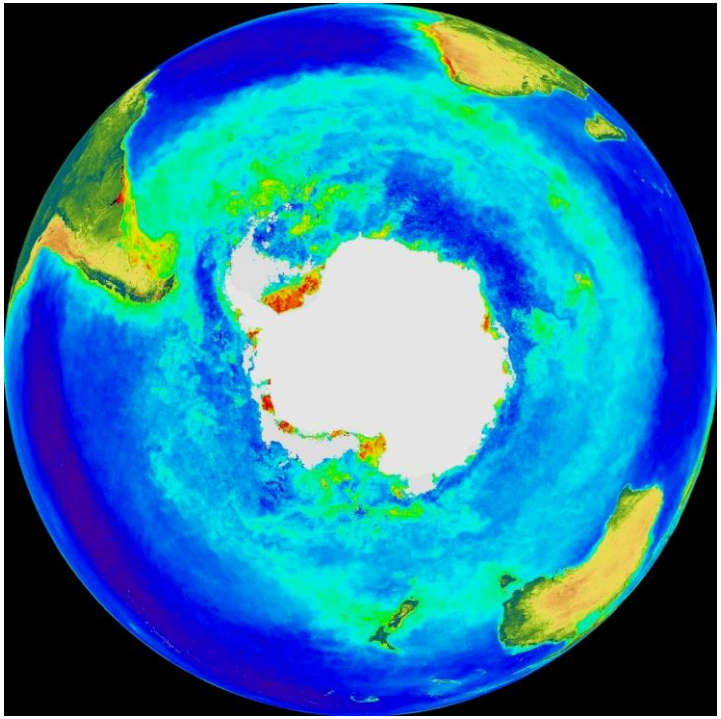
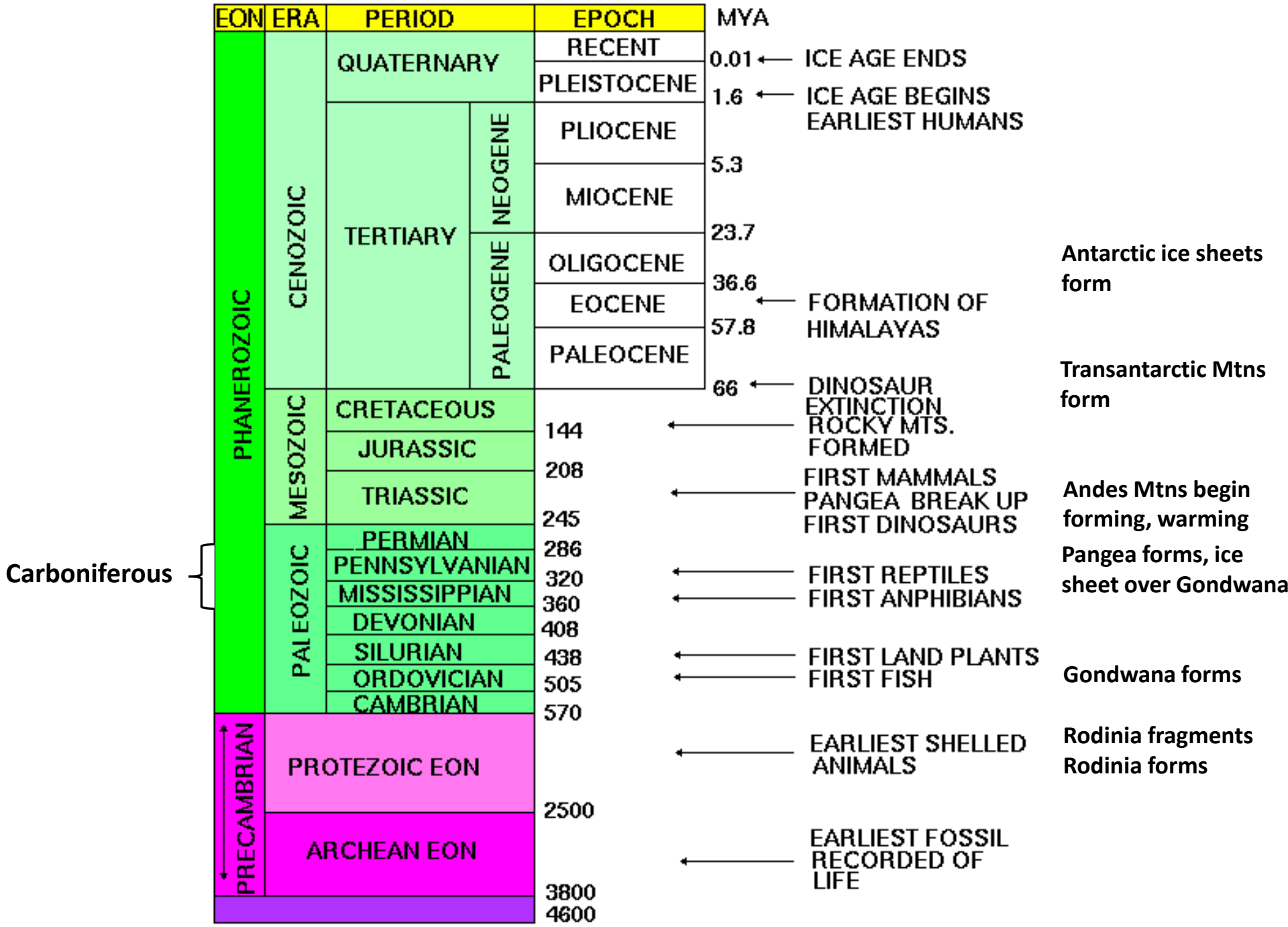
Antarctic Origins

I. Geologic timescale
II. Plate Tectonics
III. Rodinia, Pangea and Gondwana
IV. Antarctic Continent and Geology

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FORMATION OF HIMALAYAS
57.8
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CRETACEOUS
JURASSIC
TRIASSIC
66
DINOSAUR EXTINCTION
144
ROCKY MTS. FORMED
208
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PANGEA BREAK UP
FIRST DINOSAURS
Transantarctic Mtns form
Andes Mtns begin forming, warming
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286
PENNSYLVANIAN
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MISSISSIPPIAN
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SILURIAN
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CAMBRIAN
570
Carboniferous
Pangea forms, ice sheet over Gondwana
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FIRST ANPHIBIANS
FIRST LAND PLANTS
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Gondwana forms
PRECAMBRIAN
PROTEZOIC EON
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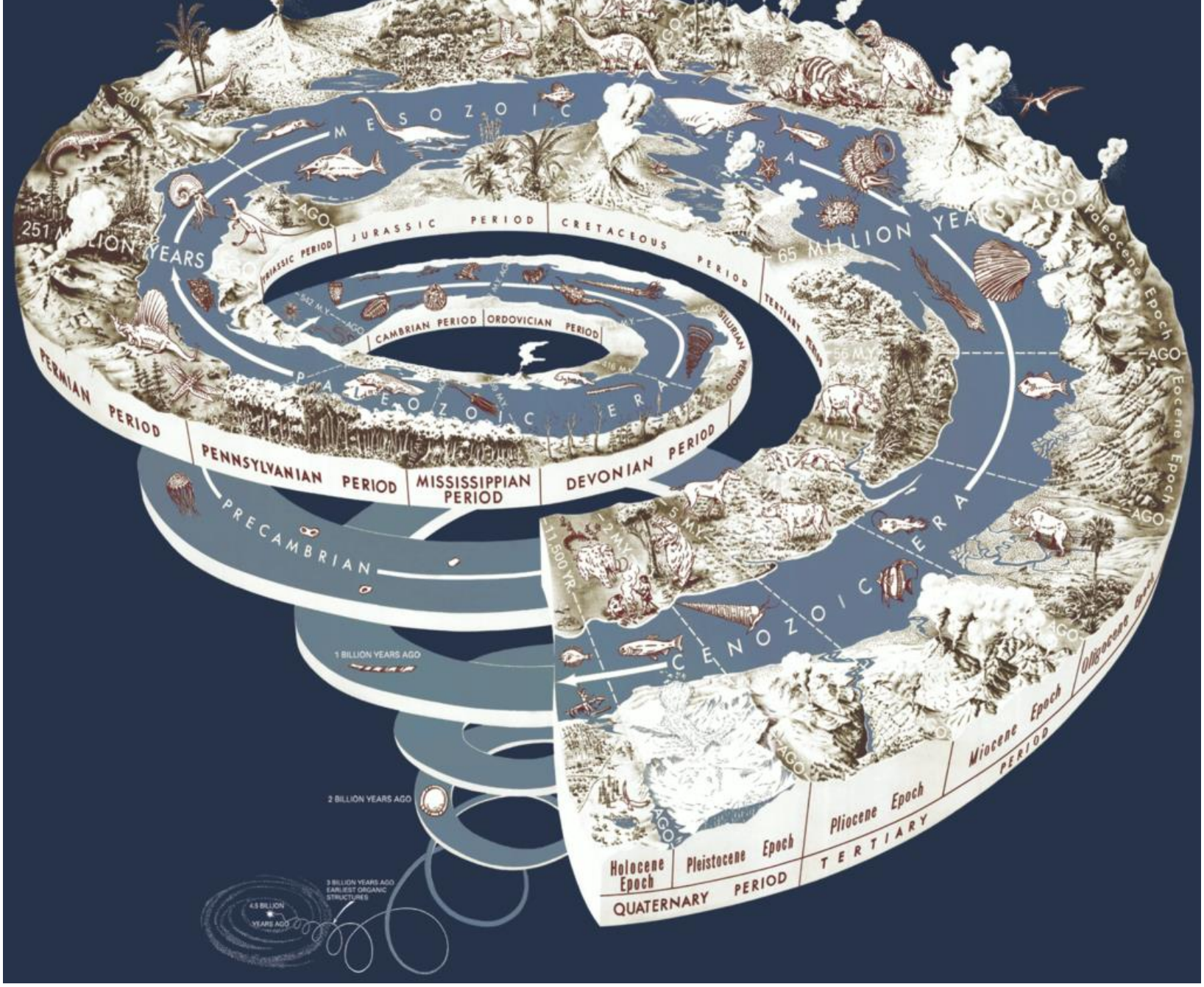
EARLIEST SHELLED ANIMALS
Rodinia fragments
Rodinia forms
EARLIEST FOSSIL RECORDED OF LIFE



https://en.wikipedia.org/wiki/Geochronology

Three major types of rocks:

1. **Igneous: liquid to solid, basalt, granite**

2. **Sedimentary: accumulation of pieces of other rocks, sandstone**

3. **Metamorphic: changed rock from melting or pressure, schist, marble**

Plate Tectonics (Continental Drift)

