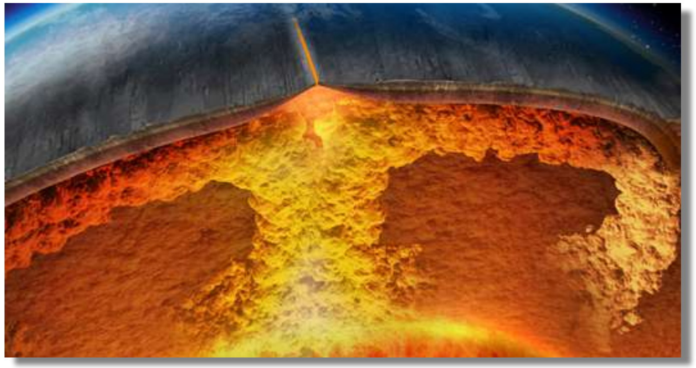


Geological time • Plate tectonics

Biogeography and Evolution of Marine Organisms

History of Biogeography

outline

CLIMATE CHANGE: THE EFFECT OF GLACIATIONS

HISTORY OF THE EARTH

THE OPENING of THE ATLANTIC OCEAN

THE CHANGES IN THE INDIAN OCEAN

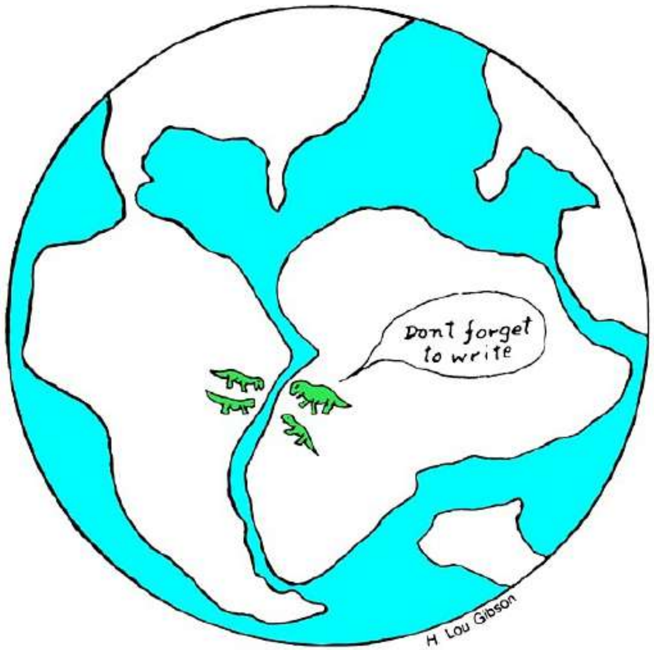
TETHYS SEA and the MEDITERRANEAN

THE MESSINIAN SALINITY CRISIS

THE SOUTHERN OCEAN

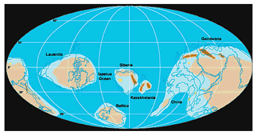
THE CLOSURE of THE ISTHMUS OF PANAMA: GLOBAL CONSEQUENCES

THE OPENING OF THE BERING STRAIT

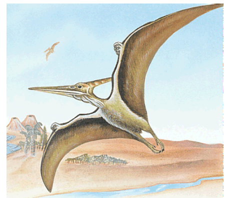


Earth is a Dynamic and Evolving Planet

- Changes in its surface

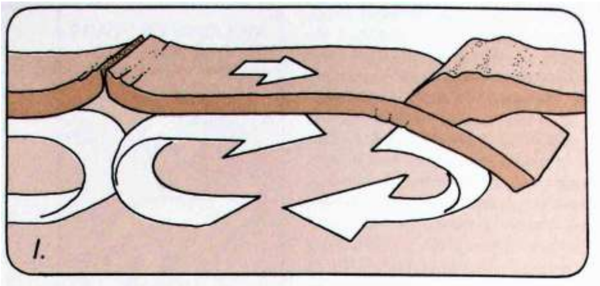


- Changes in life



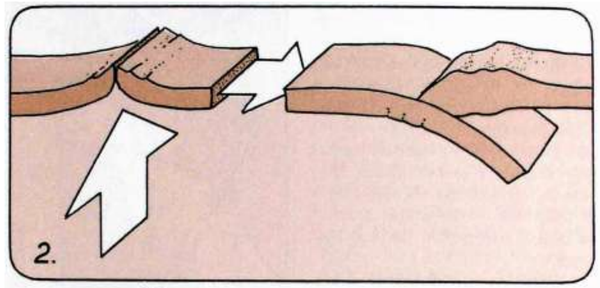
What drives sea-floor spreading?

Convection loops in asthenosphere plates pulled along by current



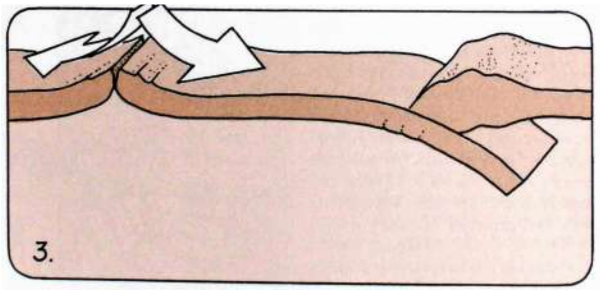
What drives sea-floor spreading?

Force of rising magma pushes plates apart



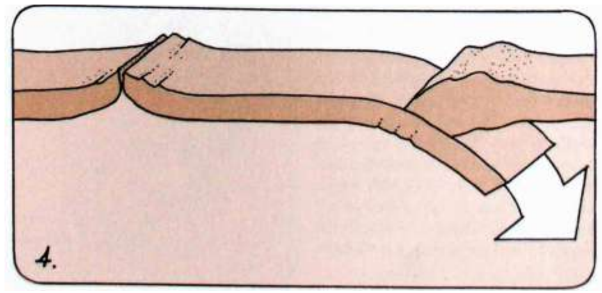
What drives sea-floor spreading?

Gravity pushes mid-ocean ridges down and forces plates apart



What drives sea-floor spreading?

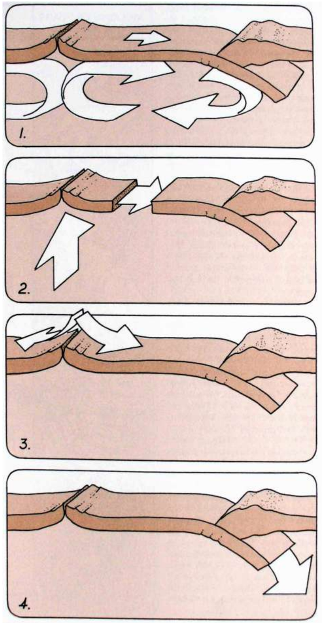
Weight of subducted plate pulls ocean plates apart



What drives sea-floor spreading?

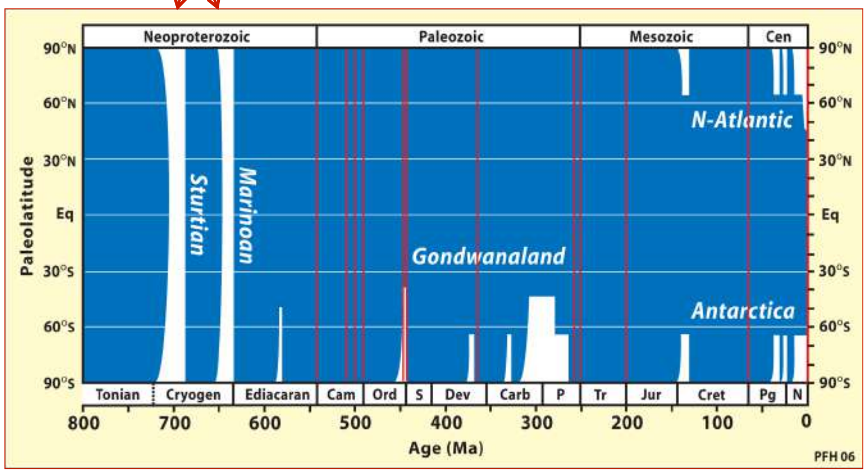
1. Convection loops in asthenosphere plates pulled along by current
2. Force of rising magma pushes plates apart
3. Gravity pushes mid-ocean ridges down and forces plates apart
4. Weight of subducted plate pulls ocean plates apart

