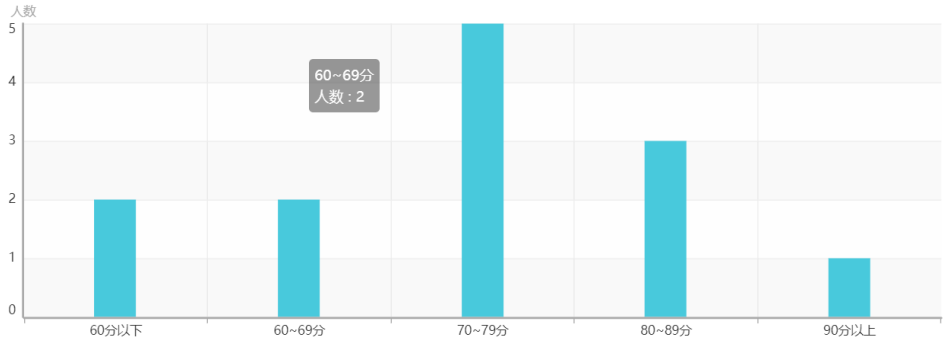
最后作答时间	已批改 / 提交	原始成绩	最终成绩
03.10 16:53	2 / 2	70	70
03.10 21:30	1 / 1	87	87
03.10 17:32	1 / 1	60	60
03.10 20:19	2 / 2	72	72
03.14 03:19	1 / 1	45	45
03.10 21:42	1 / 1	70	70
03.10 18:05	2 / 2	81	81
03.10 15:56	2 / 2	66	66
03.10 15:15	2 / 2	78	78
03.10 17:09	2 / 2	82	82
03.10 20:38	1 / 1	75	75
03.10 22:26	2 / 2	90	90
03.10 18:10	2 / 2	47	47

测试成绩统计

平均成绩	最高成绩	最低成绩	平均尝试次数
71 分	90 分	45 分	1.6 次



1. The major components of outgassing process

简答题 (5 分) (难易度: 易)

答题数据分析 最高分: 5 最低分: 3 平均分: 4.2

---

2. Which method can you use to determine the seafloor features, why?

简答题 (10 分) (难易度: 中)

答题数据分析 最高分: 10 最低分: 2 平均分: 6.8

---

3. Please list the Five Oceans and at least five seas

简答题 (5 分) (难易度: 易)

答题数据分析 最高分: 5 最低分: 5 平均分: 5

4. Principles to determine the relative age

简答题 (10 分) (难易度: 中)

答题数据分析 最高分: 10 最低分: 5 平均分: 9.4

---

5. Please state the decay product, half-life, determination range, and applications of radiocarbon dating.

简答题 (15 分) (难易度: 中)

答题数据分析 最高分: 15 最低分: 5 平均分: 10.8

---

6. Typical features of convergent plate boundaries and divergent plate boundaries.

简答题 (15 分) (难易度: 中)

答题数据分析 最高分: 15 最低分: 8 平均分: 9.8

7. The behavior of seismic waves within Earth's interior.

简答题 (30 分) (难易度: 难)

答题数据分析 最高分: 25 最低分: 10 平均分: 16.2

[无标题]

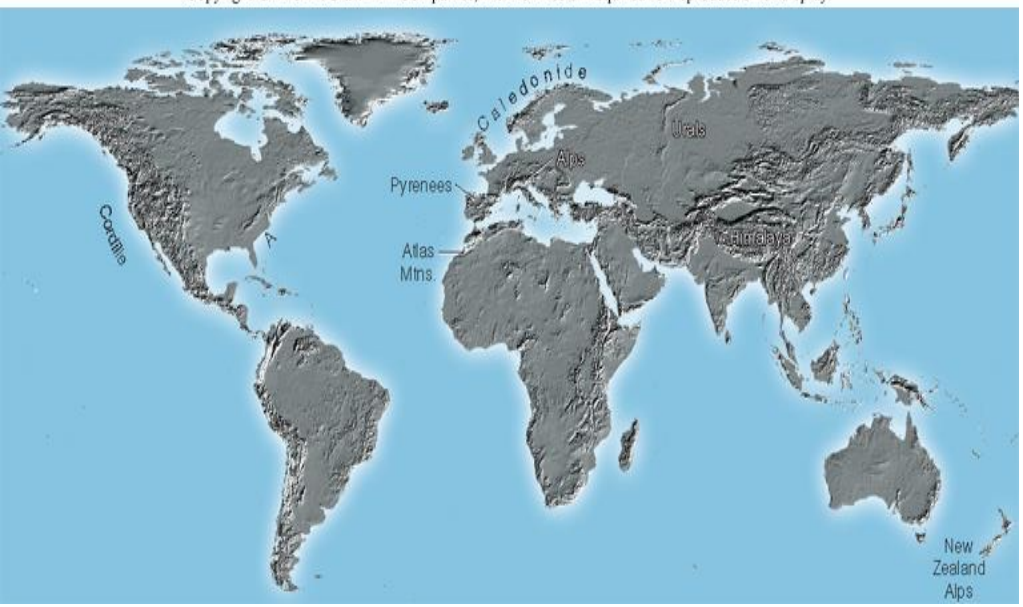
---

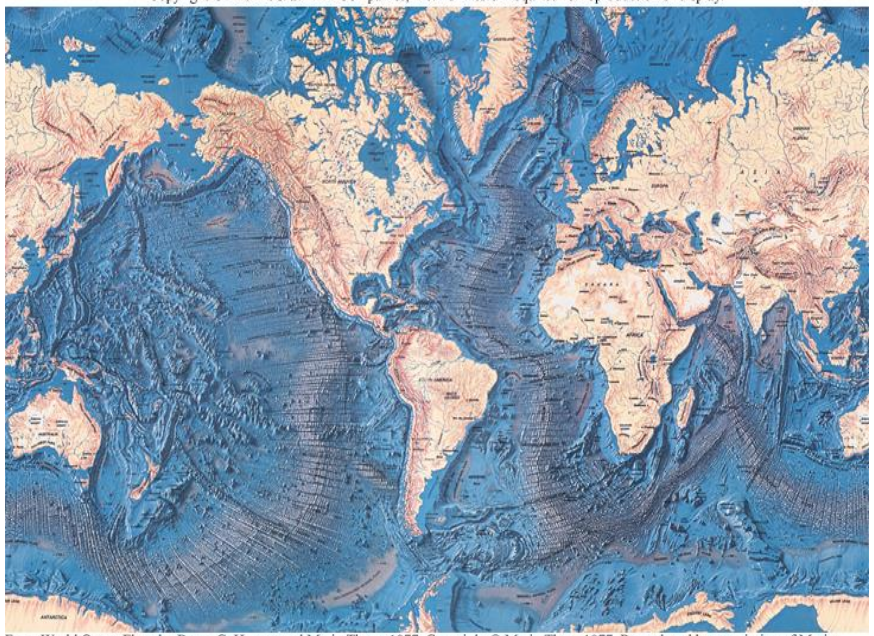
8. How could you distinguish reverse fault and normal fault?

简答题 (10 分) (难易度: 中)

答题数据分析 最高分: 10 最低分: 7 平均分: 9.2

Continental Drift & Sea-Floor Spreading



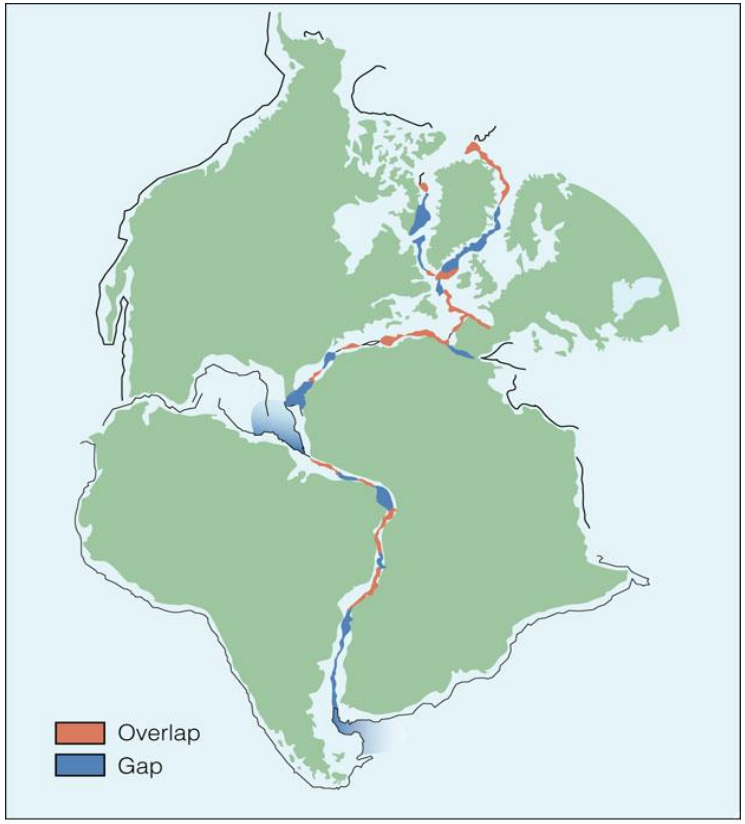


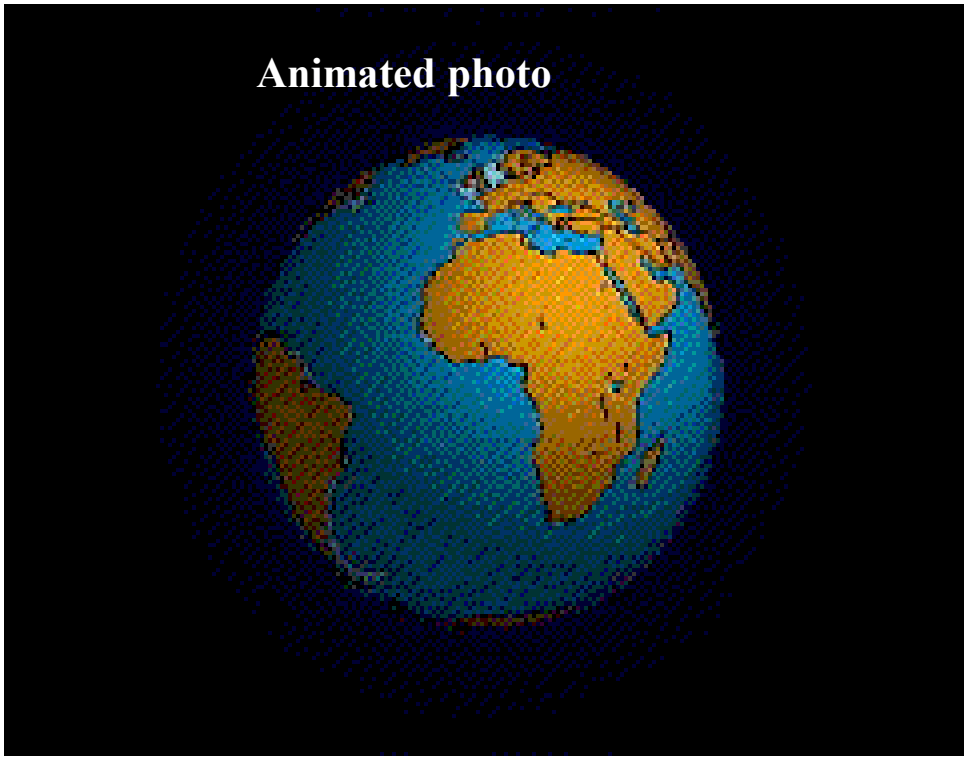
I. Continental Drift

Proposed by Alfred Wegener ~1912

Evidences:

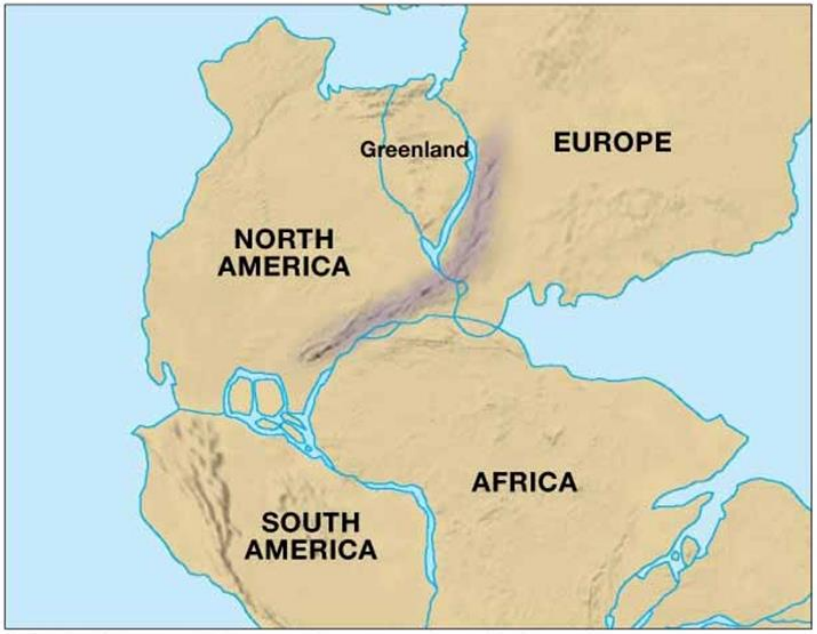
1)Outlines of continents fit very well together

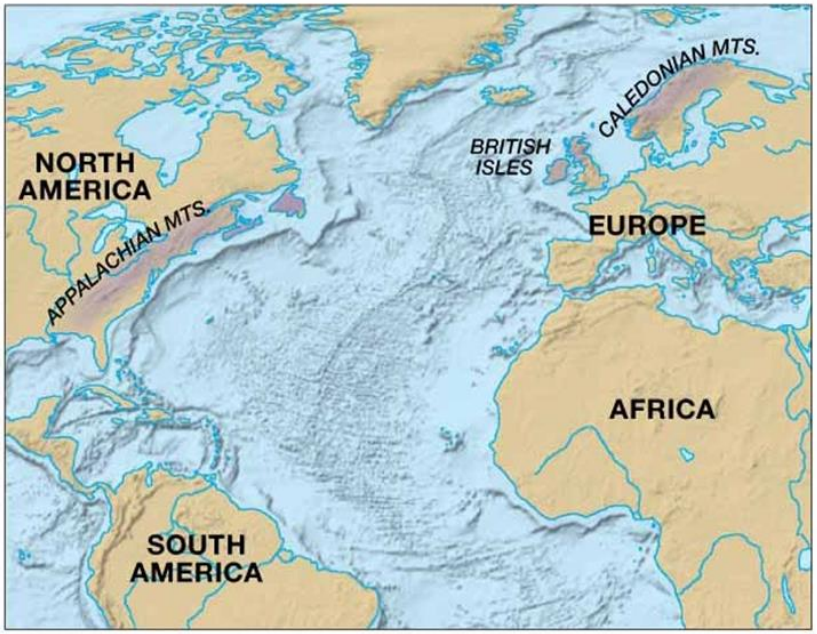




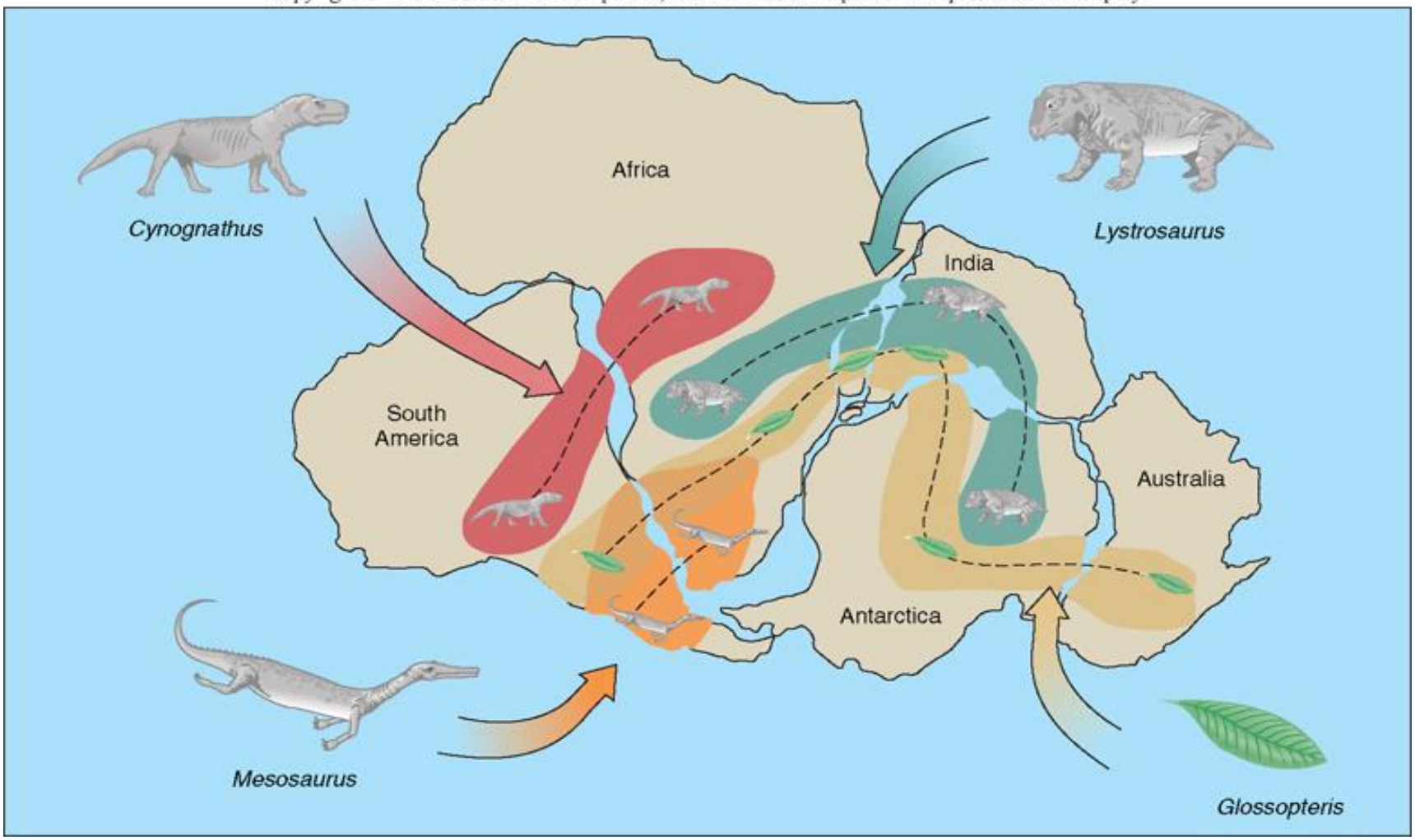
Super-continent before ~ 200 million ago: **Pangaea**

2) similar sequences of rock types, ages, and structures in mountain belts across continents when they are fit together



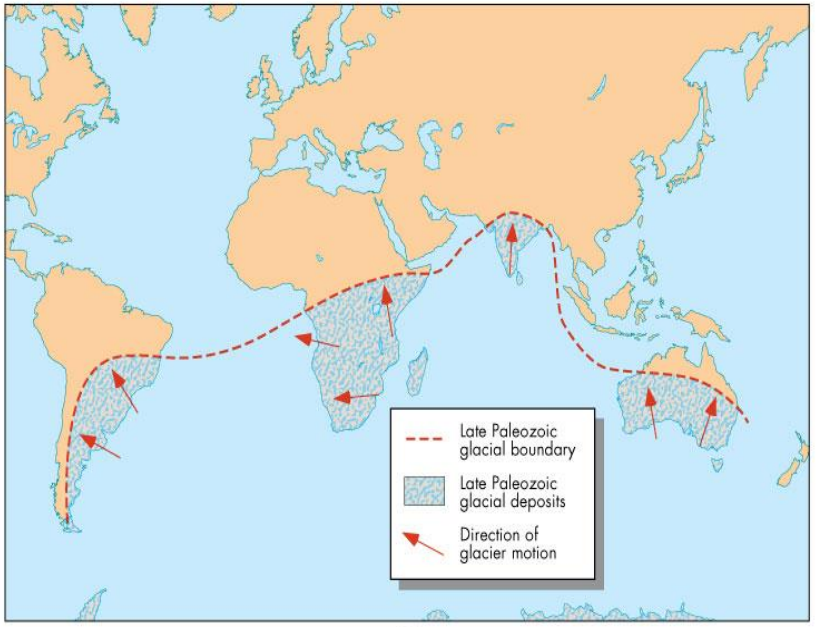


3) Similar fossils across continents when they are fit together

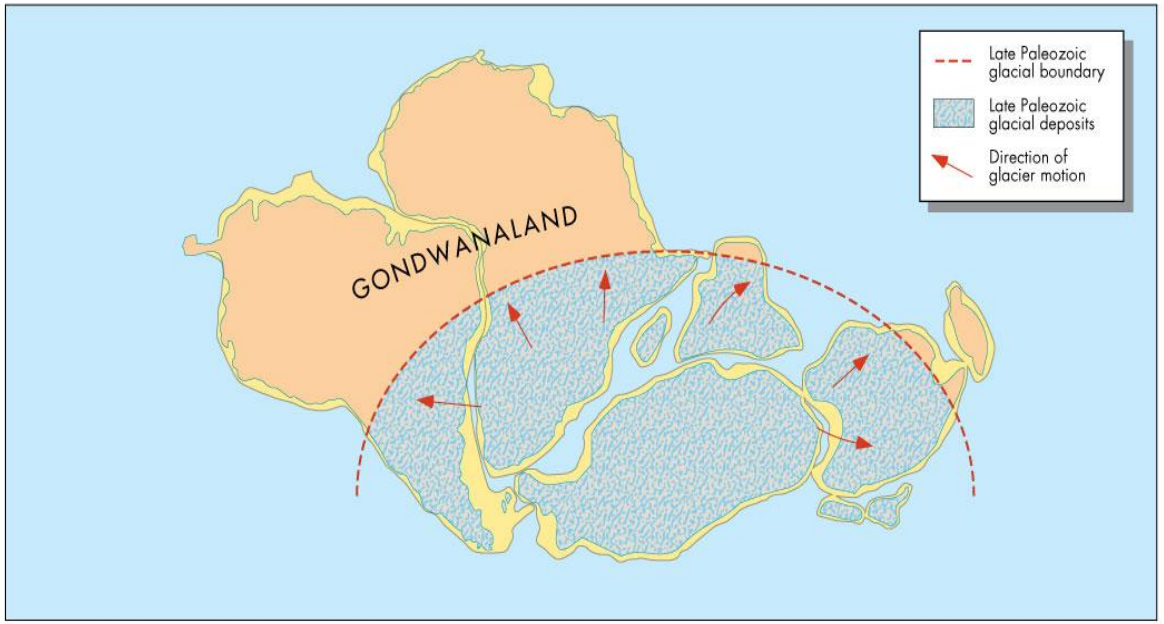


Evidence:

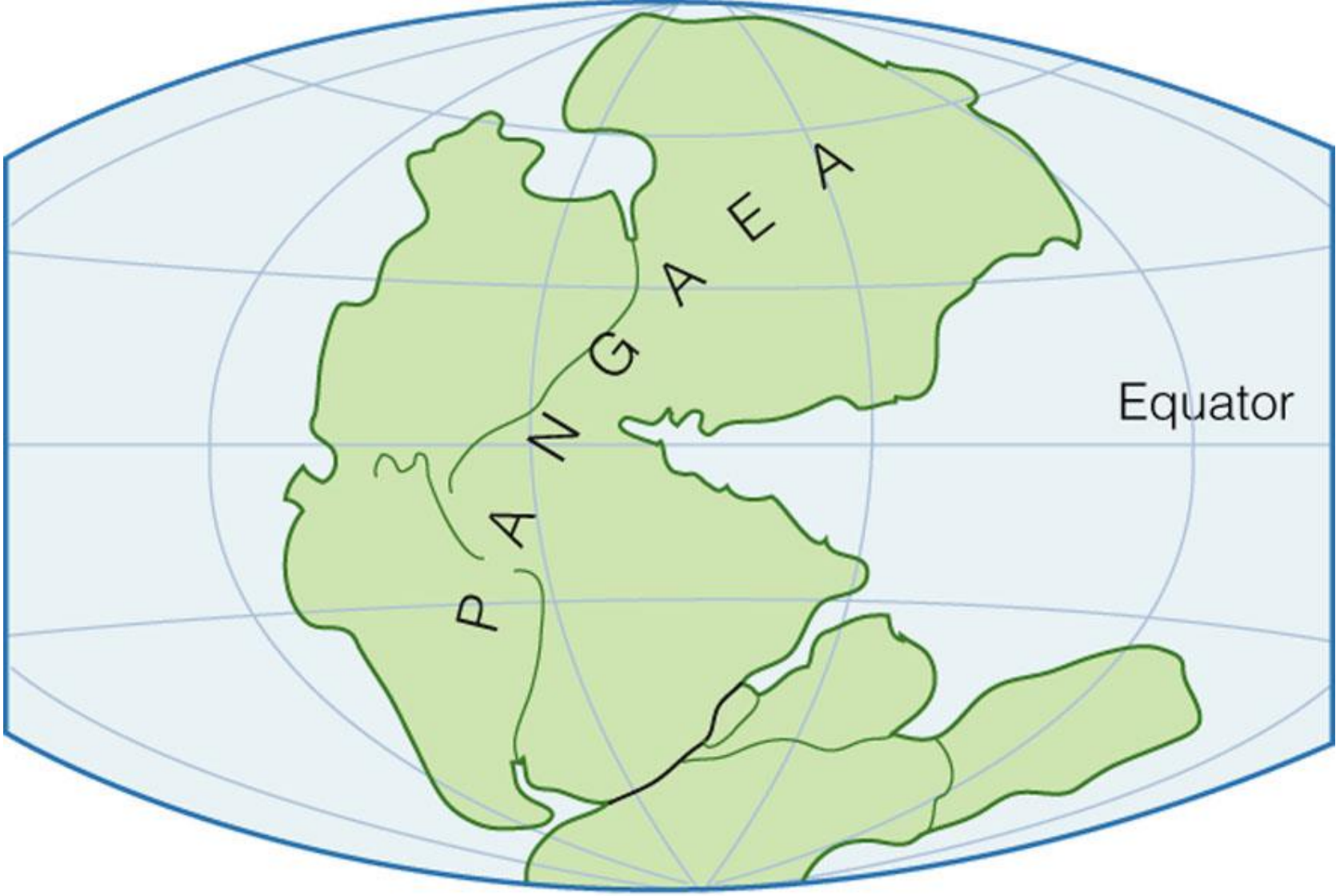
4) Similar paleo-climate condition when continents are fit together



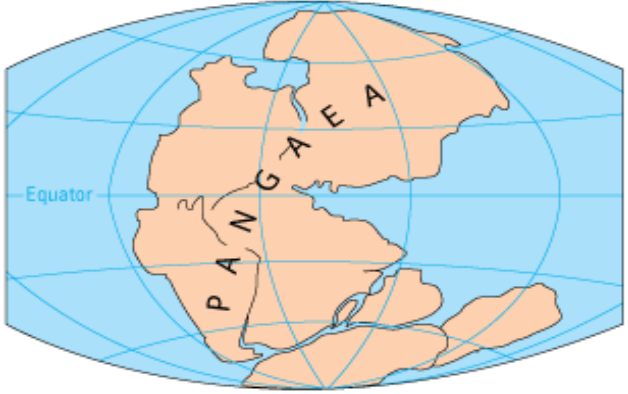
(a)



(b)

