



Santorini

*(and the history of
Megatsunamis!)*

Michael Wyession

Professor of Geophysics

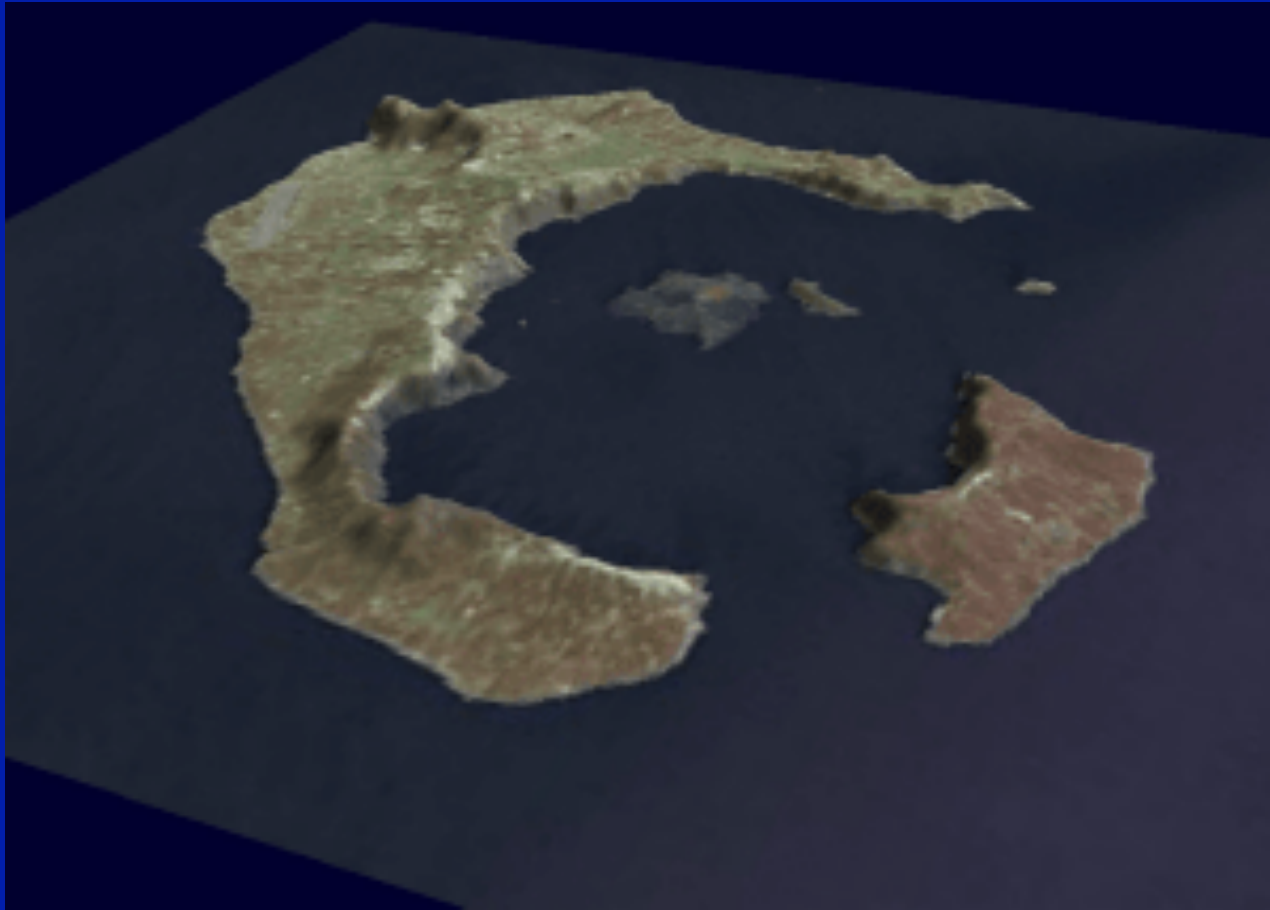
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Planetary Sciences***

Washington University

St. Louis, Missouri, USA

Santorini





Santorini













Steep “caldera” walls run around the inside of Santorini

Nea Kameni, Santorini





Volcanic layers on Santorini: 60 meters of white tephra on top of ancient soil!!



Volcanic layers on Santorini: 60 meters of white tephra on top of ancient soil!!

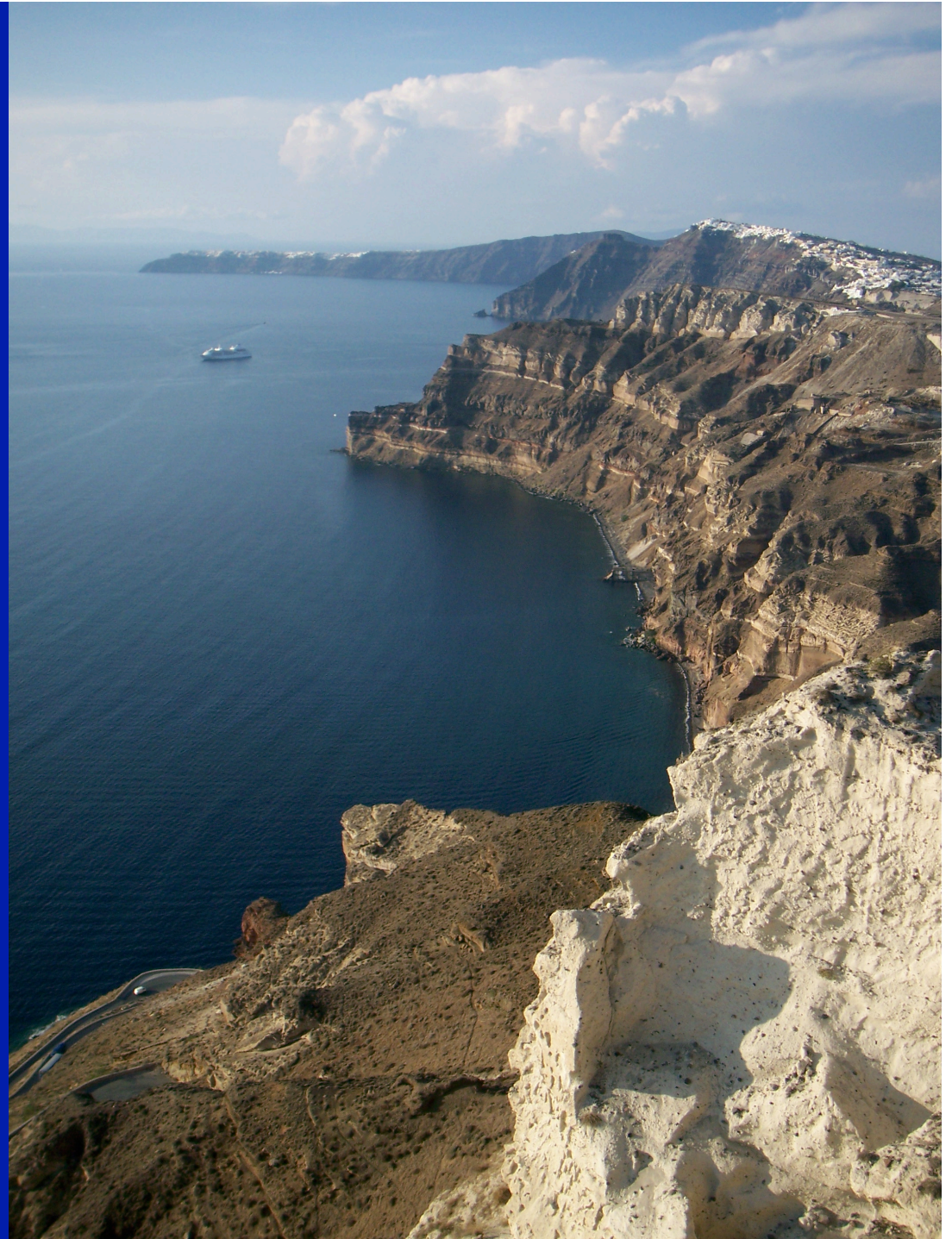


Result of a previous giant volcanic eruption

The volume of tephra suggests an eruption of 60 cubic kilometers of rock/magma!

Created 100 km³ of tephra!

15x larger than the Vesuvius eruption of 79 CE



Where is Santorini?



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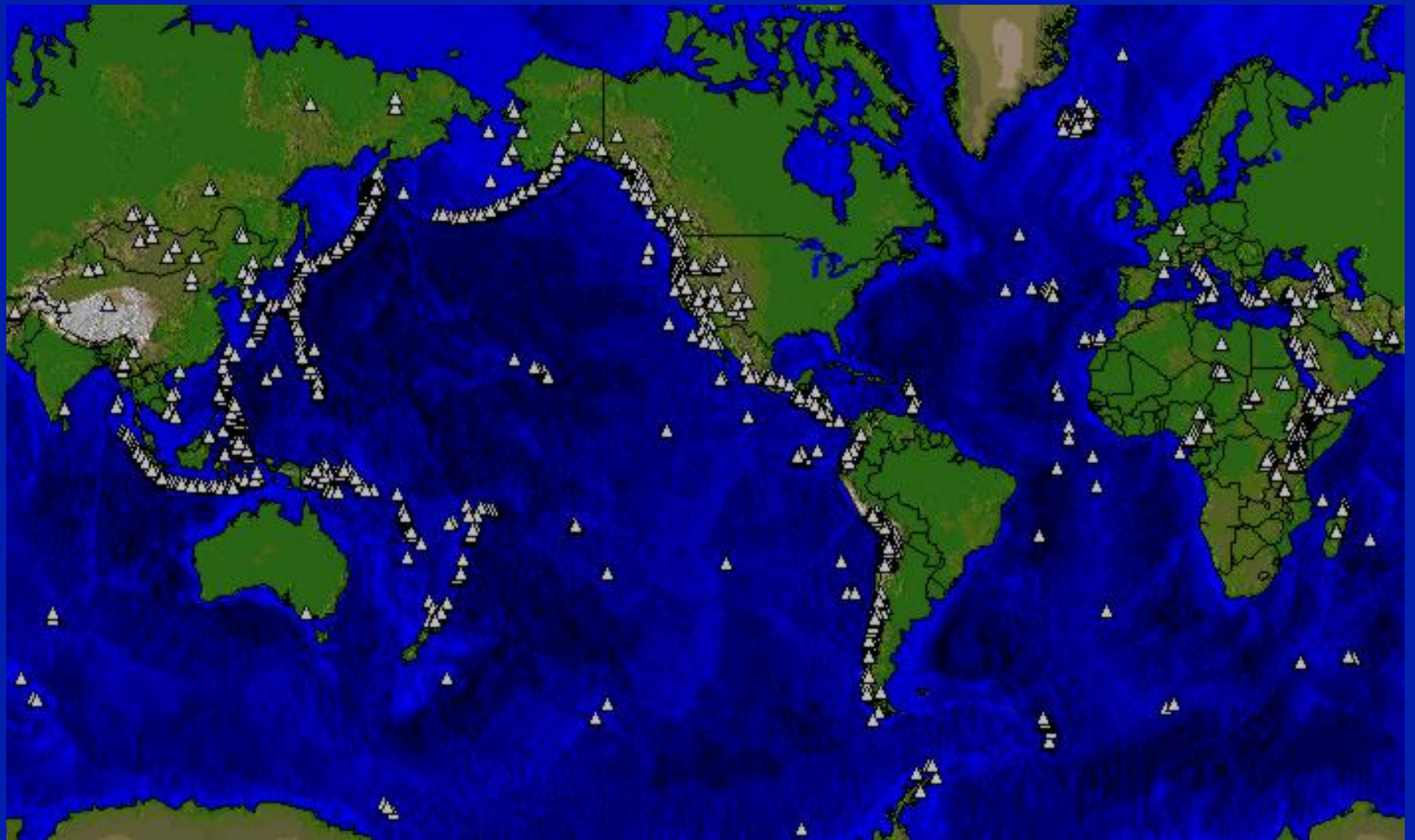
Dem Mittelmeer auf den Grund gesehen

Das Mittelmeer blickt ohne Wasser. Ein Panorama, wie es noch keiner sah. Es zeigt wertvolle Vorstellungen, an die man sich gewöhnt hat, nicht die Mündung ins Meer ist das Ende eines Flusses: Er wälzt sich fort auf dem Meeresboden; so die Rhône in 1600 Meter Tiefe, um schließlich der Nil, der nicht allein auf dem Festland stehen Geologie! Von der Barentssee bis

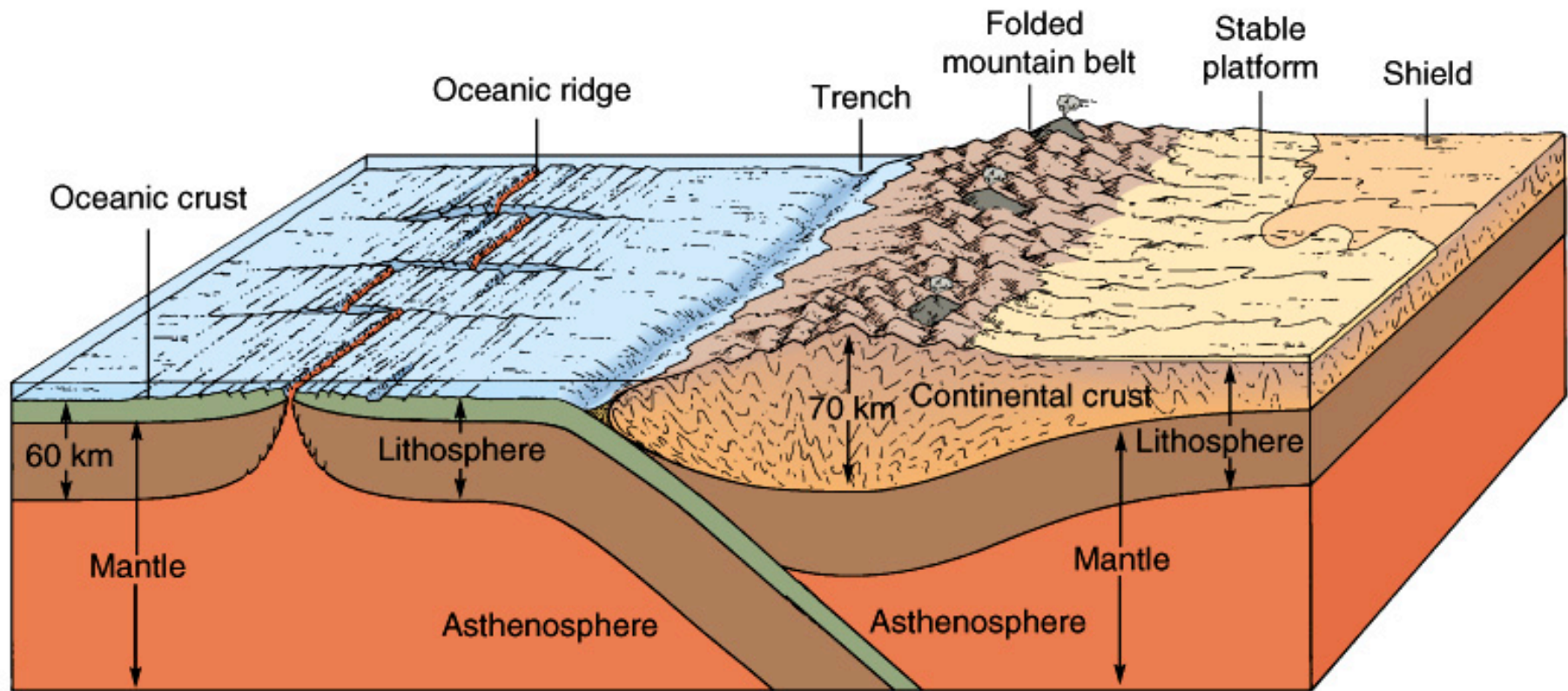
Indien hier bis nach Zypern zieht sich ein untermeerisches Meer, die höchsten Gipfel noch 2500 Meter unter Wasser, es wird sich in Jahrhunderten auflösen, den Meerespiegel durchstoßen und neue Alpen bilden. Das Mittelmeer ist gänzlich vermessert, und alle Tiefen (1120 Meter vor Griechenland) wurden ausgeleitet. Der Meeresgrund hat seine Geheimnisse mehr

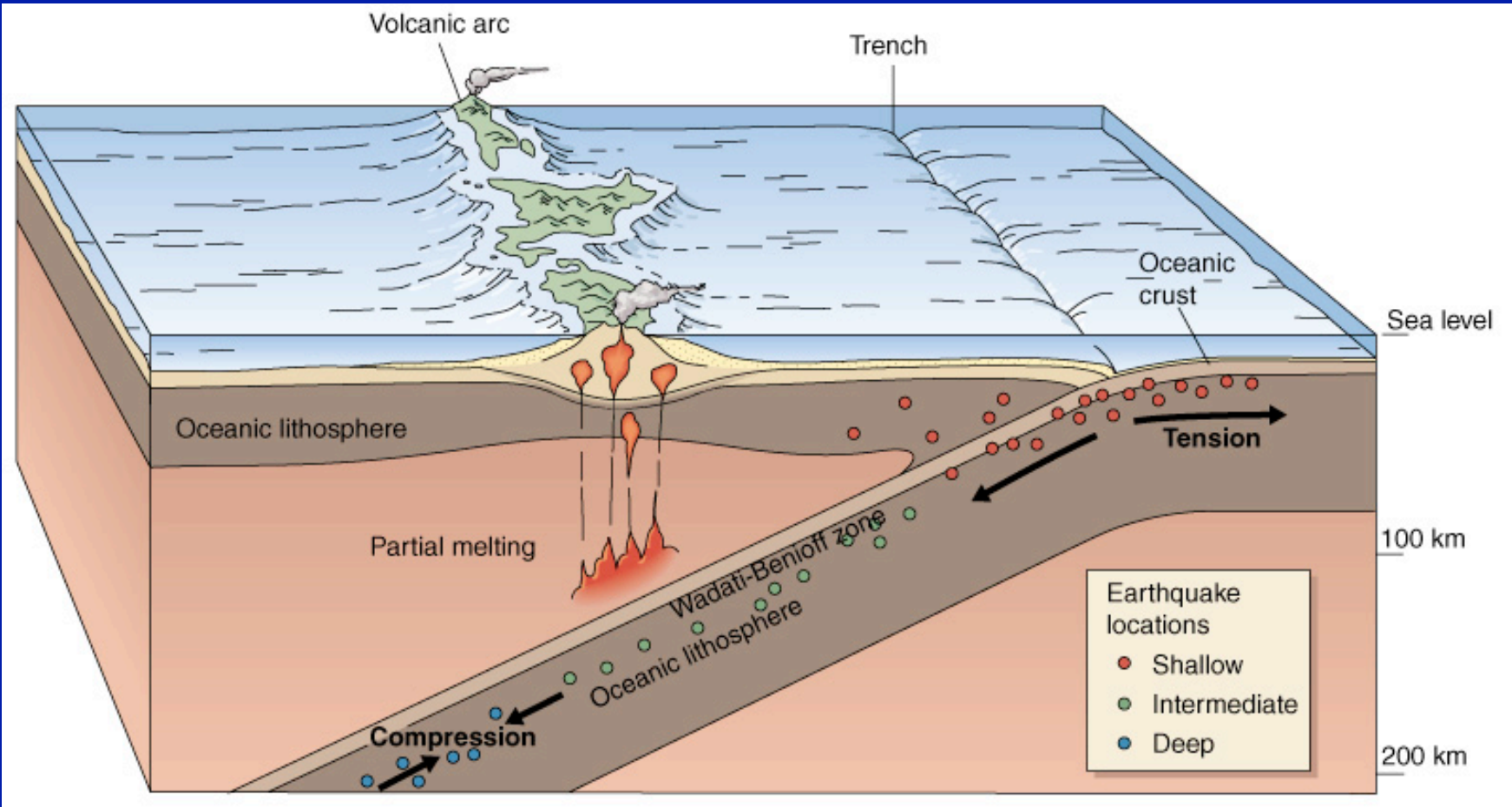


Where do Volcanoes occur??

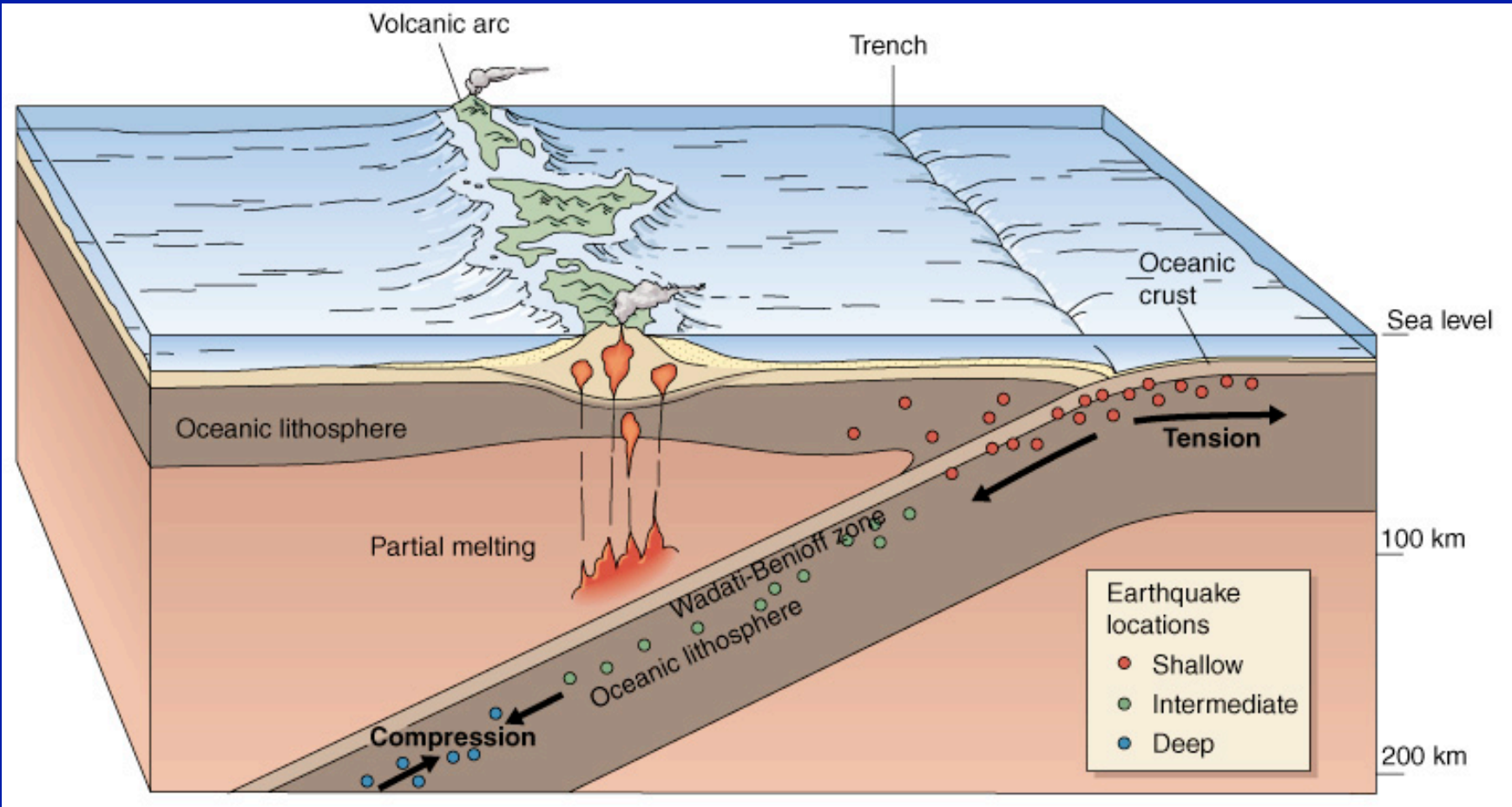


“Plate Tectonics,” The Basic Idea:



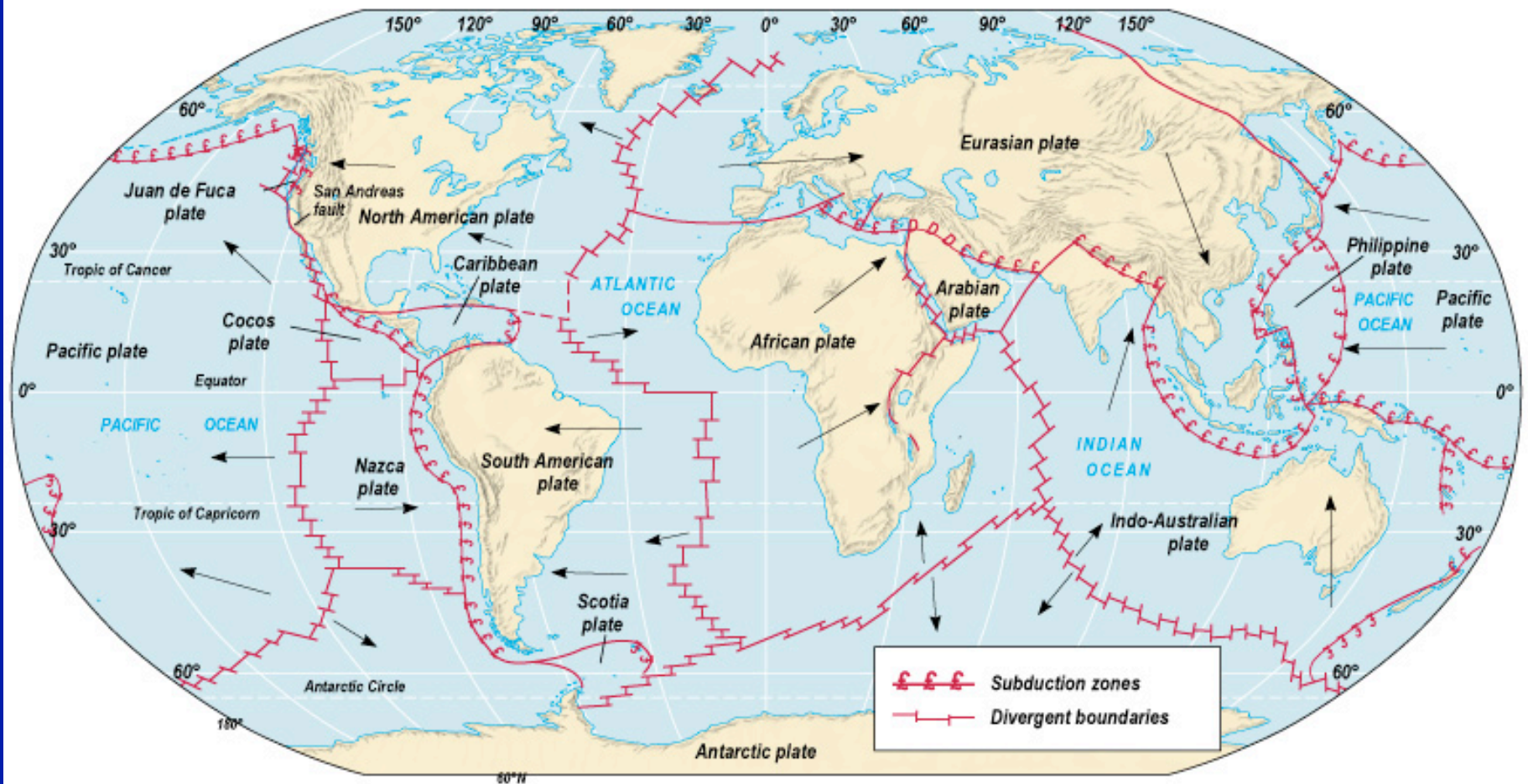


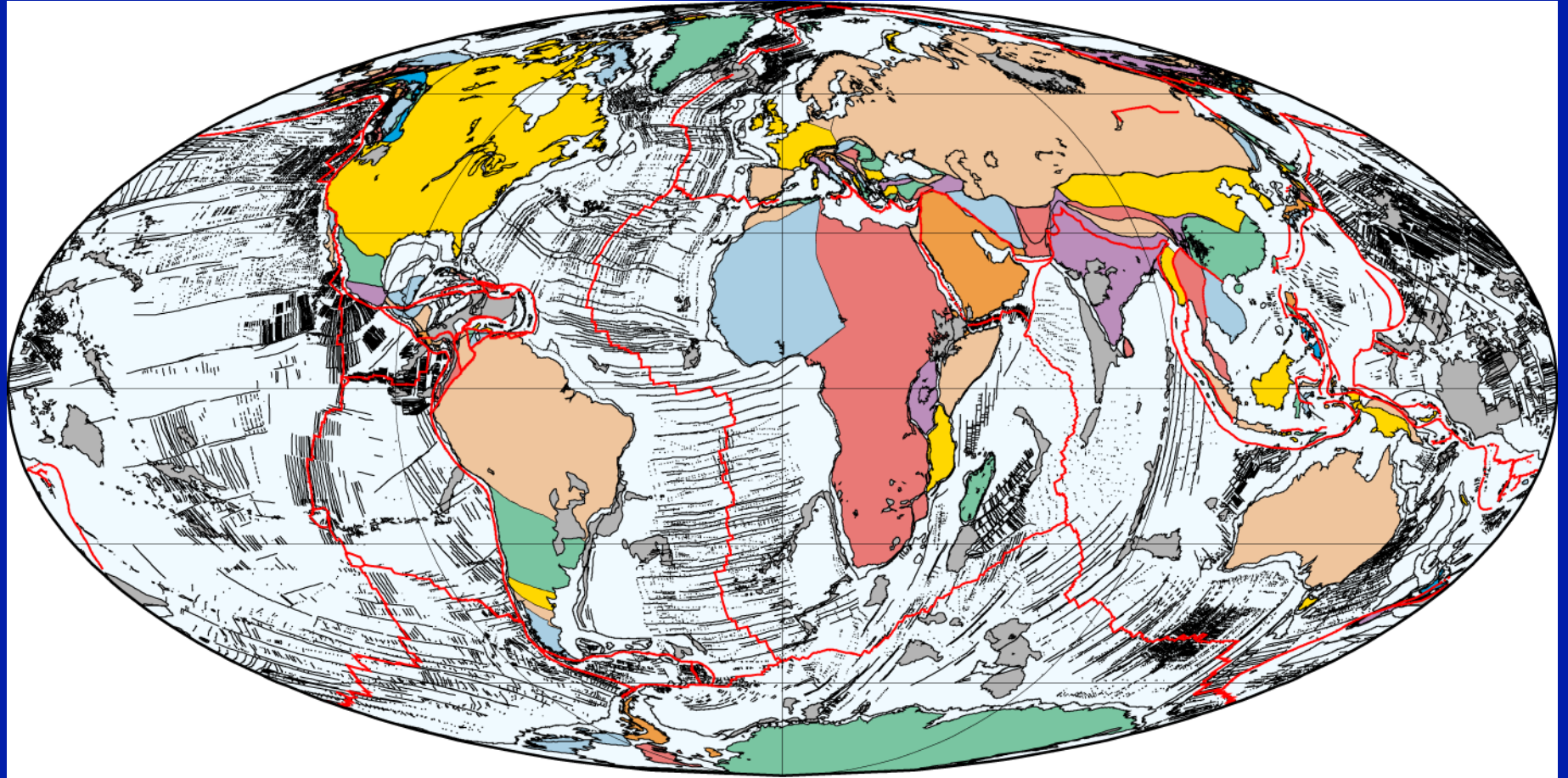
Why does rock melt beneath subduction zones?



Why does rock melt beneath subduction zones? WATER!

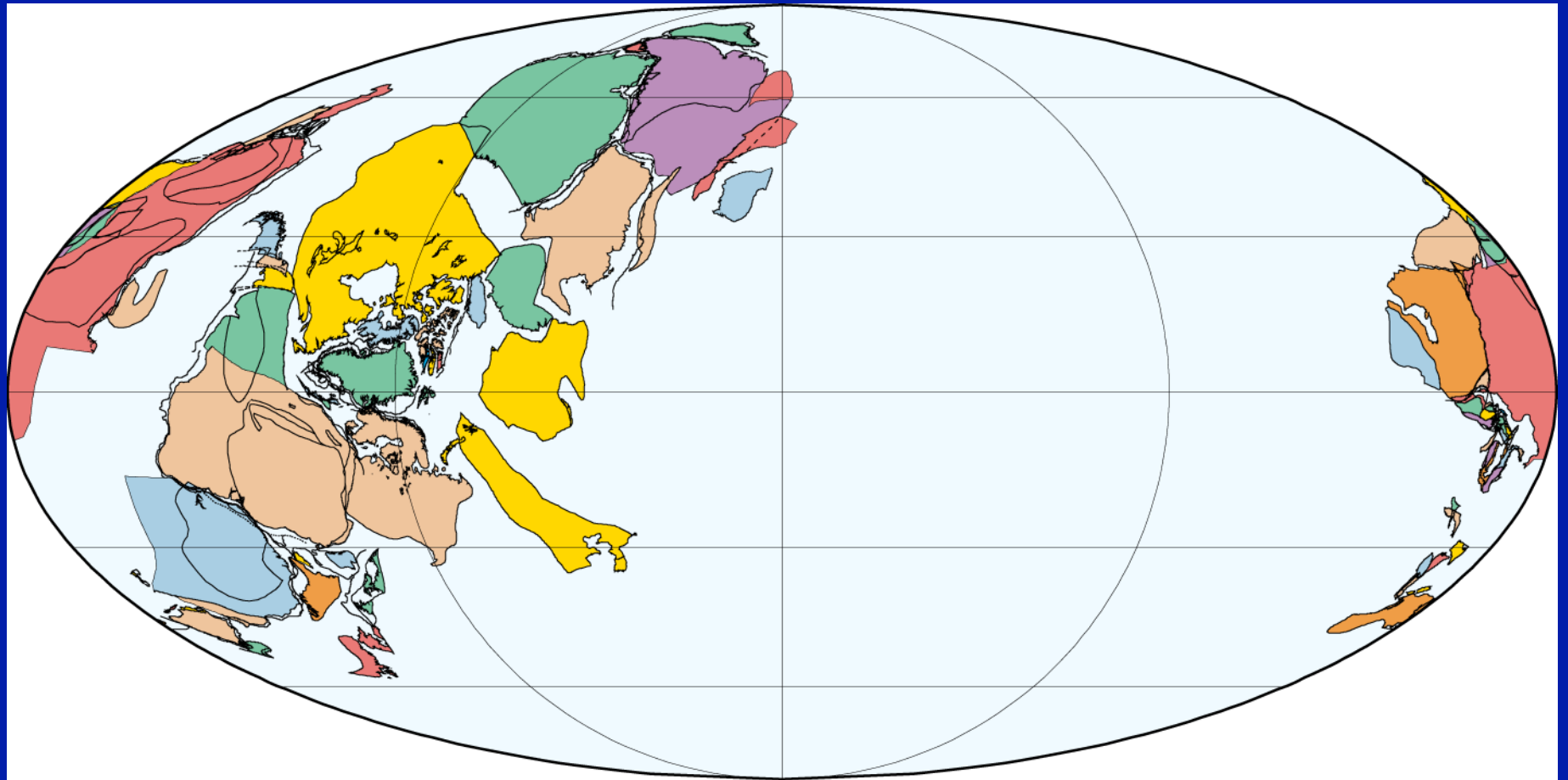
Locations of the Major Tectonic “Plates”





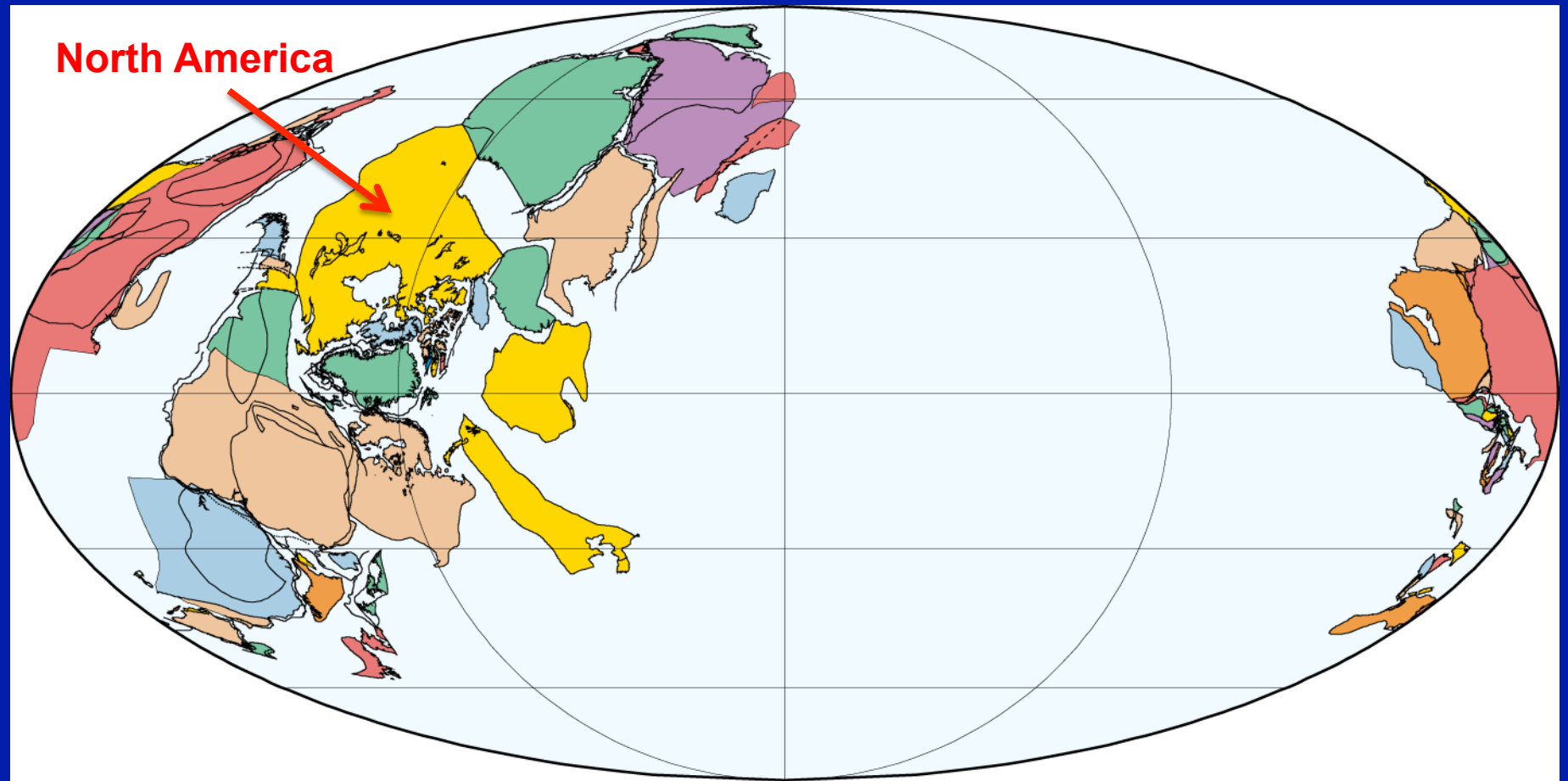
0Ma
Present Day

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750 Ma
Late Proterozoic

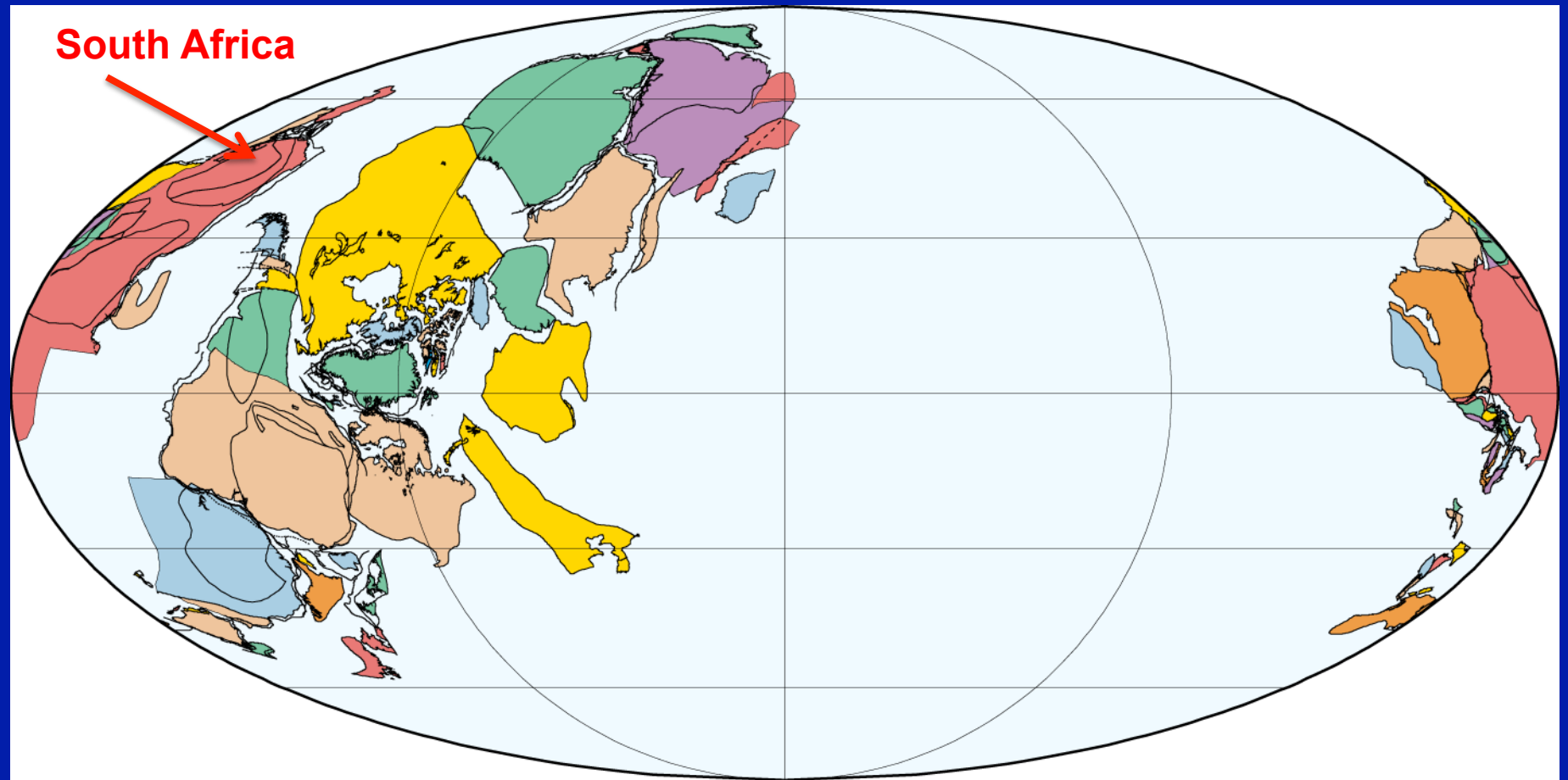
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North America

750 Ma
Late Proterozoic

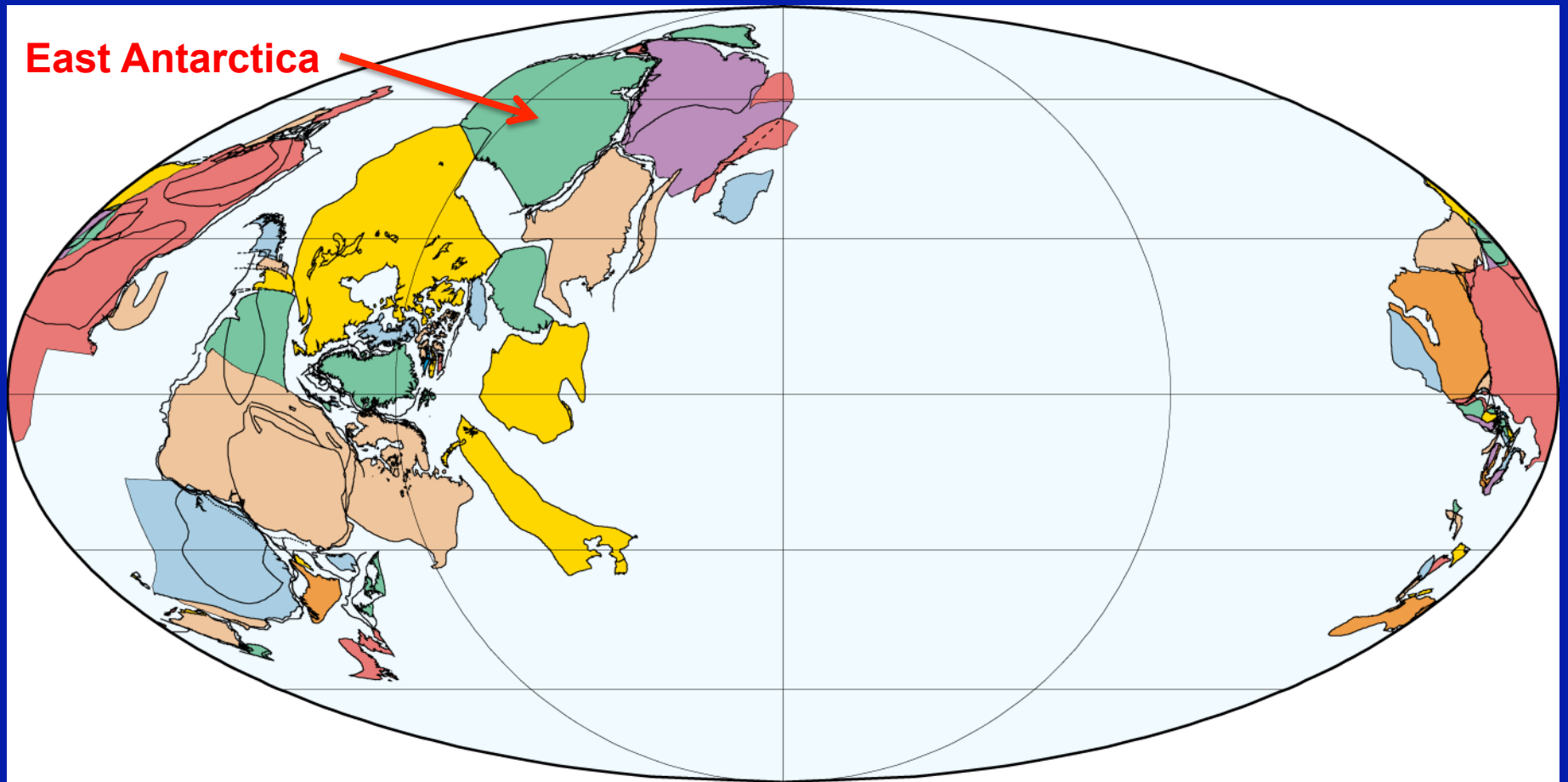
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South Africa

750 Ma
Late Proterozoic

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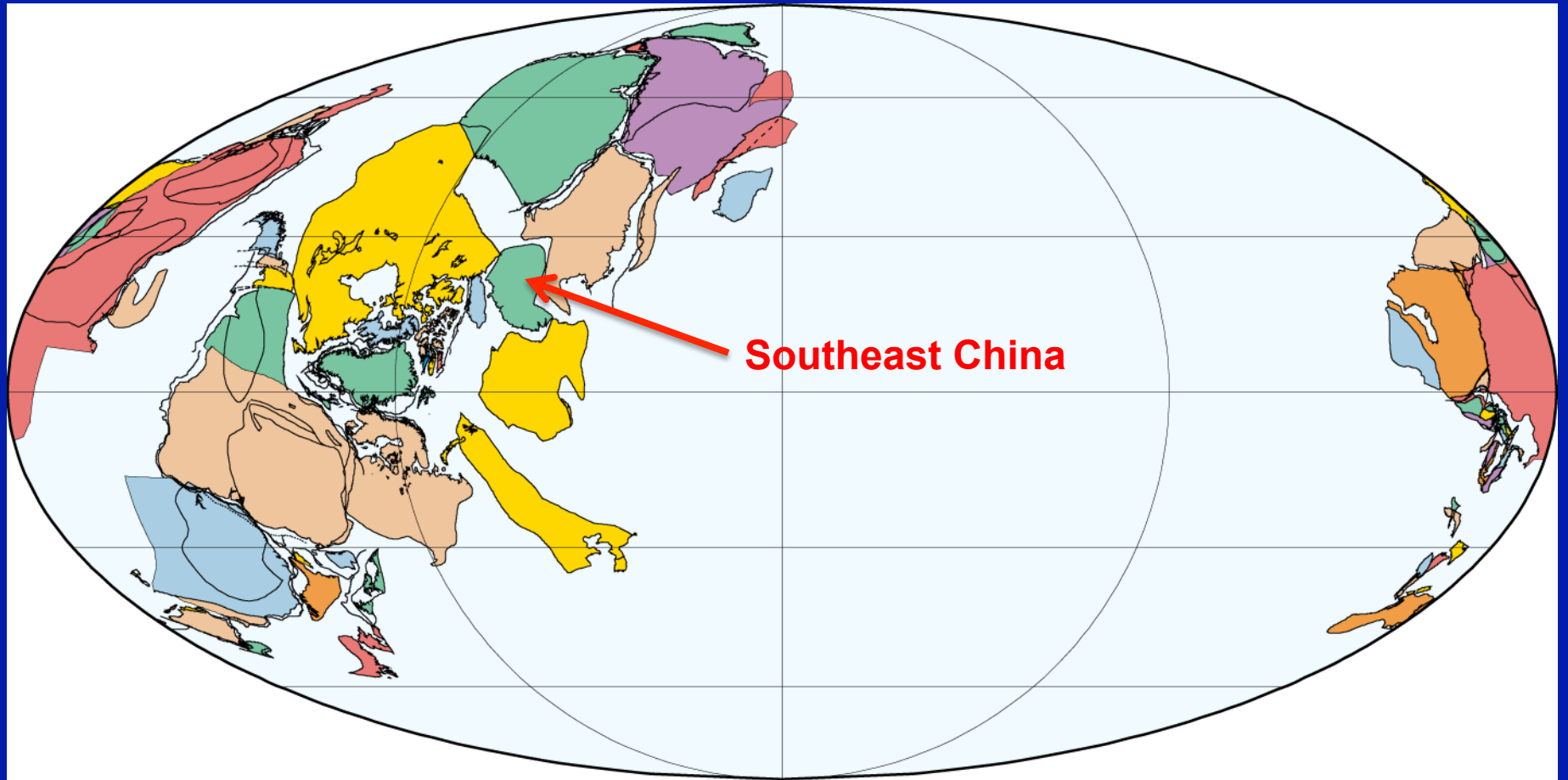
750 Ma
Late Proterozoic

