# TIME TRAVEL AMIDST THE WAVES

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LOPS
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# About me

A husky mum and a doctoral student at
University of Cape Town and
Universite de Bretagne Occidentale

I study upwelling and numerical modelling

Part-time lecturer (GIS and physical oceanography)

172 days at sea in total

# TIME TRAVEL AMIDST THE WAVES

- **How do we time travel in the past?**
- Ancient oceans
- Present day
- Time travel in the future

# HOW DO WE TIME TRAVEL AMIDST THE WAVES?

- Why would you want to know about oceans in the past?
- What are some major breakthroughs which help reconstruct the past?
- In 2023, how can science help us reconstruct the ancient superoceans?

# WHY WOULD YOU WANT TO KNOW ABOUT OCEANS IN THE PAST?

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- Life originated from the oceans
- Oceans have a strong influence on our climate.
- Understanding tectonic and continental drift
- Understanding ocean currents and circulation
- Sea level changes
- Impacts on human history
- Predicting future changes in ocean circulations

# MAJOR BREAKTHROUGH

**Early 20th Century: Continental Drift Hypothesis Emerges**
- **1912:** Alfred Wegener introduces the theory of continental drift, suggesting that continents were once connected.

**1960s - 1970s: Plate Tectonics Revolution**
- **1968:** The theory of plate tectonics gains widespread acceptance

**Late 20th Century: Advances in Supercontinent Understanding**
- **1980s:** Paleomagnetic research and geological data support the existence of Rodinia.
- **1990s:** Paleomagnetic evidence helps reconstruct the breakup of Rodinia and the opening of the Iapetus Ocean.

**21st Century: Modern Techniques and Ongoing Research**
- **2000s - Present:** High-resolution satellite altimetry and deep-sea drilling
- **2000s - Present:** Advanced numerical modeling, machine learning and artificial intelligence

# IN 2023, HOW CAN SCIENCE HELP US RECONSTRUCT THE ANCIENT SUPEROCEANS?

- **Paleomagnetism:**
    - Measures the alignment of magnetic minerals in rocks to infer past continental positions.

- **Geological Mapping:**
    - Identifies features like fold belts, rift valleys, and mid-ocean ridges.

- **Sediment Cores:**
    - Extracts sediment samples from ocean floor or lake beds.
    - Reveals layers of sediment that accumulate over millions of years.

- **Isotopic Analysis:**
    - Measures ratios of isotopes (variants of an element) in rocks and minerals.
    - Offers insights into past ocean temperatures, seawater chemistry, and continental drift.

# IN 2023, HOW CAN SCIENCE HELP US RECONSTRUCT THE ANCIENT SUPEROCEANS?

- **Geochronology:**
  - Applies radiometric dating techniques to determine the ages of rocks and minerals.

- **Geophysical Surveys:**
  - Measures variations in Earth's gravity and magnetic fields.

- **Paleoclimatology:**
  - Studies past climate indicators in rocks, ice cores, and sediment records.

- **Geochemical Tracers:**
  - Traces the movement of elements through Earth's crust and subduction zones.

# IN 2023, HOW CAN SCIENCE HELP US RECONSTRUCT THE ANCIENT SUPEROCEANS?

- **Fossil Record:**
  - Studies ancient marine fossils found in sedimentary rocks.

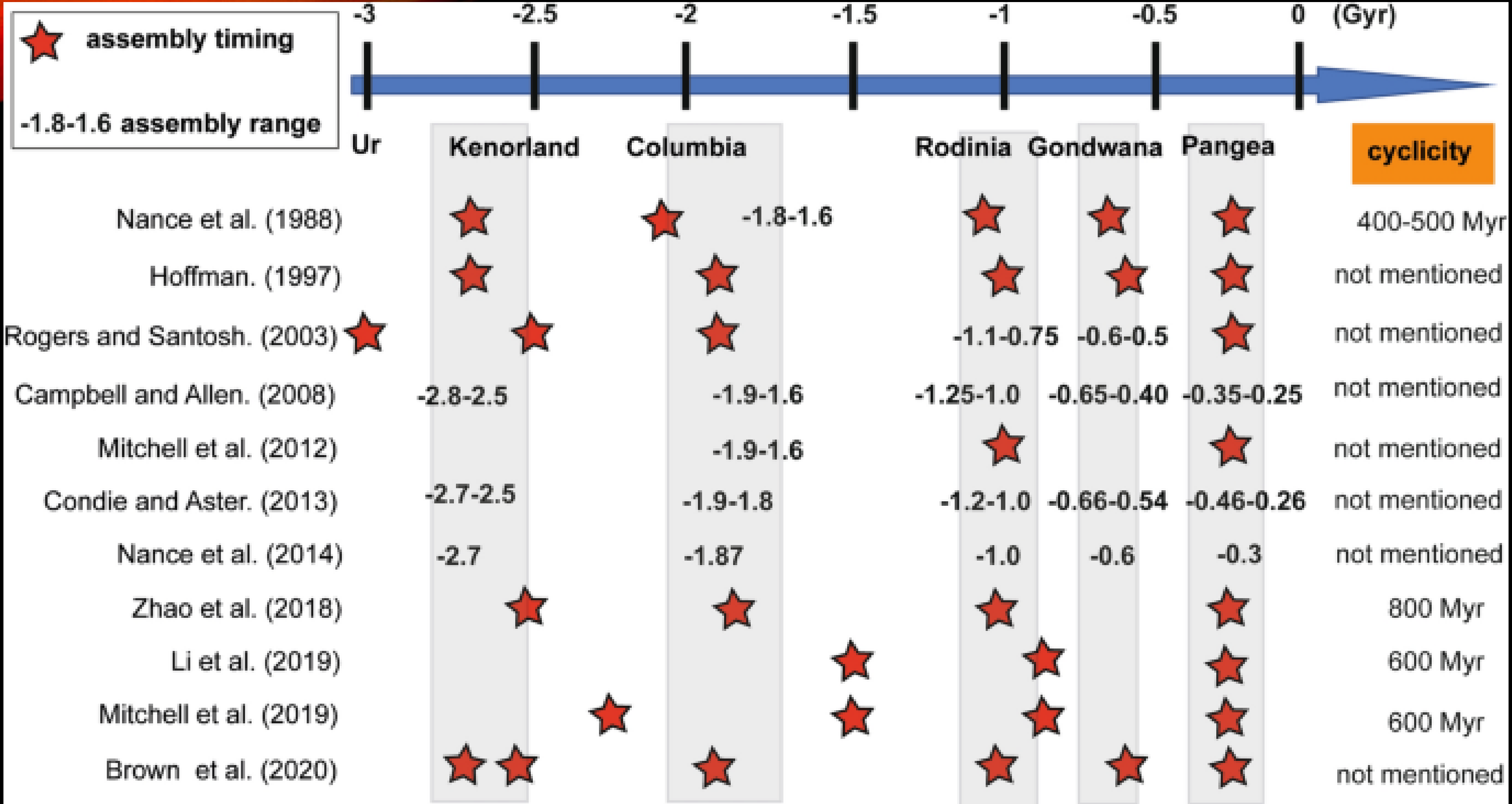
- **Satellite Altimetry:**
  - Detects underwater features like seamounts, mid-ocean ridges, and ocean basins.