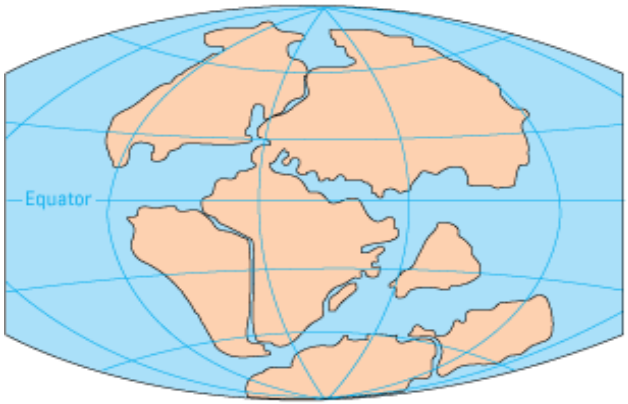


Pangea: supercontient at ~ 225 million ago

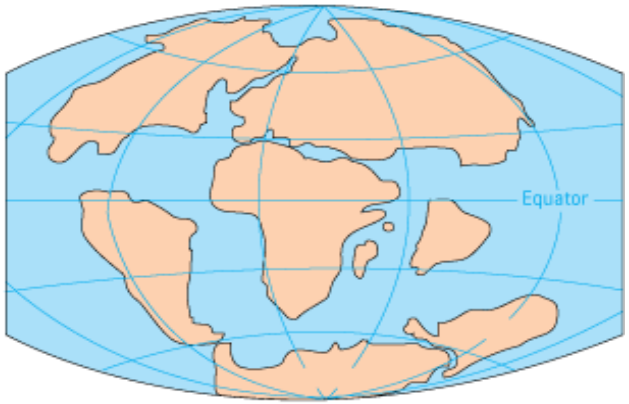


PERMIAN
225 million years ago

TRIASSIC
200 million years ago



JURASSIC
150 million years ago



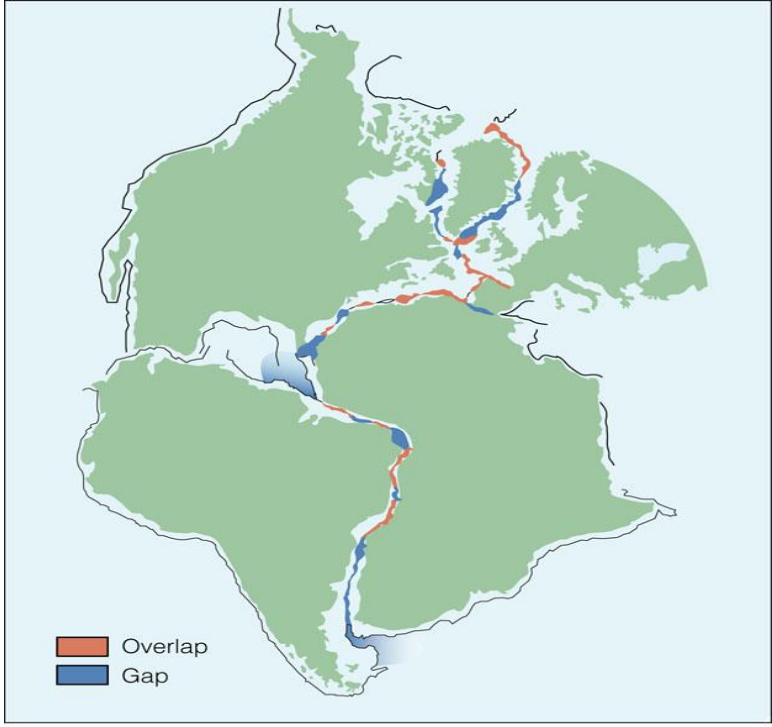
CRETACEOUS
65 million years ago

PRESENT DAY

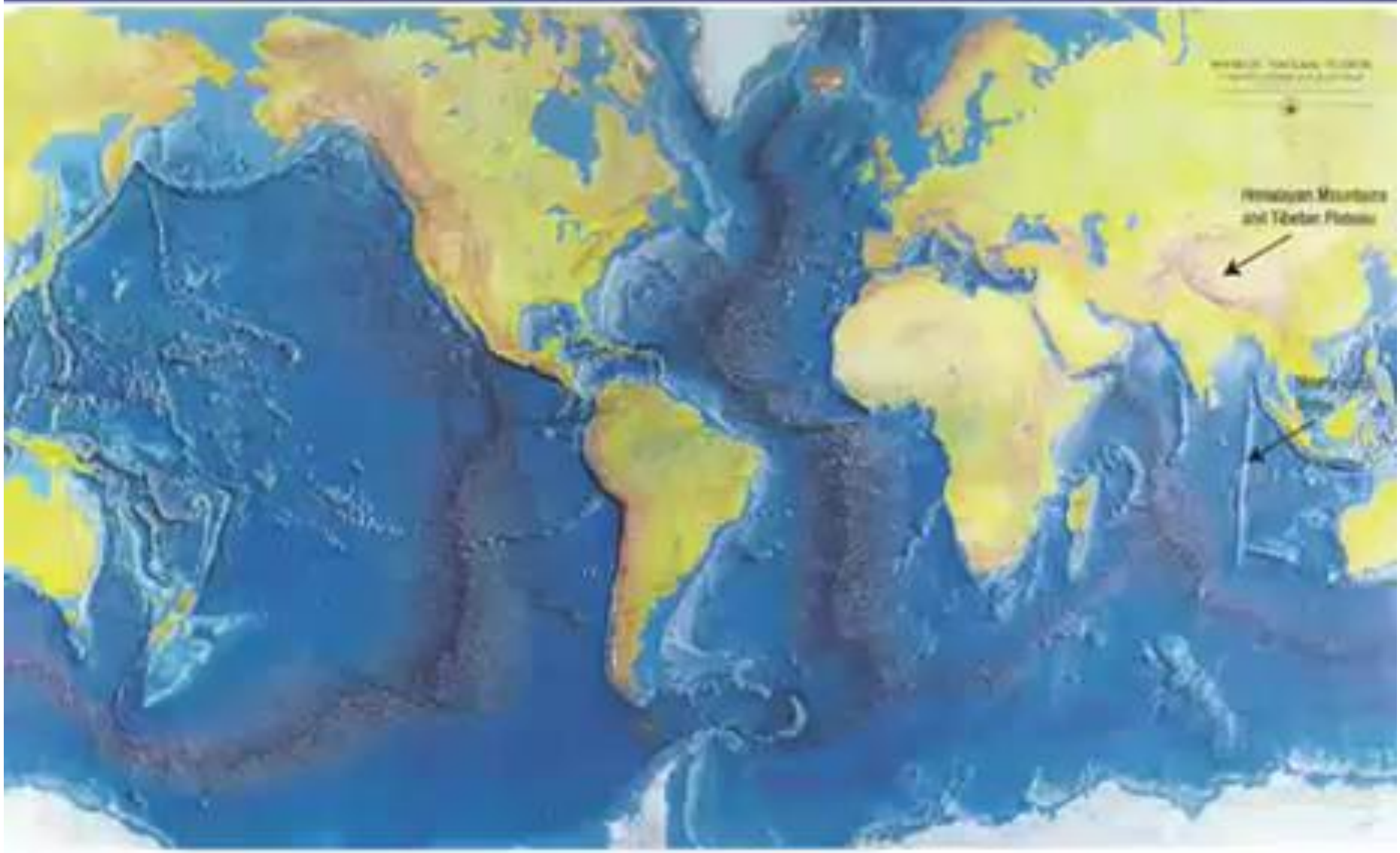
Mechanical problem

: both continental crust and ocean crust are brittle

Continents can't drift over ocean crust without breaking into small pieces



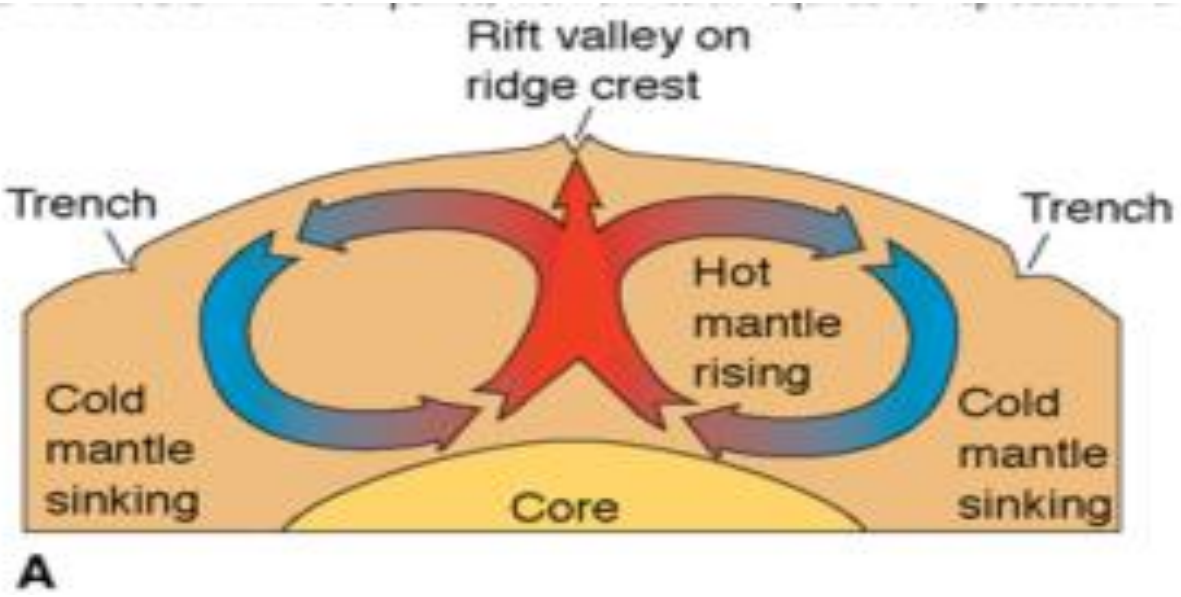
SEA-FLOOR SPREADING

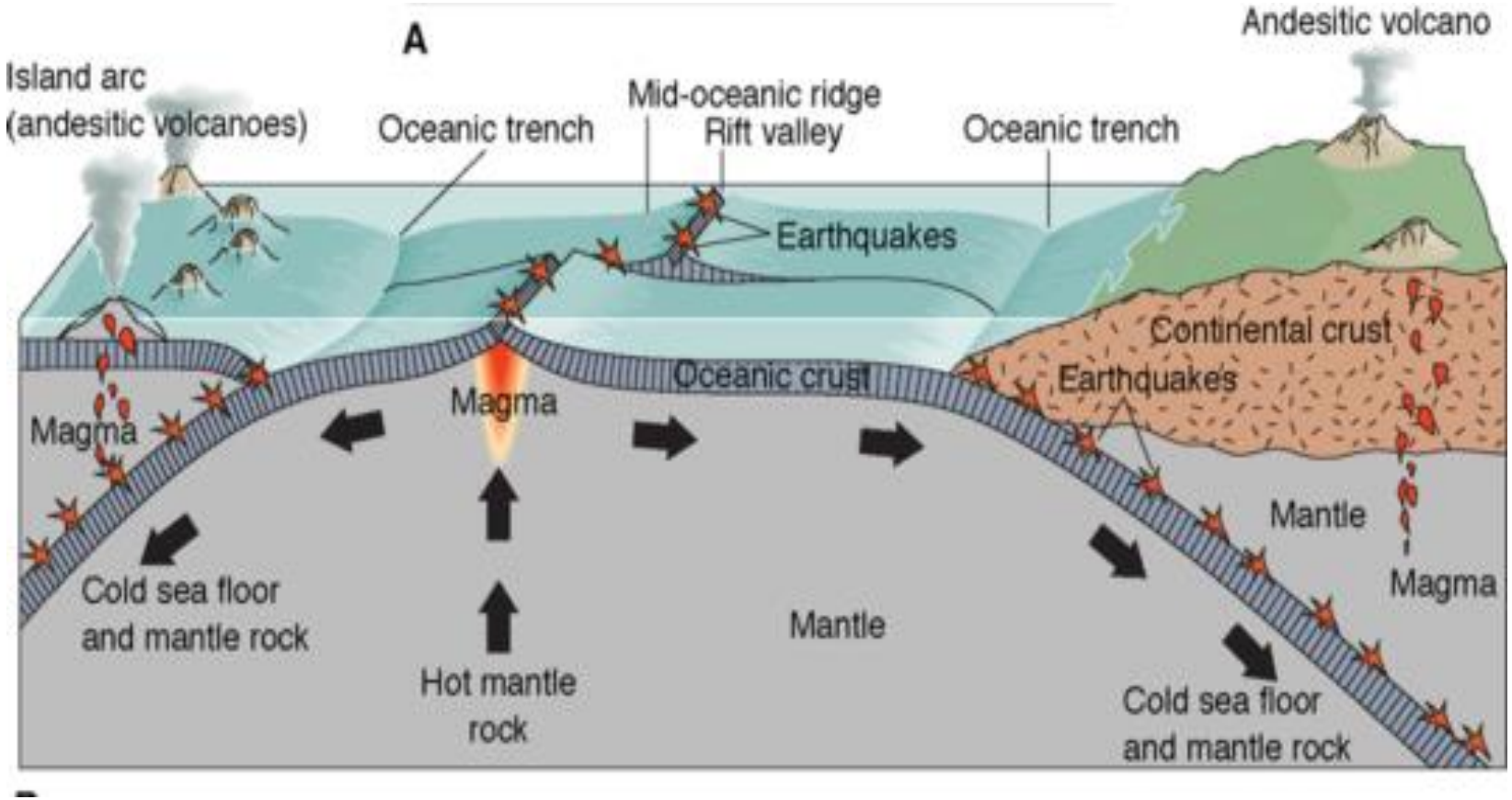


II. Sea-Floor Spreading
(~1962 by Adm. Harry H. Hess)

-- sea-floor is NOT permanent
-- created at mid-ocean ridge (MOR) and spreads away from MOR; then recycled

-- cause by thermal convection of mantle





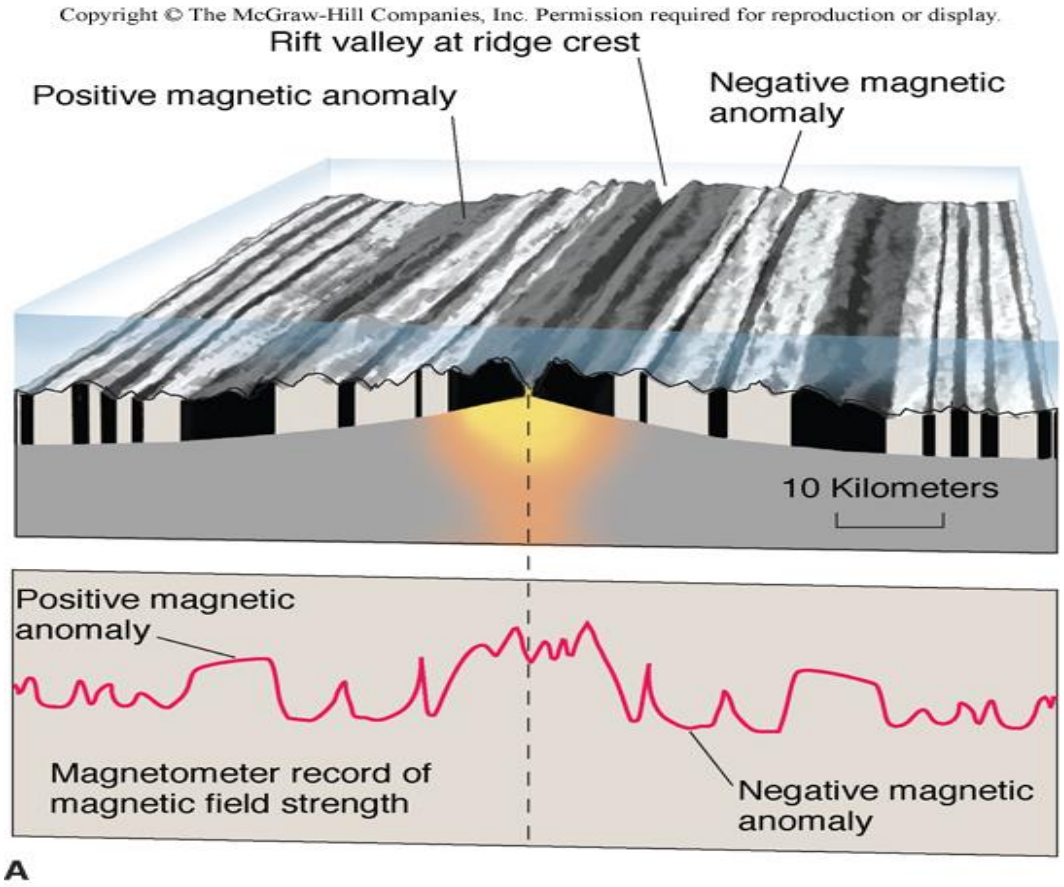
Hess calculated the **spreading rate**: **~ 2.5 cm/year across the Mid-Atlantic Ridge**

If correct, the whole Atlantic Ocean floor would be created in ~ 180 million years ago

Seafloor Spreading

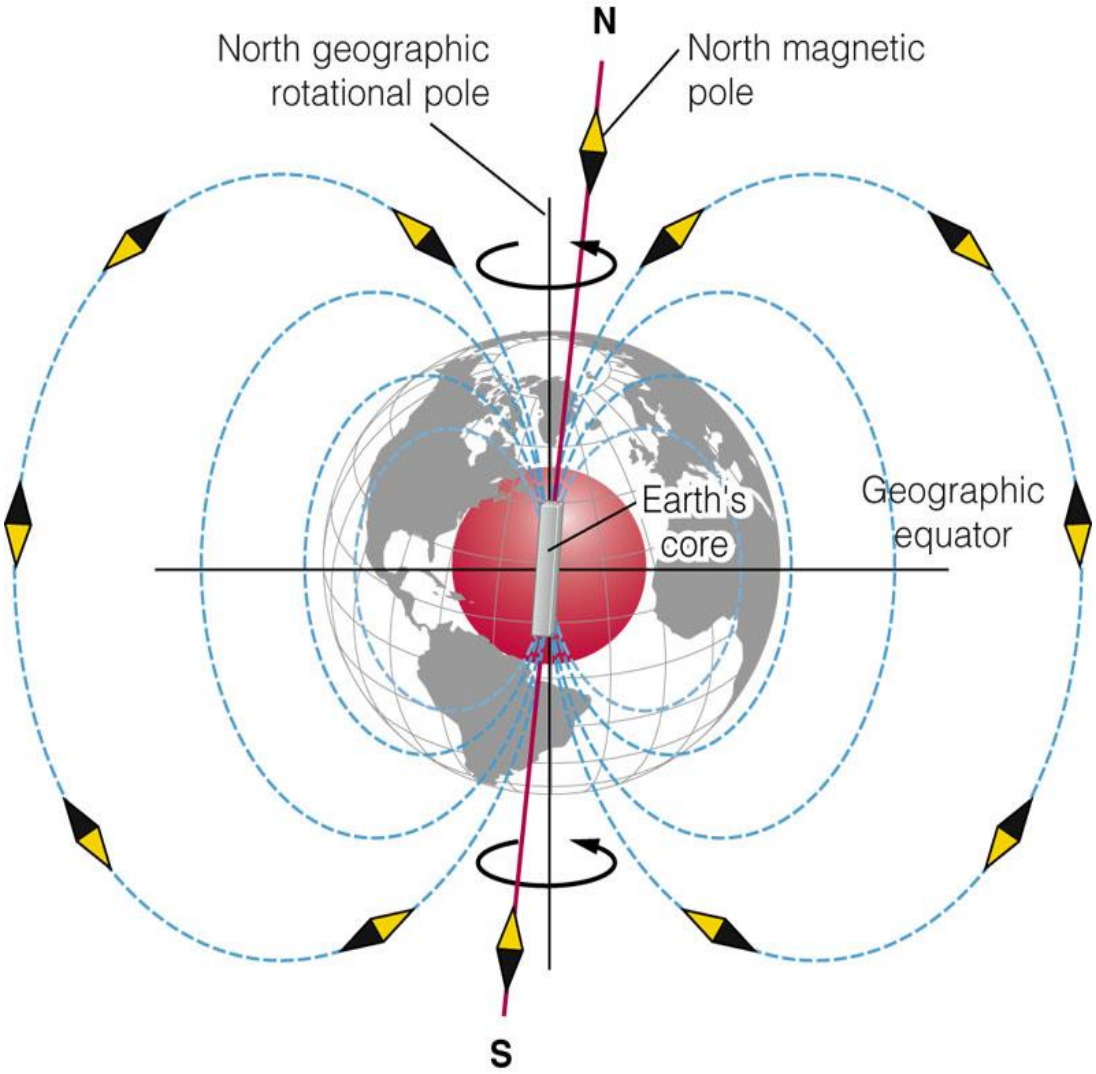
Vine-Matthews' interpretations

Symmetrical magnetic pattern about the ridge crest



Geomagnetism- Earth's magnetic field

: causes by **thermal convection** in **liquid outer core**

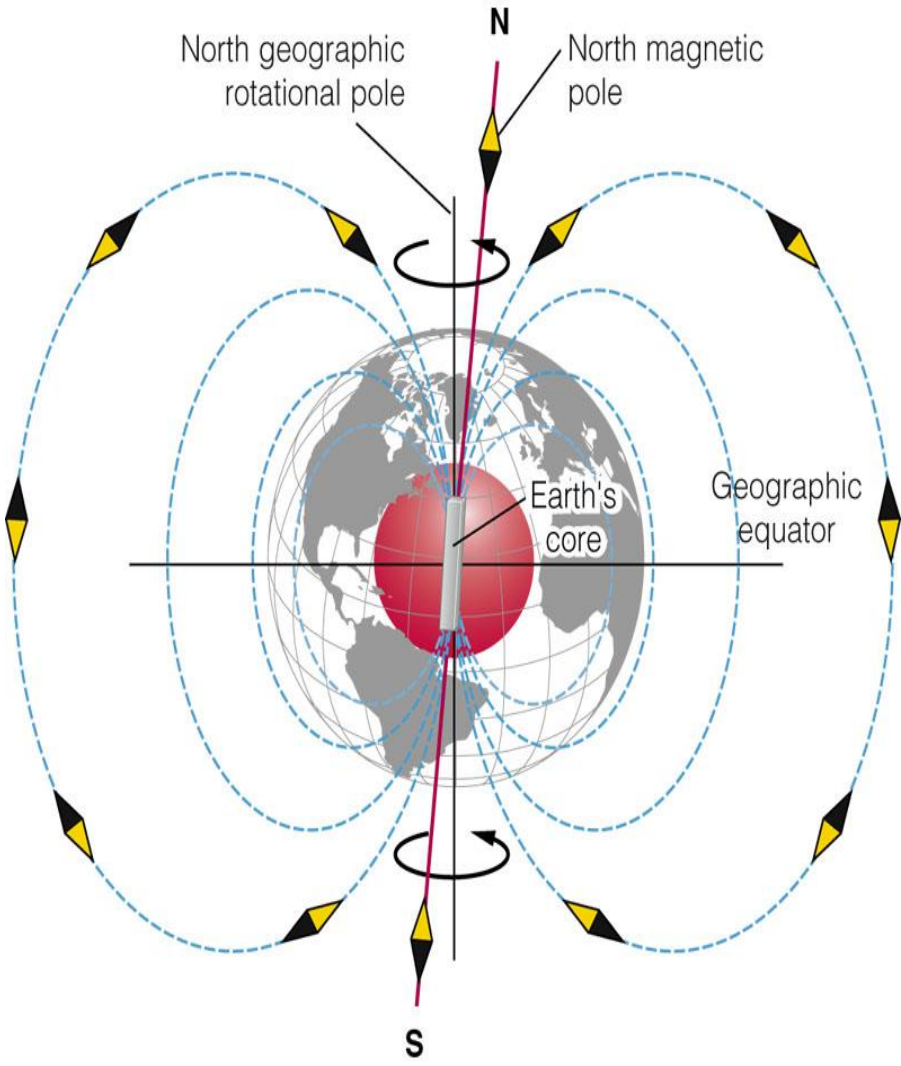


Compass needles // magnetic lines of force

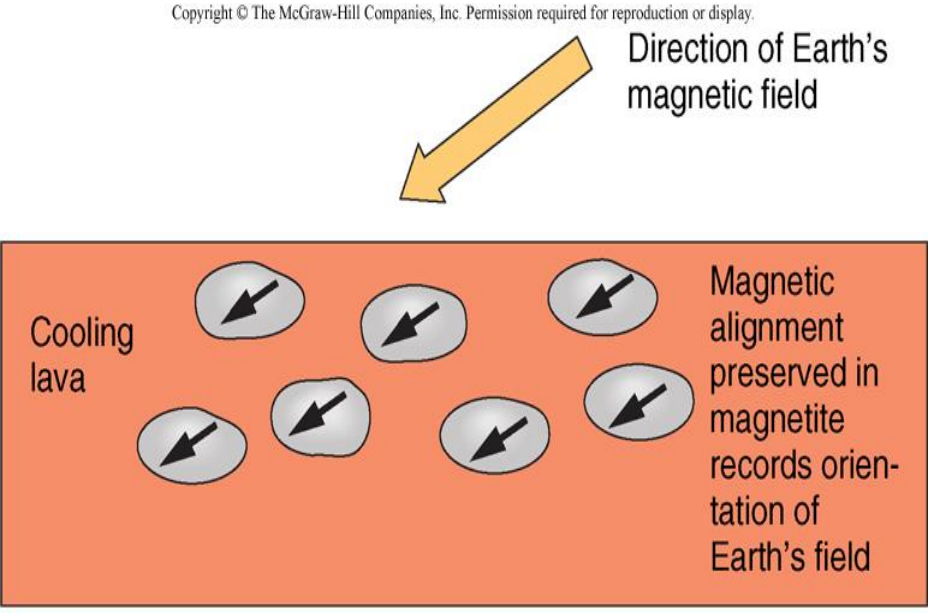
-- horizontal at equator

-- vertical at the geomagnetic poles

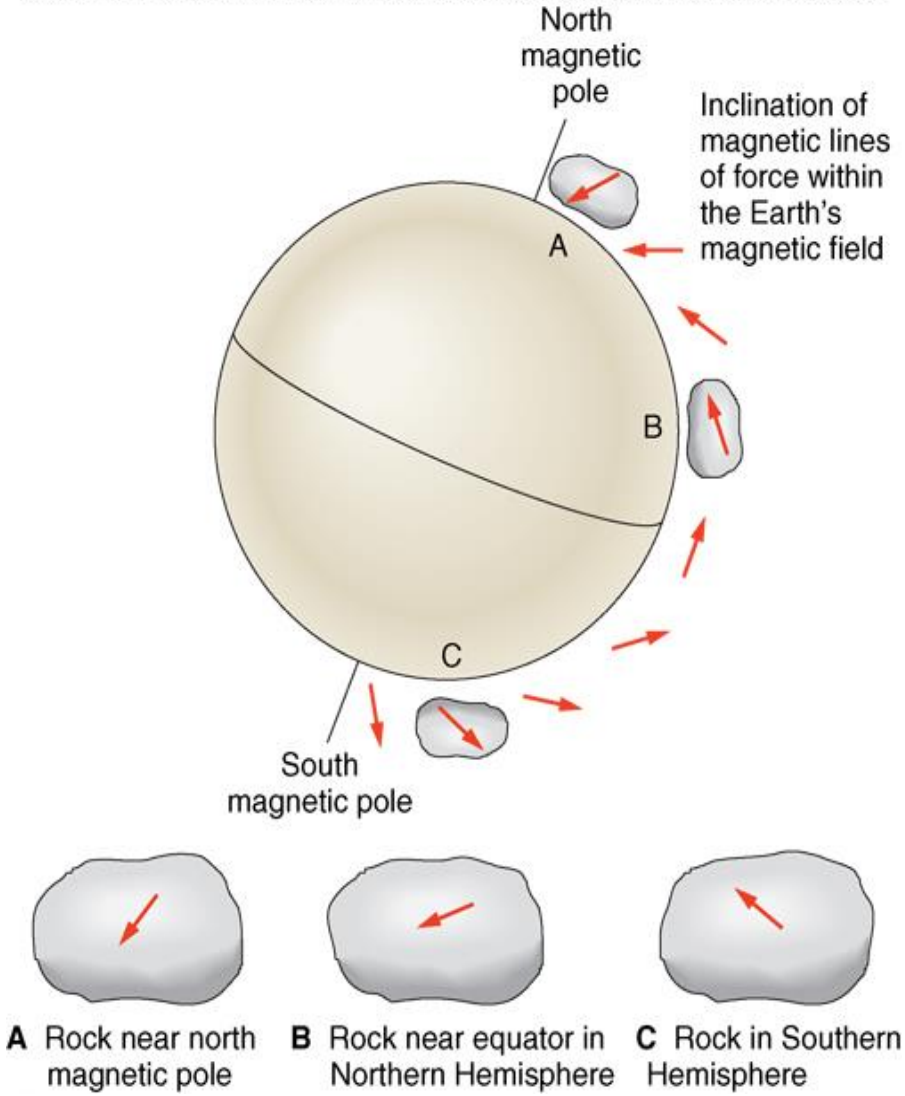
-- angle of magnetic inclination reflects magnetic latitude



Paleomagnetism: magnetic field of the Earth in the PAST preserved by magnetic minerals in rocks

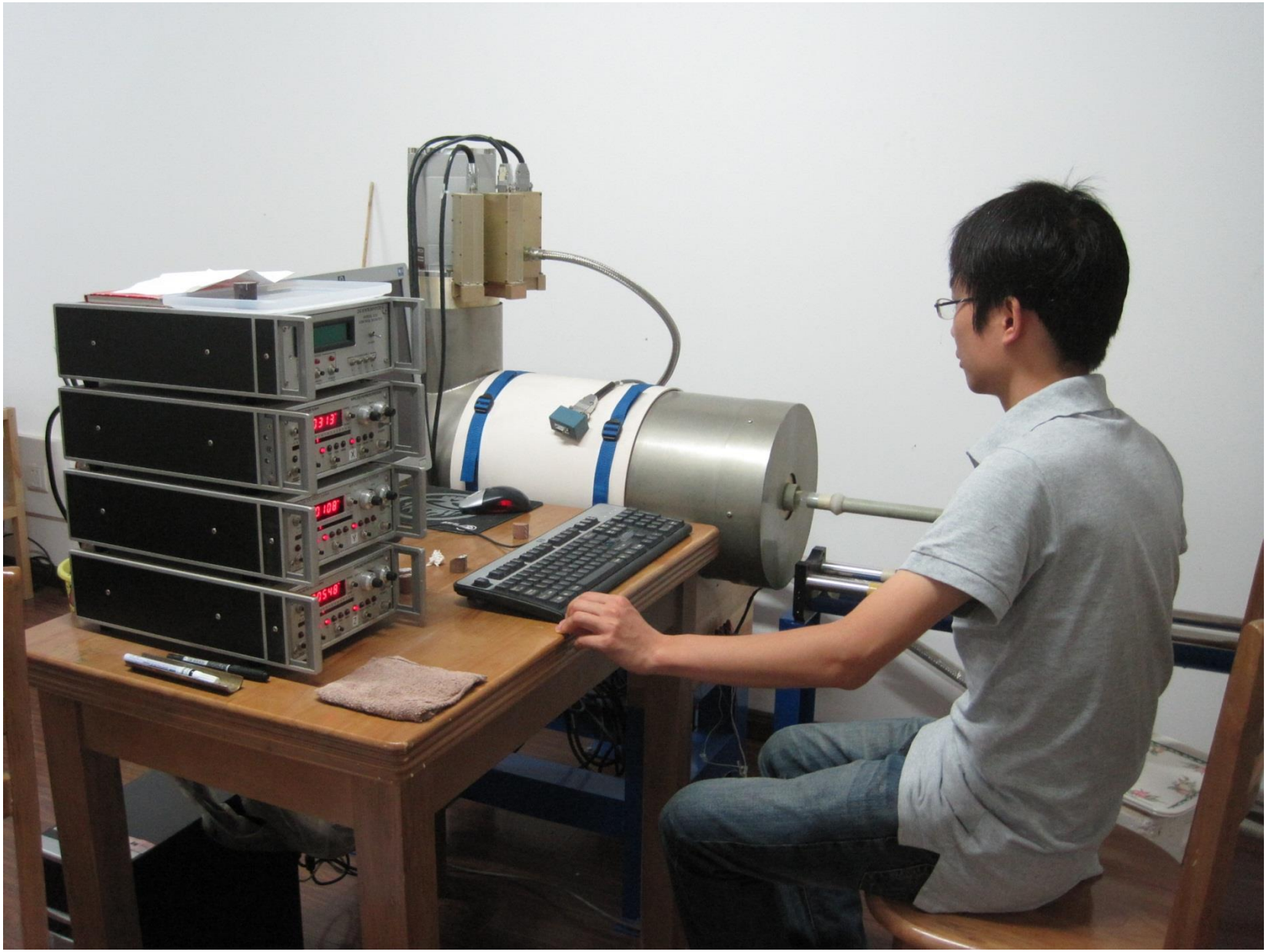


A

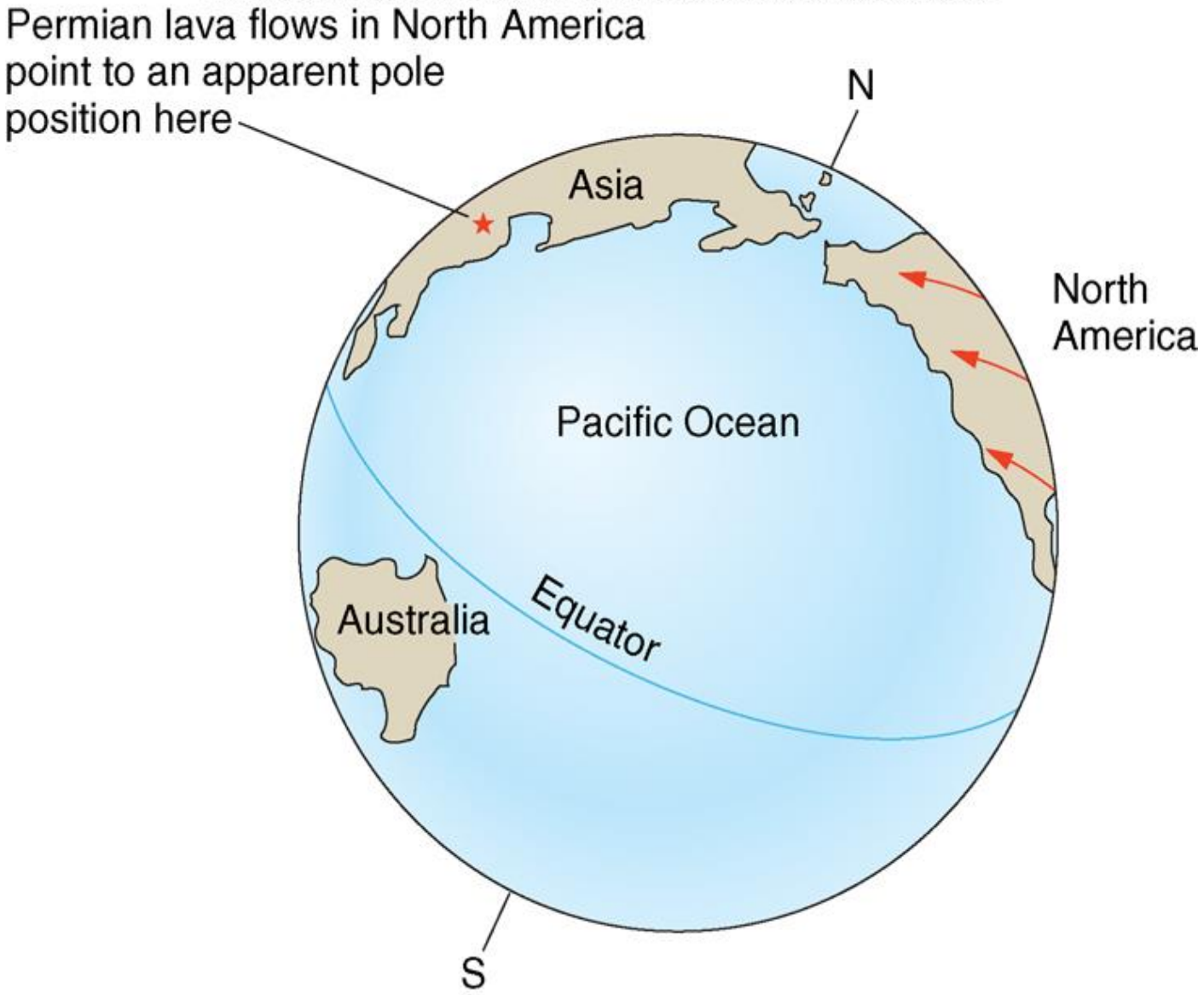


"Magnetic inclination" or "Magnetic dip"