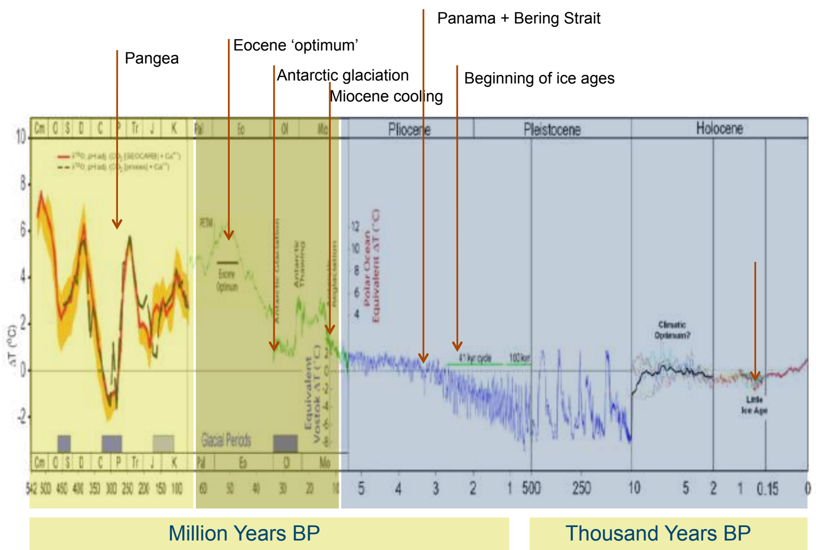
All these mechanisms may be operating

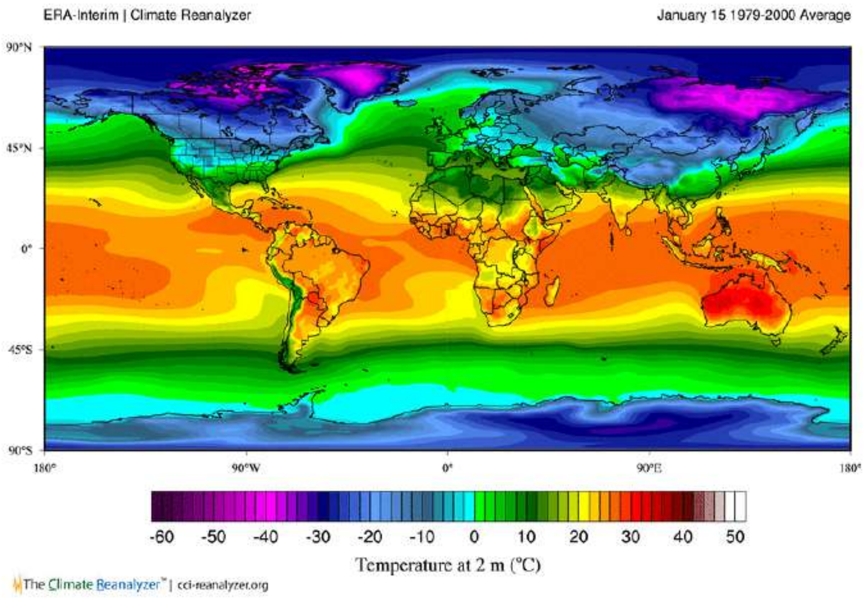


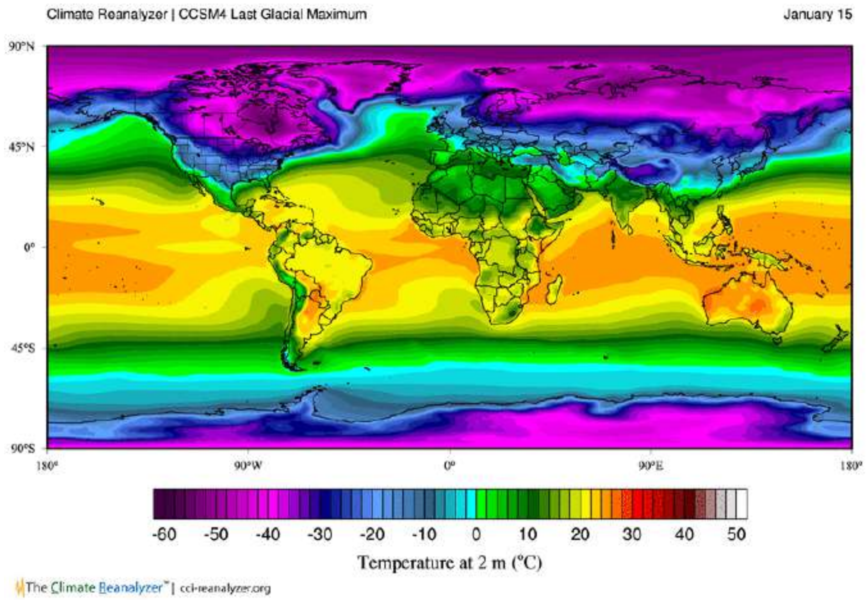
Snowball Earth

Major ice ages

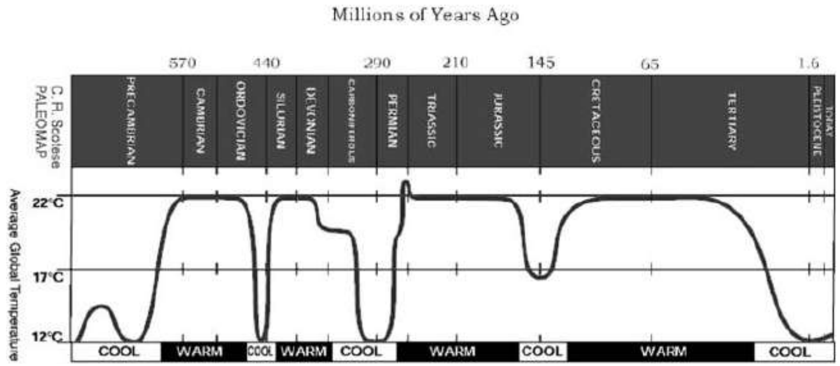






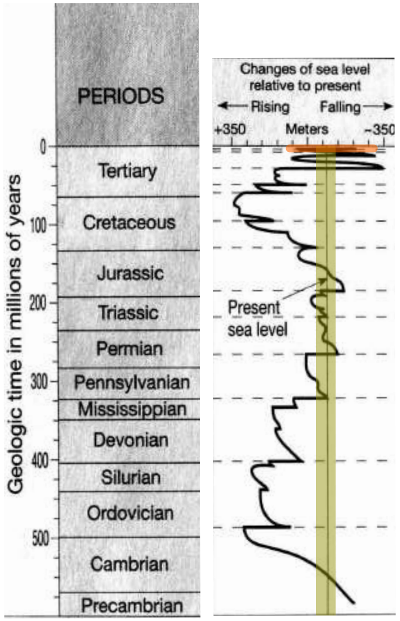


Temperature

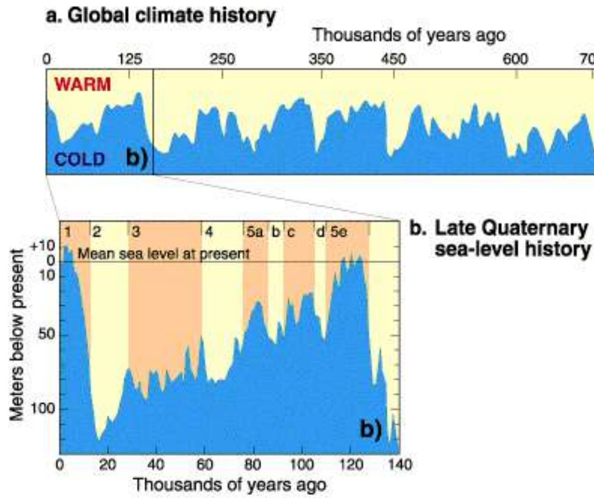


Hallam (1994) afterVail *et al*. (1977)

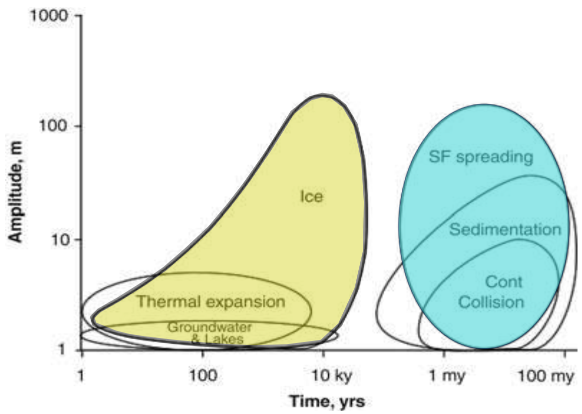
Sea level



Sea level



Factors controlling sea level

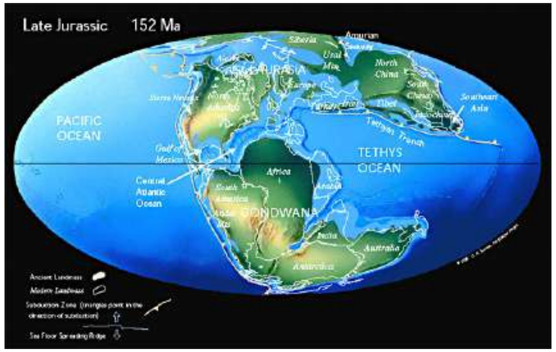


Miller et al. (2005)