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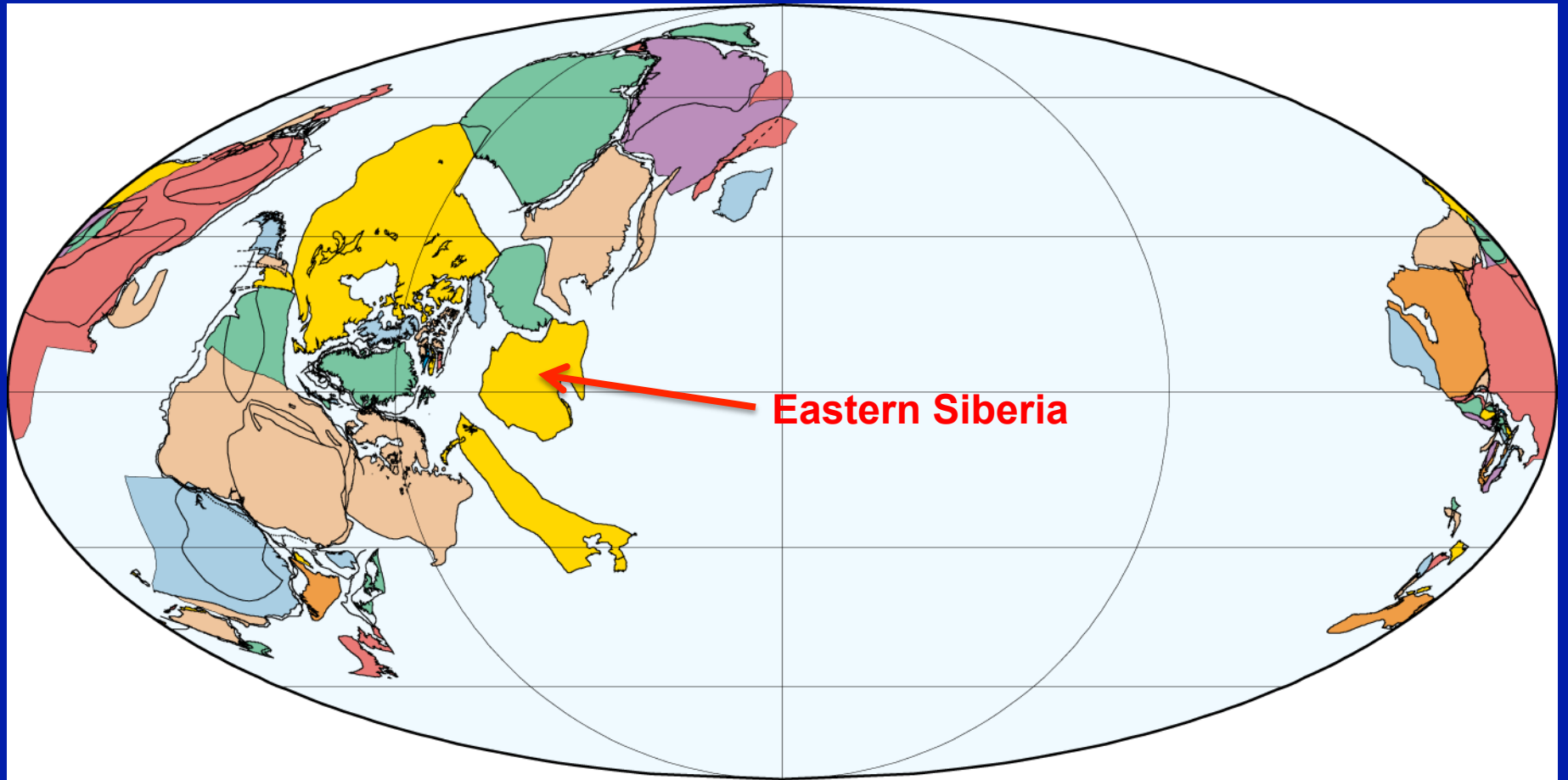
750 Ma
Late Proterozoic

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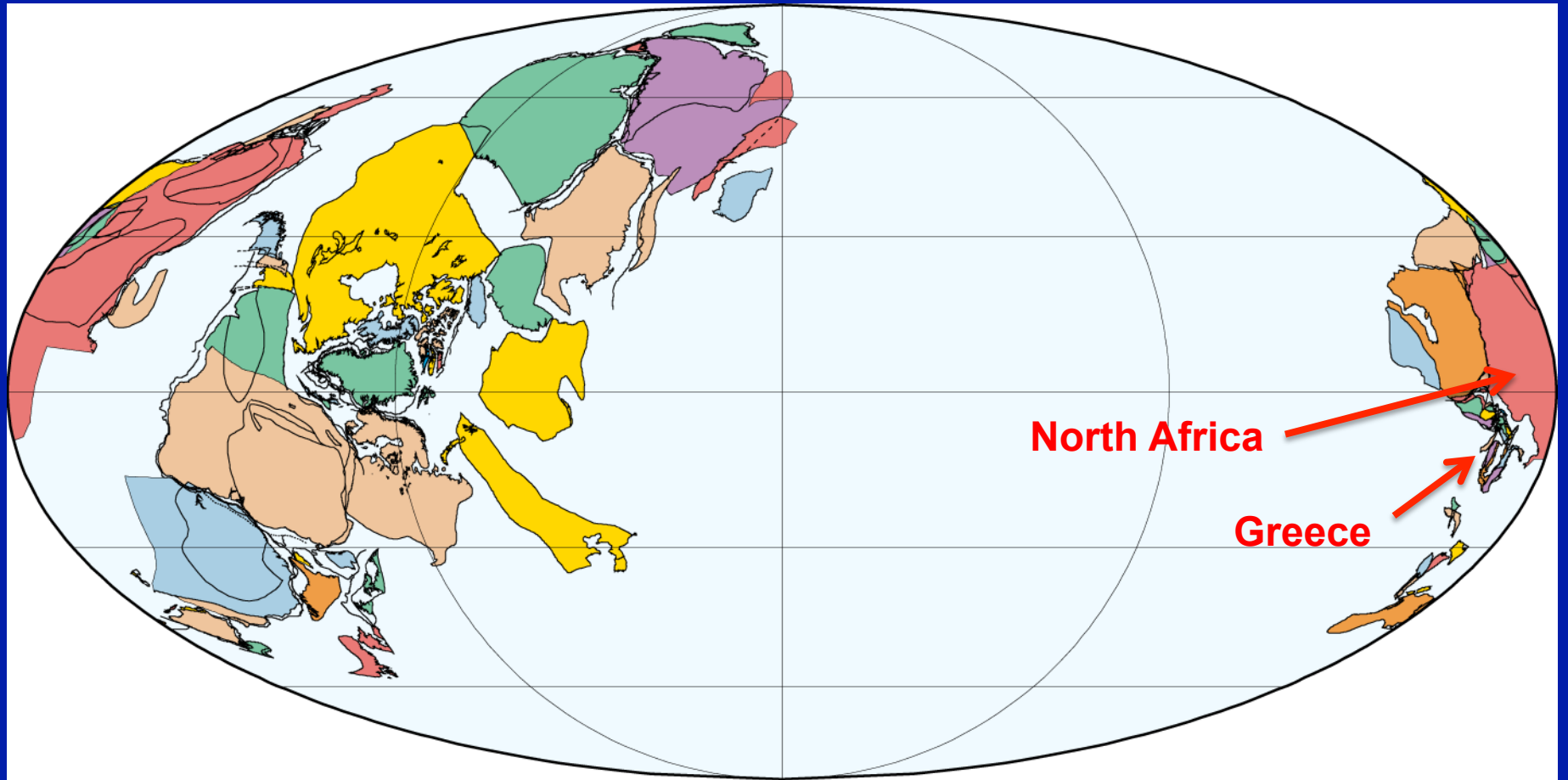
750 Ma
Late Proterozoic

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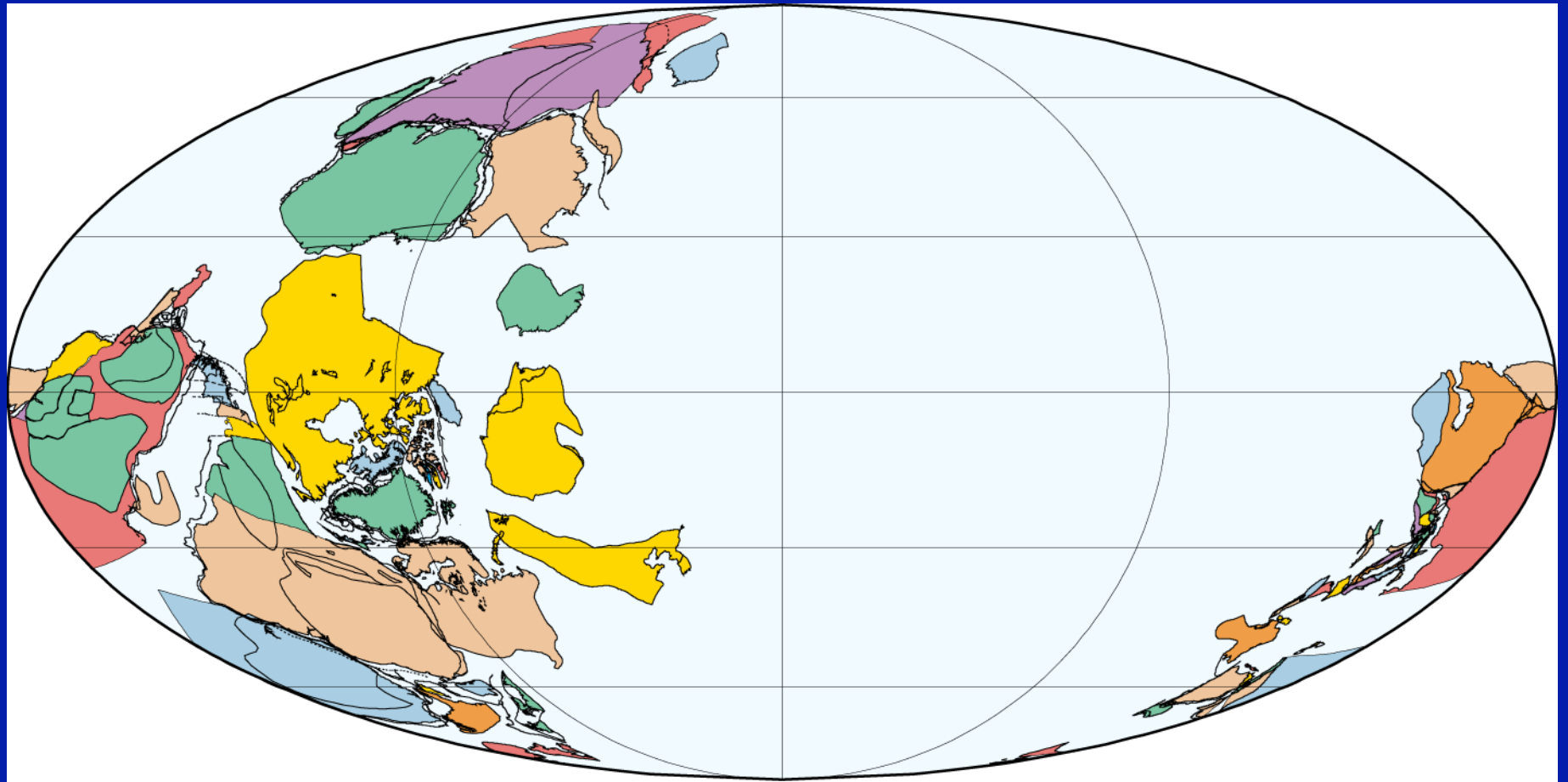
750 Ma
Late Proterozoic

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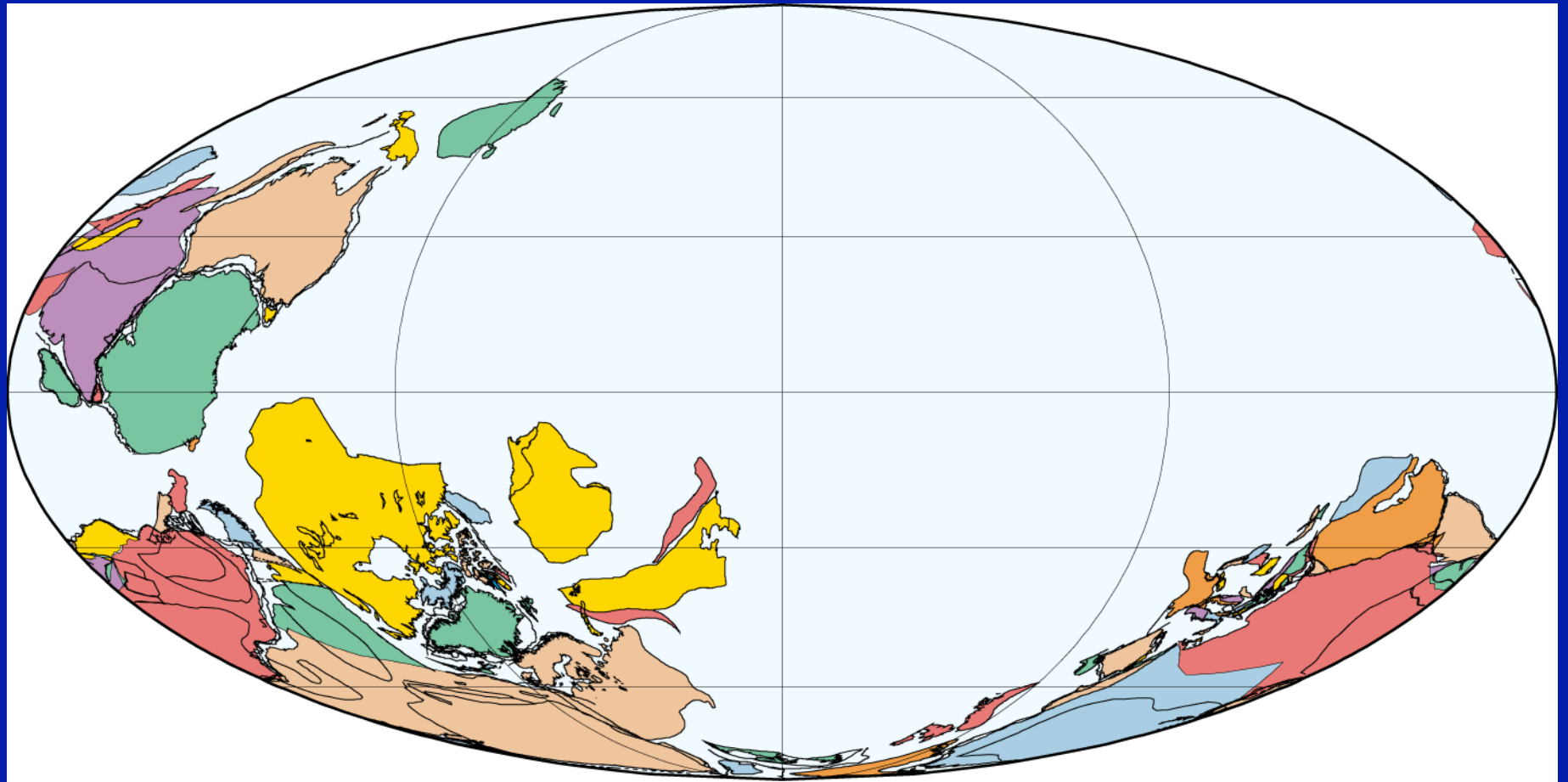
750 Ma
Late Proterozoic

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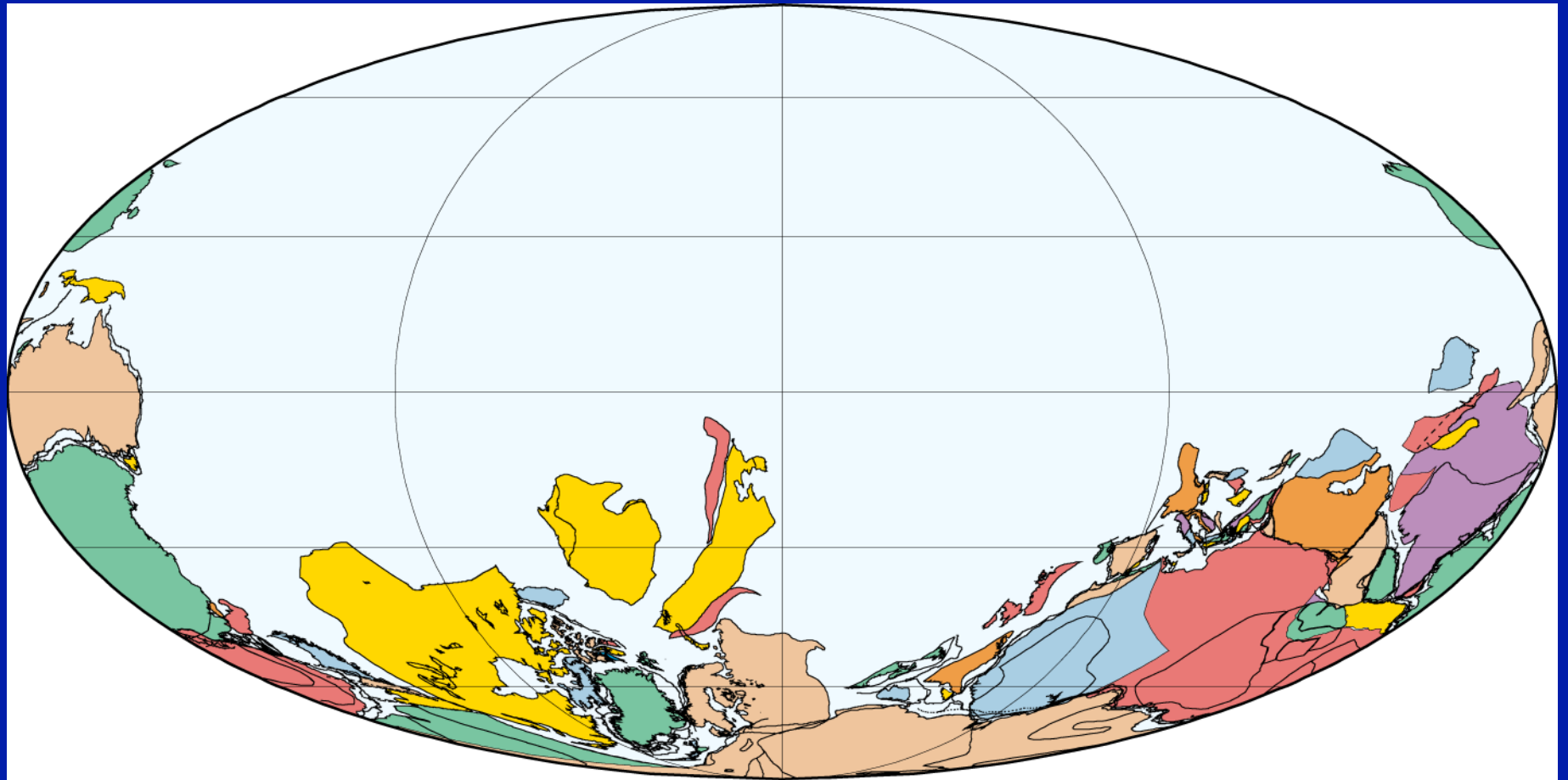
700 Ma
Late Proterozoic

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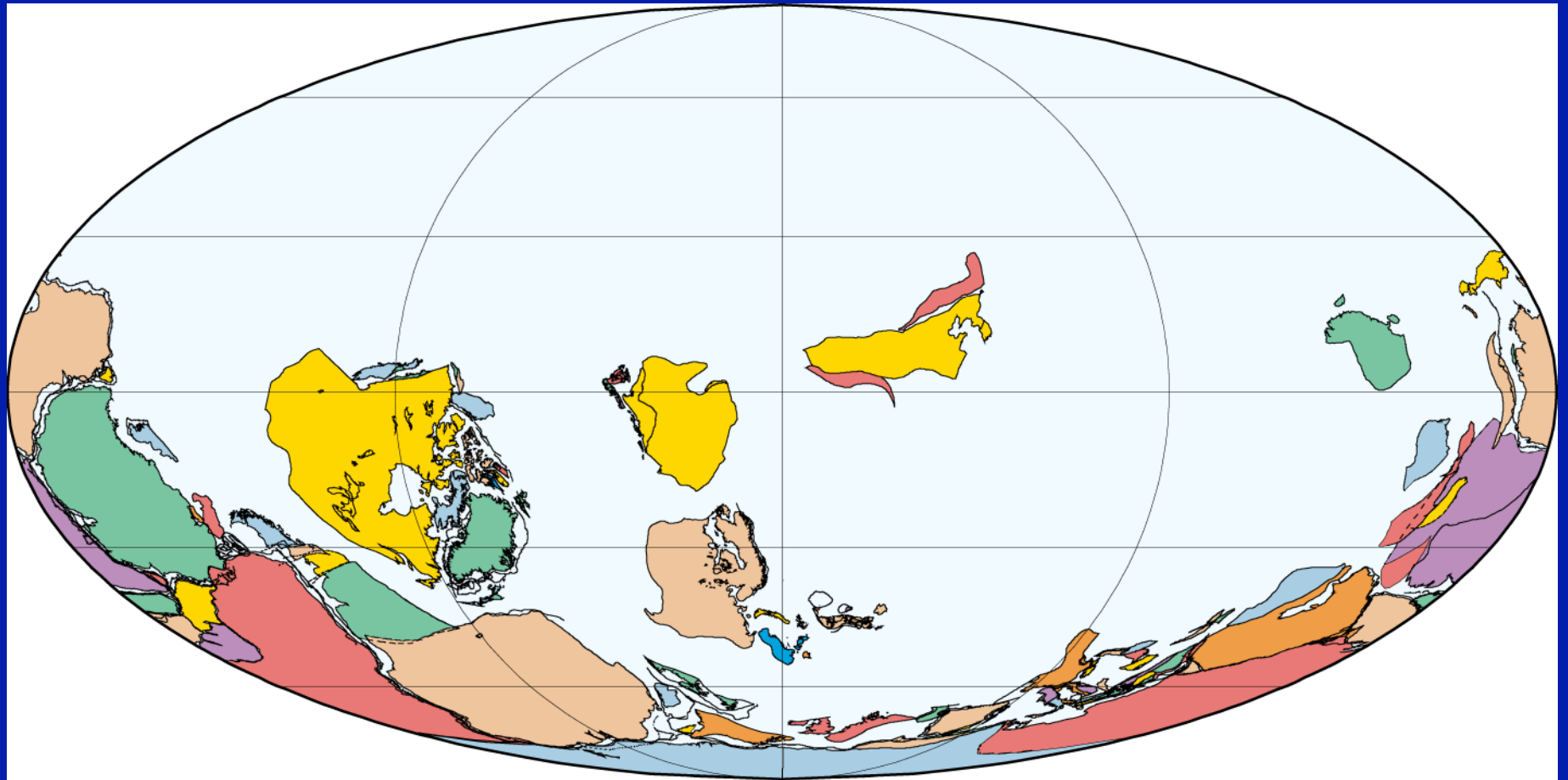
650 Ma
Late Proterozoic

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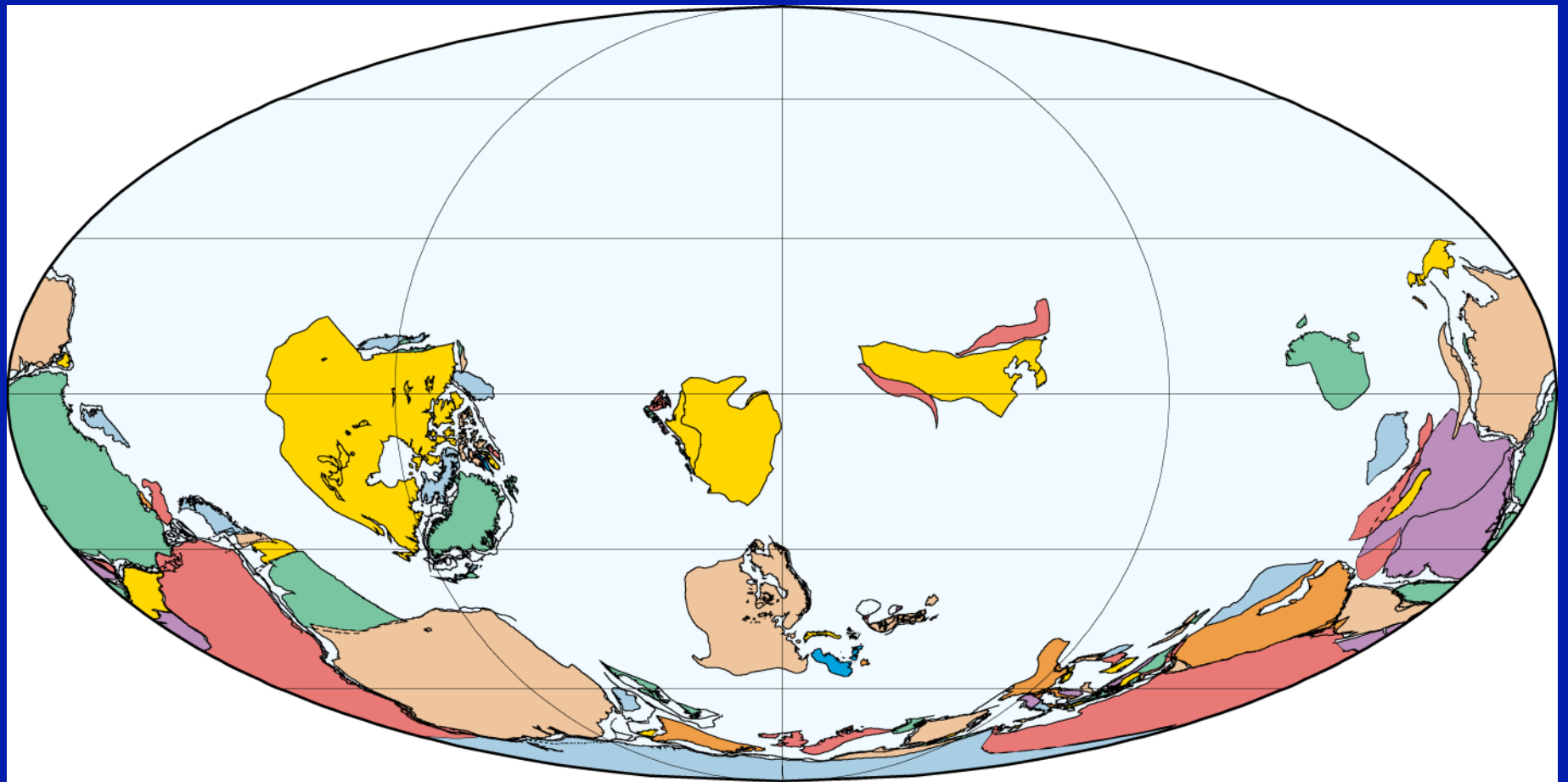
600 Ma
Late Proterozoic

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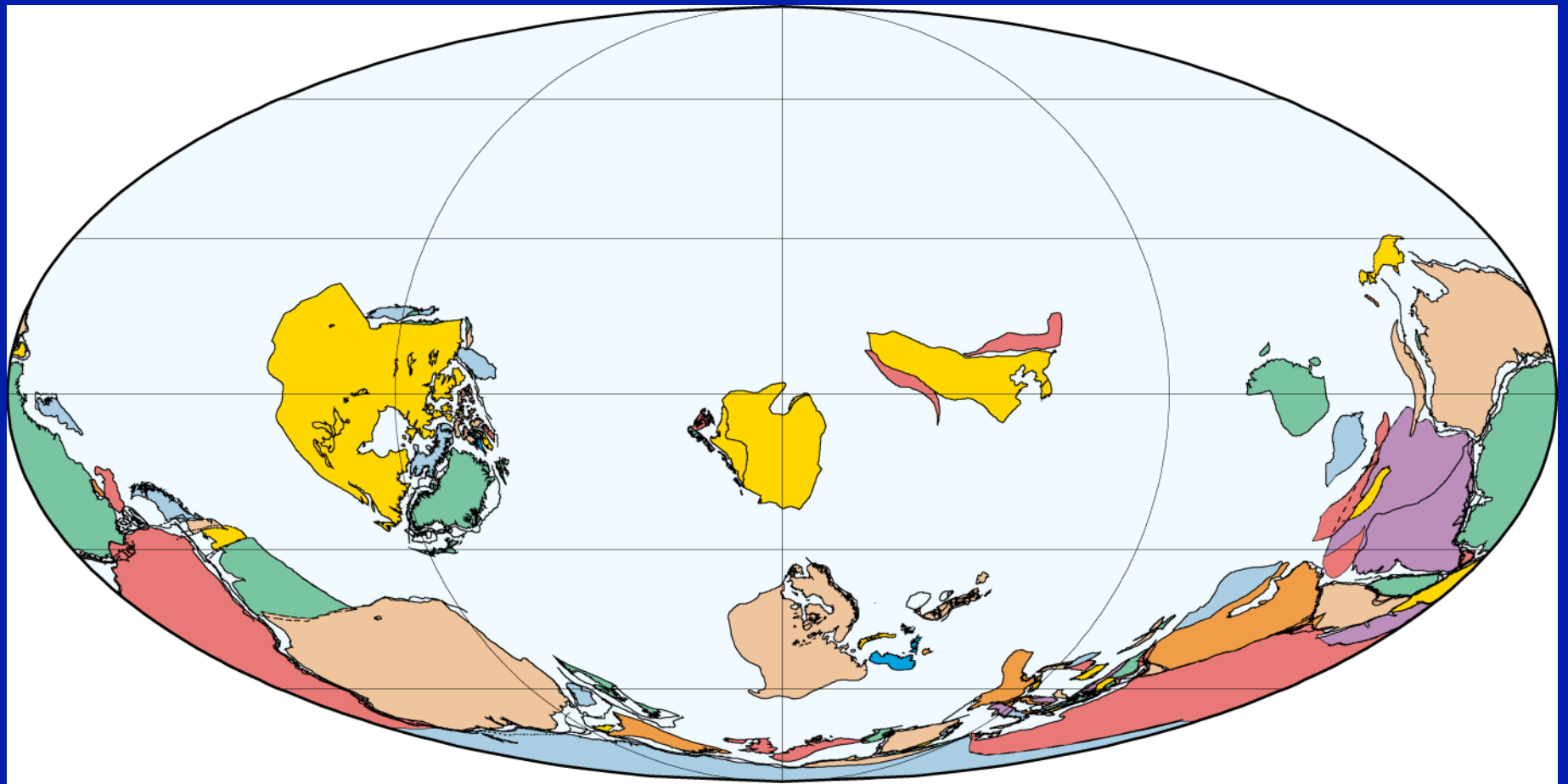
540 Ma
Nemakitian-Daldynian (Early Cambrian)

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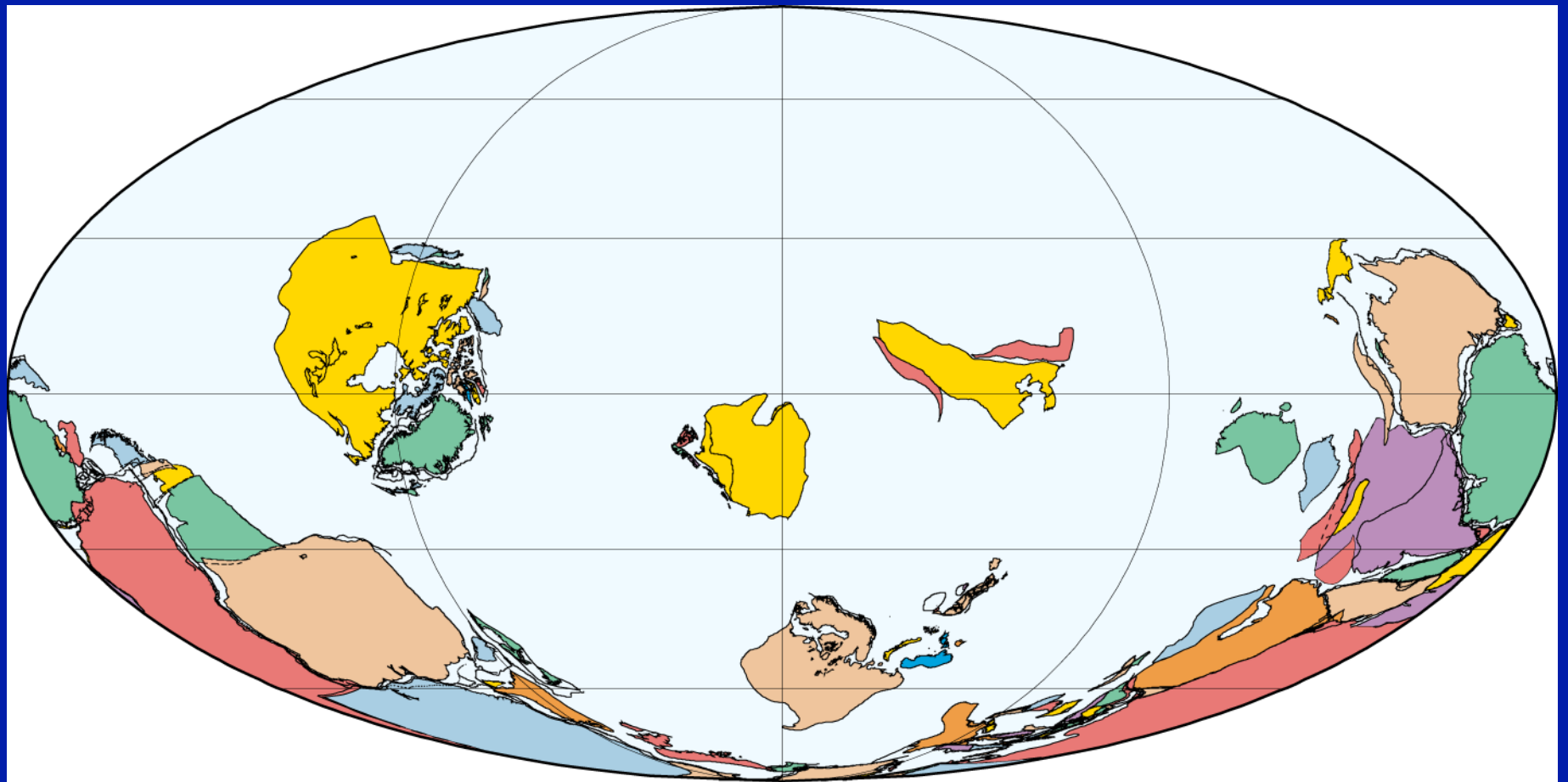
530 Ma
Late Tommotian/Early Atdabanian (Early Cambrian)

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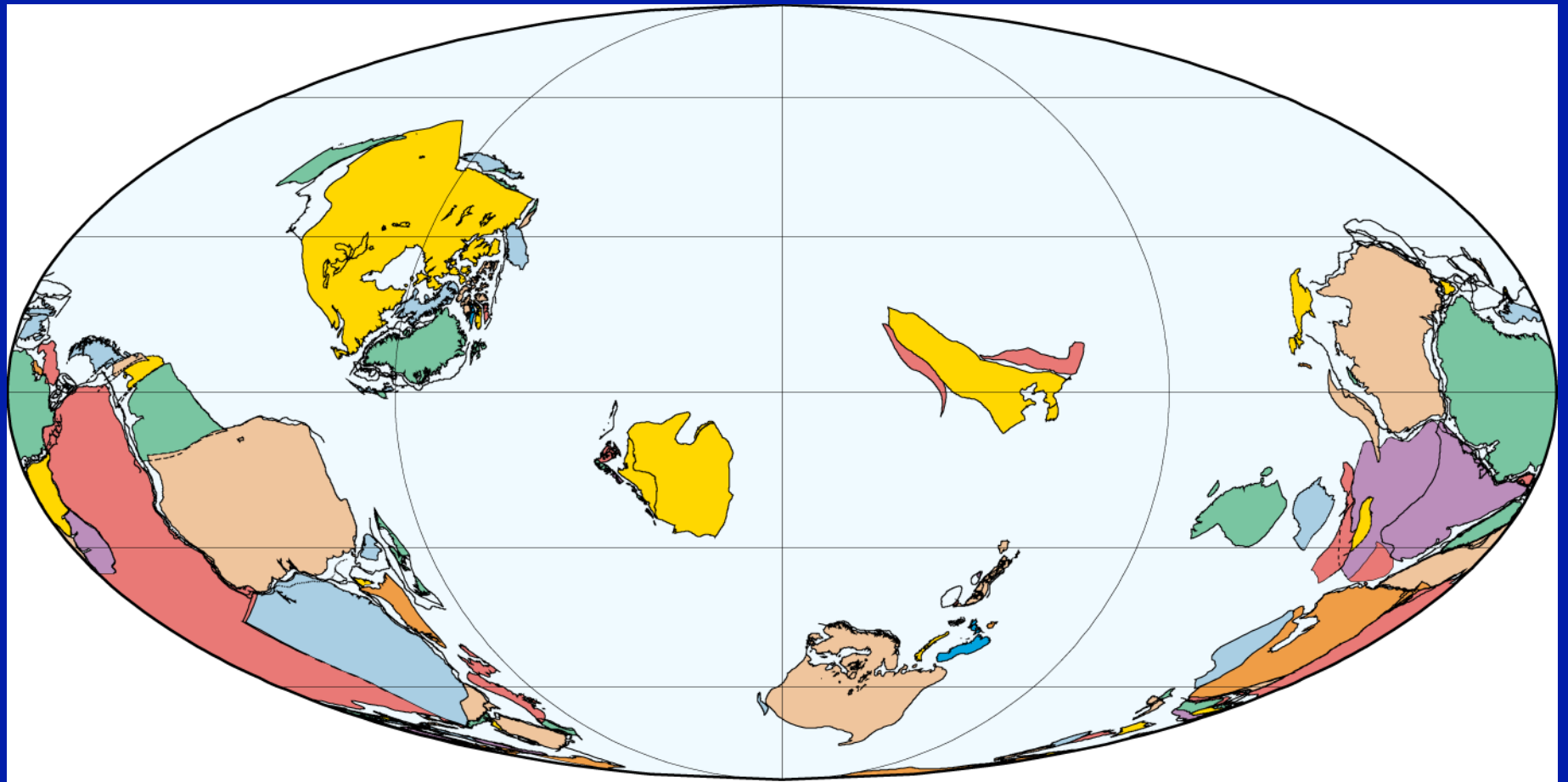
520 Ma
Lenian (Early Cambrian)

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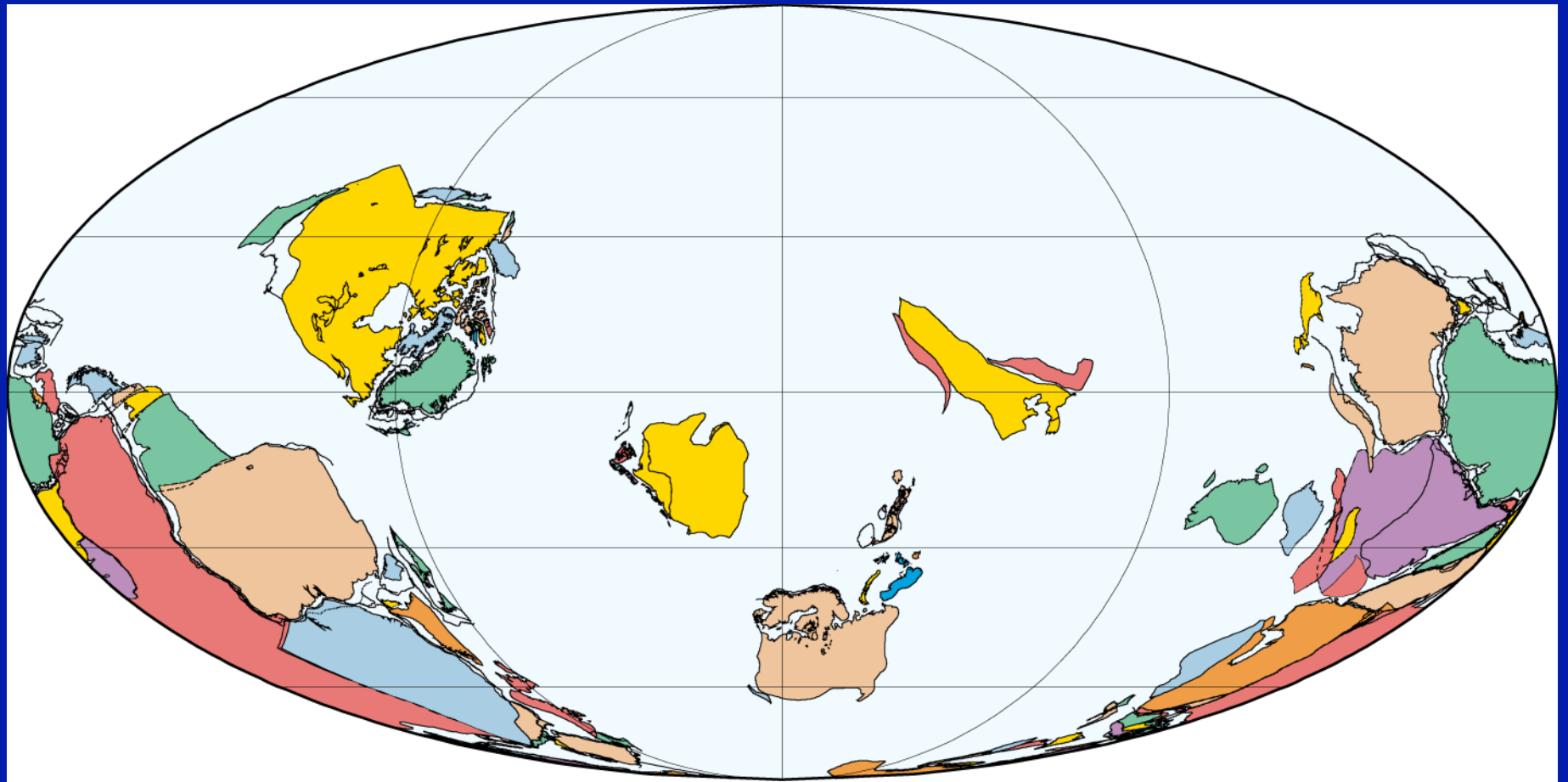
510 Ma
Middle Cambrian

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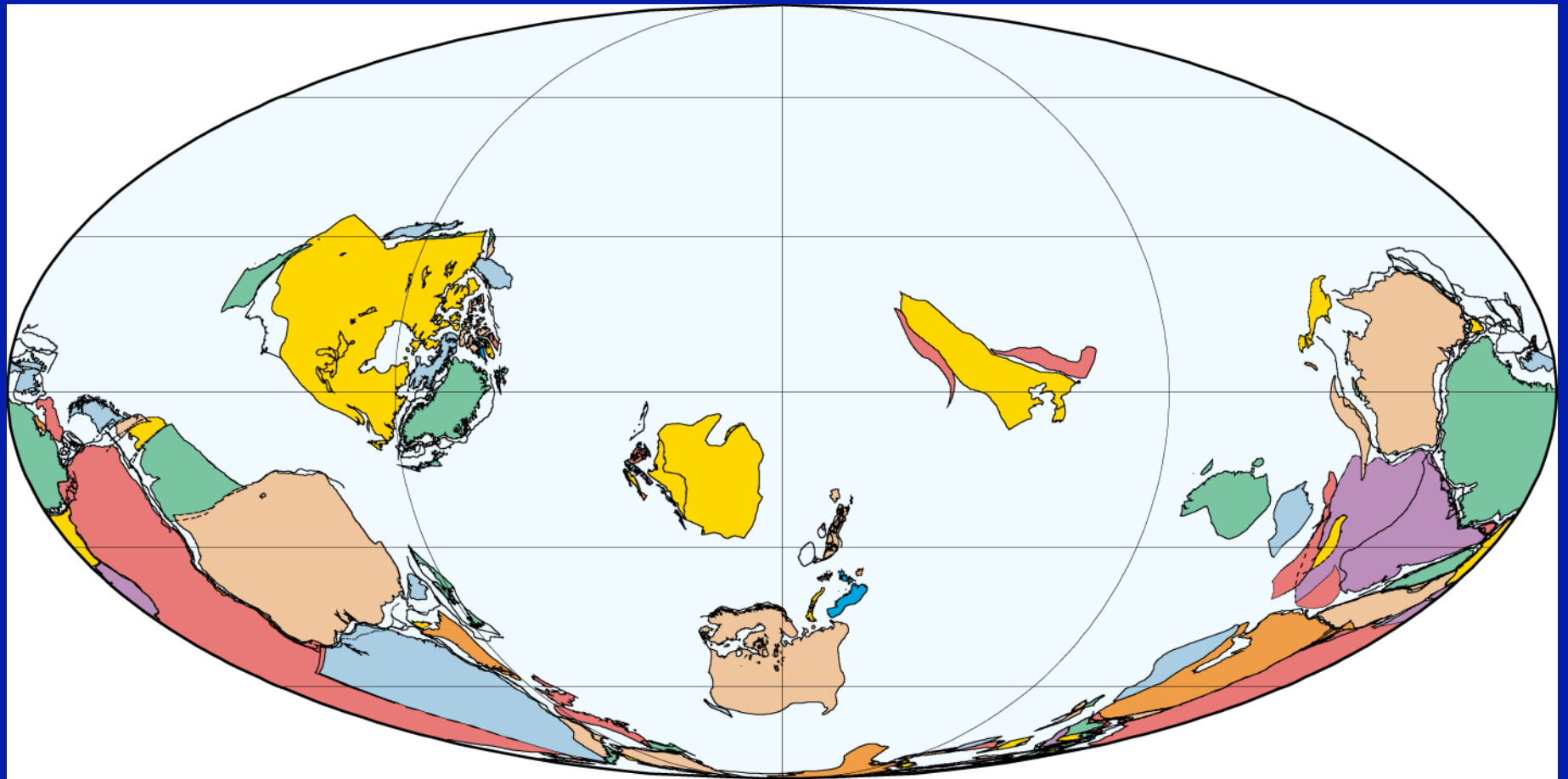
500 Ma
Late Cambrian

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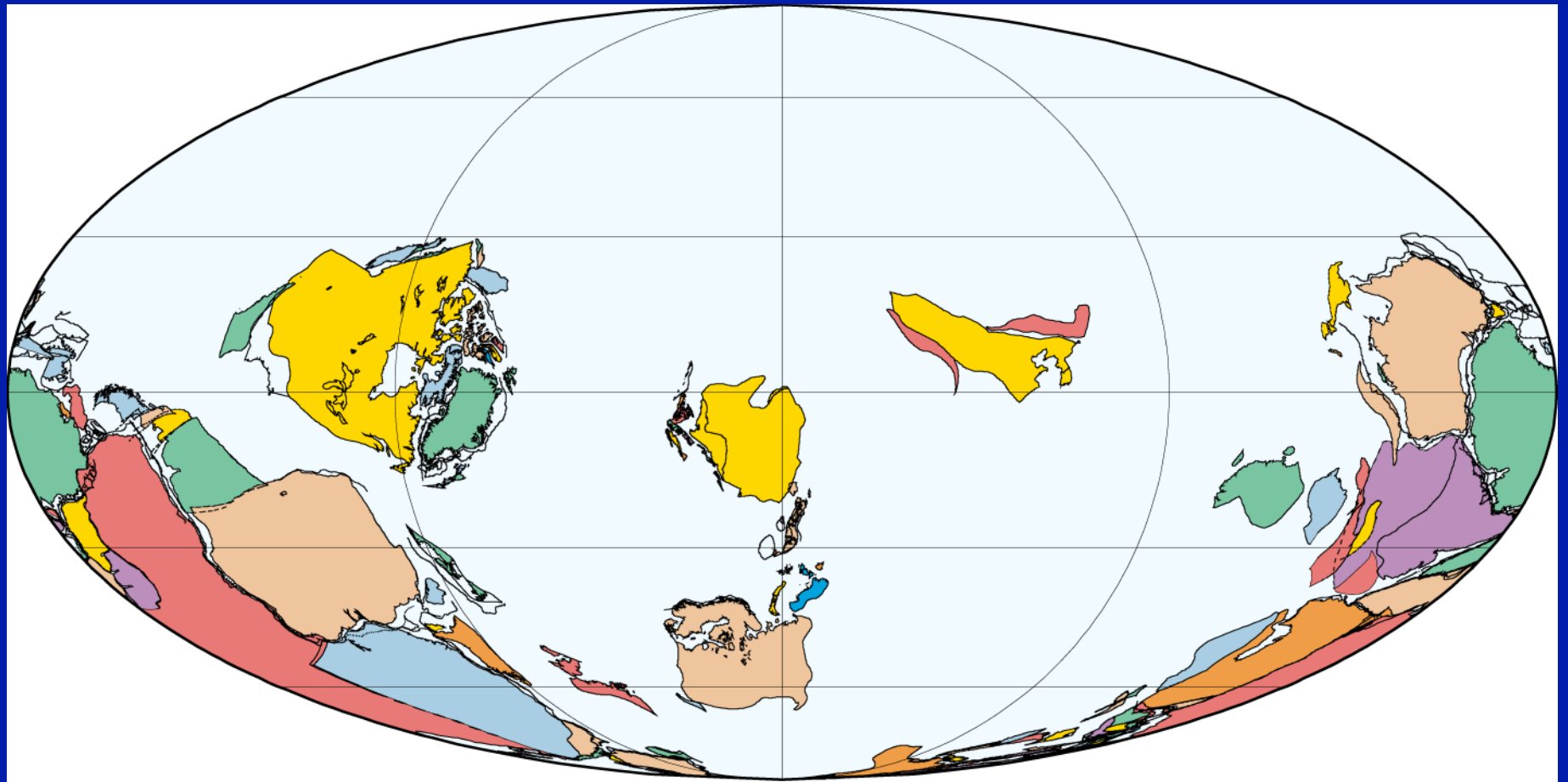
490 Ma
Tremadocian (Early Ordovician)

