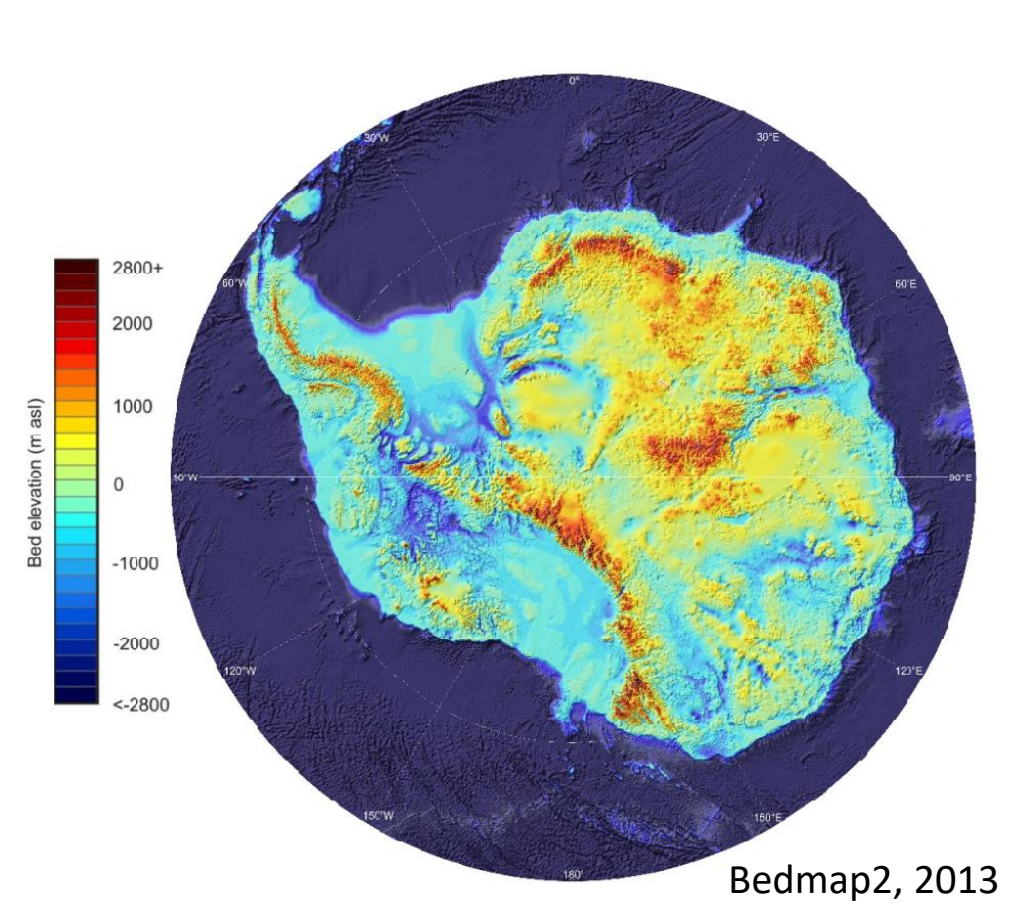
Topography



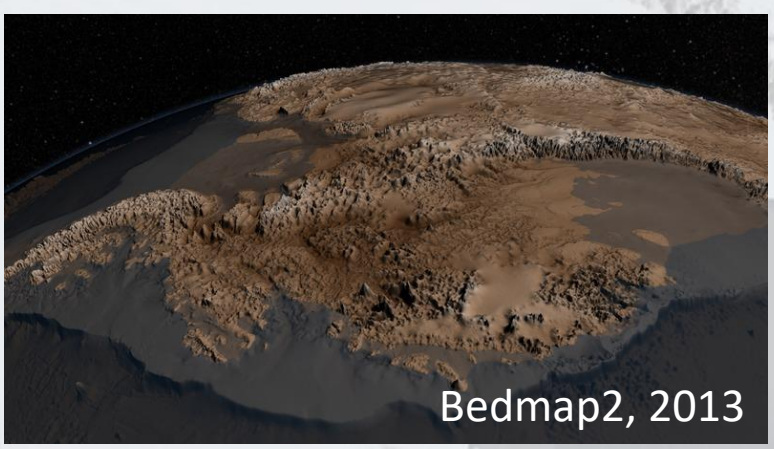


Bedmap2, 2013

Bedrock elevation

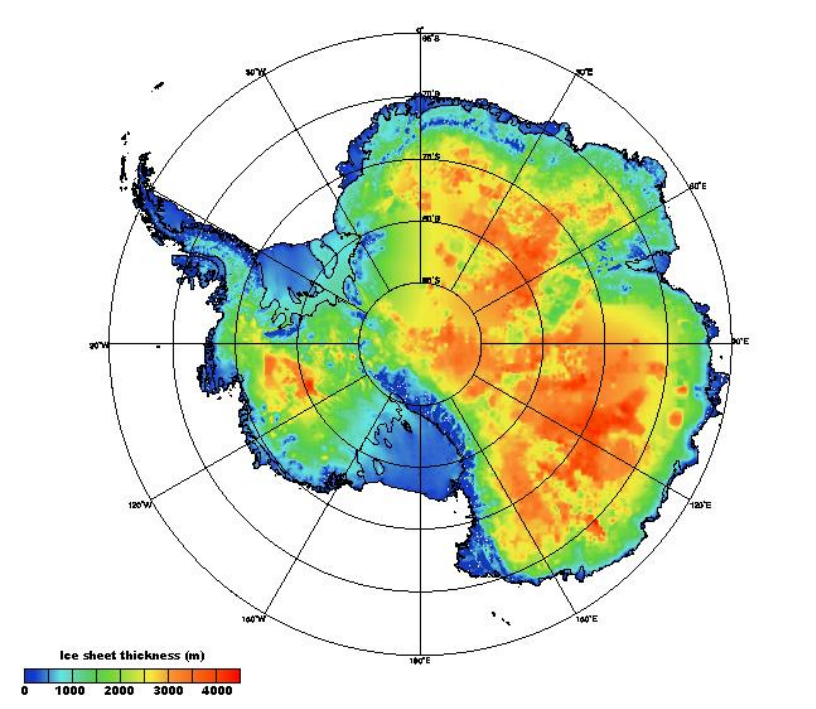


Bedmap2, 2013