Atlantic Ocean

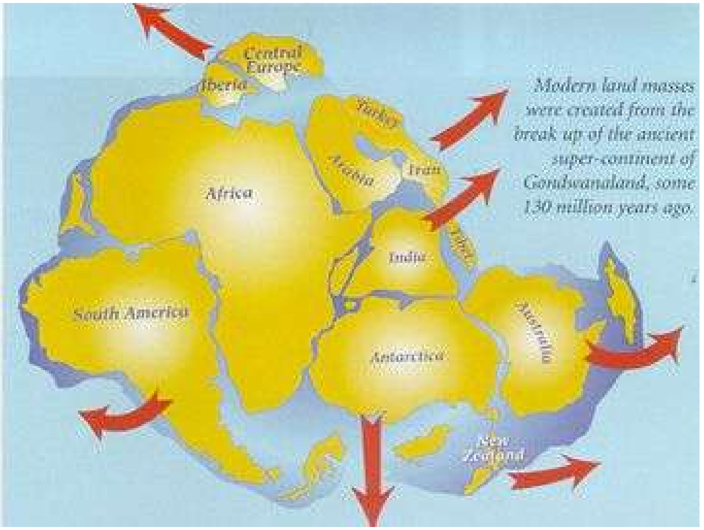
205-138 MA

Gondwana



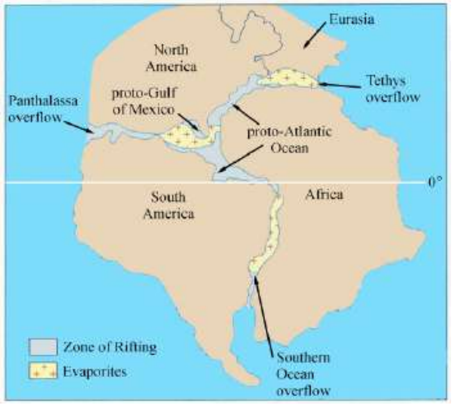
205-138 MA

Gondwana

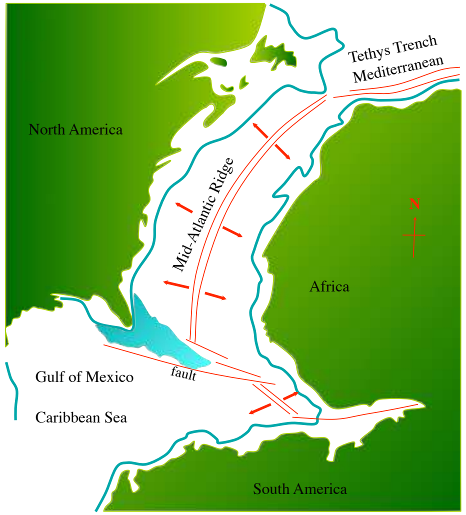


205-138 MA

Gondwana

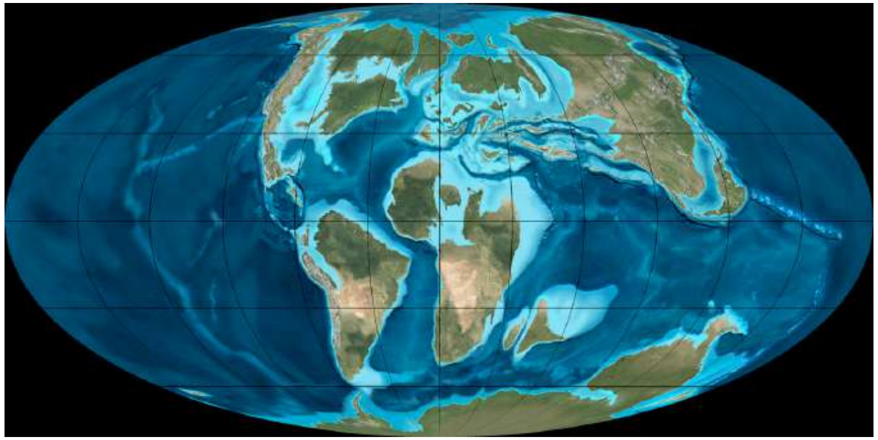


Pangea Pulls Apart

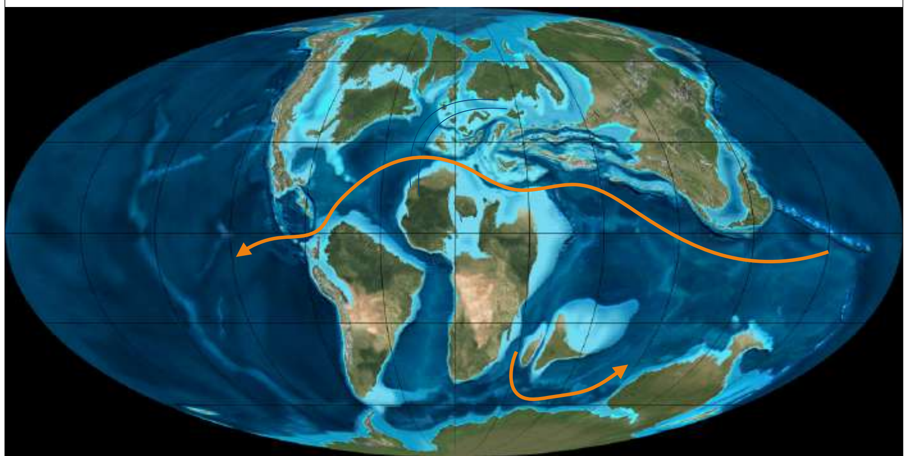


- 200 MYA
- Stretches continental crust
- Atlantic Ocean Banks

138-65 MA



Late Cretaceous (65 Ma)



Indian Ocean

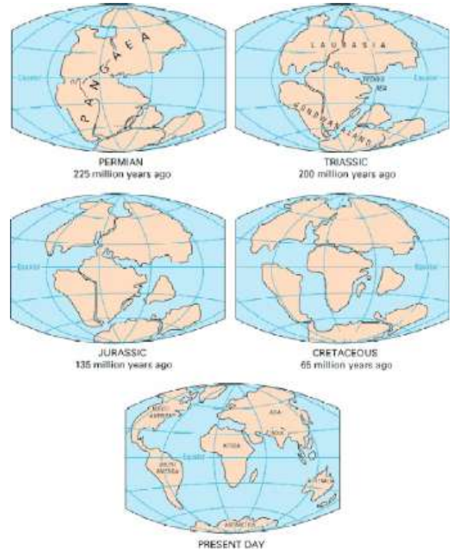
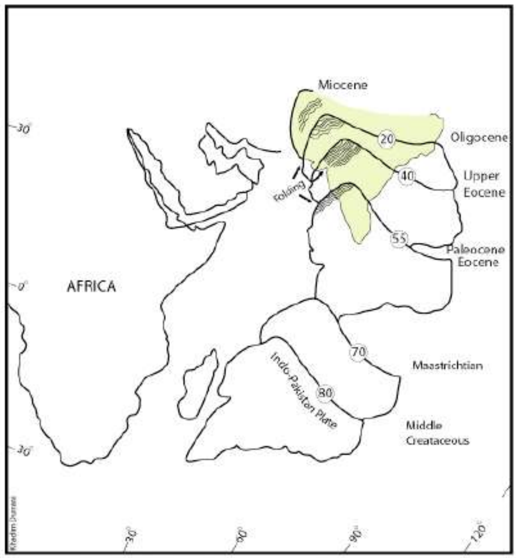
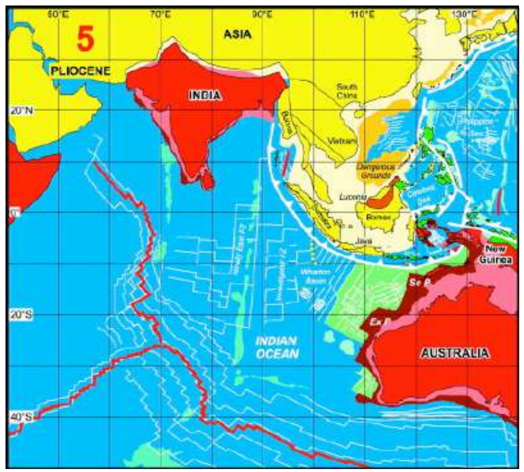


Plate tectonics and continental drift



Northward drift of Indo-Pakistan Plate during Middle Cretaceous through Miocene (modified after Bender & Raza 1996)

Plate tectonics and continental drift

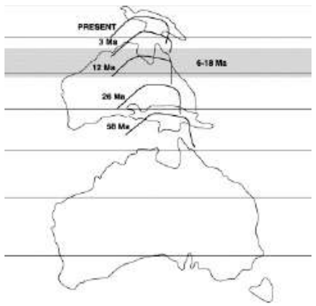


Hall R (2012) Late Jurassic–Cenozoic reconstructions of the Indonesian region and the Indian Ocean. Tectonophysics 570-571:1–41. doi: 10.1016/j.tecto.2012.04.021

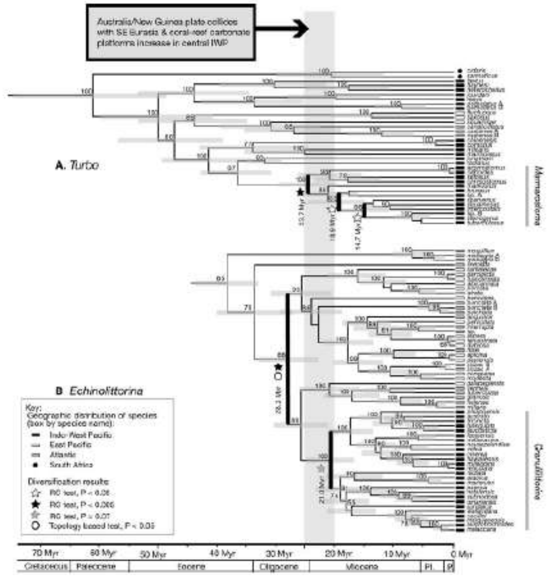
Plate tectonics and continental drift

DID TECTONIC ACTIVITY STIMULATE OLIGO–MIOCENE SPECIATION IN THE INDO-WEST PACIFIC?

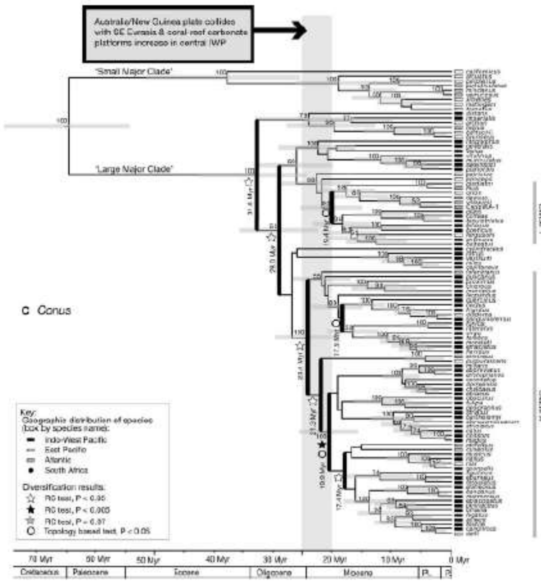
Australia-New Guinea plate colliding with SouthEast Eurasia and coral reef platforms



Williams ST, Duda TF Jr (2008) Did tectonic activity stimulate Oligo-Miocene speciation in the Indo-West Pacific? Evolution 62:1618–1634.

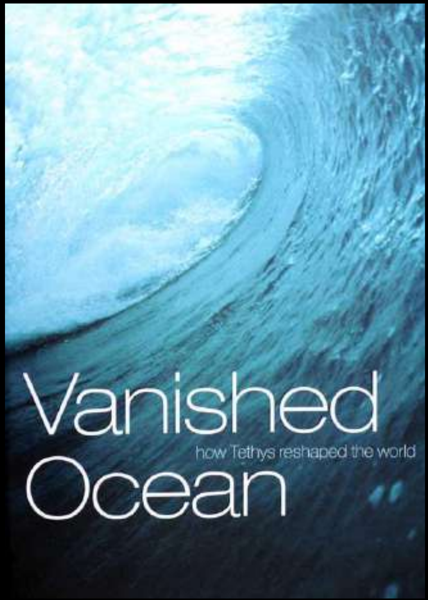


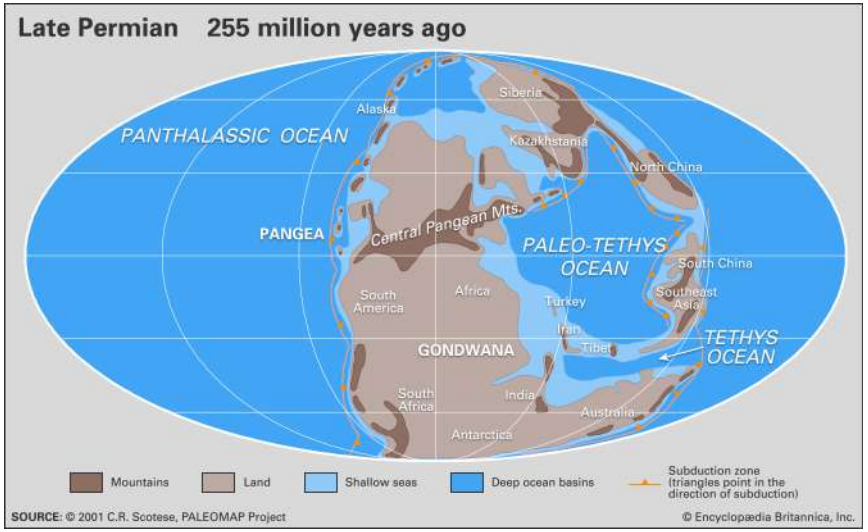
Williams ST, Duda TF Jr (2008) Did tectonic activity stimulate Oligo-Miocene speciation in the Indo-West Pacific? Evolution 62:1618–1634.