- **Seismic Imaging:**
  - Identifies oceanic ridges, trenches, and tectonic boundaries.

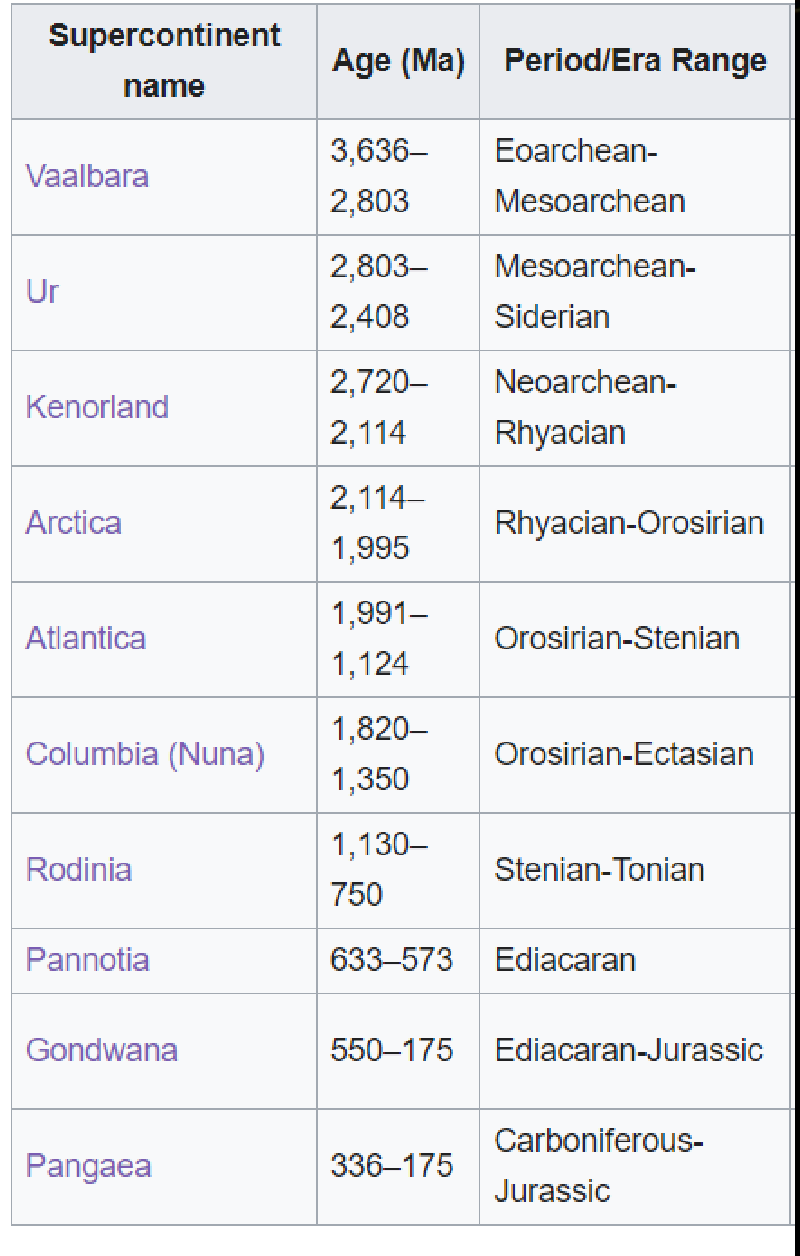
- **Numerical Modeling and artificial intelligence:**
  - Models tectonic plate movements, continental drift, and supercontinent formations.
  - Big data analytics and machine learning techniques help process and interpret vast amounts of oceanographic data.