de-magnetization

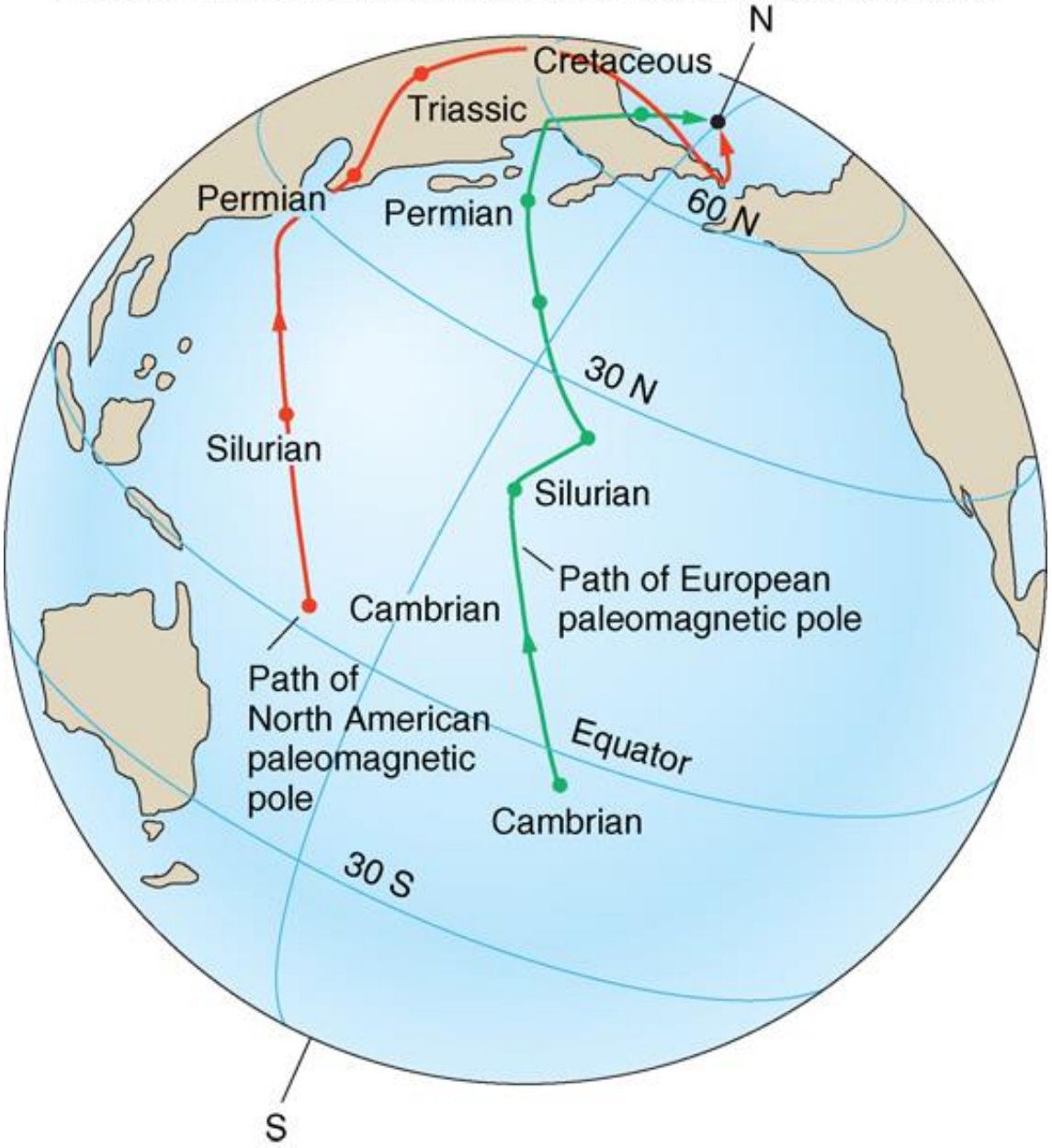


Paleomagnetism study on the locations of the **earth's poles**

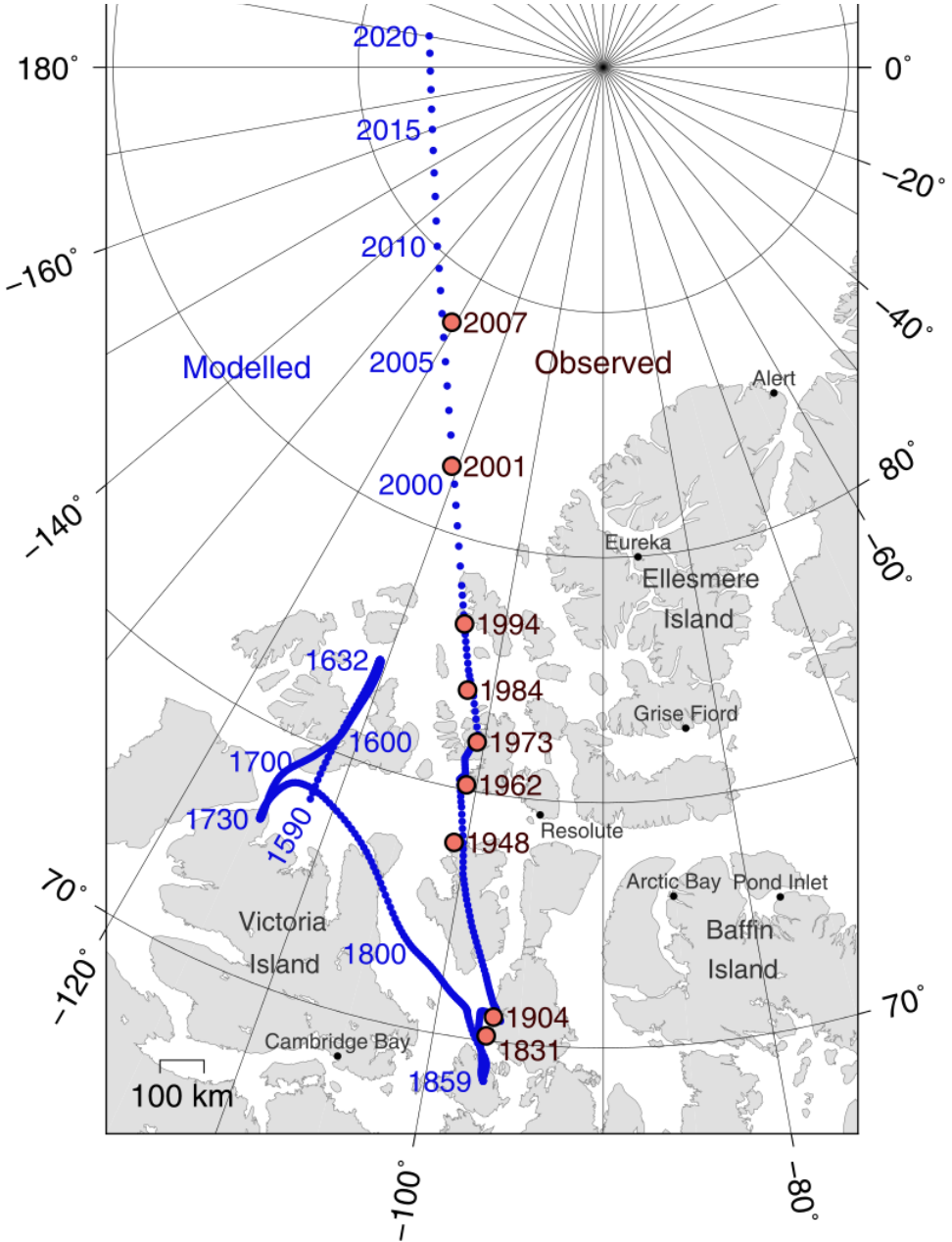


Apparent Polar Wander

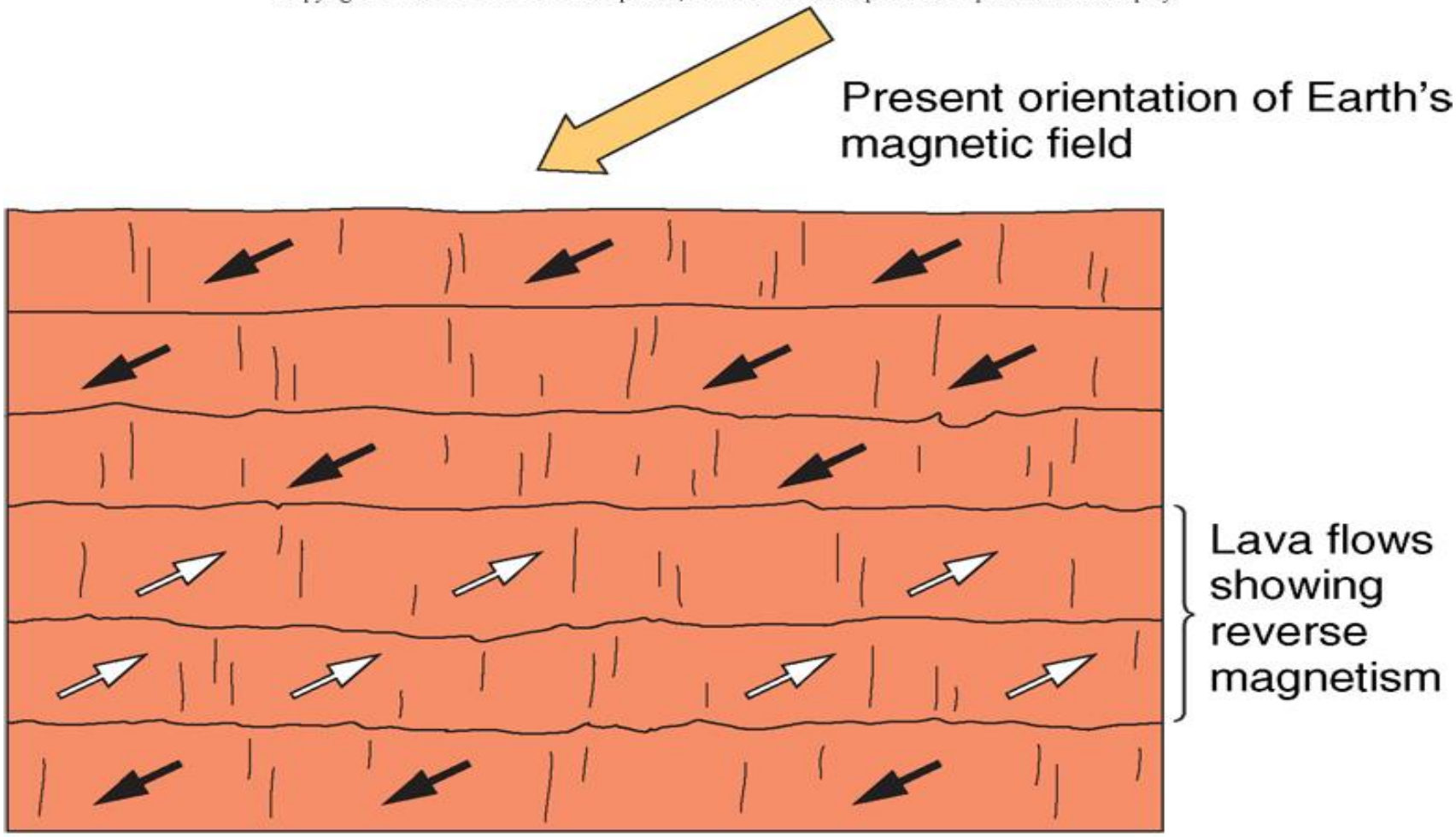
Based on paleomagnetism, the **earth's poles show apparent motions at various paths**



True Polar Wander

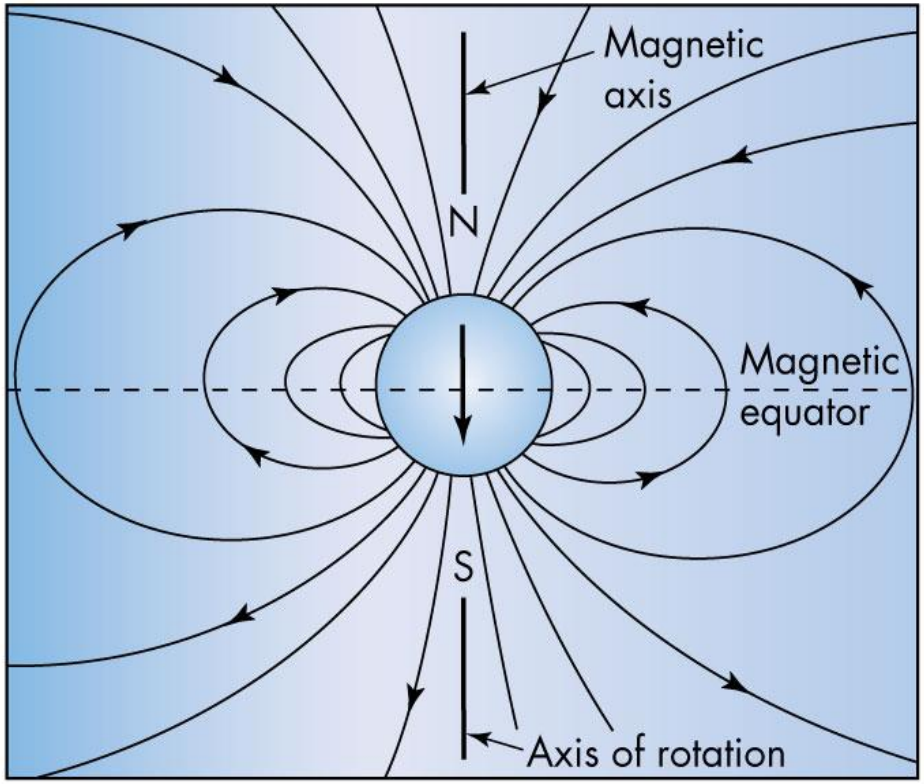


Magnetic reversals: periodic changes in the polarity of the earth's magnetic field

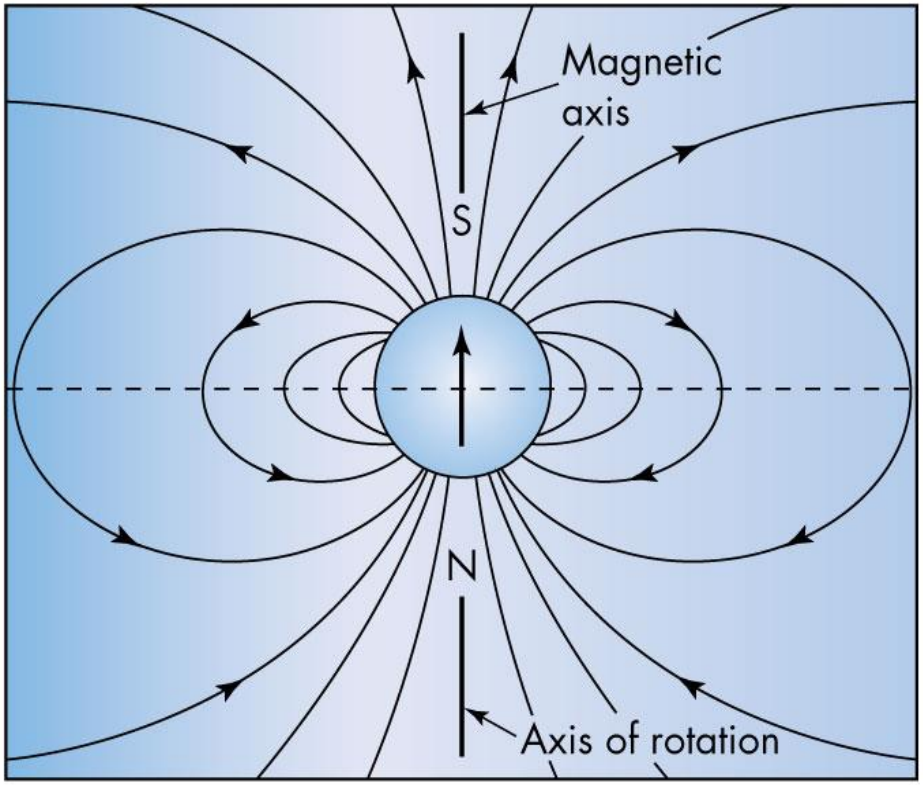


B

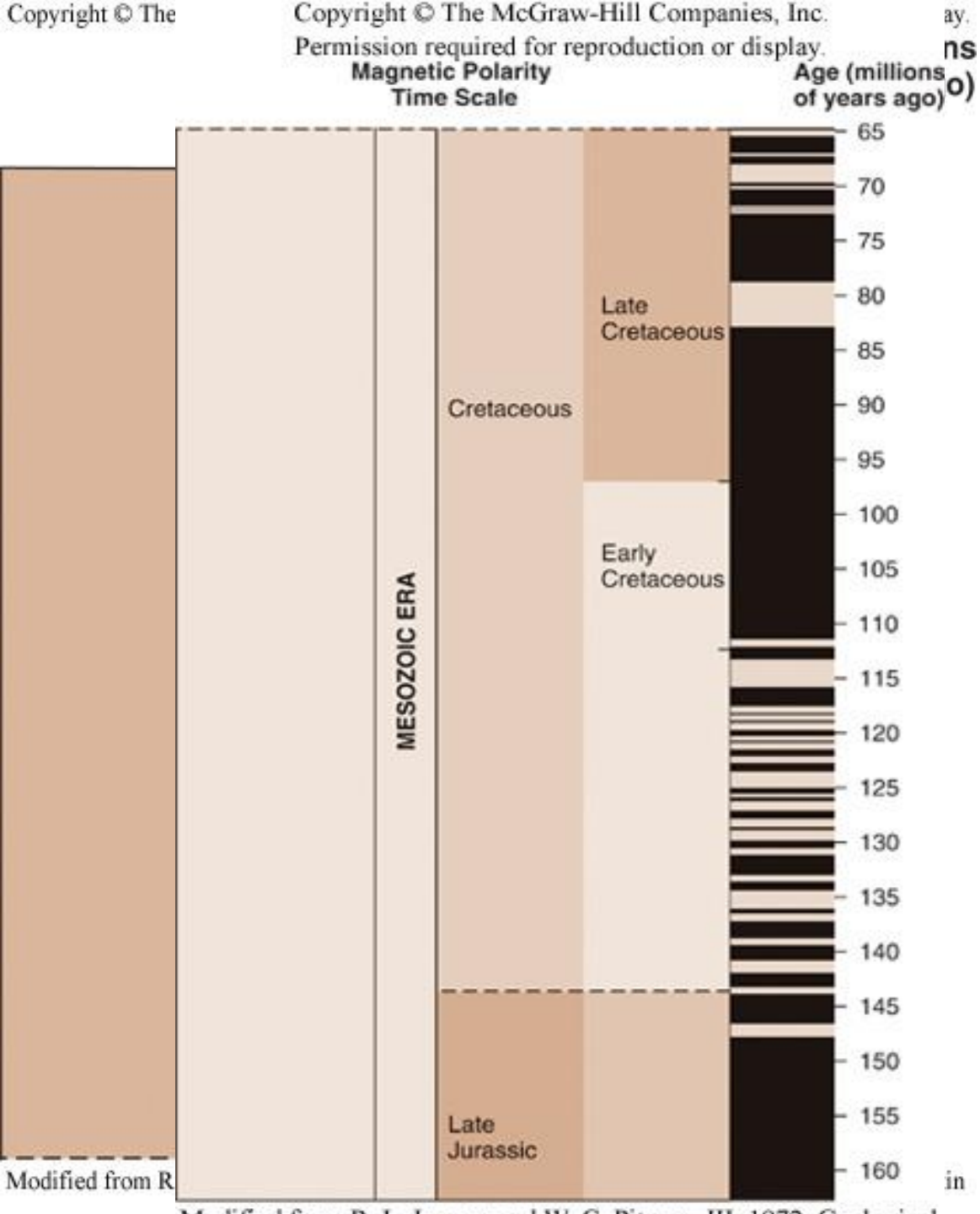
Geomagnetism



(a) Normal polarity



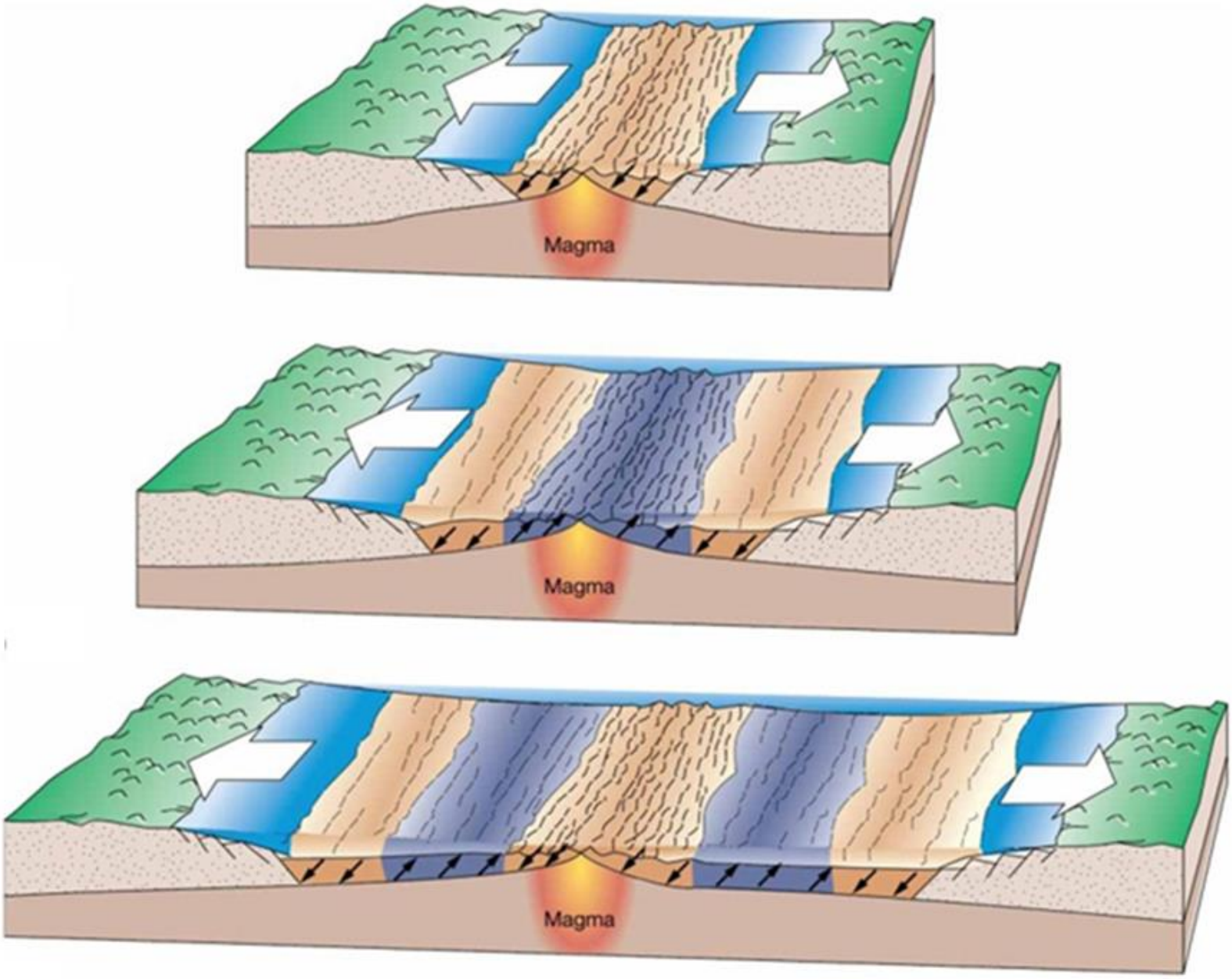
(b) Reversed polarity

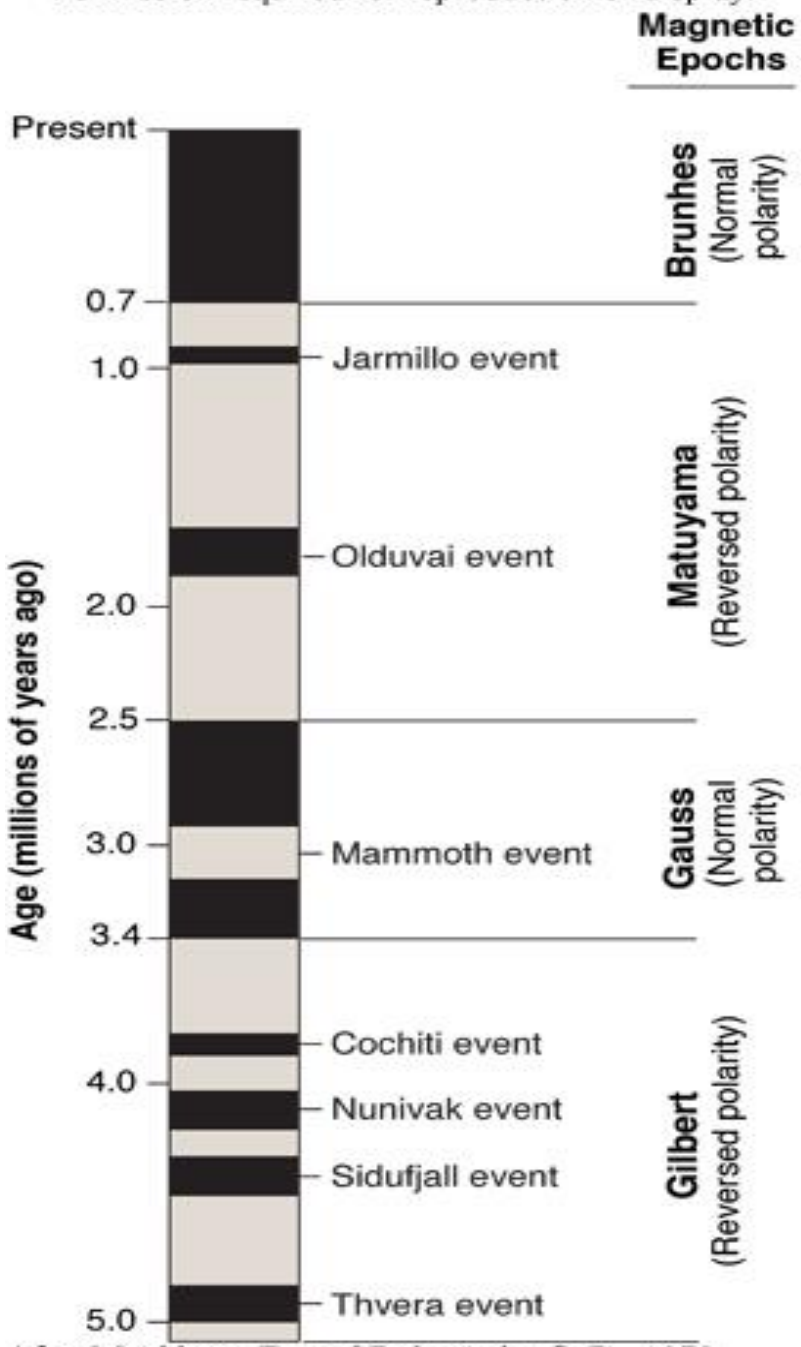


"Magnetic Polarity Time Scale"

Magnetic anomalies of ocean rocks

Patterns of **alternating stripes** of above-average & below average magnetism **around ridge crest**


Magma
Magma
Magma

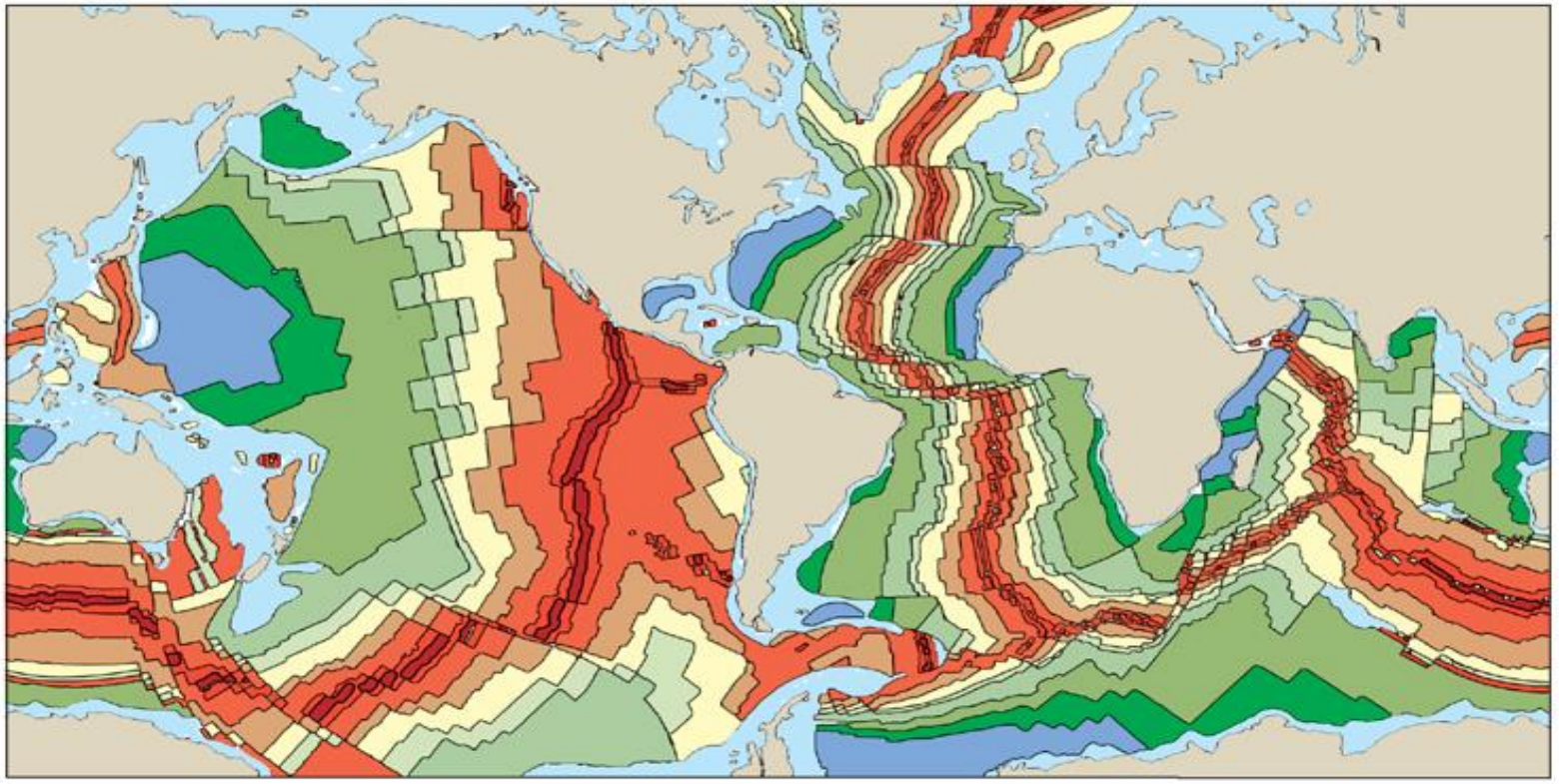


After Mankinen, E., and Dalrymple, G. B., 1979.