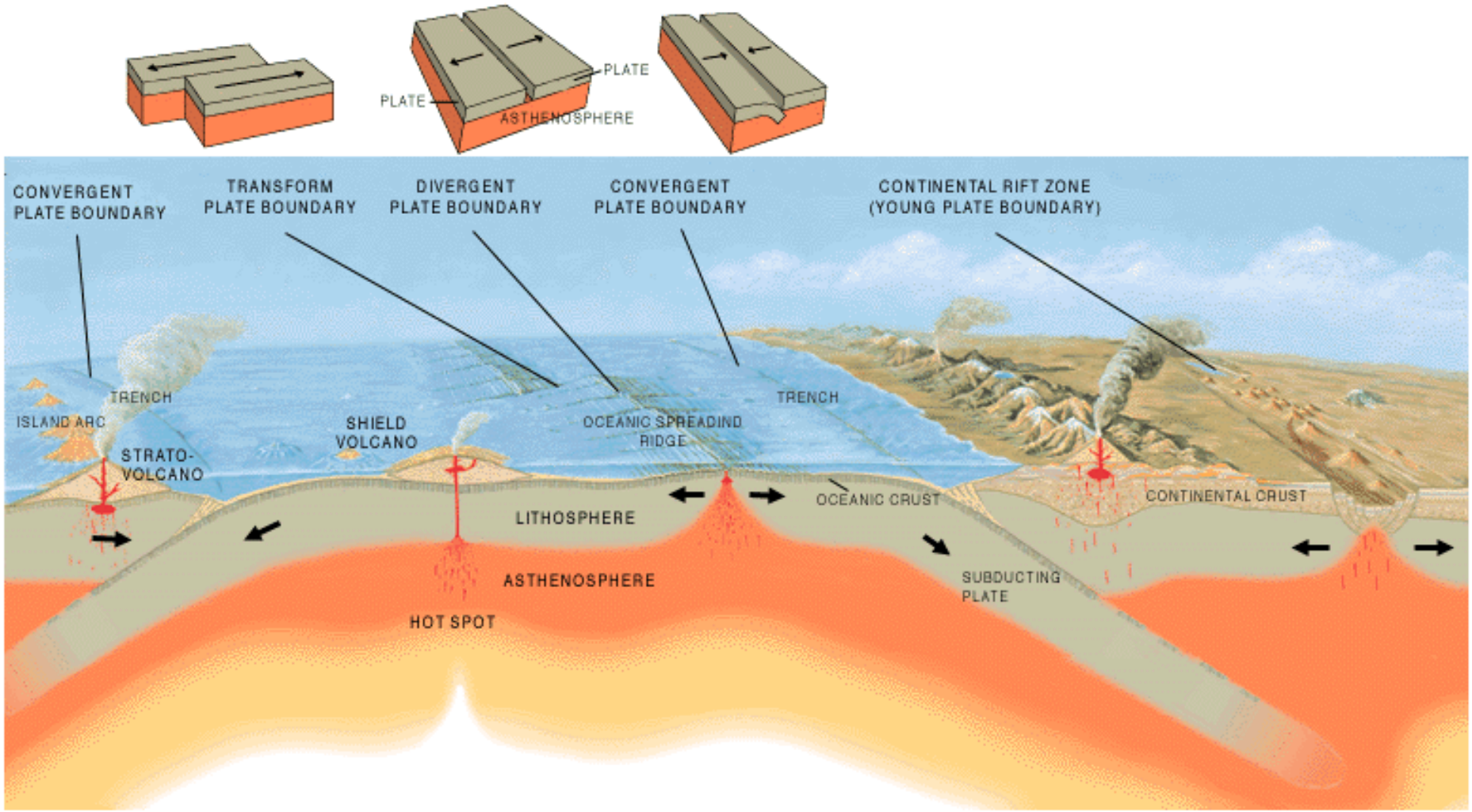
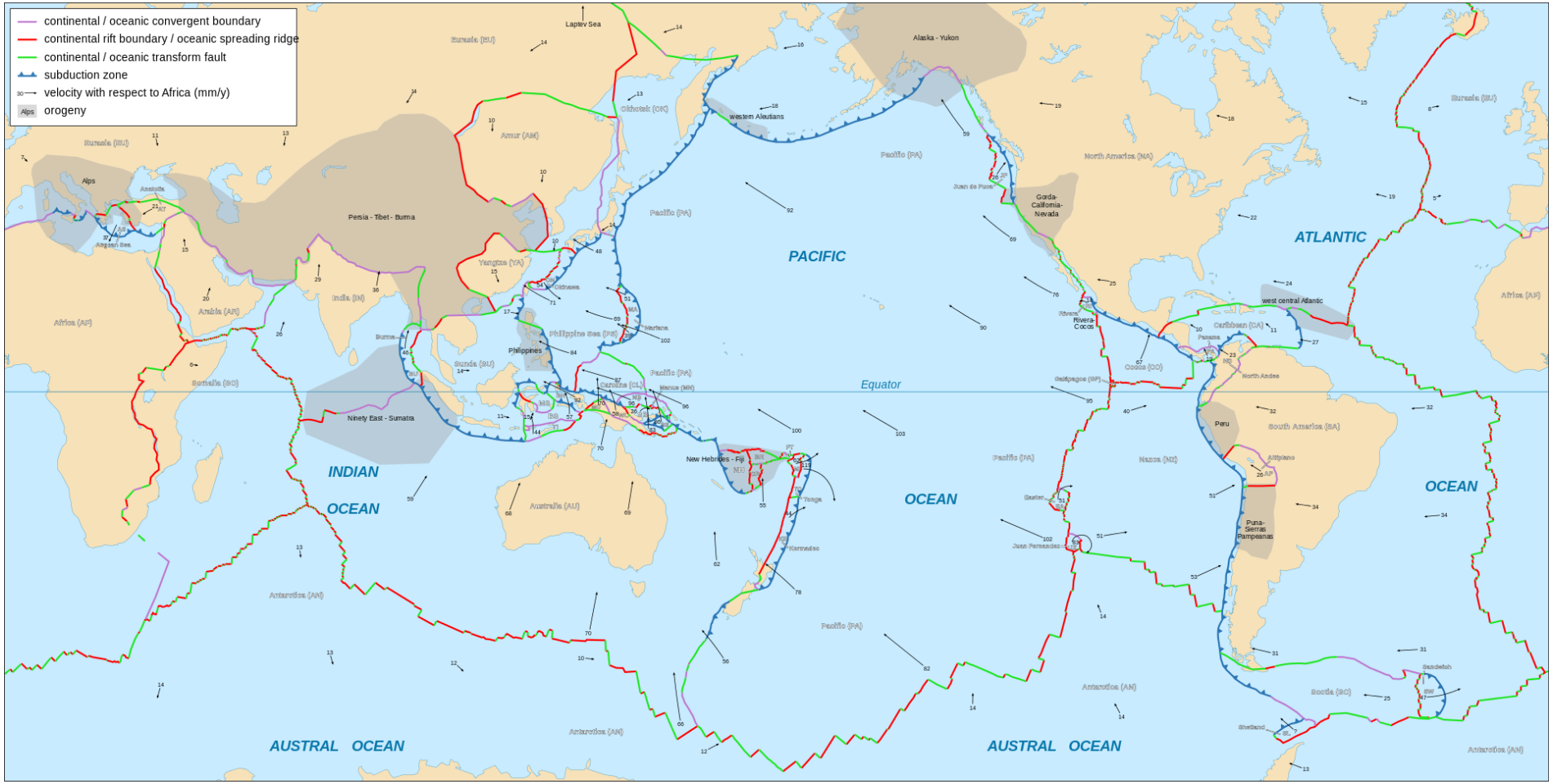


Plate Tectonics

The Earth's lithosphere is broken up into chunks called *plates*. Oceanic plates are made of basalts (cooled volcanic rock made of silicon, oxygen, iron, aluminum, & magnesium). Oceanic *crust* is only about 6 kilometers thick. The continental plates are made of another volcanic type of silicates called granite. Continental *crust* is much thicker than oceanic crust---up to 35 kilometers thick. Continental plates are less dense than the oceanic plates. The mantle convection causes the crustal plates to slide next to or under each other, collide against each other, or separate from one another in a process called **plate tectonics**. **Plate tectonics** is the scientific theory that describes this process and how it explains the Earth's surface geology.

http://www.astronomynotes.com

Modern Tectonic Plates and Movements



http://commons.wikimedia.org/

Plate boundaries can be:

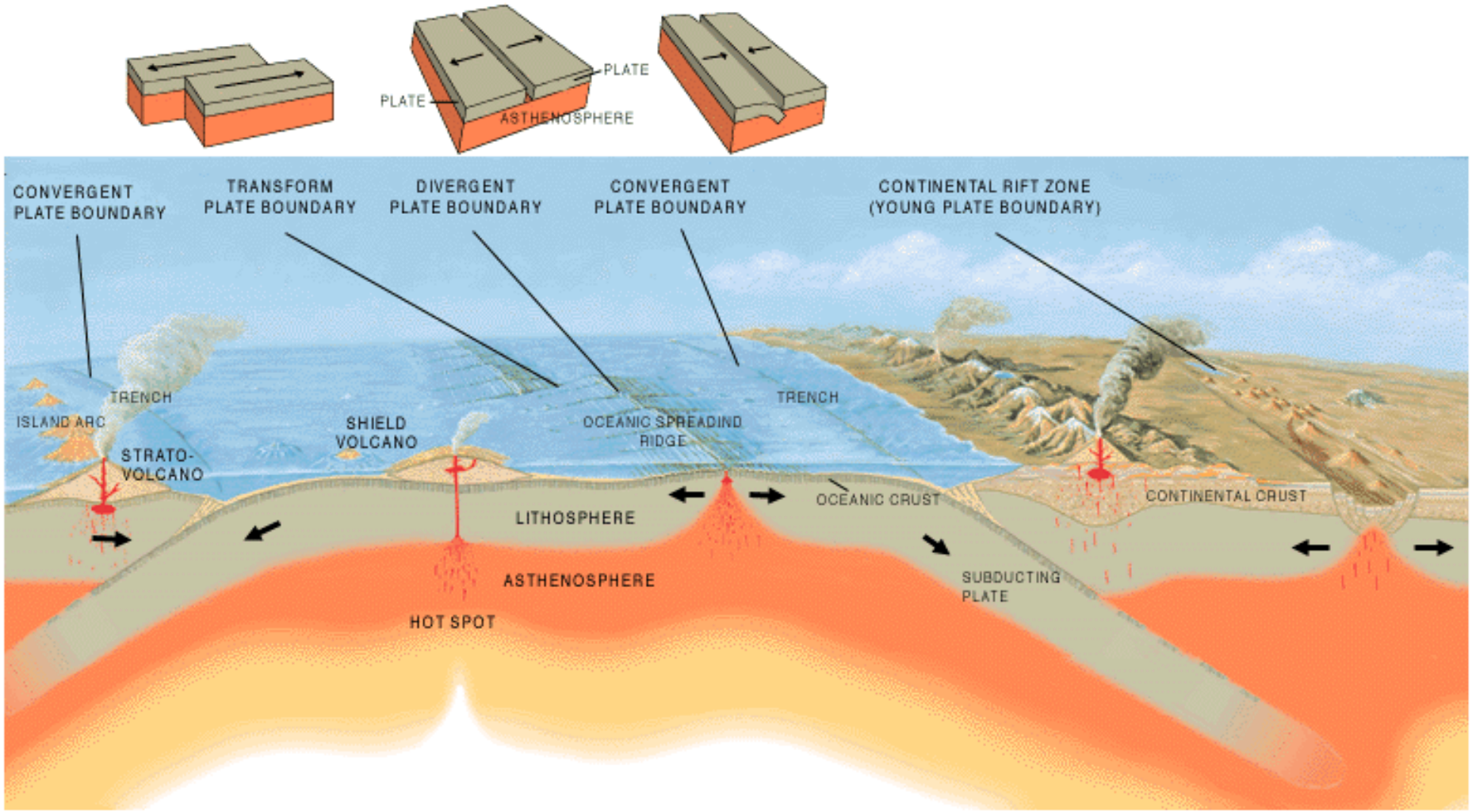
Transform: grinding past each other

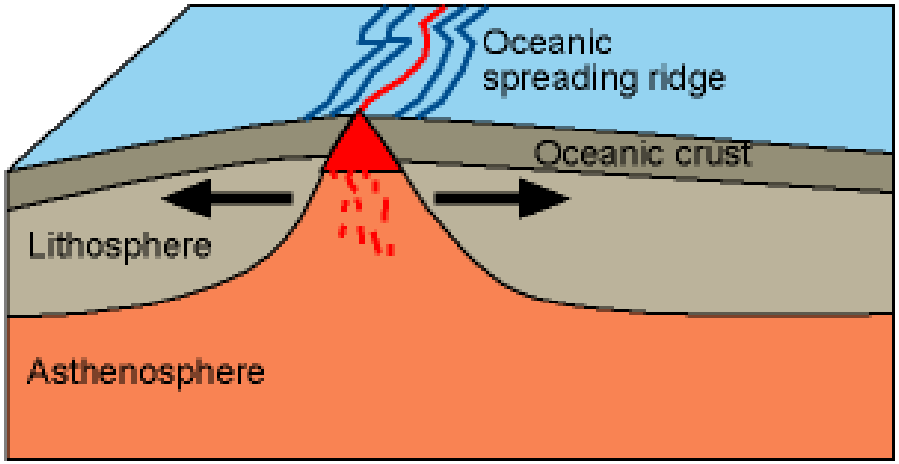
Divergent: separating

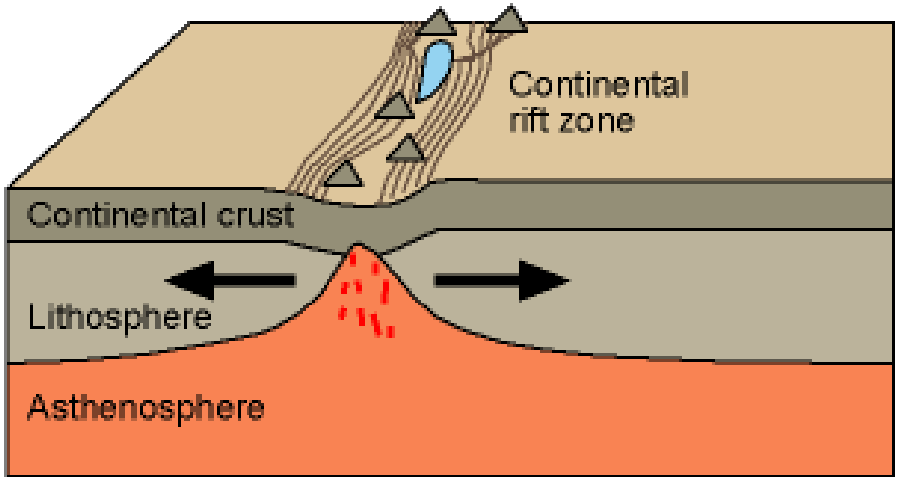
Convergent: colliding

- **Subduction**
- **Uplift**

Plate Tectonics (Continental Drift)