# TIME TRAVEL AMIDST THE WAVES

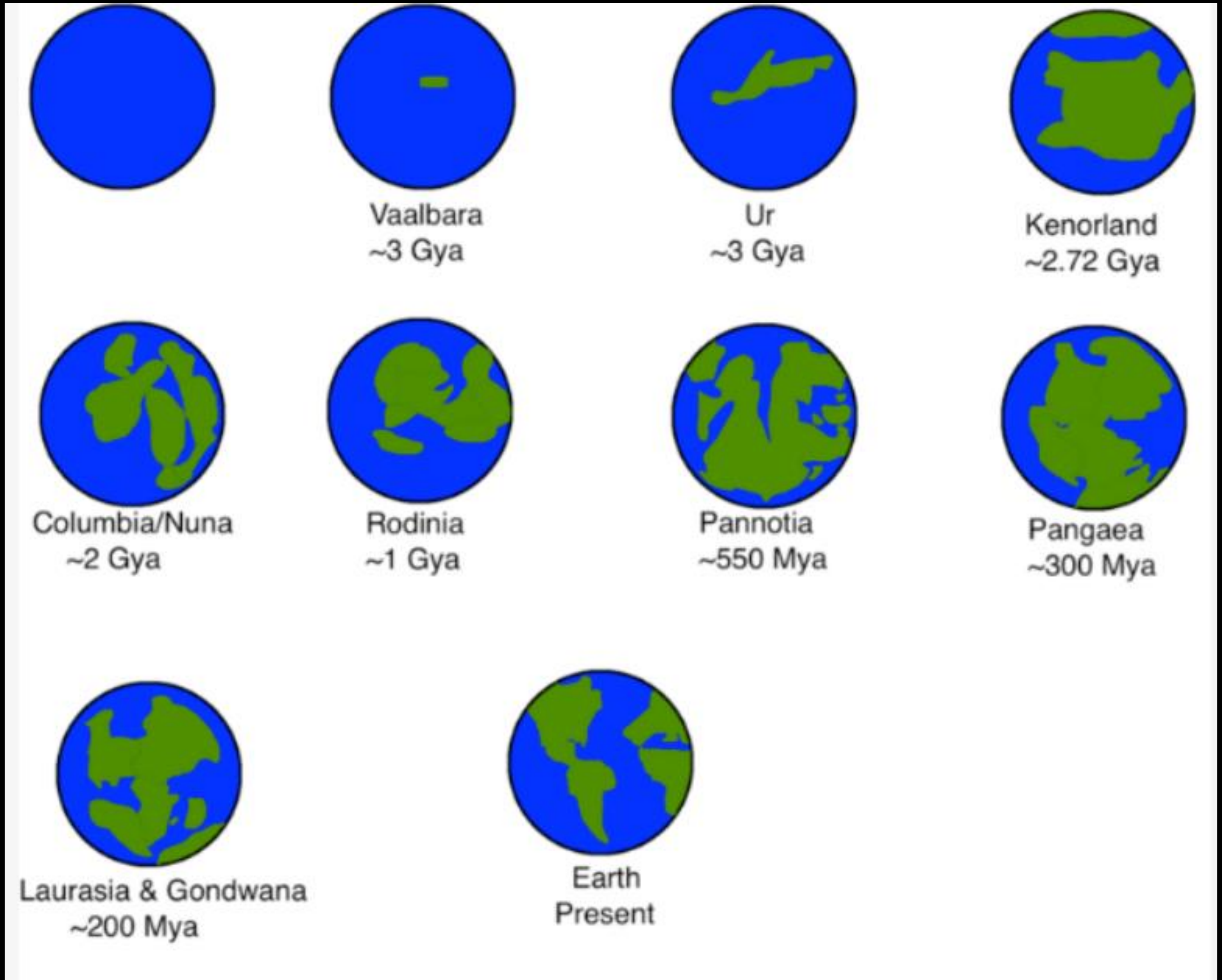
- How do we time travel in the past?
- **Ancient oceans**
- Present day
- Time travel in the future



| | Ur | Kenorland | Columbia | Rodinia | Gondwana | Pangea | cyclicity |
|---|---|---|---|---|---|---|---|
| Nance et al. (1988) | | ★ | ★ -1.8-1.6 | ★ | ★ | ★ | 400-500 Myr |
| Hoffman. (1997) | | ★ | ★ | ★ | ★ | ★ | not mentioned |
| Rogers and Santosh. (2003) | ★ | ★ | ★ | -1.1-0.75 | -0.6-0.5 | ★ | not mentioned |
| Campbell and Allen. (2008) | | -2.8-2.5 | -1.9-1.6 | -1.25-1.0 | -0.65-0.40 | -0.35-0.25 | not mentioned |
| Mitchell et al. (2012) | | | -1.9-1.6 | ★ | | ★ | not mentioned |
| Condie and Aster. (2013) | | -2.7-2.5 | -1.9-1.8 | -1.2-1.0 | -0.66-0.54 | -0.46-0.26 | not mentioned |
| Nance et al. (2014) | | -2.7 | -1.87 | -1.0 | -0.6 | -0.3 | not mentioned |
| Zhao et al. (2018) | | ★ | ★ | ★ | | ★ | 800 Myr |
| Li et al. (2019) | | | ★ | ★ | | ★ | 600 Myr |
| Mitchell et al. (2019) | | ★ | ★ | ★ | | ★ | 600 Myr |
| Brown et al. (2020) | | ★ ★ | ★ | ★ | ★ | ★ | not mentioned |



| Supercontinent name | Age (Ma) | Period/Era Range |
|---|---|---|
| Vaalbara | 3,636–2,803 | Eoarchean-Mesoarchean |
| Ur | 2,803–2,408 | Mesoarchean-Siderian |
| Kenorland | 2,720–2,114 | Neoarchean-Rhyacian |
| Arctica | 2,114–1,995 | Rhyacian-Orosirian |
| Atlantica | 1,991–1,124 | Orosirian-Stenian |
| Columbia (Nuna) | 1,820–1,350 | Orosirian-Ectasian |
| Rodinia | 1,130–750 | Stenian-Tonian |
| Pannotia | 633–573 | Ediacaran |
| Gondwana | 550–175 | Ediacaran-Jurassic |
| Pangaea | 336–175 | Carboniferous-Jurassic |