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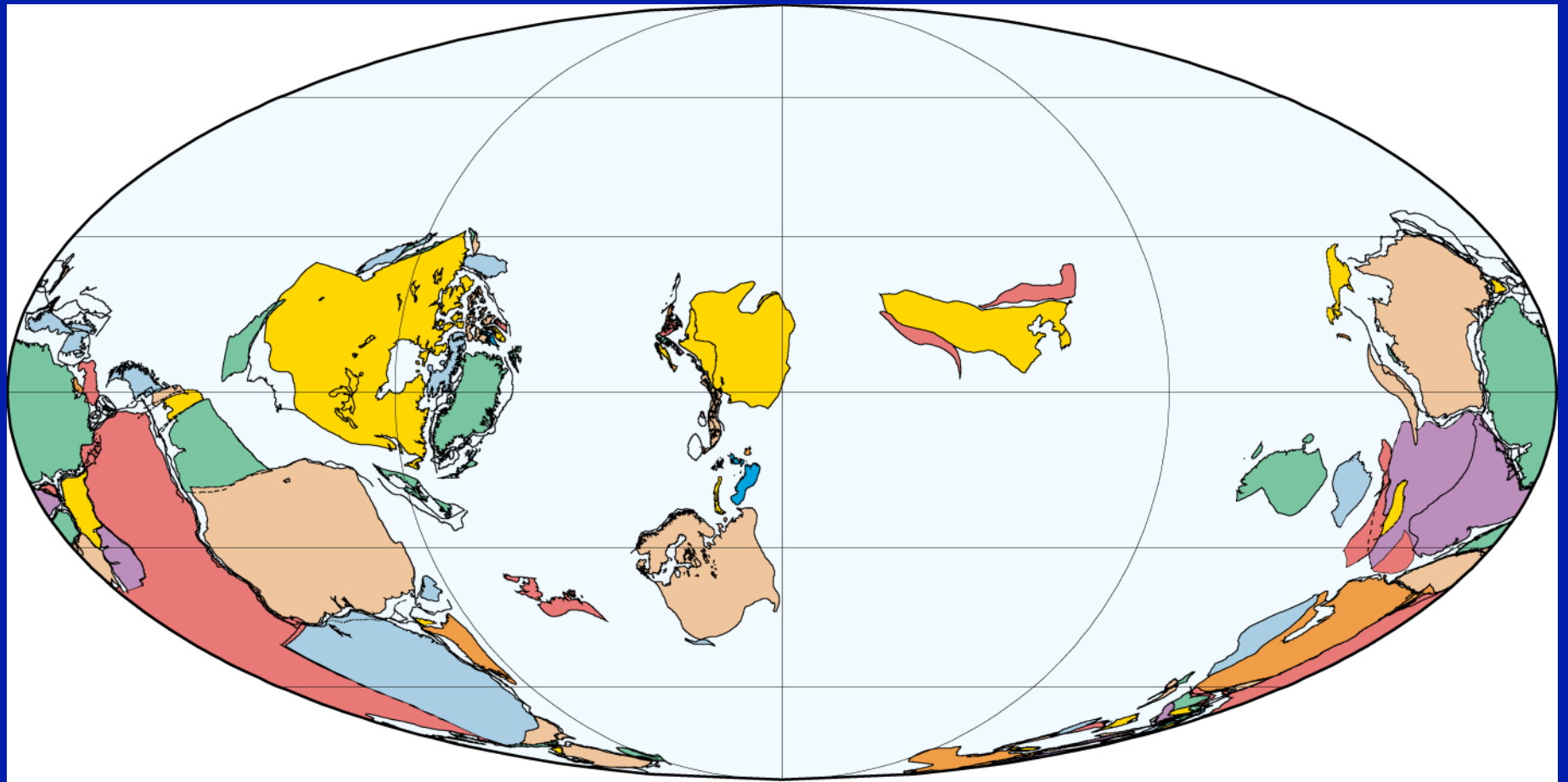
480 Ma
Arenigian (Early Ordovician)

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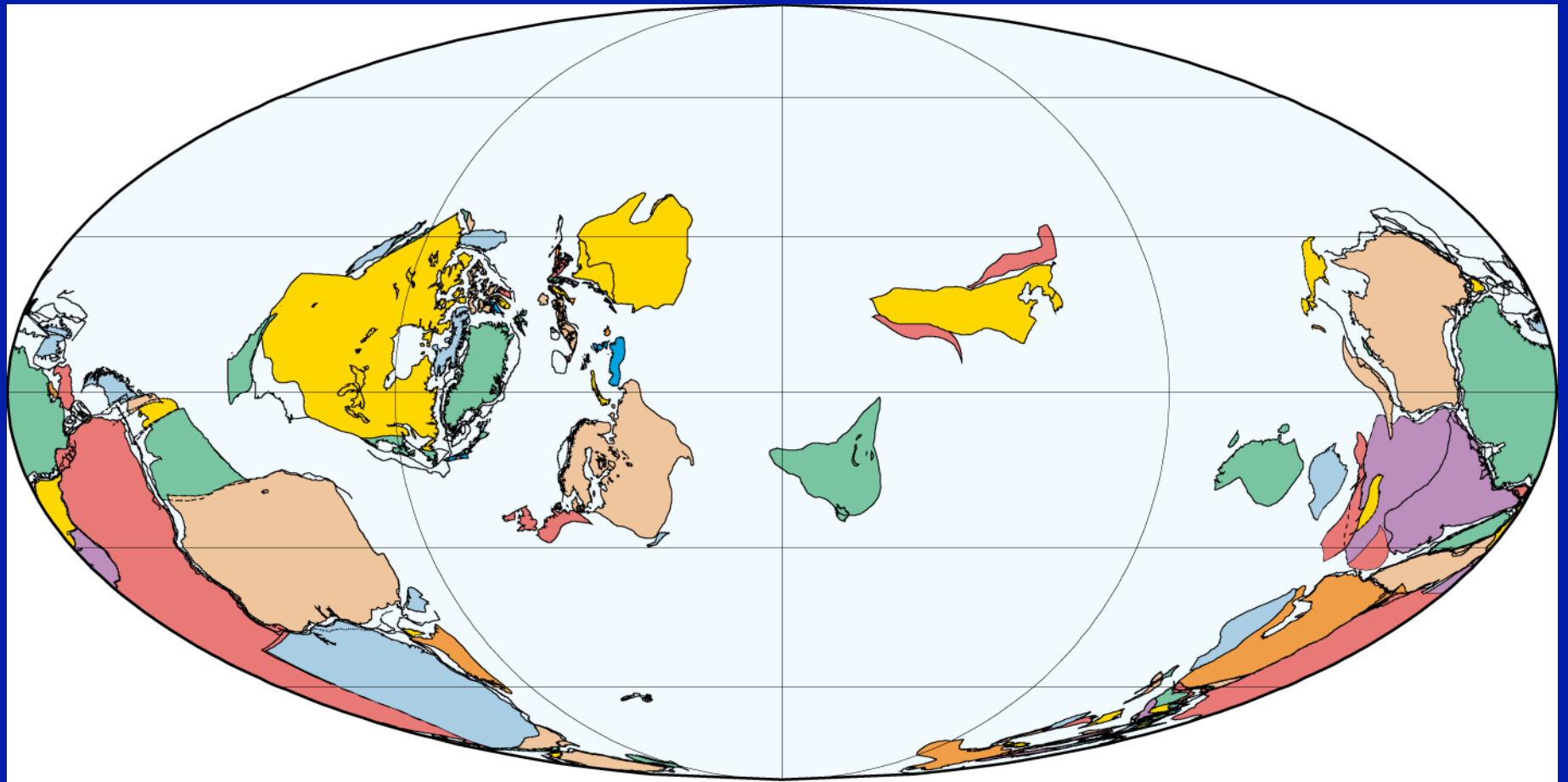
470 Ma
Late Arenigian/Early Llanvirnian (Early/Middle Ordovician)

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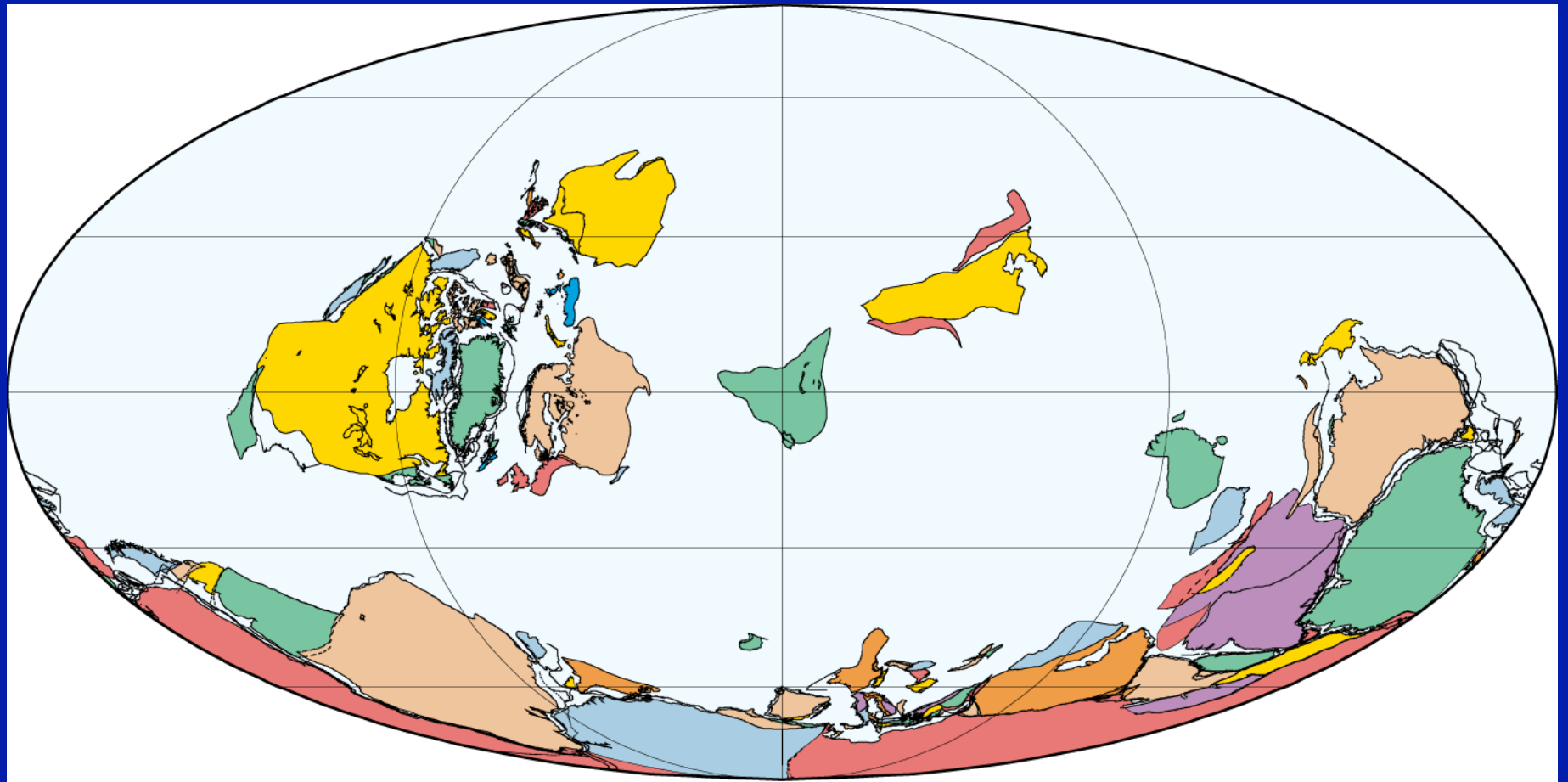
460 Ma
Llandeilan (Middle Ordovician)

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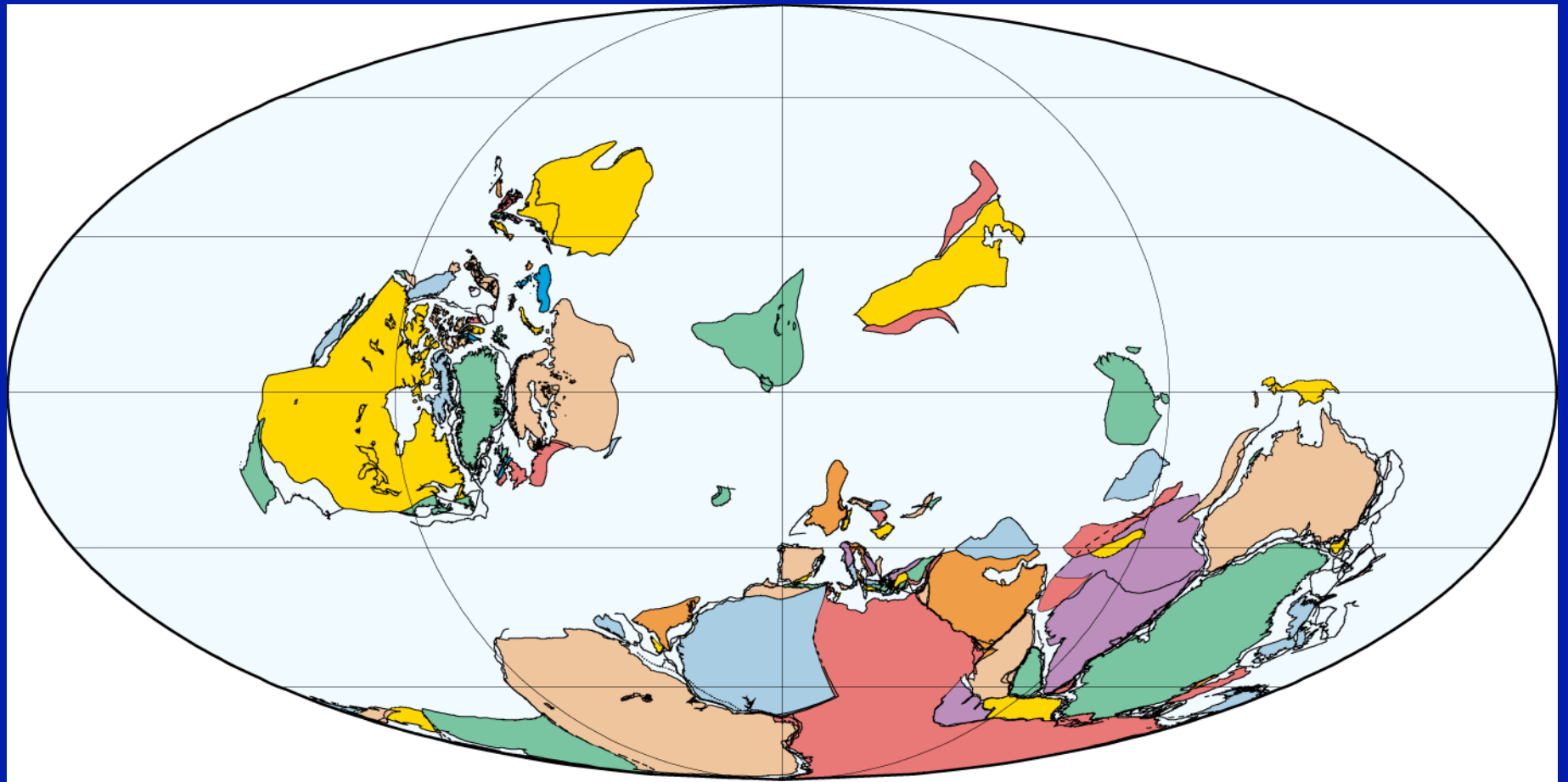
450 Ma
Caradocian (Late Ordovician)

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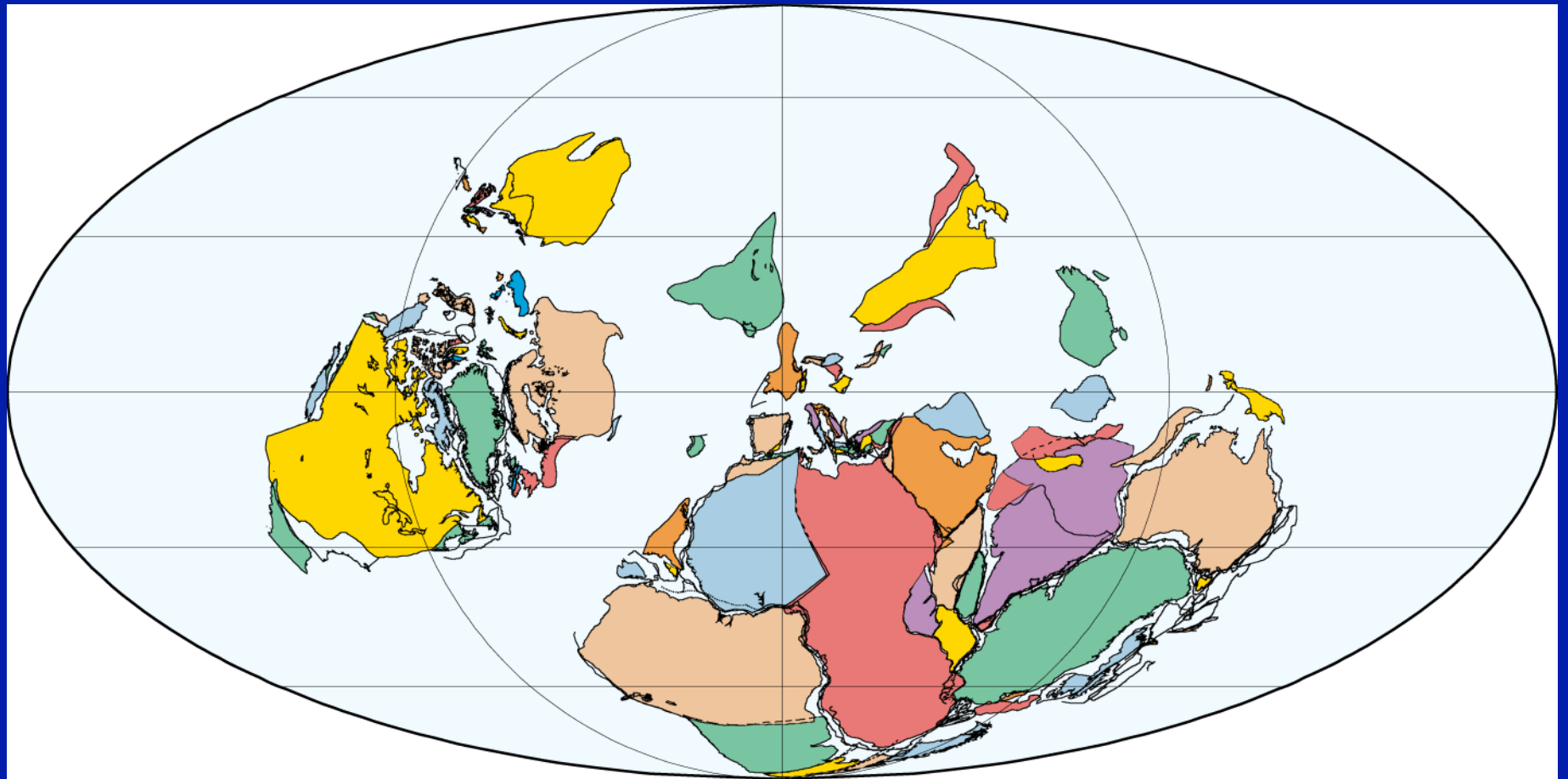
440 Ma
Early Llandoveryan (Early Silurian)

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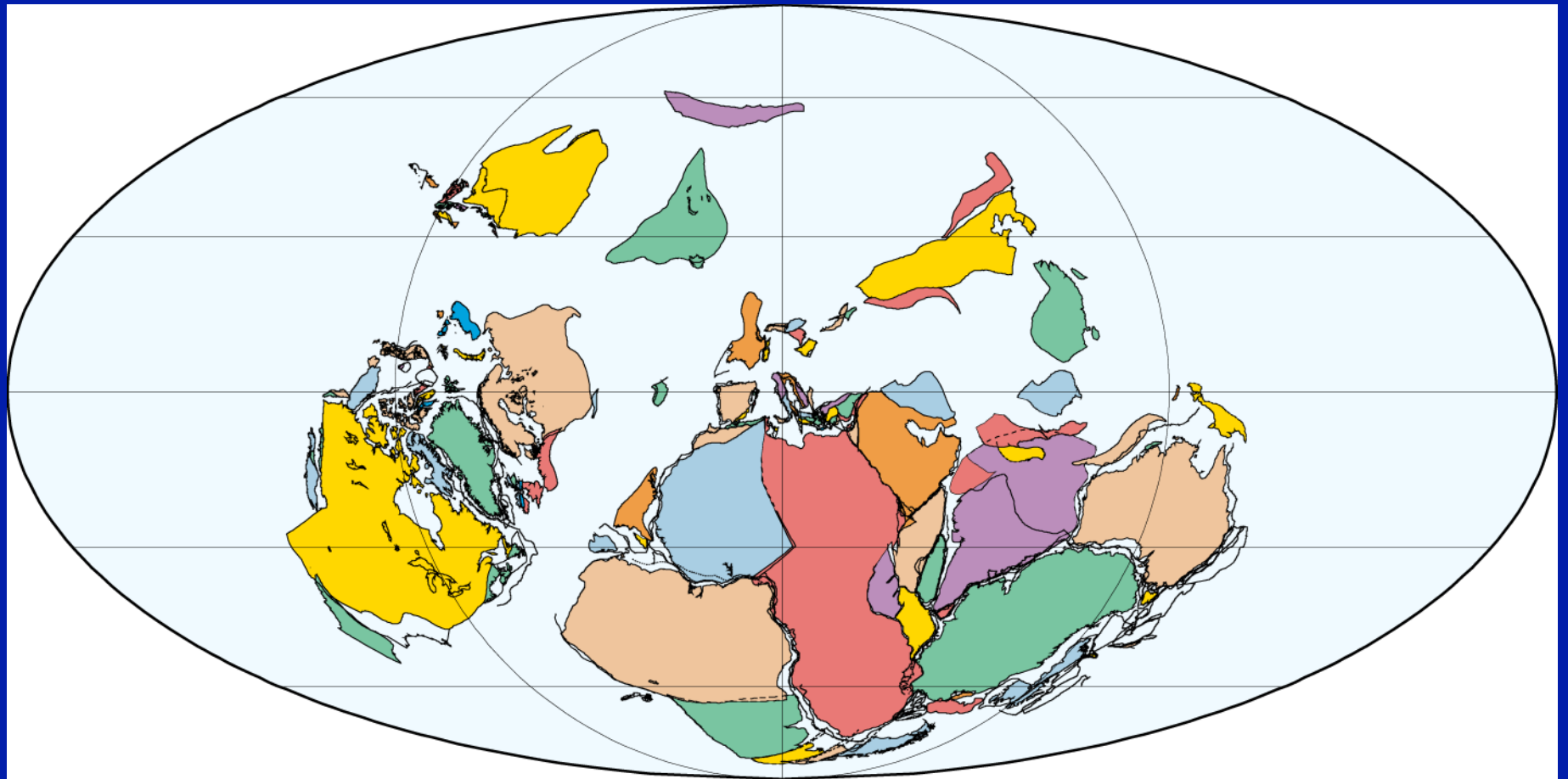
430 Ma
Late Llandoveryan (Early Silurian)

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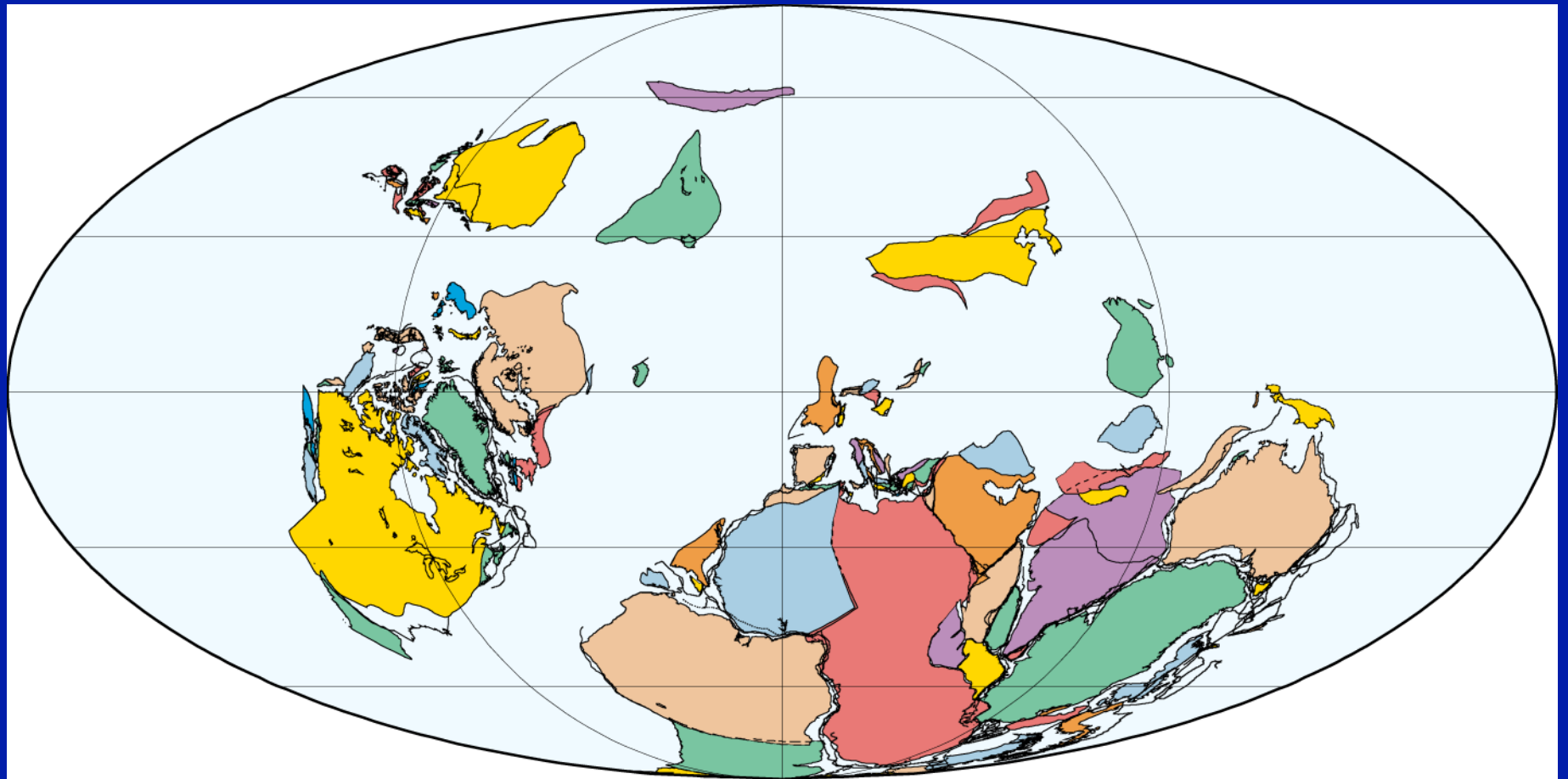
420 Ma
Ludlovian (Late Silurian)

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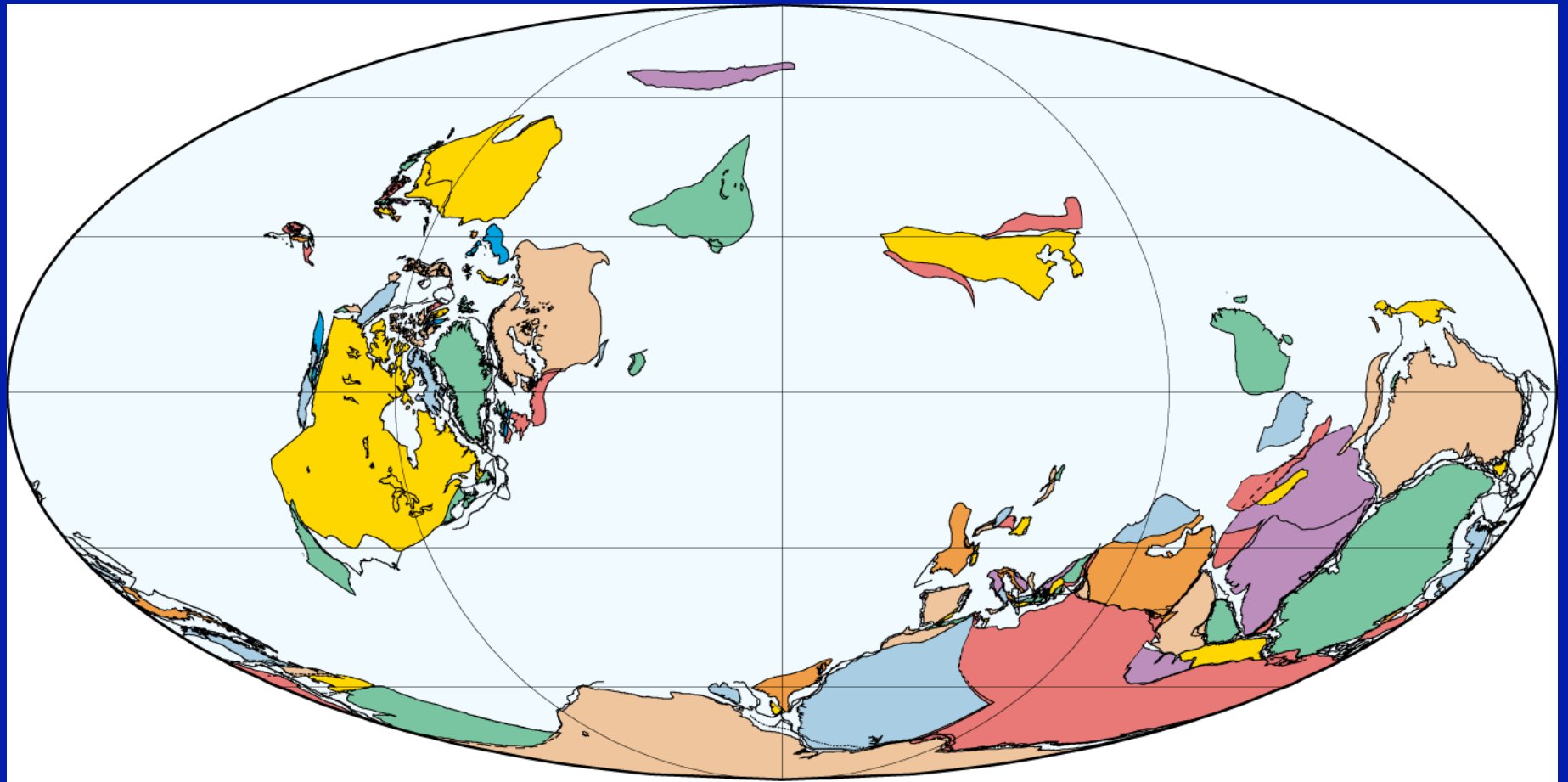
410 Ma
Early Praghian (Early Devonian)

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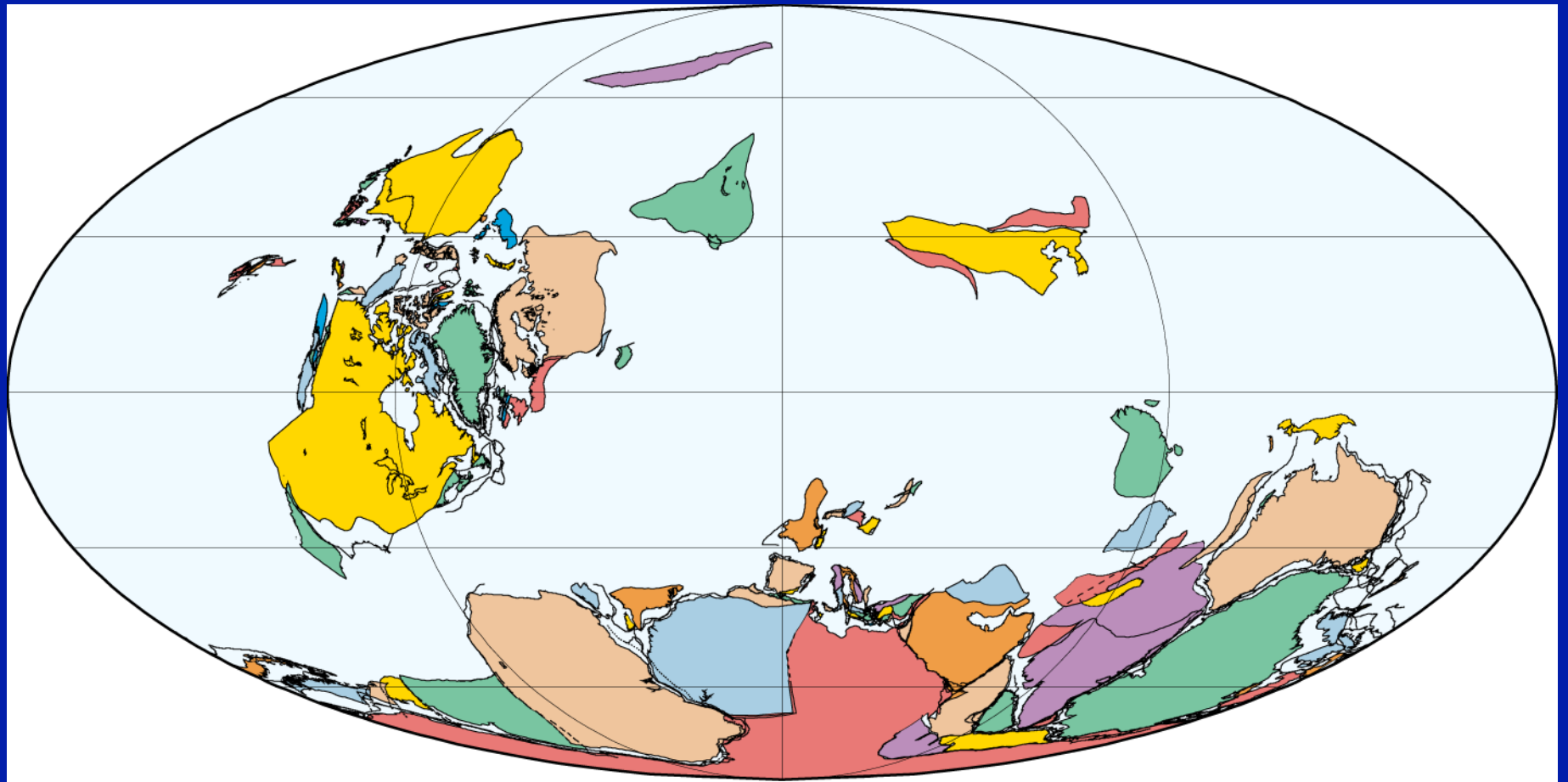
400 Ma
Late Praghian/Early Emsian (Early Devonian)

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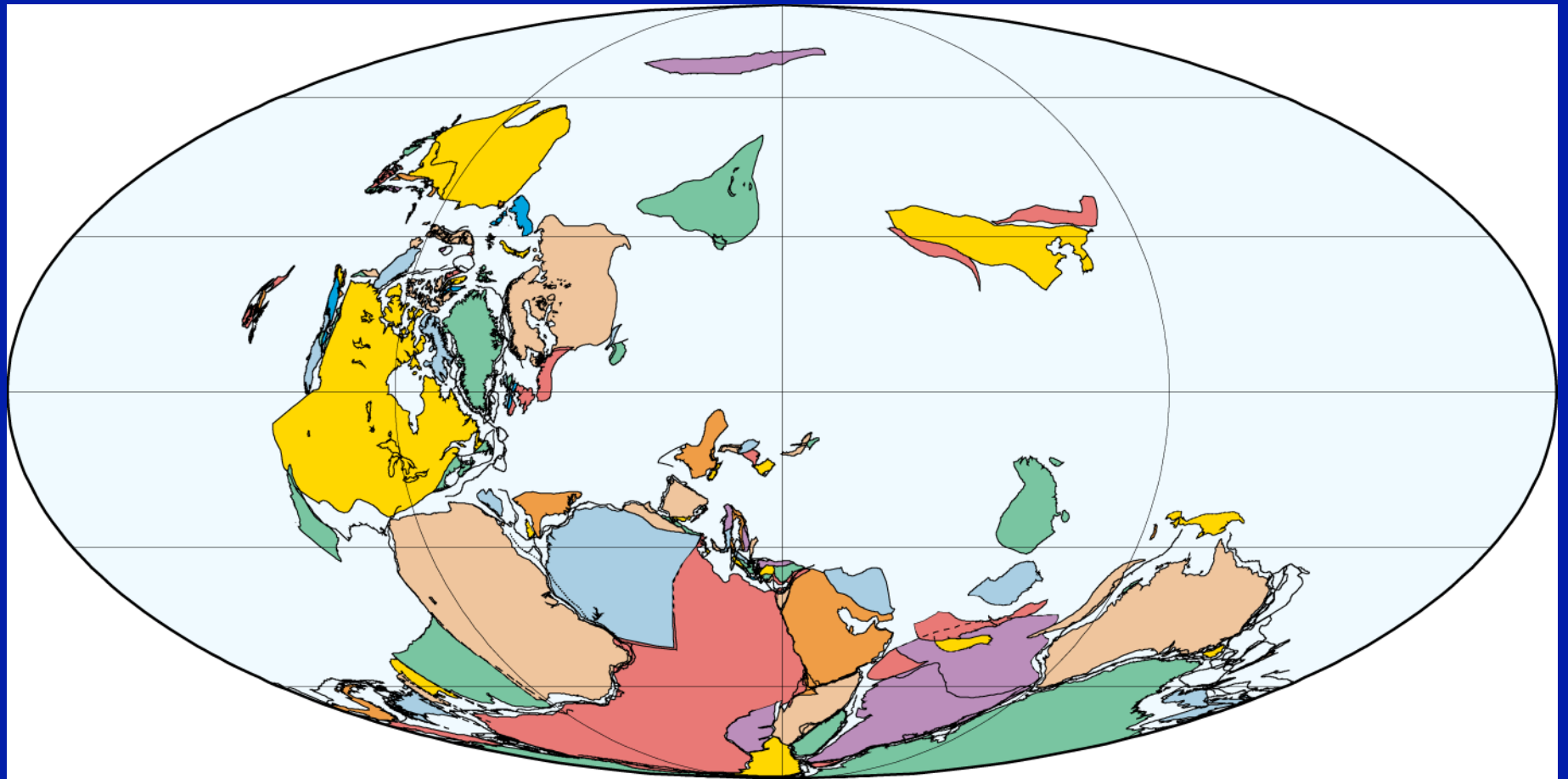
390 Ma
Early Eifelian (Early Devonian)

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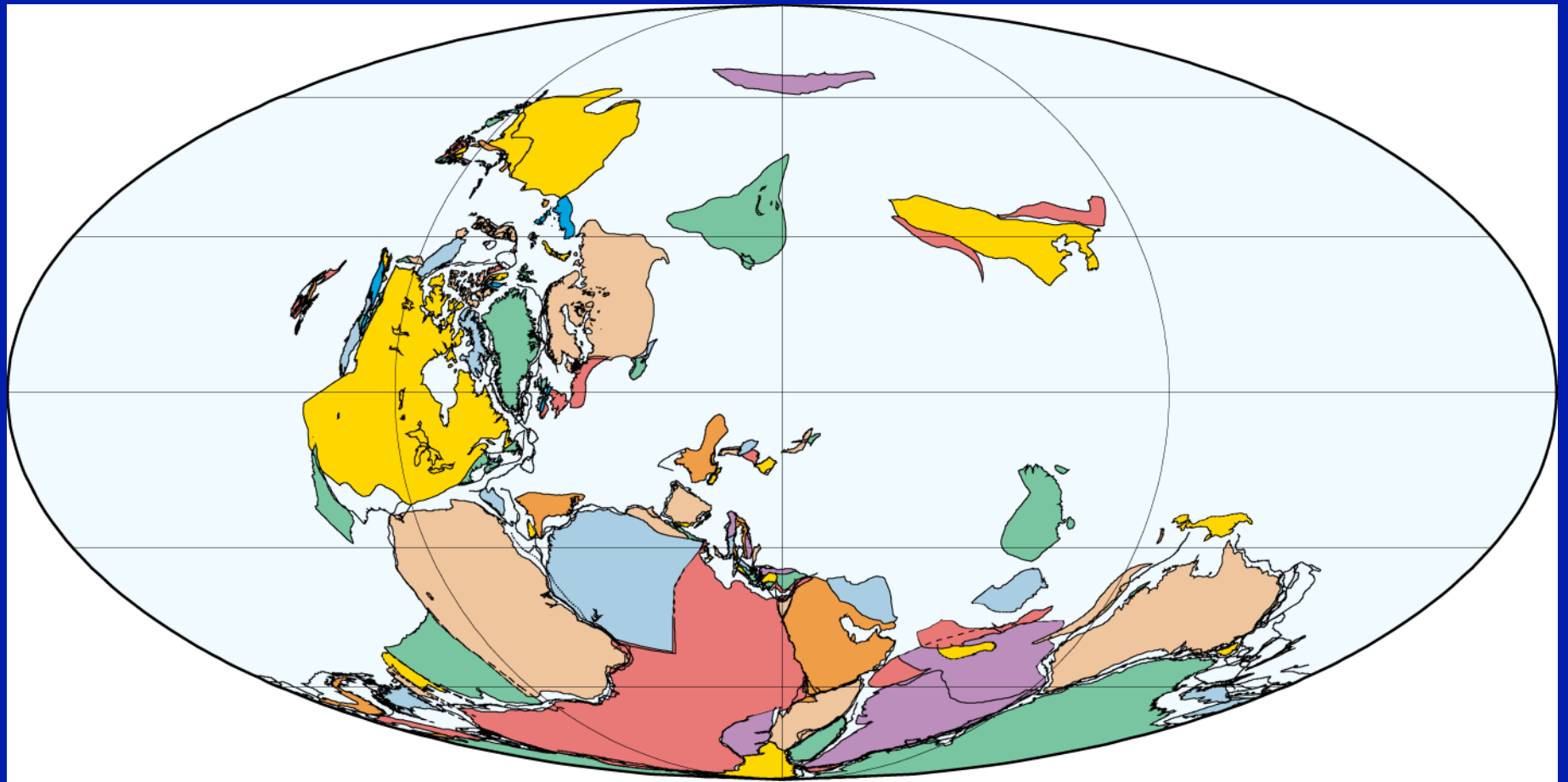
380 Ma
Late Eifelian/Early Givetian (Middle Devonian)

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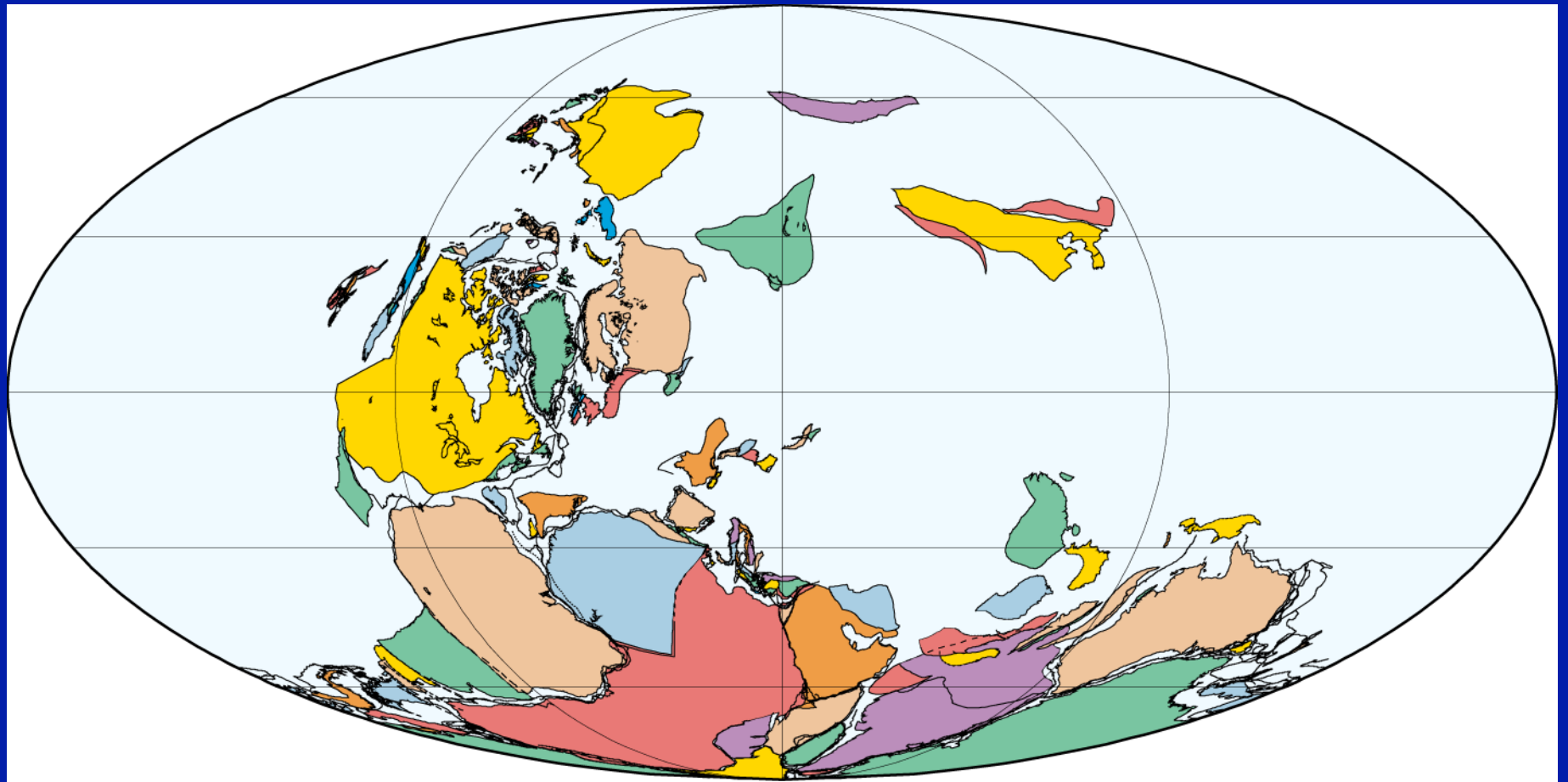
370 Ma
Late Givetian/Early Frasnian (Late Devonian)