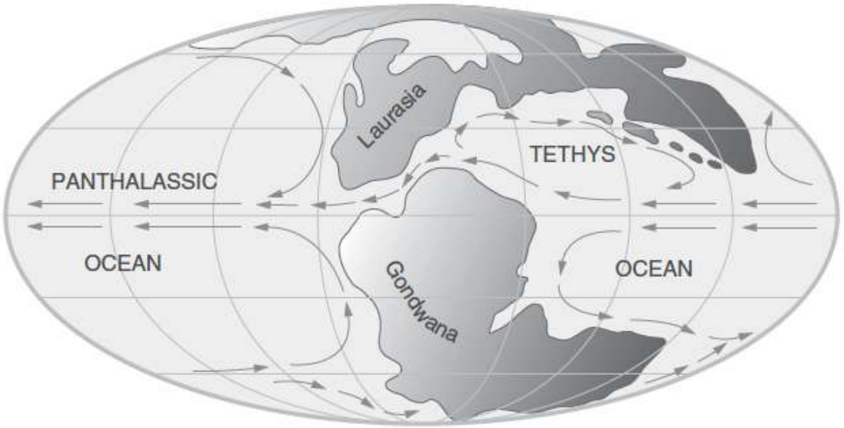
Williams ST, Duda TF Jr (2008) Did tectonic activity stimulate Oligo-Miocene speciation in the Indo-West Pacific? Evolution 62:1618–1634.