# ANCIENT SUPEROCEANS

- Vaikinia (4.2–3.2 Ga)
- Ur (Vaalbara) Superocean (3.2-2.8 Ga)
- Kenorland Superocean (2.723–2.1 Ga)
- Columbia Superocean (1.41–1.065 Ga)
- Mirovia Superocean (1.3–0.9 Ga)
- Pannotia Superocean (600–540 Ma)
- Pan-African Ocean (600–300 Ma)
- Iapetus Ocean (600–400 Ma)
- Tethys Ocean (250–0 Ma)
- Atlantic Ocean (175 Ma–Present)

# FORMATION OF PRIMORDIAL OCEANS

- Around 4 billion years ago, water vapor condensed to form Earth's first oceans.
- These initial oceans regulated early Earth's temperature and began vital geological processes.
- They set the stage for the emergence of life and the complex interplay with the atmosphere.

# VAIKINIA (4.2–3.2 GA):

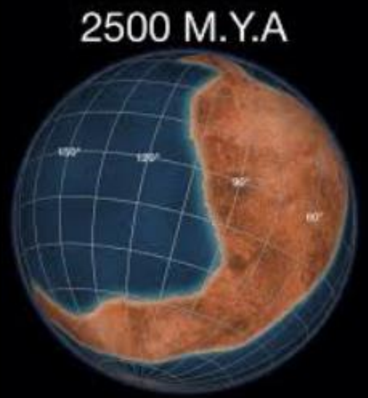
- Vaikinia, proposed as a supercontinent, existed during the early Archean Eon.
- During its existence, Vaikinia was likely surrounded by a vast ocean called the Vaikinia Ocean.
- Climate during this period was relatively warm and turbulent, with active volcanism contributing to greenhouse gases.
- Vaikinia eventually fragmented due to tectonic forces, forming smaller landmasses and new oceanic basins.

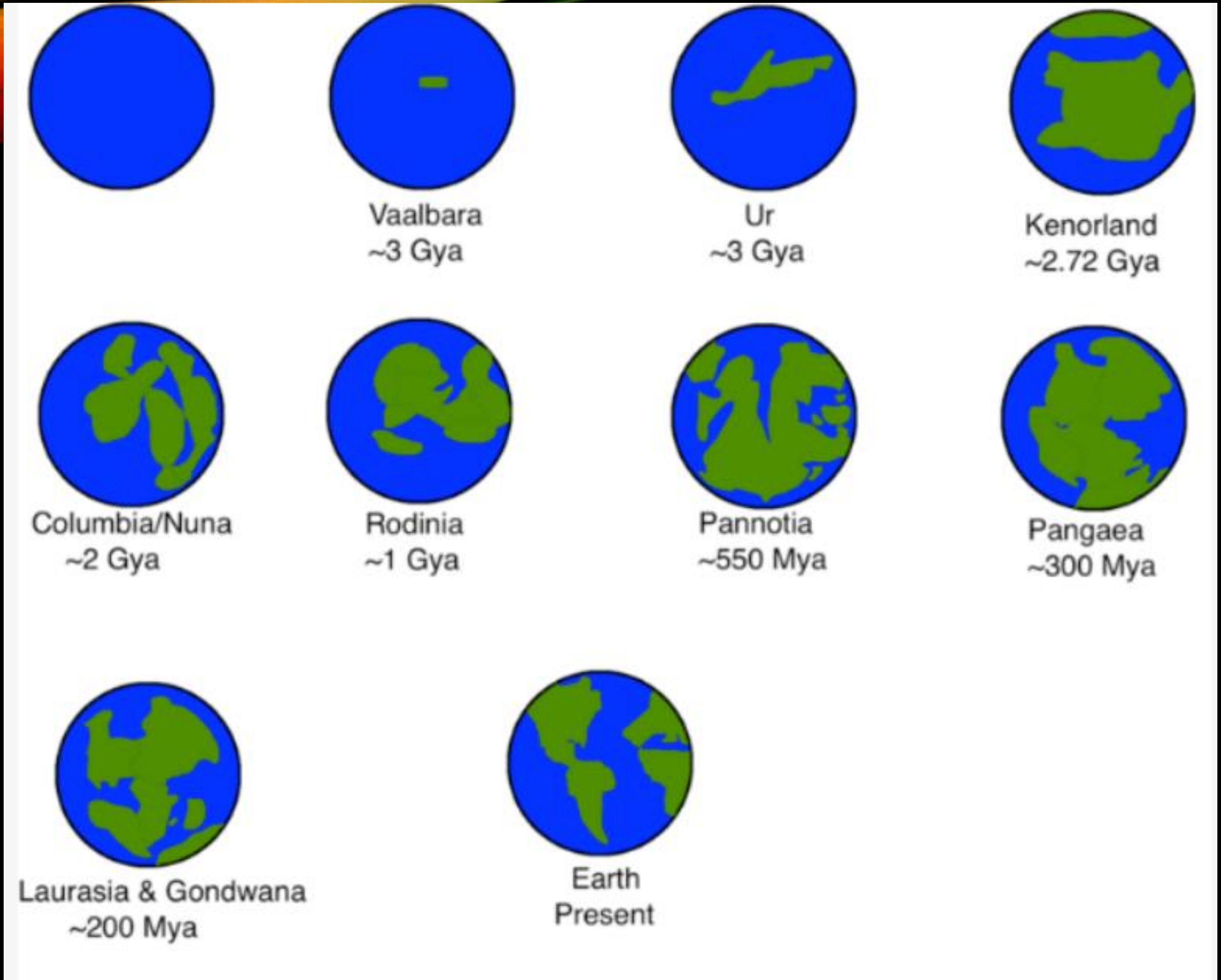
# UR SUPEROCEAN (3.2-2.8 GA):

- Ur, following Vaikinia, experienced further tectonic activity and the emergence of continental fragments.
- Ur is a hypothesized superocean that might have existed during the Archean Eon.
- It is suggested to have surrounded the early supercontinent Vaalbara, composed of present-day landmasses such as Western Australia, Eastern Canada, and parts of Africa.
- Geological and isotopic evidence, with rock formations on different continents showing similarities that could indicate a shared oceanic history.