Magnetic properties of ocean-floor rocks match the patterns of magnetic reversals known on the continents

-- can be used to **determine the age of the ocean floor**
(age: 0 **to ~200 my**)

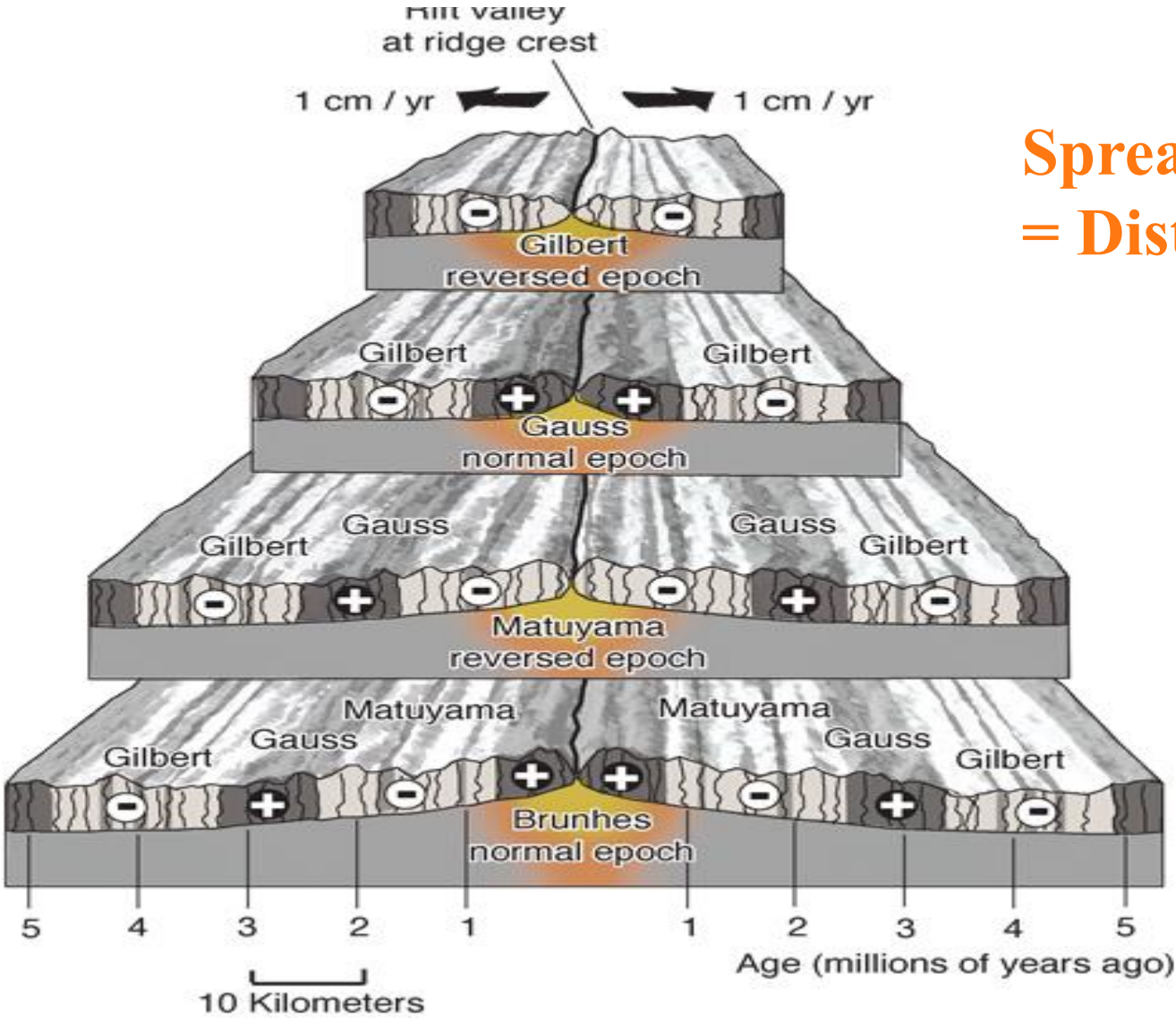
-- age of the sea floor become **older toward the trench**



After The Bedrock Geology of the World by R. L. Larson, W. C. Pitman, III, et al., W. H. Freeman

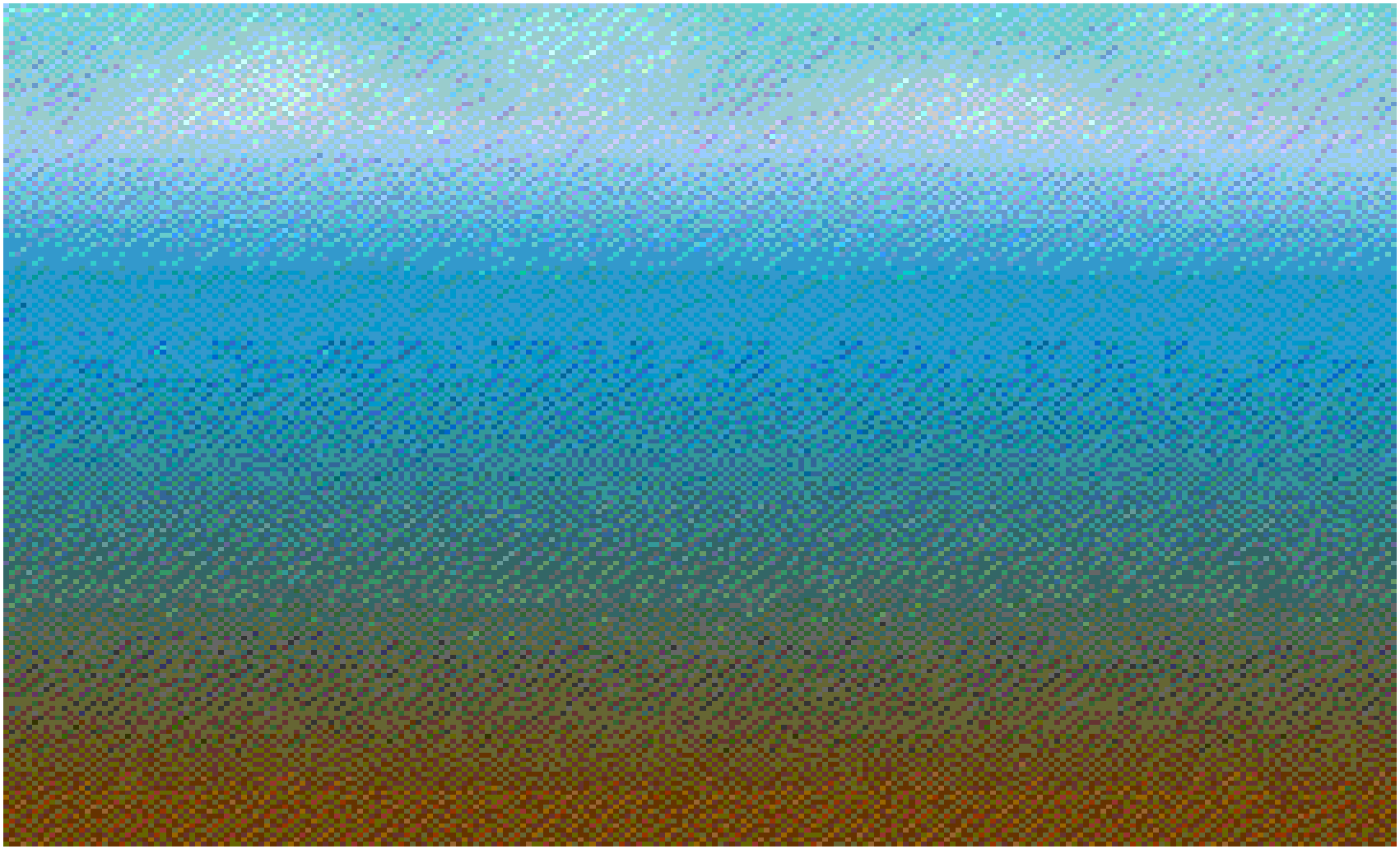
-- can **calculate spreading rate**

Sea-floor spreading rate: **a few cm/year**



Spreading Rate
= Distance/Age

Magnometer



Magnetic reversal

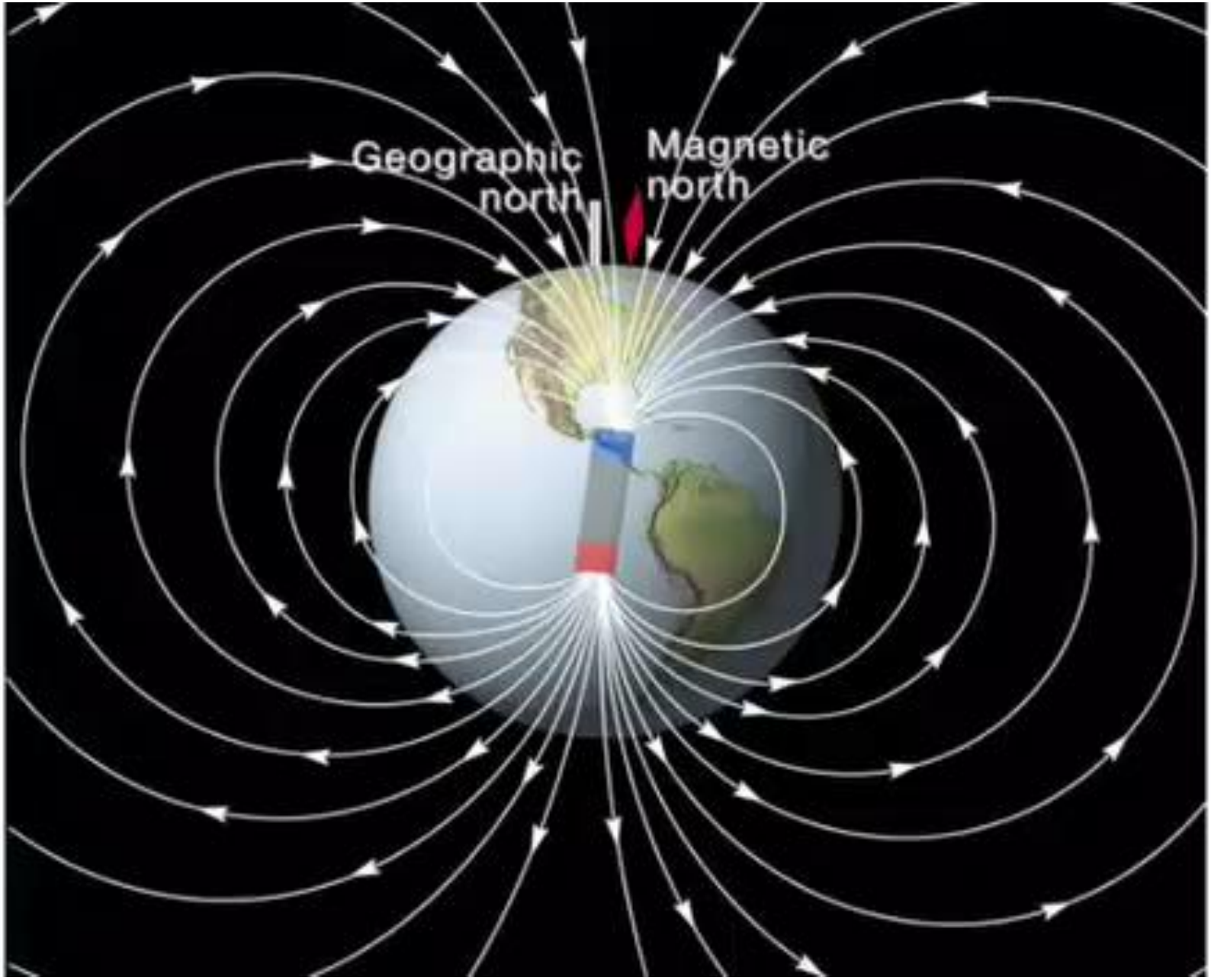
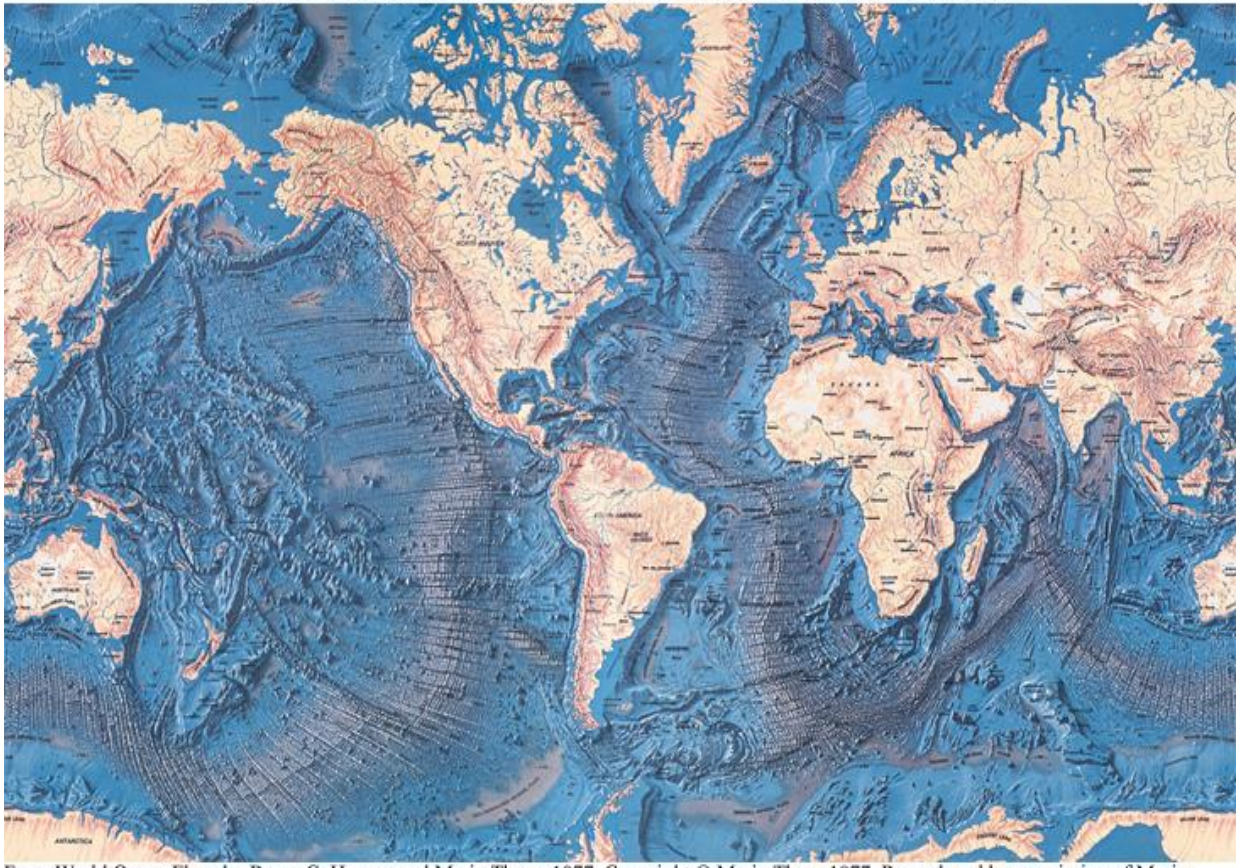

Geographic north
Magnetic north

Plate Tectonics



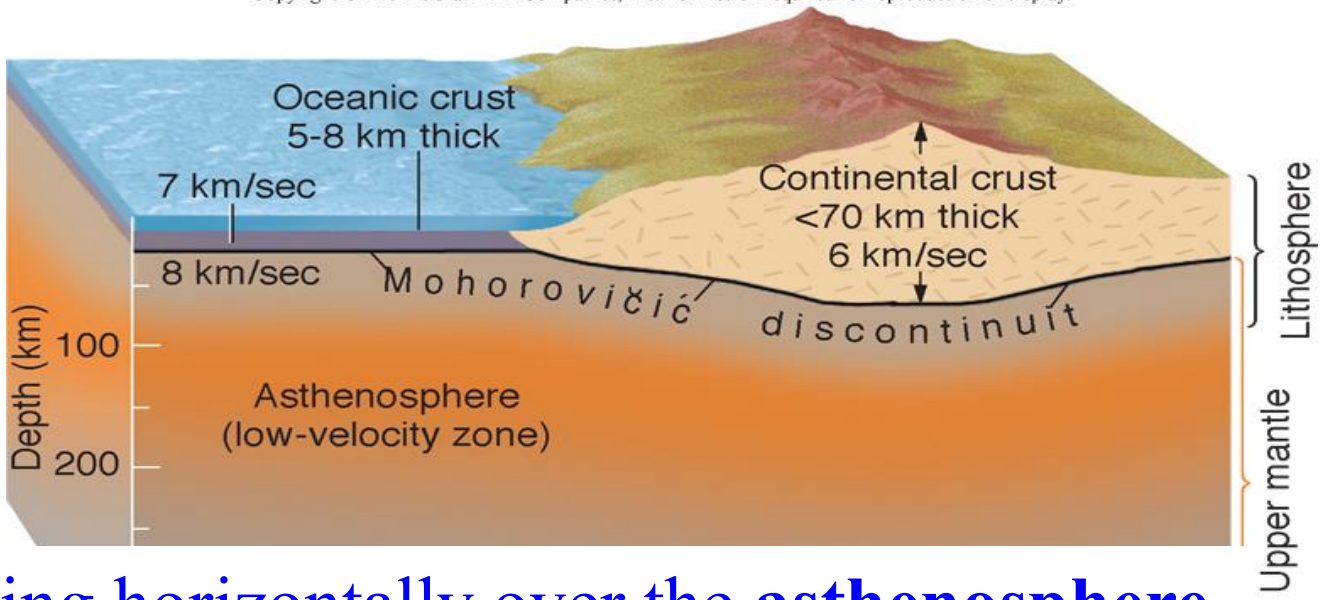
From World Ocean Floor by Bruce C. Heezen and Marie Tharp, 1977. Copyright © Marie Tharp 1977. Reproduced by permission of Marie Tharp, 1 Washington Ave., South Nyack, NY 10960

Plate Tectonics

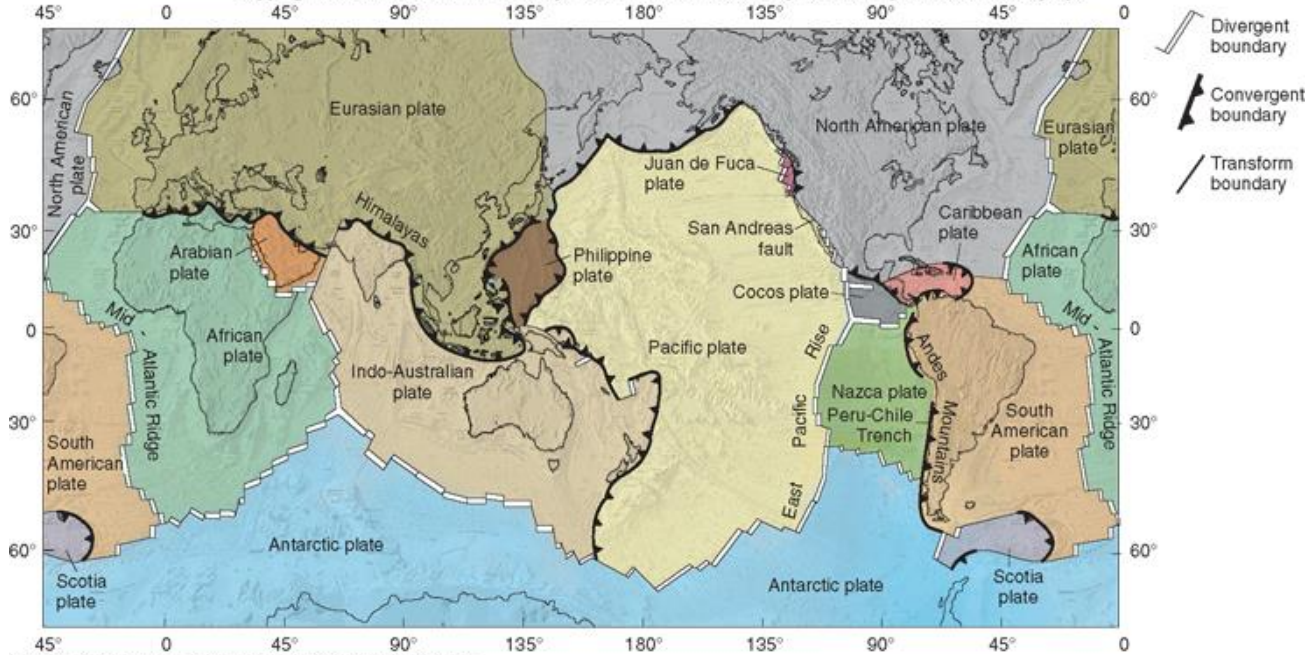
Tectonics: from Greek "tekton" --> "builder"

Plates: large, rigid, mobile segments of the **lithosphere**

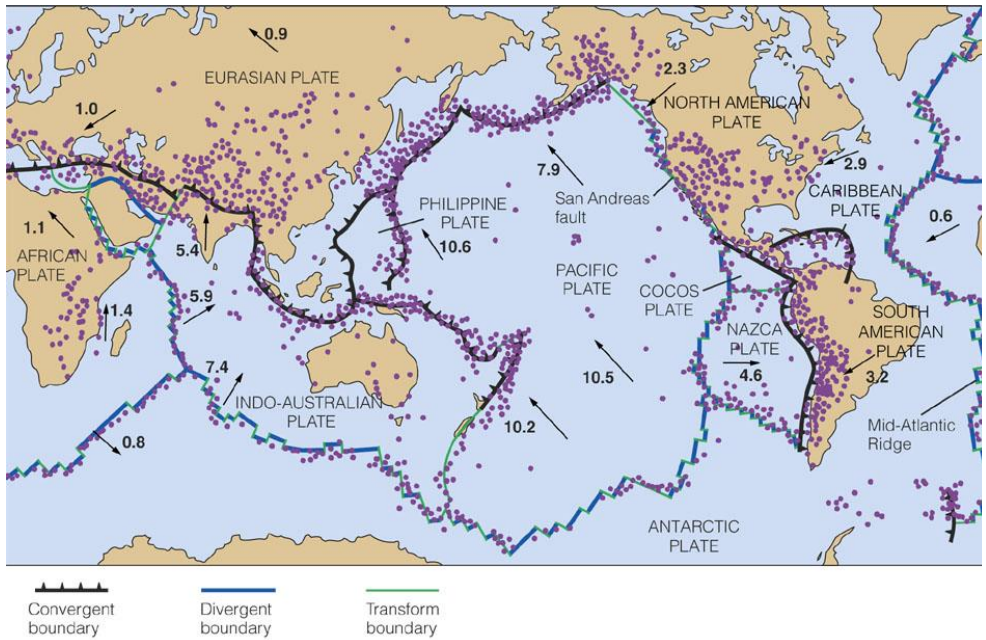
Plate Tectonics: study the movement & deformation of tectonic plates

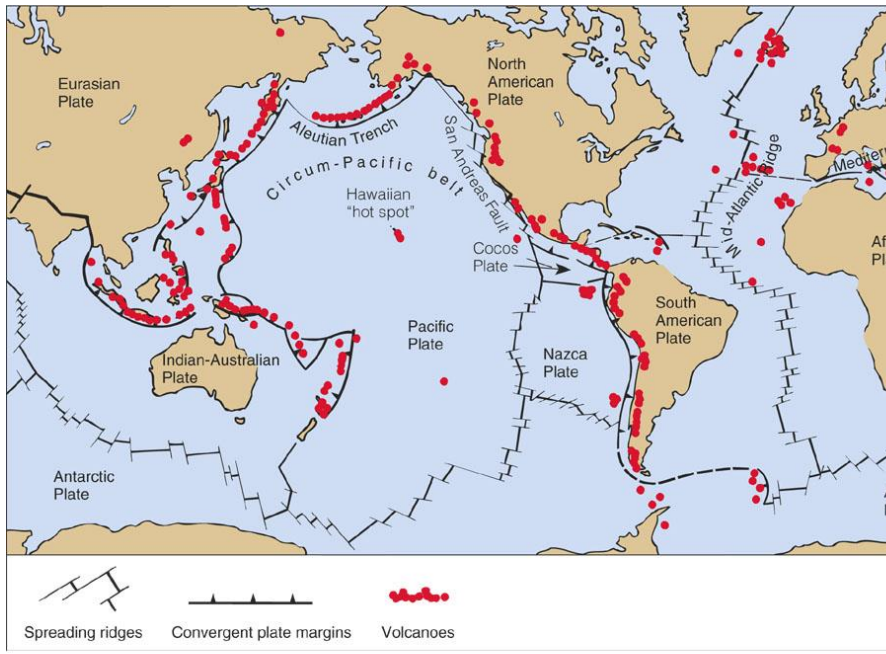


- **lithosphere** moving horizontally over the **asthenosphere**



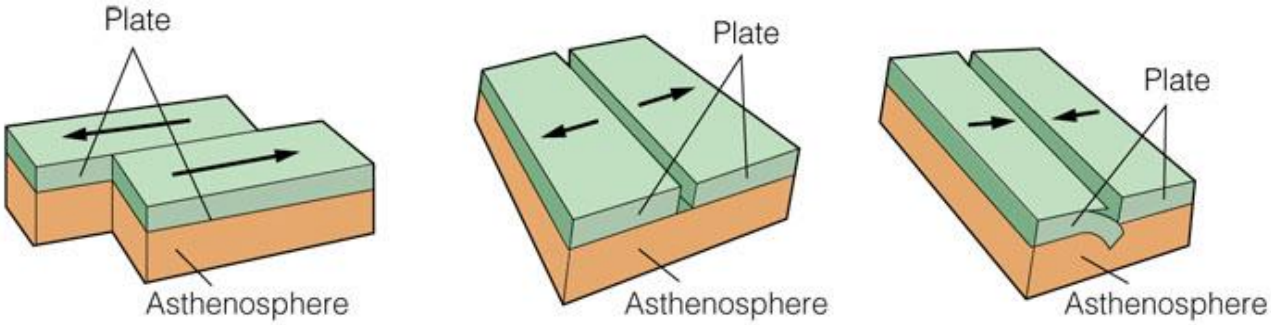
Modified from W. Hamilton, U.S. Geological Survey





© 2006 Brooks/Cole - Thomson

Types of Plate Boundaries



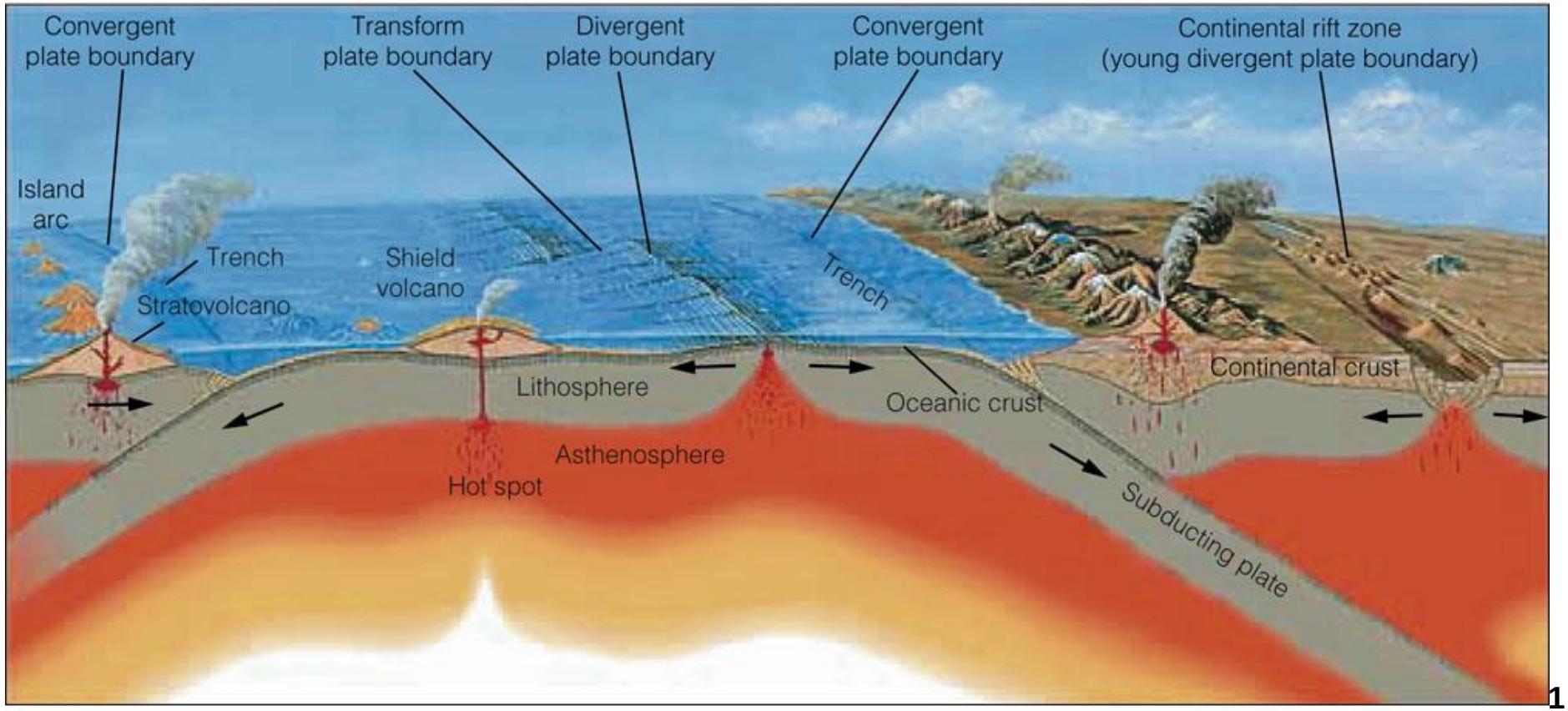


Plate Boundaries: Convergent, Divergent, and Transform Boundaries

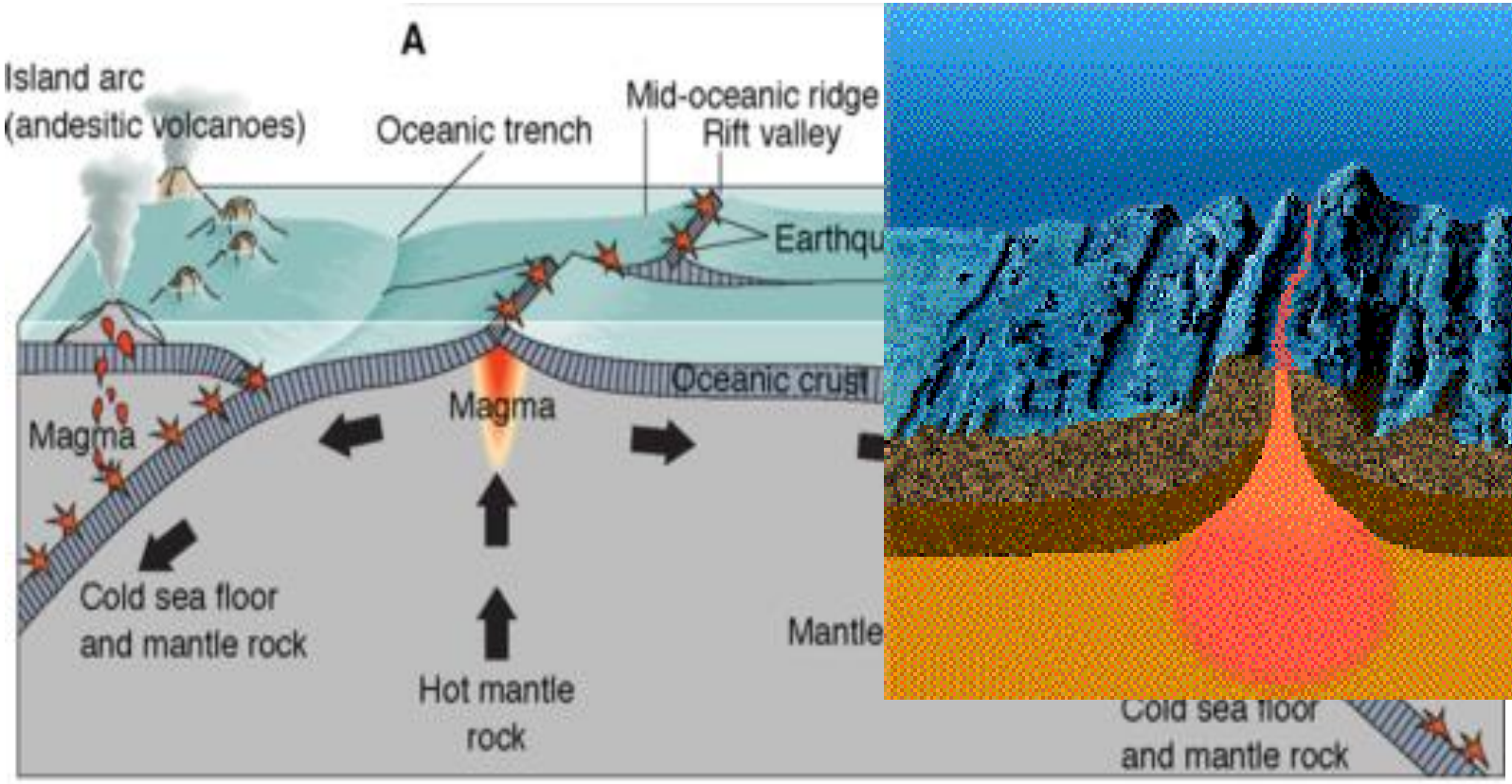
Types of Plate Boundaries

1) **Divergent plate boundaries**

: 2 plates move apart from each other

tensional forces; normal faults

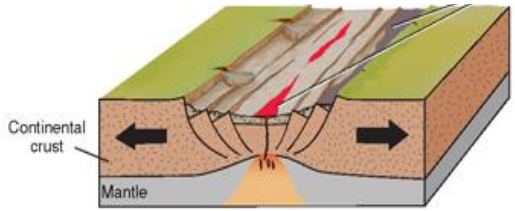
e.g., **Mid-ocean ridge (spreading center)**