When plates separate: *(top)* new oceanic crust is created as parts of the lithosphere are pushed apart by rising molten rock at a midoceanic ridge. *(bottom)* new continental crust is created at a continental rift zone.

http://www.astronomynotes.com


SOUTHERN OCEAN
SOUTHERN OCEAN
SOUTHERN OCEAN
KONG HAKON VII HAV
Antarctic Circle 66°34'S
South Orkney Is
Signy (UK)
South Shetland Is
Palmer (USA)
Rothera (UK)
Halley (UK)
WEDDELL SEA
ANTARCTIC PENINSULA
PALMER LAND
Alexander I.
BELLINGSHAUSEN SEA
AMUNDSEN SEA
RONNE ICE SHELF
ROSS ICE SHELF
ROSS SEA
DRONNING MAUD LAND
COATS LAND
ENDERBY LAND
KEMP LAND
MACROBERTSON LAND
PRINCESS ELIZABETH LAND
WILHELM II LAND
QUEEN MARY LAND
WILKES LAND
TERRE ADÉLIE
GEORGE V LAND
OATES LAND
EAST ANTARCTICA
WEST ANTARCTICA
ELLSWORTH LAND
MARIE BYRD LAND
Transantarctic Mountains
VICTORIA LAND
South Pole
Amundsen-Scott (USA)
McMurdo (USA)
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90°E
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80°S
69°S
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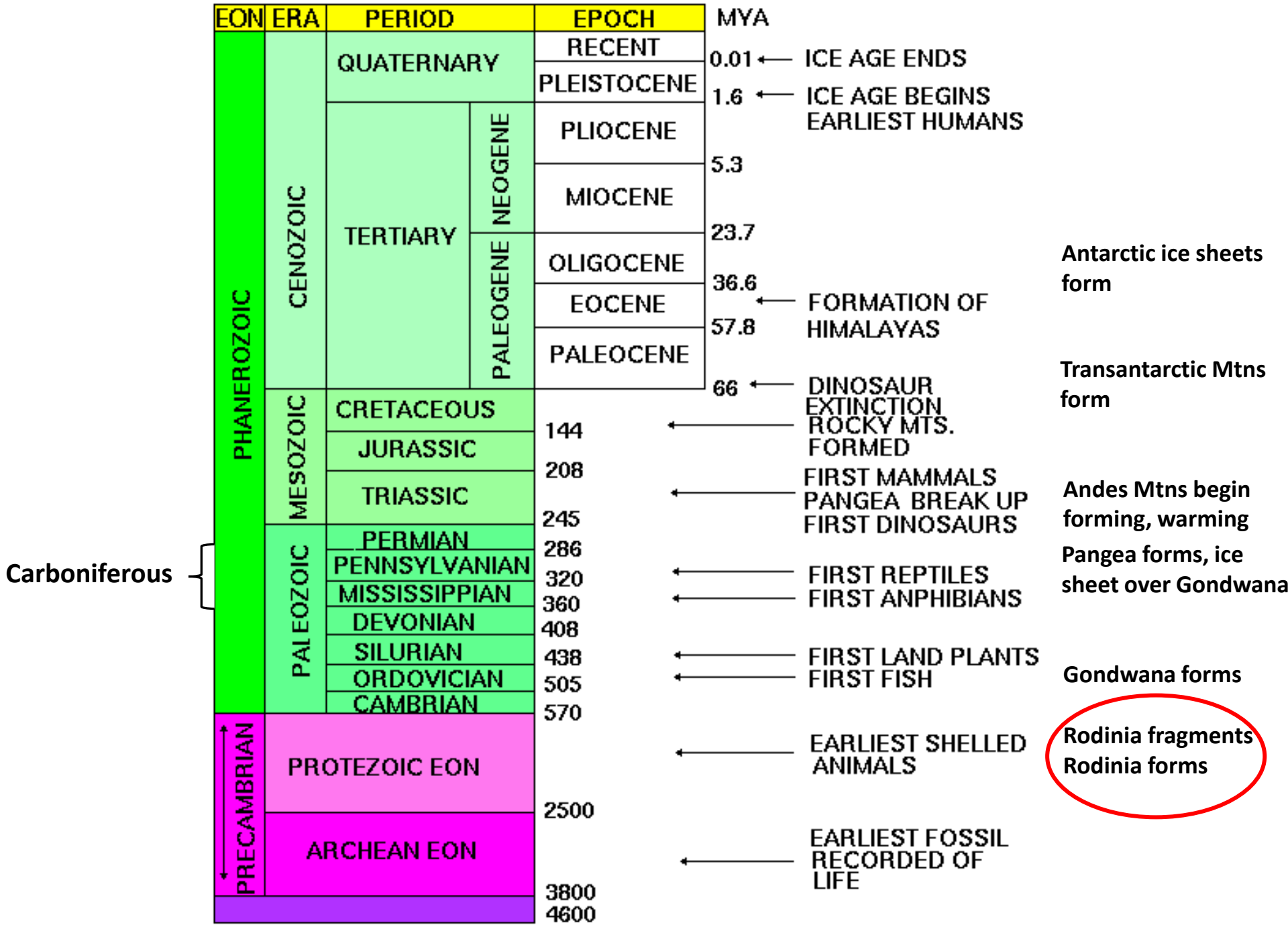
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ICE AGE BEGINS
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JURASSIC
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PRECAMBRIAN
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2500
ARCHEAN EON
EARLIEST FOSSIL RECORDED OF LIFE
3800
4600
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Transantarctic Mtns form
Andes Mtns begin forming, warming
Pangea forms, ice sheet over Gondwana
Gondwana forms
Rodinia fragments
Rodinia forms

SWEAT Hypothesis: Southwest U.S. – East Antarctica Connection
From Walton text, p. 47

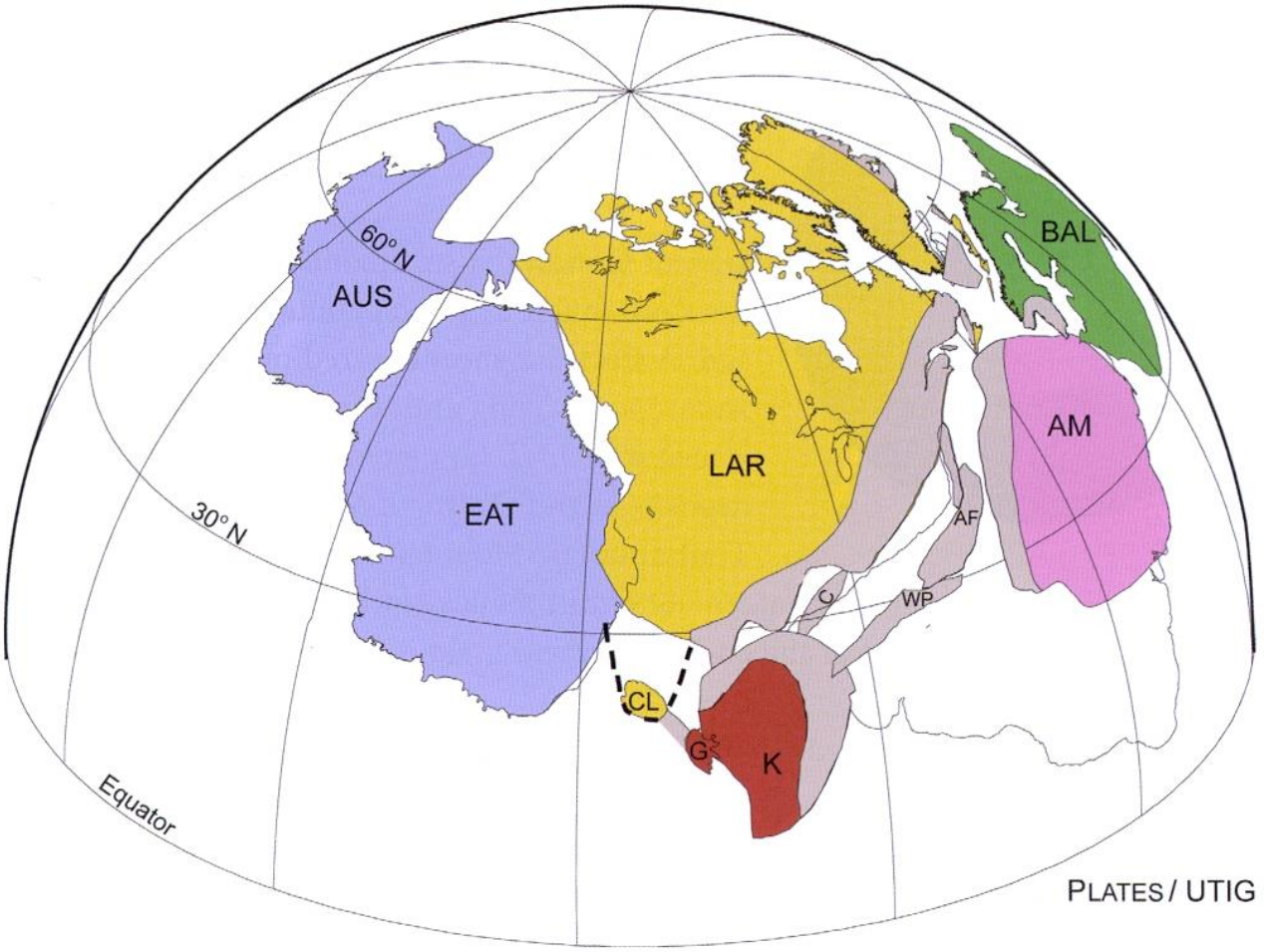
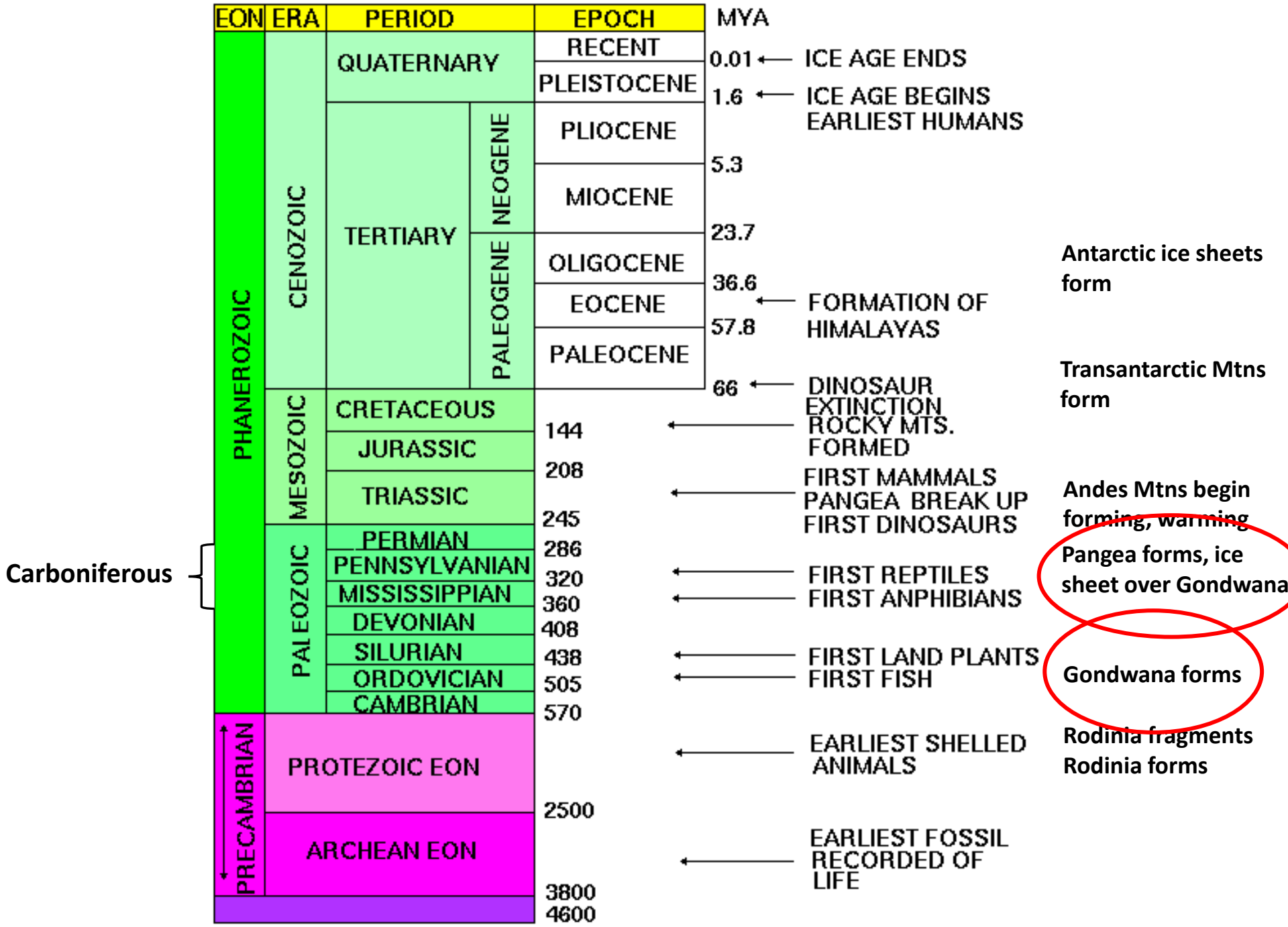