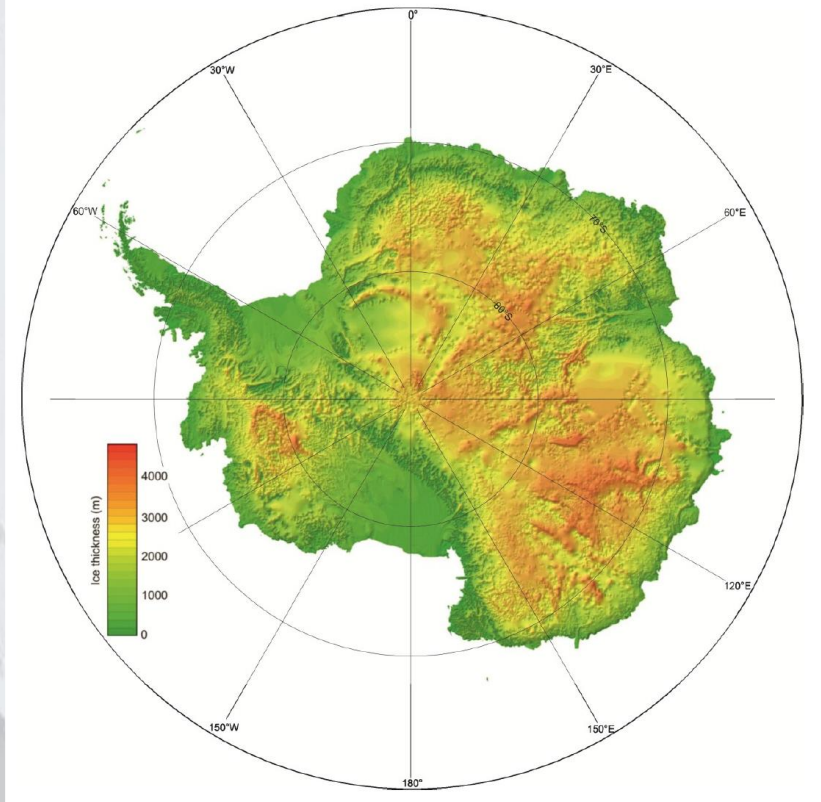


http://www.nasa.gov/topics/earth/features/antarctic-map.html

Ice thickness



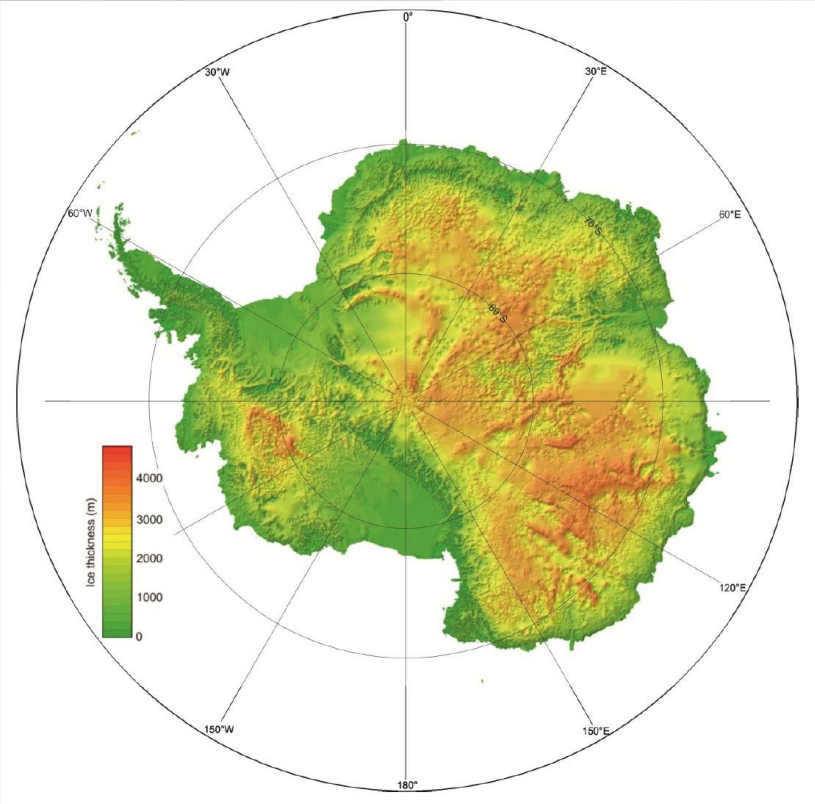
Bedmap, 2000