# KENORLAND SUPEROCEAN (2.723–2.1 GA):

- Kenorland is proposed to have existed during the Proterozoic Eon, covering portions of present-day continents like North America, Greenland, and western Australia.
- Its existence is inferred from geological and isotopic data.
- The climate of this era was characterized by fluctuations between icehouse and greenhouse conditions.
- Kenorland's eventual breakup led to the dispersal of continental fragments and the initiation of new ocean basins.



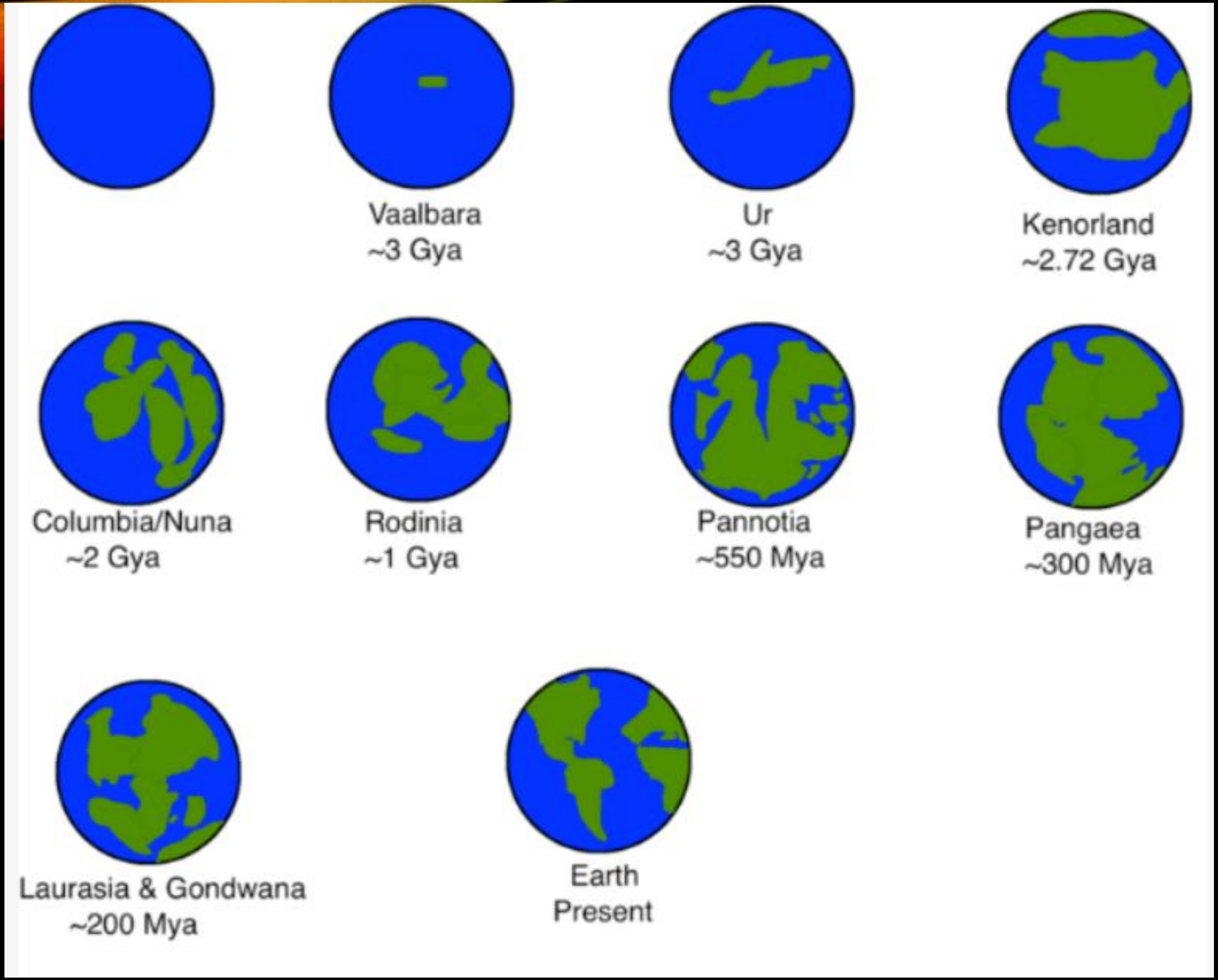

Vaalbara
~3 Gya
Ur
~3 Gya
Kenorland
~2.72 Gya
Columbia/Nuna
~2 Gya
Rodinia
~1 Gya
Pannotia
~550 Mya
Pangaea
~300 Mya
Laurasia & Gondwana
~200 Mya
Earth
Present

# COLUMBIA SUPEROCEAN (1.41–1.065 GA):

- Columbia formed during the Paleoproterozoic Era and encompassed the supercontinent Columbia, which included landmasses like North America, Baltica, and Siberia.
- It played a role in redistributing heat and nutrients across the planet, influencing climate and oceanic circulation patterns.
- Columbia's breakup contributed to the assembly of the next supercontinent, Rodinia.
- Earth's climate during this time experienced variations, with evidence of glaciations and warming trends.