Figure 2.14 A continental reconstruction for a supercontinent named Rodinia showing how East Antarctica (EAT) was most likely joined to North America (LAR) 750 million years ago. (Credit: Ian Dalziel)

Granite boulder from glacial moraine with isotopic geochemistry similar to those from southwestern Laurentia

From Goodge et al. 2008 *Science*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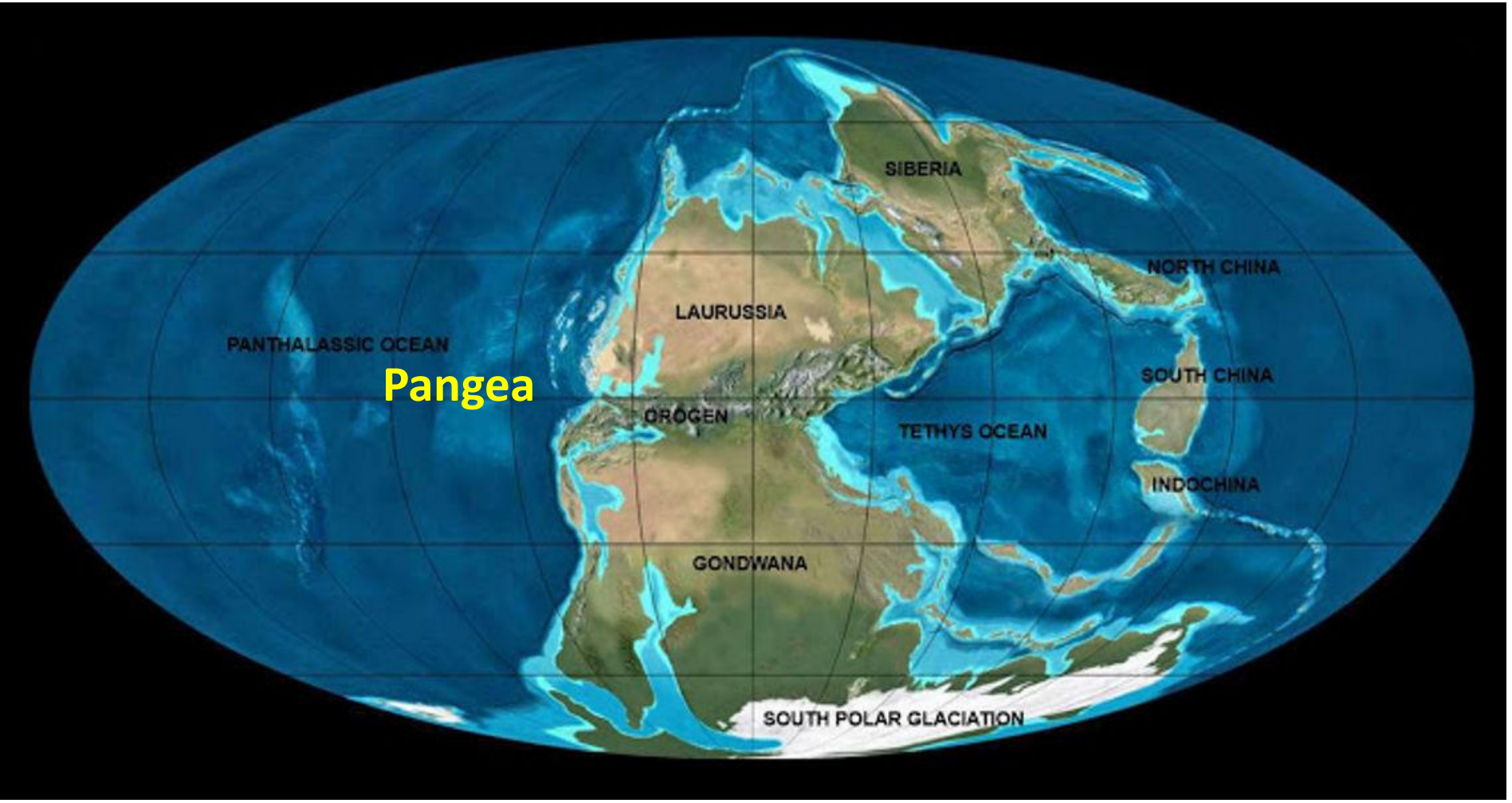
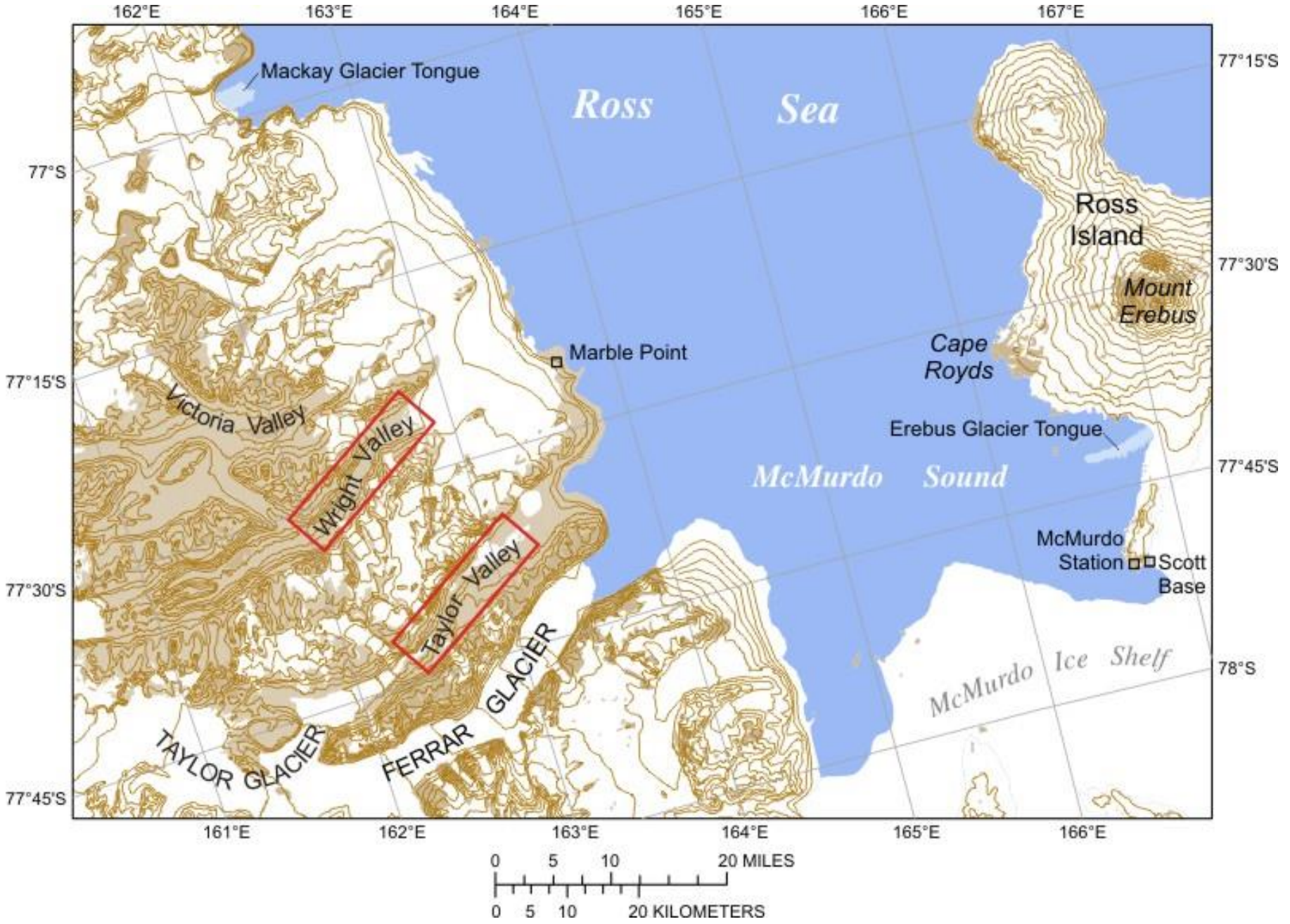
Carboniferous ice sheet, 300 Ma



Abundant fossil deposits in the Dry Valleys where there are many layers of sedimentary rocks