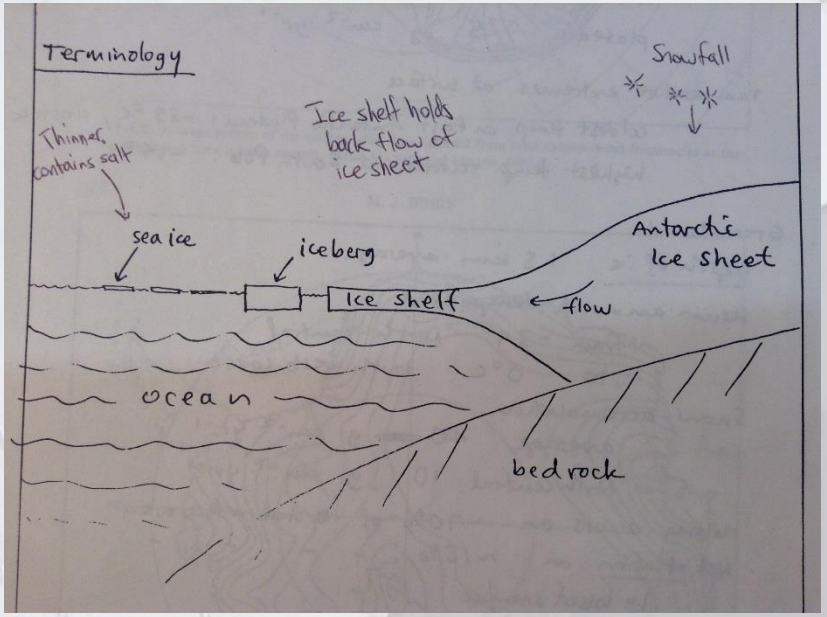


Bedmap2, 2013

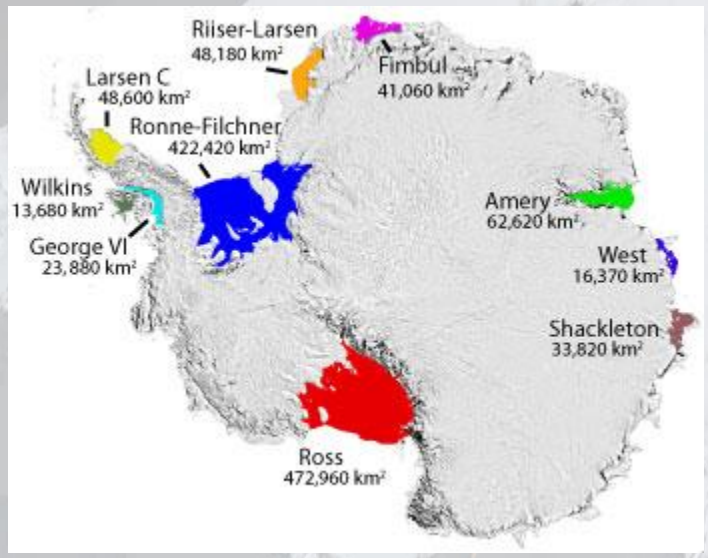
Mean ice thickness 2,126 m

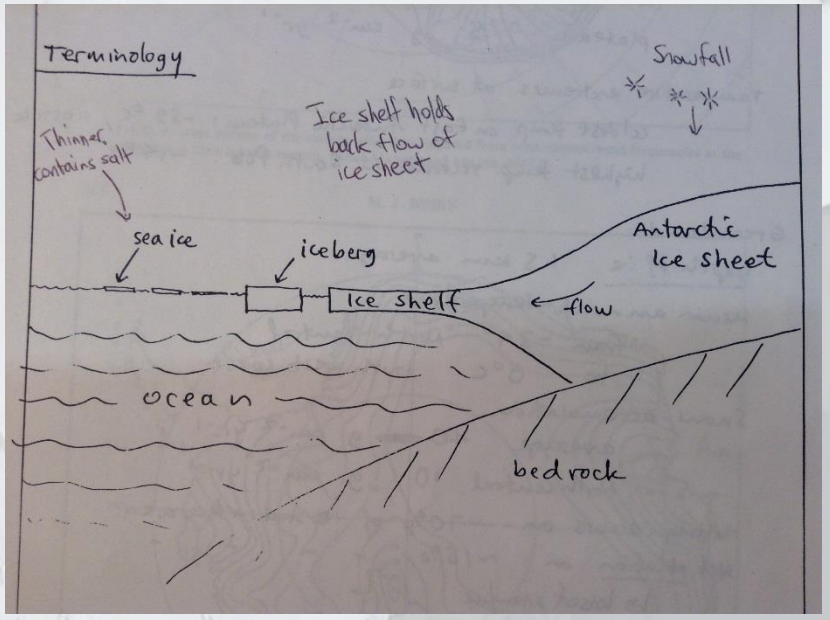
What is an ice sheet?