# MIROVIA SUPEROCEAN (1.3–0.9 GA):

- Rodinia was a supercontinent that existed during the Mesoproterozoic and Neoproterozoic Eras, surrounded by a vast global ocean, Mirovia.
- This ocean played a significant role in shaping Rodinia's climate, geology, and tectonics.
- The breakup of Rodinia led to Pannotia, also the formation of new oceans, such as the Iapetus Ocean, an ancient generation of the Atlantic ocean.
- Snowball effect possibly led to the breakup of Rodinia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~200 Mya
Earth
Present

# PANNOTIA SUPEROCEAN (600–540 MA):

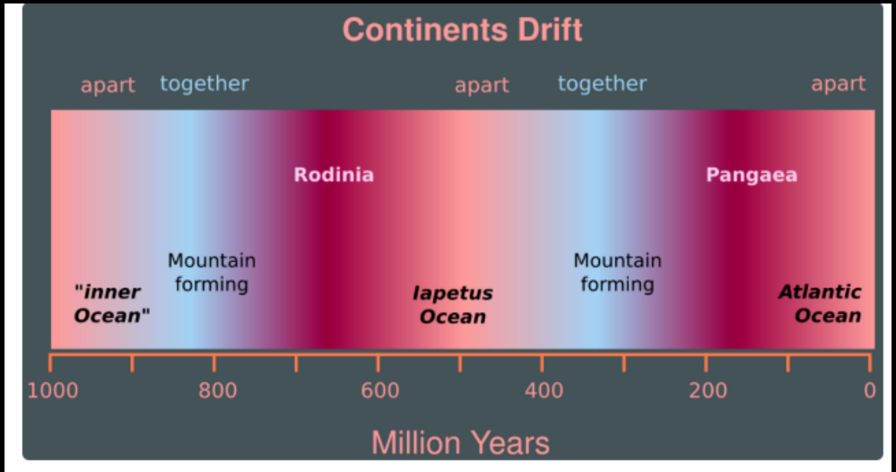
- Pannotia is thought to have formed during the late Precambrian and early Cambrian periods, assembling landmasses from various continents.
- It was surrounded by the "Pannotia Ocean" and played a crucial role in Earth's tectonic and climatic evolution.
- The climate of this period saw the transition from a snowball Earth to more temperate conditions.
- Pannotia's breakup from rapid sea level changes, dramatic climate change and ocean chemistry contributed to the opening of the Proto-Atlantic Ocean.

# PAN-AFRICAN OCEAN (600–300 MA):

- The Pan-African Ocean formed during the assembly of the supercontinent Gondwana, encompassing regions such as Africa, South America, Antarctica, and India.
- It played a crucial role in the collision of landmasses, leading to the formation of the Pangea supercontinent.
- Oceans such as Rheic Ocean also surrounded Gondwana.
- Gondwana's eventual breakup led to the formation of smaller landmasses and the opening of new oceanic gateways.
- Its closure shaped the geological features of modern continents.

# IAPETUS OCEAN (600–400 MA):

- Laurasia, forming alongside Gondwana, was bordered by the Iapetus Ocean.
- Earth's climate during this time saw cycles of glaciations and warm intervals.
- Its closure was marked by the collision of these landmasses during the Caledonian and Appalachian orogenies.
- The remnants of the Iapetus Ocean are preserved in geological formations and mountain ranges.



# PANTHALASSA SUPEROCEAN (335–175 MA):

- Panthalassa was a global ocean that surrounded the supercontinent Pangaea during the Mesozoic Era.
- Pangaea was centered on the equator and surrounded by the superocean Panthalassa and the Paleo-Tethys and subsequent Tethys Oceans.
- Panthalassa's closure marked the breakup of Pangaea and the opening of new ocean basins, including the Atlantic Ocean.
- It could be expected that the large size would result in relatively simple ocean current circulation patterns, such as a single gyre in each hemisphere, and a mostly stagnant and stratified ocean, but…
- Modelling studies, however, suggest that an east-west sea surface temperature (SST) gradient was present in which the coldest water was brought to the surface by upwelling in the east while the warmest water extended west into the Tethys Ocean.

# TETHYS OCEAN (250–0 MA):

- The Tethys Ocean evolved during the Mesozoic Era, as Pangaea began to break apart into Laurasia and Gondwana.
- The Tethys Ocean eventually closed due to the collision of the African and Eurasian plates, giving rise to the Alpine-Himalayan mountain ranges.

# ATLANTIC OCEAN (175 MA–PRESENT):

- The Atlantic Ocean began forming as Pangaea broke apart, leading to the separation of the Americas from Europe and Africa.
- It's characterized by mid-ocean ridges, like the Mid-Atlantic Ridge, where new oceanic crust forms due to seafloor spreading.

# OPENING OF DRAKE PASSAGE

- Around 50 million years ago, the Antarctic Circumpolar Current formed due to South America and Antarctica's separation.
- The event underscores how geological shifts can drive significant changes in oceanic currents and climate.