Dry Valleys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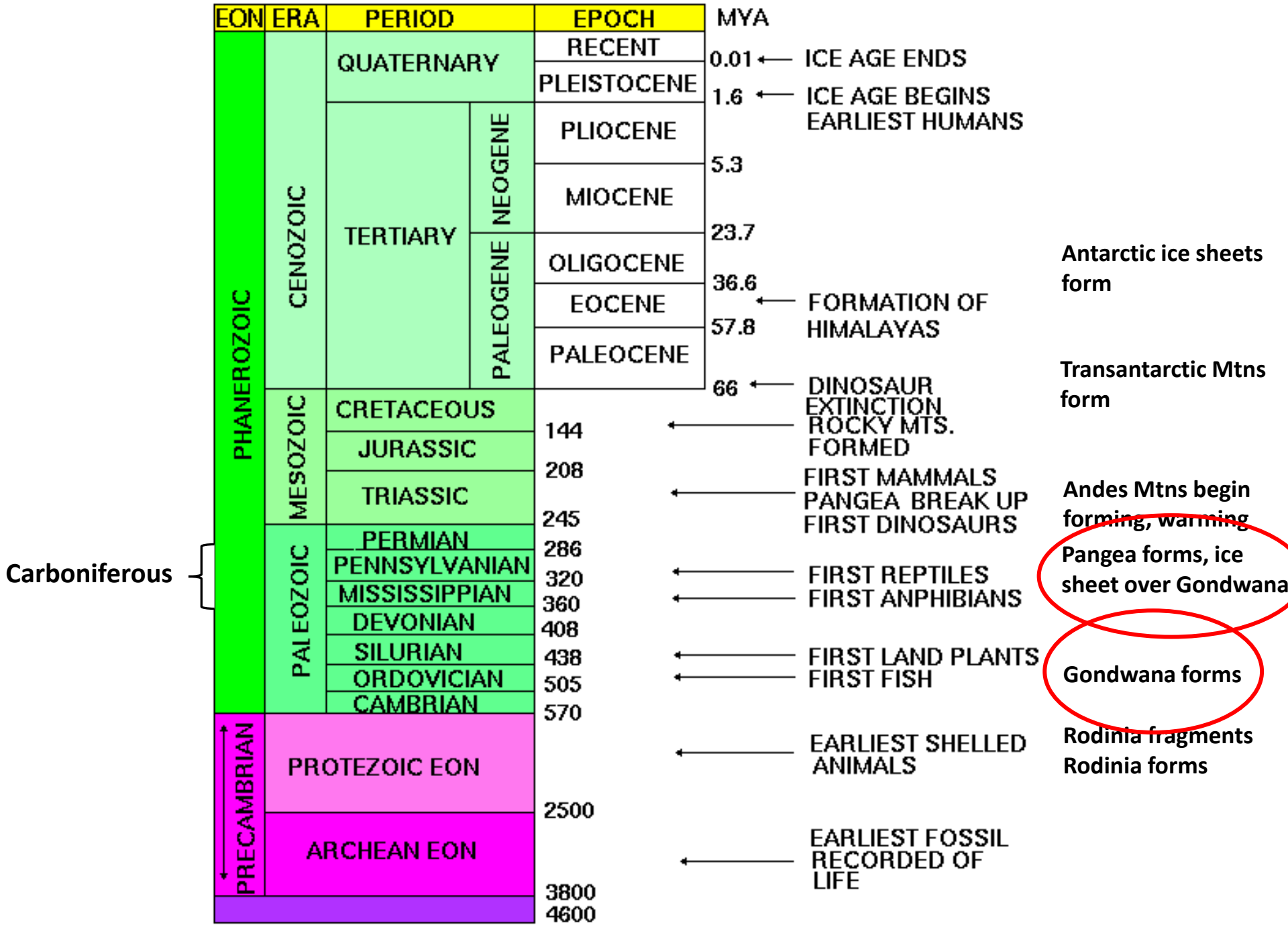
77°15'S
77°S
77°30'S
77°15'S
77°45'S
78°S
161°E
162°E
163°E
164°E
165°E
166°E
Mackay Glacier Tongue
Ross Sea
Ross Island
Mount Erebus
Cape Royds
Marble Point
Victoria Valley
Wright Valley
Taylor Valley
Erebus Glacier Tongue
McMurdo Sound
McMurdo Station
Scott Base
McMurdo Ice Shelf
TAYLOR GLACIER
FERRAR GLACIER
0 5 10 20 MILES
0 5 10 20 KILOMETERS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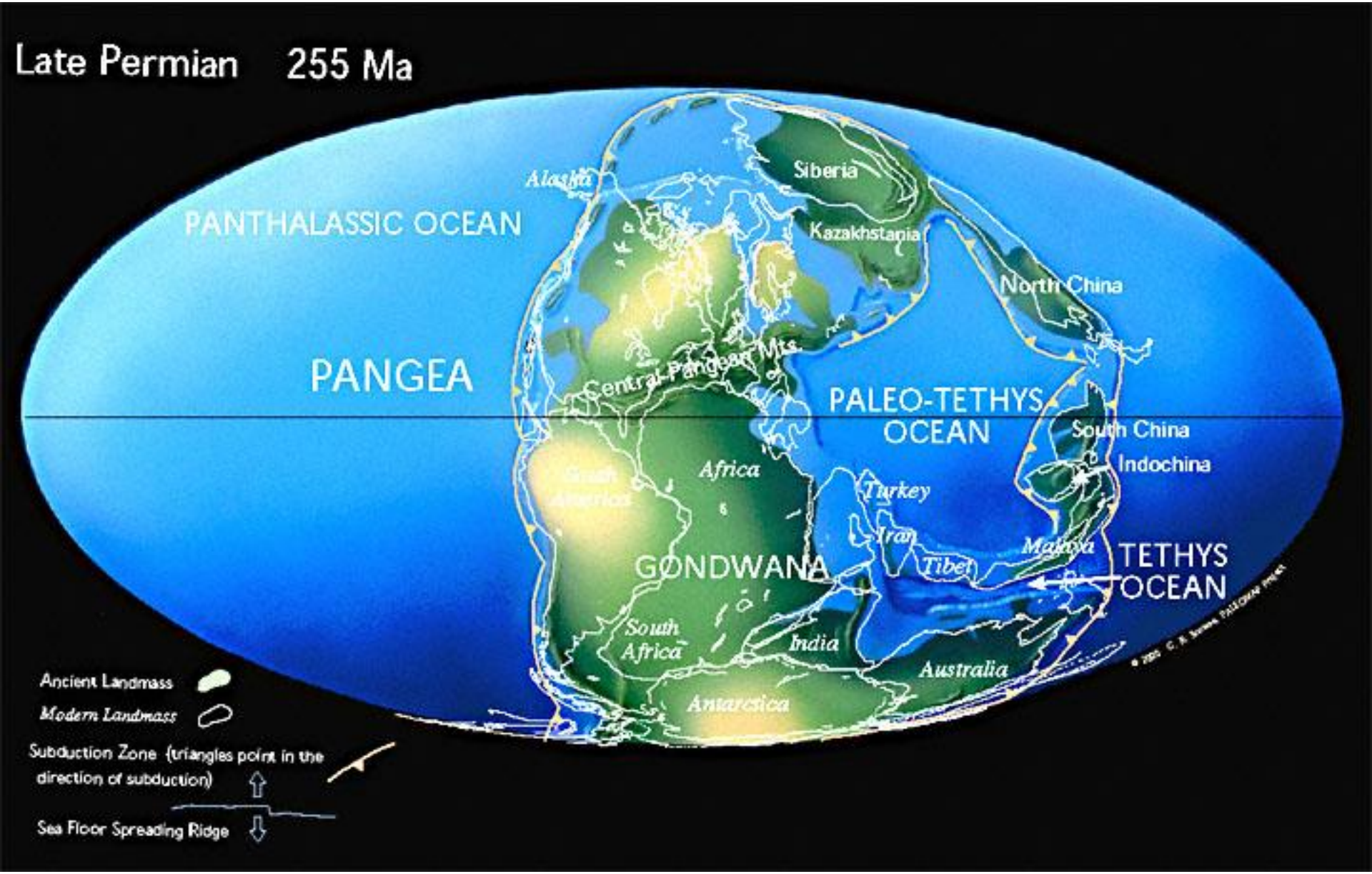
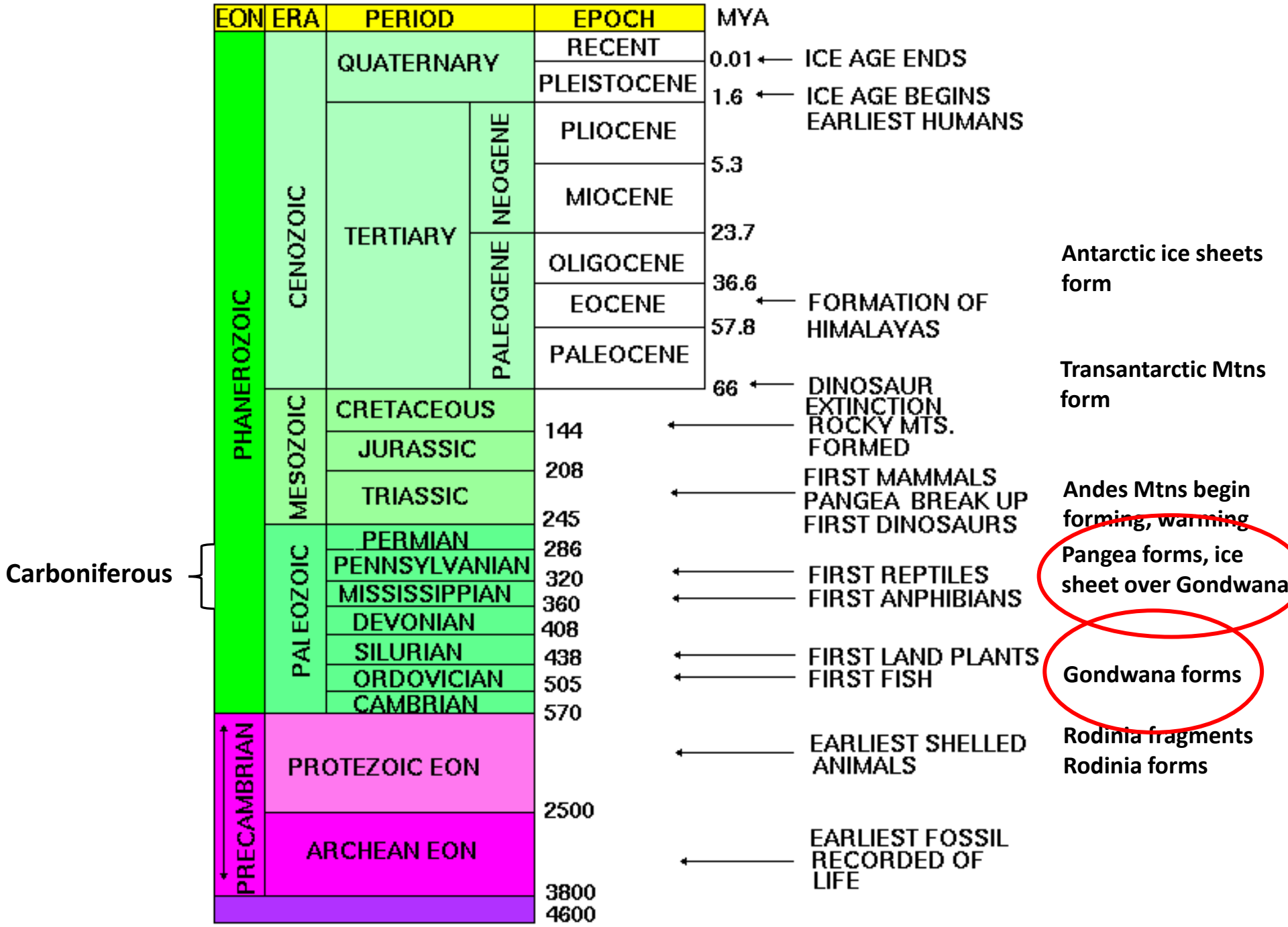
Rodinia forms

Climate warming, lots of vegetation, formation of coal deposits in Antarctica

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Glossopteris

https://wyrdscience.wordpress.com/2011/01/02/fossil-forests-reveal-a-subtropical-antarctica/