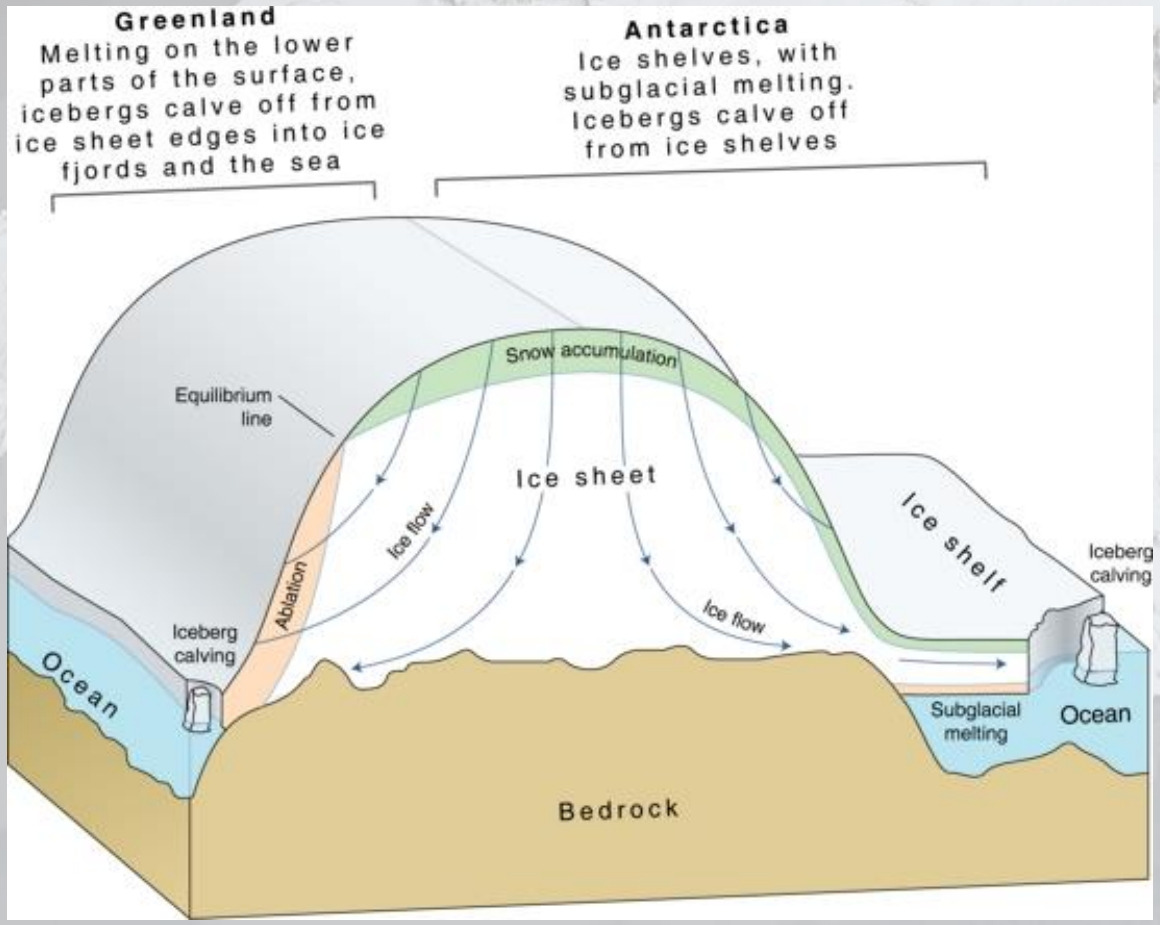
Ice Shelves - Glacier ice that flows into ocean