Divergent plate boundaries

Continental Rift

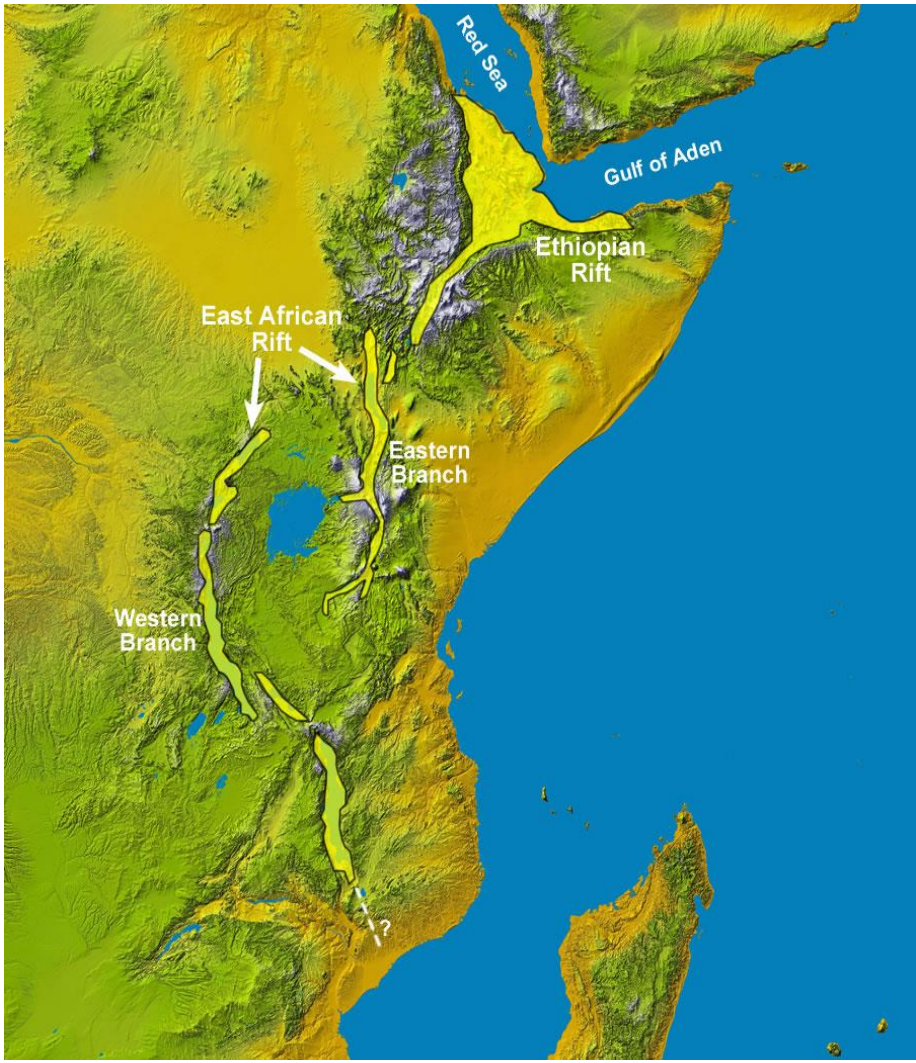
- Normal faults
- Breaking up of a continent
- Thinning of continental crust



A Continent undergoes extension. The crust is thinned and a rift valley forms.

a) Rifting stage

e.g., **East African Rift Valley**

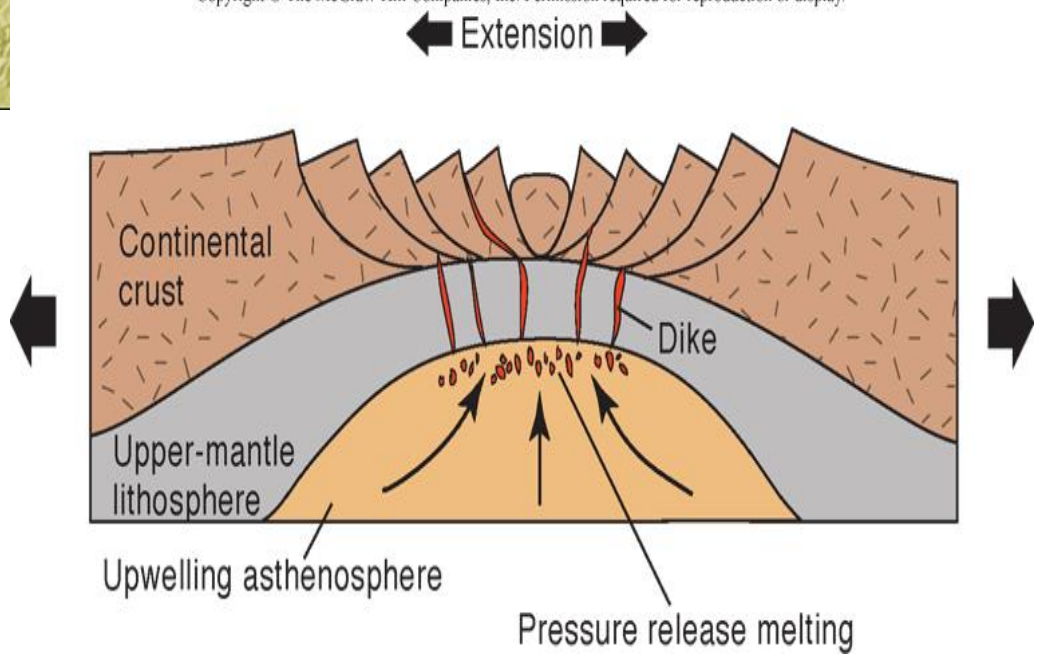


Continental rift

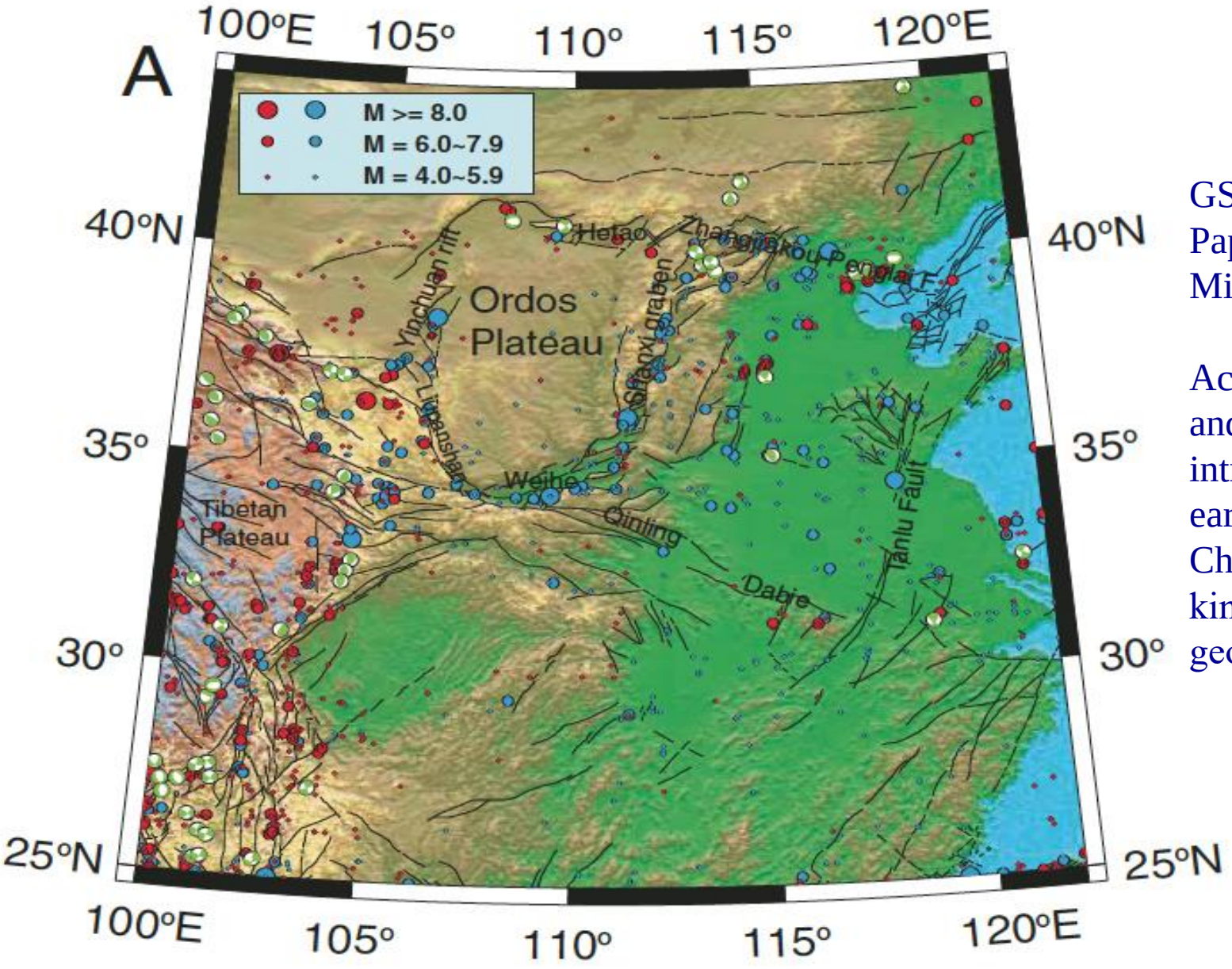
e.g.,

Basin and Range

(graben & horst)



Continental rift valley
e.g., Shanxi Graben



GSA Special Paper 425 2007 , Mian Liu et. al.

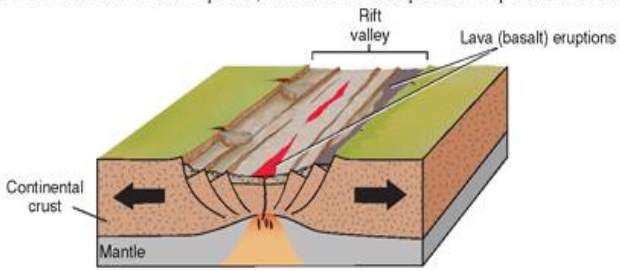
Active tectonics and intracontinental earthquakes in China: The kinematics and geodynamics

Divergent plate boundaries

Continental Rift

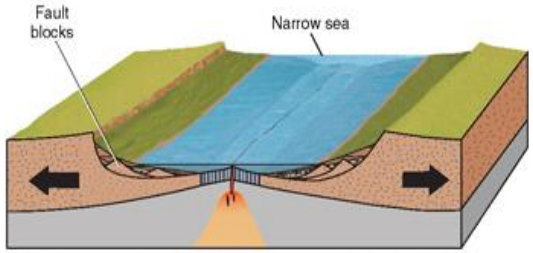
b) small sea stage: e.g., **Red Sea**

a)

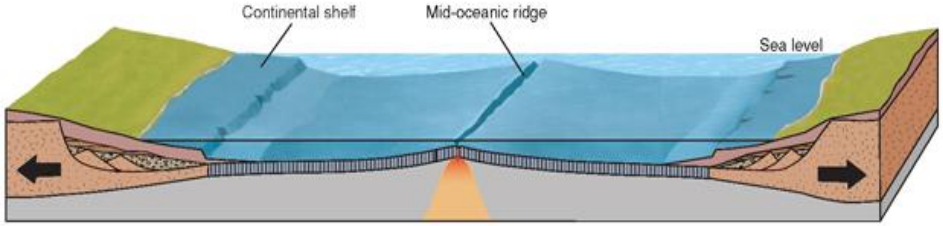


A Continent undergoes extension. The crust is thinned and a rift valley forms.

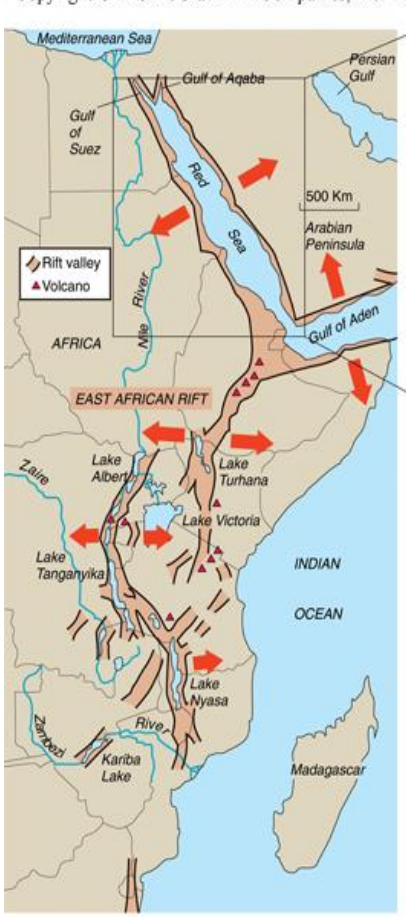
b)



B Continent tears in two. Continent edges are faulted and uplifted. Basalt eruptions form oceanic crust.



C Continental sediments blanket the subsiding margins to form continental shelves. The ocean widens and a mid-oceanic ridge develops, as in the Atlantic Ocean.



B

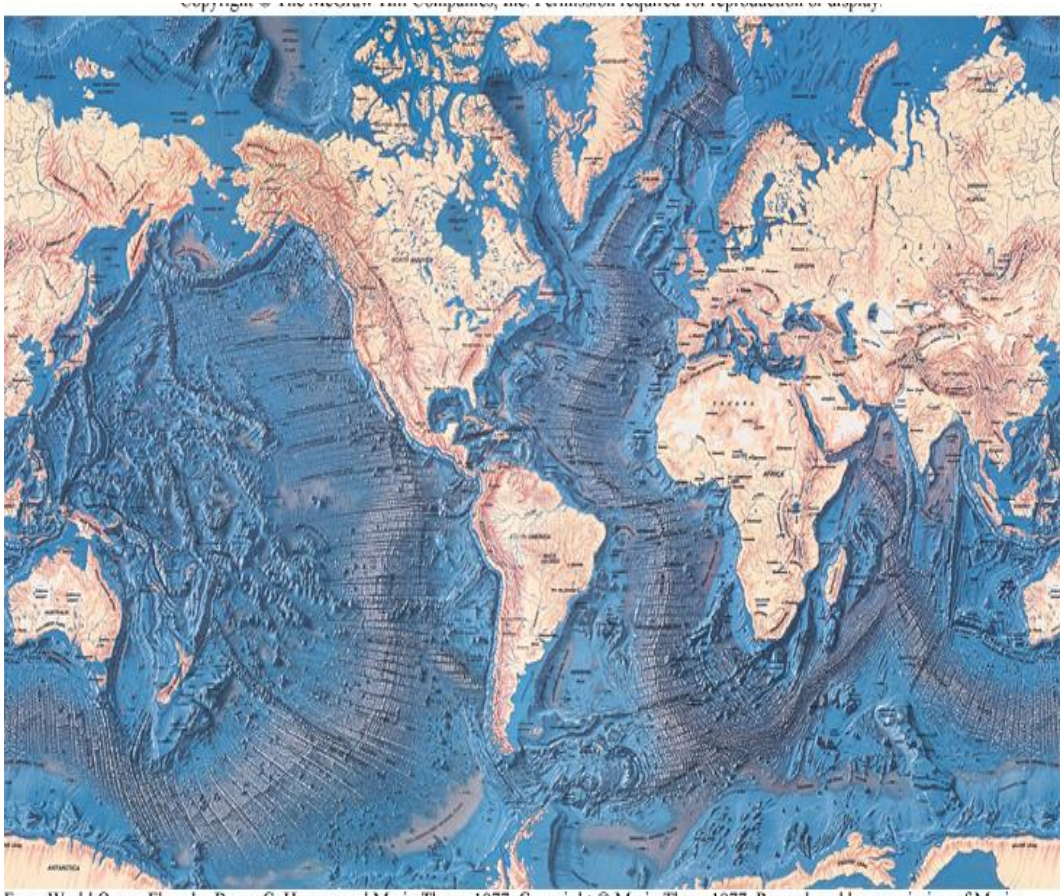
A

Photo by Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC (http://visibleearth.nasa.gov/)

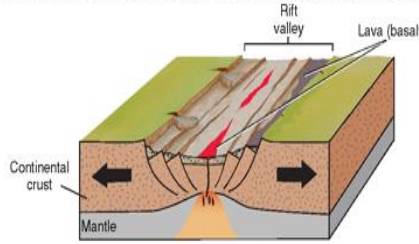
Divergent plate boundaries

Continental Rift

(c) Mid-ocean Ridge as a spreading center
e.g., Atlantic Ocean

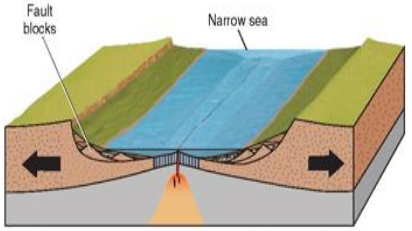


From World Ocean Floor by Bruce C. Heezen and Marie Tharp, 1977. Copyright © Marie Tharp 1977. Reproduced by permission of Marie Tharp, 1 Washington Ave., South Nyack, NY 10960



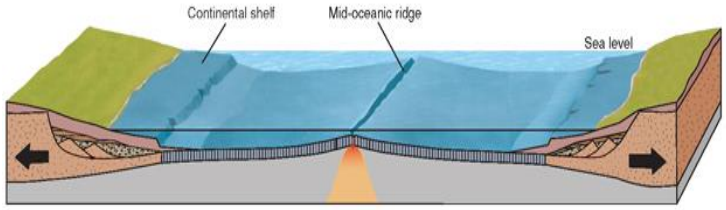
(a)

A Continent undergoes extension. The crust is thinned and a rift valley forms.



(b)

B Continent tears in two. Continent edges are faulted and uplifted. Basalt eruptions form oceanic crust.



C Continental sediments blanket the subsiding margins to form continental shelves. The ocean widens and a mid-oceanic ridge develops, as in the Atlantic Ocean.

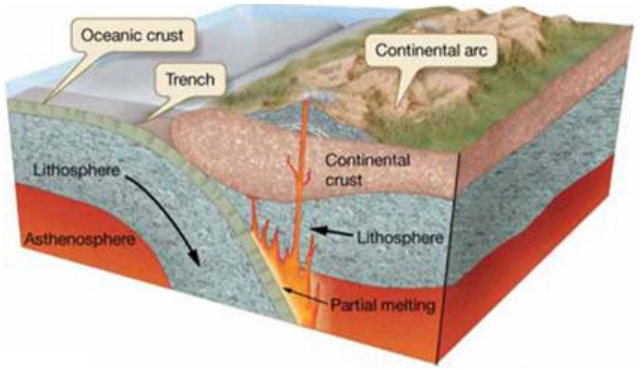
(c)

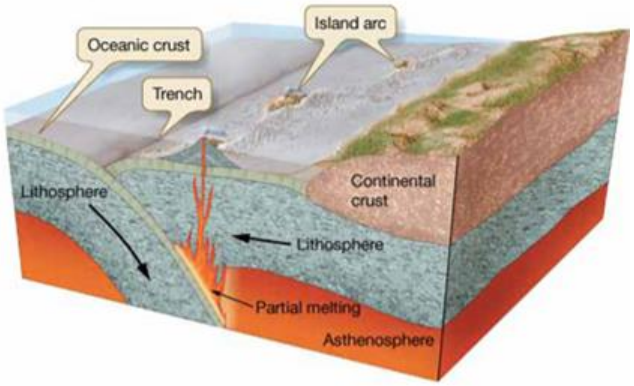
Types of Plate Boundaries

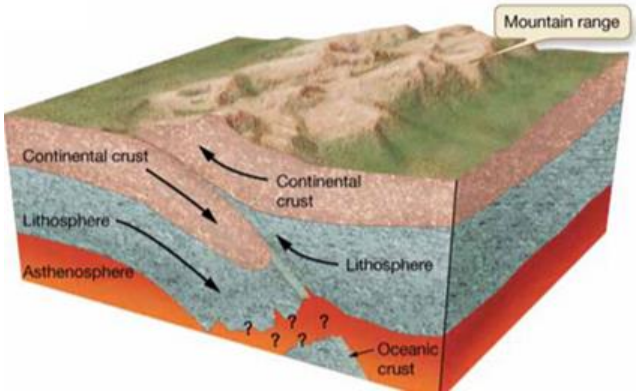
2) **Convergent Plate Boundary**

: two plates move toward each other (compressive forces)

- **Recycling of lithosphere**
- **reverse & thrust faults**





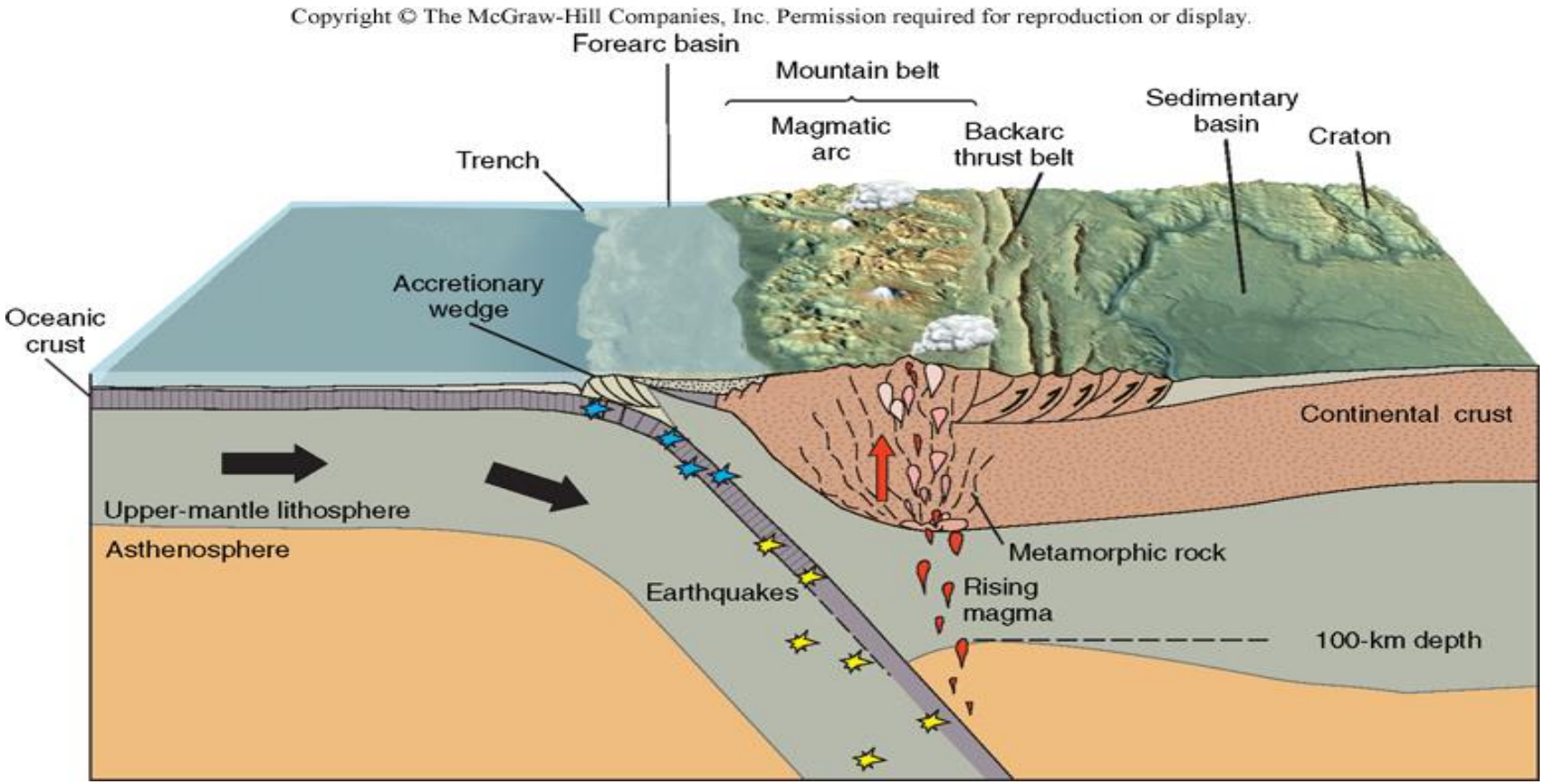


Ocean-Continent Convergence (Subduction Zones)