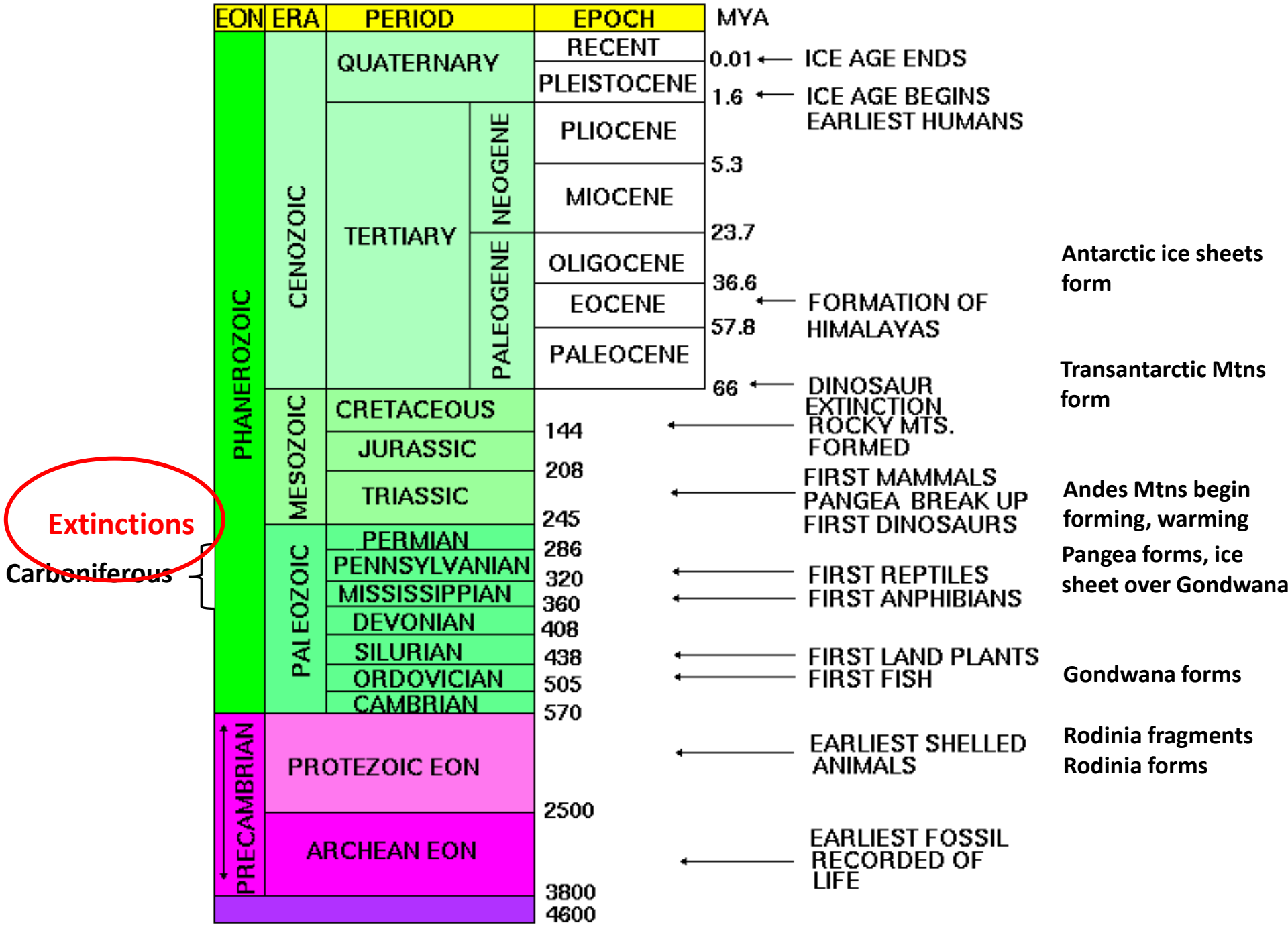
Fossil leaves from Mt. Wild, Antarctica

www.teara.govt.nz

Also found in India, Australia, Africa, and South America

Also found in India, Australia, Africa, and South America

Ginkgo Tree (*Ginkgo biloba*), a living fossil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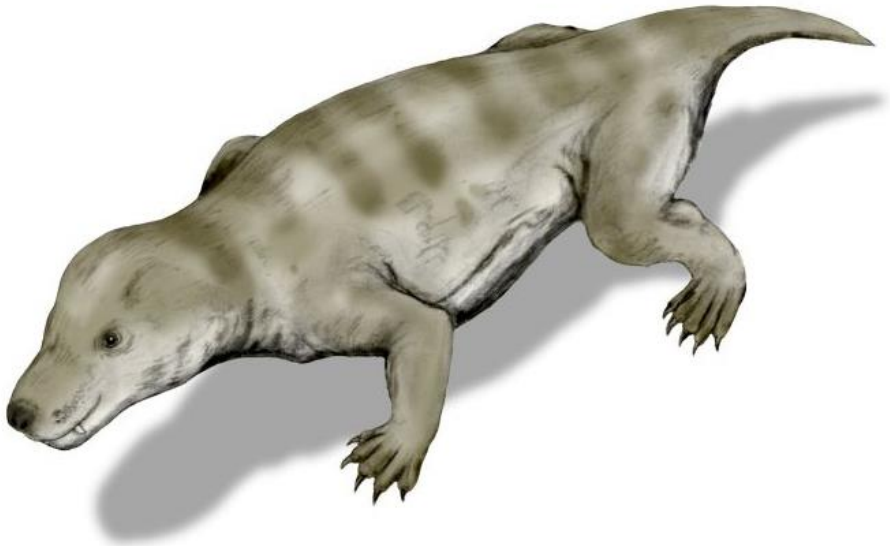
Extinctions
Carboniferous

Lystrosaurus, a therapsid dicynodont reptile

Dr. Edwin H. Colbert
(1905 – 2001)

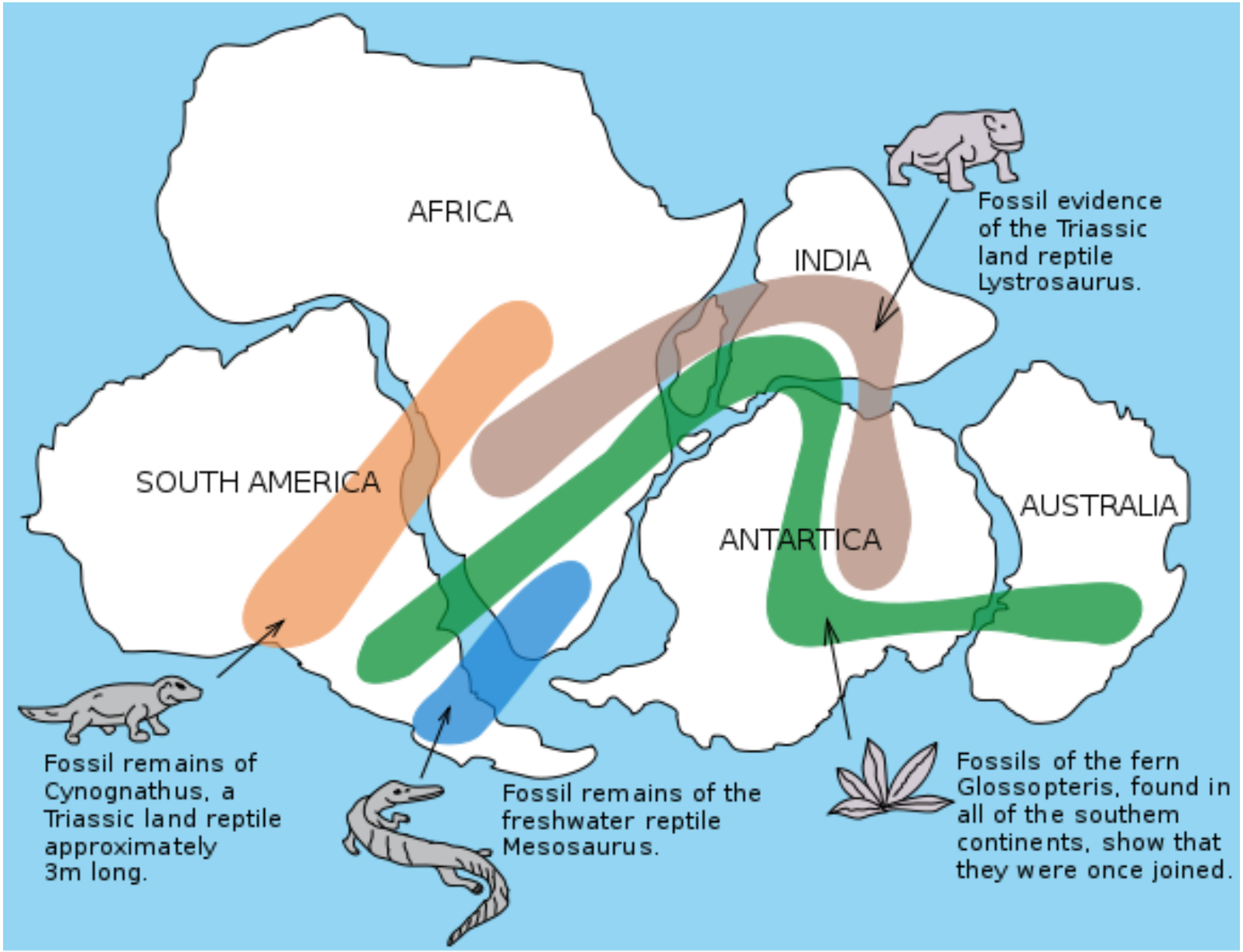
First a skeptic of continental drift, found *Lystrosaurus* in India and Africa

In 1960s, went to Antarctica to confirm presence of *Lystrosaurus* there too



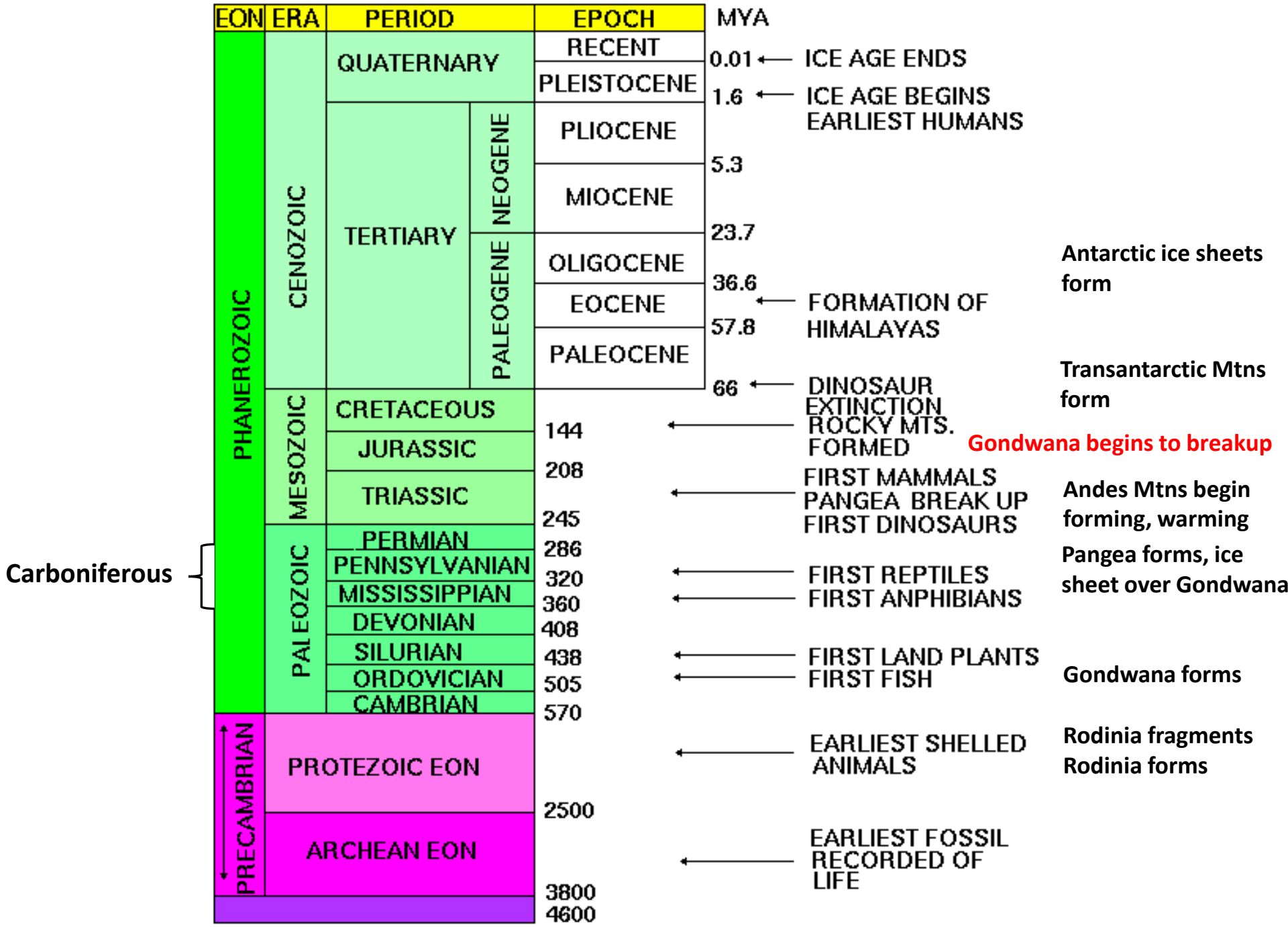
Thrinaxodon, cynodont therapsid from S. Africa and Antarctica

Fossil Evidence for Plate Tectonics



South African discoveries of *Lystrosaurus* were in the Karoo Desert

See the book 'Gorgon' by Peter Ward (2004) for a good read about these discoveries and possible cause of the Permian extinctions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3800
4600

Quiz

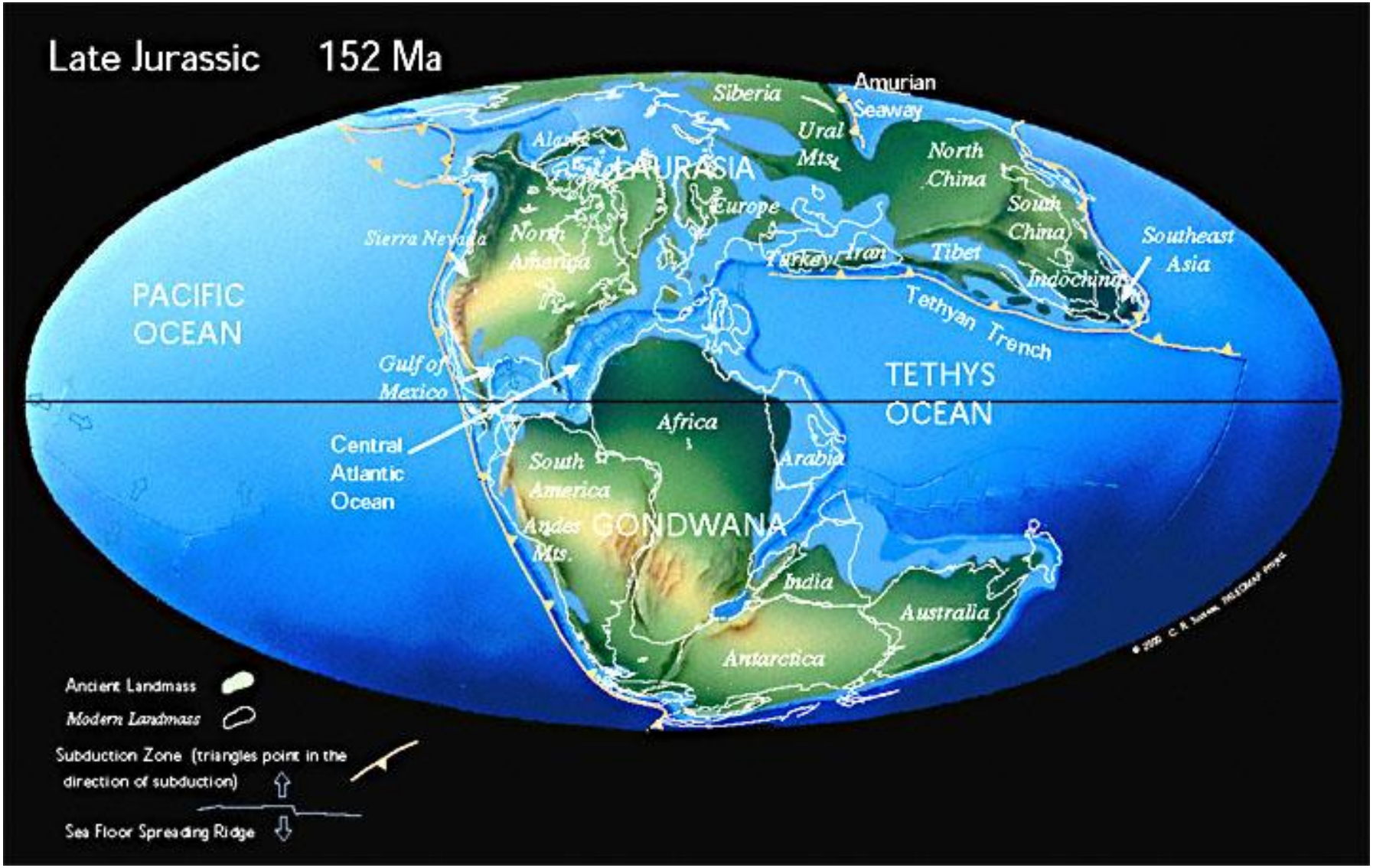
1. What is plate tectonics?