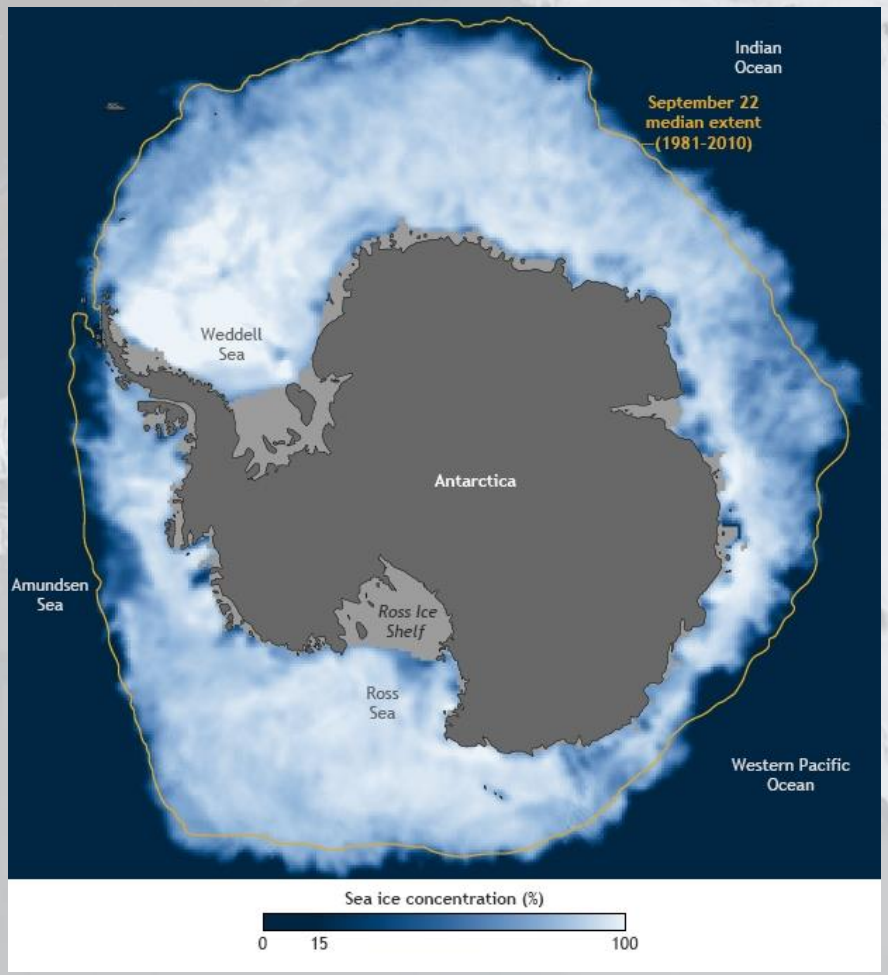


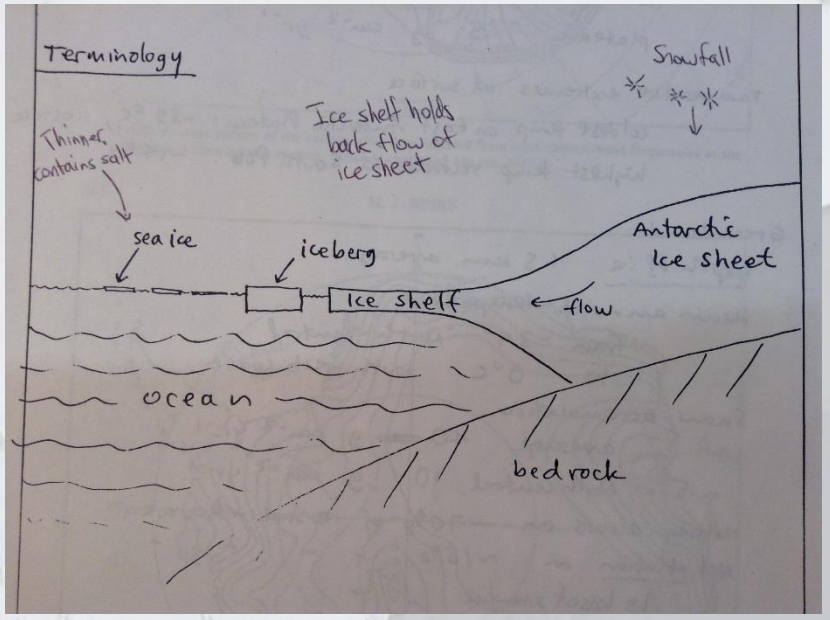
http://earthobservatory.nasa.gov/Features/WorldOfChange/larsenb.php