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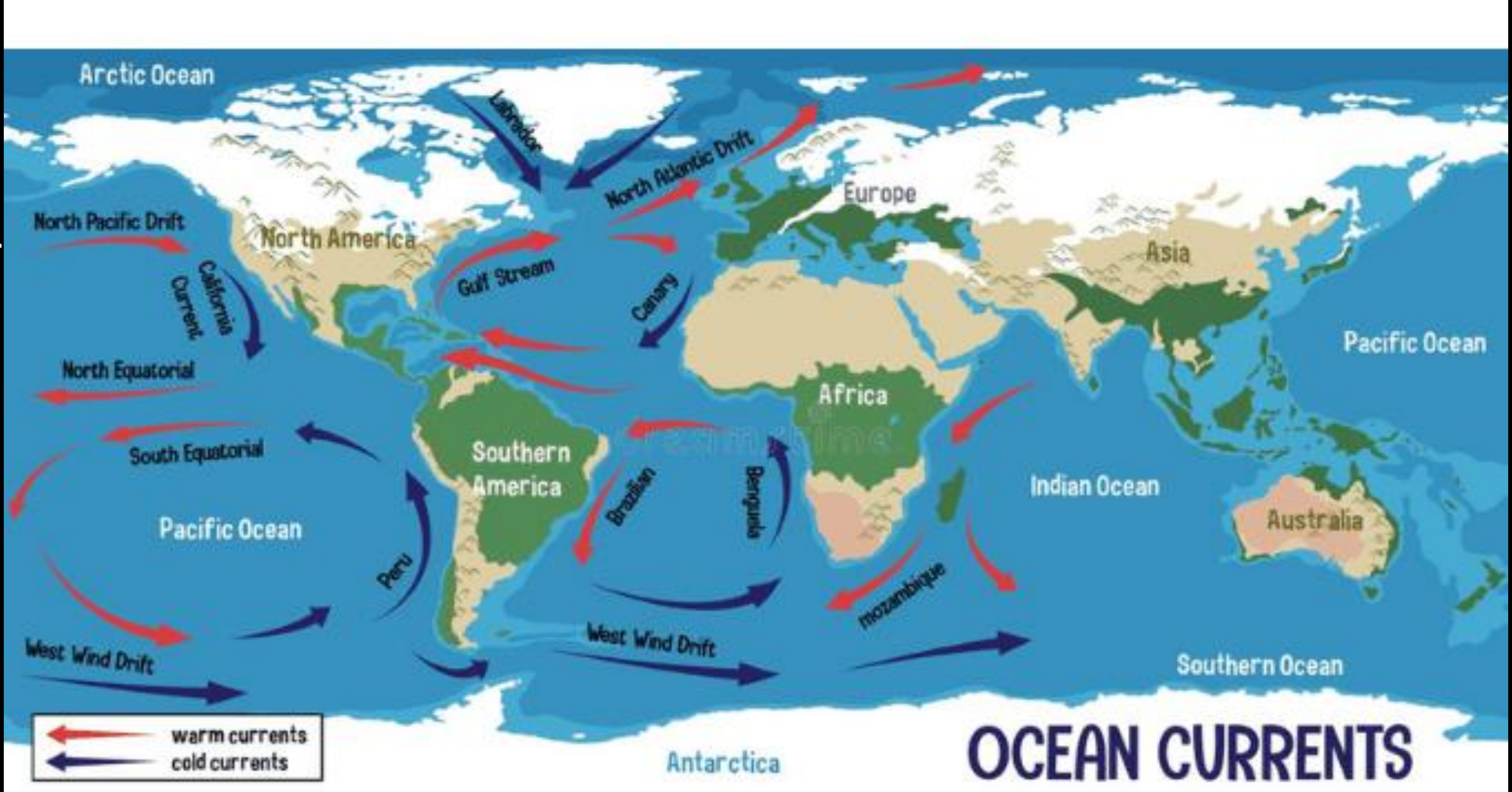
# PRESENT DAY

- The Gulf Stream
- North Atlantic Drift
- Antarctic Circumpolar Current



# BRIEF SNAPSHOT OF PRESENT DAY

- Present-day ocean currents play a central role in Earth's climate regulation.
- The Gulf Stream, North Atlantic Drift, and Antarctic Circumpolar Current influence weather patterns and marine ecosystems.

# GULF STREAM

- Current State: The Gulf Stream is a warm and swift ocean current that flows from the Gulf of Mexico along the east coast of North America to the North Atlantic.
- Potential Changes: Further weakening of the Atlantic Meridional Overturning Circulation (AMOC) could lead to altered heat distribution in the North Atlantic, affecting regional climates, sea levels, and marine ecosystems.

# ANTARCTIC CIRCUMPOLAR CURRENT

- Current State: The ACC is the world's largest ocean current, encircling Antarctica and connecting the Atlantic, Indian, and Pacific Oceans.

- Potential Changes: As global temperatures rise, the ACC's behavior might change due to the melting of Antarctic ice shelves and altered wind patterns, affecting its influence on global climate systems.

# NORTH PACIFIC CURRENTS

- Current State: The North Pacific Ocean is influenced by currents like the Kuroshio and the California Current System.

- Potential changes: Changing wind patterns, sea surface temperatures, and atmospheric circulation will influence the strength and position of these currents.

# EQUATORIAL CURRENTS (E.G., EQUATORIAL PACIFIC CURRENTS)

- Current State: Equatorial currents play a role in redistributing heat and nutrients across tropical oceans.
- Potential Changes: Climate change could lead to altered frequency and intensity of El Niño/La Niña events, affecting equatorial currents and their impacts on weather patterns worldwide.

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# TIME TRAVEL IN THE FUTURE

- Ongoing tectonic changes and their potential impacts on seas and oceans
- Future superoceans

# ONGOING TECTONIC CHANGES AND THEIR POTENTIAL IMPACTS ON SEAS AND OCEANS

East African Rift Valley:

African Plate splitting into two.

Could form a new ocean basin.

Reshaping the coastline of eastern Africa.

North Atlantic Ridge and Iceland:

Plates moving apart in North Atlantic.