Tethys Sea

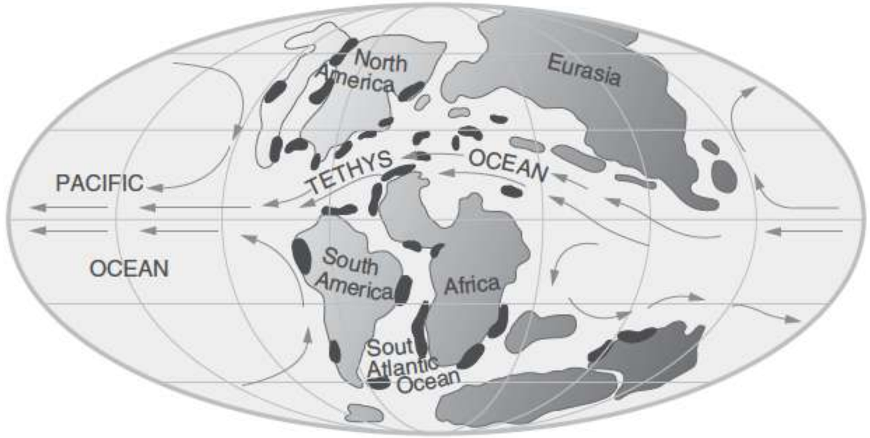




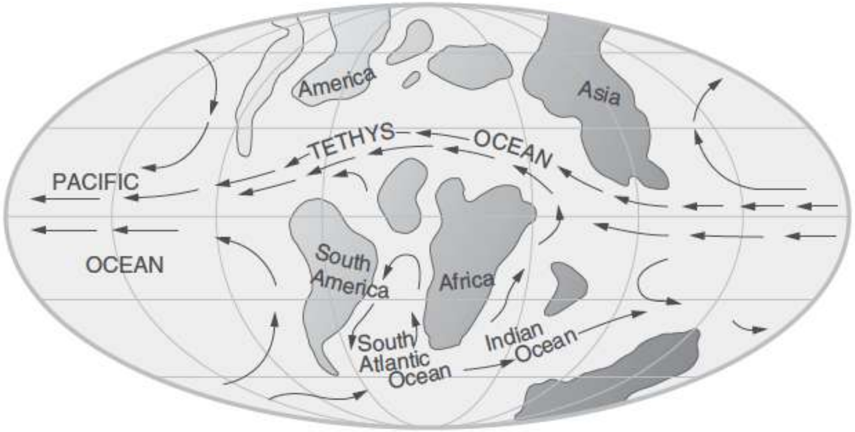
175 Mya



95 Mya

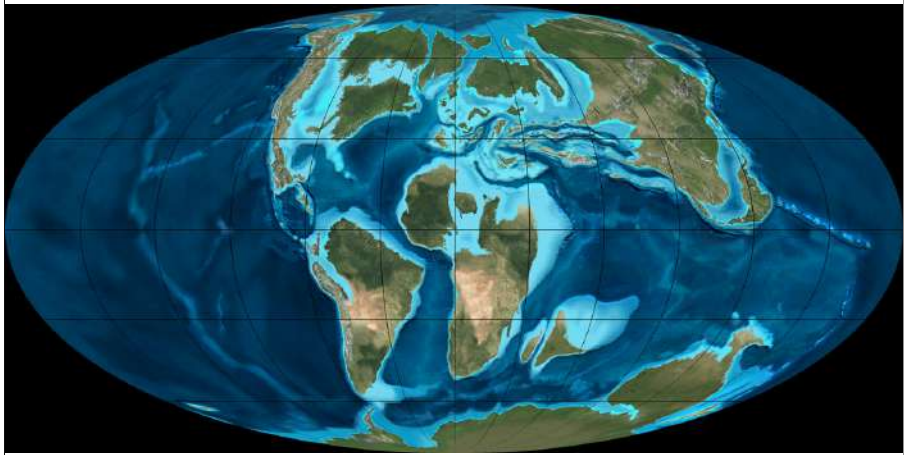


80 Mya

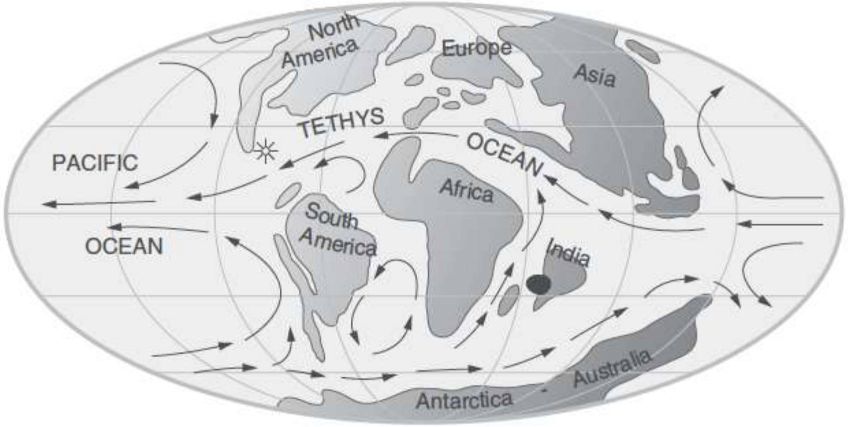


SEA LEVELS AND CONTINENTAL POSITIONS INFLUENCE OCEAN SHAPES

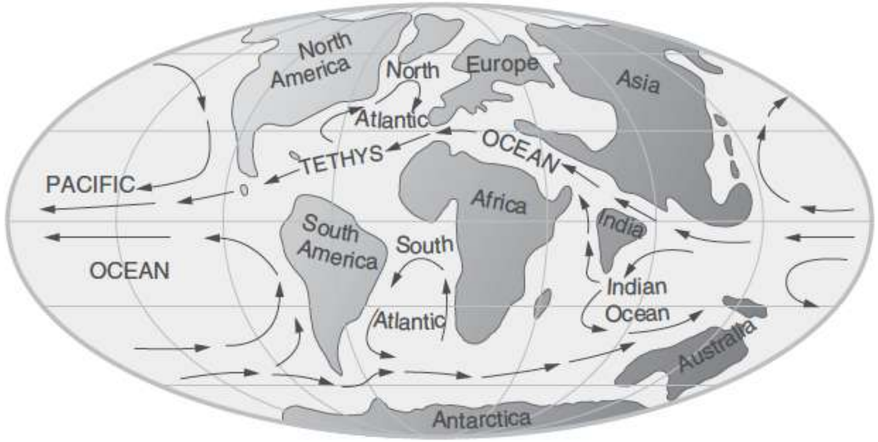
65MY



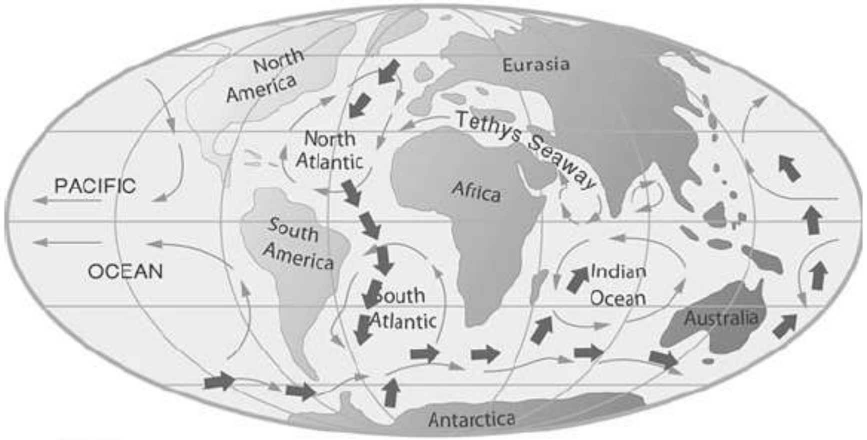
65 Mya



45 Mya

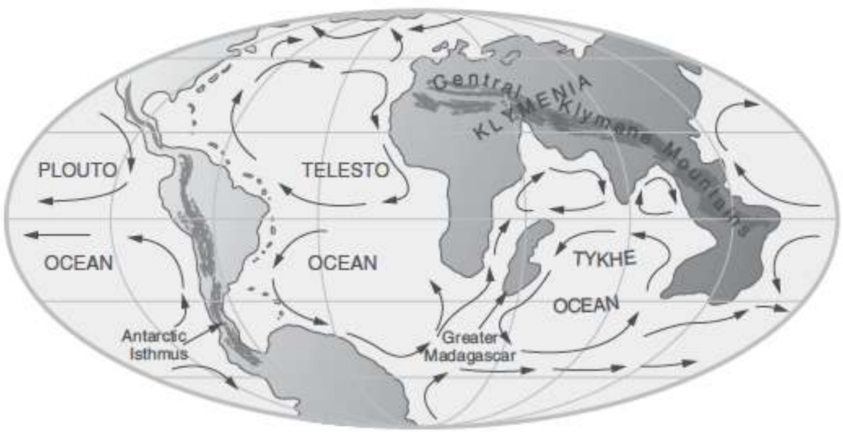


18 Mya



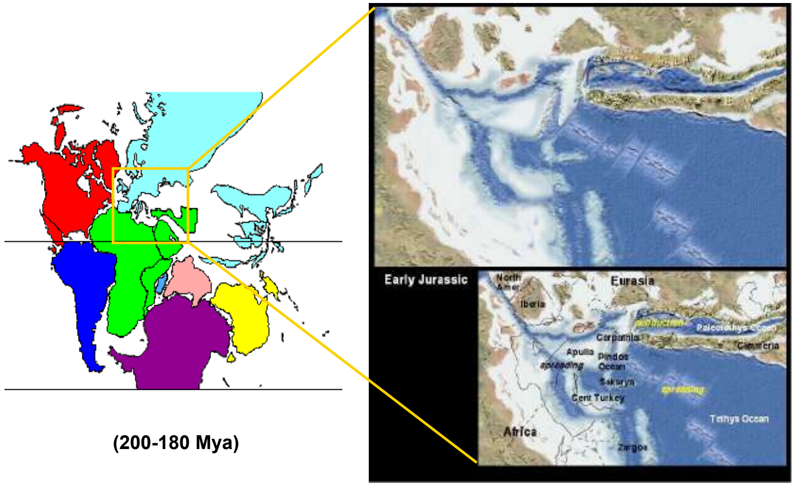
0 Mya

50 My



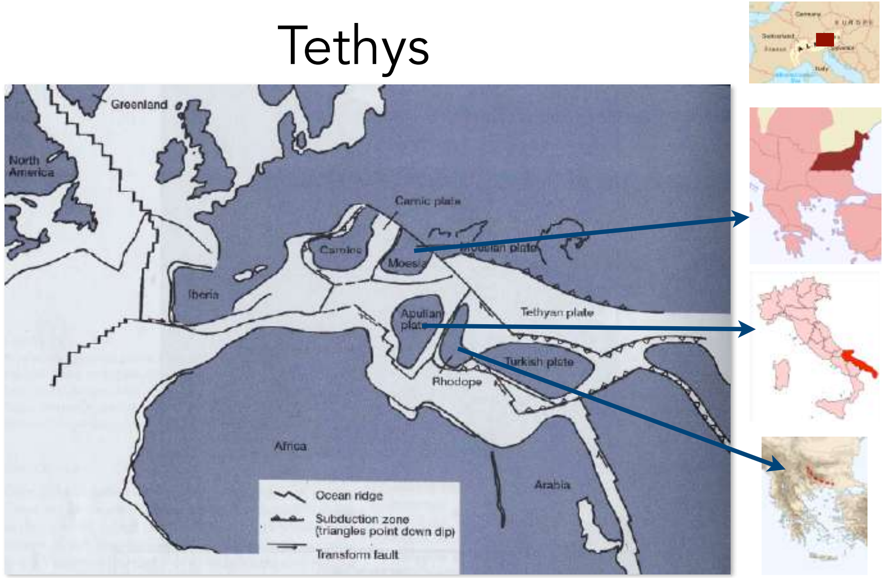
Tethys and the Mediterranean

From the Tethys Sea to the Mediterranean

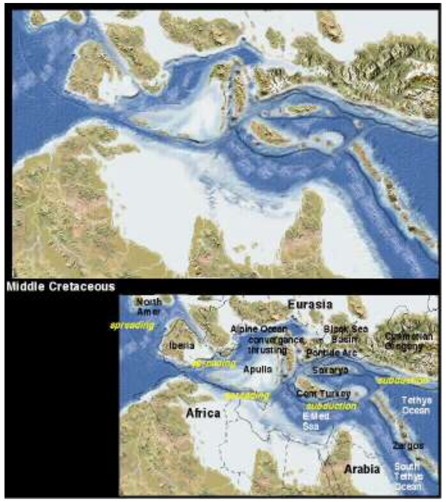


(200-180 Mya)

Tethys



Eastwards motion of Africa relative to Europe

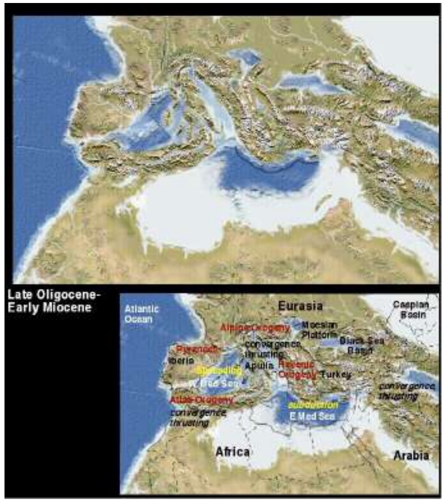


(130-85 Mya)

Eastwards and Northwards motion of Africa relative to Europe

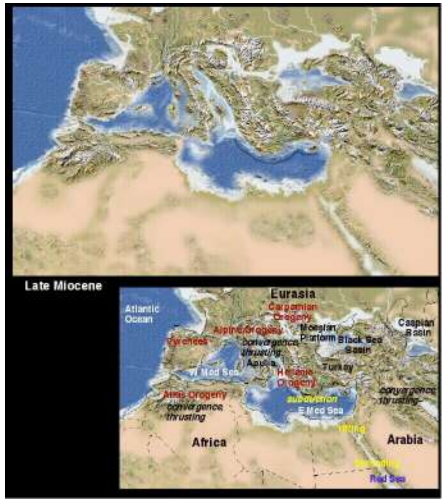
(57- 35 Mya)

Eastwards motion of Africa closes the Connection between the Mediterranean and the Indian Ocean



(18- 7 Mya)

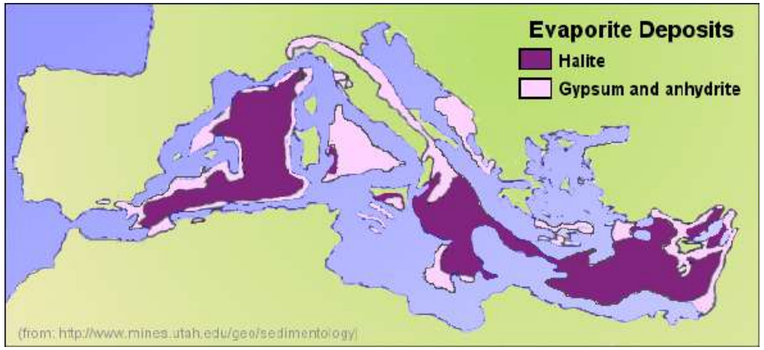
Africa moves northwards and westwards



(6-5 Mya)

Messinian salinity crisis

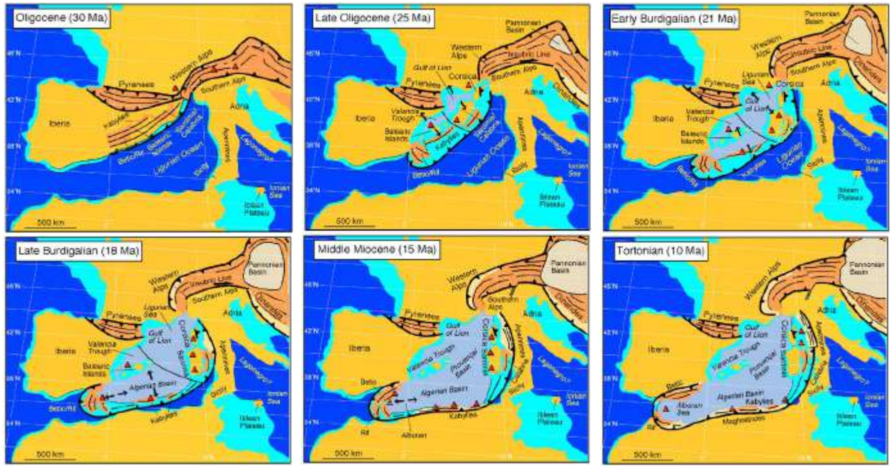
Evaporites



In August of 1970 the DSDP ship Challenger was positioned in the western Mediterranean, south of the Balearic Islands, in almost 3000 m of water. The geologists on board were looking for the source of a prominent sub-sea-floor seismic feature called the M-reflector, and, to their great surprise, they drilled into a thick layer of anhydrite - the first evidence of a vast deposit of evaporite rocks extending across the Mediterranean.

http://records.viu.ca/~earles/messinian-crisis-apr03.htm

Iberia and North Africa



Three mechanisms have been proposed to explain the isolation of the Mediterranean during the Messinian, including:

1) a 60 m global drop in sea level due to glaciation,

2) horizontal squeezing, and

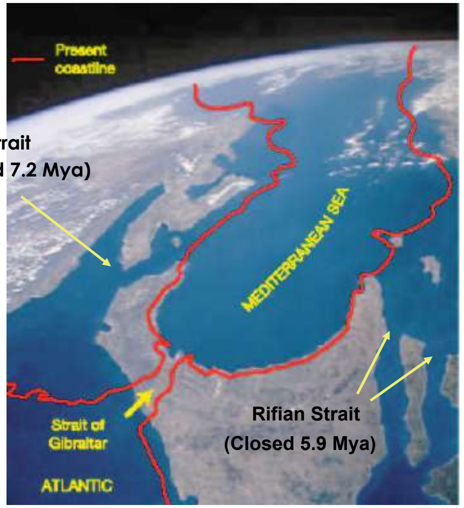
3) tectonic uplift.

Western Mediterranean (8 Myr ago)

Mediterranean annual water loss by evaporation 1600 Km3/year.
Only 10% replaced by rainfall and the influx of rivers.

The remaining 90% had to come from the Atlantic Ocean.