Ice Sheet Schematic

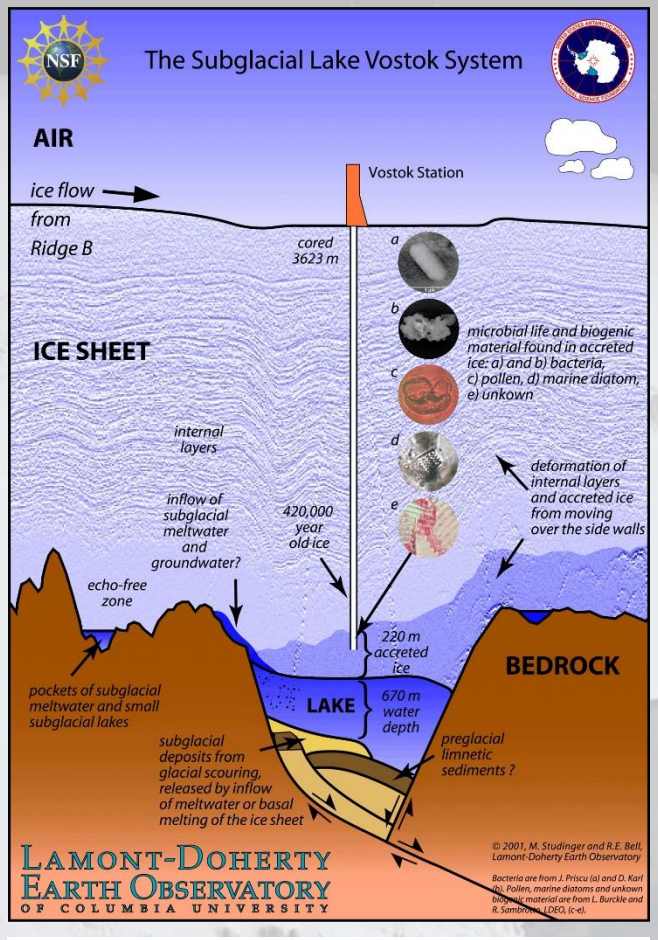


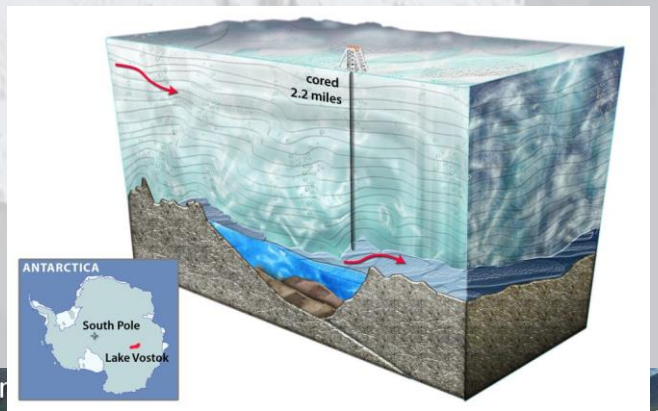
Sea ice – ocean water that freezes



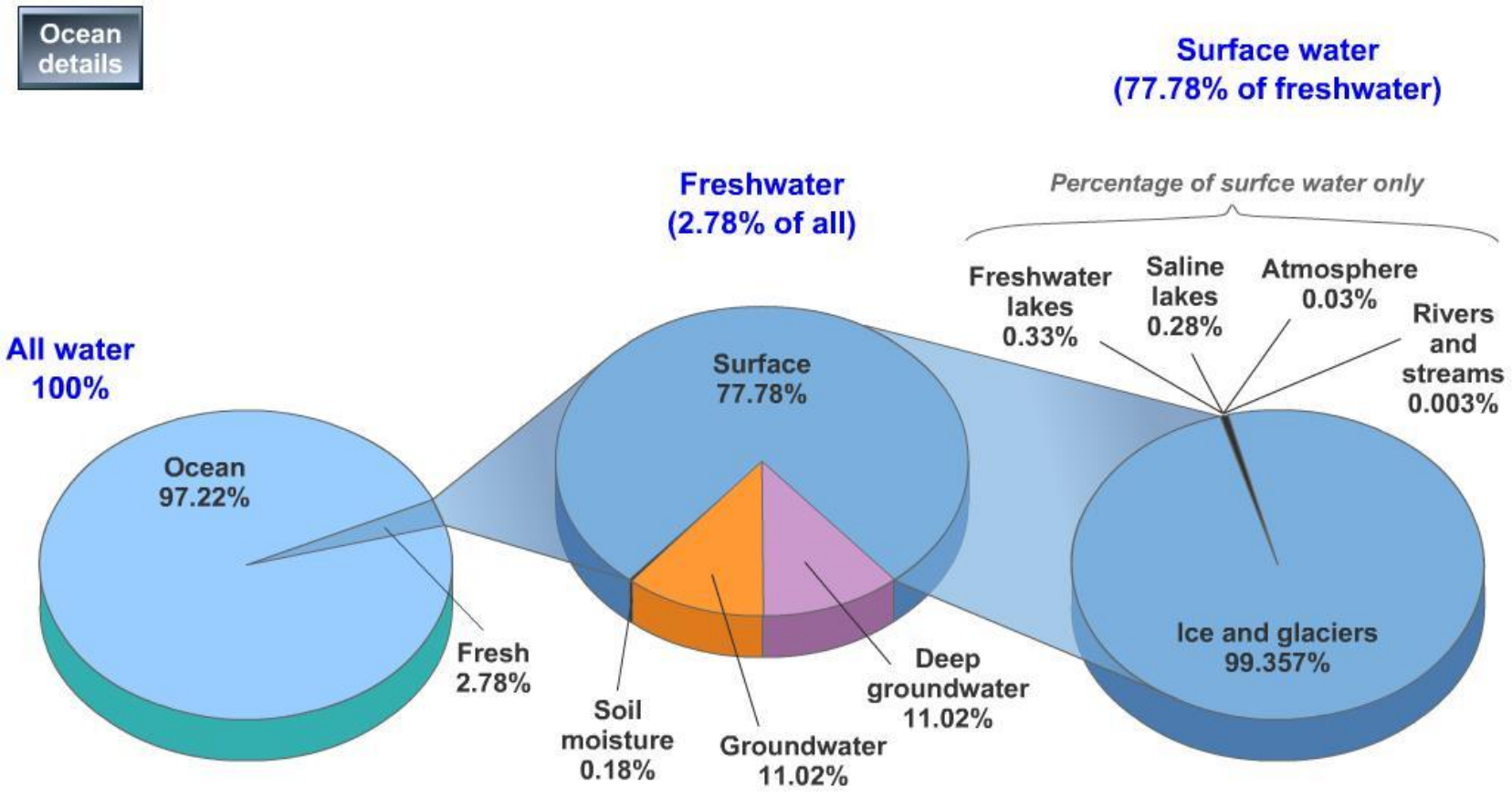


Subglacial Lakes





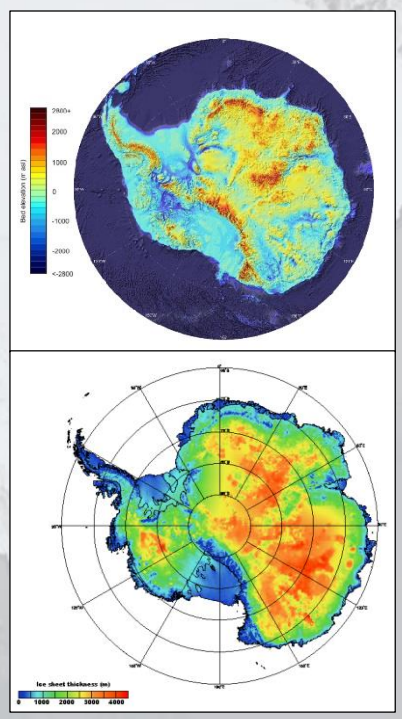
Global water budget



Volumes of ice

Ice	~Sea level equiv. (m)	% of total
Antarctica	~58	90
(East Antarctica ~52)		
(West Antarctica ~6)		
Greenland	~6	9
Other glaciers	~0.3	<1
Permafrost	~1	<1

(Change in sea level from last glacial maximum ~120m)