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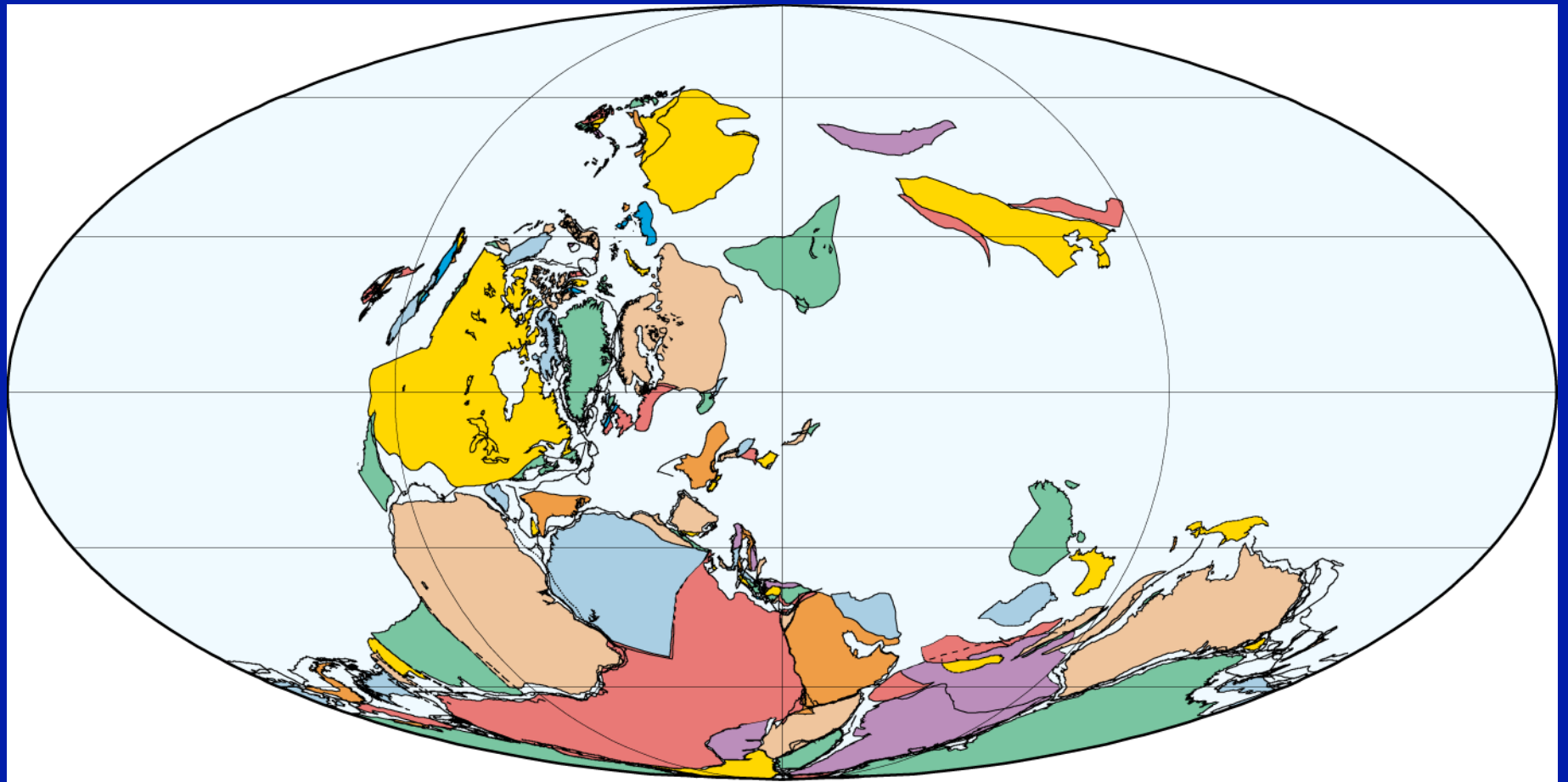
360 Ma
Famennian (Late Devonian)

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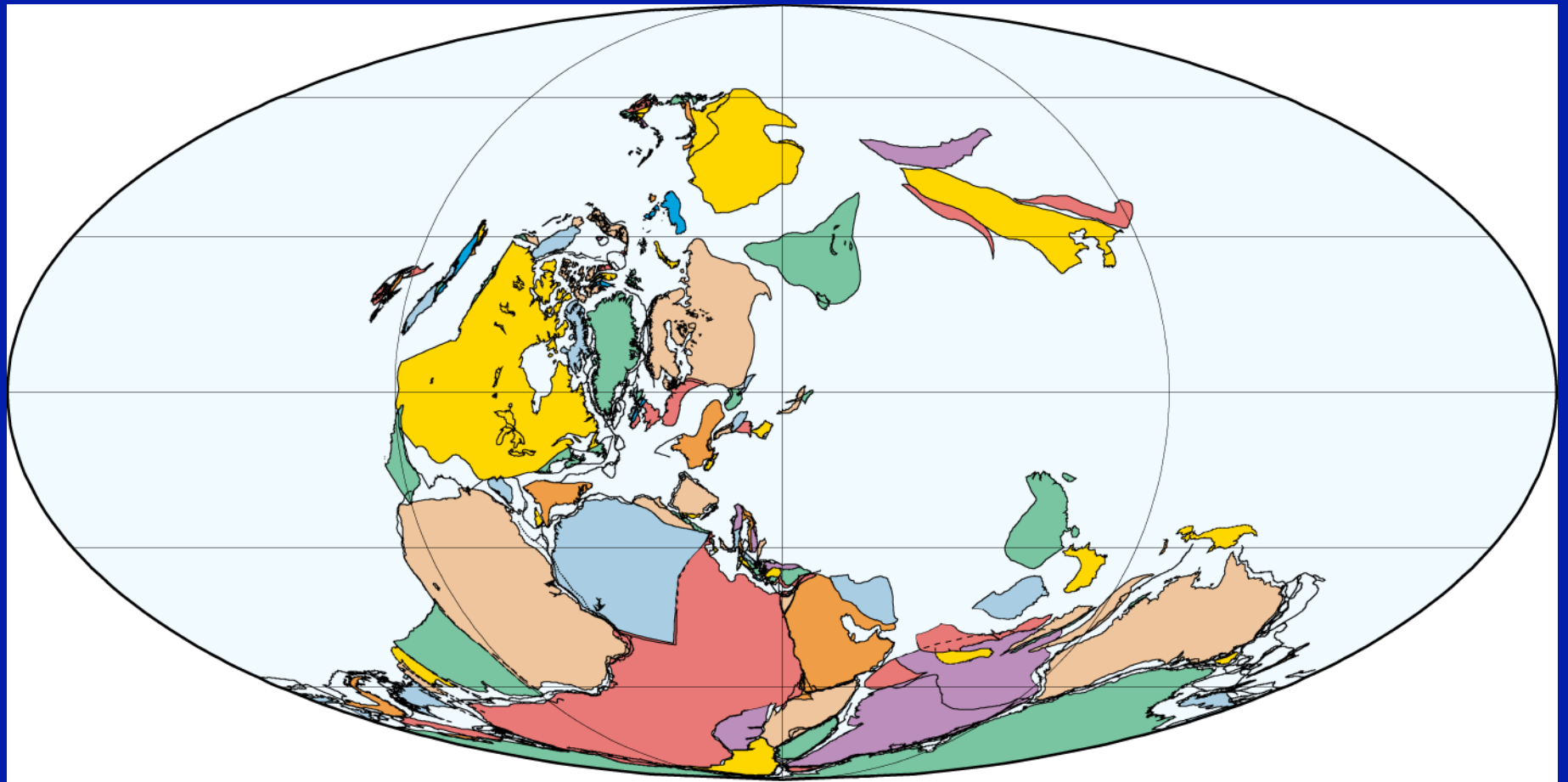
350 Ma
Tournaisian (Mississippian)

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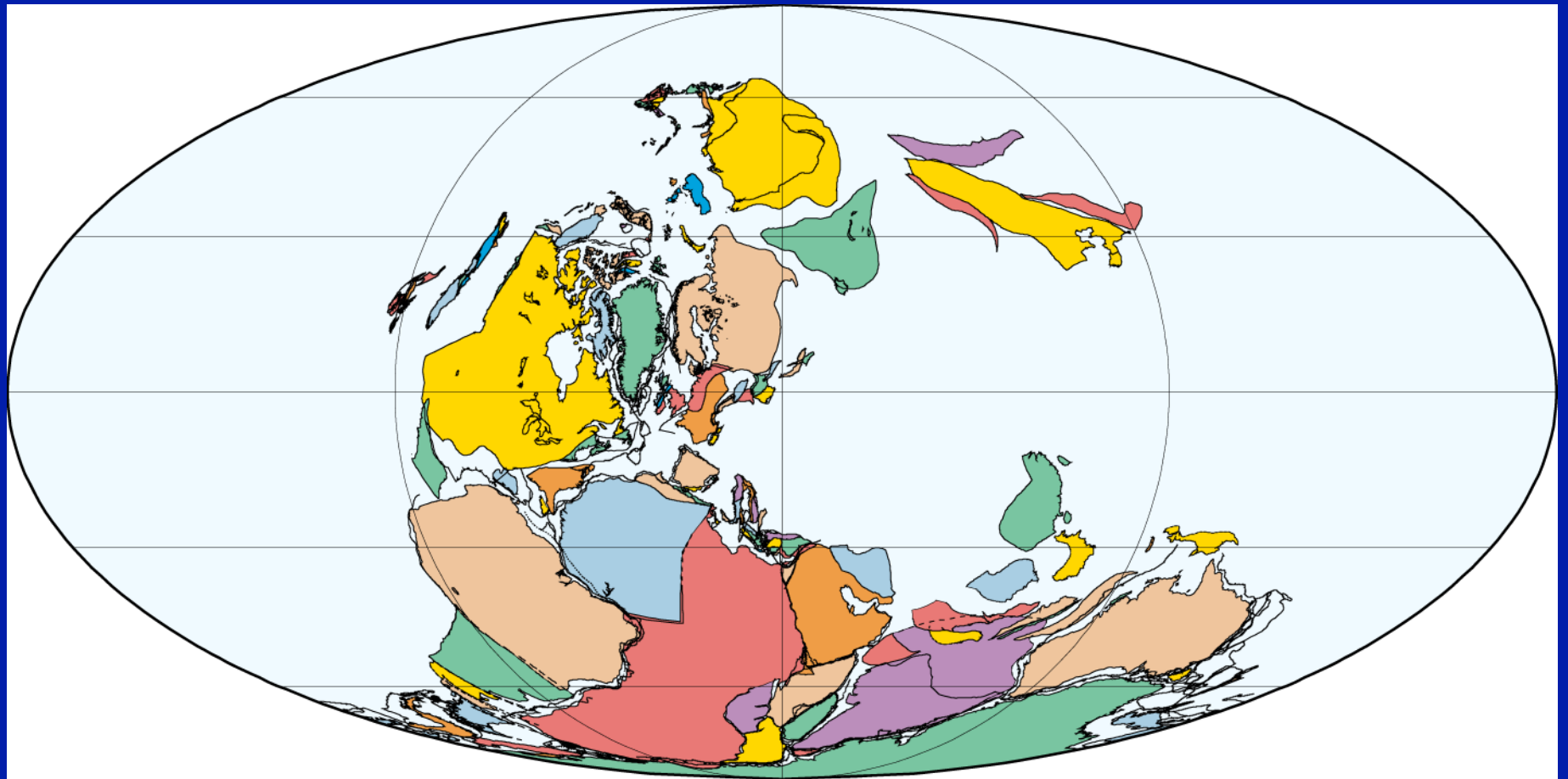
340 Ma
Early Visean (Mississippian)

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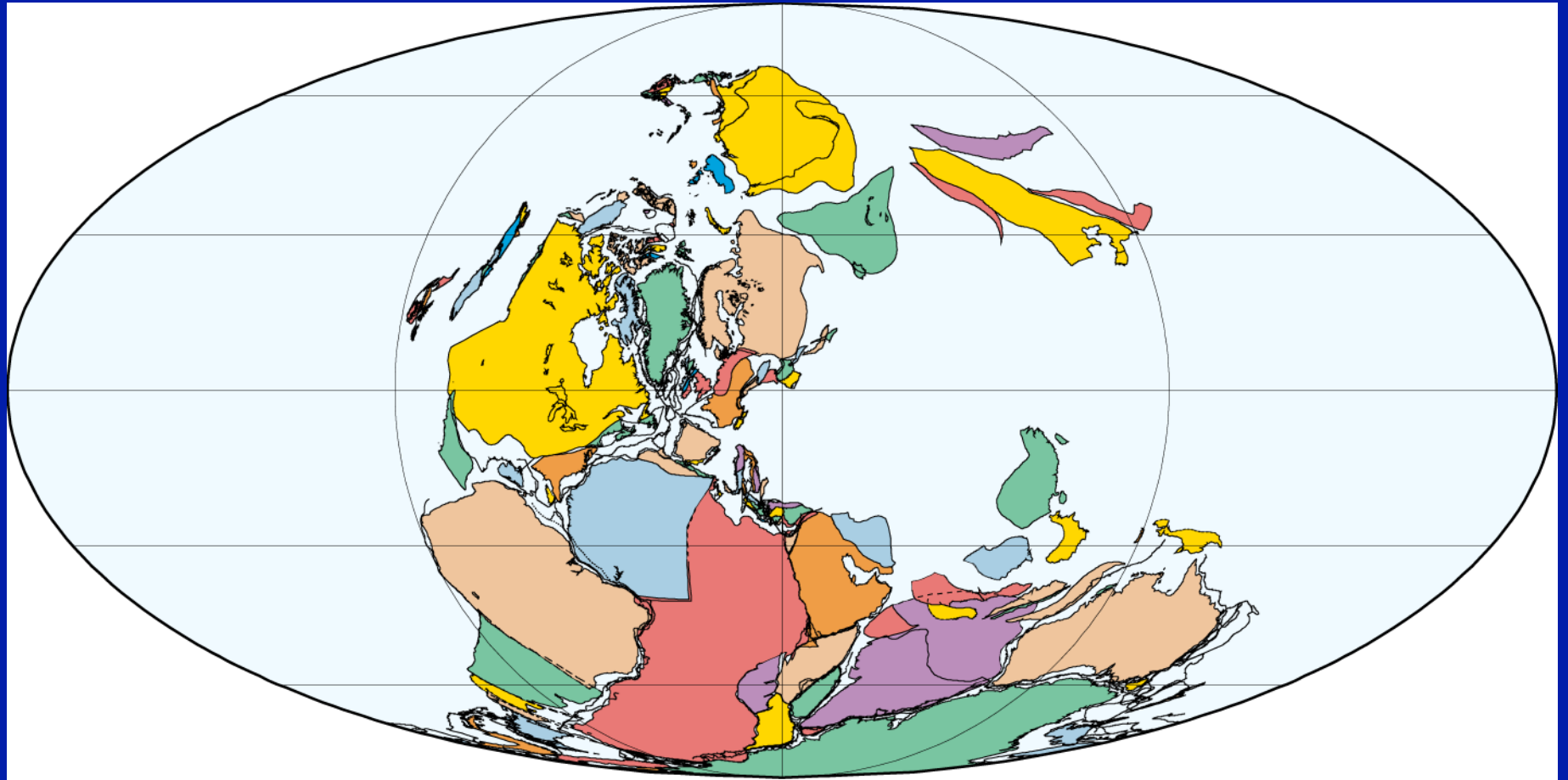
330 Ma
Late Visean (Mississippian)

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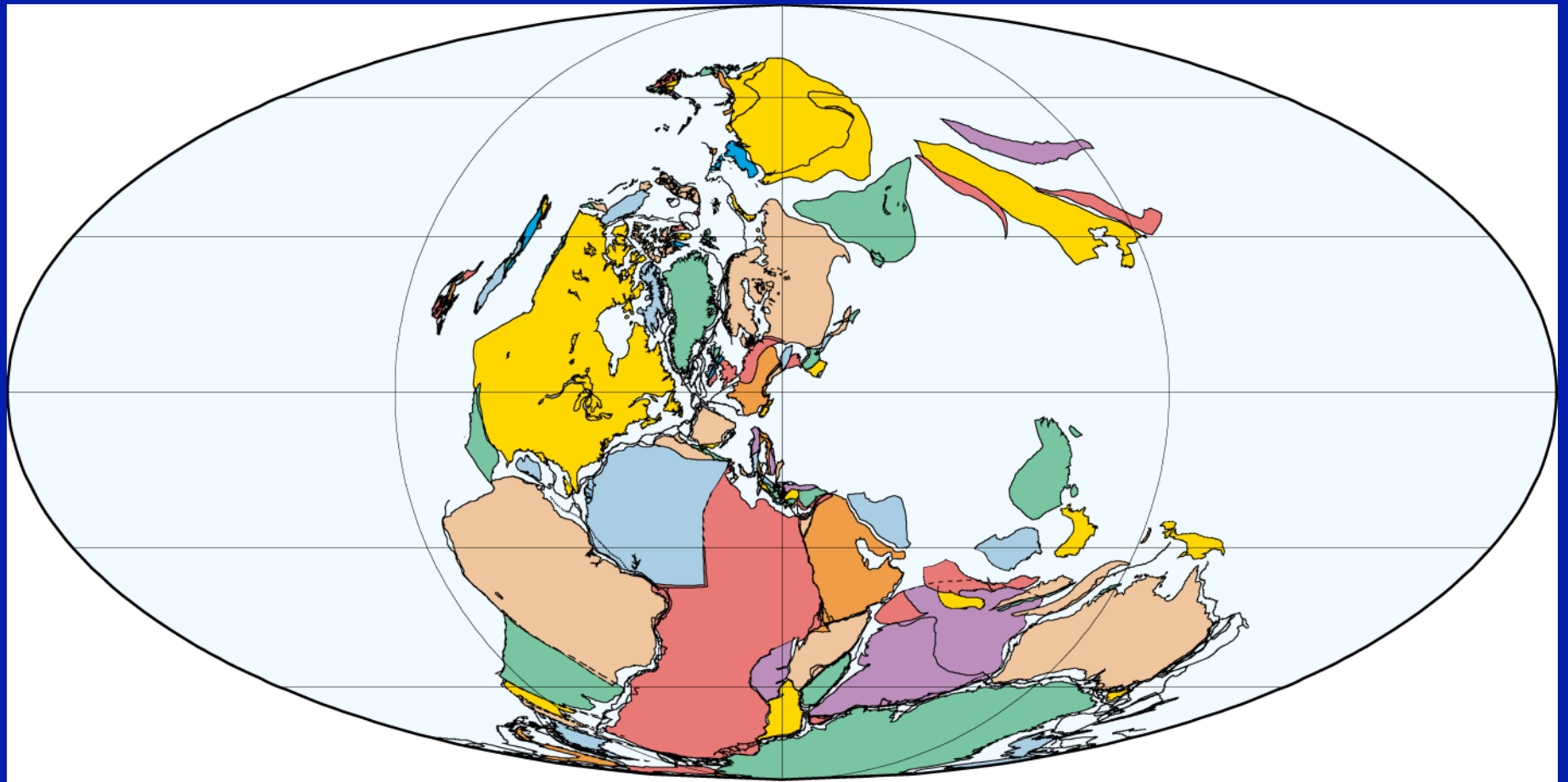
320 Ma
Bashkirian (Pennsylvanian)

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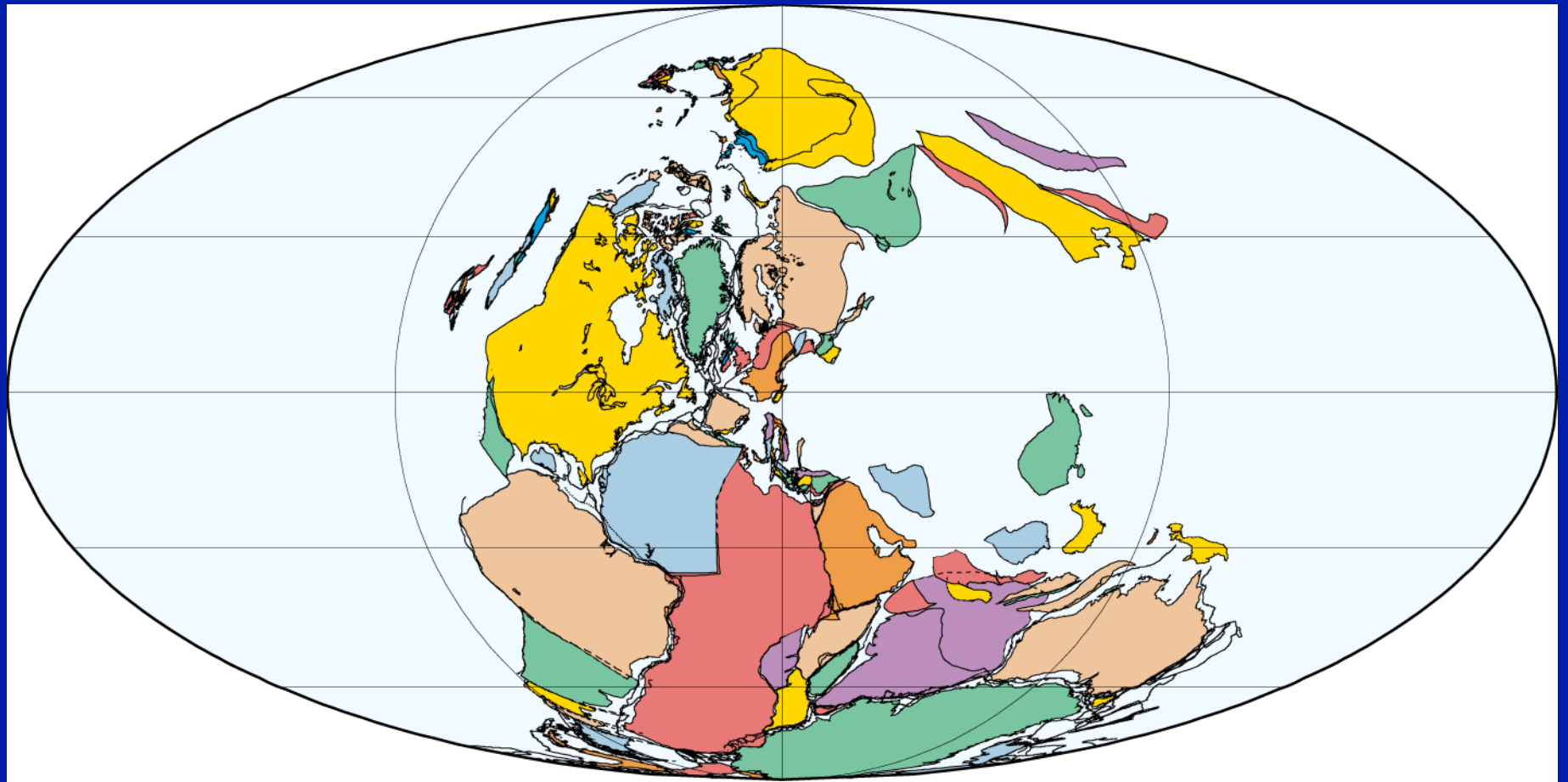
310 Ma
Moscovian (Pennsylvanian)

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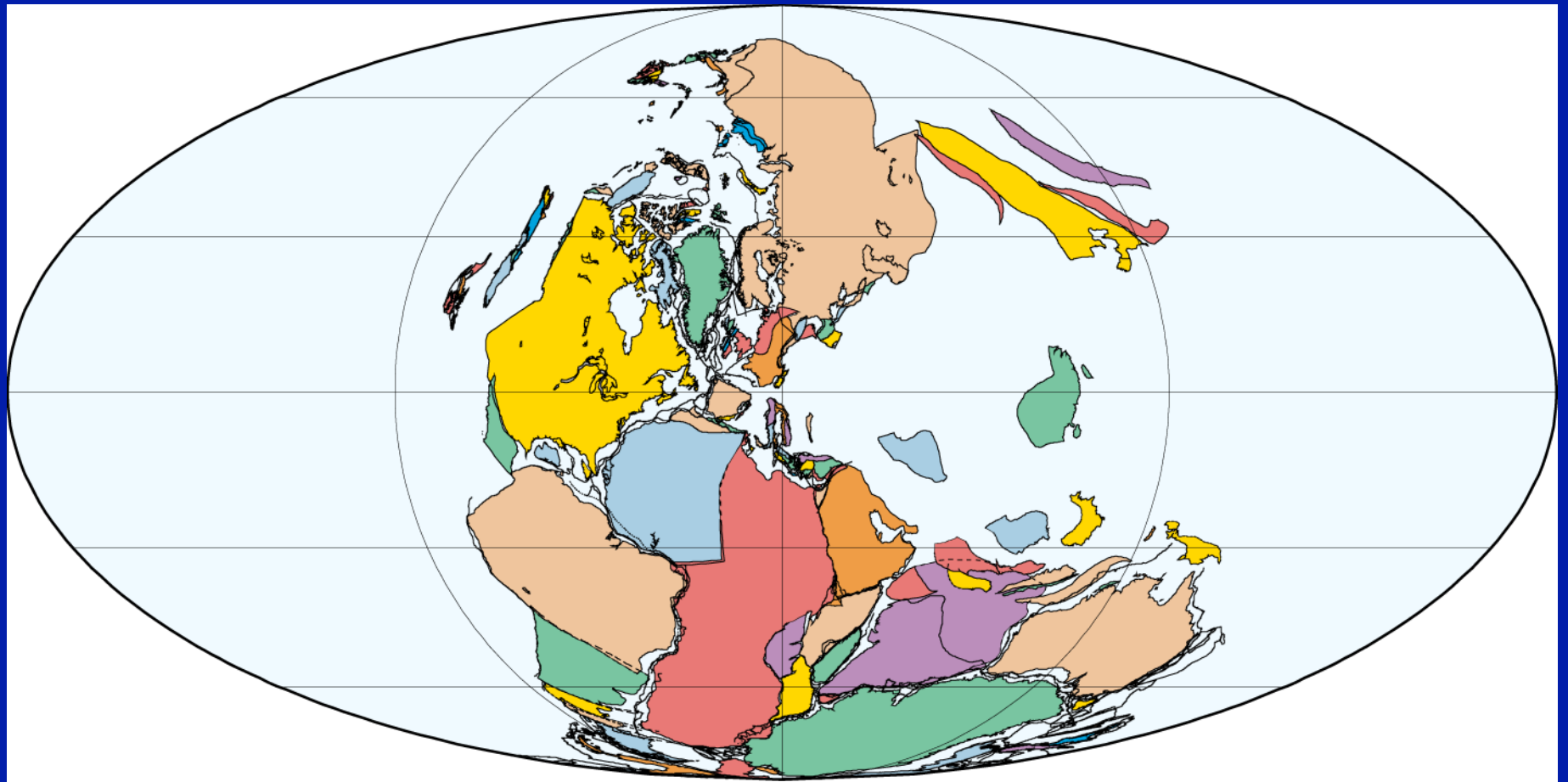
300 Ma
Kasimovian (Pennsylvanian)

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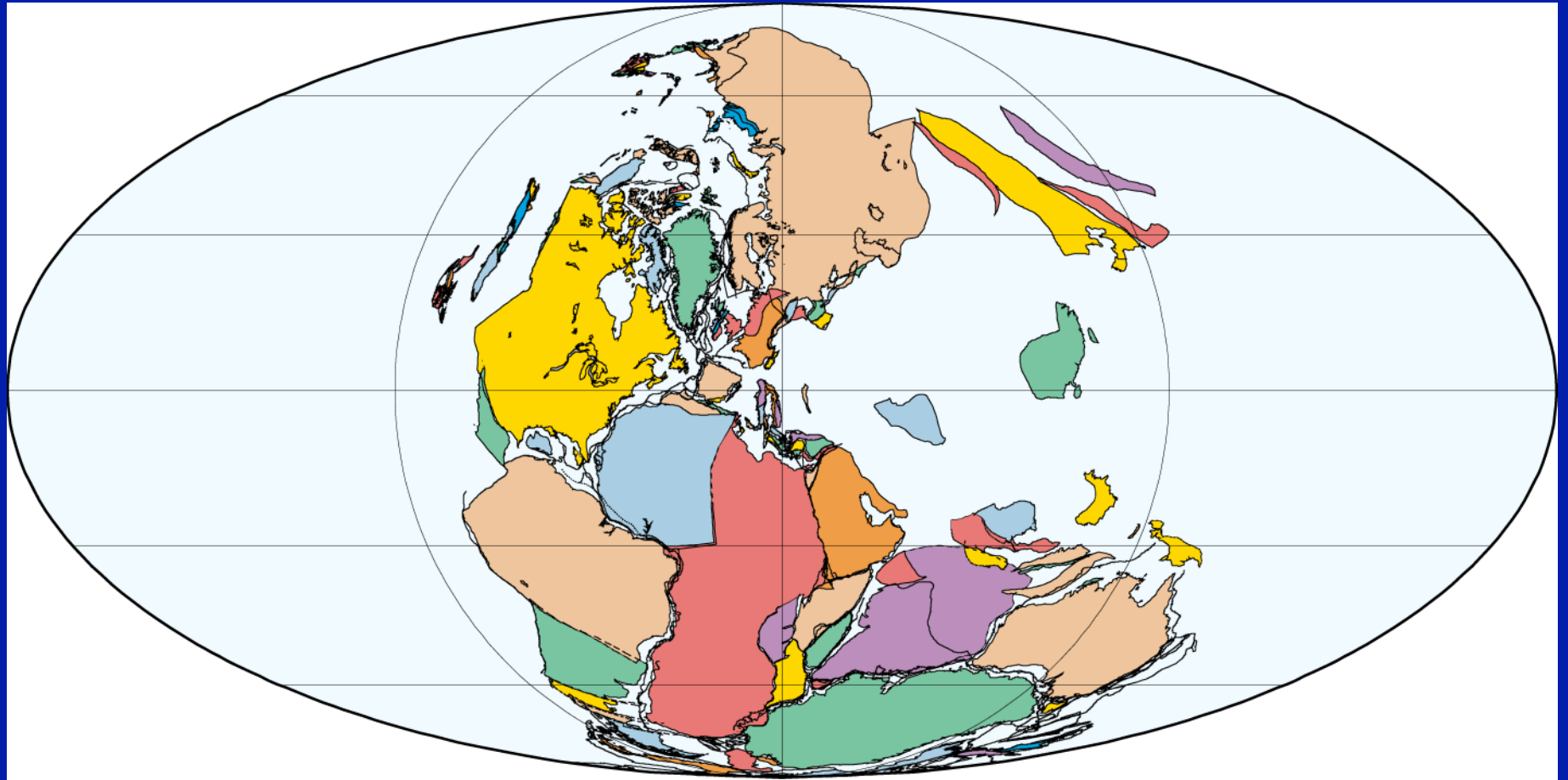
290 Ma
Late Gzelian/Early Asselian (Pennsylvanian/Permian)

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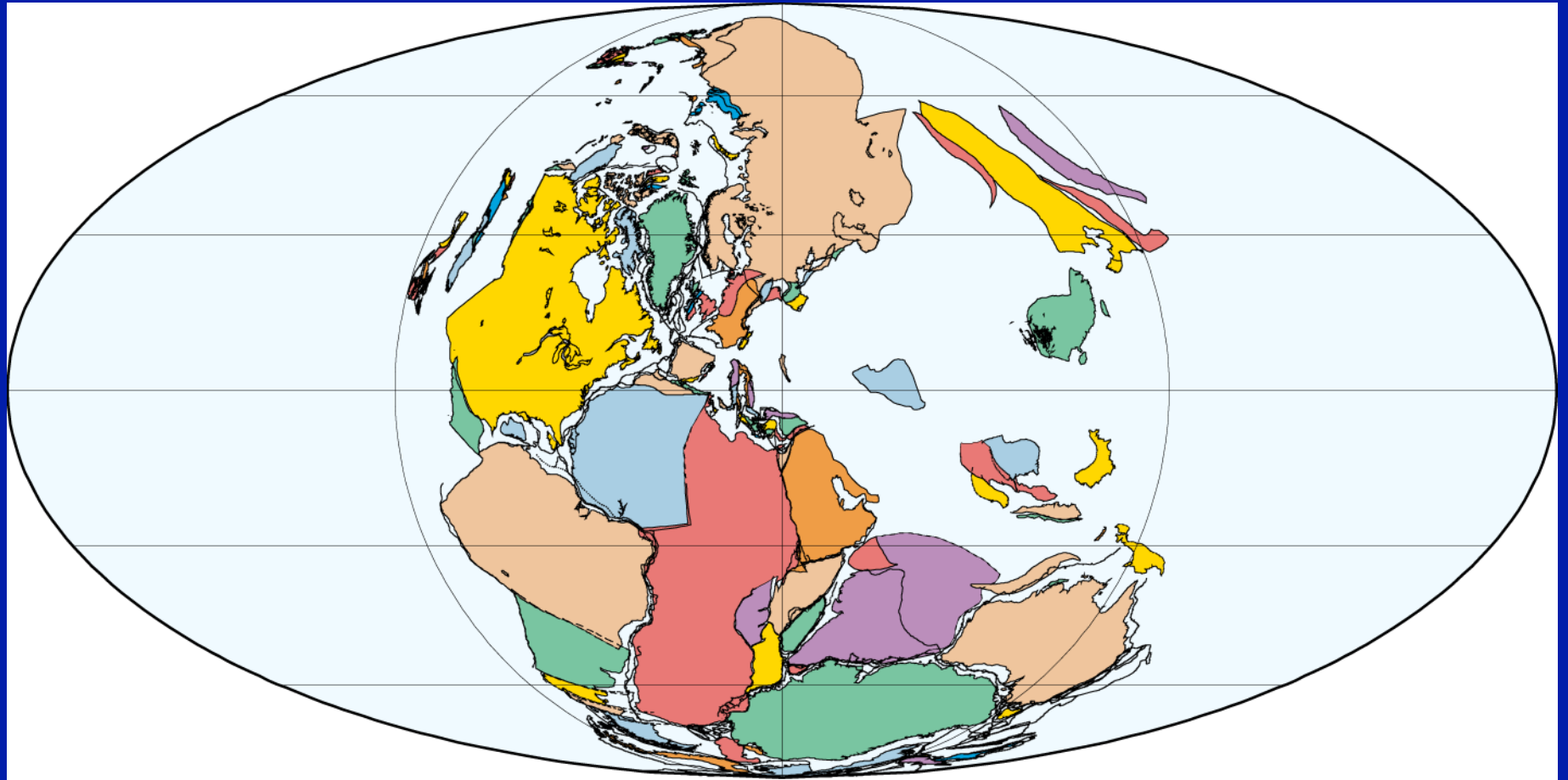
280 Ma
Early Sakmarian (Early Permian)

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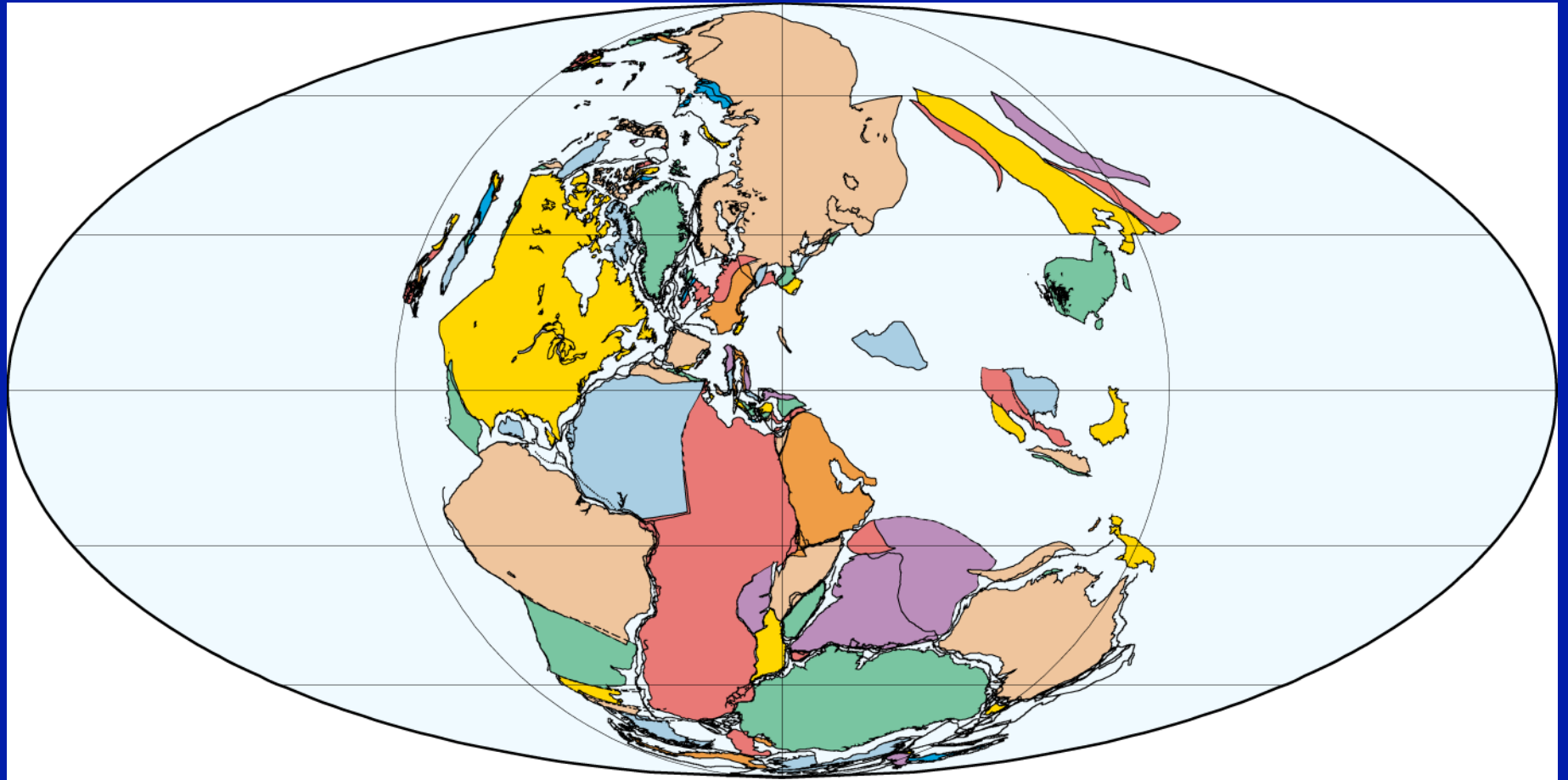
270 Ma
Late Sakmarian (Early Permian)

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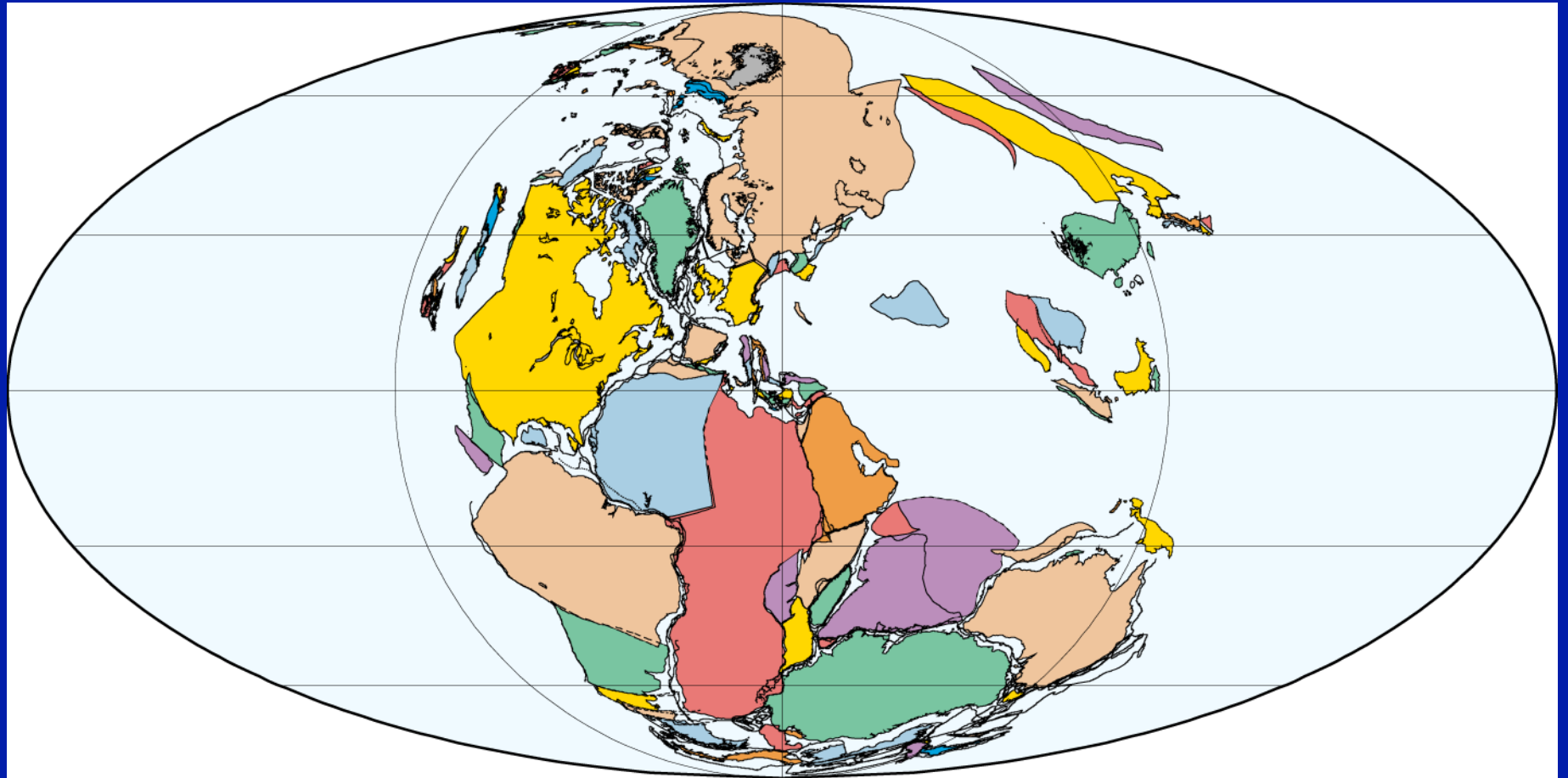
260 Ma
Late Artinskian/Early Kungurian (Early Permian)

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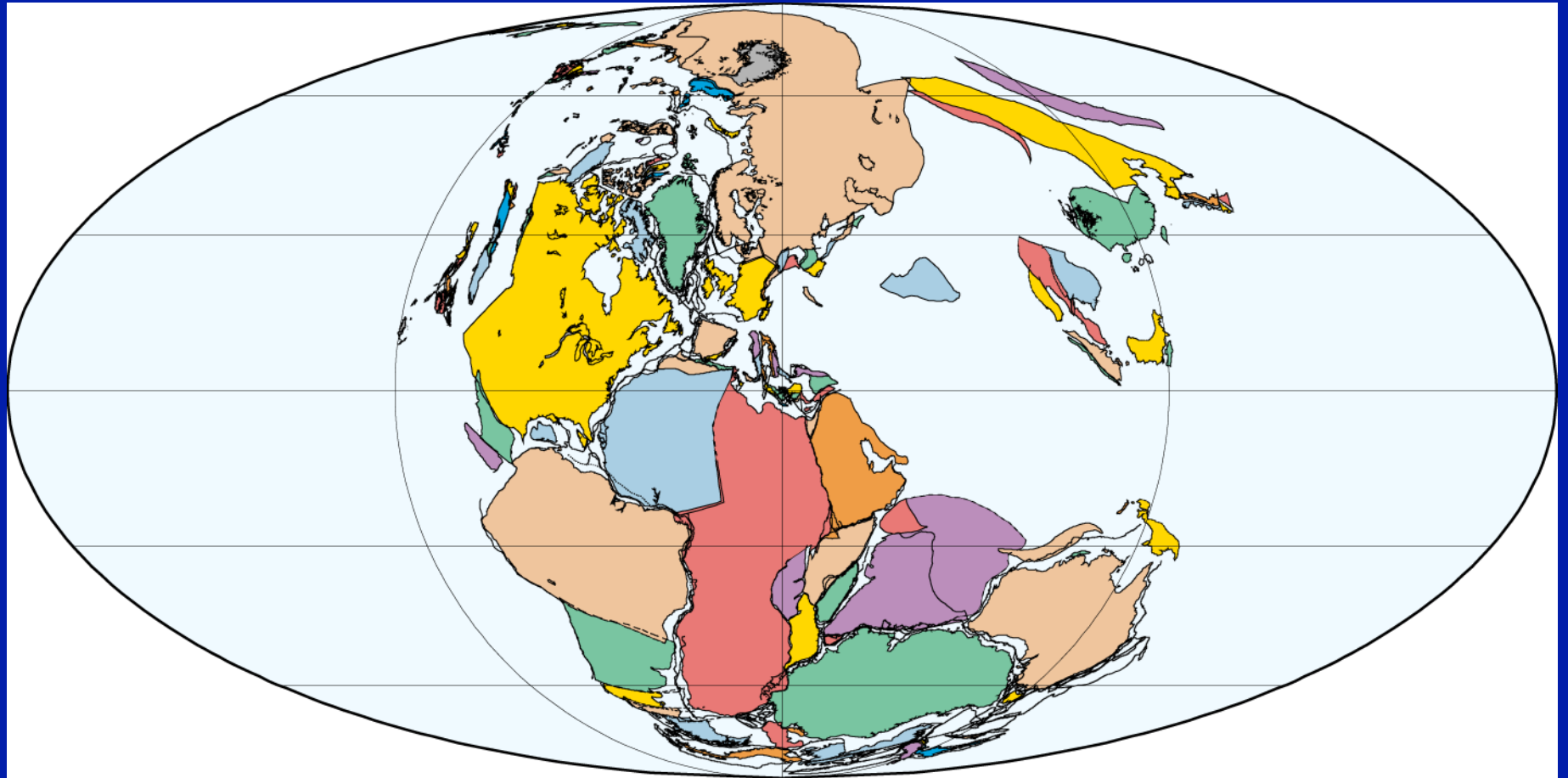
250 Ma
Tatarian (Late Permian)

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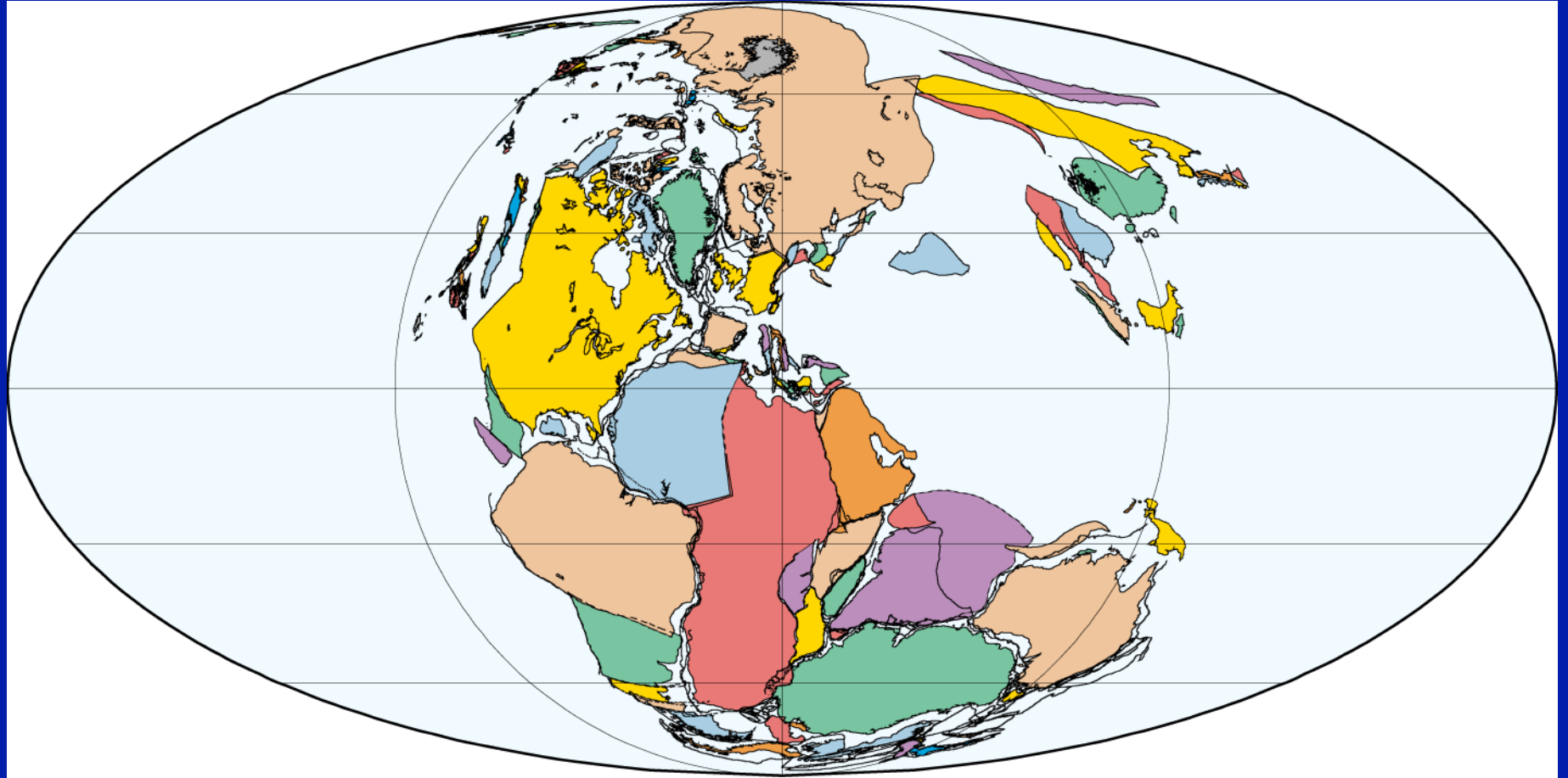
240 Ma
Anisian (Middle Triassic)