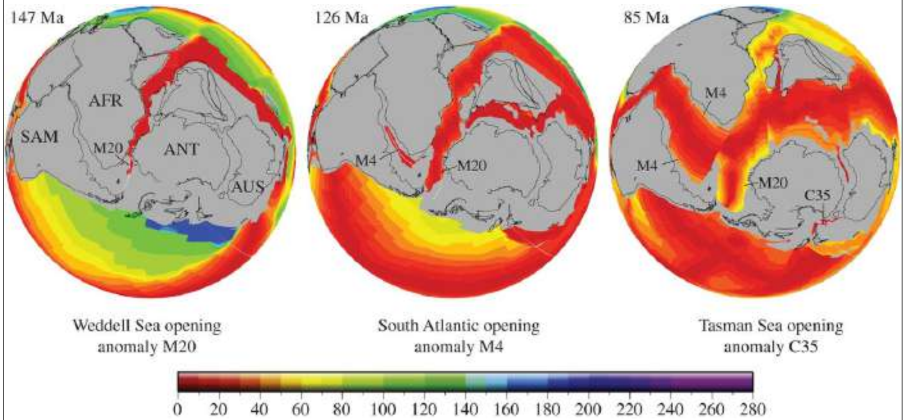
With the Atlantic connection closed and climatic conditions in the lower Pliocene much warmer than at present, water level dropped approximately 1.4 m/year taking less than 1000 years to dry up.



Duggen et al. (2003) *Nature*, 422: 602-606

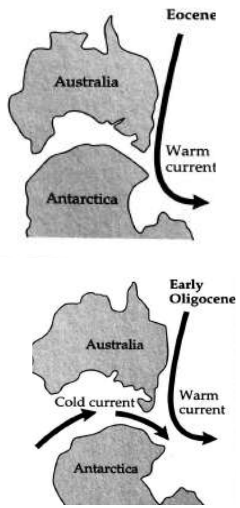
http://www.geo.uu.nl/Research/Paleomagnetism/people/Wout/res_wout.htm

Southern Ocean

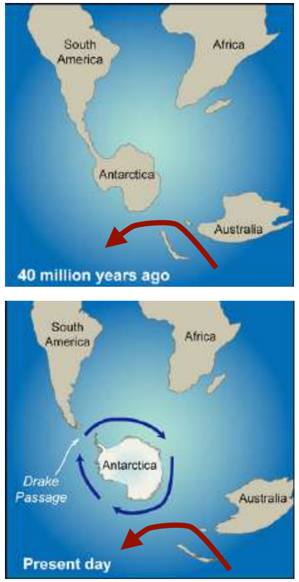


Sea levels and continental positions influence ocean shapes

55MY



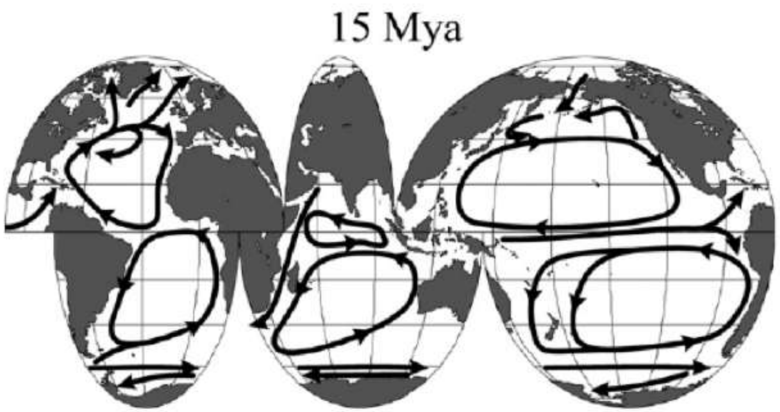
34MY



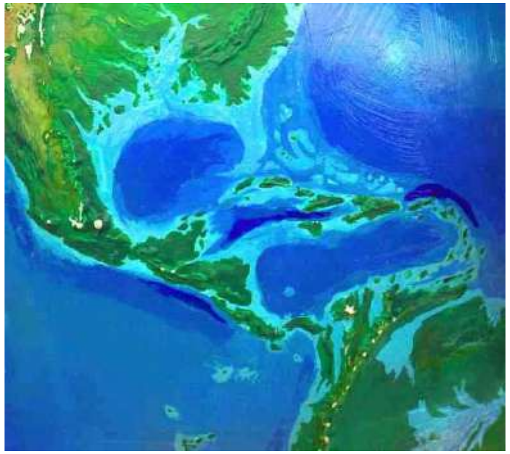
Isthmus of Panama

Sea levels and continental positions influence ocean shapes

ISTHMUS OF PANAMA

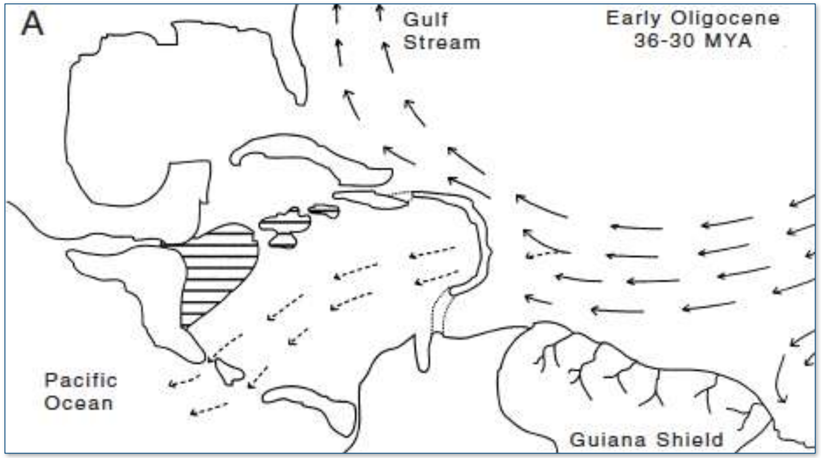


Sea levels and continental positions influence ocean shapes



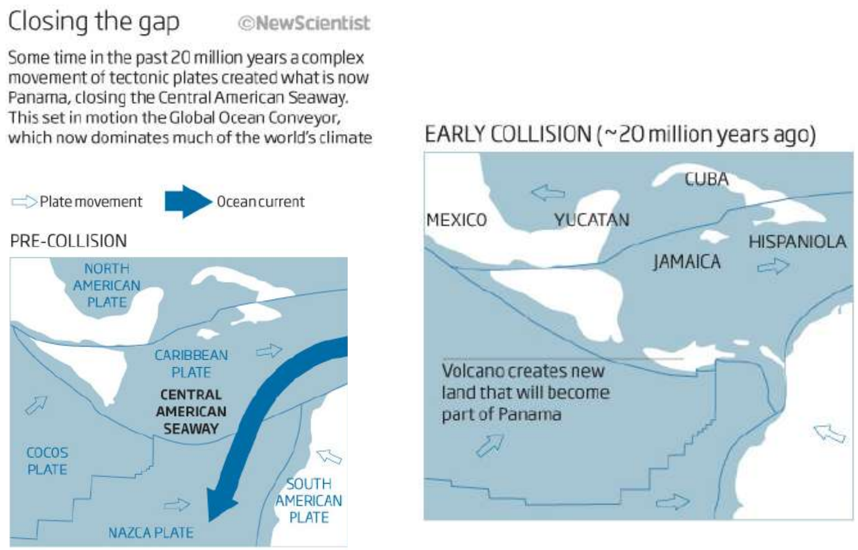
ISTHMUS OF PANAMA

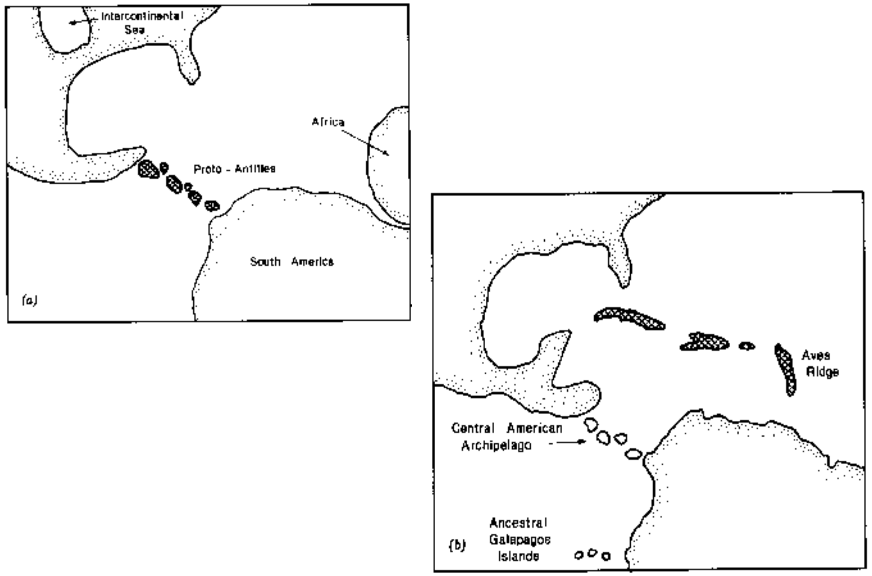
Sea levels and continental positions influence ocean shapes

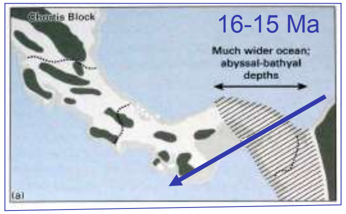


ISTHMUS OF PANAMA

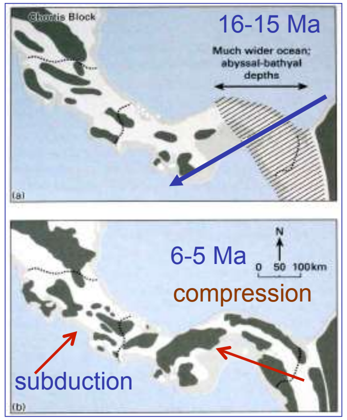
Sea levels and continental positions influence ocean shapes







Coates & Obinda (1996)