-- down-going slab = oceanic lithosphere

-- deep trench on the ocean side

-- magmatic arc on the continent side

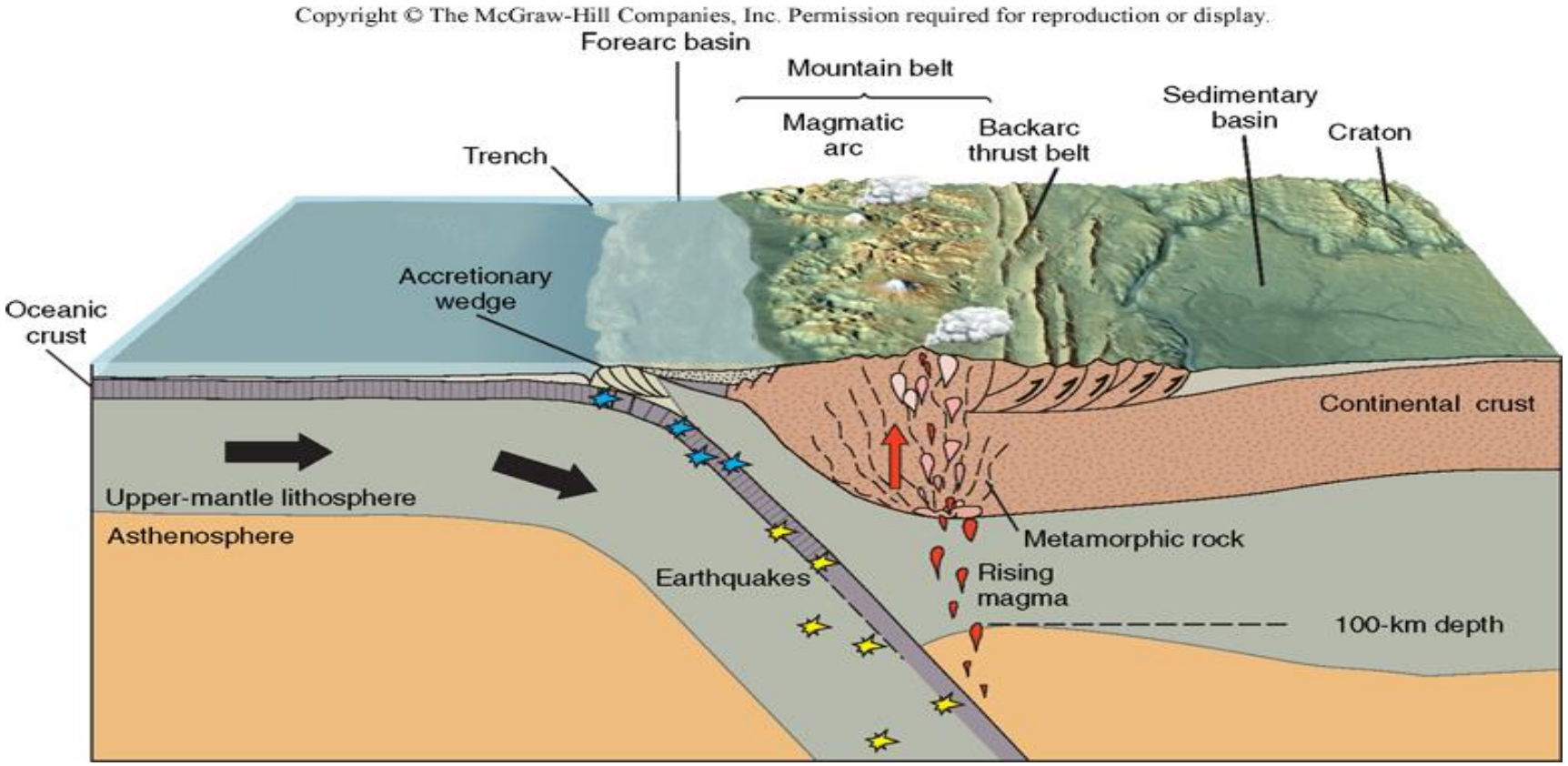


Ocean-Continent Convergence

-- forarc basin

-- backarc thrust belt

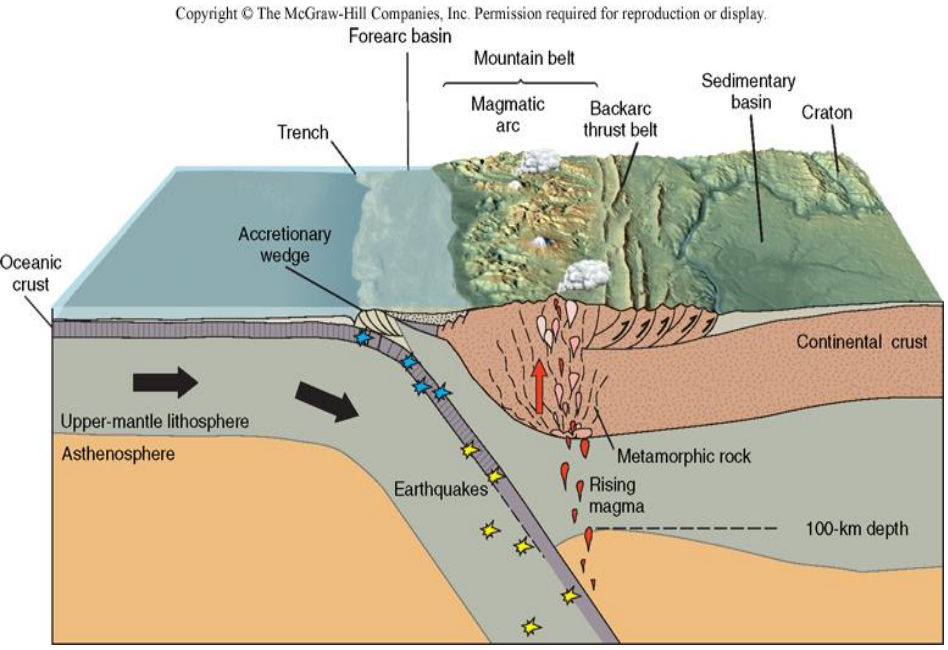
-- sedimentary basin inland

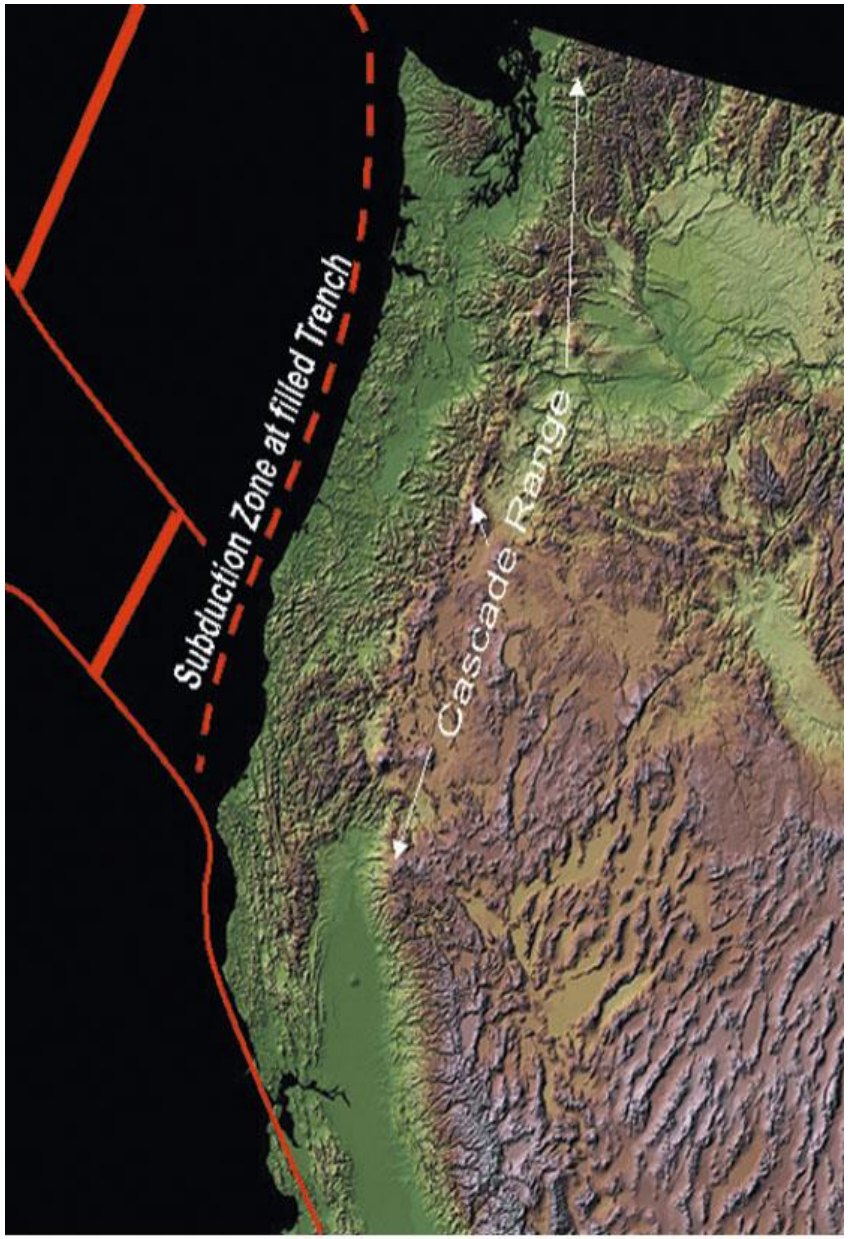


Ocean-Continent convergence

e.g.,

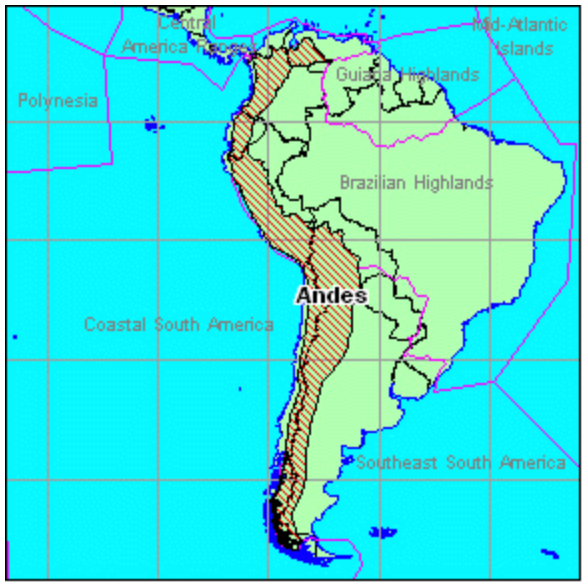
Cascade Range





Ocean-Continent Convergence

e.g., Andes

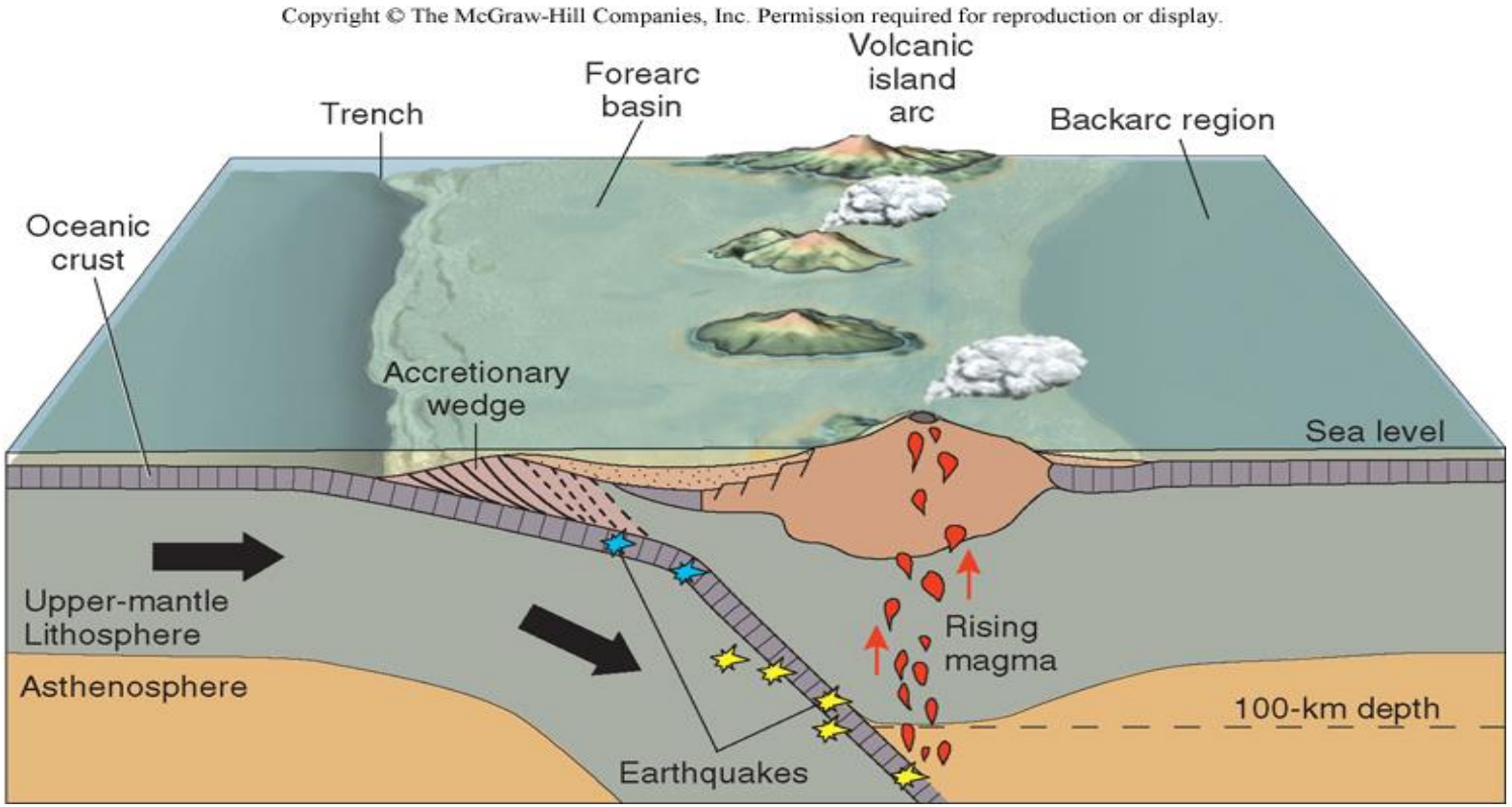


Convergent Plate Boundary

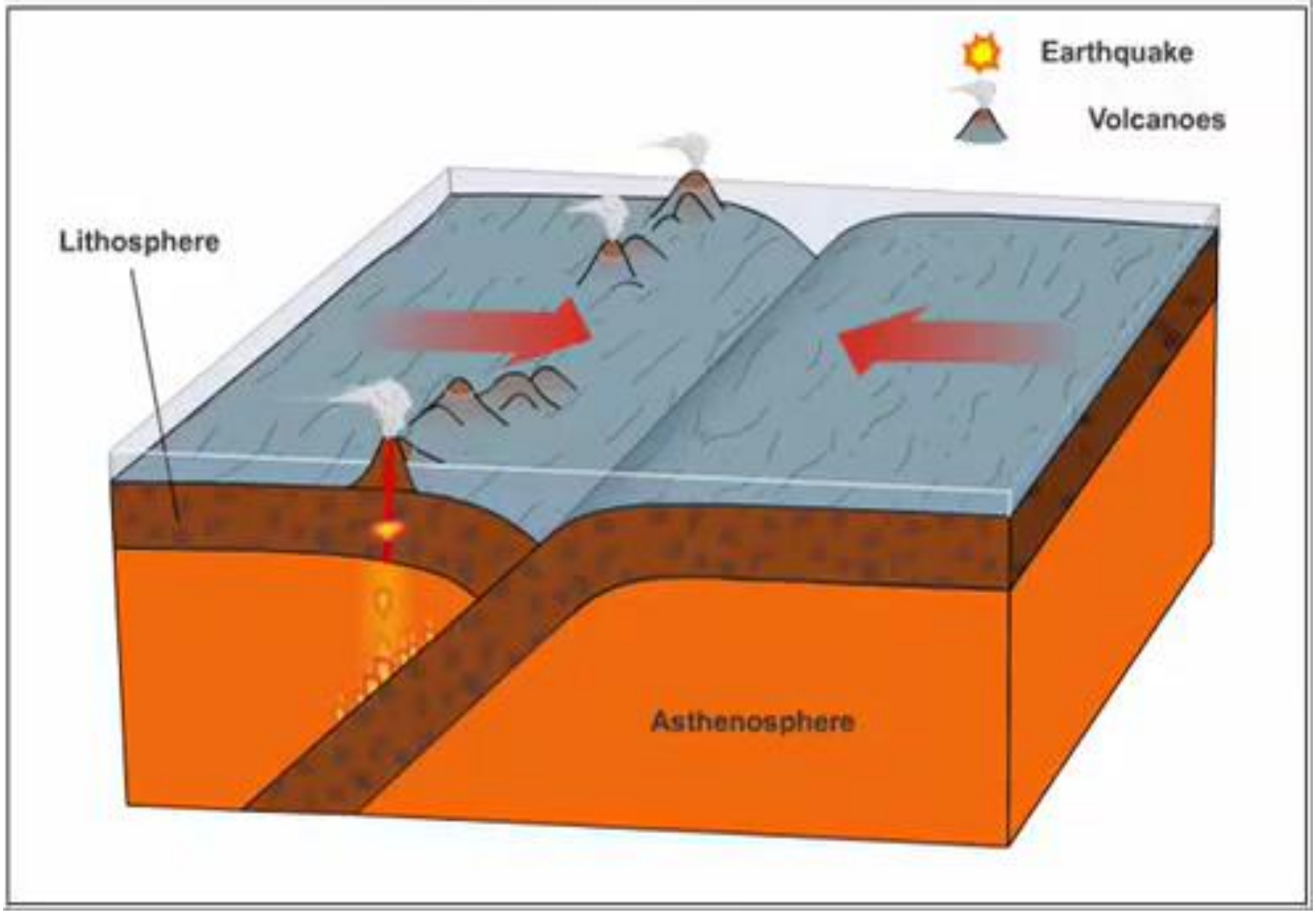
Ocean - Ocean Convergence (Subduction Zones)

-- down-going slab = older oceanic lithosphere

-- deep trench;island arcs; forearc basin & backarc basin

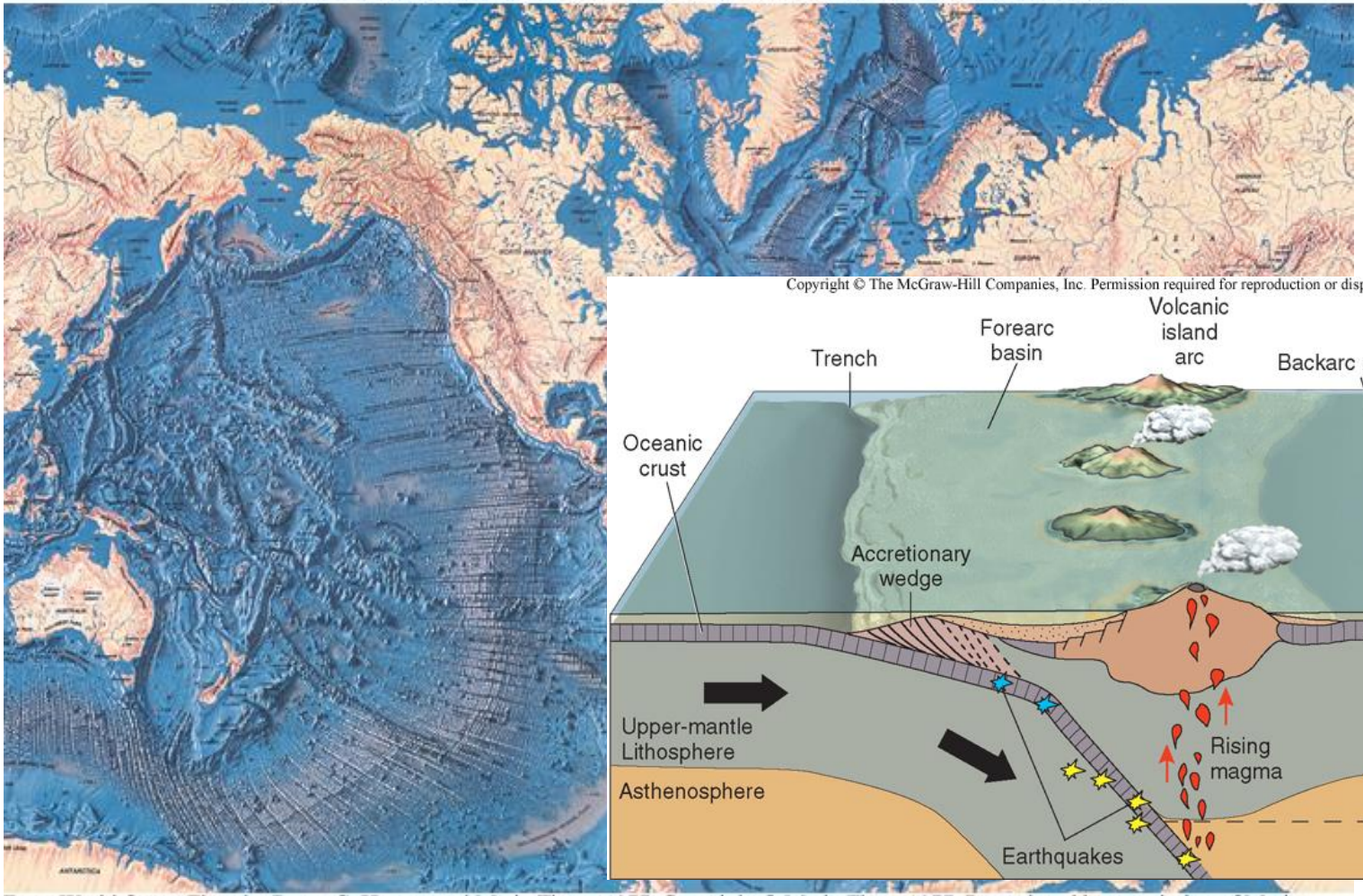


Motion at convergent boundaries



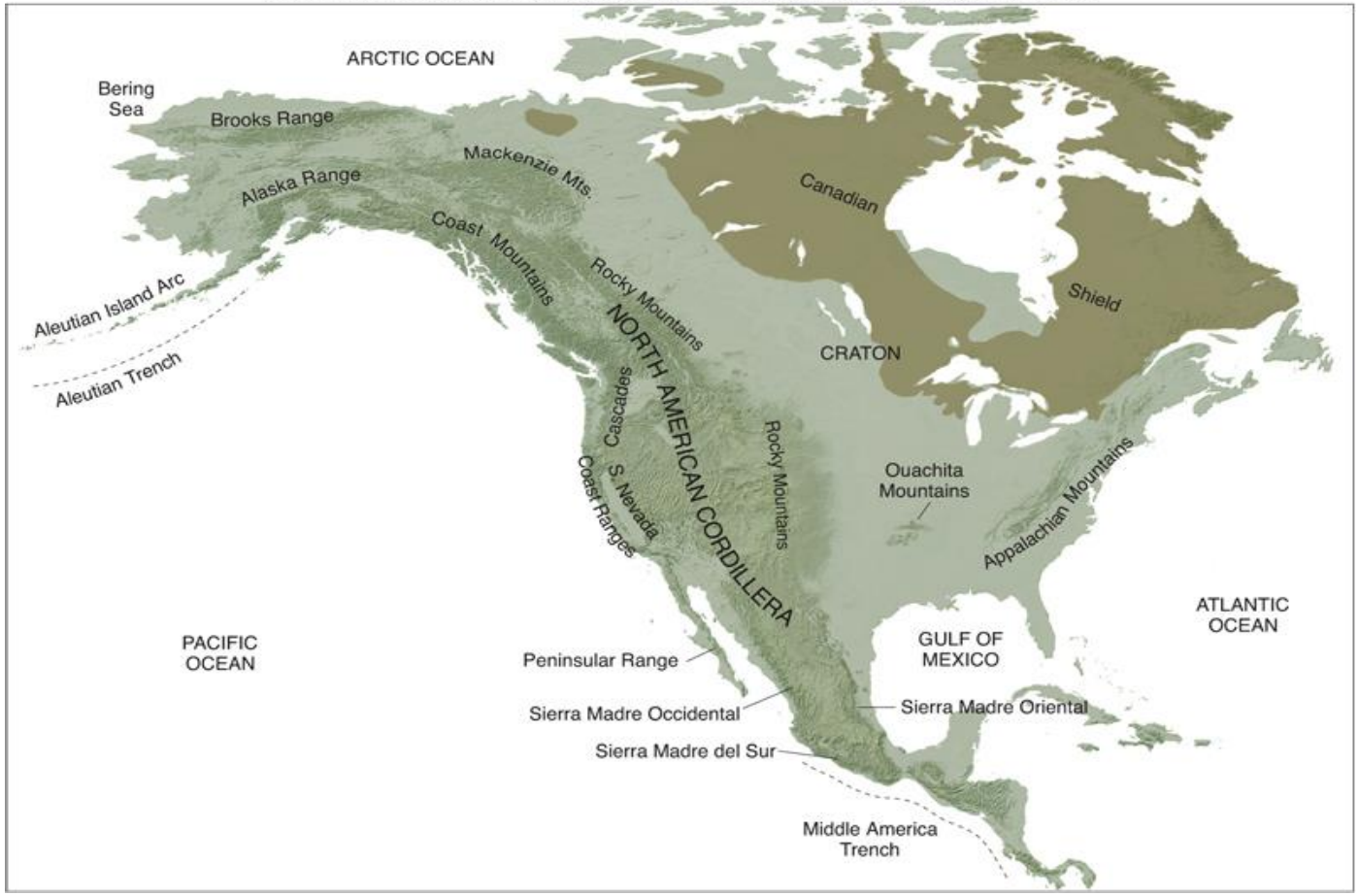
Ocean - Ocean Convergence

e.g., Western Pacific



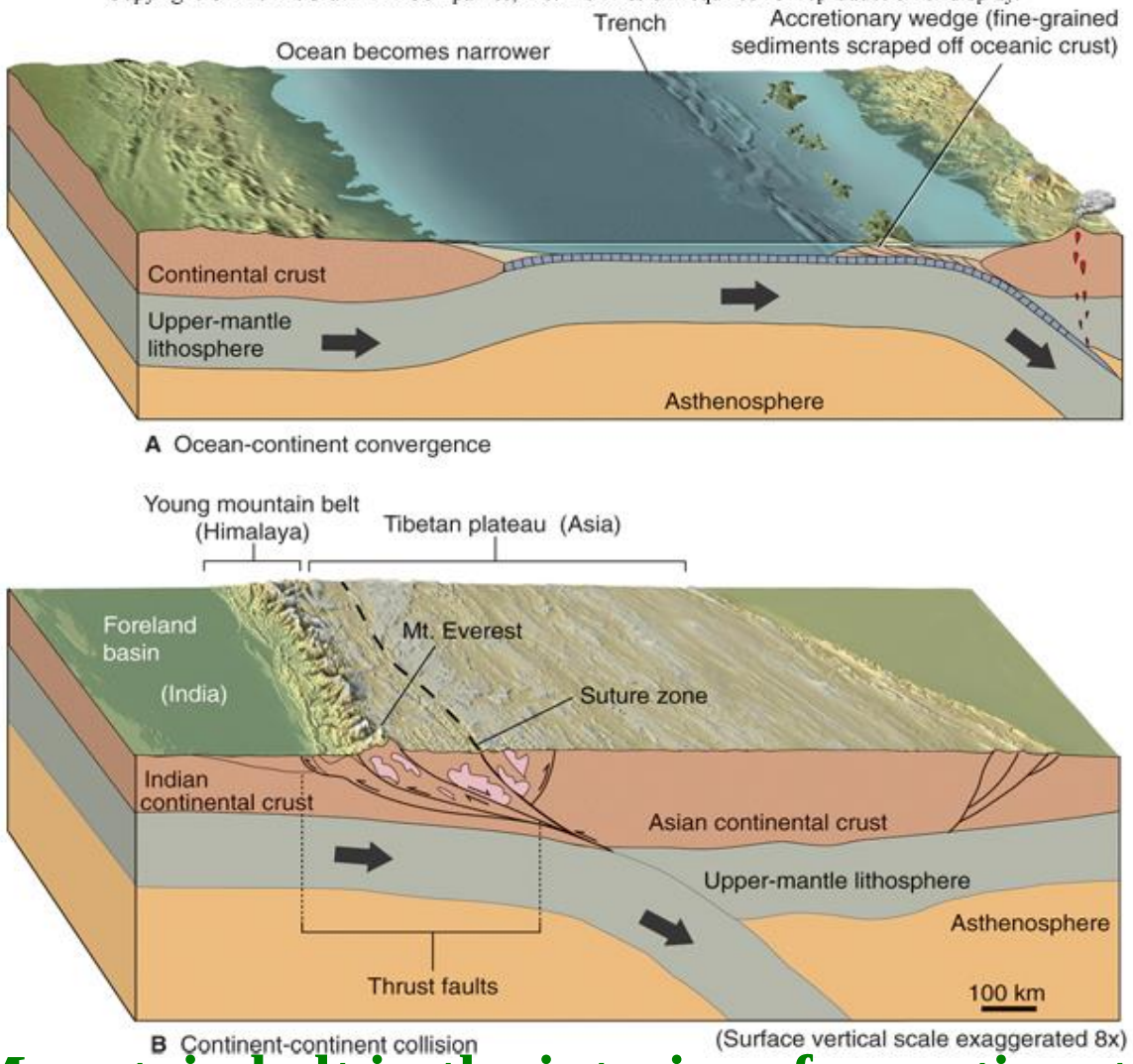
Many major mountain belts near subduction zones

e.g., **Cordillera mountain belt**
: largest mountain belt in N. America



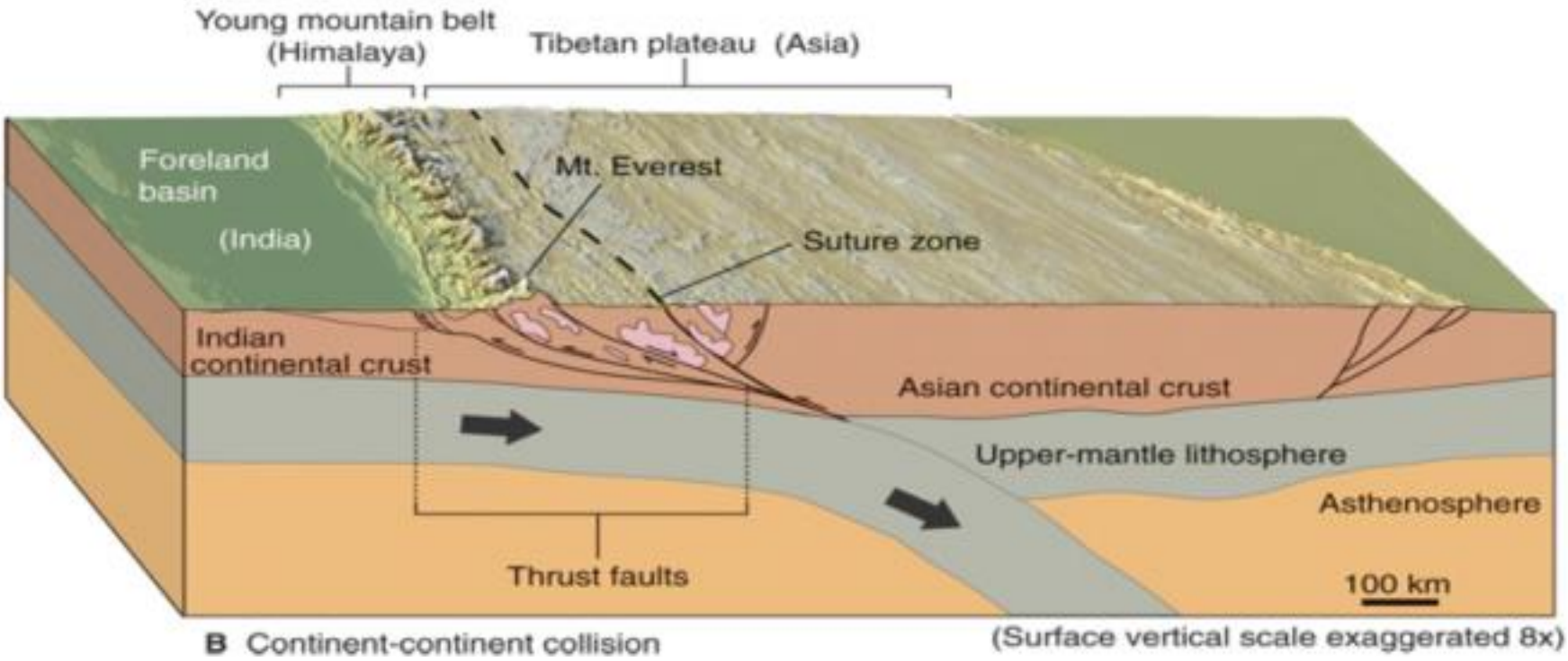
Convergent Plate Boundary

Continent - Continent Convergence



Mountain belt in the interior of a continent

Suture zone marks the old boundary



-- **thrust belts** and **basins** occur on both sides of the original magmatic arc

-- old magmatic arc become inactive

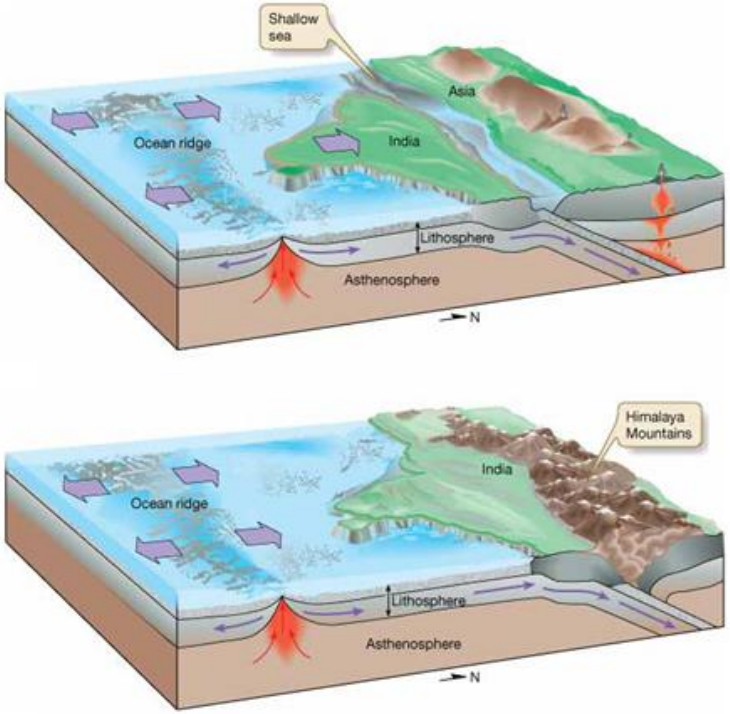
-- crustal shortening & thickening

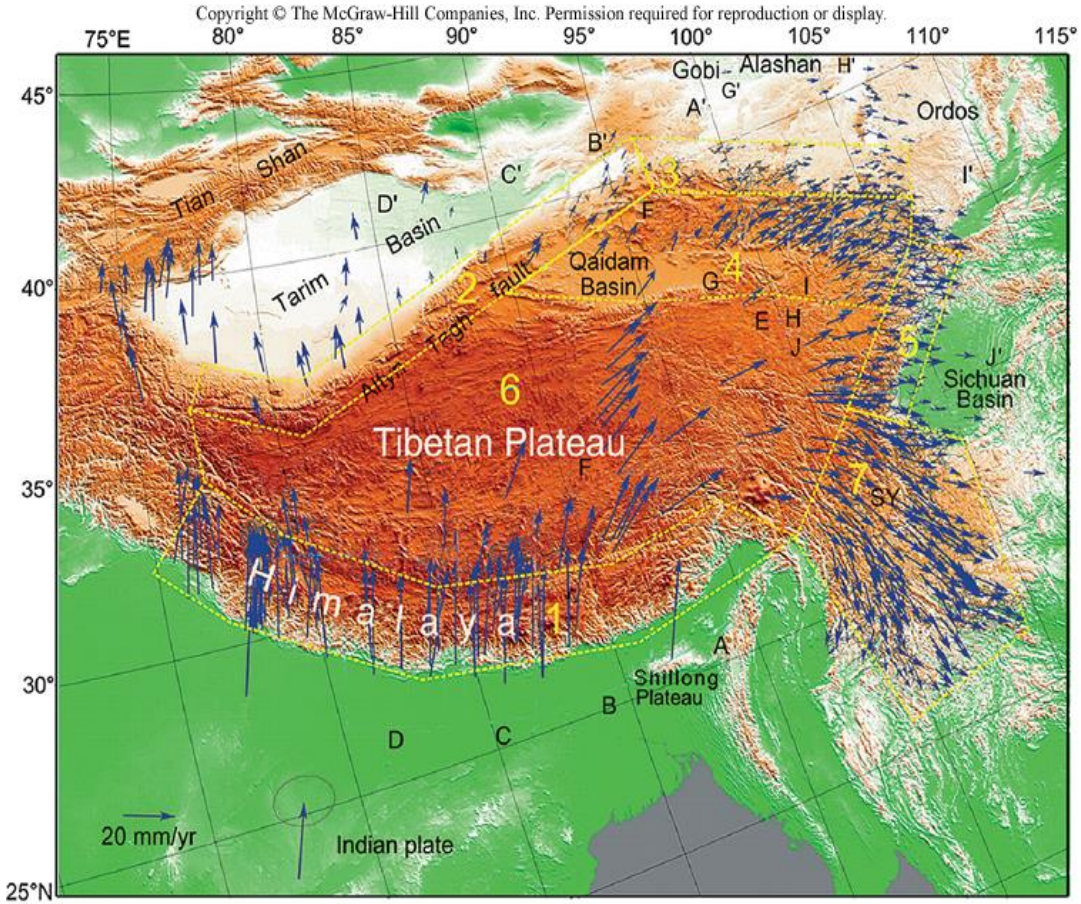
-- granite intrusion & intense metamorphism

e.g., collision of **India & Eurasia**(~ 40-45 m.y. ago)

-- building of the **Himalaya**

-- uplift of the **Tibetan plateau**





From Zhang, et al. Continuous deformation of the Tibetan Plateau from global positioning system data. Geology 2004 Vol. 32, No. 9, pp. 809–812.