2. What is Rodinia and its significance to Antarctic origins?

3. What are *Glossopteris* and *Lystrosaurus*?

4. What is the difference between Pangea and Gondwana and when did they form?

Gondwana begins to separate from Pangea



Other dinosaurs from Antarctica now include the large, long-necked Sauropods, an ankylosaur and a hadrosaurus (duck-billed dinosaur).

Reptiles include pterosaurs, plesiosaurs and mosasaurs (marine)

Fossil ferns from King George Island, Antarctic Peninsula

Gondwana began to break up in the Cretaceous from ~180 mya

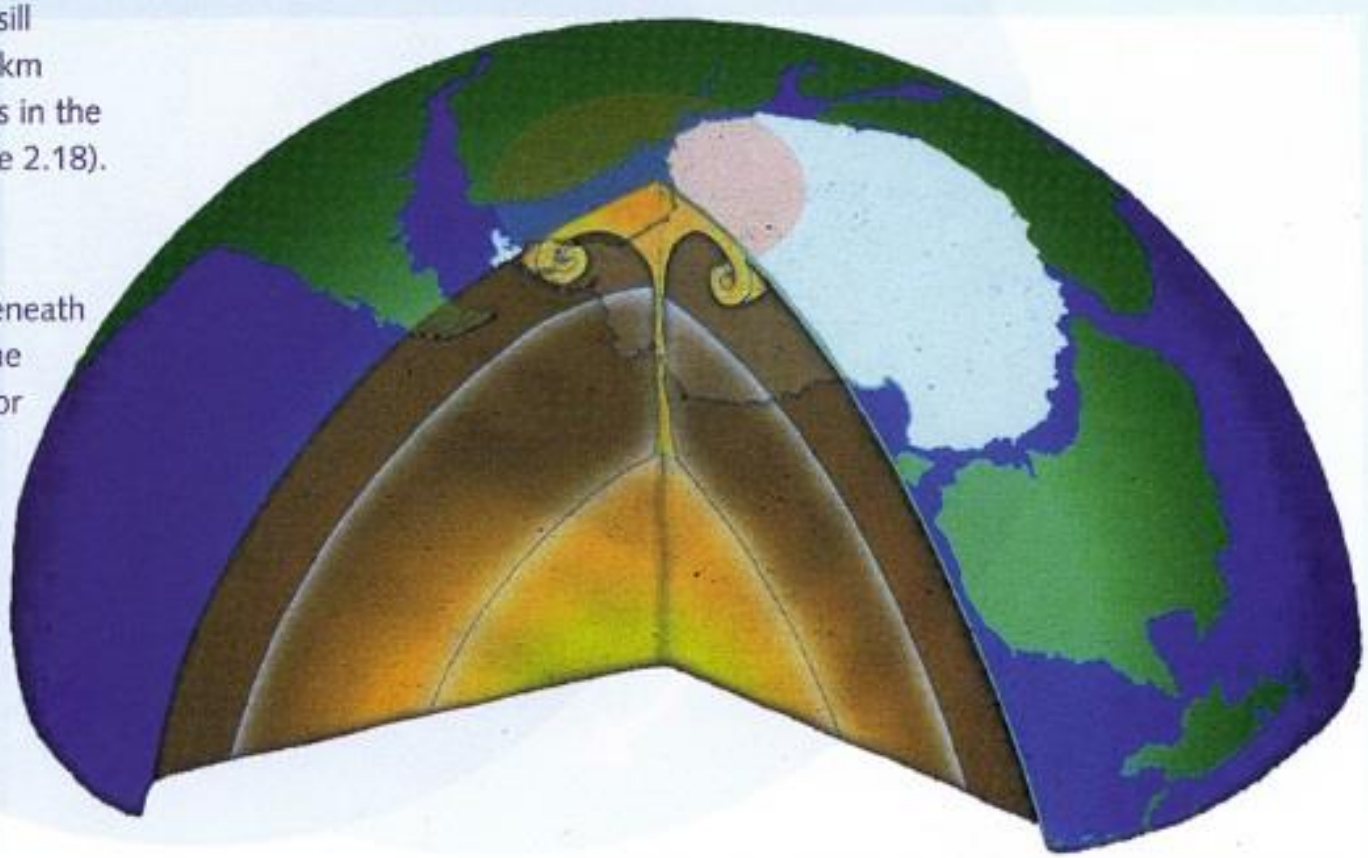
Finally separation of Antarctica occurred by 32 mya when the tip of S. America separated from the Antarctic Peninsula

This is when the current ice sheets on Antarctica today began to form

From Walton text, p. 53

Figure 2.19 A Ferrar basaltic sill in the Dry Valleys over 2500 km away from similar basaltic sills in the Theron Mountains (see Figure 2.18). (Credit: Bryan Storey)

Figure 2.20 Mantle plume beneath Gondwana. The mantle plume was most likely responsible for the extensive basaltic volcanism and may have contributed to the break up of Gondwana. (Credit: Bryan Storey)



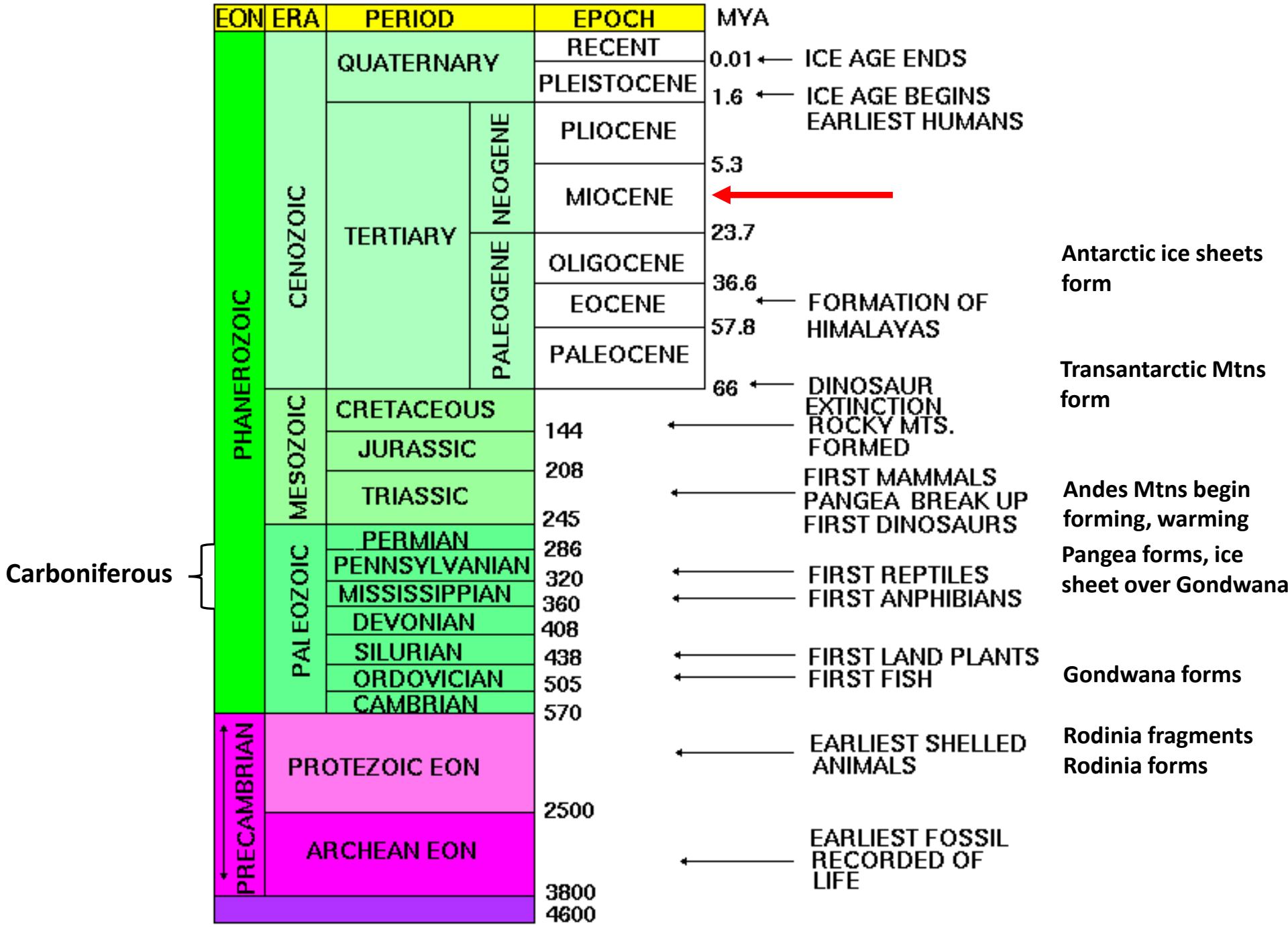
Breakup of Gondwana

Figure 2.21 in text

180 to 35 mya, Gondwana breakup

Shows Antarctic Peninsula as separate plate, moves off the tip of South America by 35-30 mya, opening Drake Passage and forming the circumpolar current that initiated cooling of Antarctica and formation of ice sheets (p. 56)

Microplates positioned themselves within the continent such as the Ellsworth Mountains with their anomalous orientation


EON
ERA
PERIOD
EPOCH
MYA
PHANEROZOIC
CENOZOIC
QUATERNARY
RECENT
PLEISTOCENE
0.01
ICE AGE ENDS
1.6
ICE AGE BEGINS
EARLIEST HUMANS
TERTIARY
NEOGENE
PLIOCENE
MIOCENE
5.3
23.7
PALEOGENE
OLIGOCENE
EOCENE
36.6
FORMATION OF HIMALAYAS
57.8
PALEOCENE
66
DINOSAUR EXTINCTION
MESOZOIC
CRETACEOUS
144
ROCKY MTS. FORMED
JURASSIC
208
FIRST MAMMALS
PANGEA BREAK UP
TRIASSIC
245
FIRST DINOSAURS
PALEOZOIC
PERMIAN
286
Carboniferous
PENNSYLVANIAN
320
FIRST REPTILES
MISSISSIPPIAN
360
FIRST ANPHIBIANS
DEVONIAN
408
SILURIAN
438
FIRST LAND PLANTS
ORDOVICIAN
505
FIRST FISH
CAMBRIAN
570
PRECAMBRIAN
PROTEZOIC EON
EARLIEST SHELLED ANIMALS
2500
ARCHEAN EON
EARLIEST FOSSIL RECORDED OF LIFE
3800
4600
Antarctic ice sheets form
Transantarctic Mtns form
Andes Mtns begin forming, warming
Pangea forms, ice sheet over Gondwana
Gondwana forms
Rodinia fragments
Rodinia forms

While the ice sheets have been present in Antarctica since ~35 Ma, recent evidence suggests a warming phase, or perhaps two warming phases, in the late Miocene (~14 Ma) and early Pliocene (5.3 – 1.8 Ma).