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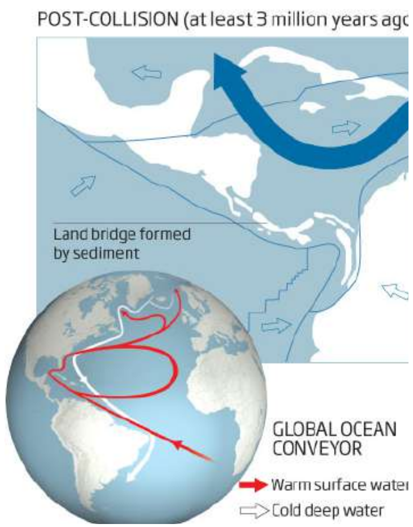
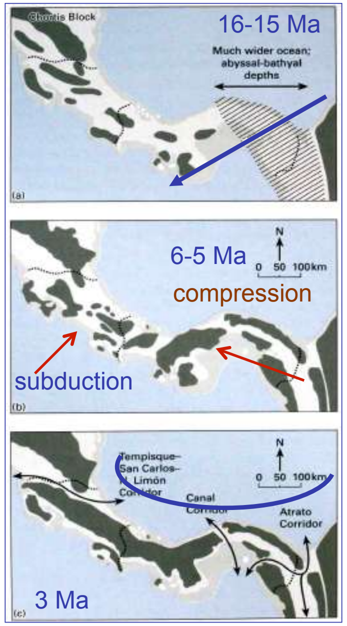
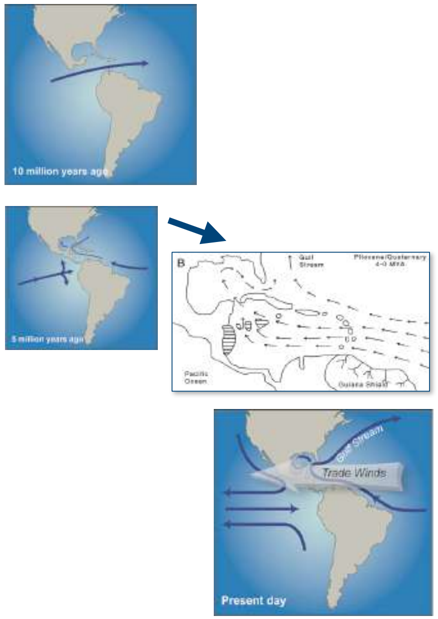
Sea levels and continental positions influence ocean shapes

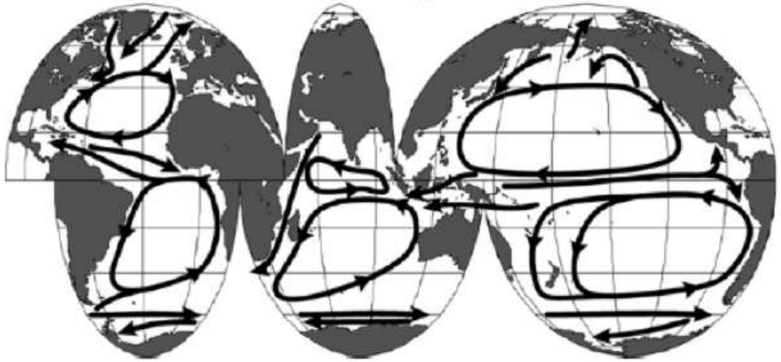




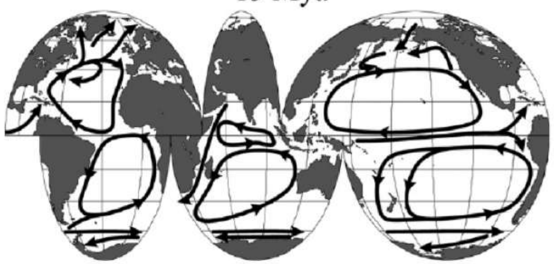
Coates & Obinda (1996)



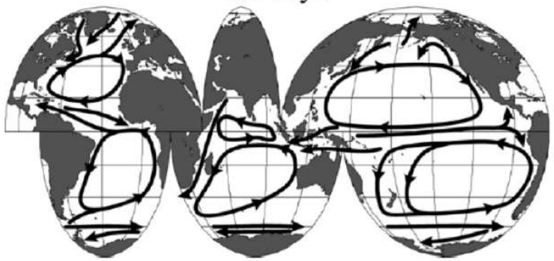
3.5 Mya

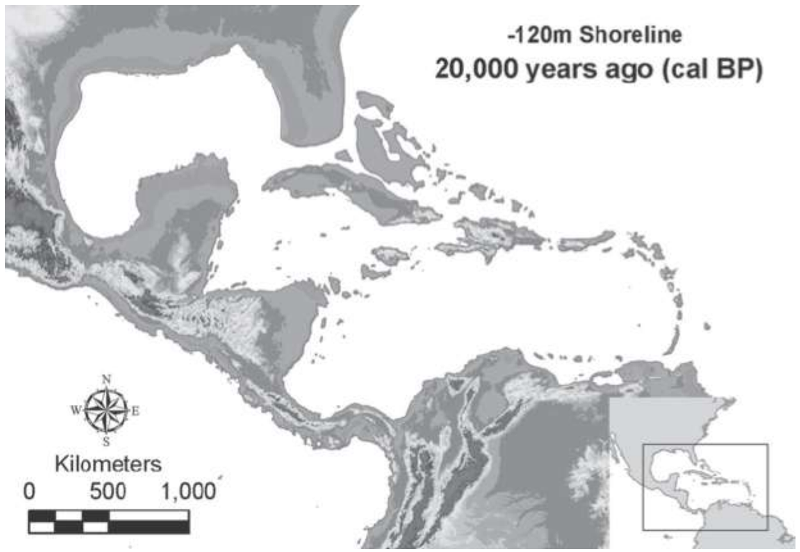


15 Mya



3.5 Mya





Anderson et al. 2010 Curr Res Pleistocene

Battle for the Americas

The formation of the Isthmus of Panama allowed the fauna of two continents to mingle, transforming biogeography. A radical new hypothesis holds that the land bridge formed millions of years earlier than scientists thought

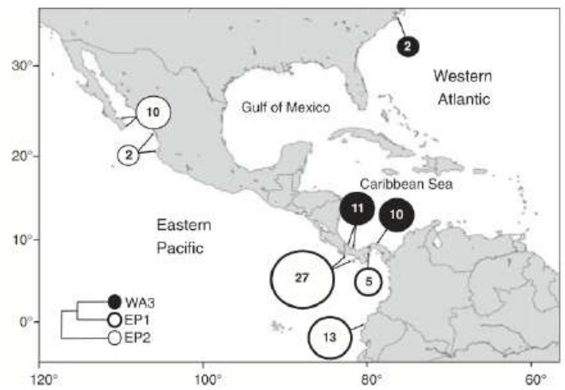
Stone R 2013. Battle for the Americas. Science.

Journal of Biogeography (J. Biogeogr.) (2009) 36, 1861–1880

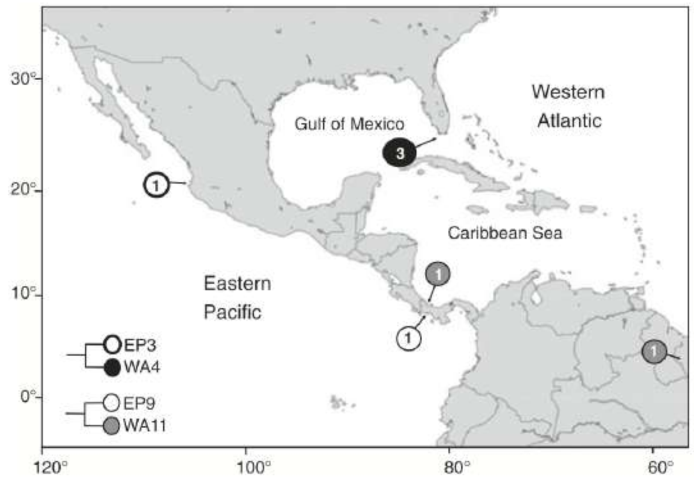
ORIGINAL ARTICLE

Out of sight, out of mind: high cryptic diversity obscures the identities and histories of geminate species in the marine bivalve subgenus *Acar*

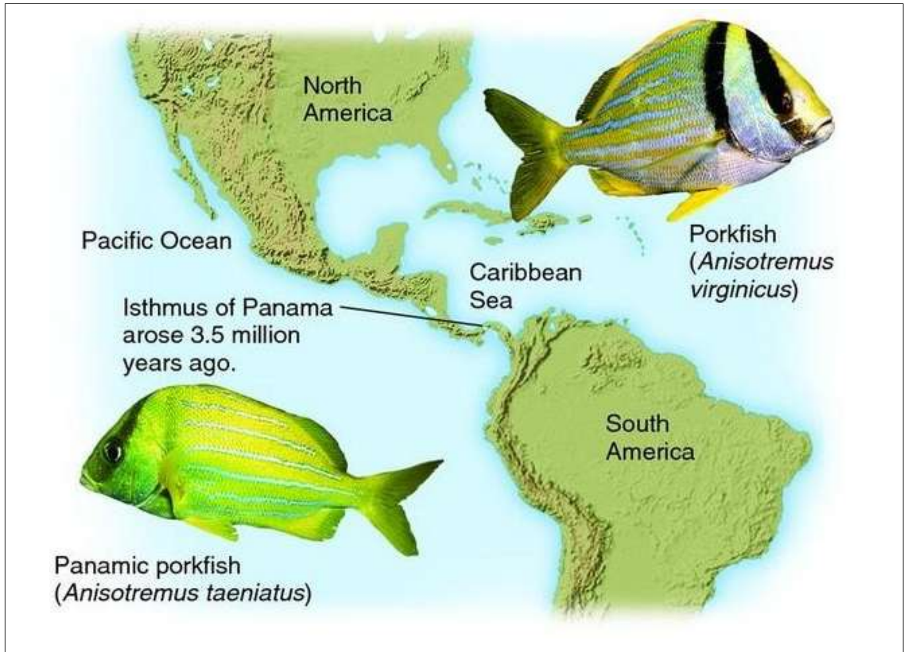
P. B. Marko and A. L. Moran



Spatial distribution of cytochrome c oxidase I (COI) haplotype clades for the EP1-2/WA3 transisthmian lineage of *Barbatia* (Acar). Numbers and the relative sizes of circles refer to sample sizes.