Germany
EUROPE
Switzerland
Austria
ALPS
France
Slovenia
Italy
Mediterranean Sea
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CANADA
Appalachian Mountains
UNITED STATES
ATLANTIC OCEAN
N
W
E
S
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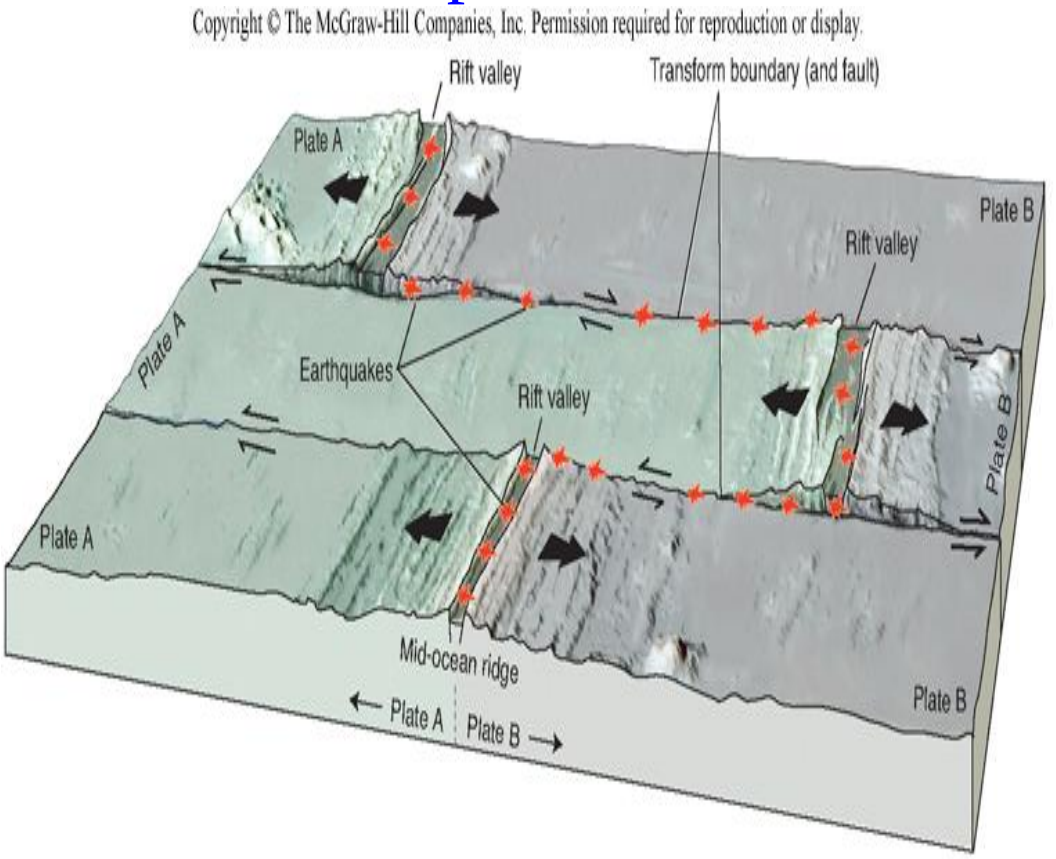
Types of Plate Boundaries

3) **Transform plate boundaries**

: 2 plates slide past each other

-- no creation or destruction of lithosphere

-- strike-slip fault

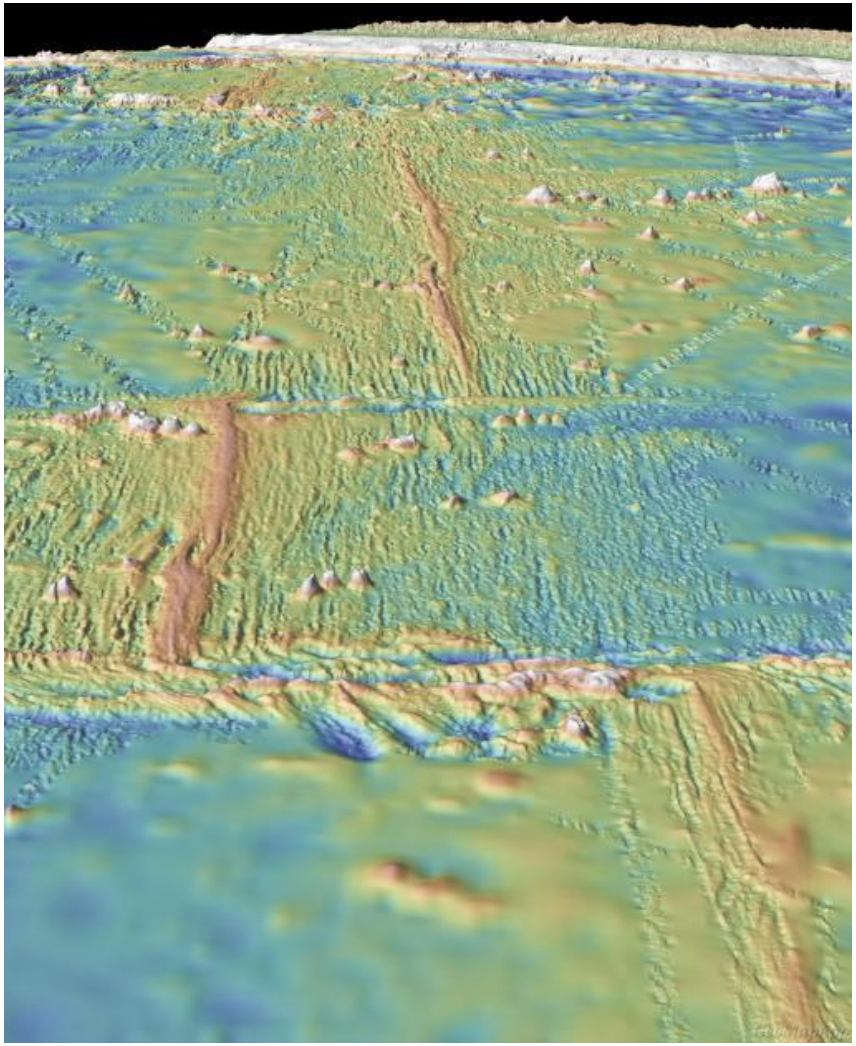


Types of Plate Boundaries

Transform fault boundary

e.g.,

Siqueiros and Clipperton Transform faults along East Pacific Rise



Types of Plate Boundaries

Transform fault boundary

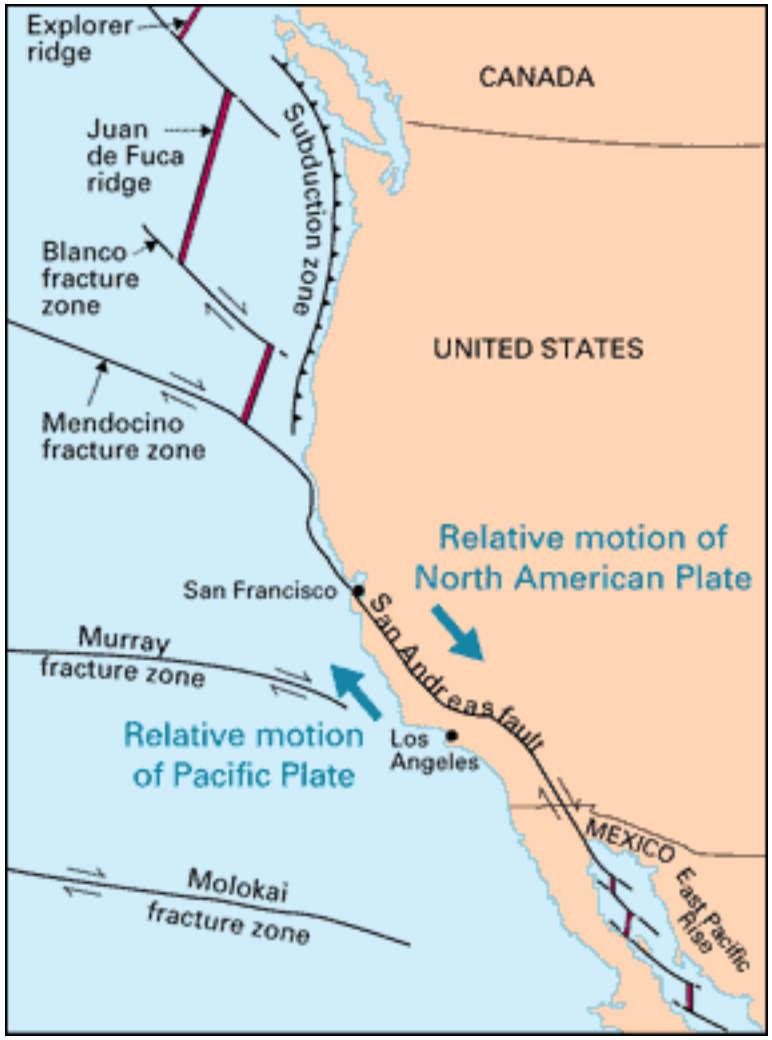
e.g.,

San Andreas Fault
separates

Pacific Plate

&

North American Plate

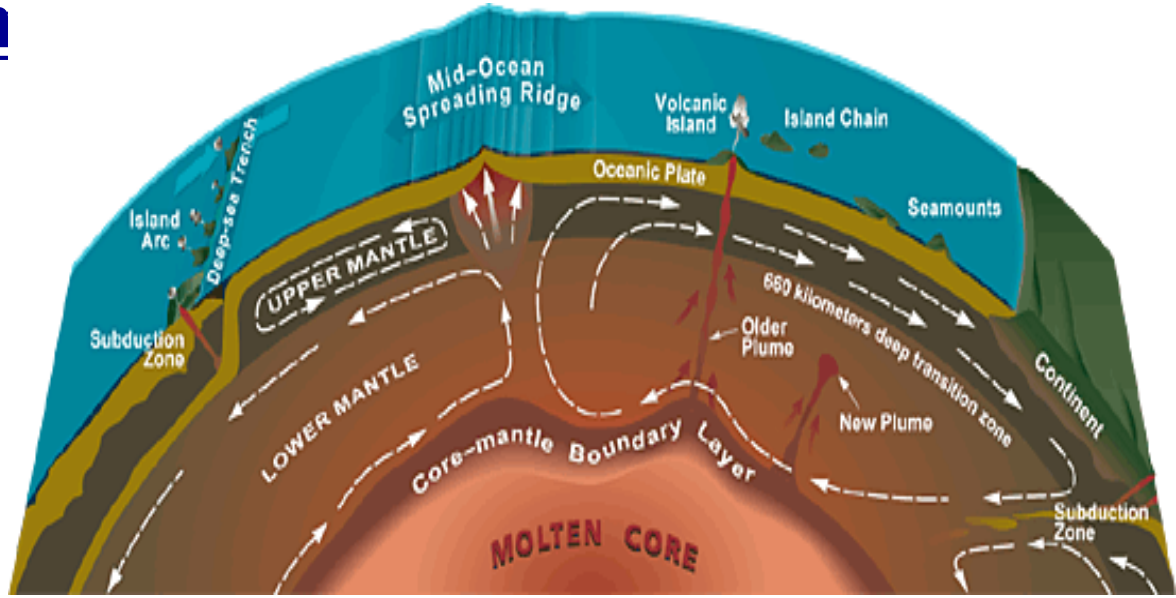


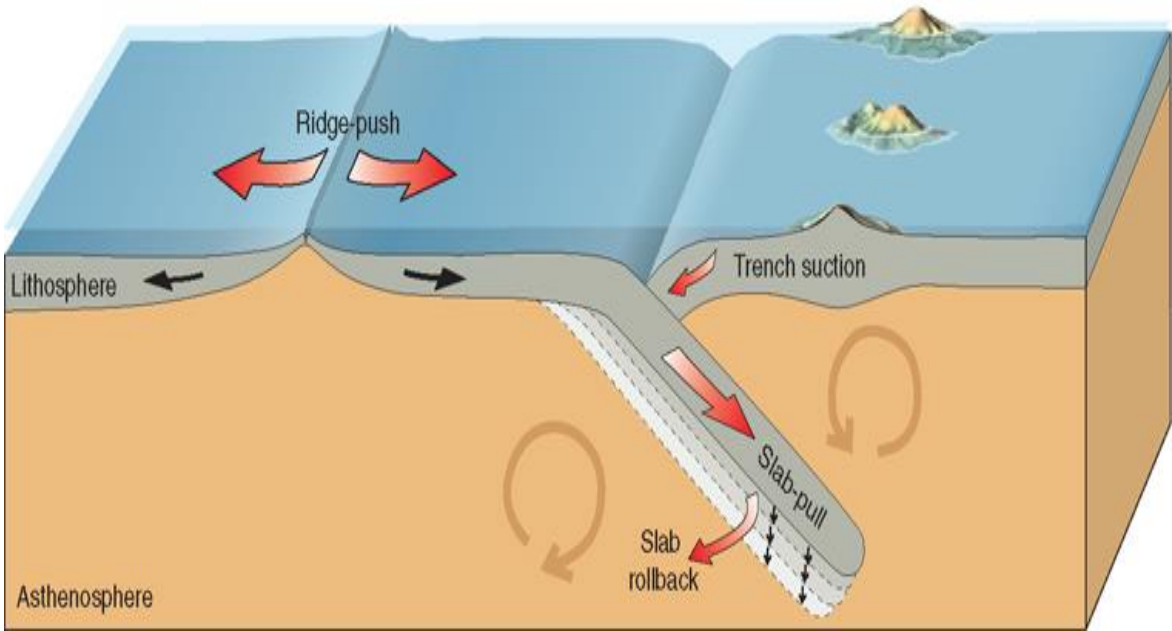
Driving mechanisn

a) whole mantle convection

b) two-tiered convection

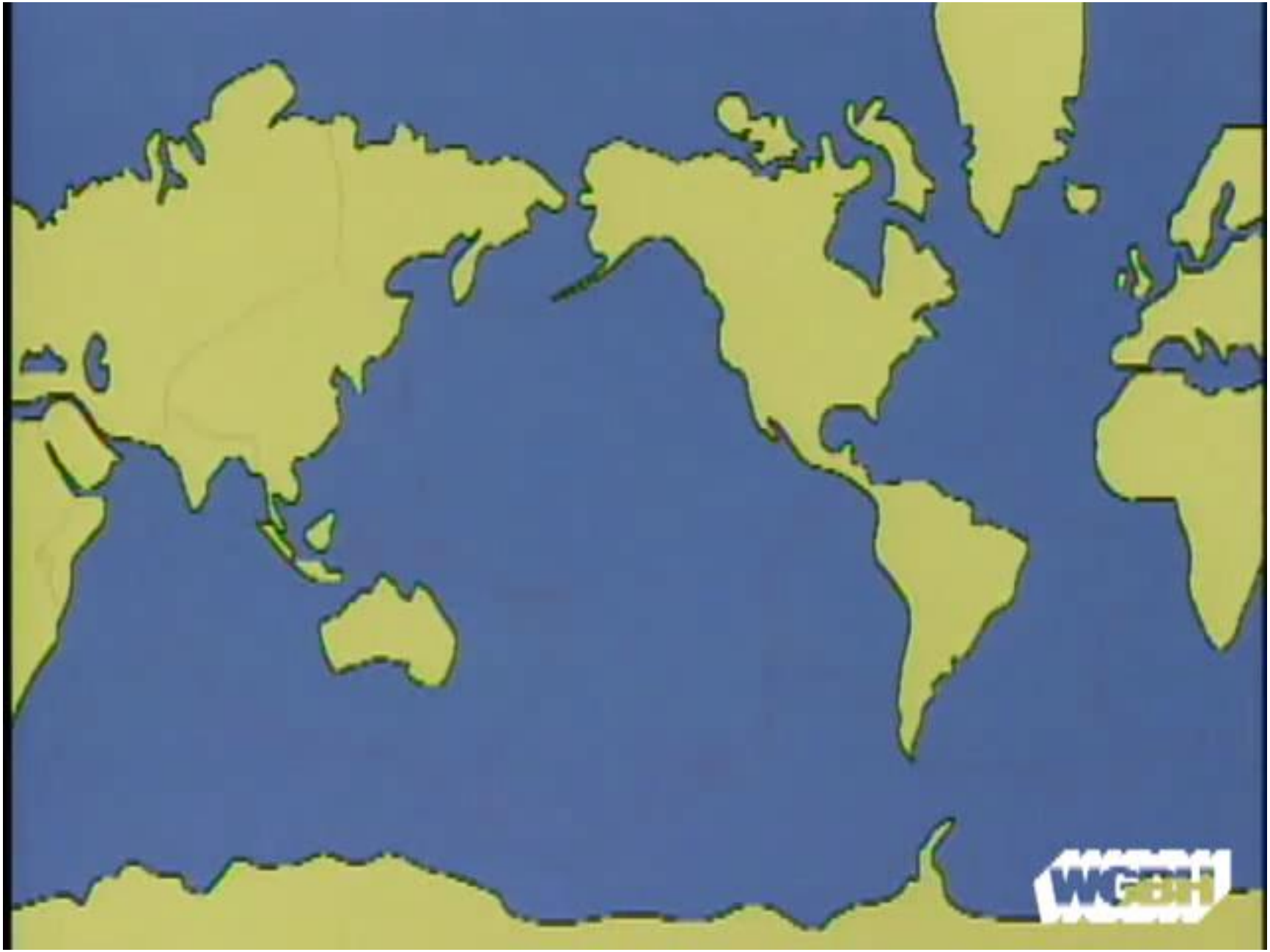
c) push-pull theory



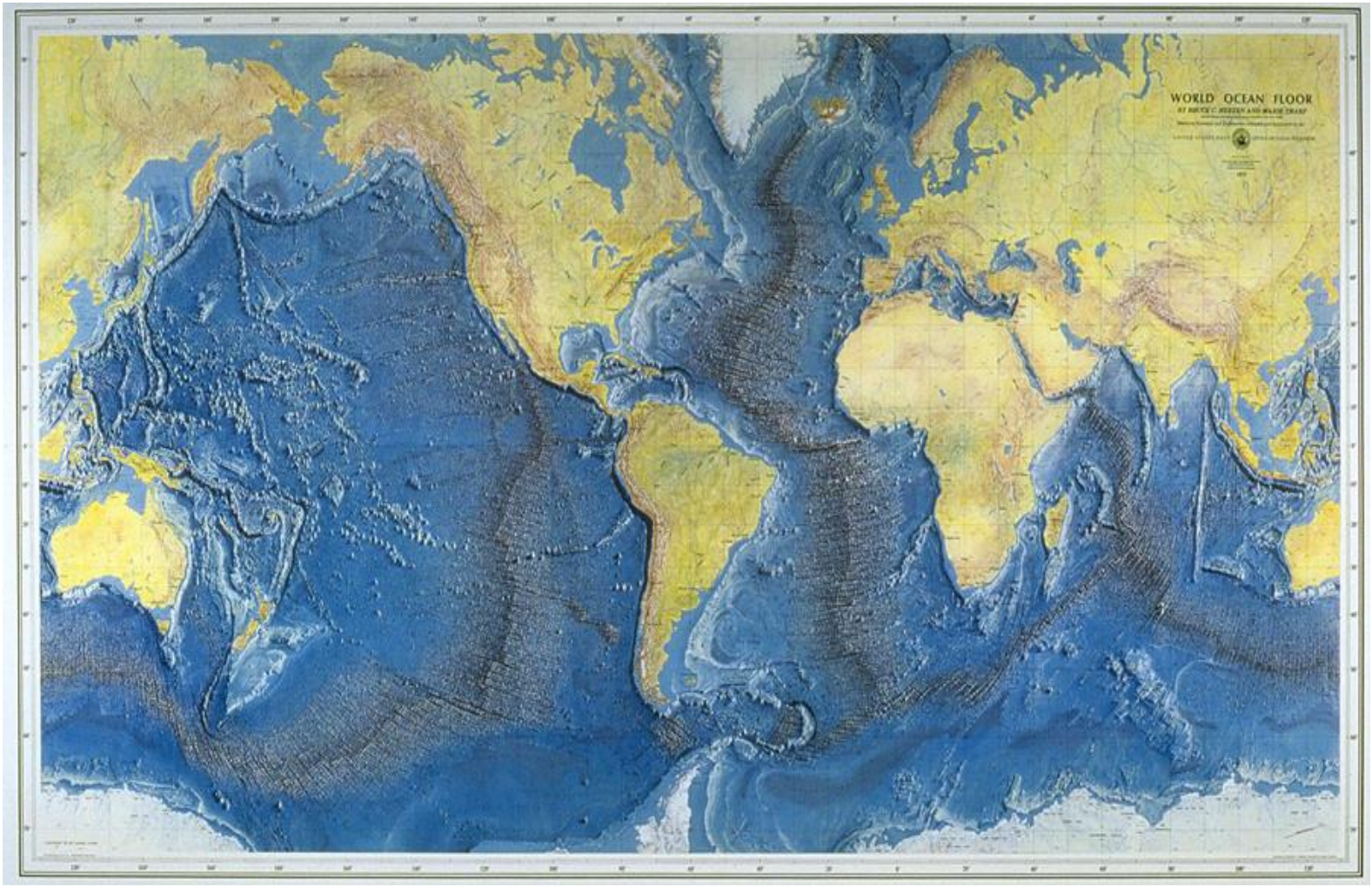


Driving force of plate tectonics

Video: Plate Tectonics: An Introduction

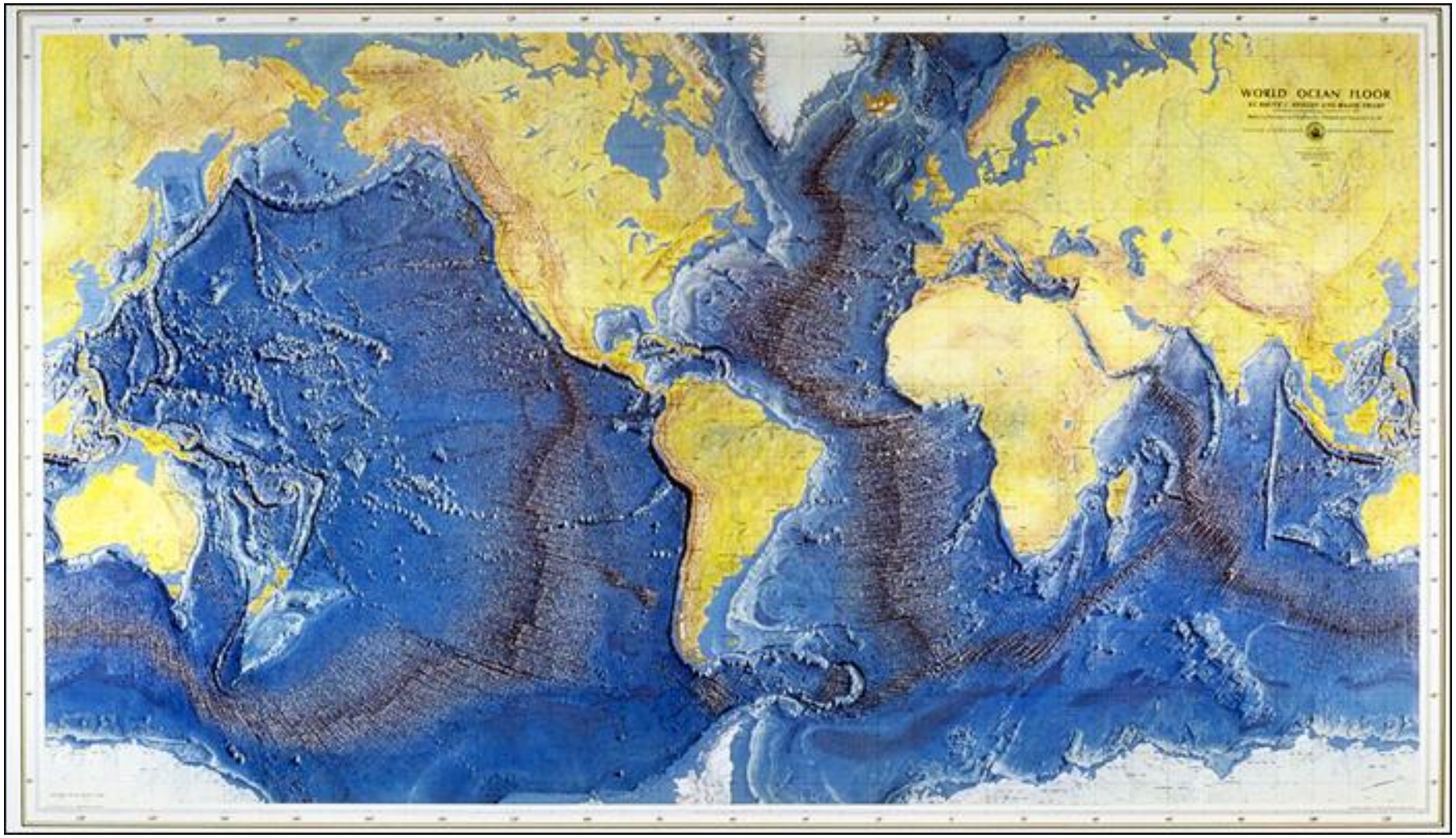


Features on Ocean Floor & Continental Margins - Tectonic Perspective

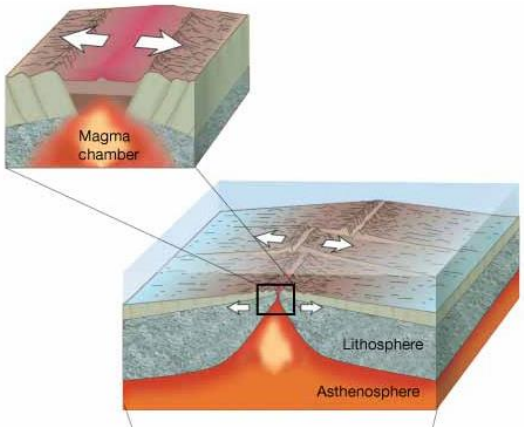


Features on Ocean Floor & Continental Margins

Mid-Ocean Ridges

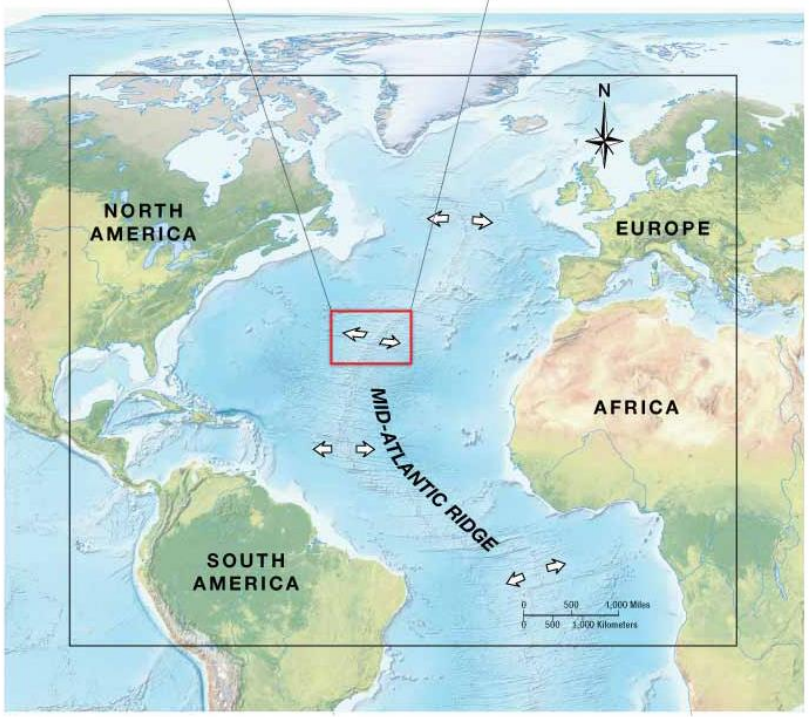


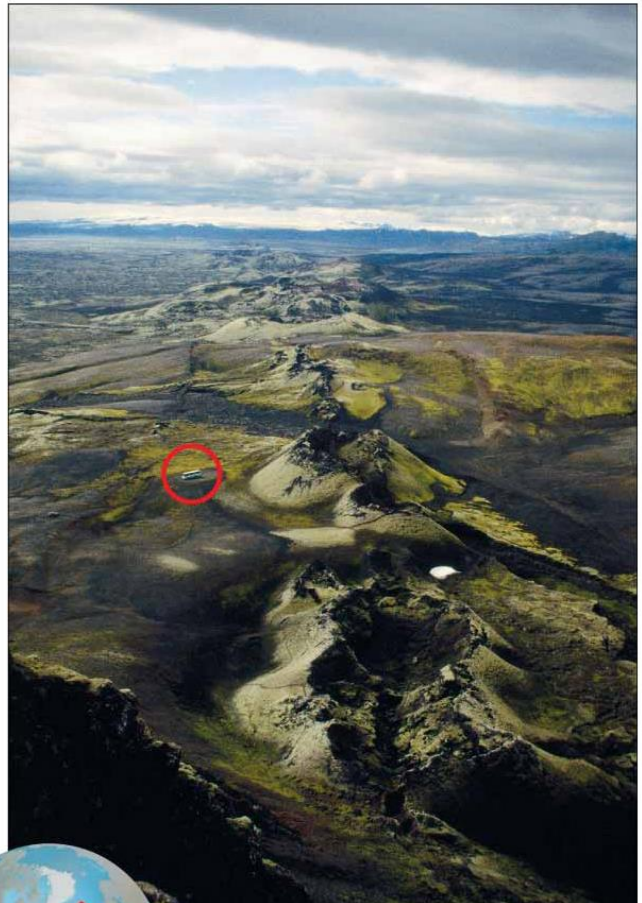
Mid-Ocean Ridges



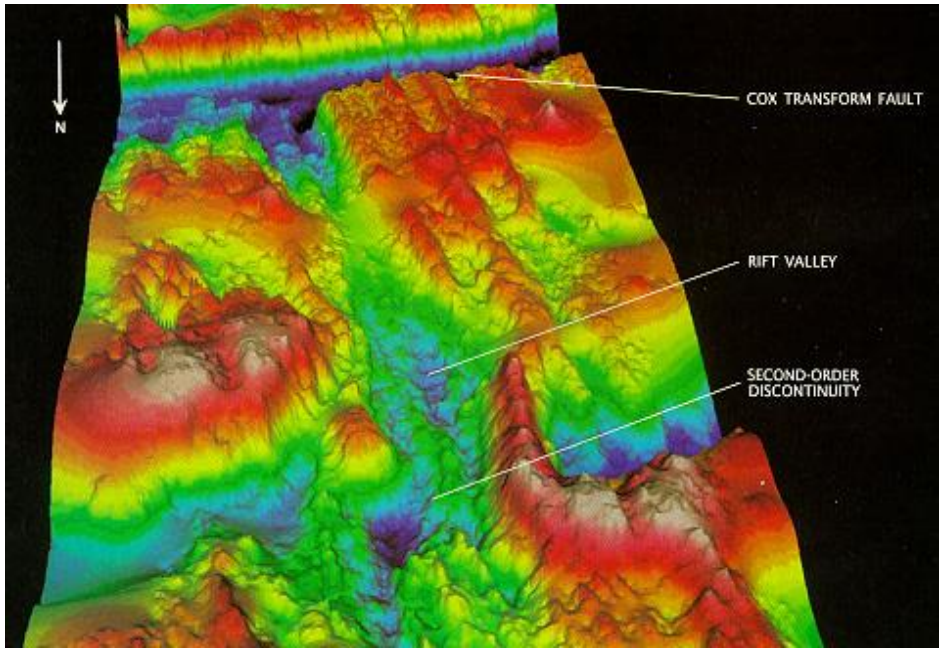
Divergent plate boundary

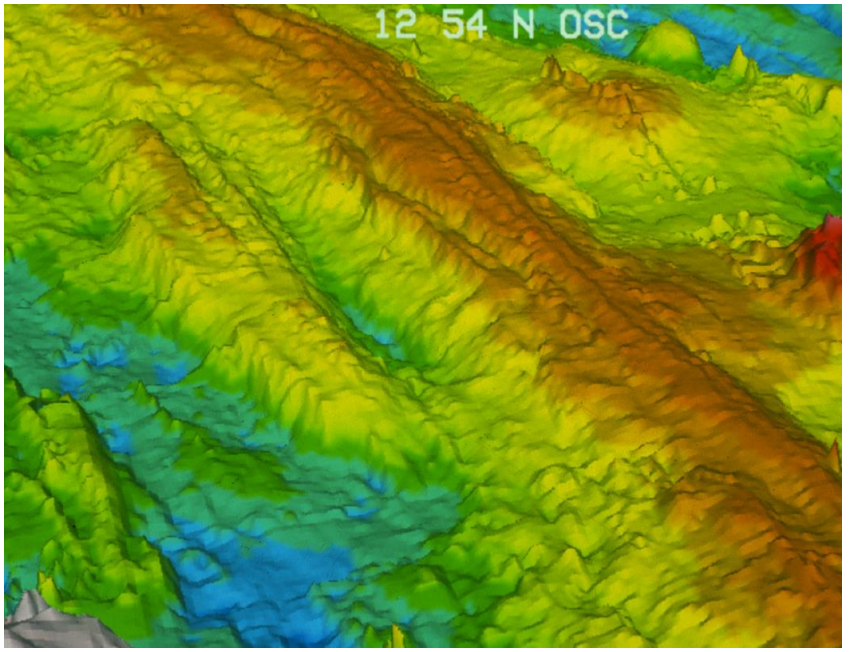
- **Tensional forces**
- **Normal faults**
- **Shallow earthquakes**
- **Spreading center**
- **Undersea volcanic eruptions**