Biology

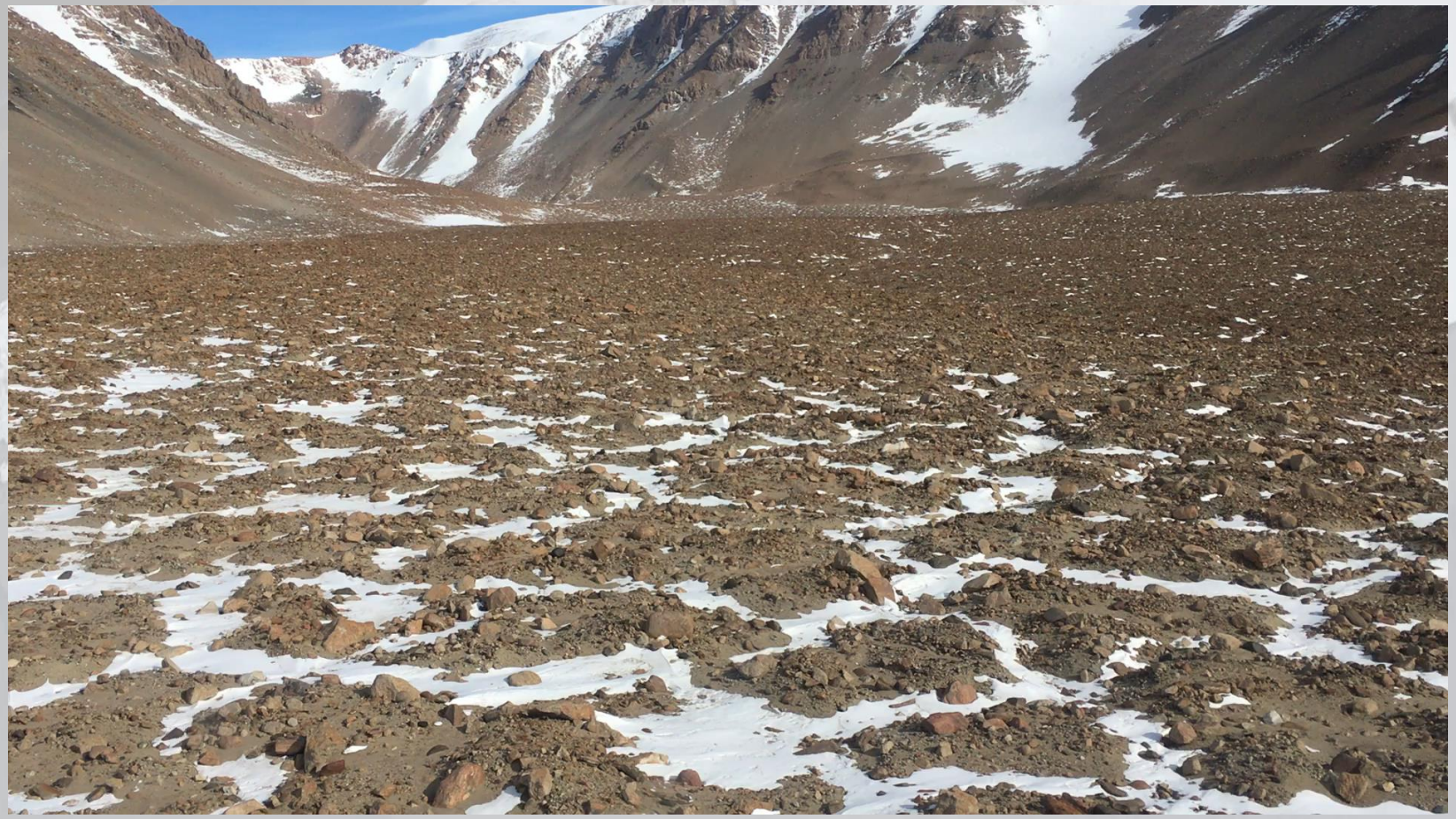
What I've seen in Antarctica

Nematodes, tardigrades, & rotifers

- Microscopic life is abundant even in apparently barren landscapes
- Nematodes (similar to worms), tardigrades (water bears), and rotifers (wheel animals) are top of food chain in most inland ecosystems
- Depend on liquid water for activity, but survive for years when cold and dry

Most of Antarctica is covered in ice

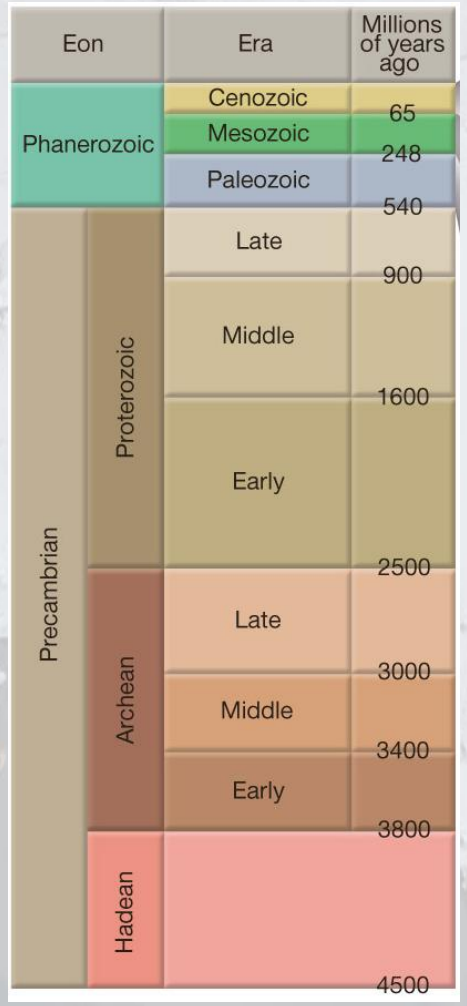
A few parts are mostly dirt

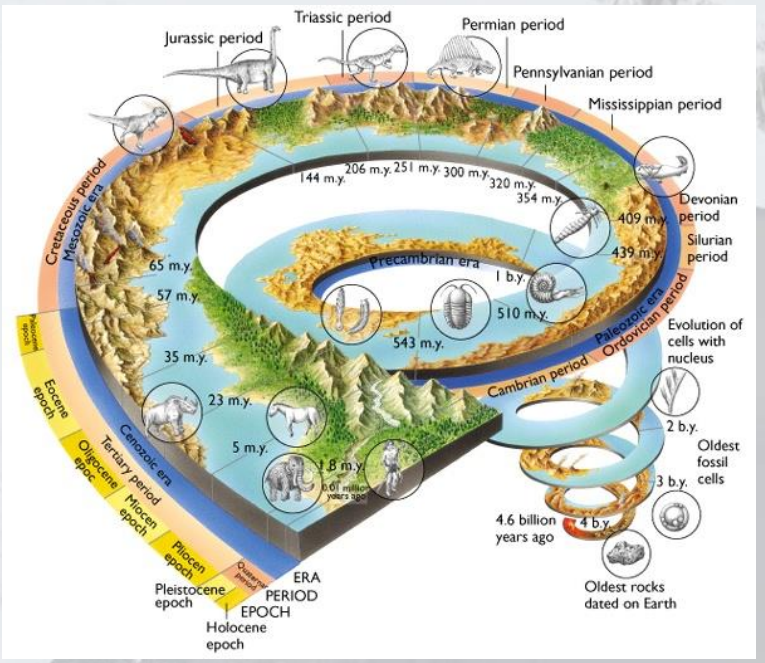


Where nothing happens that fast

Thought Questions

- How old is Earth?
- When did land plants evolve?
- What did the surface of continents look like before this?