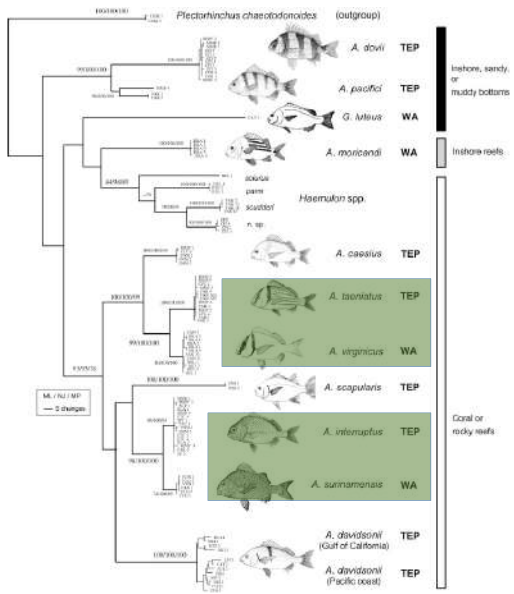


Spatial distributions of cytochrome c oxidase I (COI) haplotype clades for the EP3/WA4 and EP9/WA11 transisthmian lineages of *Barbatia* (Acar). Numbers and the relative sizes of circles refer to sample sizes.



WA
Western Atlantic

TEP
Tropical Eastern Pacific



Bernardi G, Alva-Campbell YR, Gasparini JL, Floeter SR (2008) Molecular ecology, speciation, and evolution of the reef fish genus Anisotremus. MPE 48:929–935. doi: 10.1016/j.ympev.2008.05.011

Bering Strait

Bering Strait

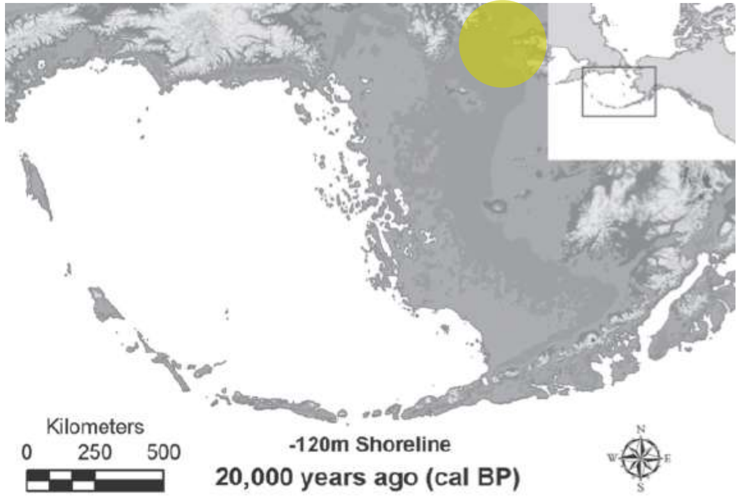
Dates for opening

3.1 Myr (Repenning and Brouwers, 1992)
3.1 Myr (Fyles et al. 1999)
3.6 Myr (Herman and Hopkins, 1980)
3.6 Myr (Vermeij, 1989)
4.1 Myr (Brigham-Grette et al., 1994)
4.1 Myr (Nolf and Marincovich, 1994)

4.8 to 7.3-7.4 Myr (Marincovich and Gladenkov, 1999)
5.32 Myr (Gladenkov et al. 2002).

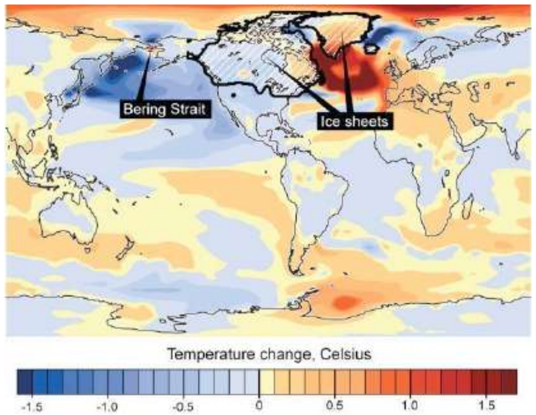
Marincovich, L., and A. Y. Gladenkov. 1999. Nature 397:149-151.

Bering Strait



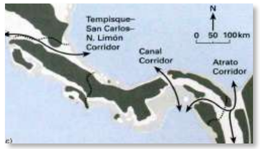
Anderson et al. 2010 Curr Res Pleistocene

Closed Bering Strait and global climate



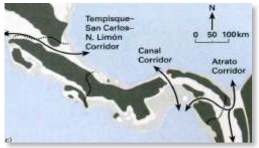
http://www.sciencedaily.com/releases/2010/01/100110151325.htm

Pacific vs. Atlantic Ocean - Closure of the Central American Seaway



Teske PR, Hamilton H, Matthee CA, Barker NP (2007) Signatures of seaway closures and founder dispersal in the phylogeny of a circumglobally distributed seahorse lineage. BMC Evol Biol 7:138. doi: 10.1186/1471-2148-7-138

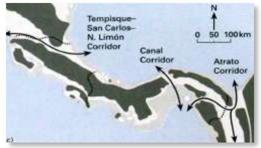
Pacific vs. Atlantic Ocean - Closure of the Central American Seaway



Indo-Pacific vs. Atlantic Ocean - Closure of the Tethyan Seaway

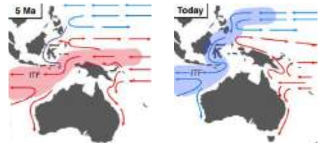
Teske PR, Hamilton H, Matthee CA, Barker NP (2007) Signatures of seaway closures and founder dispersal in the phylogeny of a circumglobally distributed seahorse lineage. BMC Evol Biol 7:138. doi: 10.1186/1471-2148-7-138

Pacific vs. Atlantic Ocean - Closure of the Central American Seaway



Indo-Pacific vs. Atlantic Ocean - Closure of the Tethyan Seaway

Indian Ocean vs. West Pacific - Closure of the Indonesian Seaway



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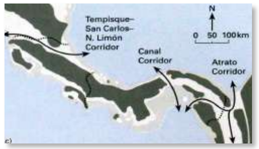
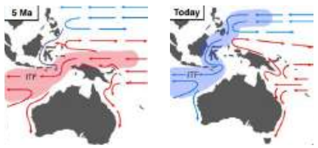


Indo-Pacific vs. Atlantic Ocean - Closure of the Tethyan Seaway

Indian Ocean vs. West Pacific - Closure of the Indonesian Seaway



Amphi-Atlantic distribution patterns - continental break-up and spreading of the Atlantic Ocean.

Teske PR, Hamilton H, Matthee CA, Barker NP (2007) Signatures of seaway closures and founder dispersal in the phylogeny of a circumglobally distributed seahorse lineage. BMC Evol Biol 7:138. doi: 10.1186/1471-2148-7-138

BMC Evolutionary Biology BioMed Central

Research article Open Access

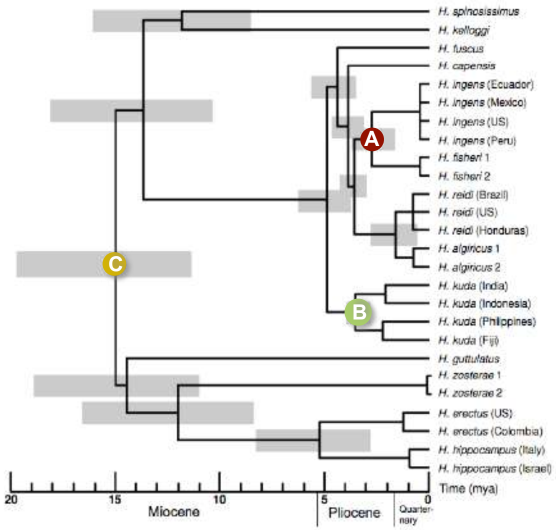
Signatures of seaway closures and founder dispersal in the phylogeny of a circumglobally distributed seahorse lineage

Peter R Teske*[1,2], Healy Hamilton[3], Conrad A Matthee[2] and Nigel P Barker[1]

A: Pacific vs. Atlantic Ocean - Closure of the Central American Seaway

B: Indian Ocean vs. West Pacific - Closure of the Indonesian Seaway

C: Indo-Pacific vs. Atlantic Ocean - Closure of the Tethyan Seaway



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Suggested dates of vicariance events:

Central American Seaway closure:
3.1 – 3.5 MY (assuming that the divergence of the trans-isthmian seahorse lineages took place when a land bridge formed in Central America [1]);
3.1 – 4.6 MY (taking into consideration that seahorse divergence may have been affected by the reorganisation of ocean currents associated with the closure of the seaway [2]);
3.1 – 8.5 MY (the upper bound being the time when the earliest recorded evolution associated with the closure of the seaway took place in marine corals and foraminiferans [3]);

Indonesian Seaway closure:
0.01 – 1.8 MY [12,13];
3 – 4 MY [11];
7 – 10 MY [9,10];
15 – 17 MY [8];

Tethyan Seaway closure:
11.2 – 14.8 MY [5,6];
18.4 – 20.5 MY [7];
23.8 – 28.5 MY [4];

Complete separation of the land masses on either side of the Atlantic Ocean: 84 mya [14].

Teske PR, Hamilton H, Matthee CA, Barker NP (2007) Signatures of seaway closures and founder dispersal in the phylogeny of a circumglobally distributed seahorse lineage. BMC Evol Biol 7:138. doi: 10.1186/1471-2148-7-138

Take home message:

The distribution of organisms and their genetic make-up is a mix between past geological events and present-day oceanographic/environmental conditions.

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Pacific vs. Atlantic Ocean - Closure of the Central American Seaway

Indo-Pacific vs. Atlantic Ocean - Closure of the Tethyan Seaway

Indo-Pacific vs. Atlantic Ocean - Closure of the Tethyan Seaway

Opening of Bering strait

Indian Ocean vs. West Pacific - Closure of the Indonesian Seaway

Continental break-up and spreading of the Atlantic Ocean.

Present-day currents
Thermo and salinity soft barriers

Take home message:

To explain a biogeographic pattern be prepared to explore different alternatives.

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Be parsimonious.

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History of Biogeography

outline

- CLIMATE CHANGE: THE EFFECT OF GLACIATIONS
- HISTORY OF THE EARTH
- THE OPENING of THE ATLANTIC OCEAN
- THE CHANGES IN THE INDIAN OCEAN
- TETHYS SEA and the MEDITERRANEAN
- THE MESSINIAN SALINITY CRISIS
- THE SOUTHERN OCEAN
- THE CLOSURE of THE ISTHMUS OF PANAMA: GLOBAL CONSEQUENCES
- THE OPENING OF THE BERING STRAIT
- CASE STUDY: THE SEA HORSES