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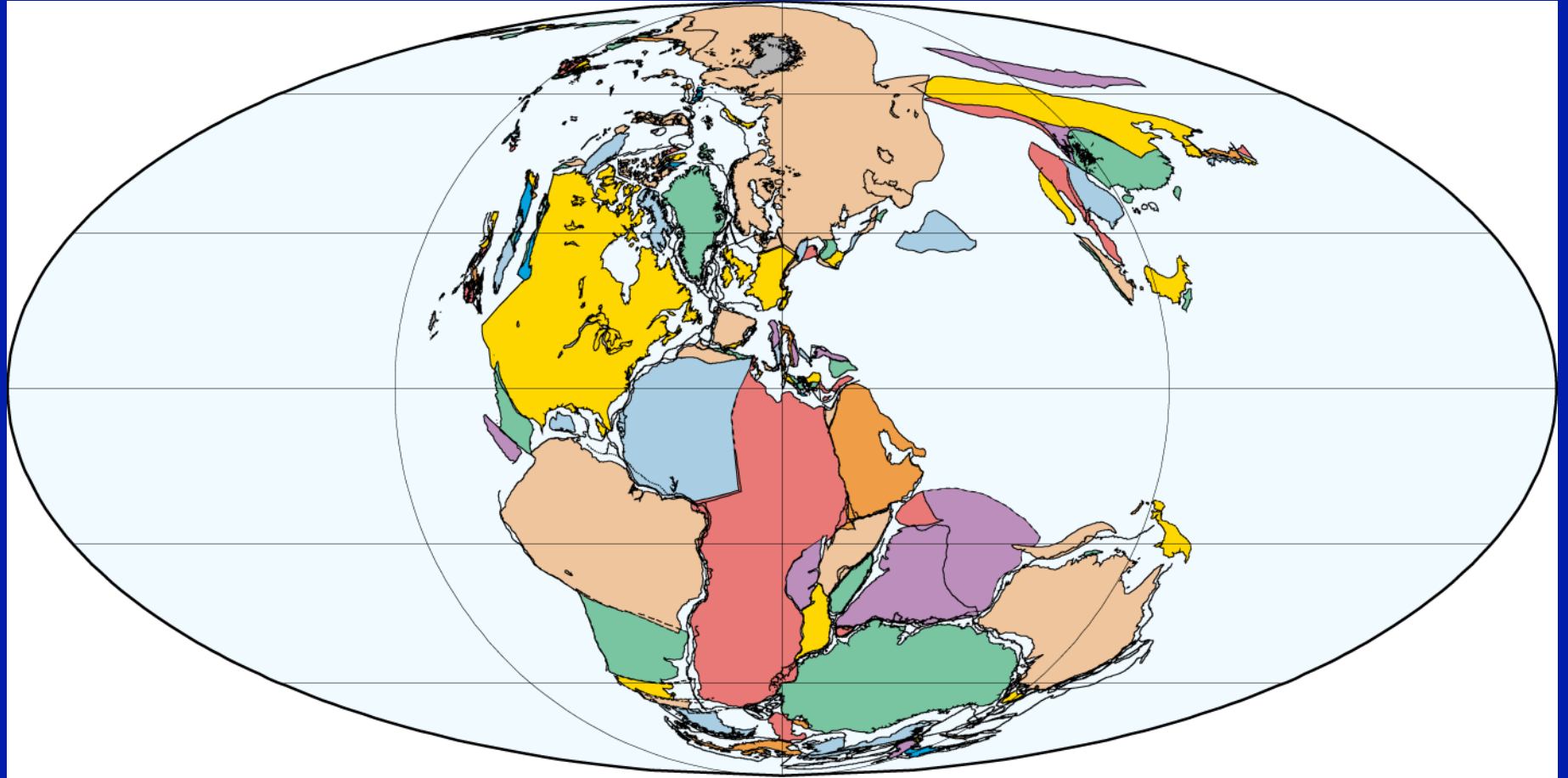
230 Ma
Ladinian (Middle Triassic)

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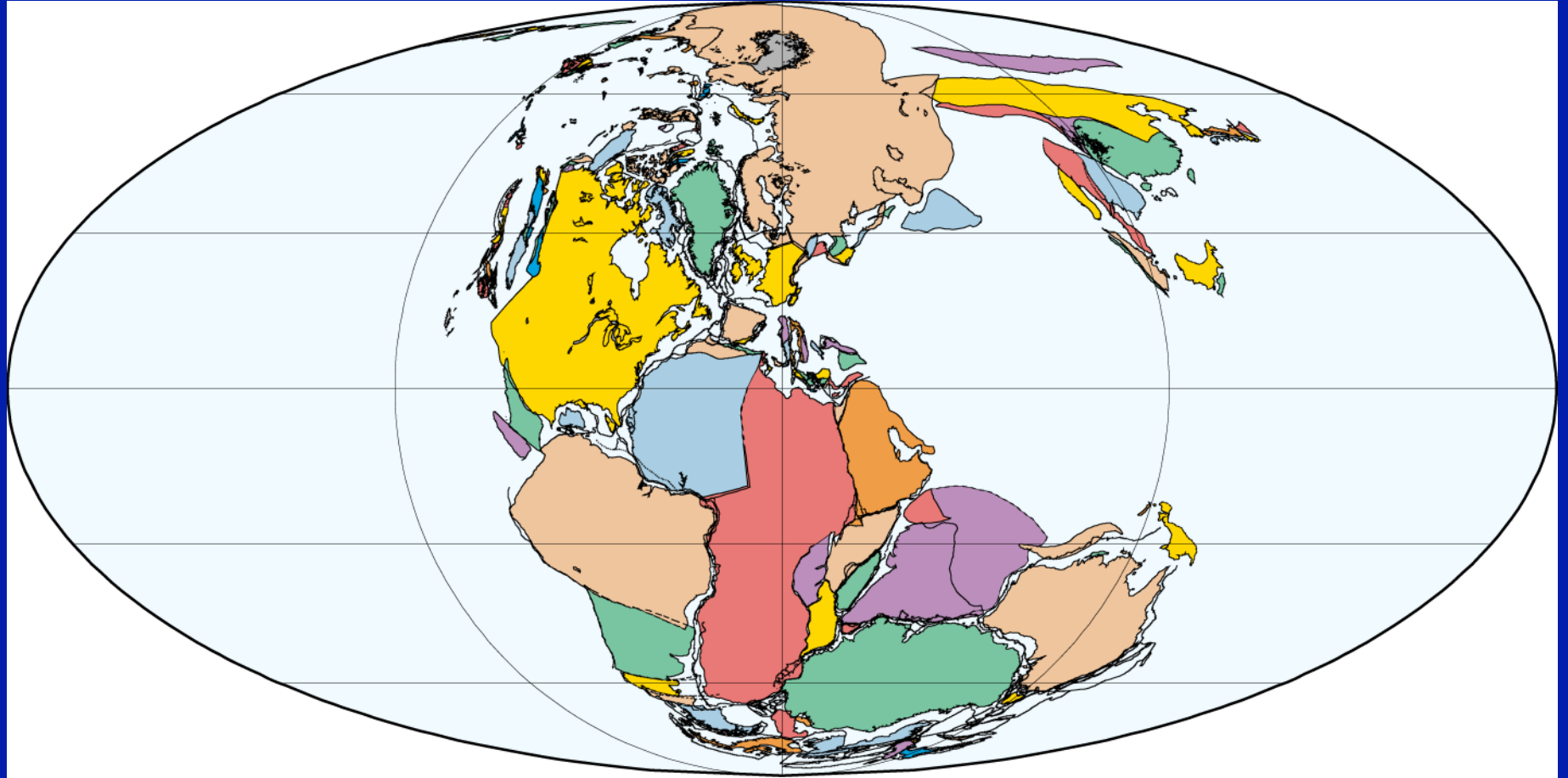
220 Ma
Early Norian (Late Triassic)

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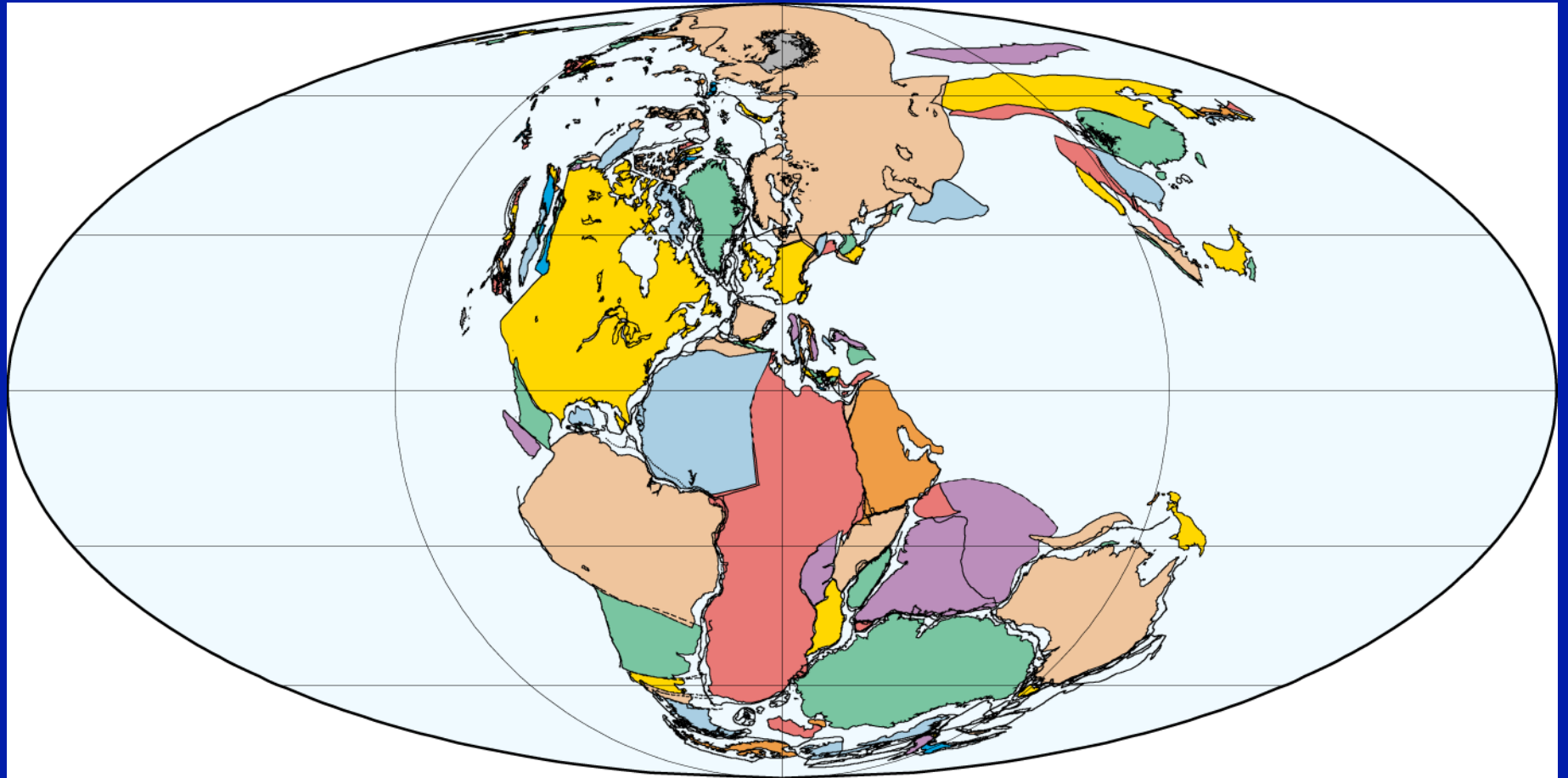
210 Ma
Late Norian (Late Triassic)

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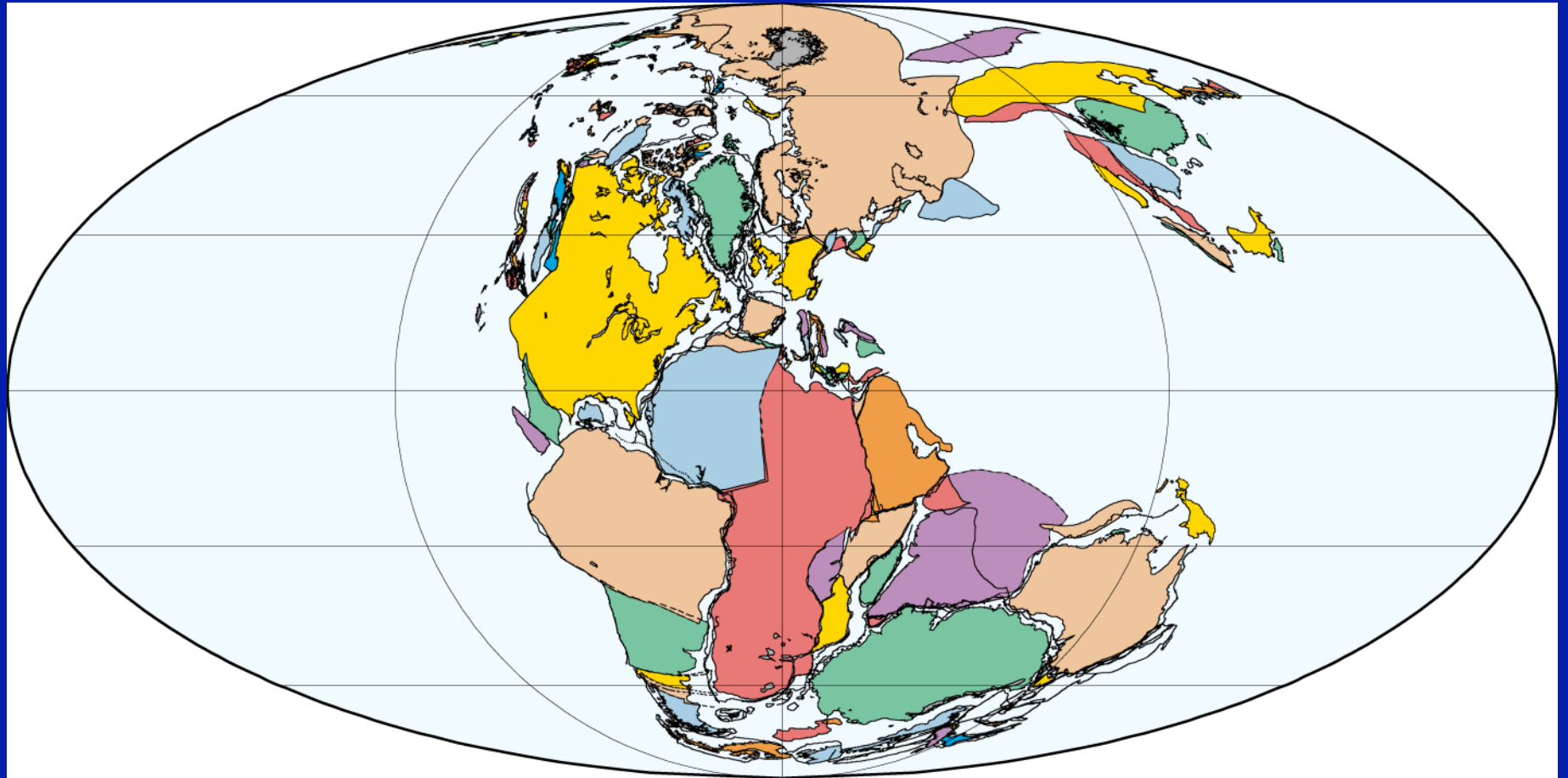
200 Ma
Sinemurian (Early Jurassic)

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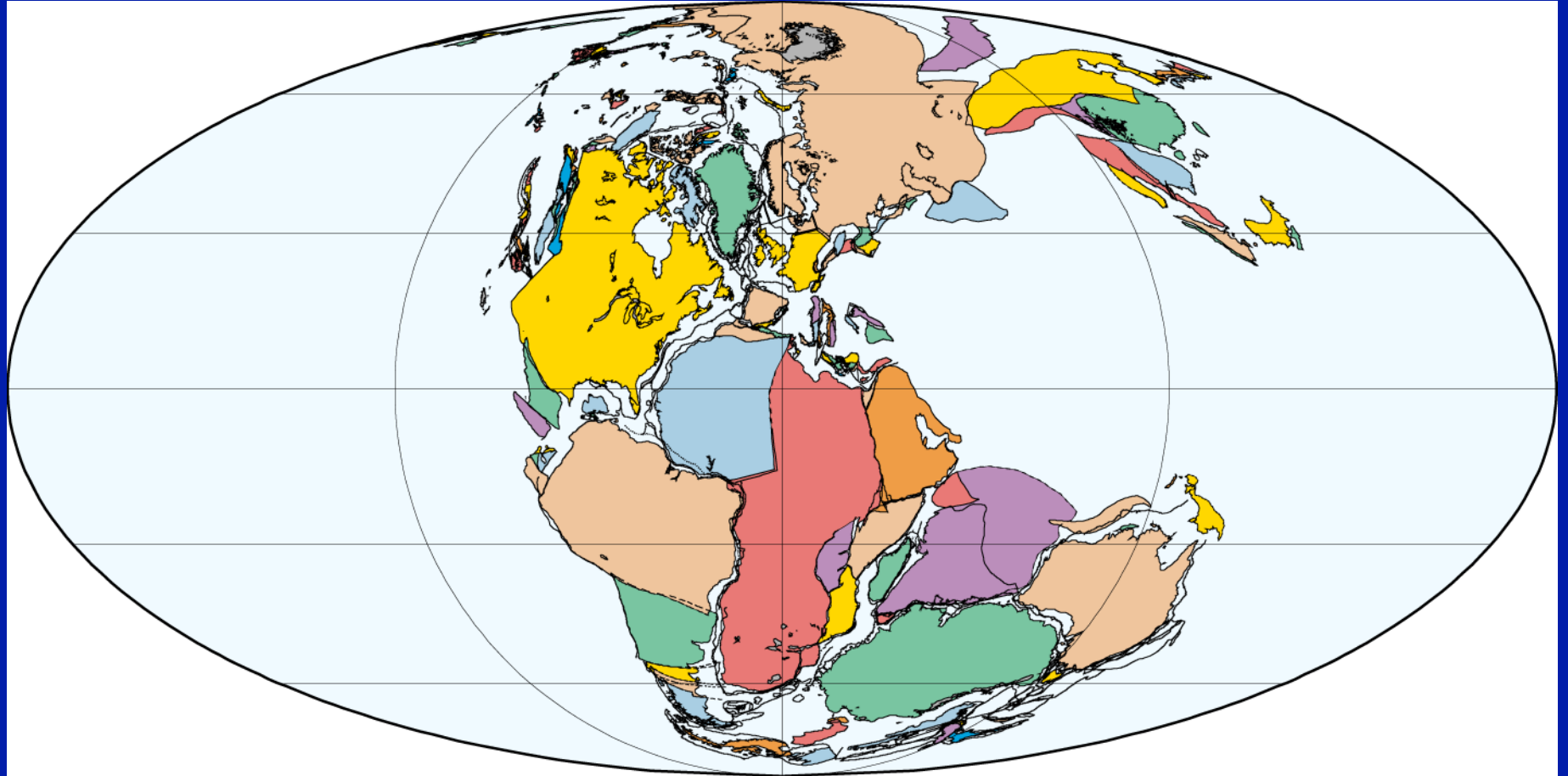
190 Ma
Pliensbachian (Early Jurassic)

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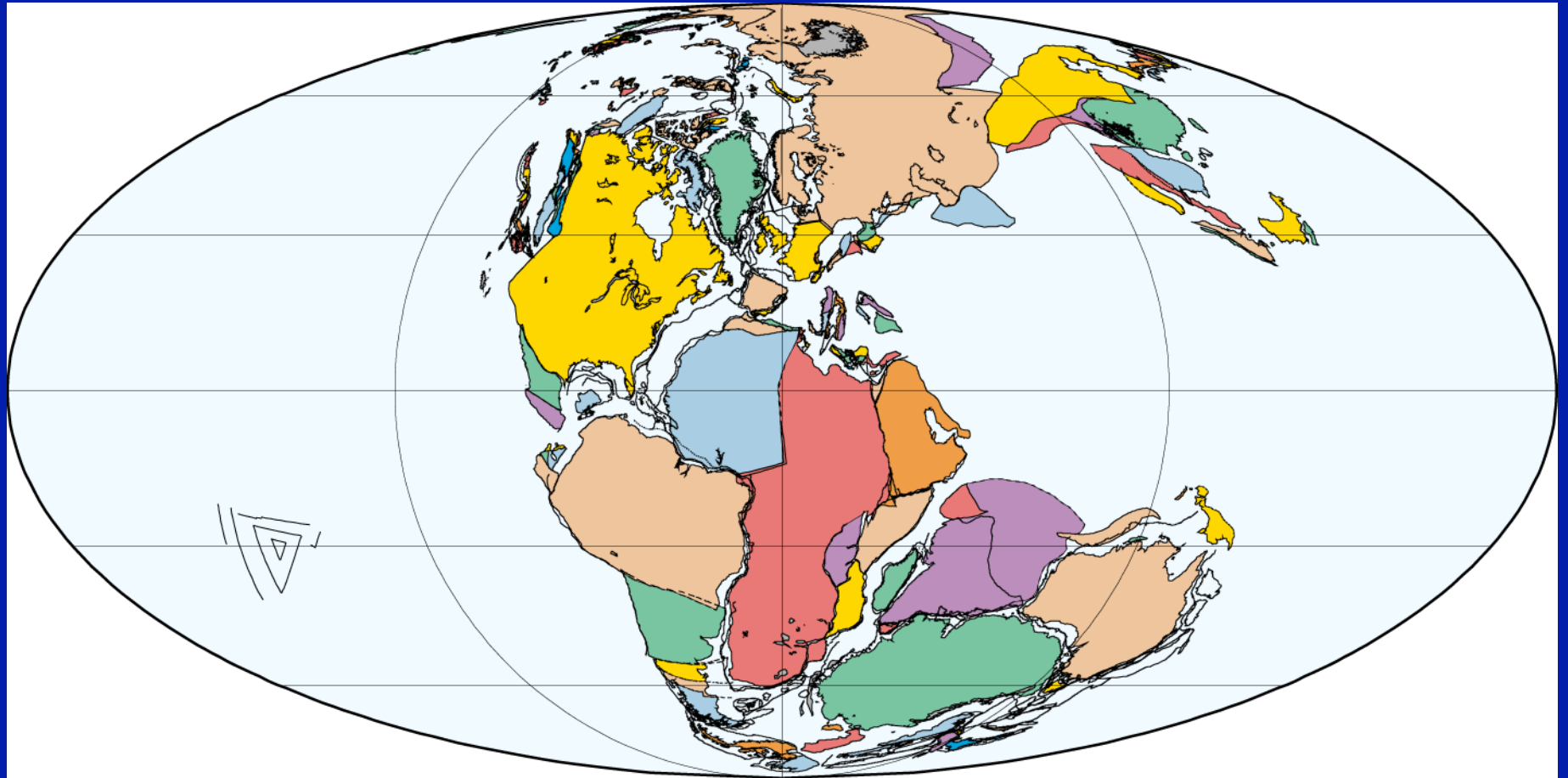
180 Ma
Aalenian (Middle Jurassic)

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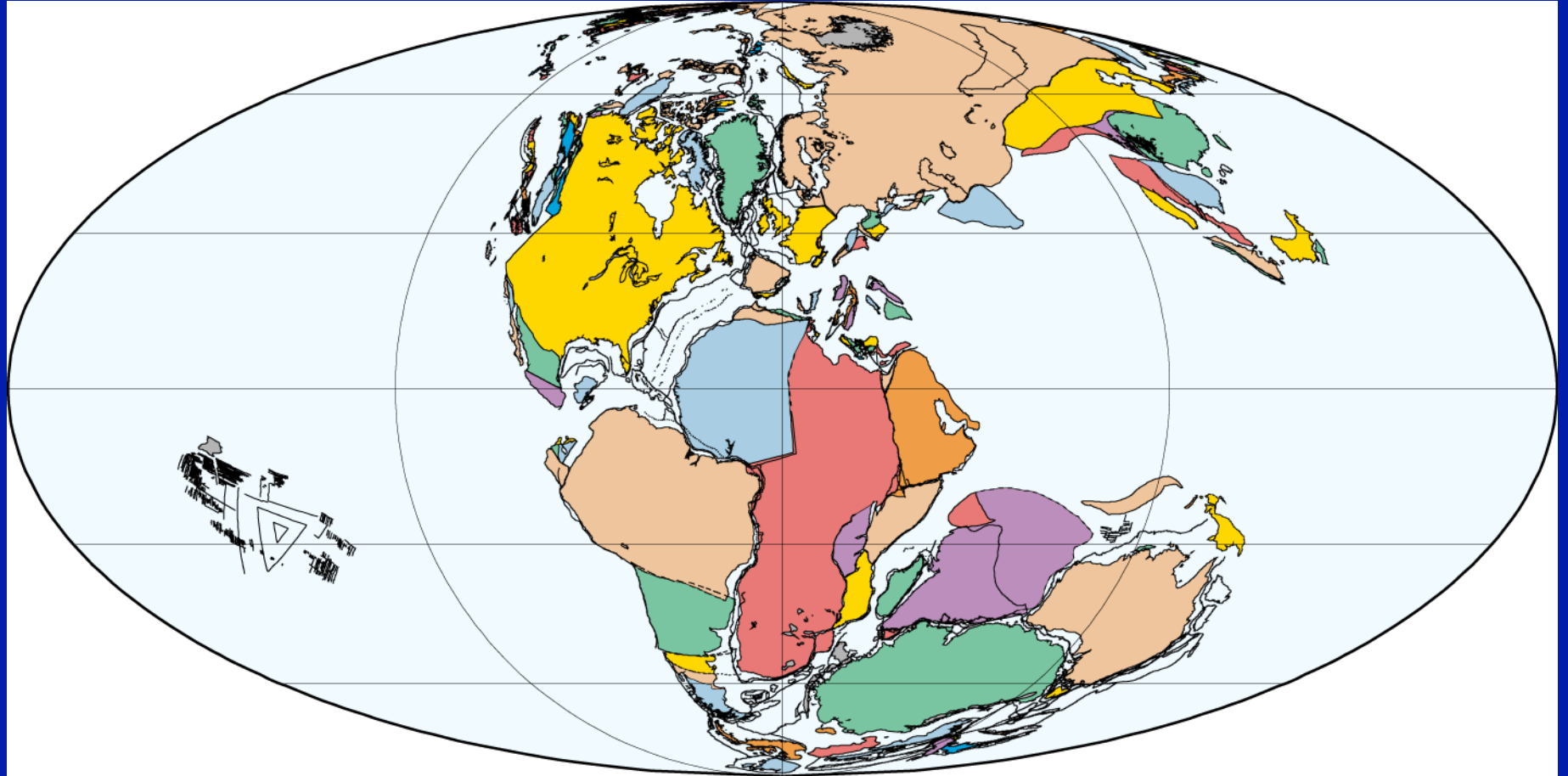
170 Ma
Bajocian (Middle Jurassic)

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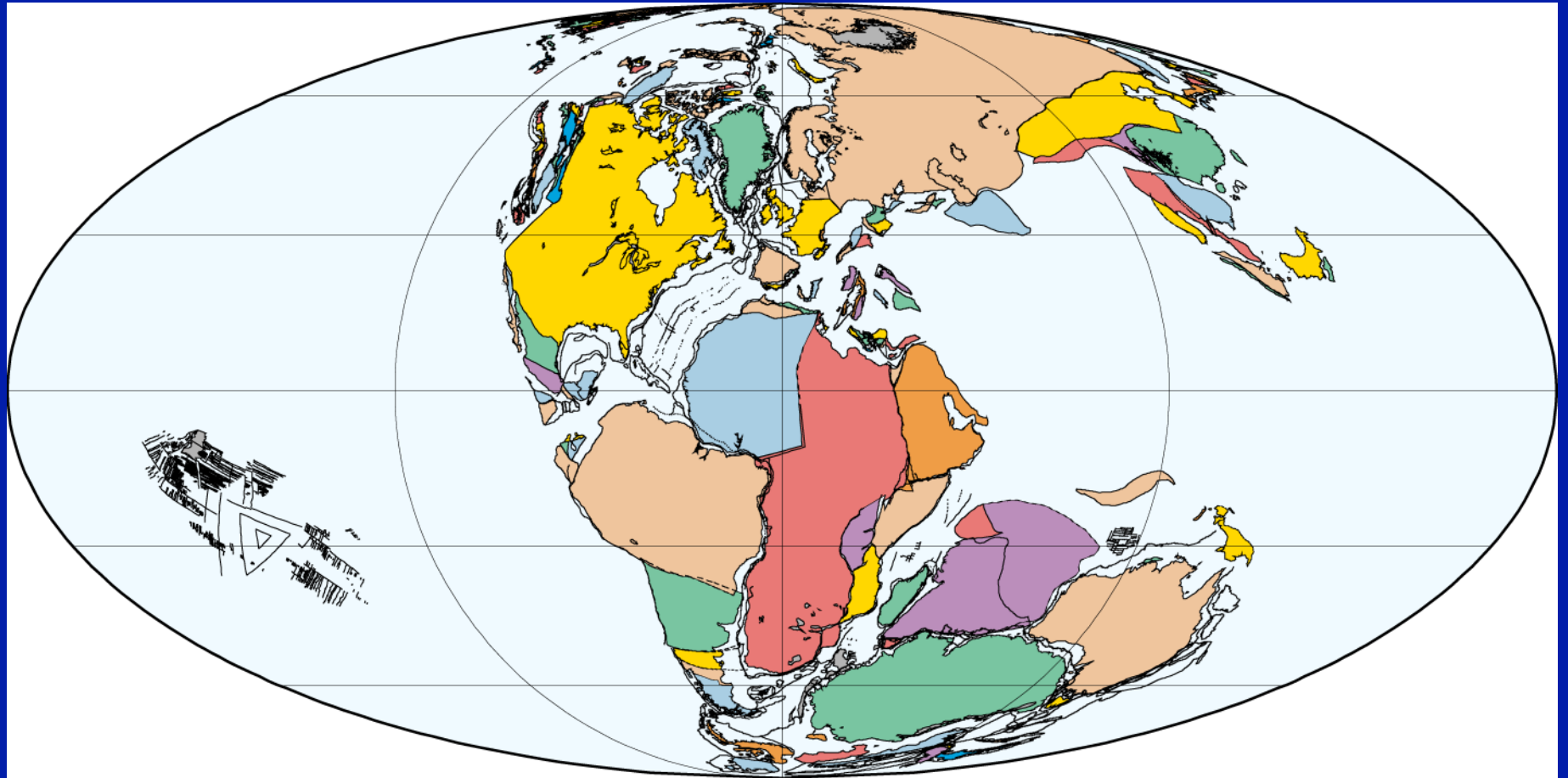
160 Ma
Callovian (Middle Jurassic)

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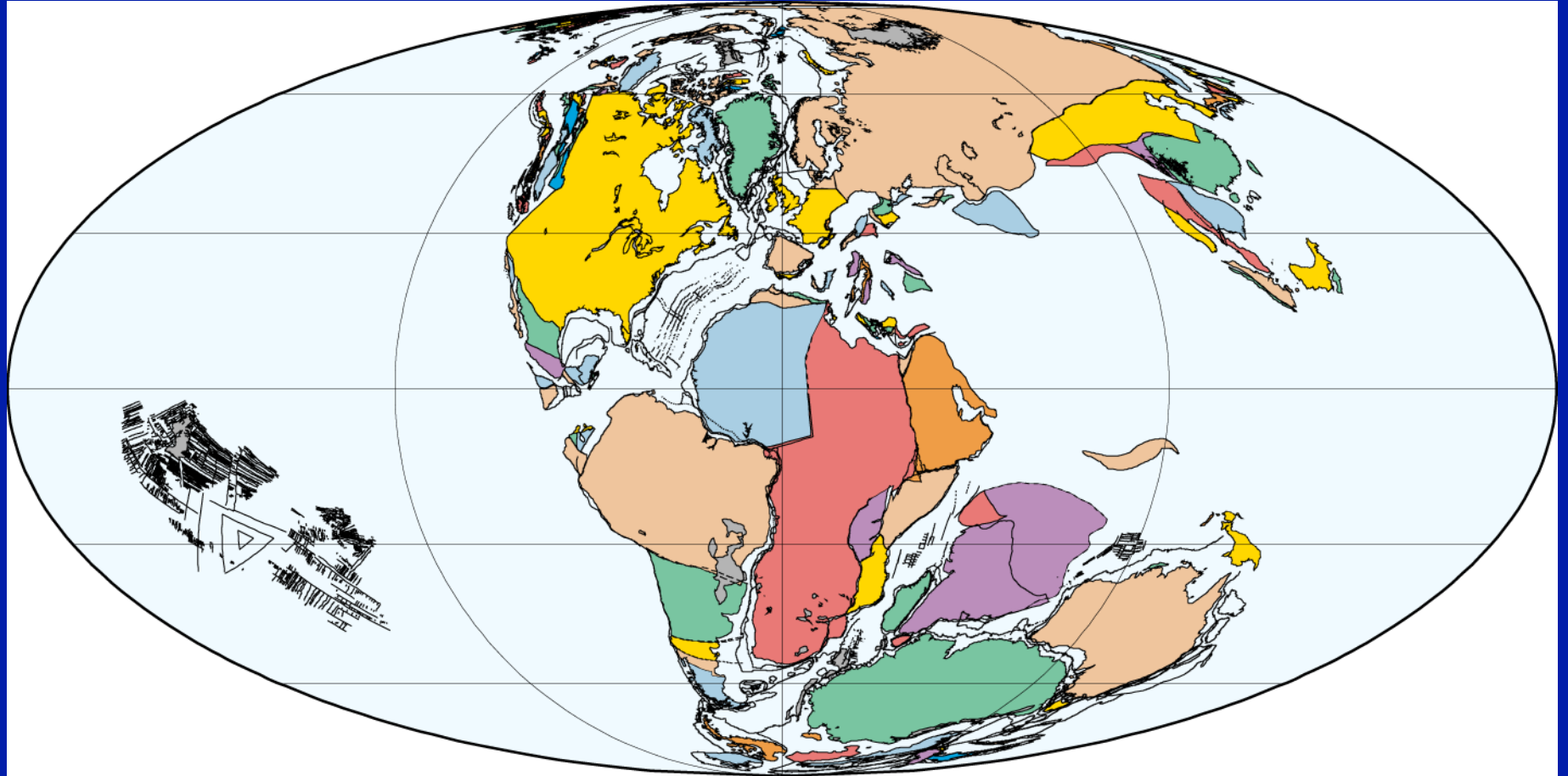
150 Ma
Volgian (Late Jurassic)

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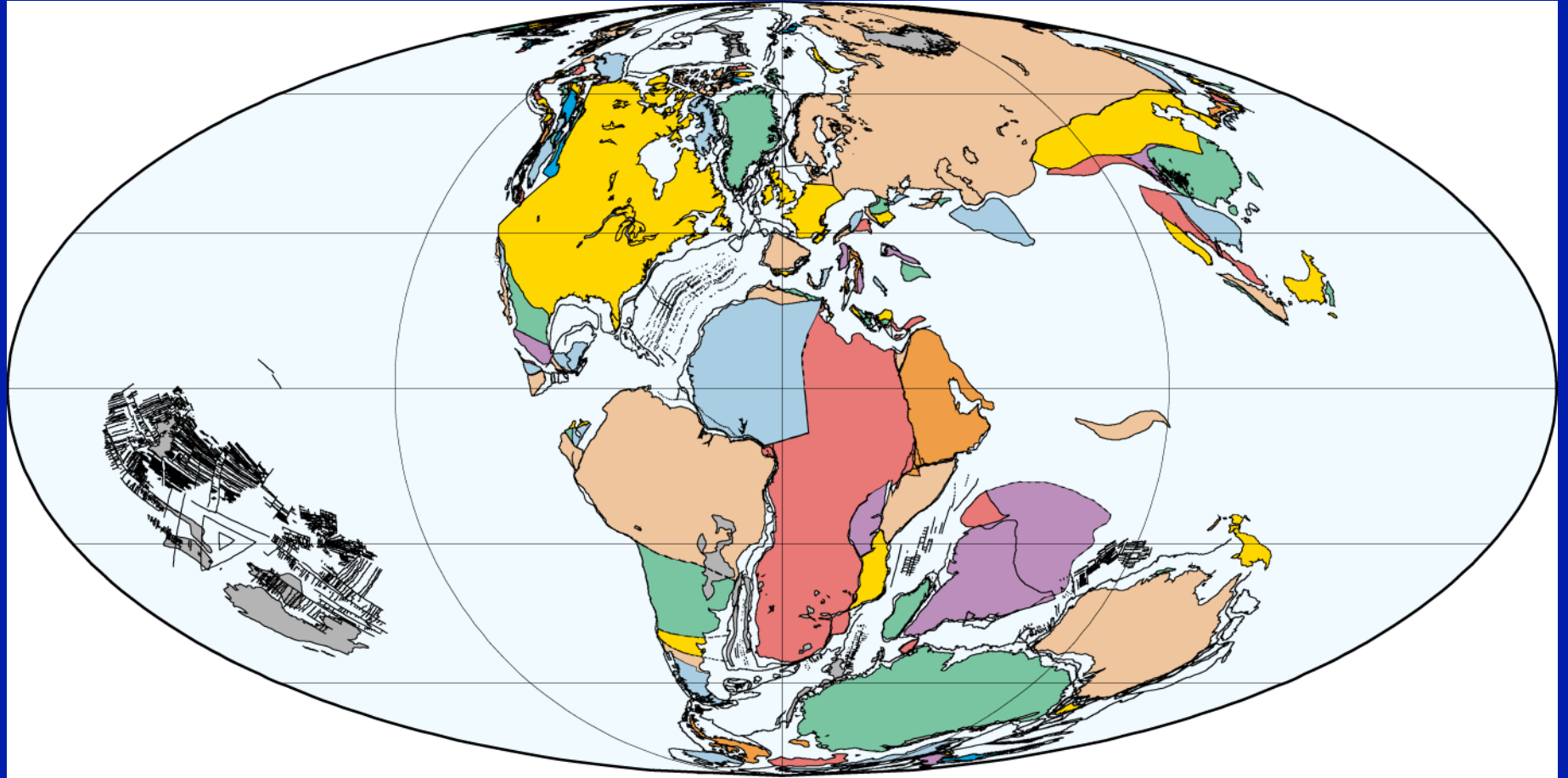
140 Ma
Ryazanian (Early Cretaceous)

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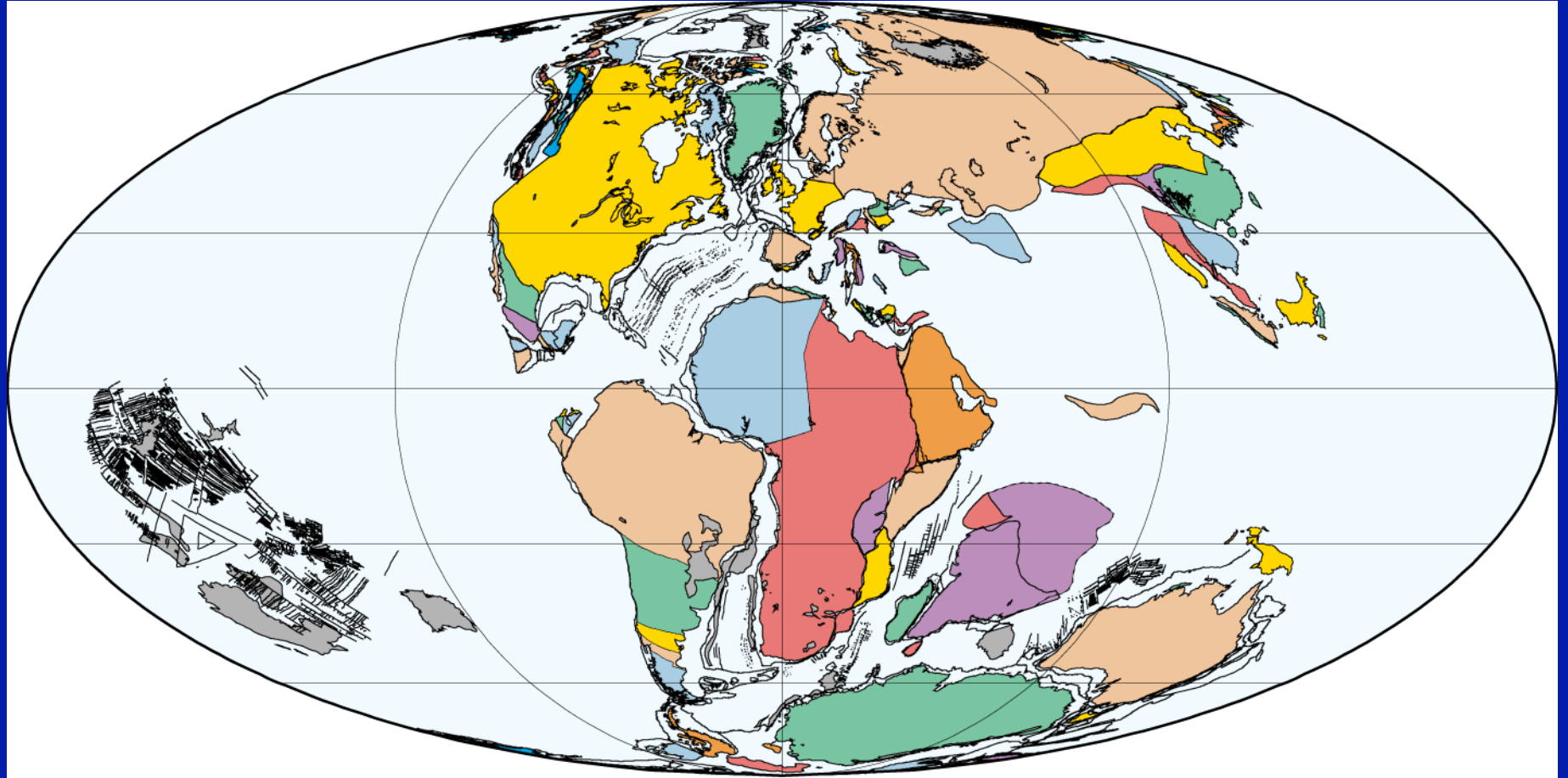
130 Ma
Hauterivian (Early Cretaceous)

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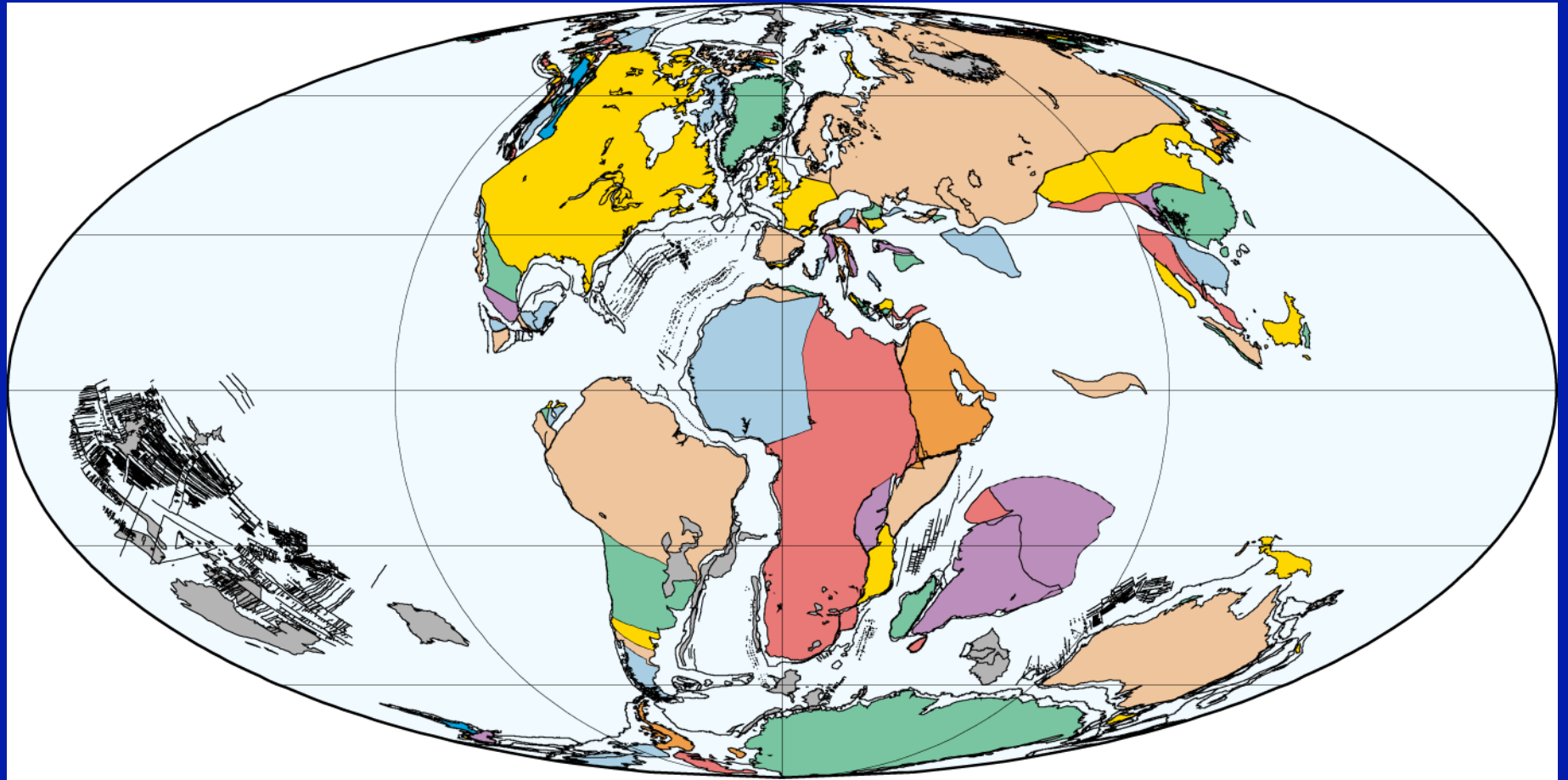
120 Ma
Aptian (Early Cretaceous)

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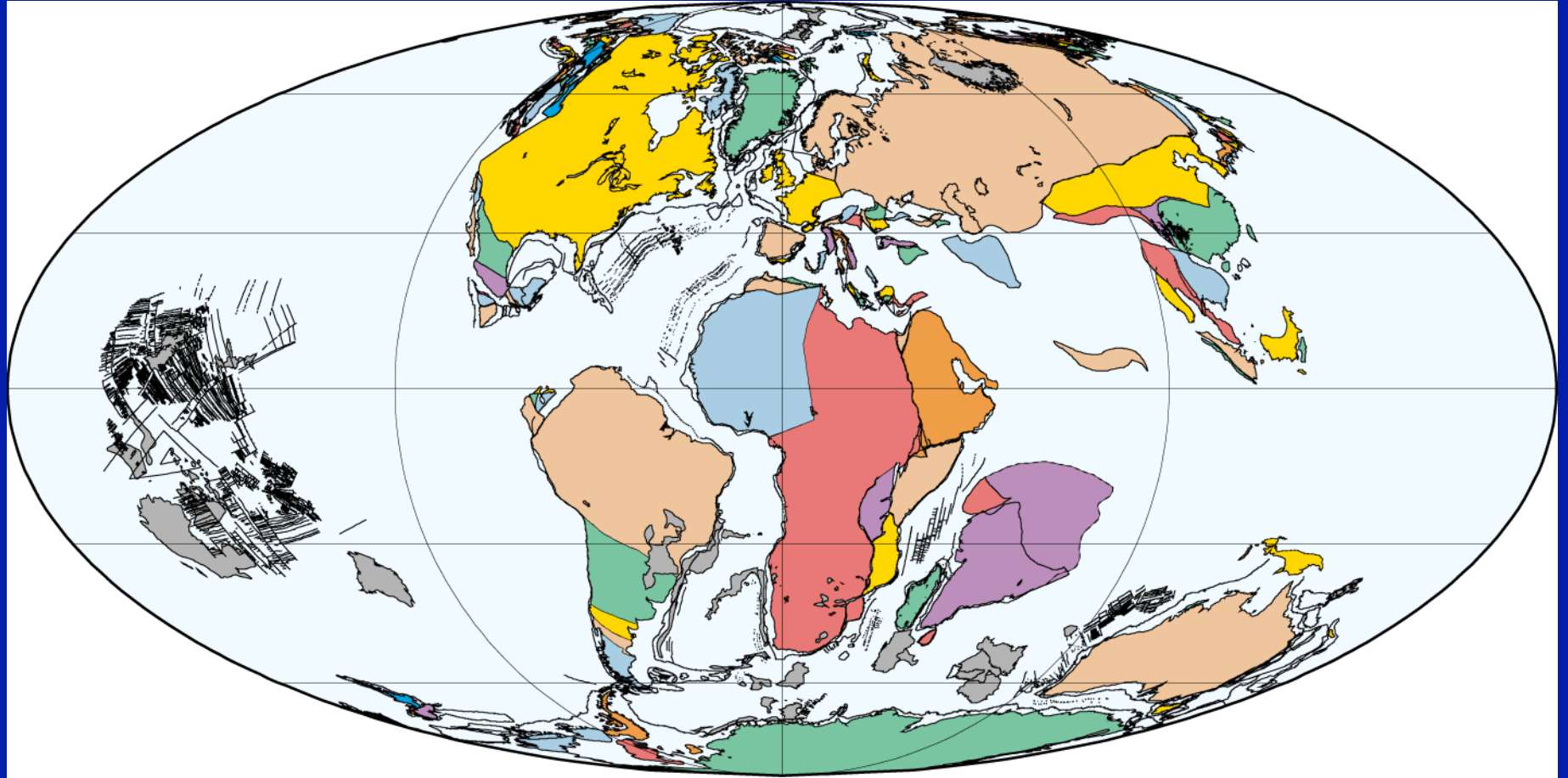
110 Ma
Early Albian (Early Cretaceous)