The warming was enough to allow tundra-like growth and dwarf *Nothofagus* trees to grow in Antarctica as shown by fossils from the Sirius Formation in the Transantarctic Mountains

The climate would have been similar to Greenland today, or the tip of South America in Patagonia

http://www.gettyimages.com

In Miocene (~14 mya), Antarctica remained about 20° C warmer than today, with tundra and beech tree (*Nothofagus*) forests, similar to Patagonia in South America today.

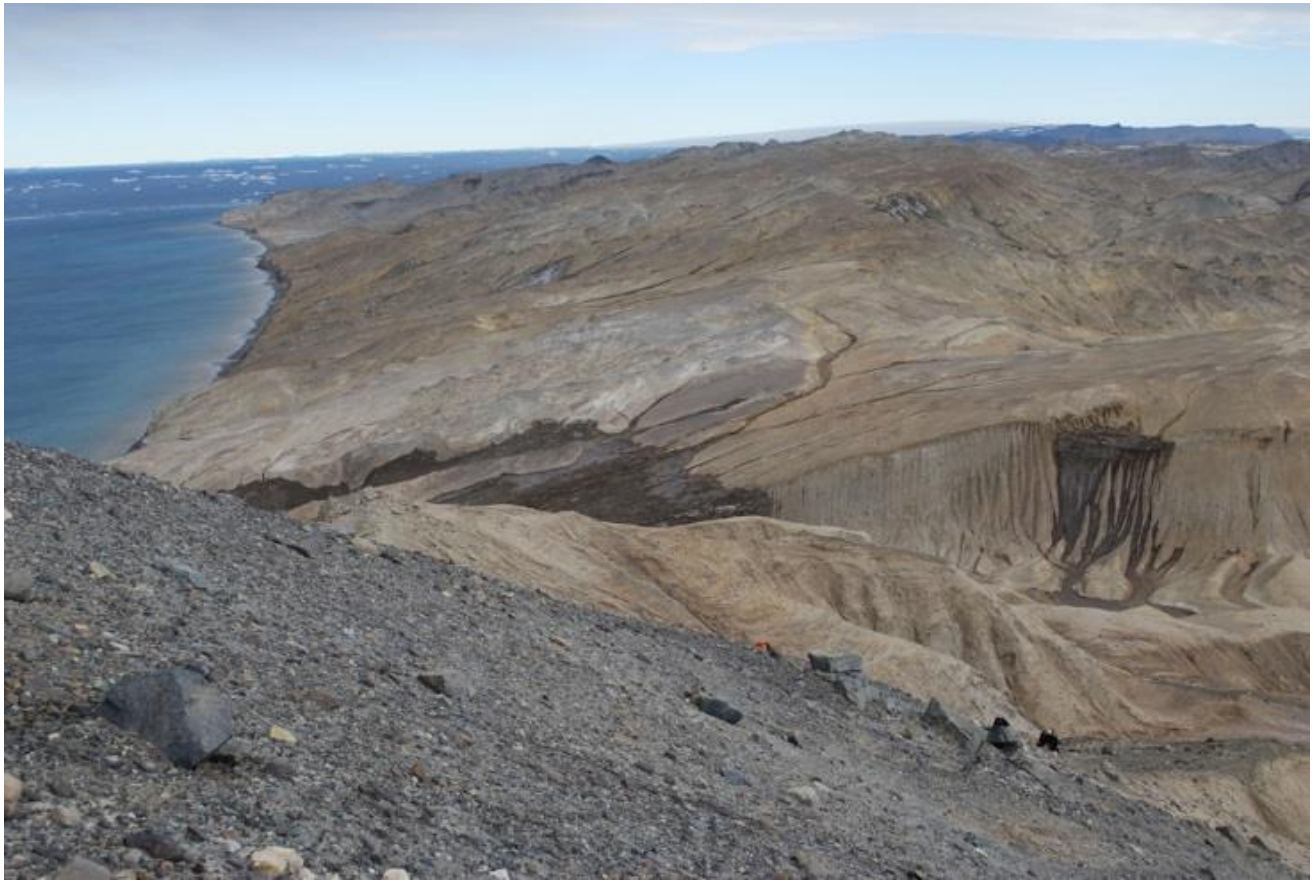
Evidence in Dry Valleys show presence of desiccated aquatic plants, algae, moss, and diatoms

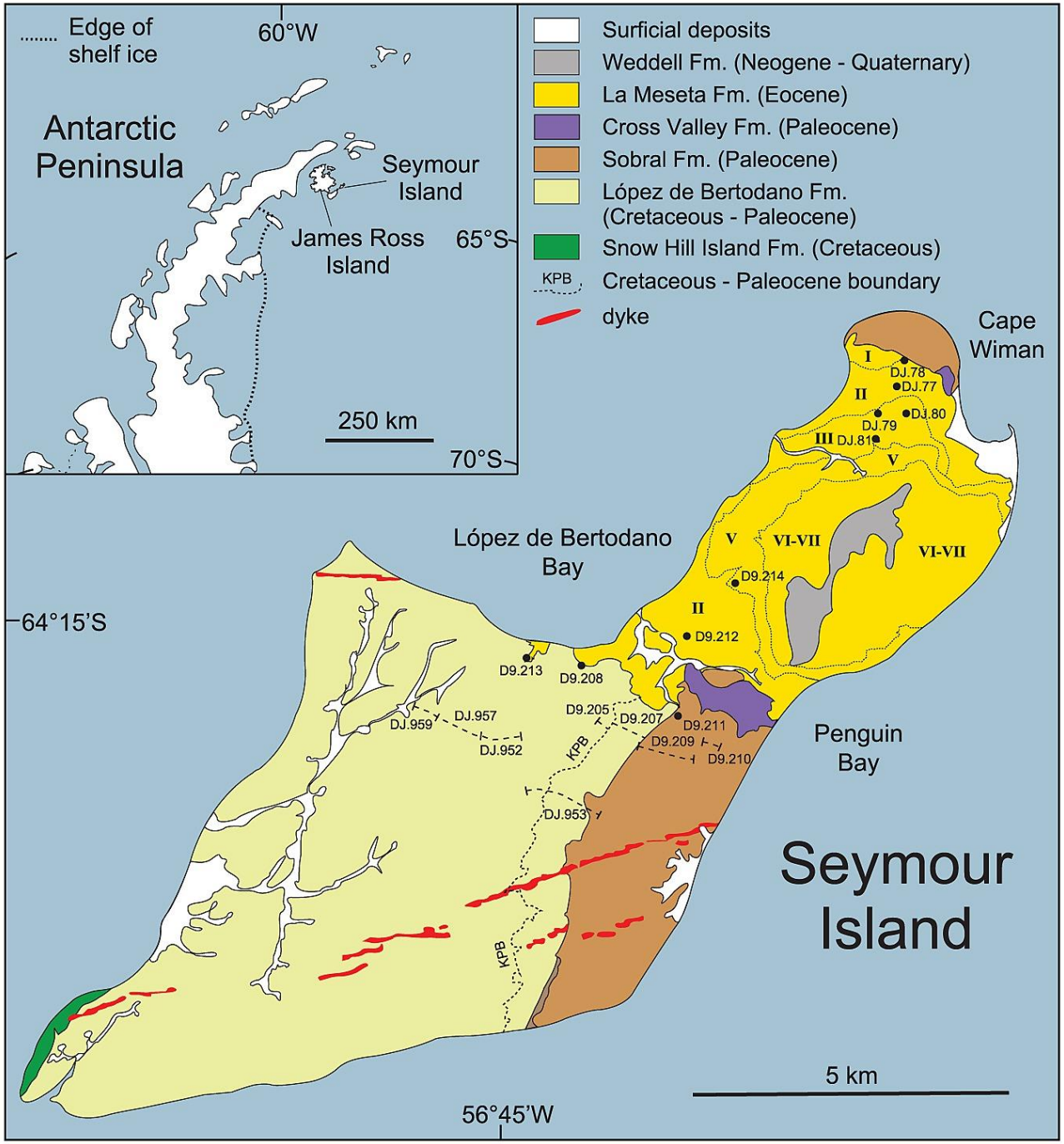
Dry Valley discovery

Cooling phase occurred after this, interrupted by early Pliocene warming at 5.3 – 1.8 Ma

Sedimentary rocks also occur extensively on Seymour Island in the Antarctic Peninsula

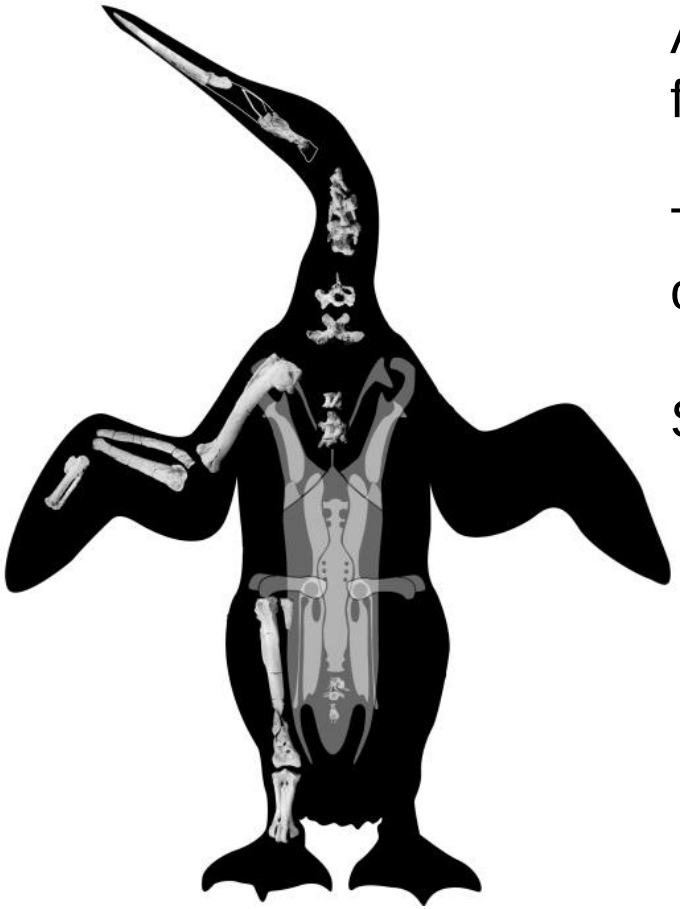
Here, some of the earliest fossil penguins are known from Eocene (~50 mya) rocks




Edge of shelf ice
60°W
Antarctic Peninsula
Seymour Island
James Ross Island
65°S
250 km
70°S
Surficial deposits
Weddell Fm. (Neogene - Quaternary)
La Meseta Fm. (Eocene)
Cross Valley Fm. (Paleocene)
Sobral Fm. (Paleocene)
López de Bertodano Fm. (Cretaceous - Paleocene)
Snow Hill Island Fm. (Cretaceous)
KPB
Cretaceous - Paleocene boundary
dyke
Cape Wiman
López de Bertodano Bay
Penguin Bay
Seymour Island
64°15'S
56°45'W
5 km
I
II
III
V
VI-VII
DJ.78
DJ.77
DJ.80
DJ.79
DJ.81
D9.214
D9.212
D9.213
D9.208
D9.205
D9.207
D9.211
D9.209
D9.210
DJ.957
DJ.959
DJ.952
DJ.953

Penguins evolved in the Southern Hemisphere

--earliest penguin-like fossil is from Paleocene of New Zealand



A reconstruction of *Waimanu tuatahi* from Slack et al. (2006).

Two species have been described, the older at 61.6 mya (*W. manneringi*)

Show evolution from a flying ancestor

Gap in penguin fossil record of over 10 my, until the Eocene at ~50 mya on Seymour Island

--high diversity of penguins, fully formed as modern species

--some quite large: *Anthropornis*

The Seymour Island fossil range from giants like *Anthropornis*, to numerous species in the same size ranges as today

Indicates the "niche" for penguins was well established in the Southern Ocean by the Eocene

Marine ecosystem must have been highly productive and rich to support all these species.

Another gap in fossil record occurs after this time, until the Miocene

A penguin humerus from the Prince Charles Mountains, East Antarctica, dated at 10.2 mya. Photo courtesy of Dr. Piotr Jadwiszczak of Bialystok University.

Quiz

1. What caused the breakup of Gondwana and when did Antarctica become fully isolated as a continent?

2. What is *Nothofagus* and when and how did it get to Antarctica?

5. When did penguins first evolve?

6. What are the Transantarctic Mountains and the Dry Valleys?