Iceland's volcanic activity due to plate divergence.

Widening Atlantic Ocean, affecting currents.

# ONGOING TECTONIC CHANGES AND THEIR POTENTIAL IMPACTS ON SEAS AND OCEANS

Subduction Zones and Volcanic Islands:
One plate forced beneath another.
Volcanic island arcs form (e.g., Japanese islands and Aleutian Islands).
Impact on ocean currents, ecosystems, weather.

Himalayan Uplift and Indian Ocean:
Indian Plate colliding with Eurasian Plate.
Uplift of Himalayas.
Altered river drainage, sediment supply to Indian Ocean.

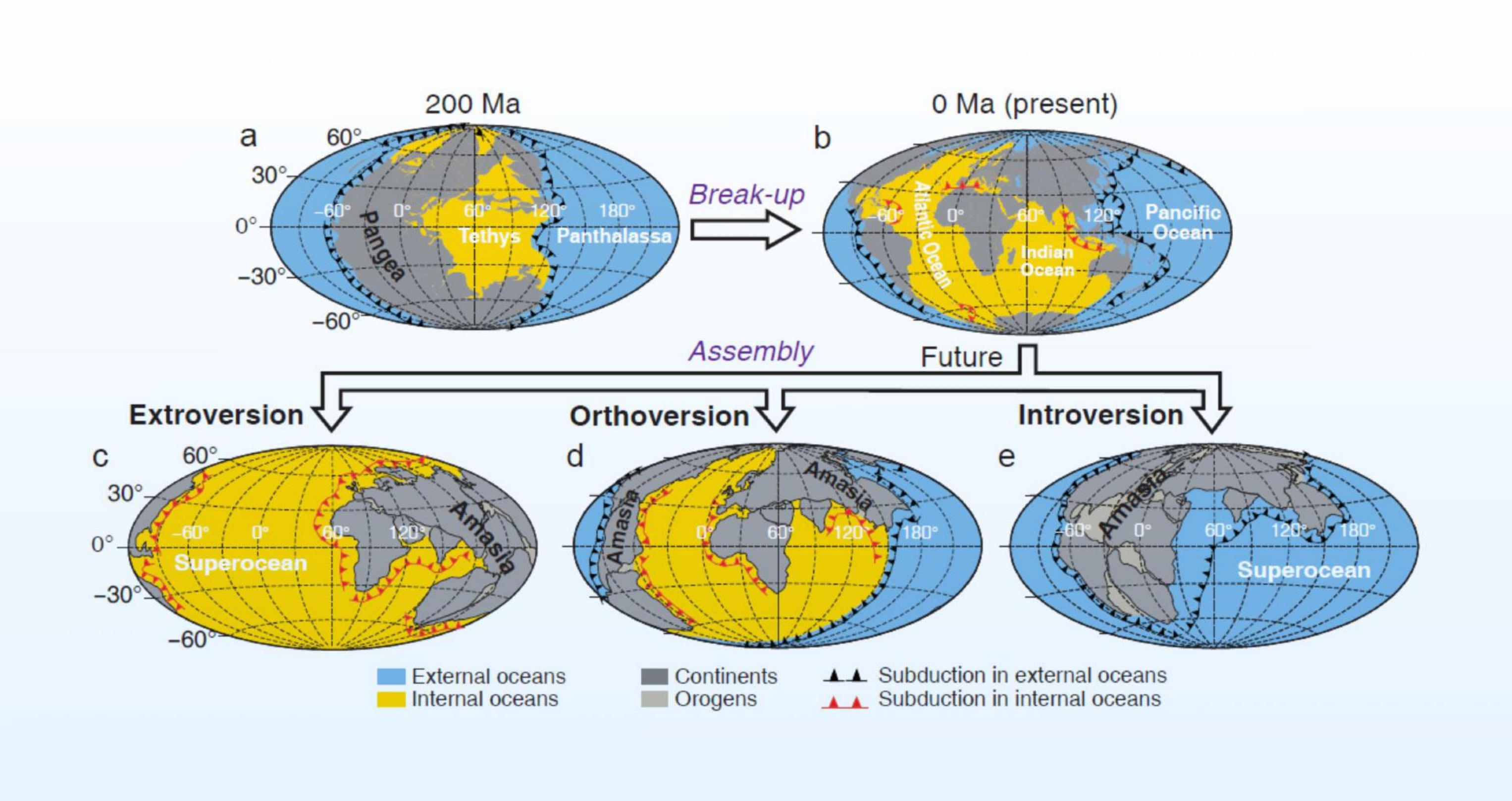
# ONGOING TECTONIC CHANGES AND THEIR POTENTIAL IMPACTS ON SEAS AND OCEANS

Formation of the Red Sea:
African Plate and Arabian Plate rift.
Creation of the Red Sea.
Widening Red Sea, potential new ocean basin.

Andean Subduction and the Pacific Ocean:
Nazca Plate subduction beneath South American Plate.
Andes mountain range, Peru-Chile Trench formed.
Volcanic activity, ocean chemistry changes.

# FUTURE SUPEROCEANS

- Novopangaea Ocean
- Amasia Ocean



# NOVOPANGAEA OCEAN

- Future Superocean Hypotheticals: The Novopangaea Ocean is a speculative future scenario.
- It assumes closure of the Pacific, docking of Australia with East Asia, and northward motion of Antarctica.

# AMASIA OCEAN

- Amasia is a possible future supercontinent which could be formed by the merger of Asia and the Americas.
- The prediction relies mostly on the fact that the Pacific Plate is already subducting under Eurasia and the Americas, a process which if continued will eventually cause the Pacific to close.