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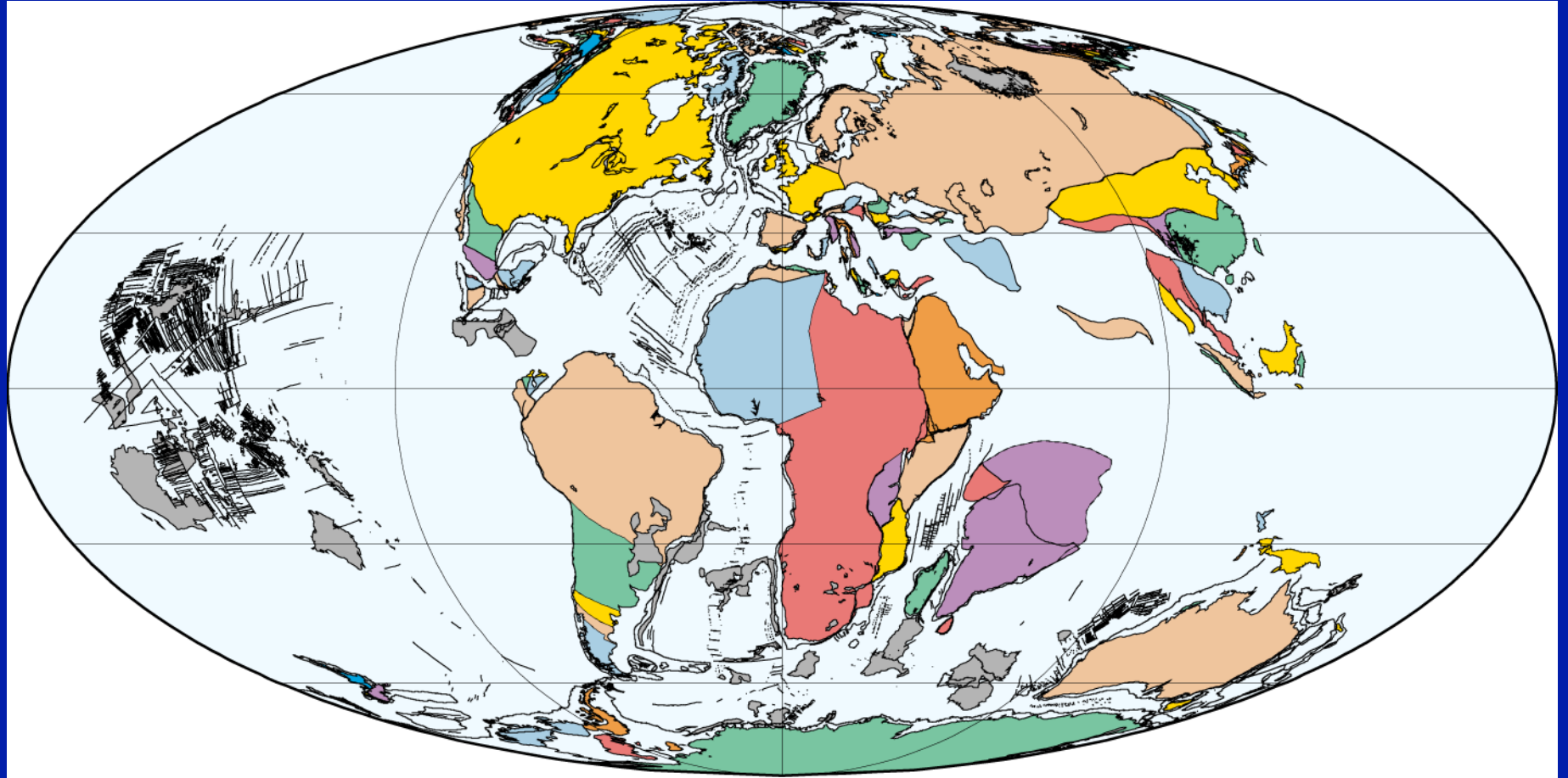
100 Ma
Late Albian (Early Cretaceous)

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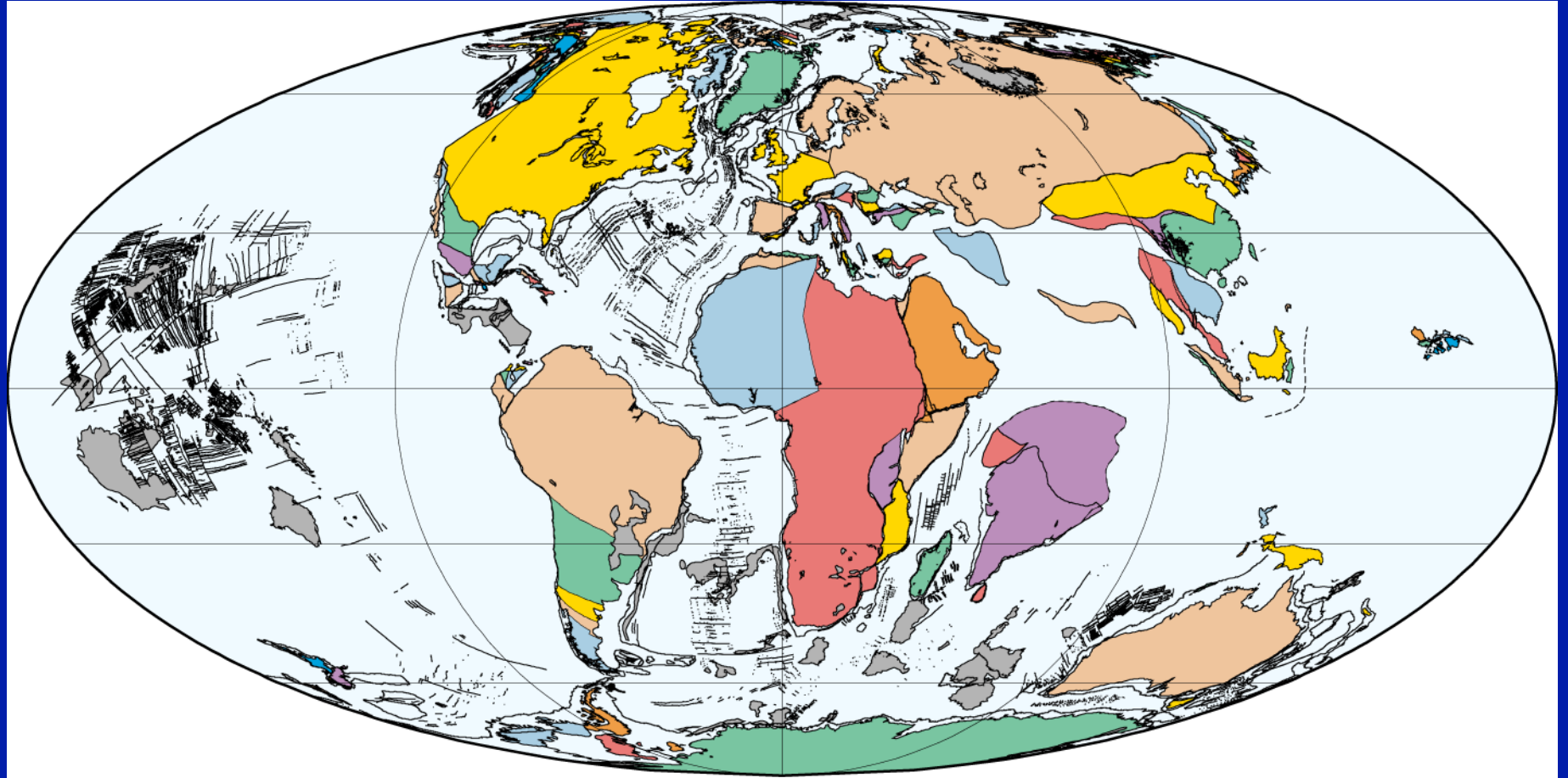
90 Ma
Turonian (Late Cretaceous)

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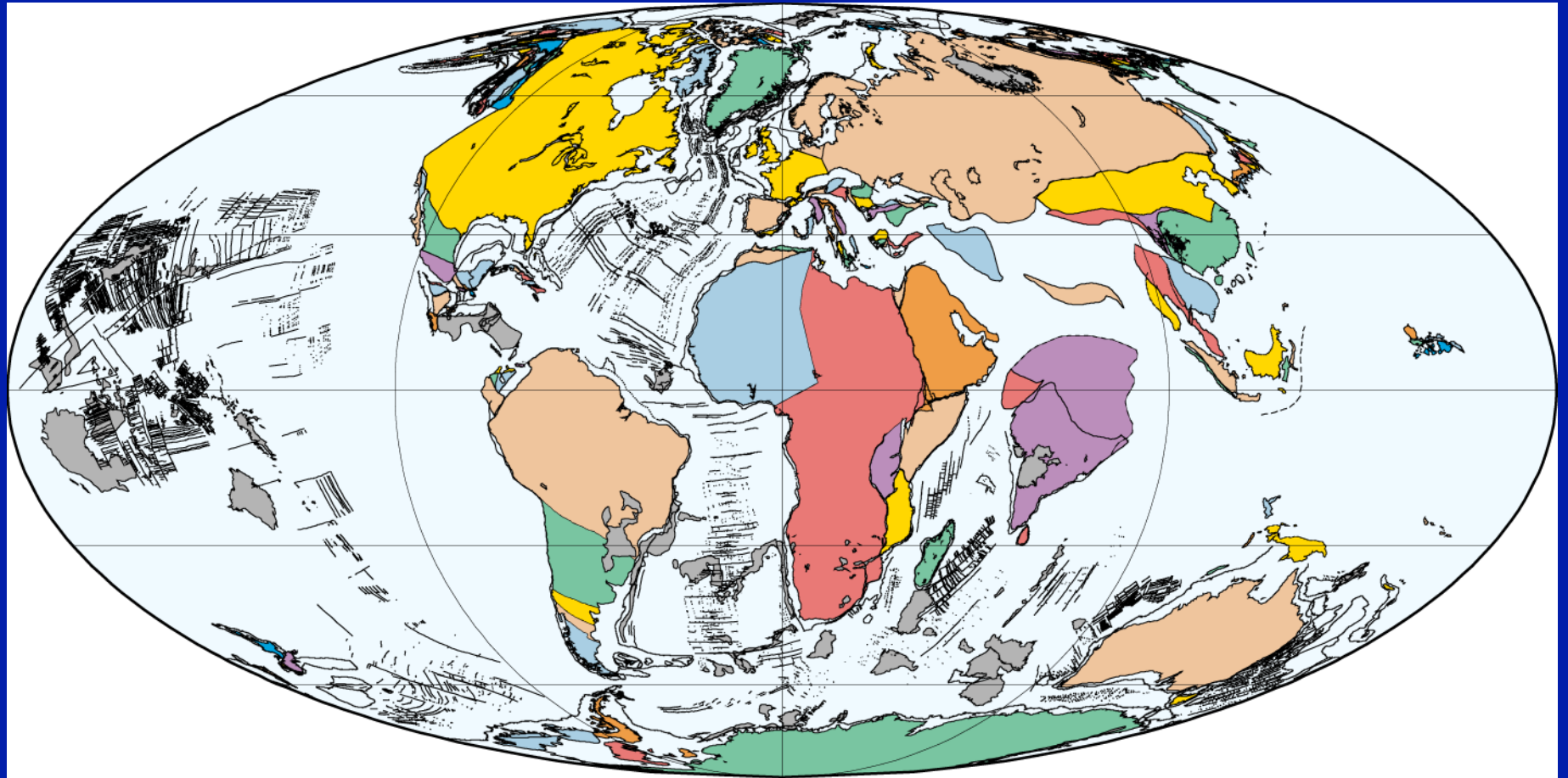
80 Ma
Campanian (Late Cretaceous)

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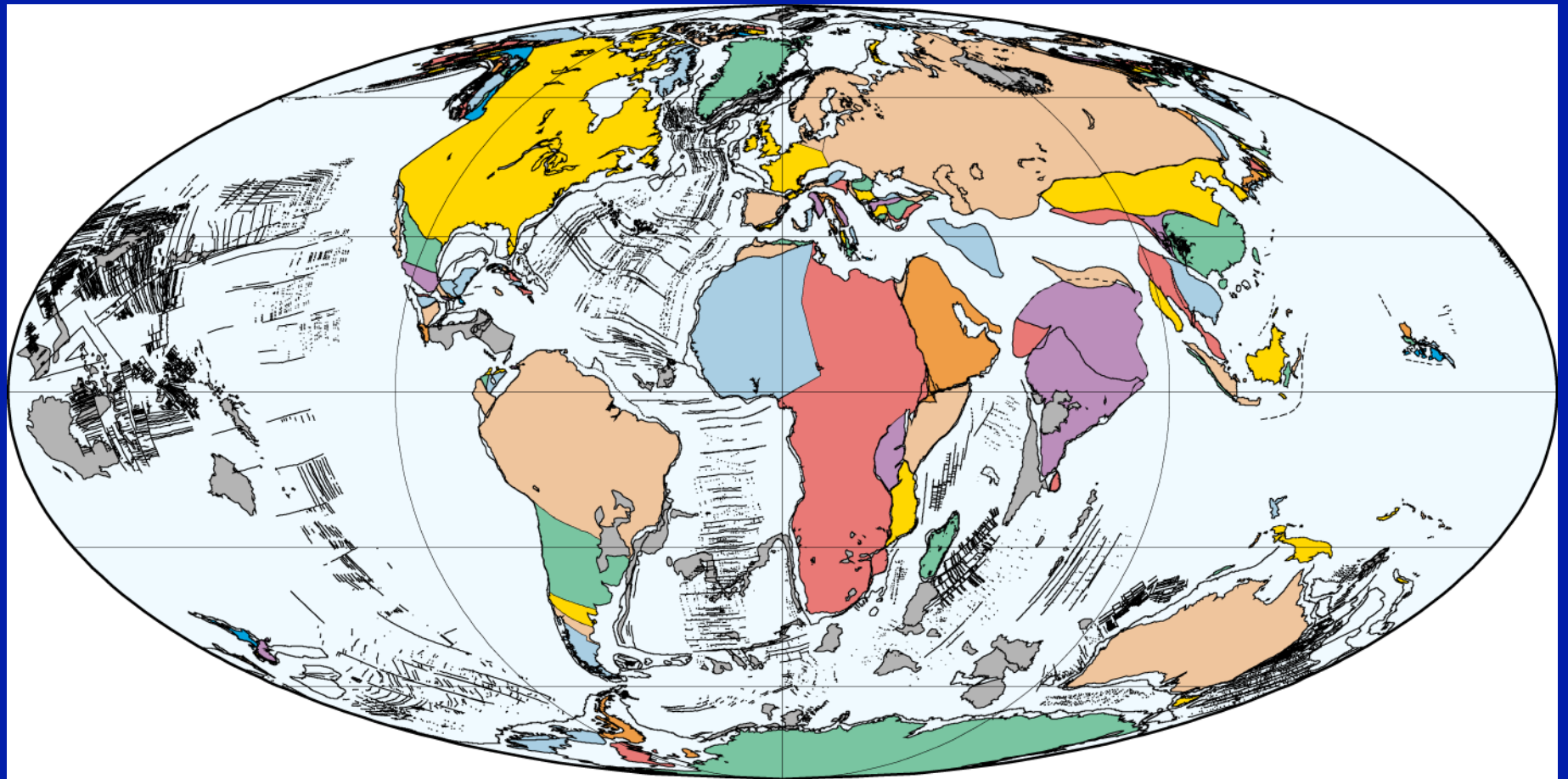
70 Ma
Maastrichtian (Late Cretaceous)

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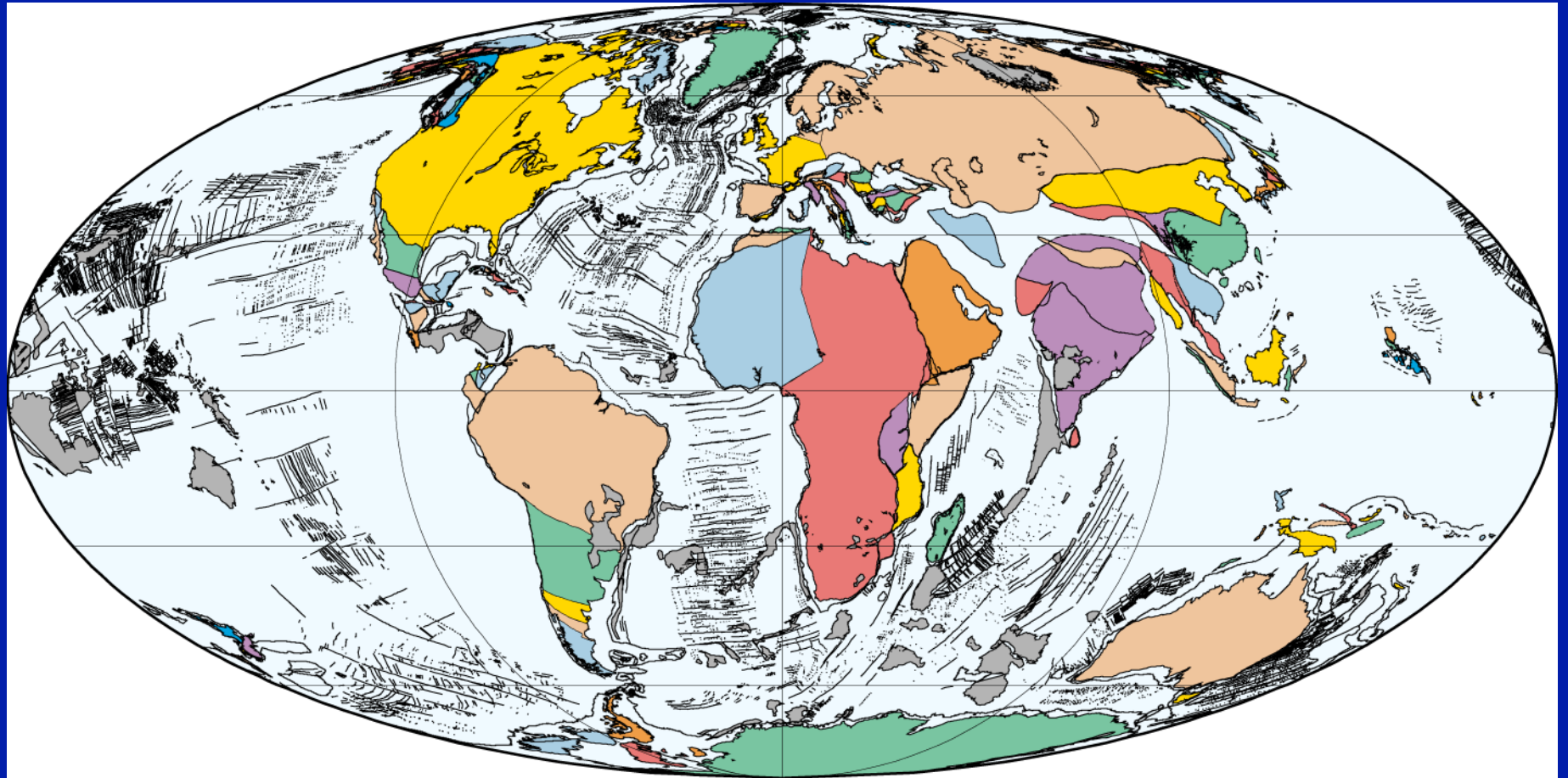
60 Ma
Late Paleocene

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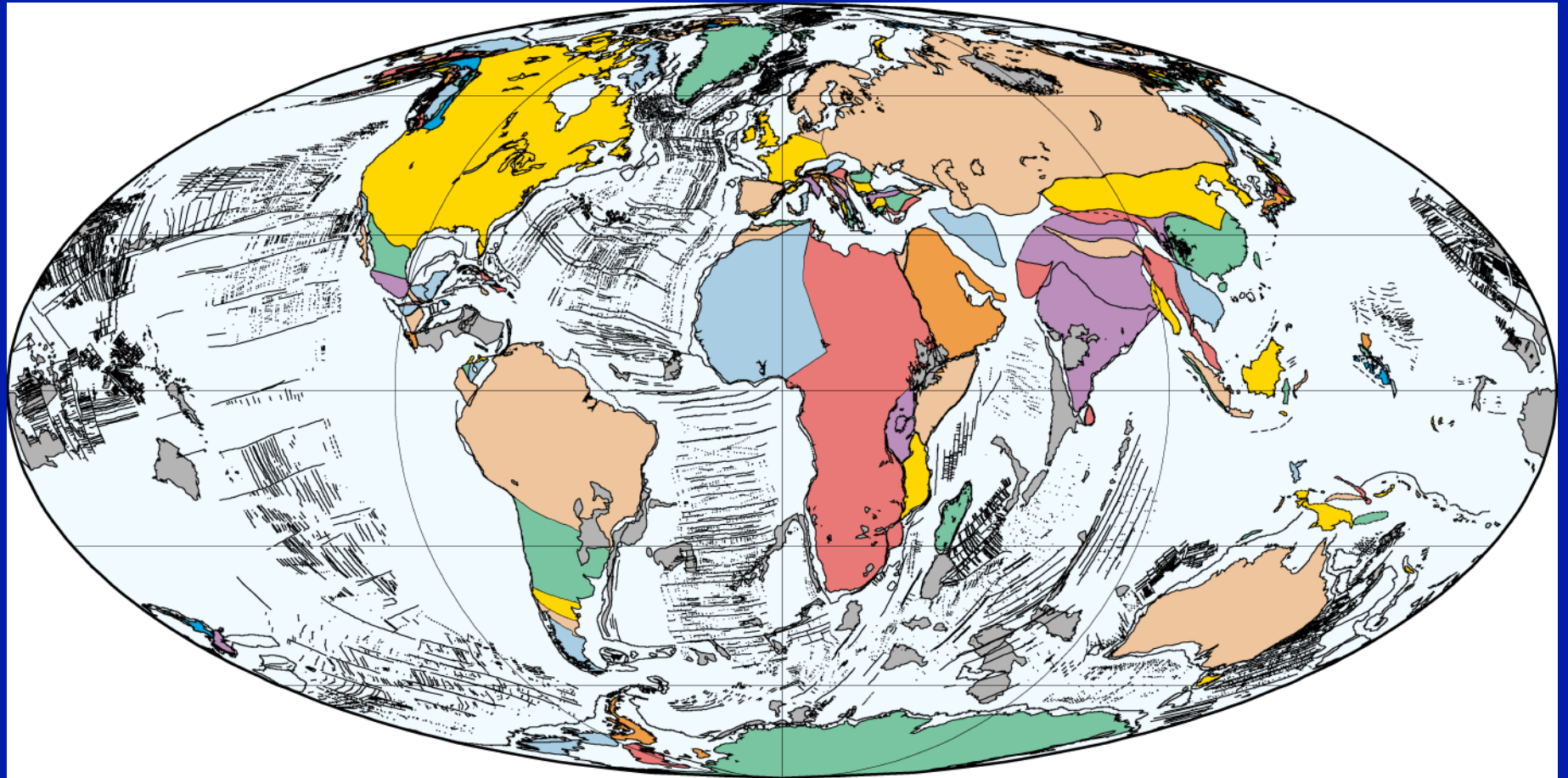
50 Ma
Early Eocene

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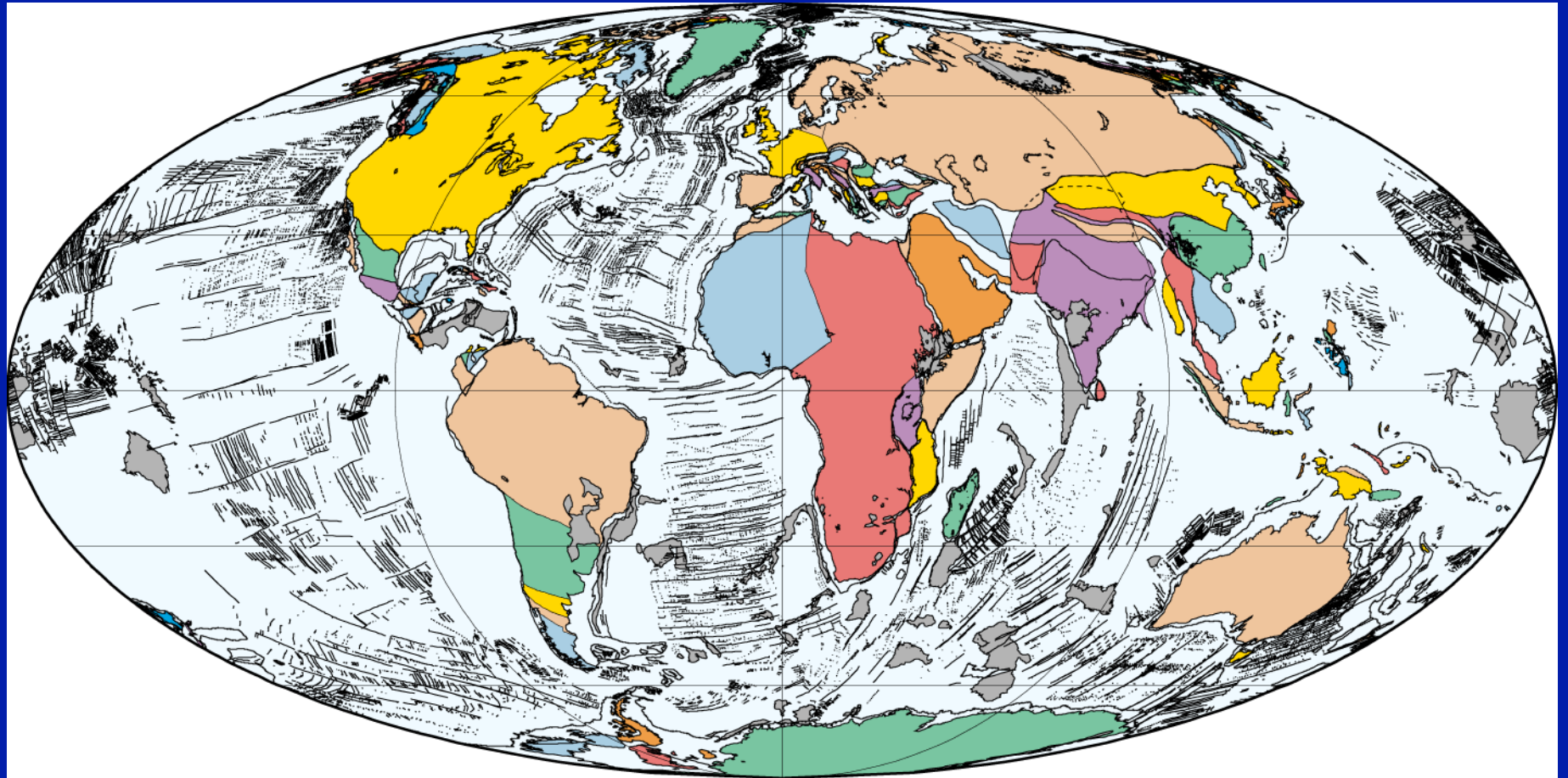
40 Ma
Middle Eocene

PLATES/UTIG
August 2002



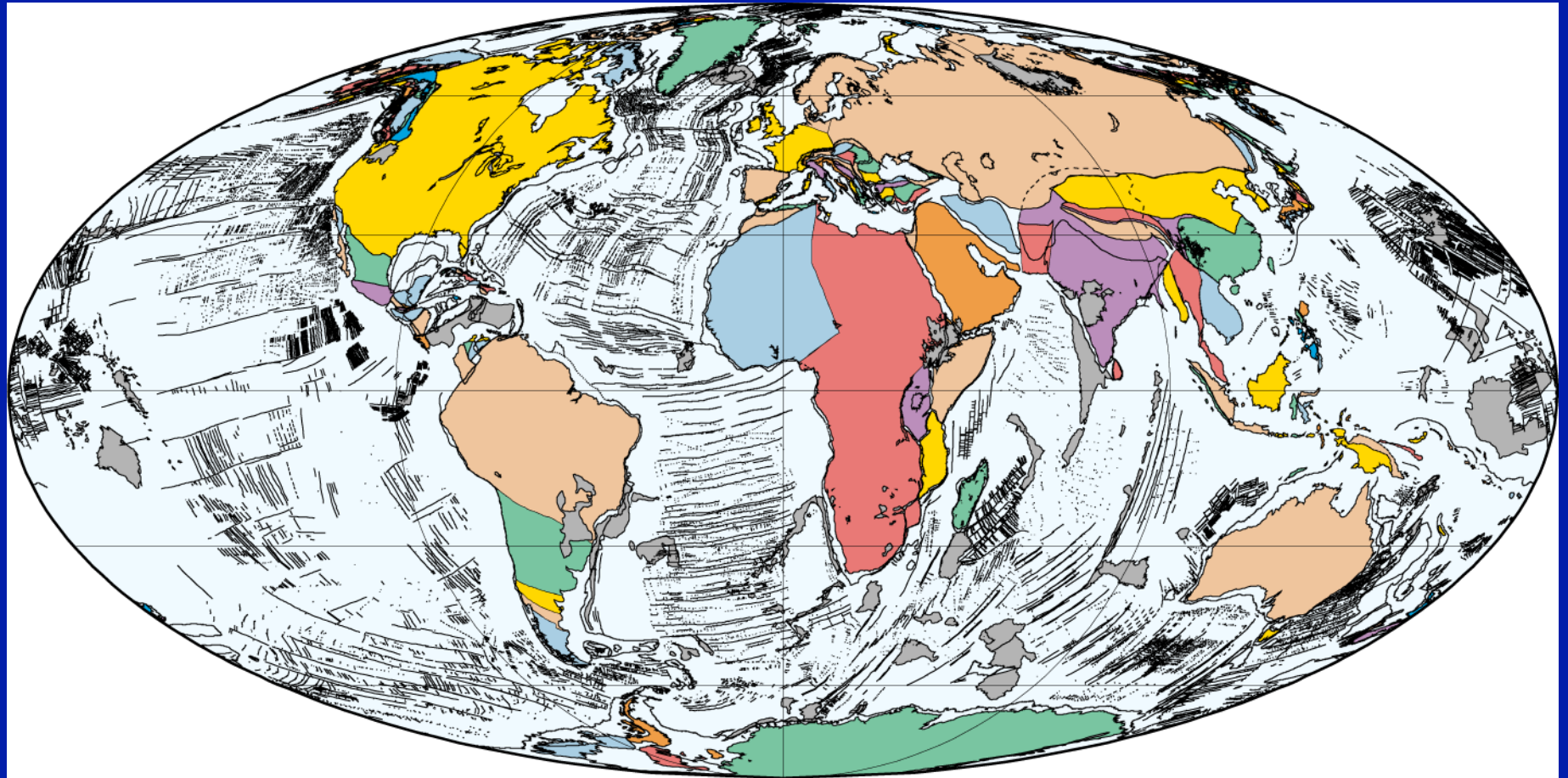
30 Ma
Early Oligocene

PLATES/UTIG
August 2002



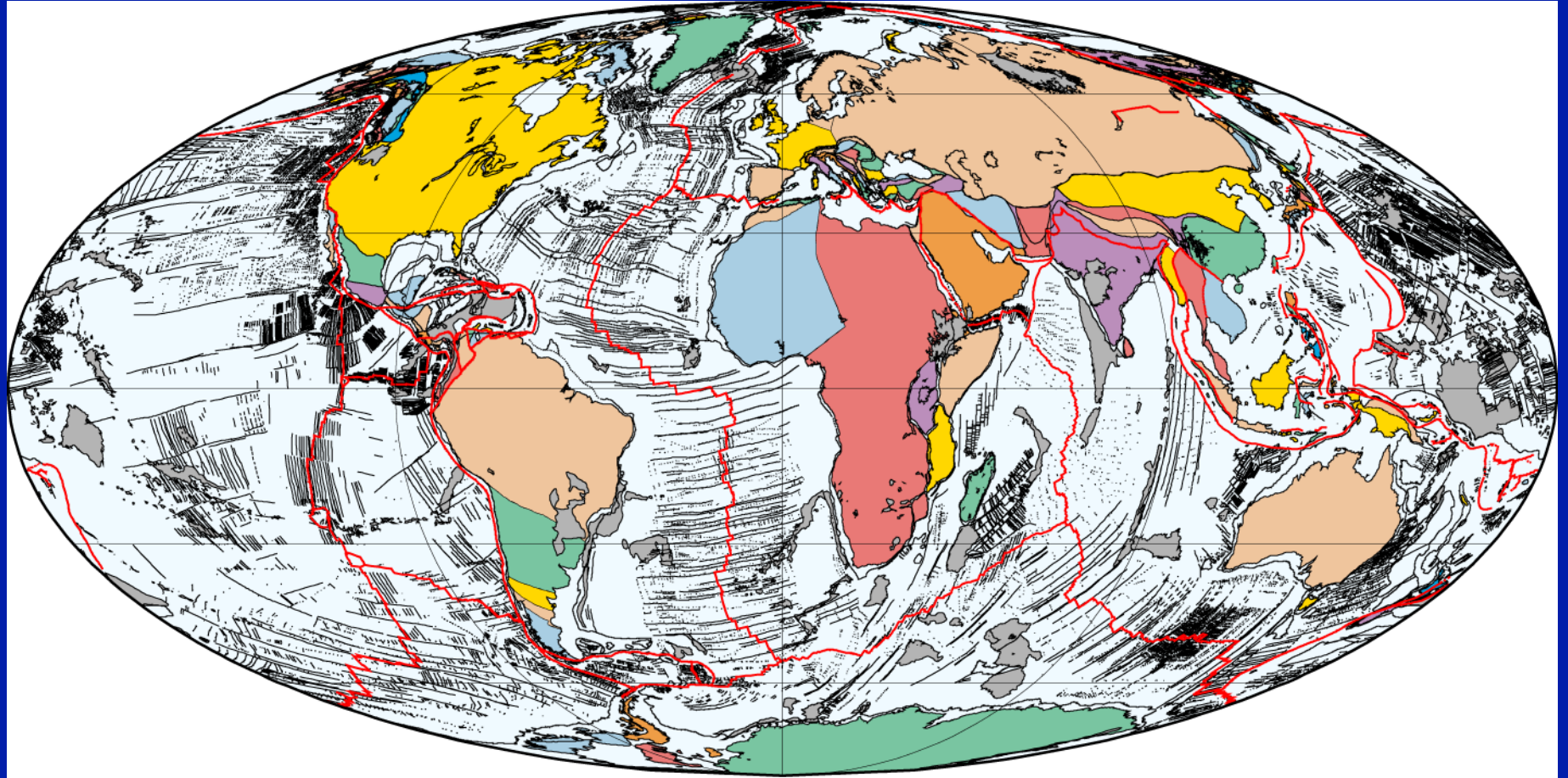
20 Ma
Early Miocene

PLATESUTIG
August 2002



10 Ma
Late Miocene

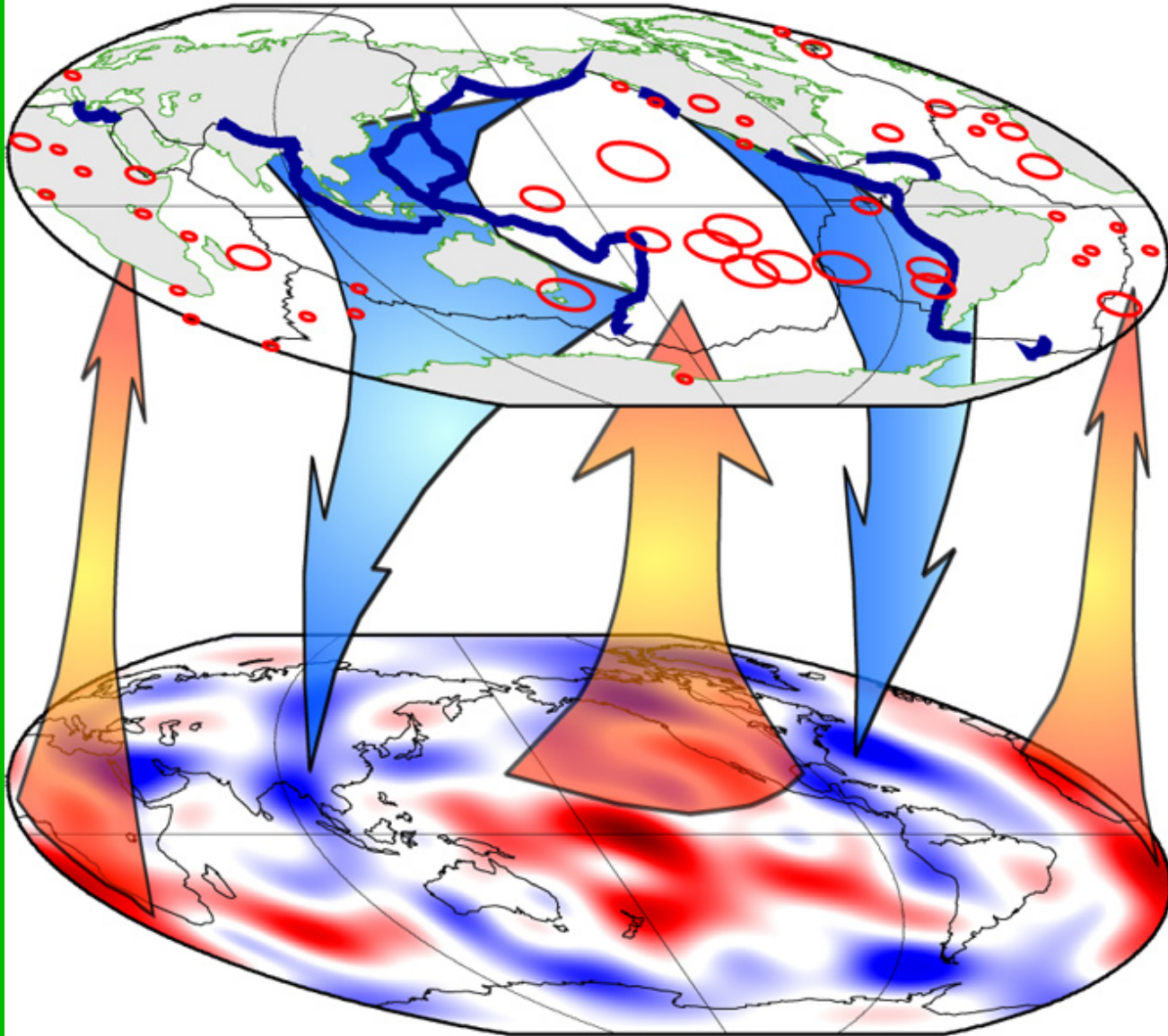
PLATES/UTIG
August 2002



0Ma
Present Day

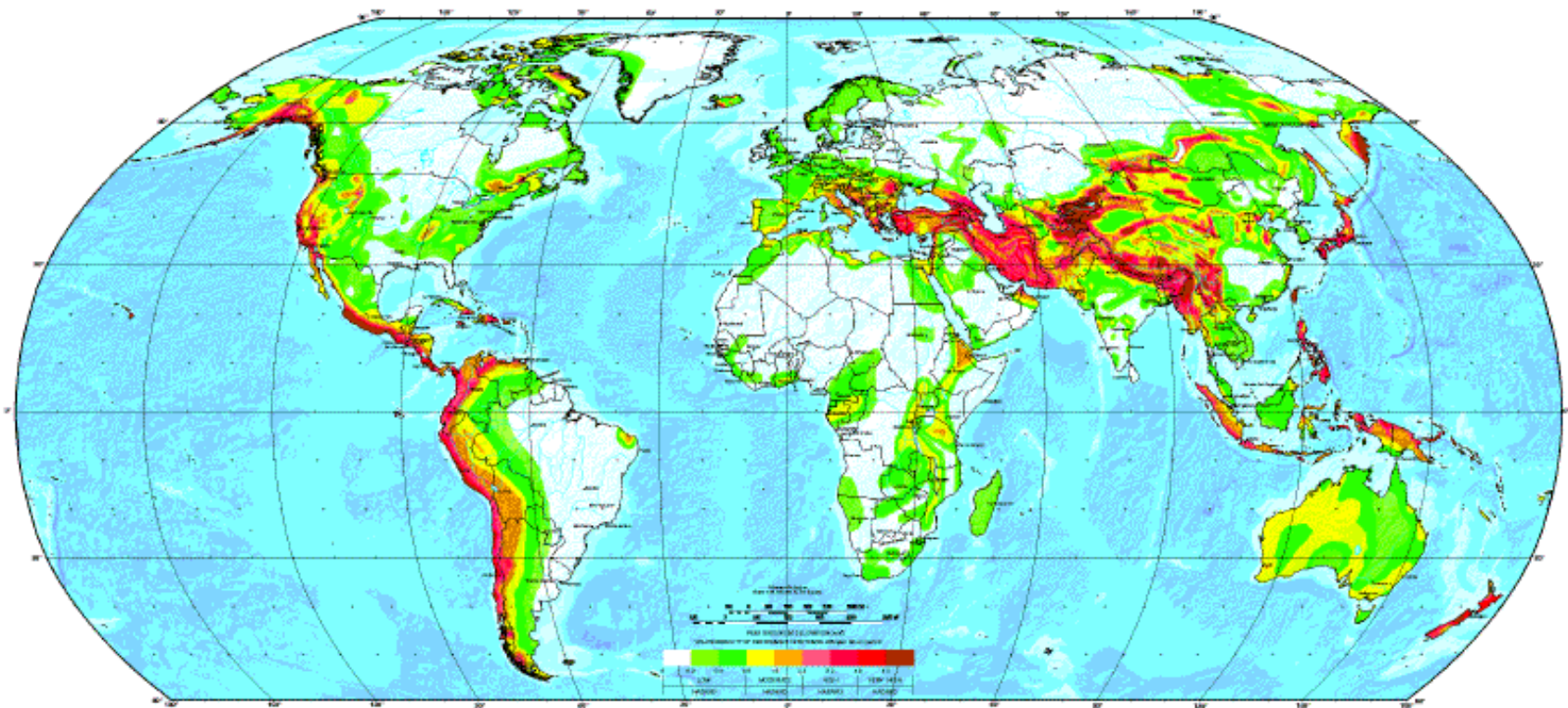
PLATES/UTIG
August 2002

Surface

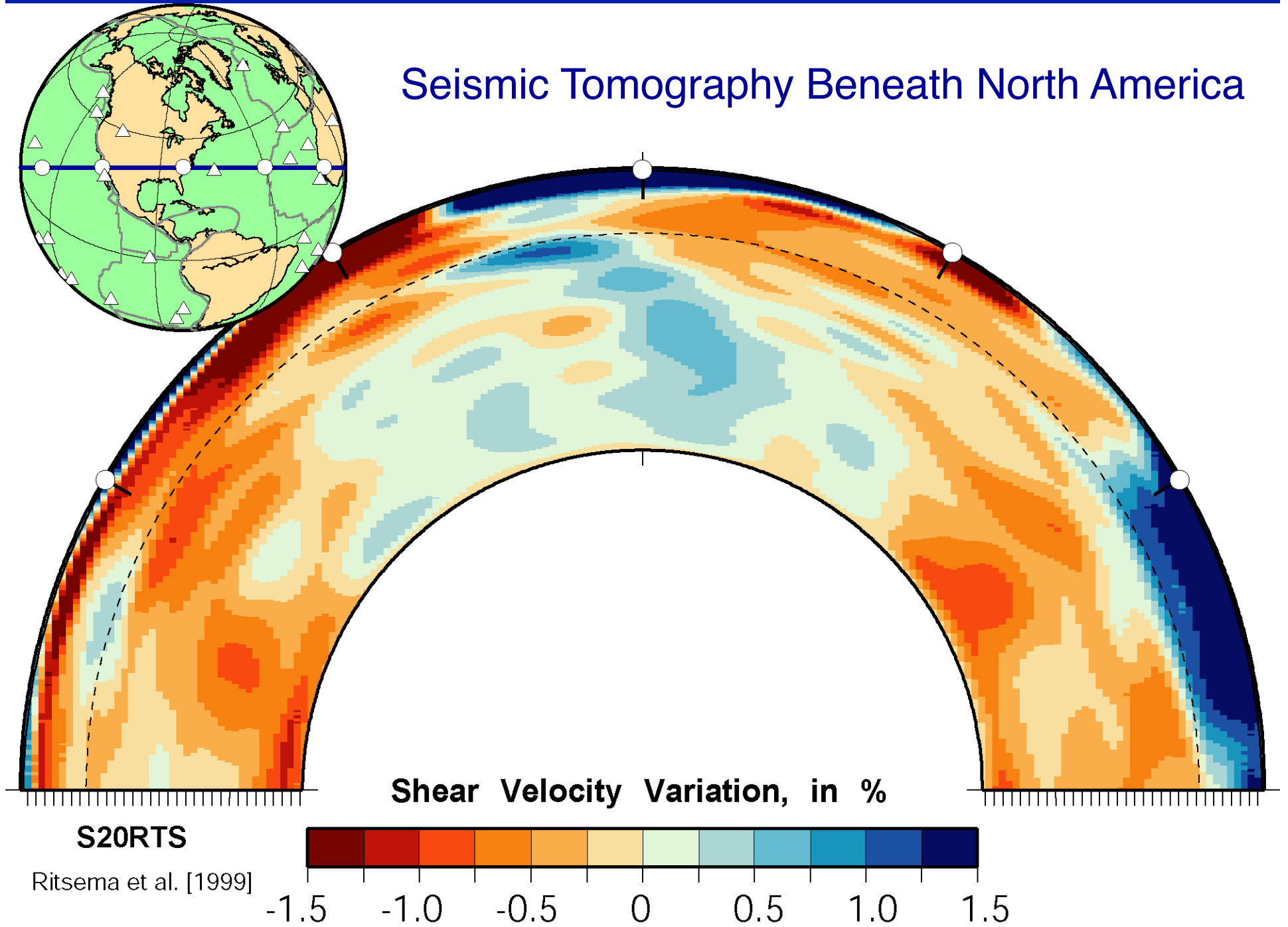


D'' / CMB

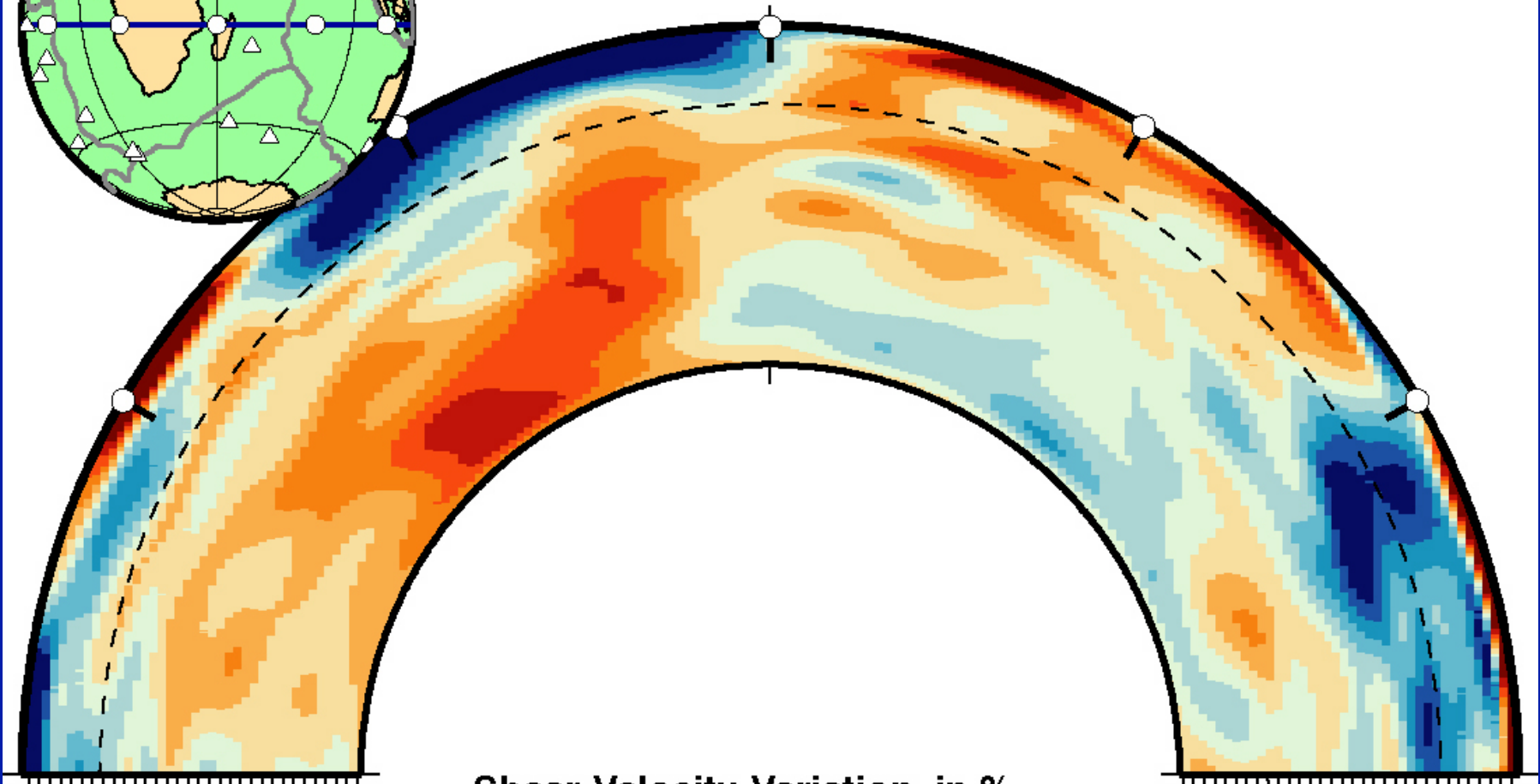
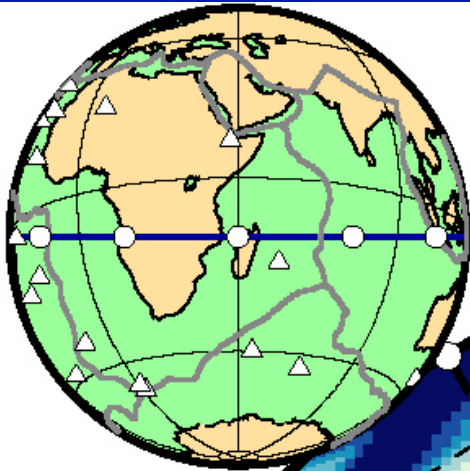
GLOBAL SEISMIC HAZARD MAP