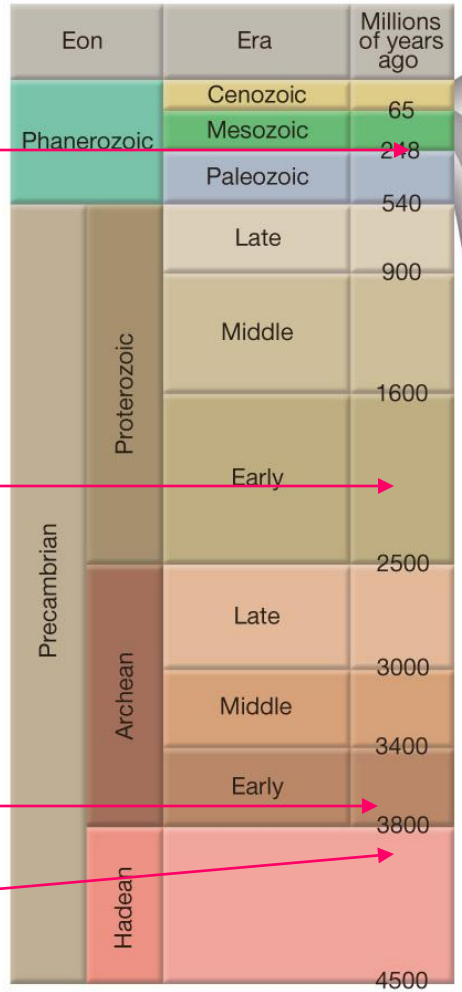


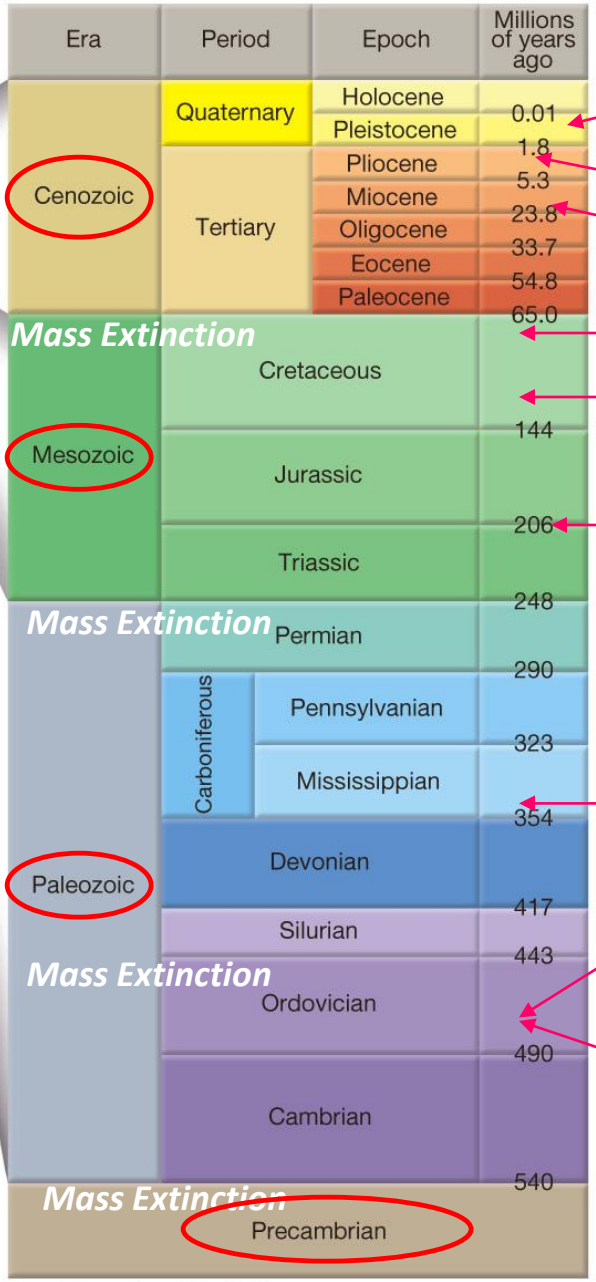
Biggest Extinction

Significant amounts of Oxygen in atmosphere

First Bacteria

Oldest known rocks





Homo sapiens

"Lucy"

Grasses

Triceratops

First Ants

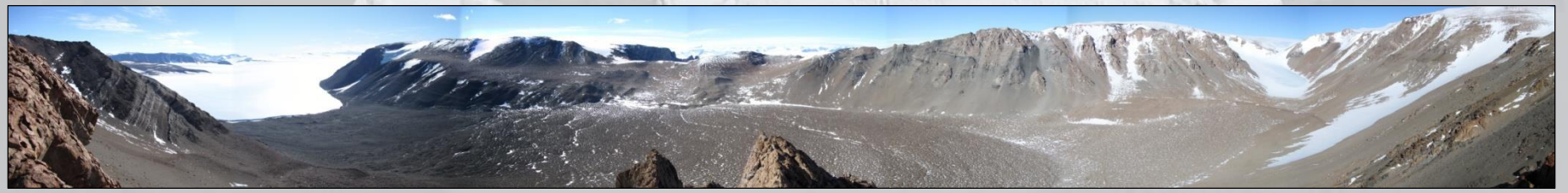
First Mammals and flowers

First Ferns

First Land Plants

First (jawless) Fish

Surfaces without vegetation



Questions