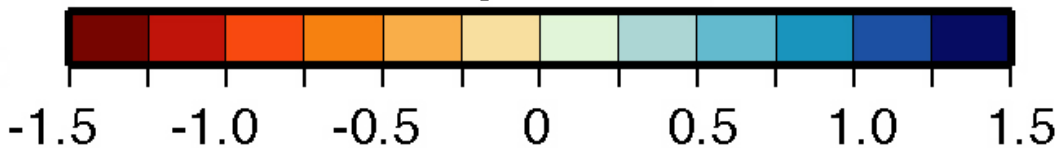
Seismic Tomography Beneath North America



Seismic Tomography Beneath Africa

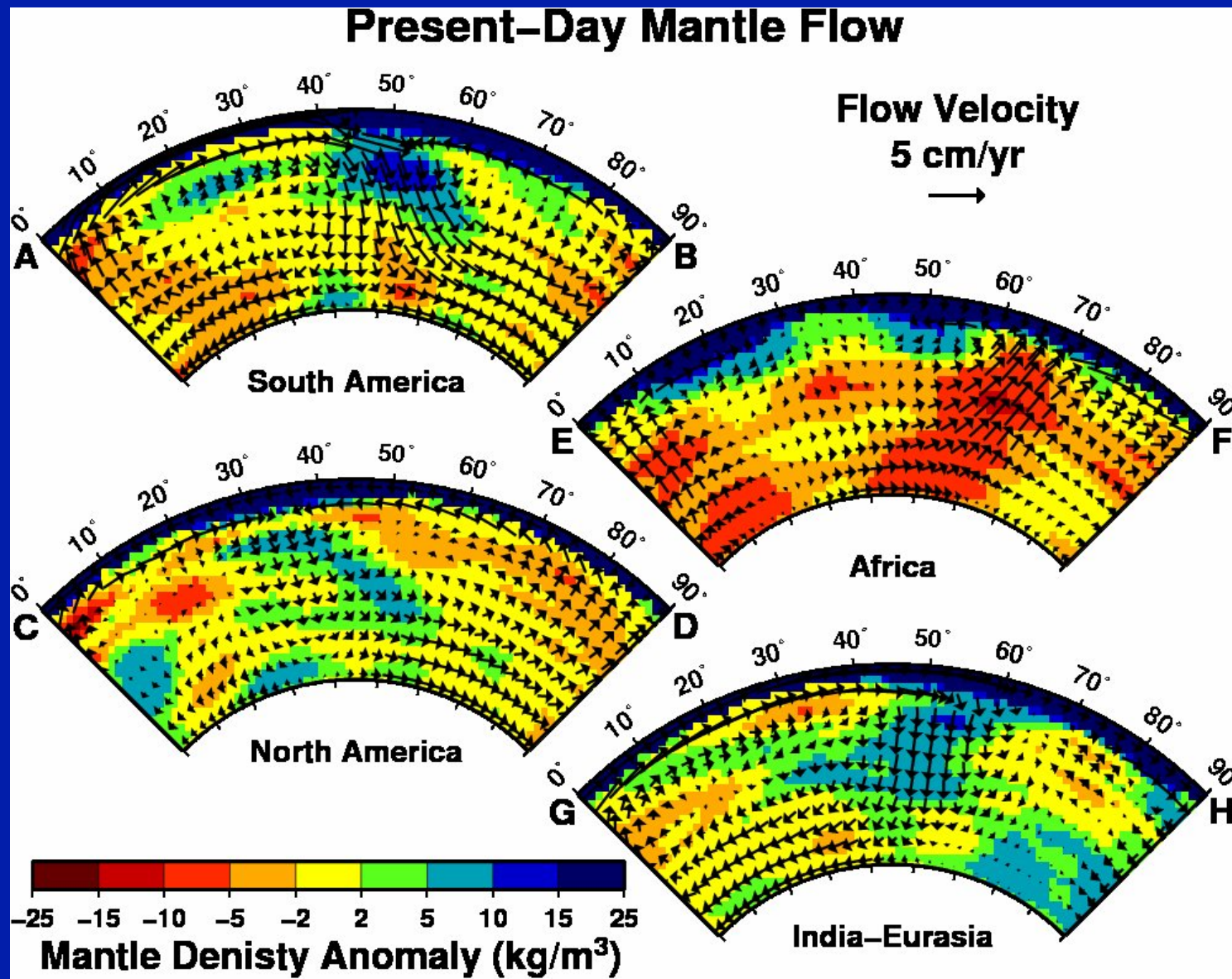


Shear Velocity Variation, in %



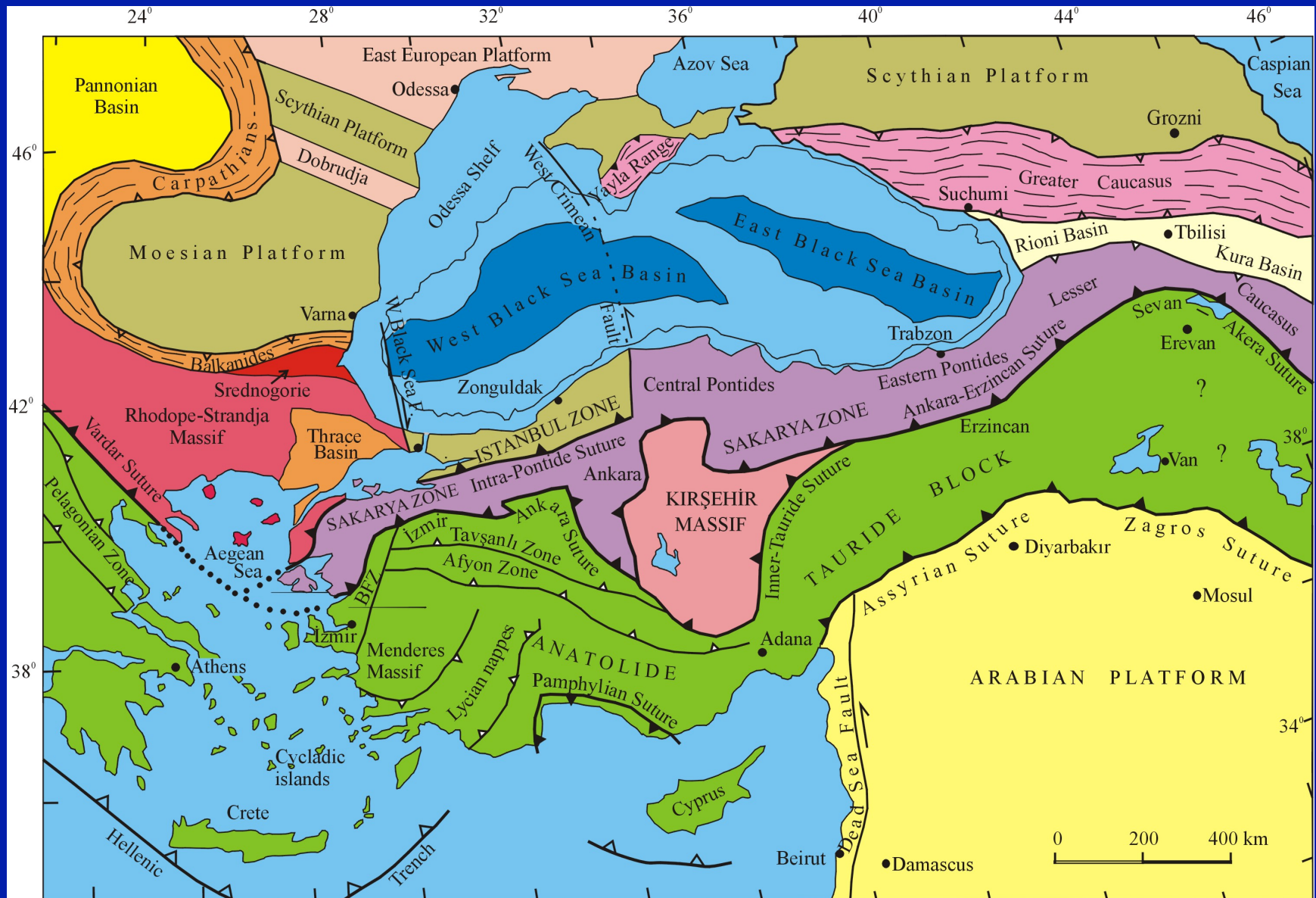
S20RTS
Ritsema et al. [1999]

Patterns of Mantle Convection

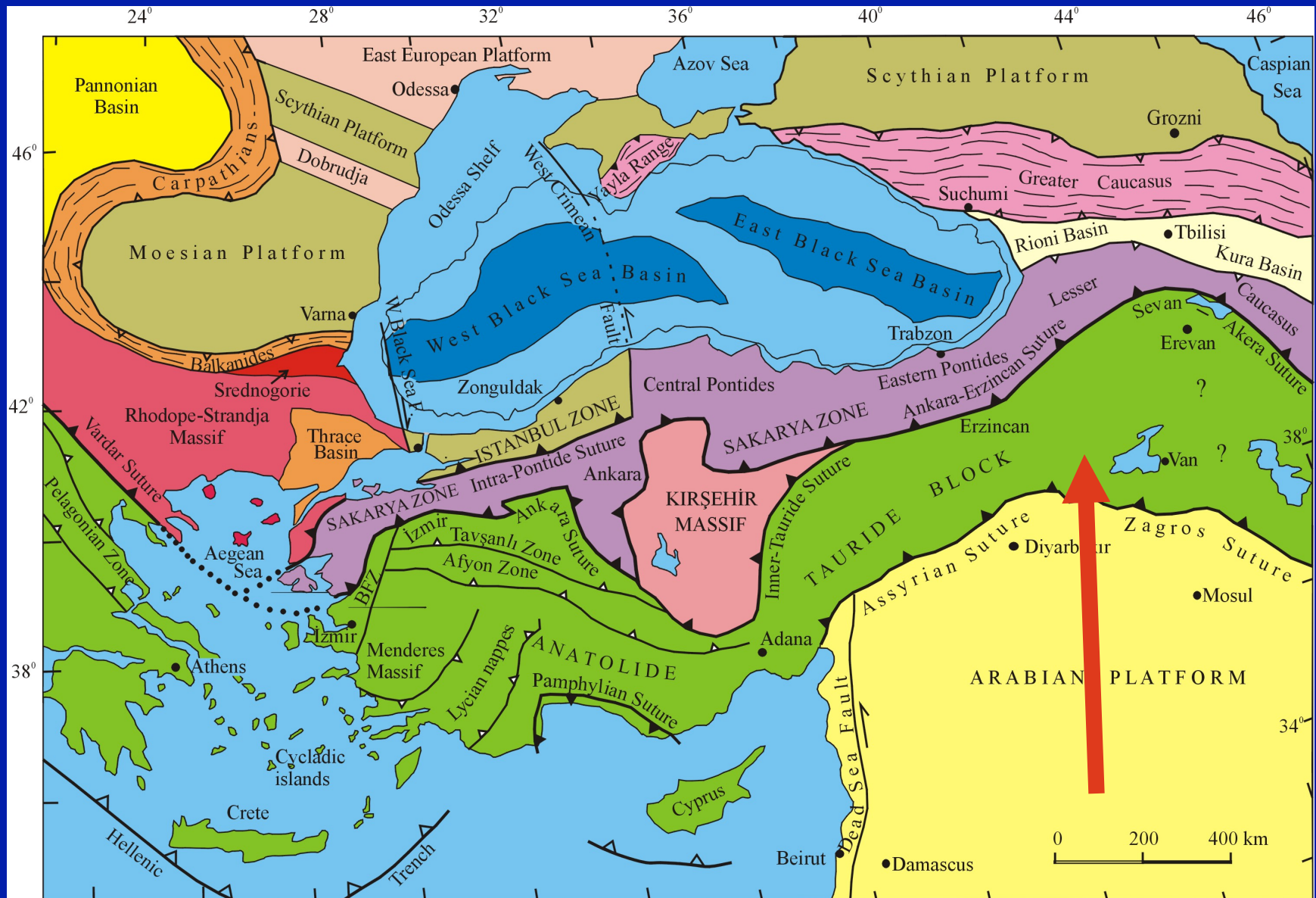


Courtesy of C. Conrad

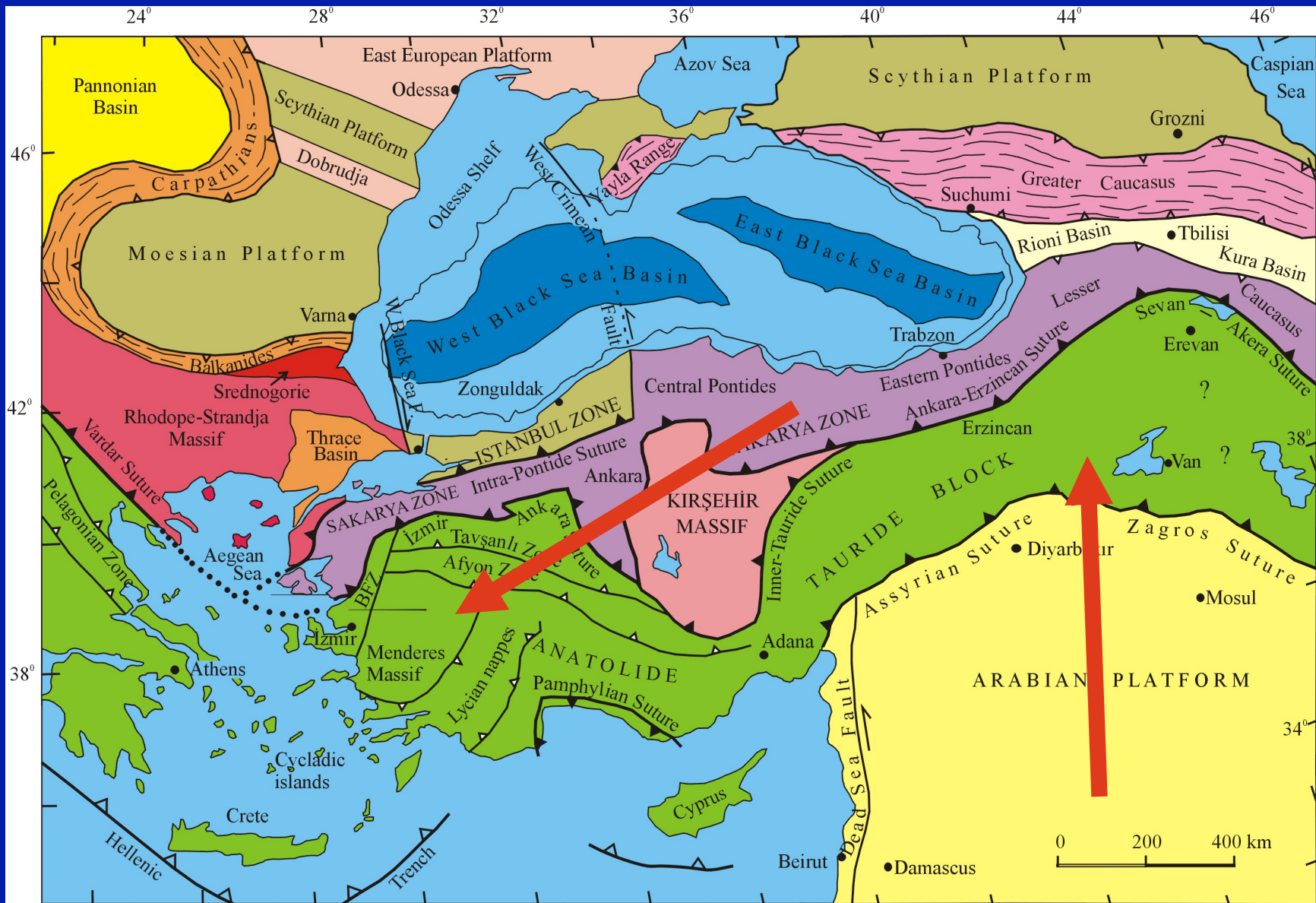




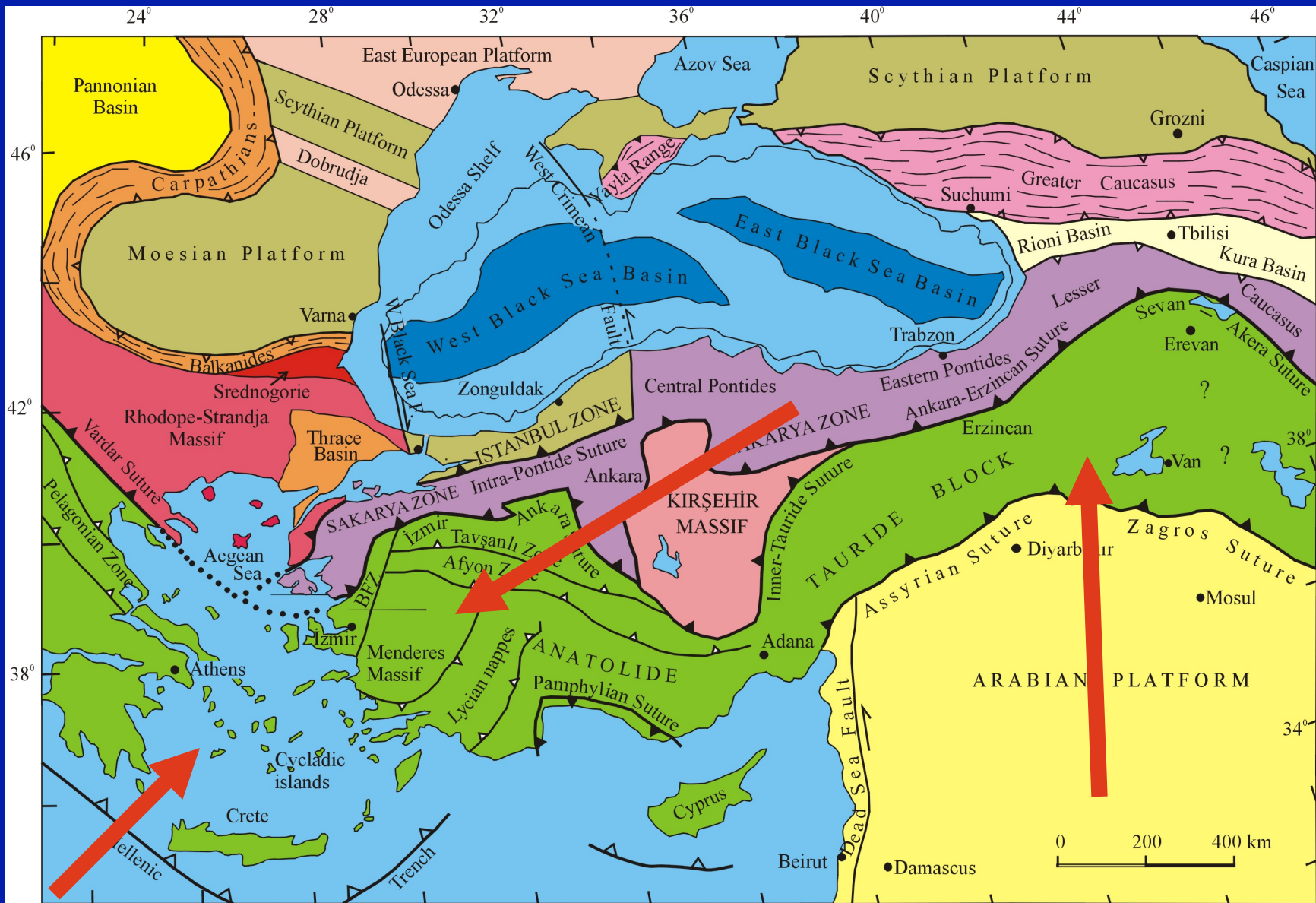
Tectonics of the Eastern Mediterranean



Tectonics of the Eastern Mediterranean

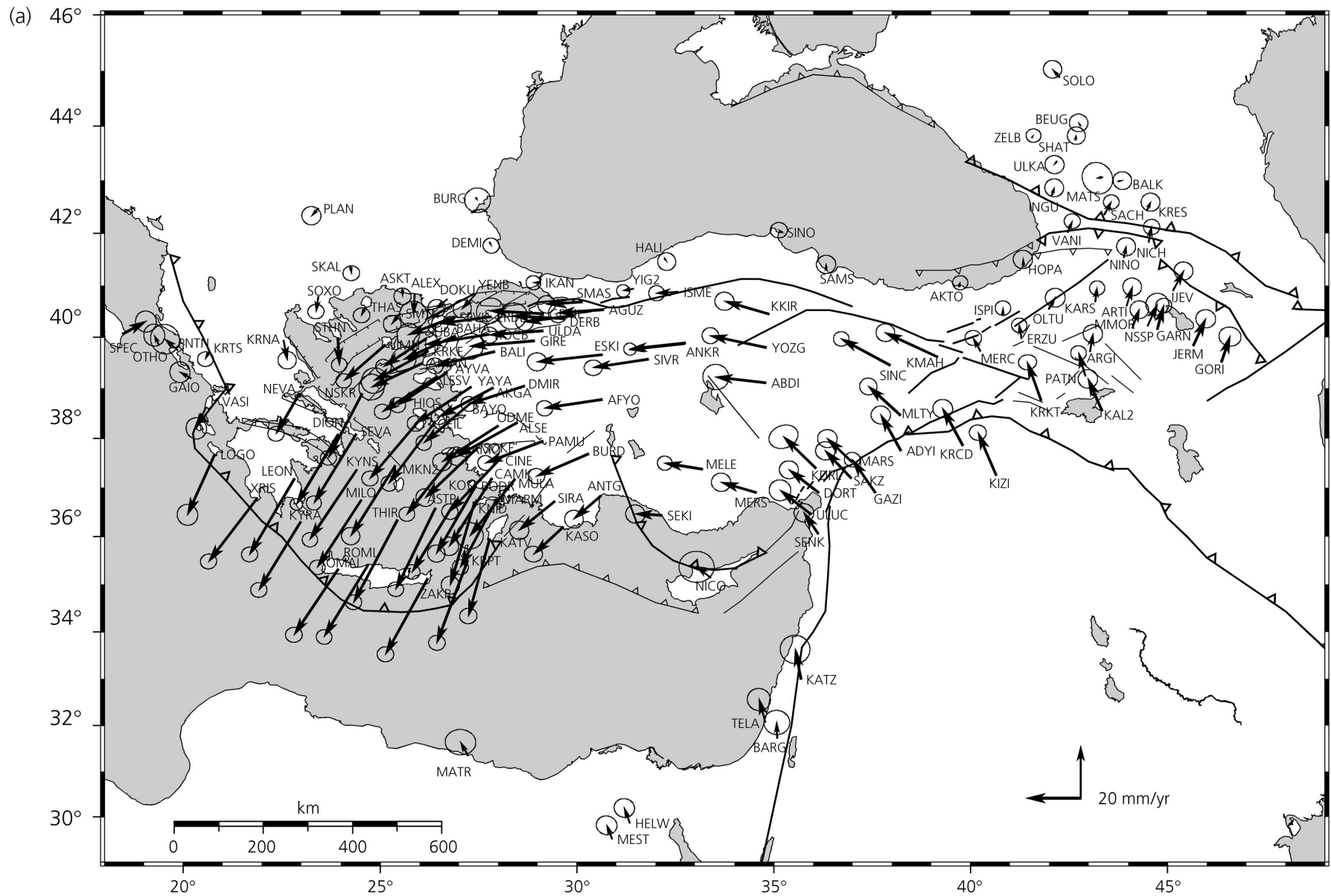


Tectonics of the Eastern Mediterranean

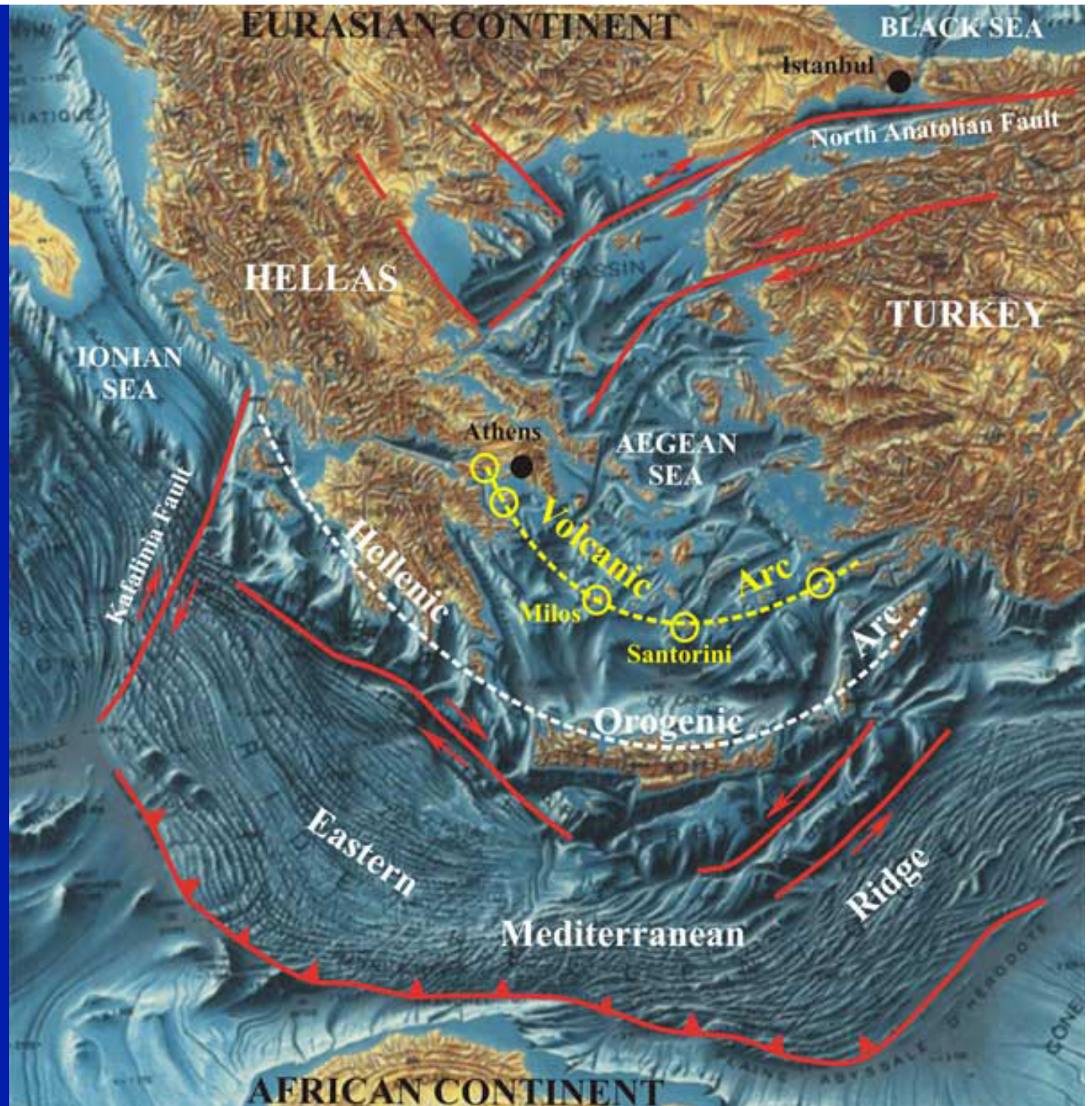


Tectonics of the Eastern Mediterranean

GPS study of Internal Deformation in the Anatolian Plate



Tectonics of the Hellenic Arc

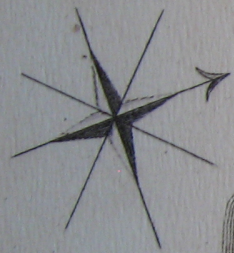


THIRA (Santorini)



Island
before
1500 BC

PLAN
DE L'ILE
THERA ou SANTORIN.





Archaeological Site at Akrotiri



Excavations started in 1967; Closed in 2005

Olympia (~ 600 BCE)



Akrotiri (up until 1630 BCE)















The blast came in 3 distinct phases

* The first is thin, and slightly eroded. People had warning and were able to evacuate (no bodies found)



Volcanic Rocks of Santorini

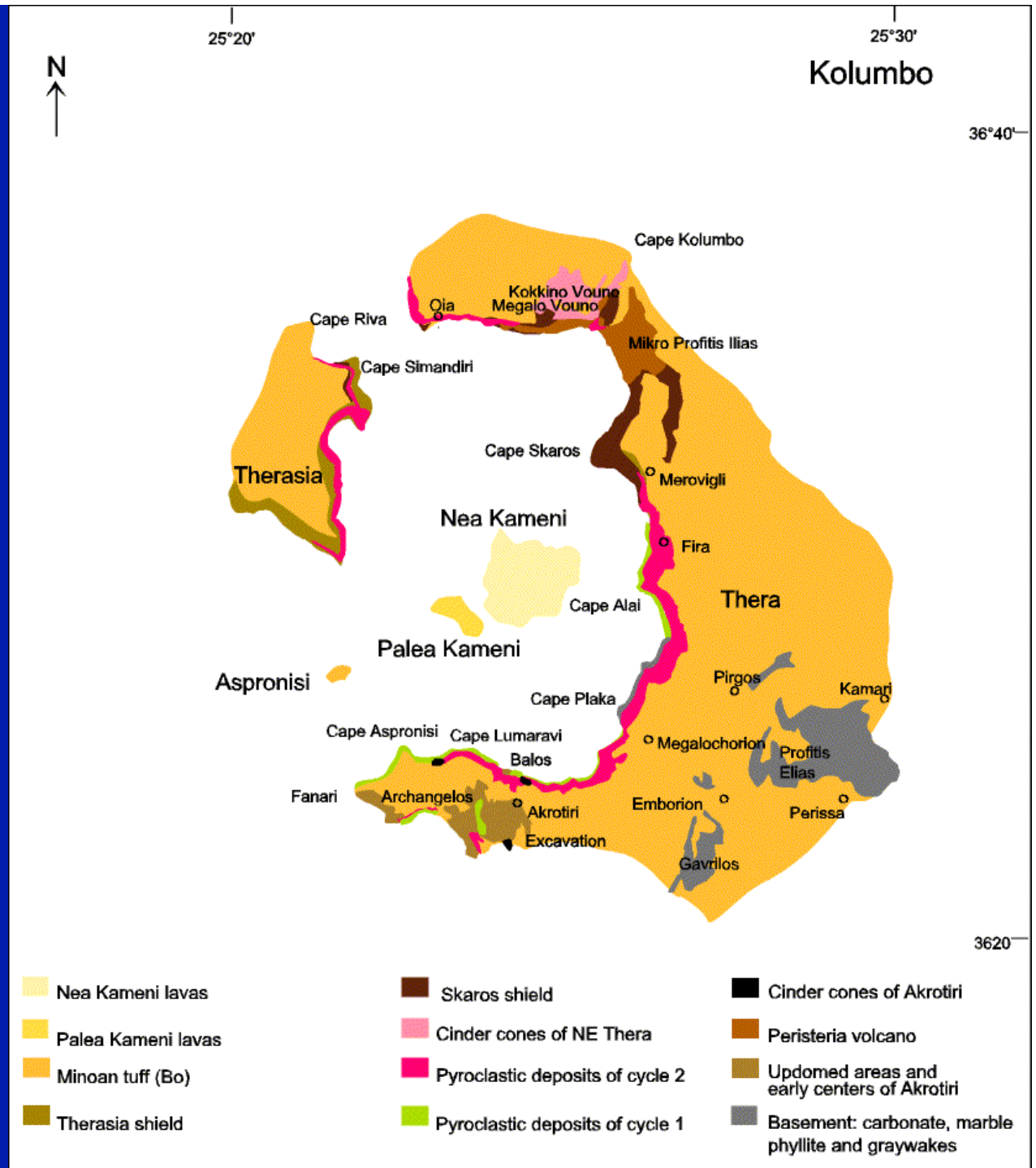
Orange is “Minoan Tuff”

Radiocarbon dates are 1600-1630 BCE

- Questions remain about exact archaeological dates

- Tree rings, Chinese crop failures → 1628 BCE

- No written texts other than Minoan “Linear A”



The Minoan civilization on Crete collapsed a century later, taken over by the Myceneans, who took “Linear B” as the basis for what became the written Greek language

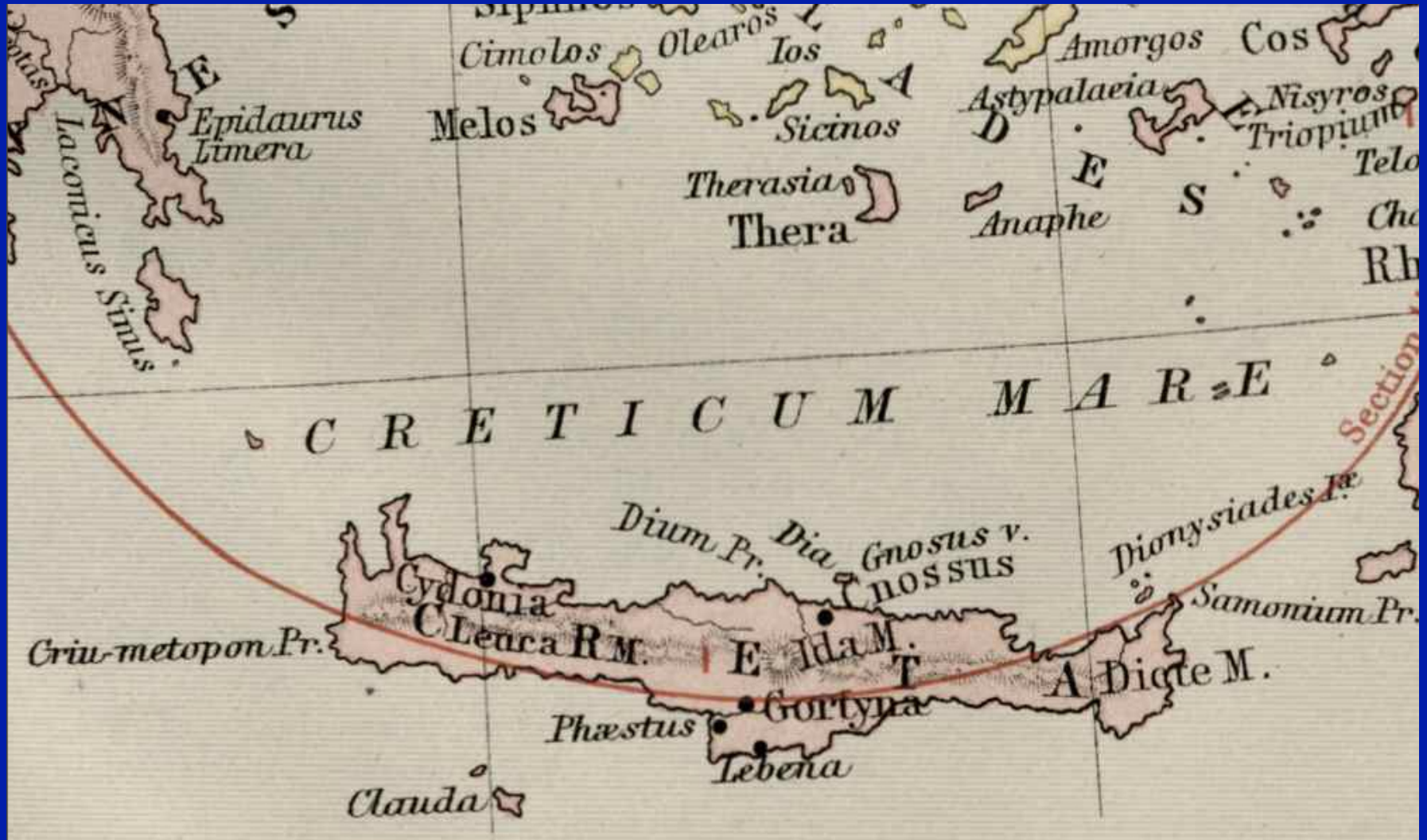
Was this related to the Eruption of Santorini?



- Only small amounts of ash fell on Crete (most blew eastward to Anatolia), but could have damaged crops
- Evidence of widespread fires on Crete could have been from the shock wave of the blast
- Tsunamis are a very possible cause of delayed collapse of Minoan culture (damaging seagoing economy)



The tsunami from the 1610 BCE eruption of Mt. Thera may have been 10-35 meters along the northern coast of Crete



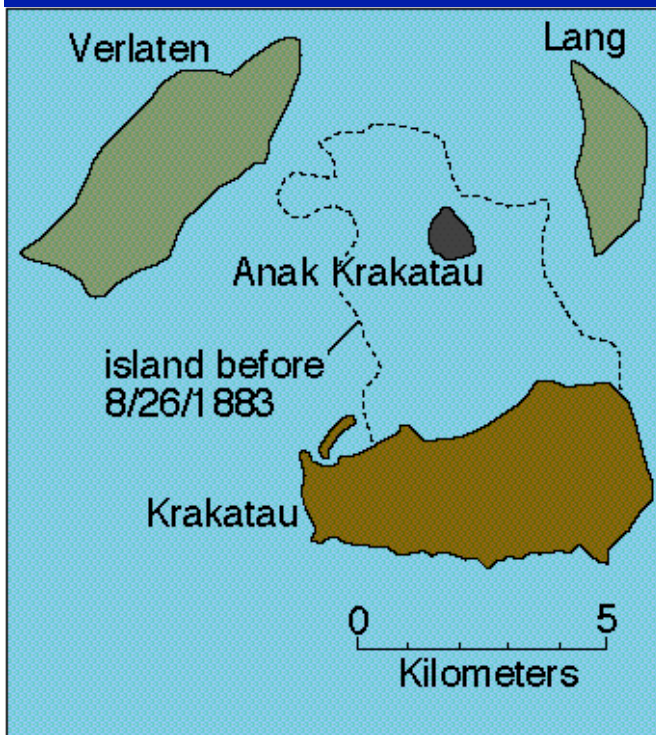
Where else do you see an island like Santorini?

Where else do you see an island like Santorini?



Krakatau Eruption of 1883:

- 18 cubic kilometers of ejected tephra
- Tsunami killed 36,000

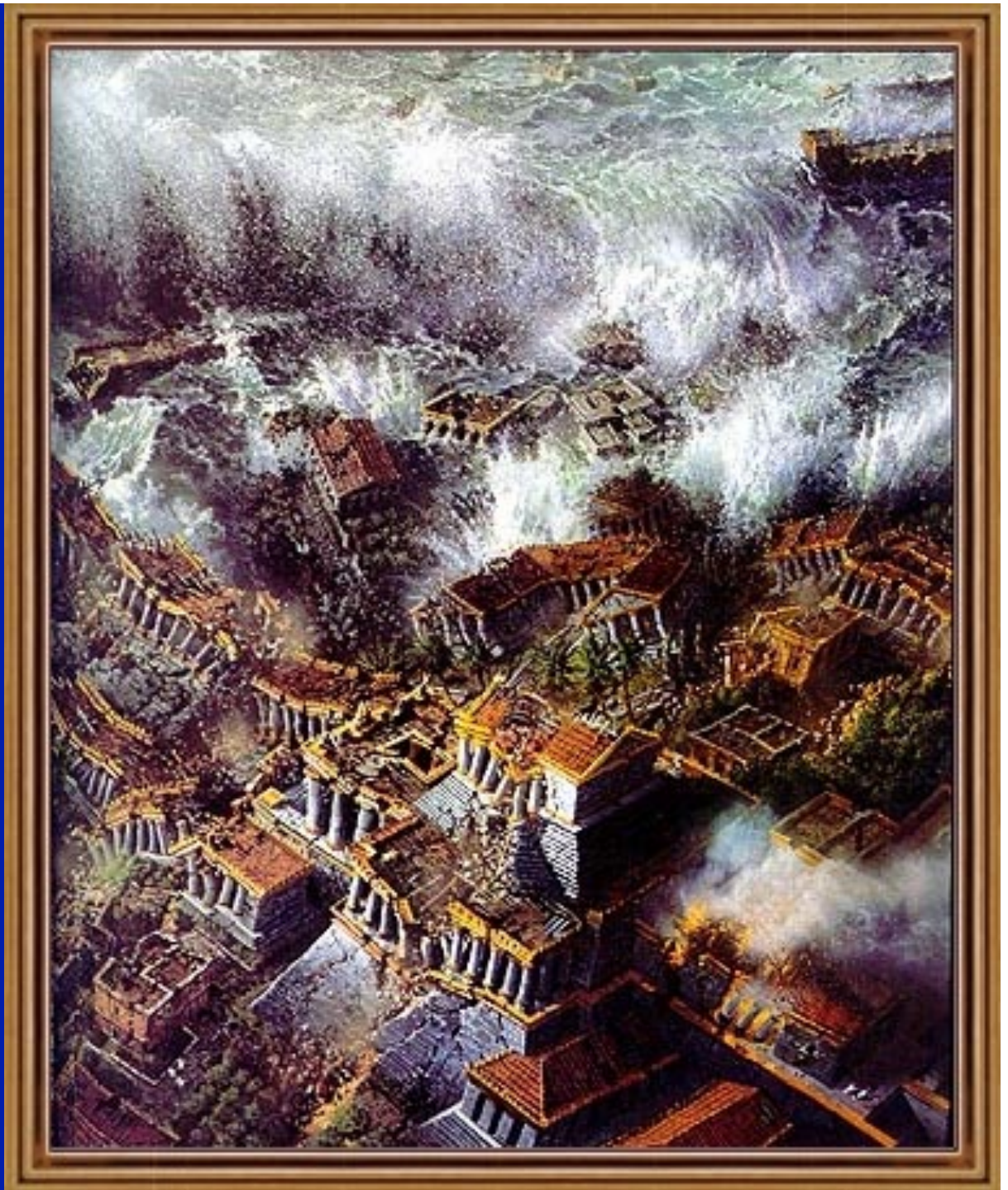


From Simkin and Fiske, 1983

Was Akrotiri or Crete
“Atlantis?”

Plato (~350 BCE):

*Dialogues of Timaeus
and Critias*



Plato:

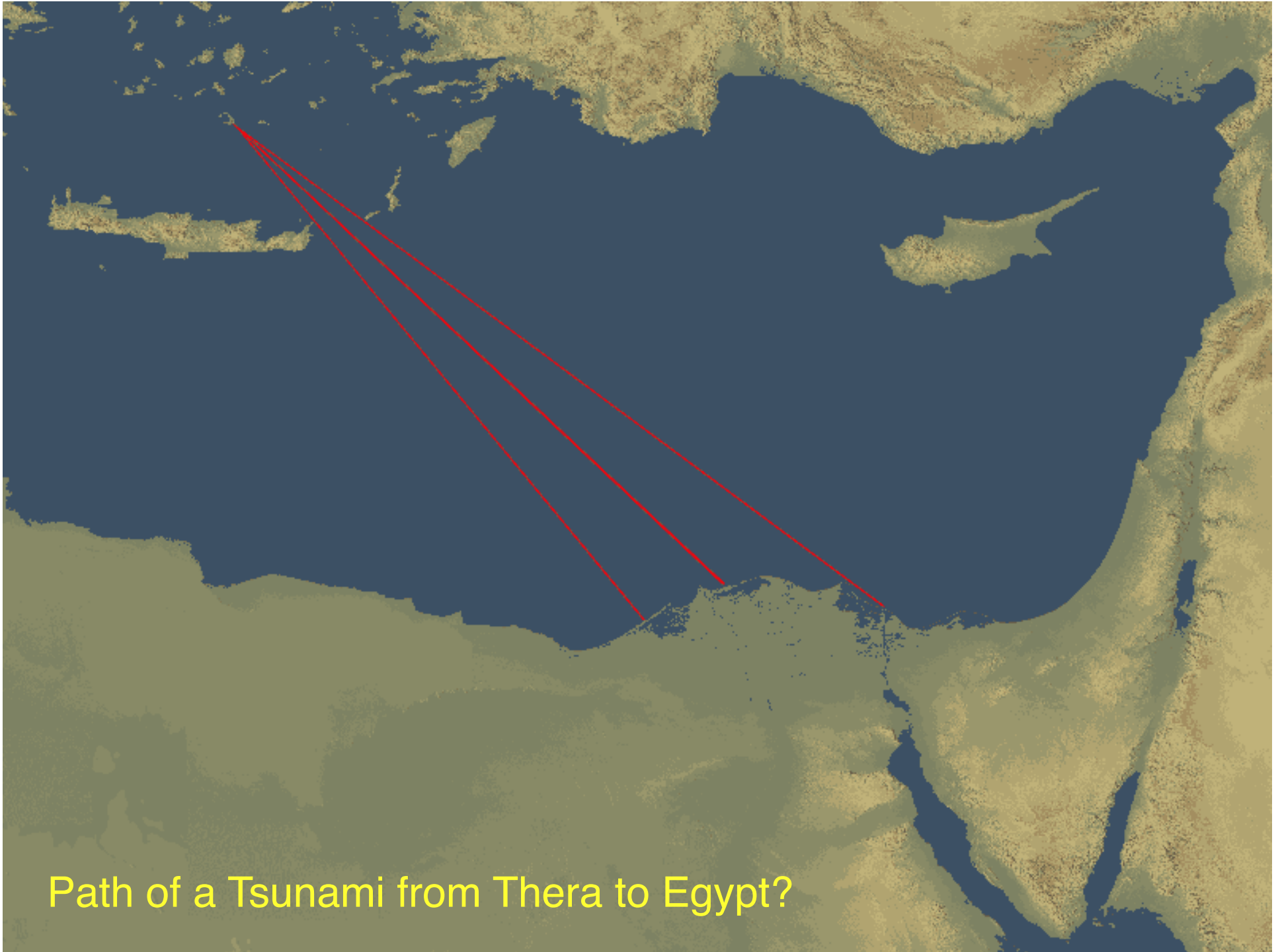
“there was an island situated in front of the straits which by you are called the pillars of Heracles. The island....was the way to other islands, and from these you might pass to the whole of the continent....Now in this island of Atlantic there was a great and wonderful empire which had rule over the whole island and several others, and over parts of the continent.....But....there occurred violent earthquakes and floods, and in a single day and night of misfortune....the island of Atlantis....disappeared in the depths of the sea.”

Supposedly....Critias heard the story of Atlantis from his grandfather

- who heard it from his father
- who heard it from Solon (law giver of Athens)
- who in 600 BCE heard from people in Lower Egypt
- who said it happened 900 years earlier



Plagues of Egypt, JMW Turner (1800)



Path of a Tsunami from Thera to Egypt?

Plagues of Egypt:

Water turned to blood, infestations of frogs, gnats and flies, darkness, violent hail

The Israelites were guided by a “pillar of cloud” by day and a “pillar of fire” by night.

Dates of the Israelite exodus are often estimated to be around 1450 BCE --- long enough ago for the events of Thera's eruption to become part of legend

Other Possible Myth Origins from the Eruption of Thera:

- Deucalion and the Flood: Prometheus warns his son Deucalion of Zeus' planned flood. Deucalion and his wife build an ark and survive, and their son Hellen is the father of the Greeks, or Hellenes
- Jason and Argonauts: attacked by a bronze giant named Talos who threw rocks down on them from the top of a mountain and had a "red-hot embrace" and whose son Leukos destroyed cities on Crete and drove away its king.



Akrotiri – only written language is Linear A, still undeciphered



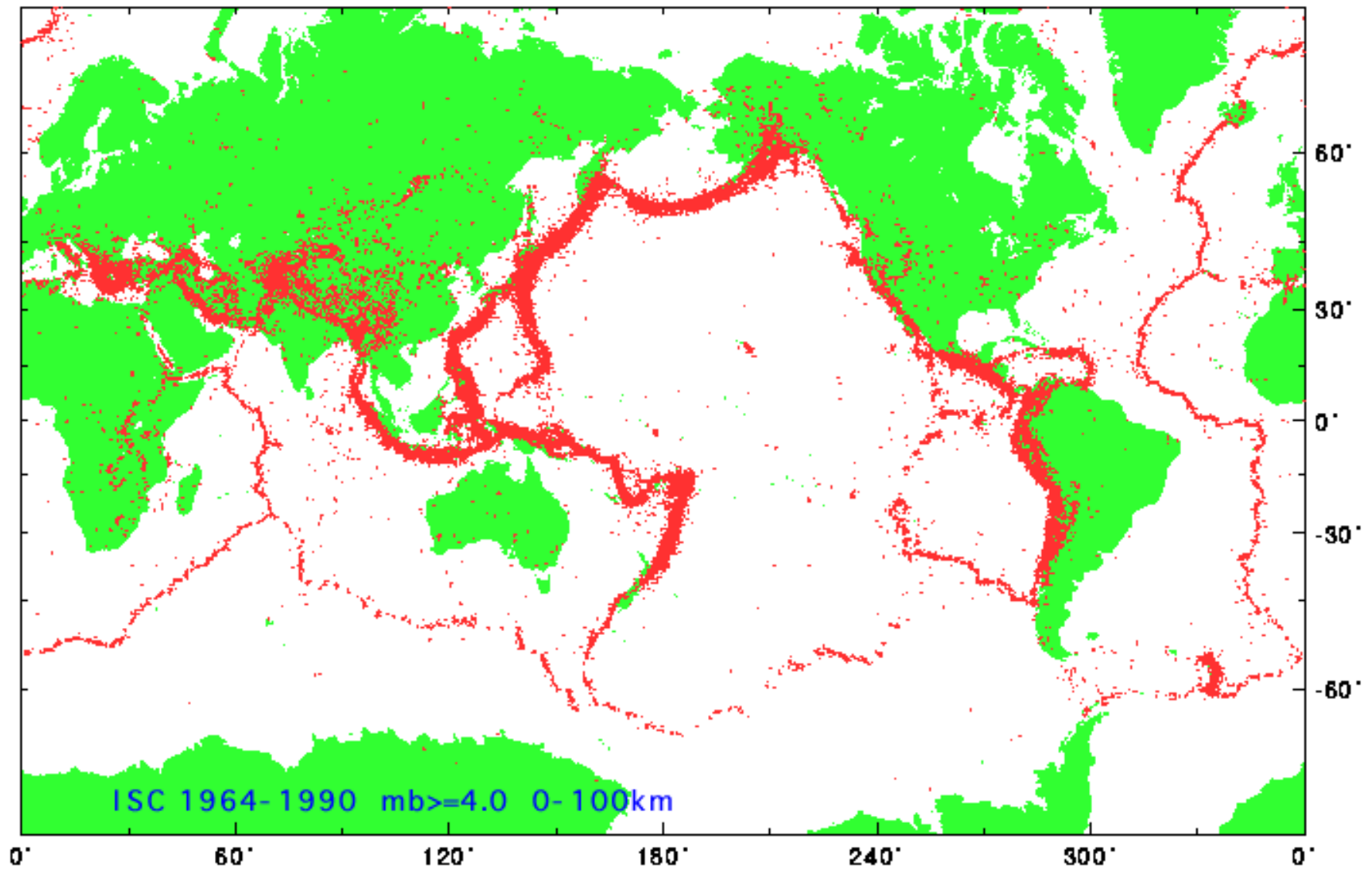
Akrotiri – only written language is Linear A, still undeciphered

So....could this happen again?!?



What is the cause of most tsunamis?

What is the cause of most tsunamis? **EARTHQUAKES!**



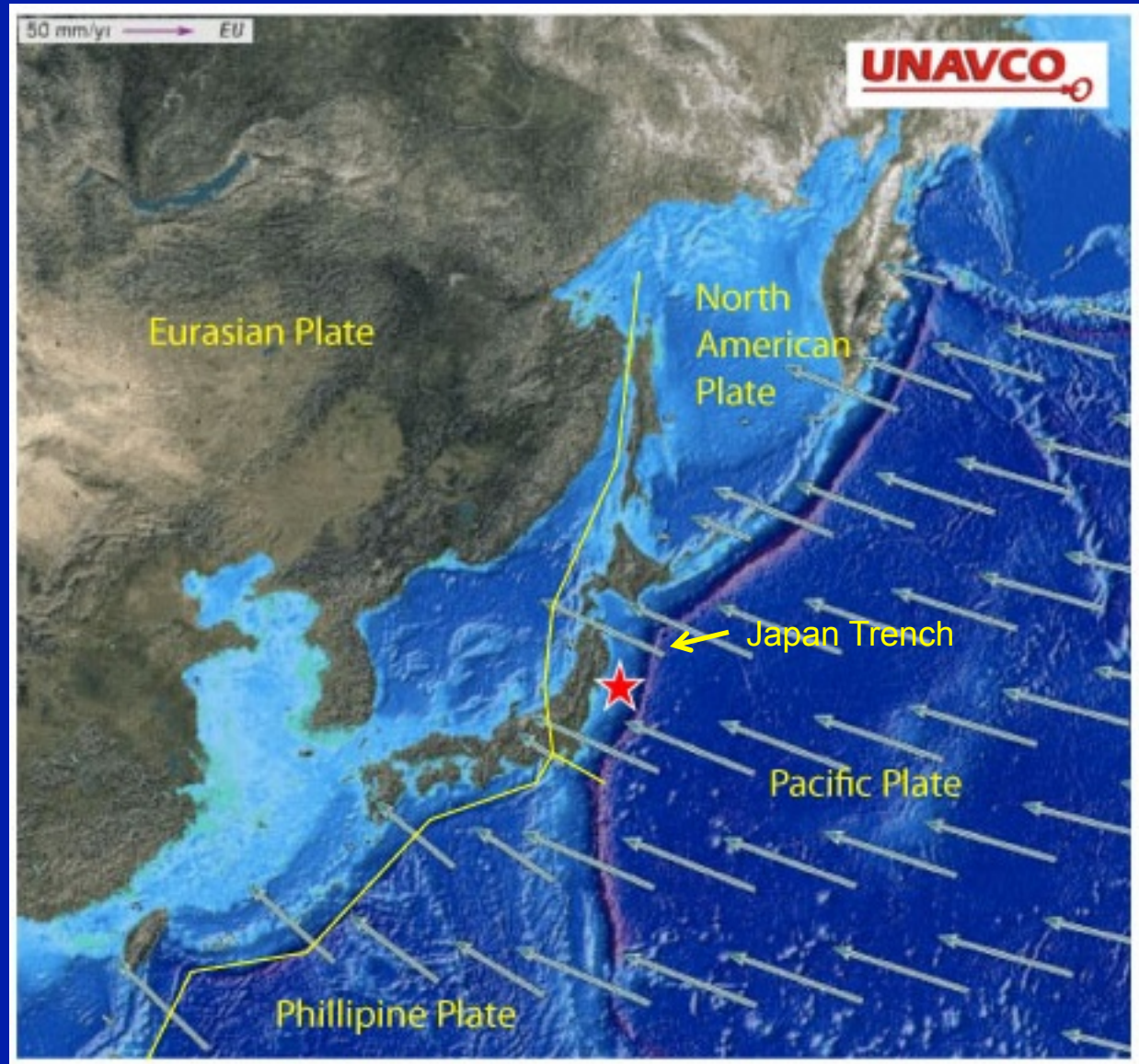
Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN

Friday, March 11, 2011 at 05:46:23 UTC

Most recent large tsunami: 2011 Tohoku (Japan) earthquake

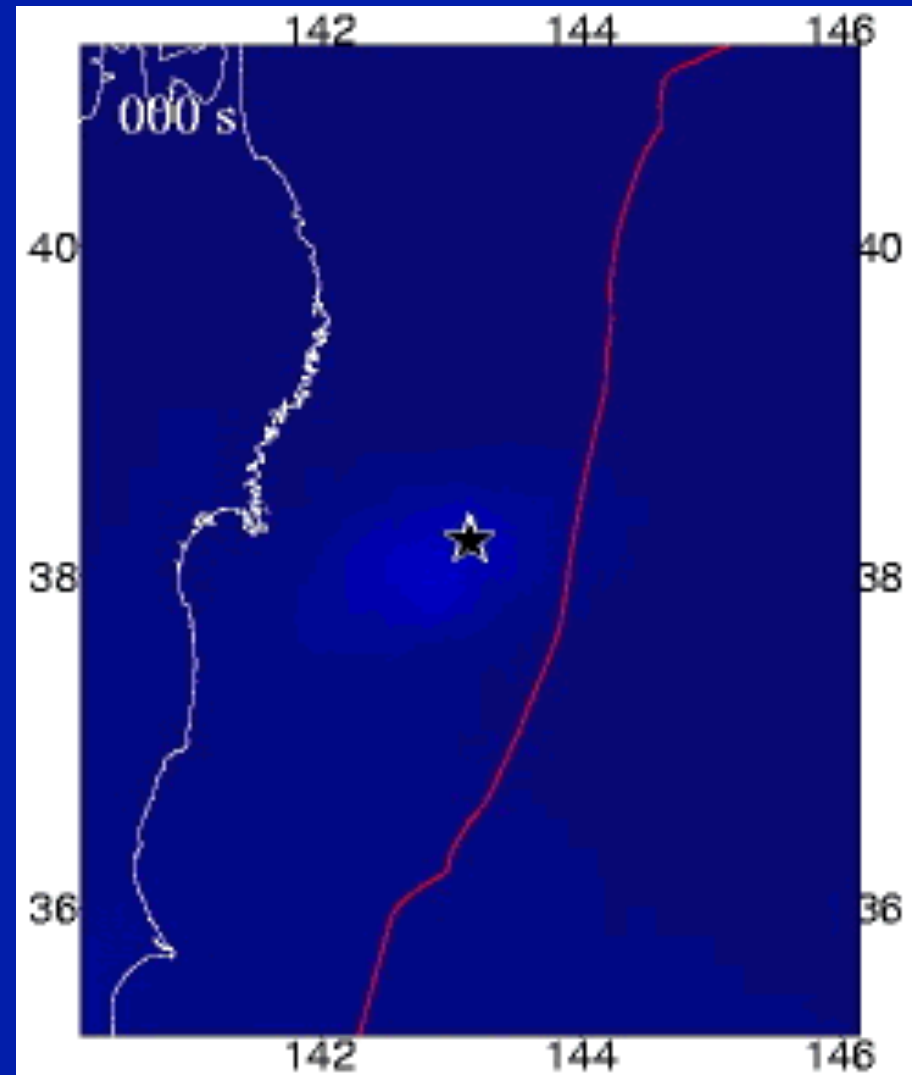
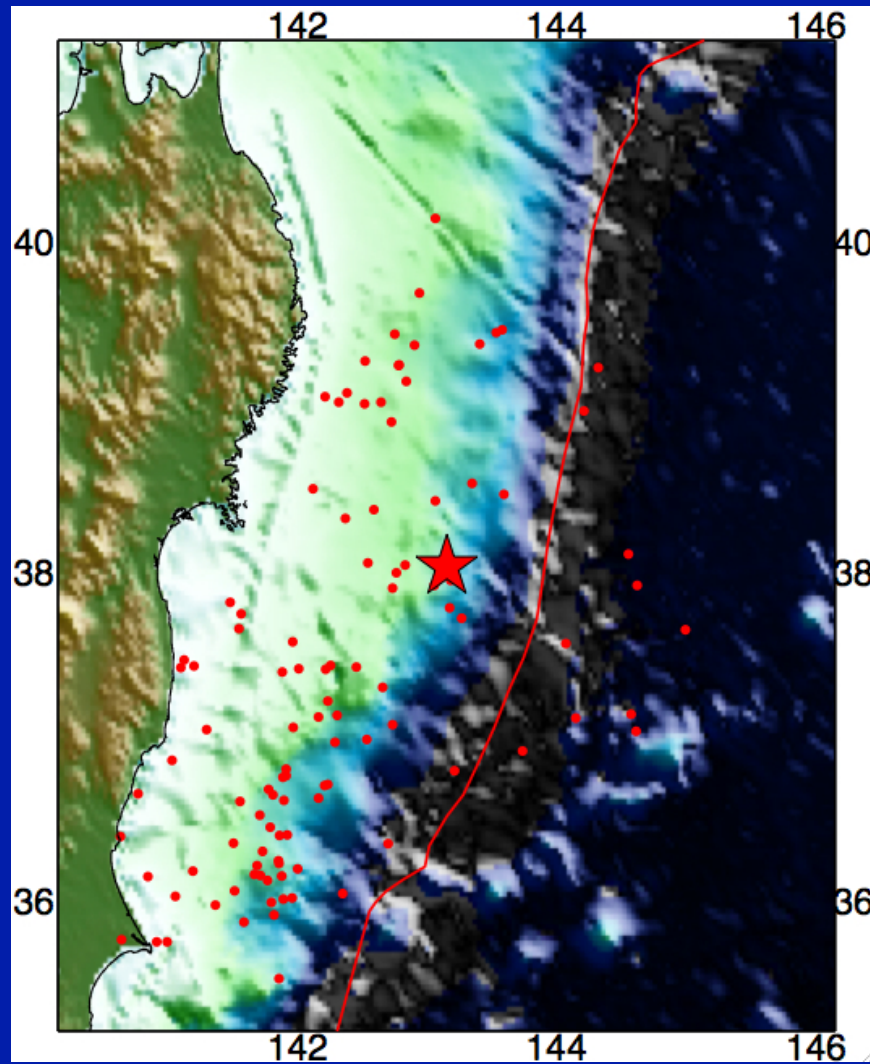
Japan is one of the most seismically active places in the world.

It sits at the intersection of 4 tectonic “plates.”



Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN
Friday, March 11, 2011 at 05:46:23 UTC

The earthquake rupture was unusually long: > 3 minutes

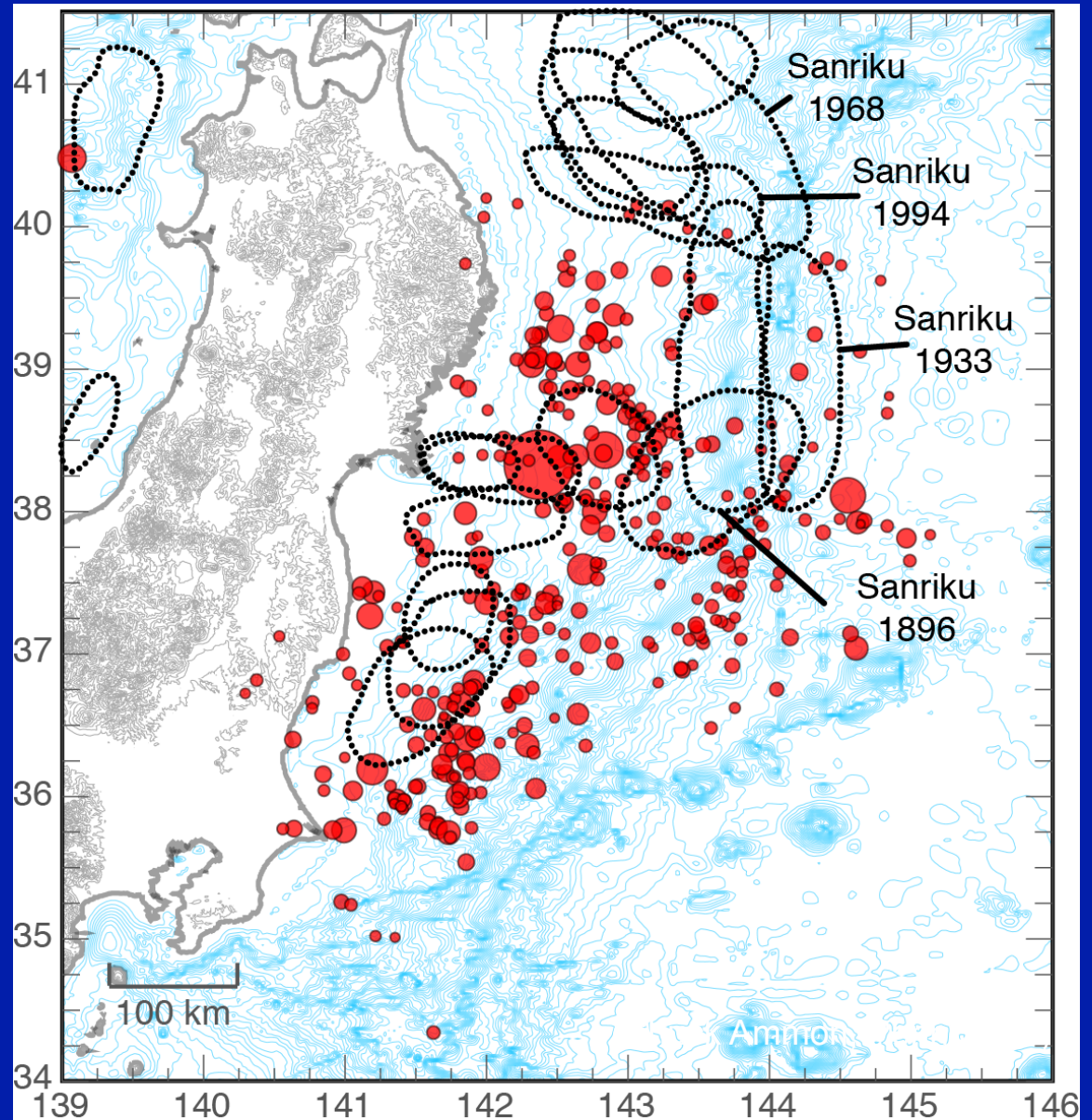


(Miaki Ishii, Harvard Univ)

Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN

Friday, March 11, 2011 at 05:46:23 UTC

A magnitude 9.0 earthquake was not expected based on historical seismicity



Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN
Friday, March 11, 2011 at 05:46:23 UTC

The tsunami was greater than 15 m (50 ft) in places along the Japan coast.



Sendai. *New York Times*



Miyagi prefecture. *AP*

The tsunami was responsible for most of the damage and most of the lives lost (>10,000)

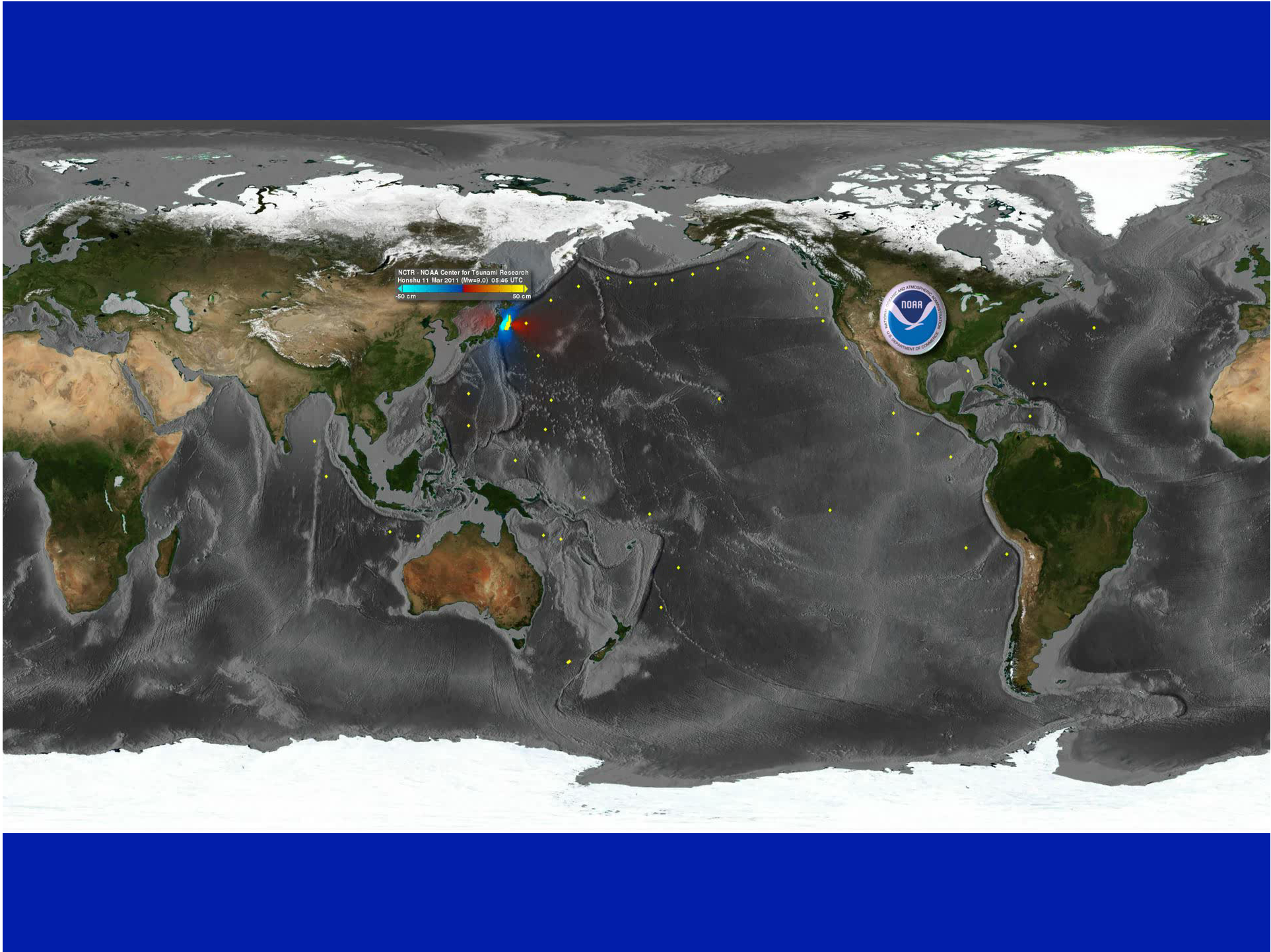
Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN
Friday, March 11, 2011 at 05:46:23 UTC



The tsunami was felt 45 ft high when it hit the Fukushima Nuclear Power Plant

The 19-ft seawall was insufficient

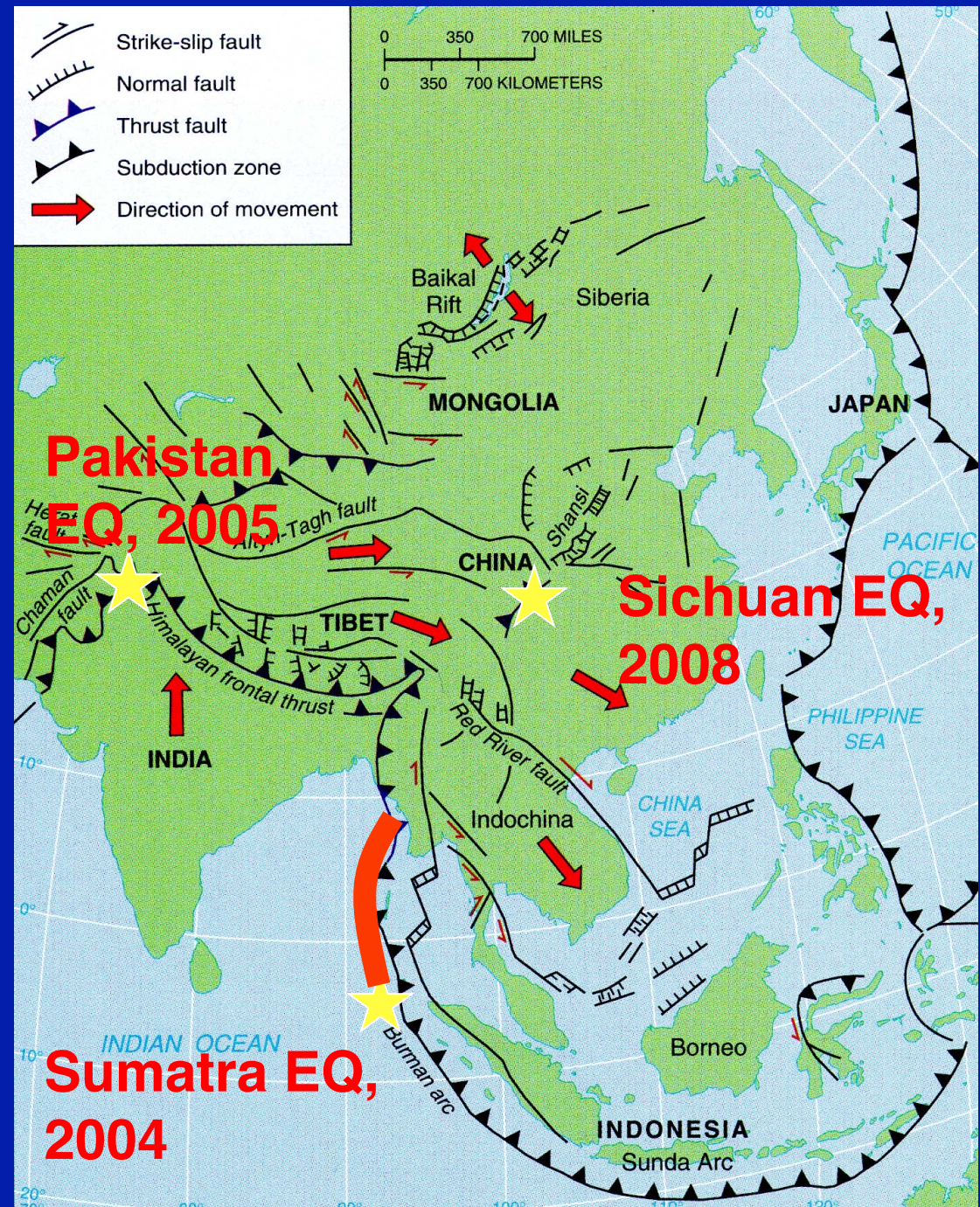


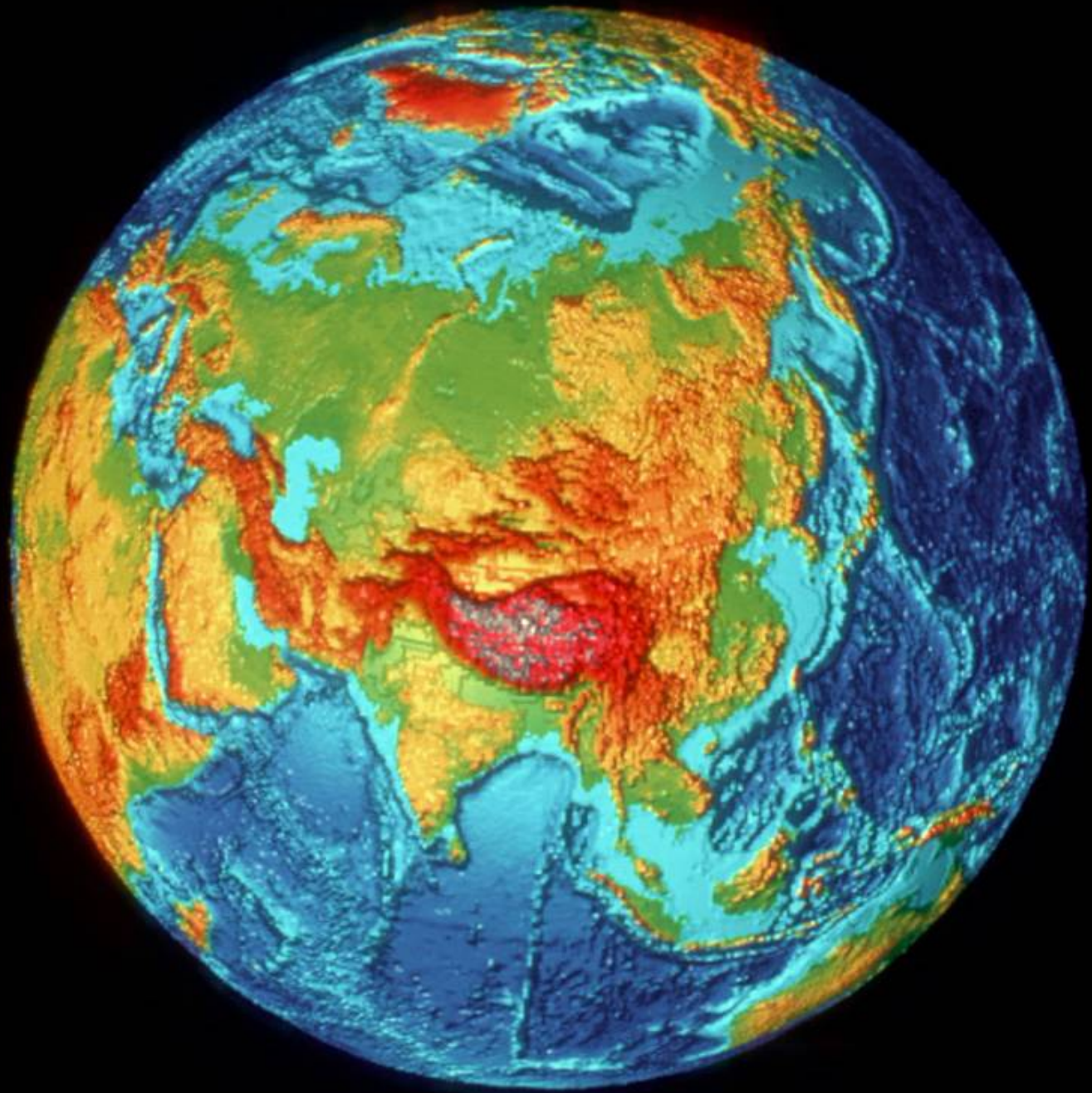


COMPLEX PLATE BOUNDARY ZONE IN ASIA

Northward
motion of India
deforms much of
the region

Creates many
LARGE
EARTHQUAKES







(FAMILY PHOTO/AF)



(FAMILY PHOTO/AF)



(FAMILY PHOTO/AP)



(FAMILY PHOTO/AF)



(FAMILY PHOTO/AF)

**Banda
Aceh:
Before....**



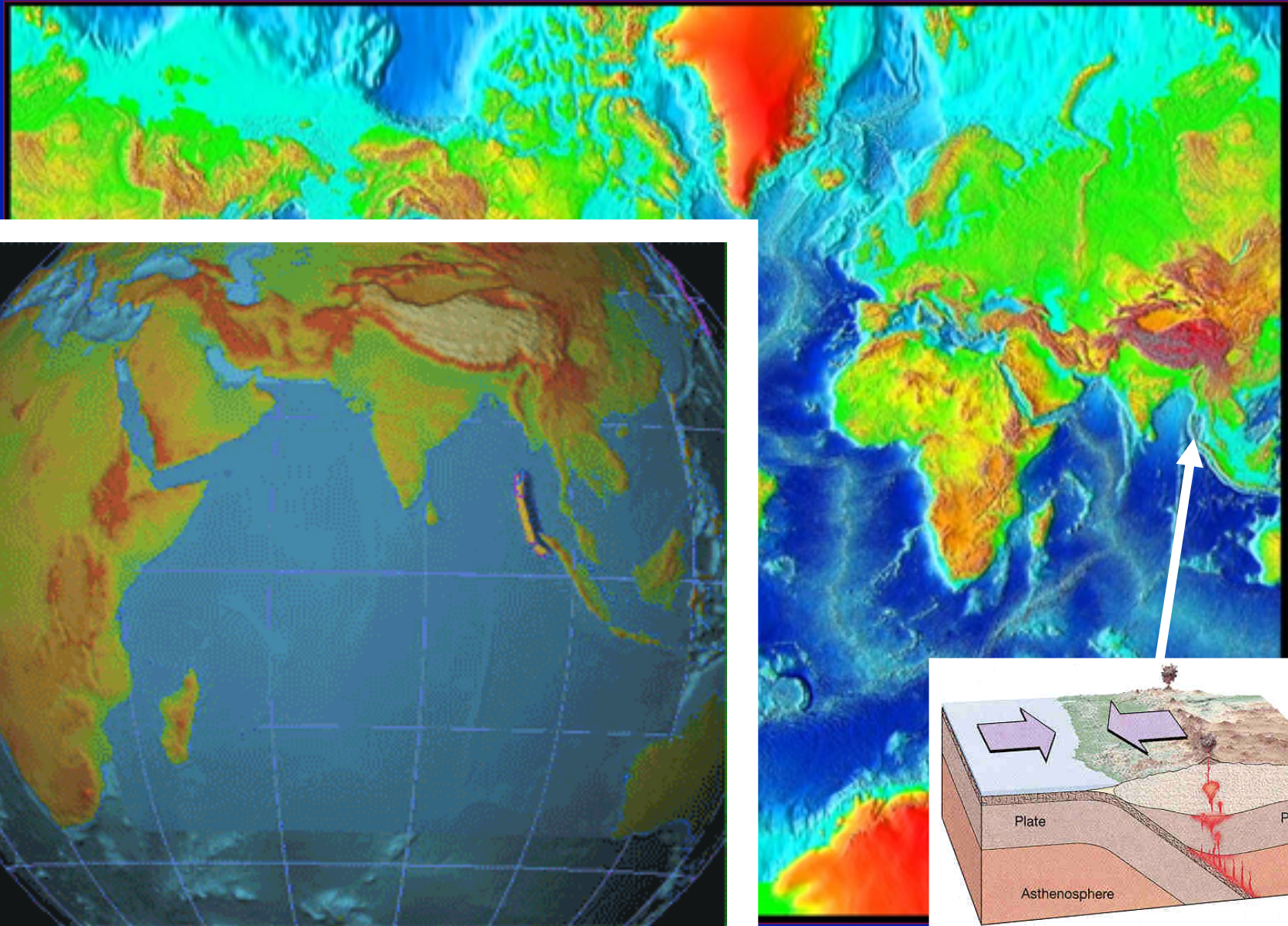
**Banda
Aceh:
Before....**



**and
After.....**



Sumatra-Andaman Dec 26, 2004 EQ & Tsunami





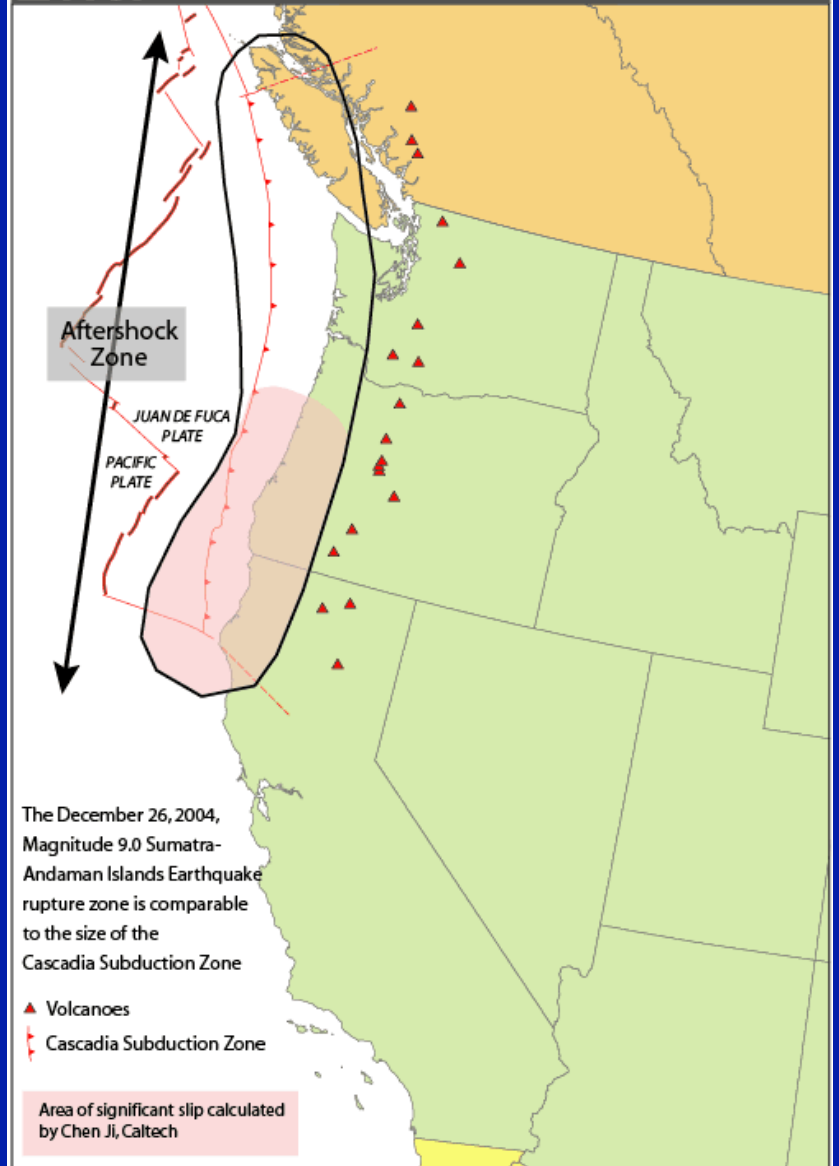
Comparable Size
of Rupture Zone
of Magnitude 9.0
Sumatra-Andaman Islands Earthquake
December 26, 2004

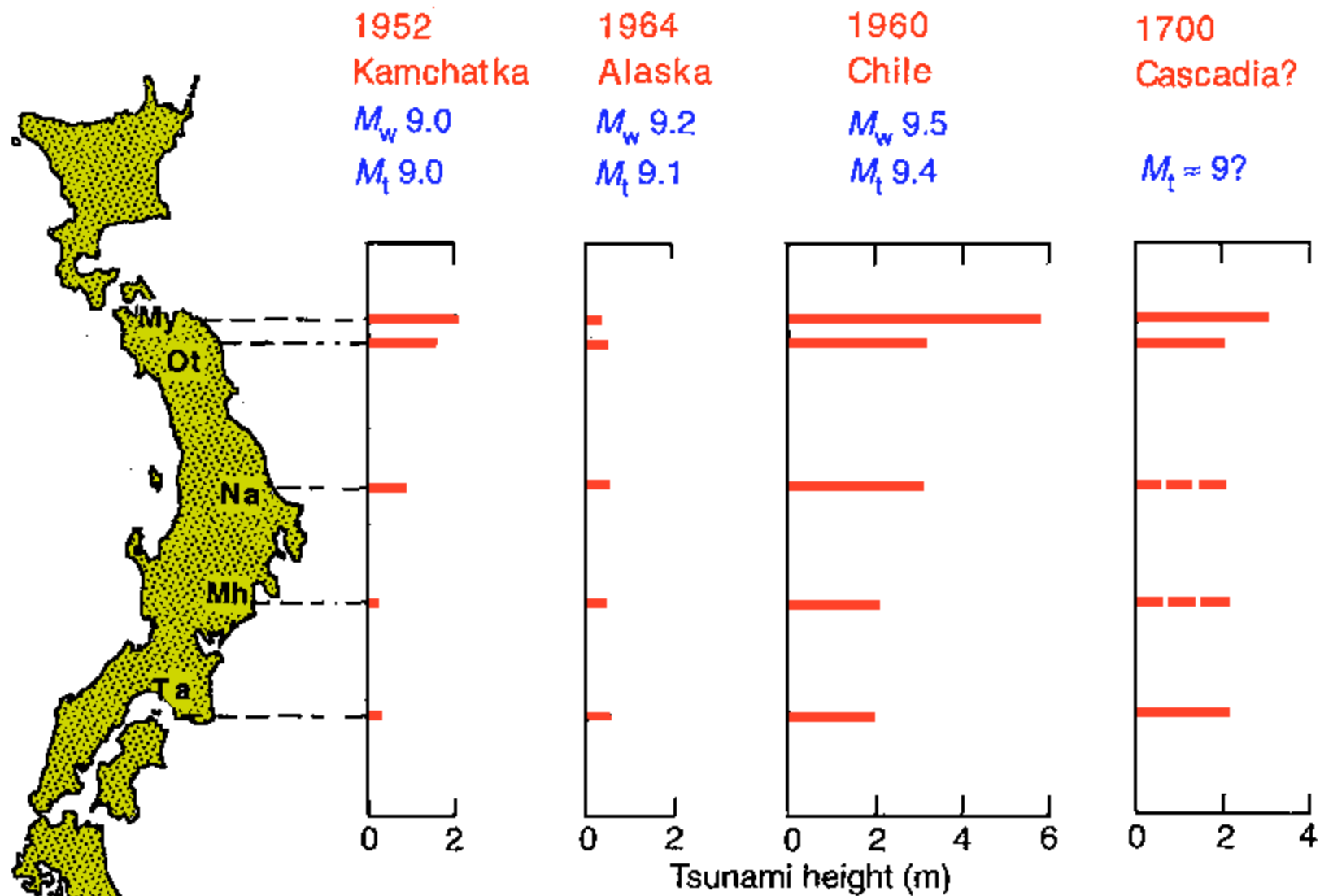


Area of significant slip
calculated by Chen Ji, Caltech



Comparable Size
of Rupture Zone
of Magnitude 9.0
Sumatra-Andaman Islands Earthquake
December 26, 2004

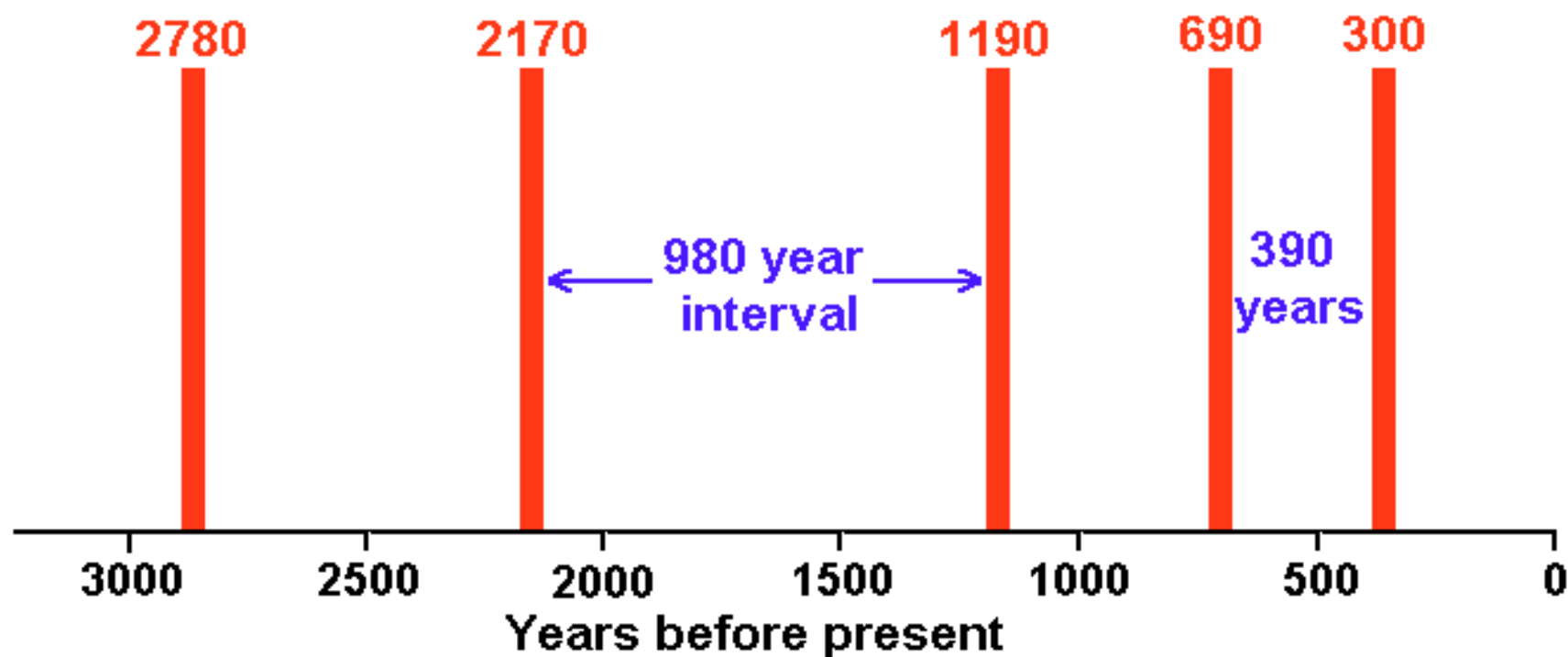




Japanese Tsunami Records

[Satake et al., 1996]

History of large Juan de Fuca Earthquakes based on submarine landslide deposits



(data from Adams, 1990)

Lisbon, 1755



From *“Volcanoes and Earthquakes: A Popular Description in the Movements in the Earth's Crust,”* by Georg Ludwig Hartwig, 1887

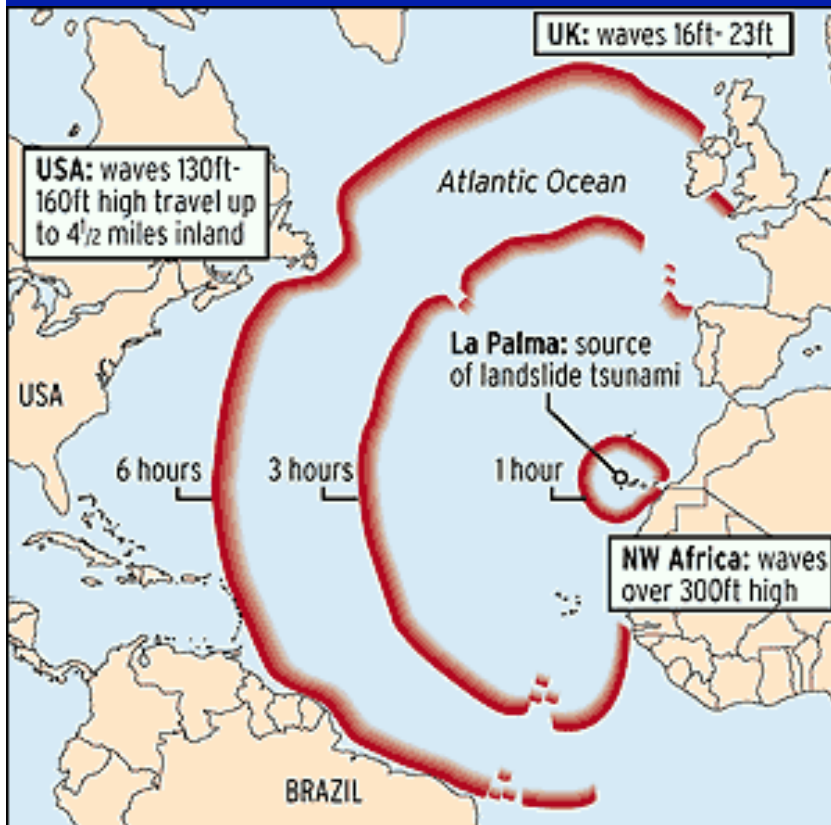
Lisbon, 1755



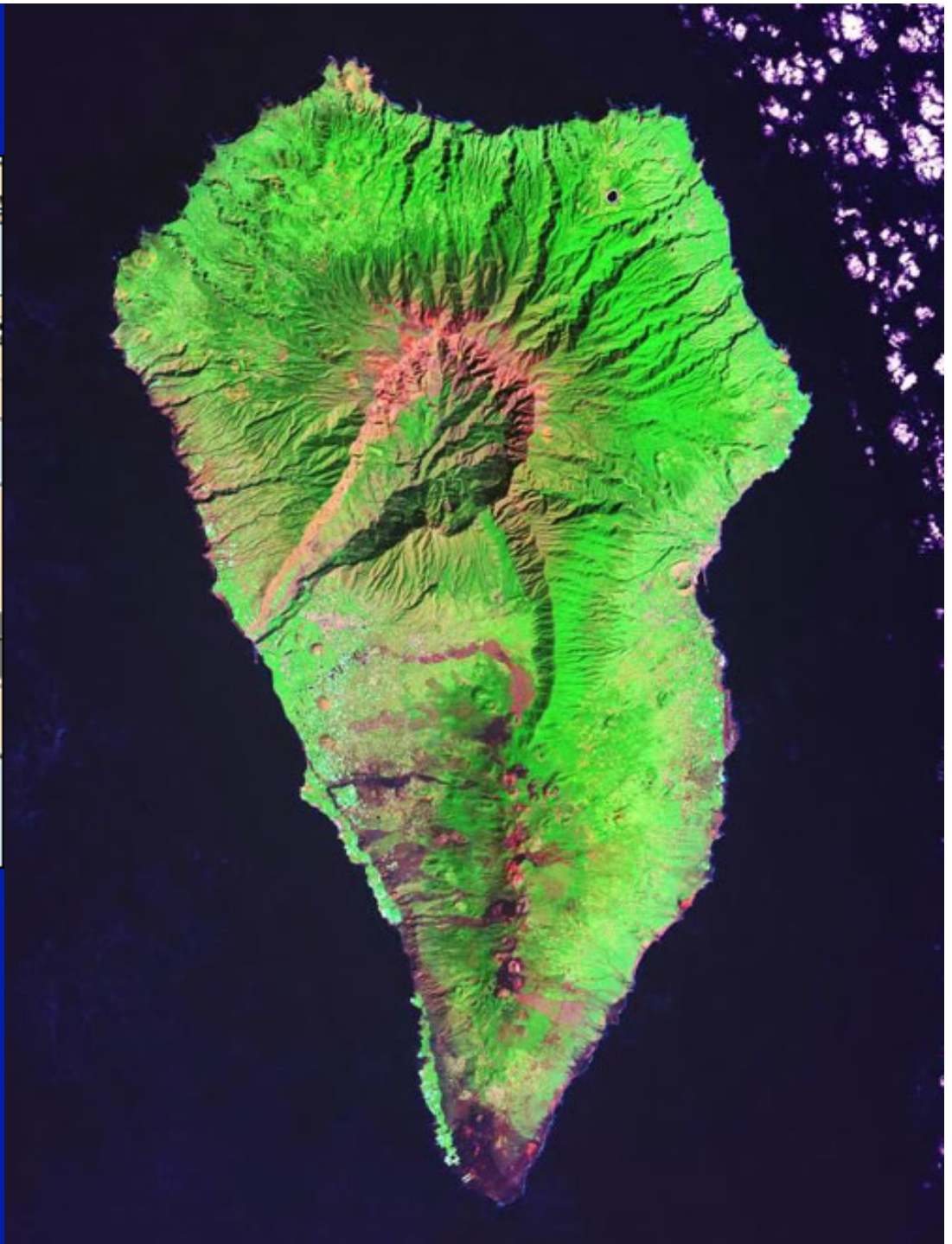
Lisbon, 1755



La Palma (Canary Islands)



Massive landslides in places like the Canary Islands could cause large Atlantic tsunamis!



Evidence of Giant Undersea Landslides in the Puerto Rico Trench