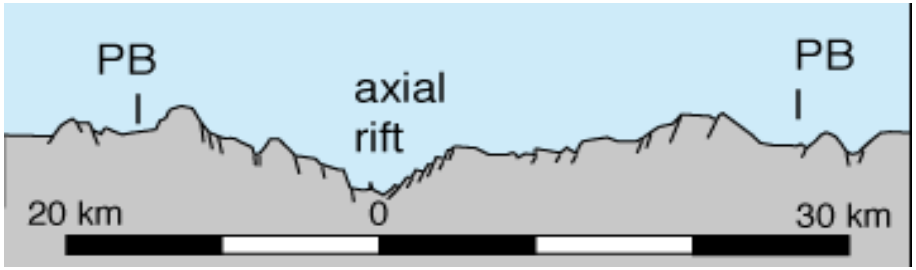
Rift Valley at Mid-Ocean Ridges

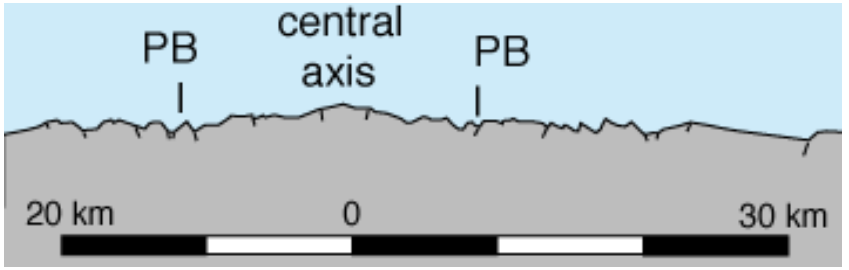




Mid-Atlantic Ridge

East Pacific Rise





Mid-Atlantic Ridge- slow spreading rate

East Pacific Rise - fast spreading rate

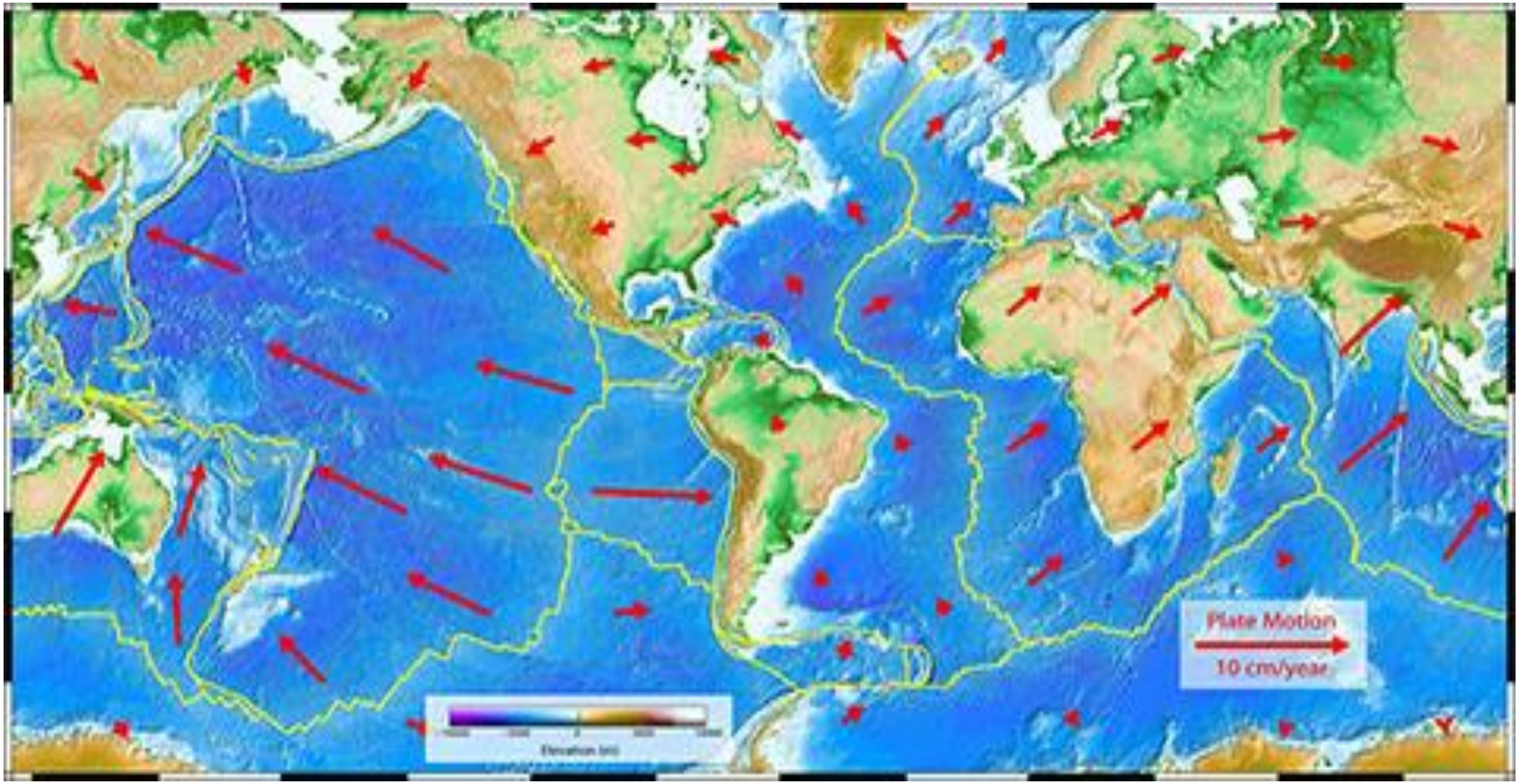
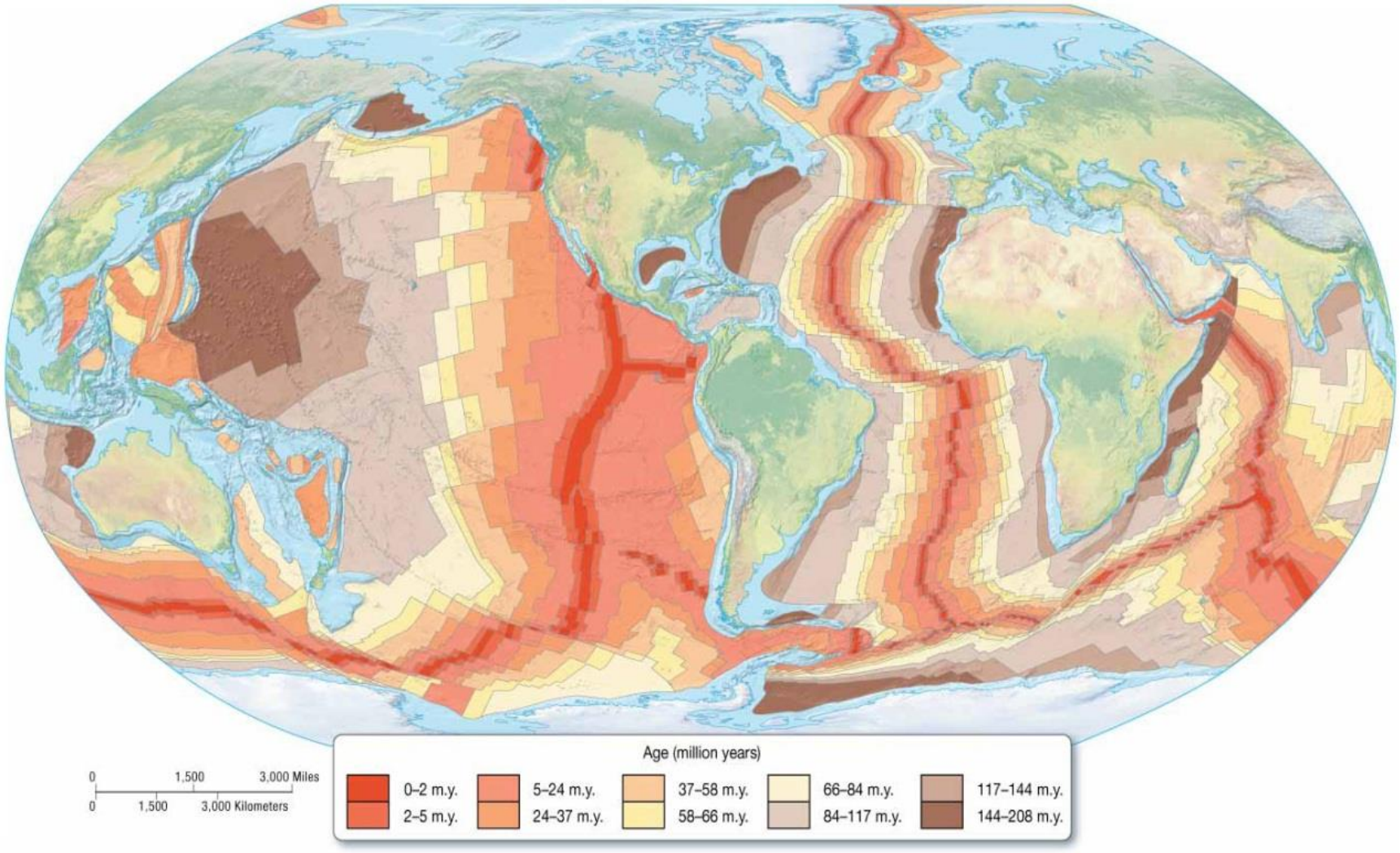
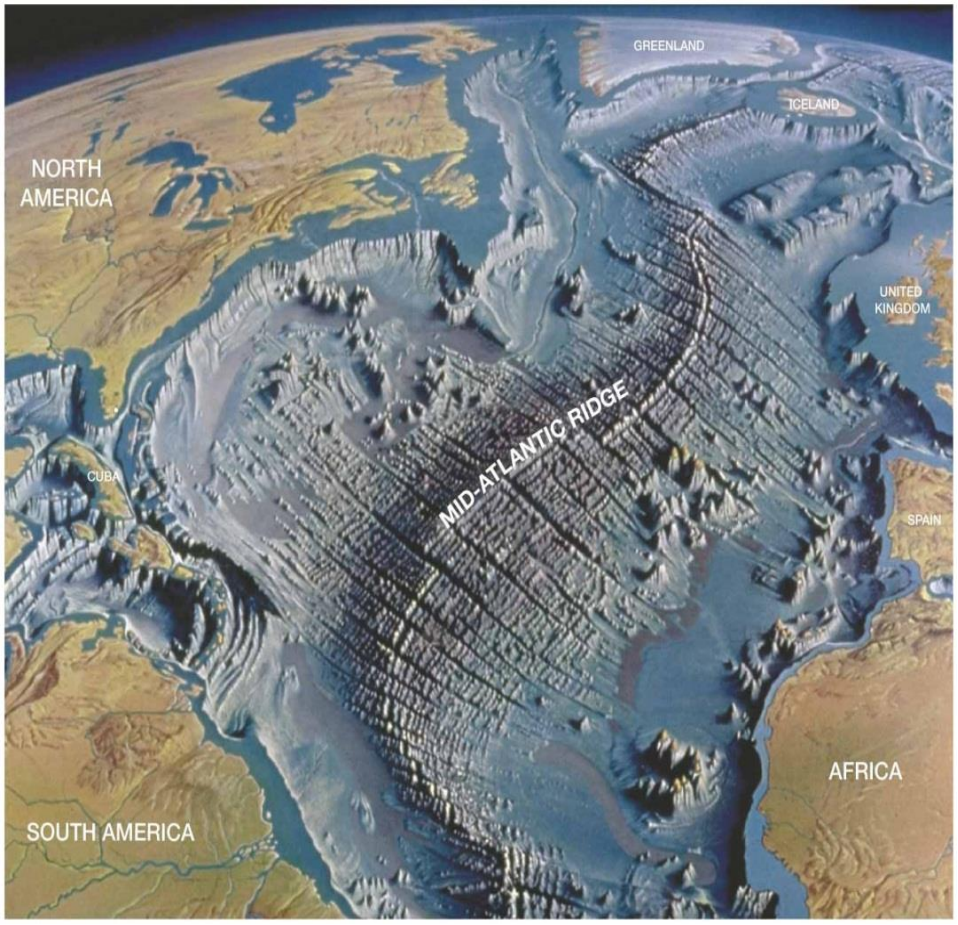


Plate Motion
10 cm/year


0 1,500 3,000 Miles
0 1,500 3,000 Kilometers
Age (million years)
0–2 m.y.
2–5 m.y.
5–24 m.y.
24–37 m.y.
37–58 m.y.
58–66 m.y.
66–84 m.y.
84–117 m.y.
117–144 m.y.
144–208 m.y.

Fracture Zones

- Offset mid-ocean ridge

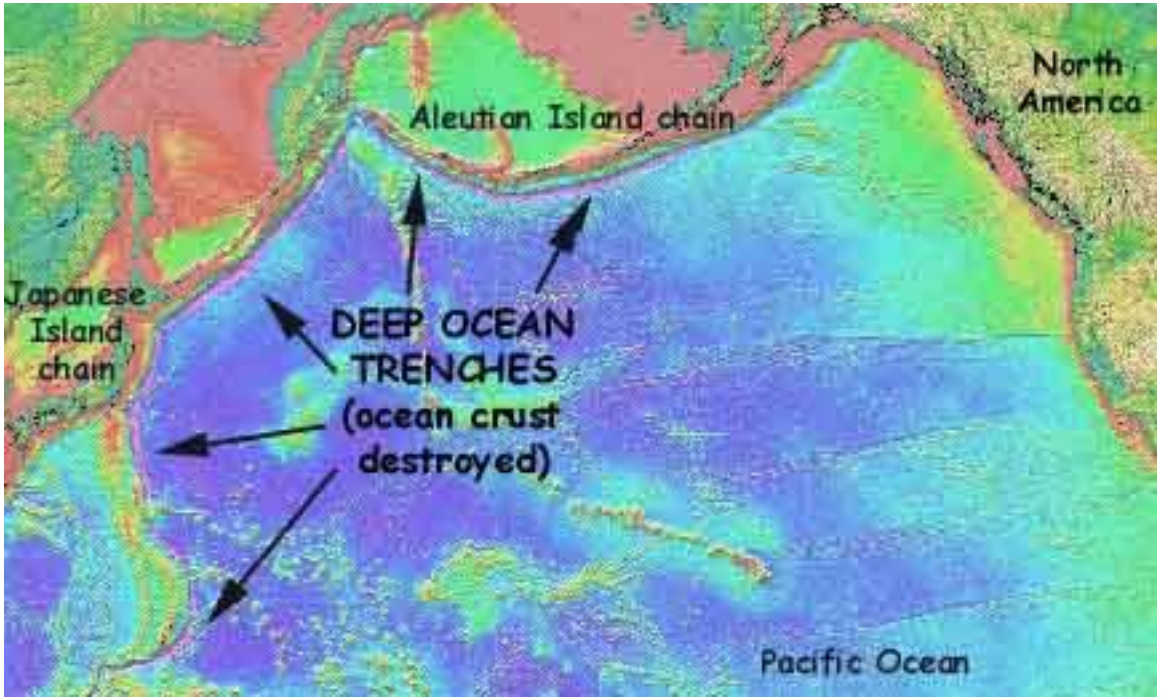


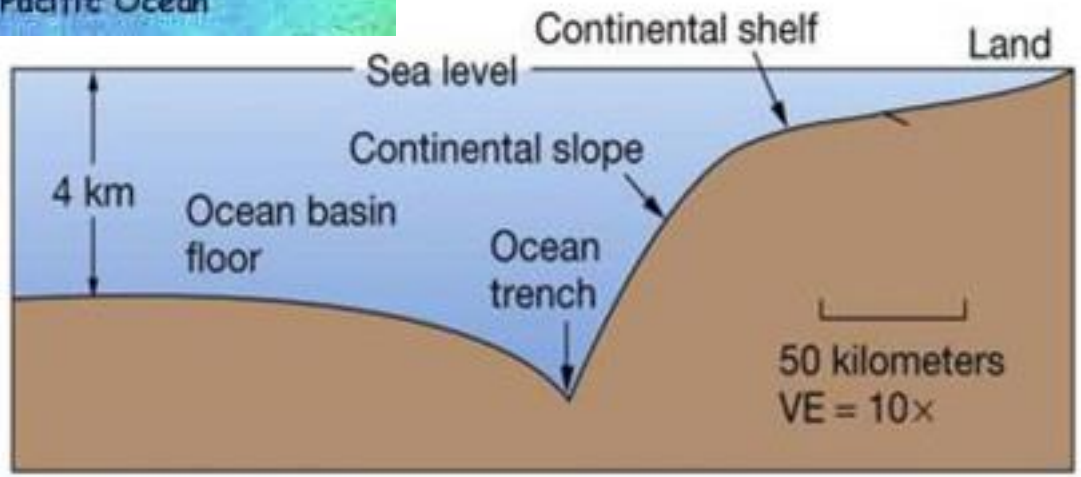
Transform Boundary
-horizontal movement
-Strike slip fault

Continental Margins

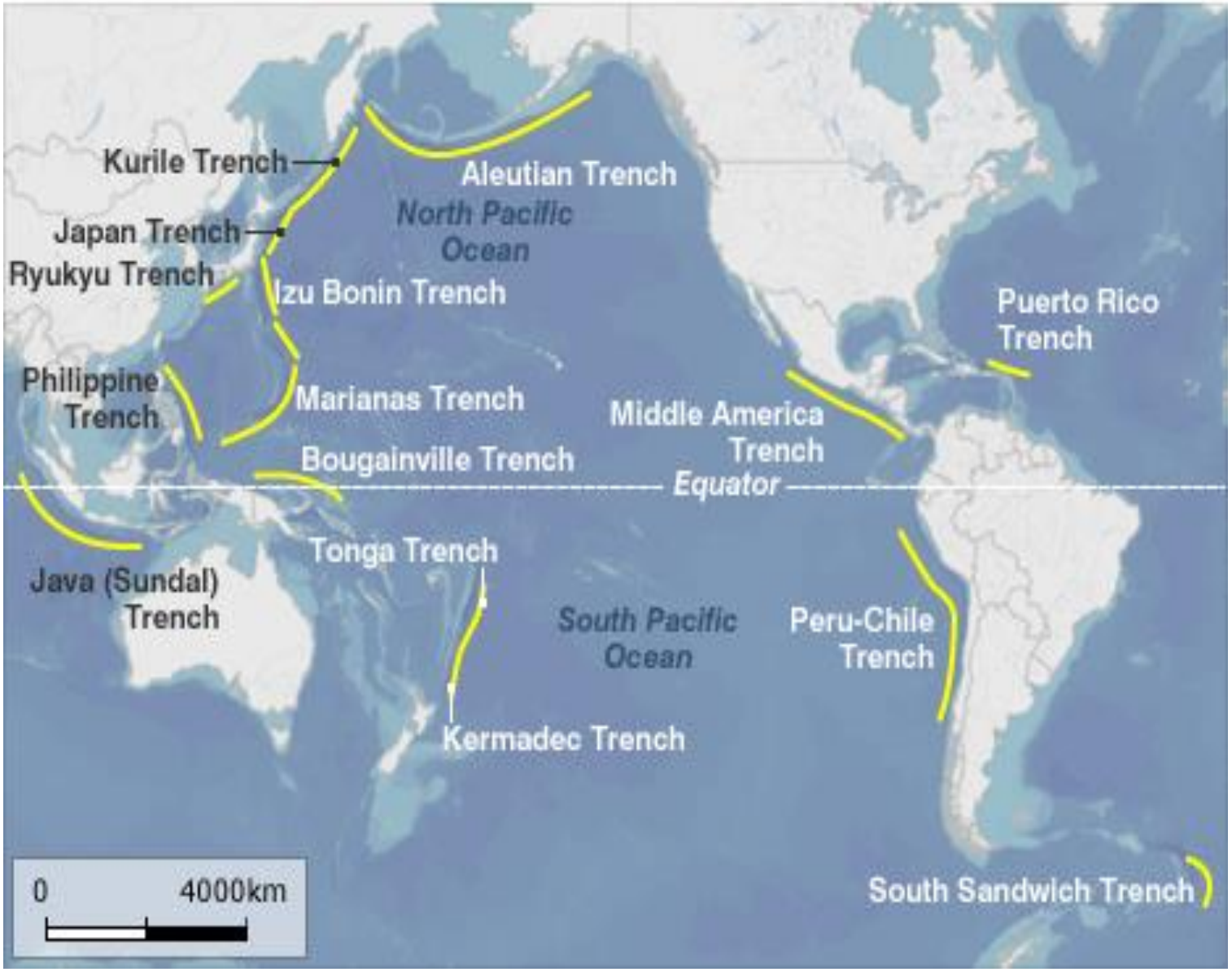
1) Active Continental Margins

Continental shelf, Continental slope, Ocean trench

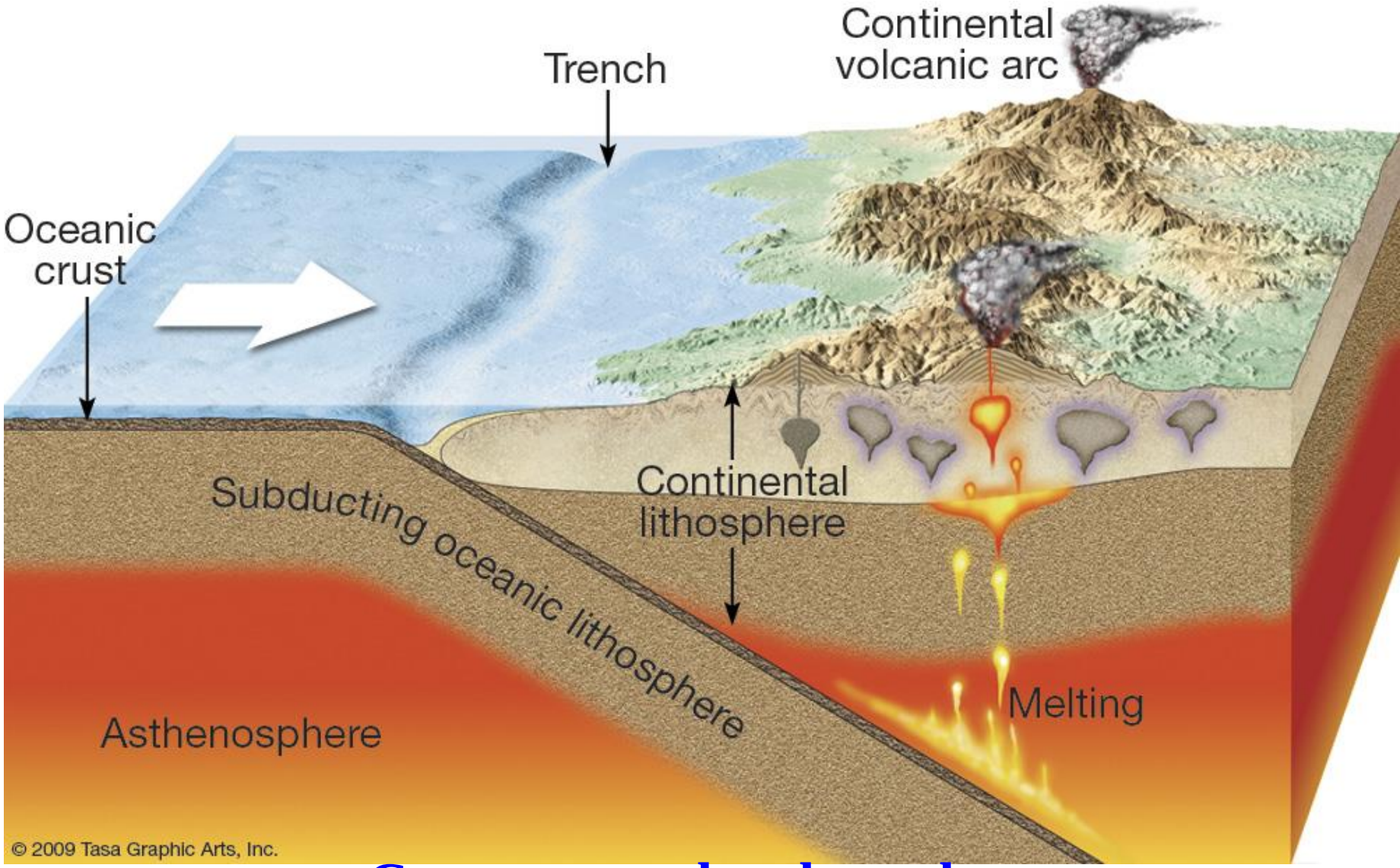




Oceanic Trenches in the Pacific Ocean



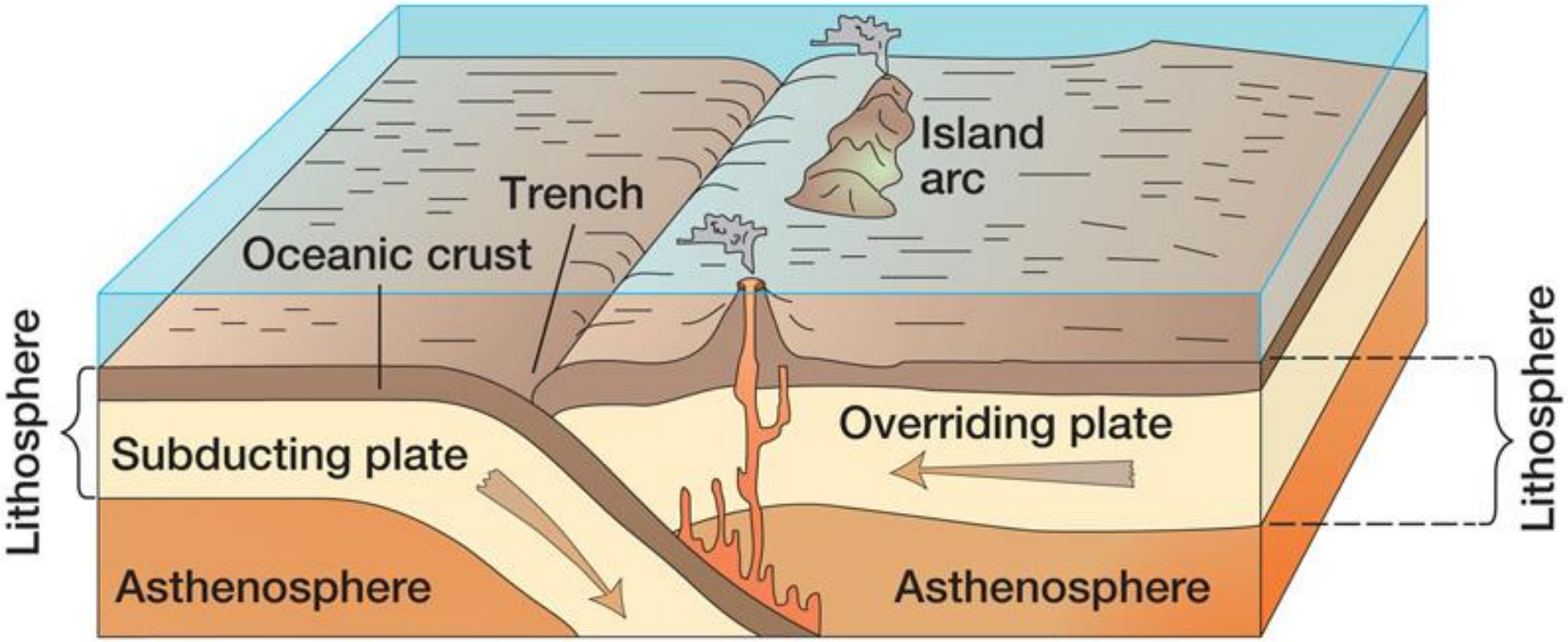
Active Continental Margin



Convergent plate boundary

Ocean-Continent convergence (subduction zone)

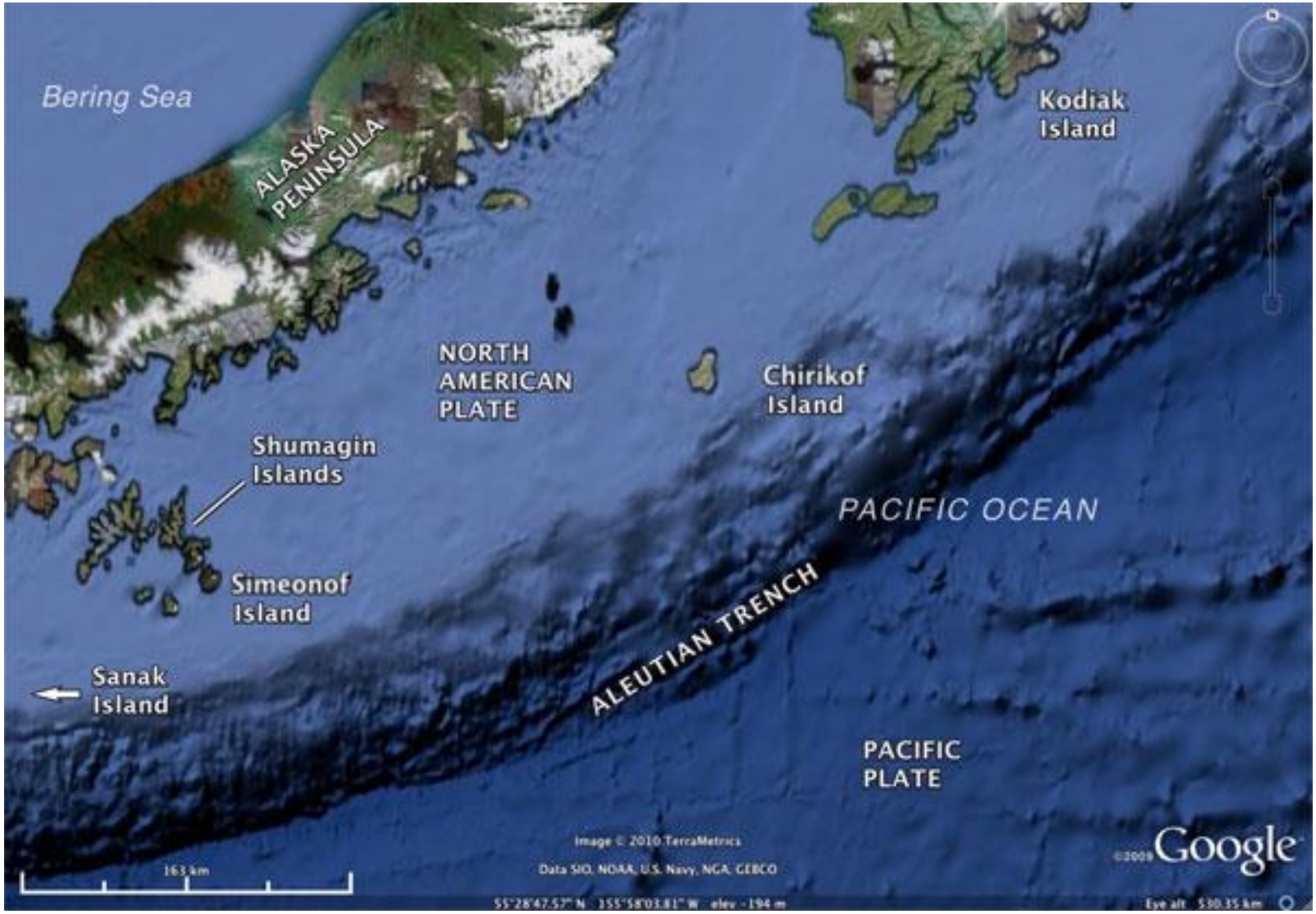
Convergent plate boundary
Ocean-Ocean convergence
(subduction zone)



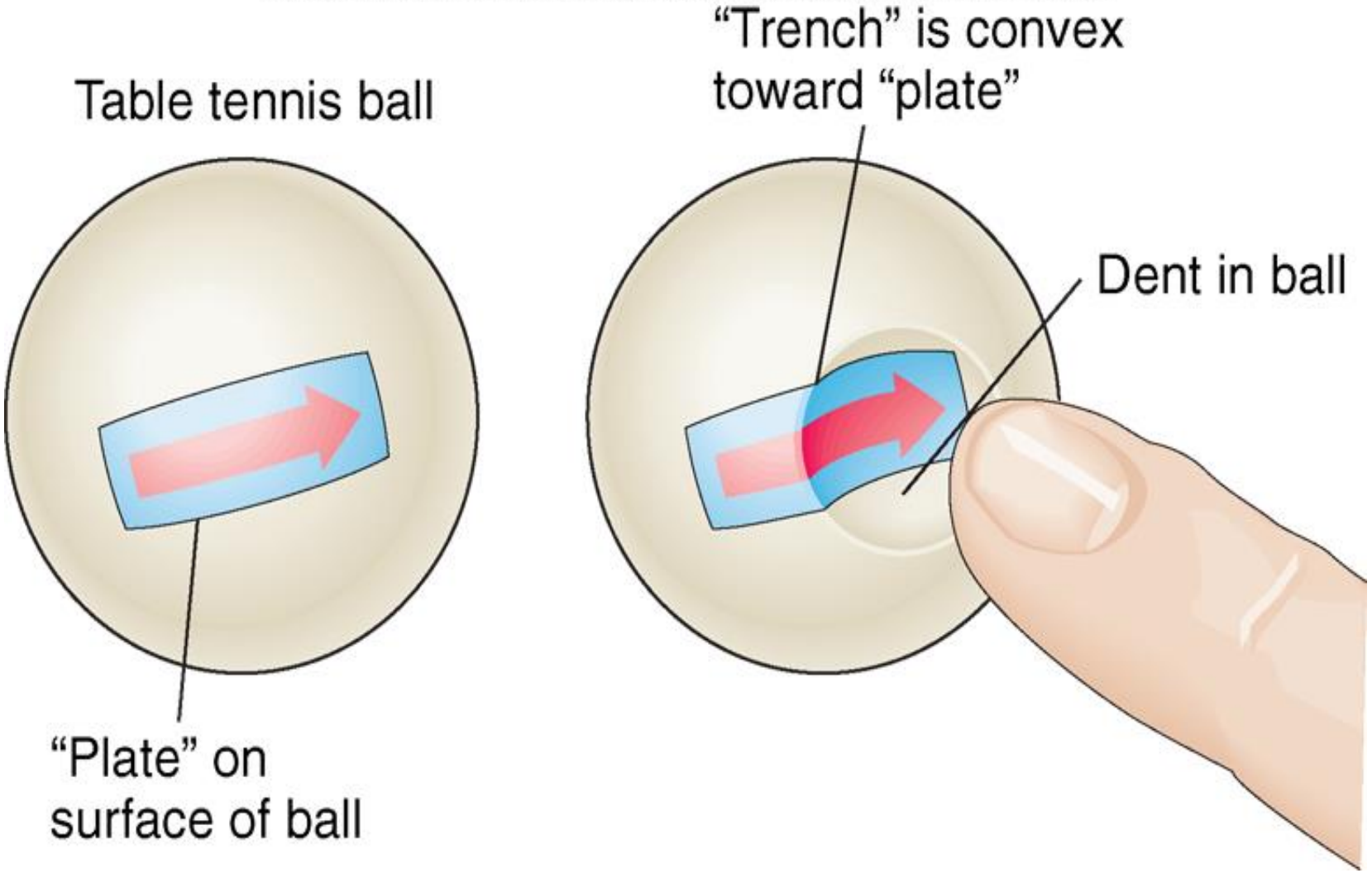
(b)

Features on the Seafloor

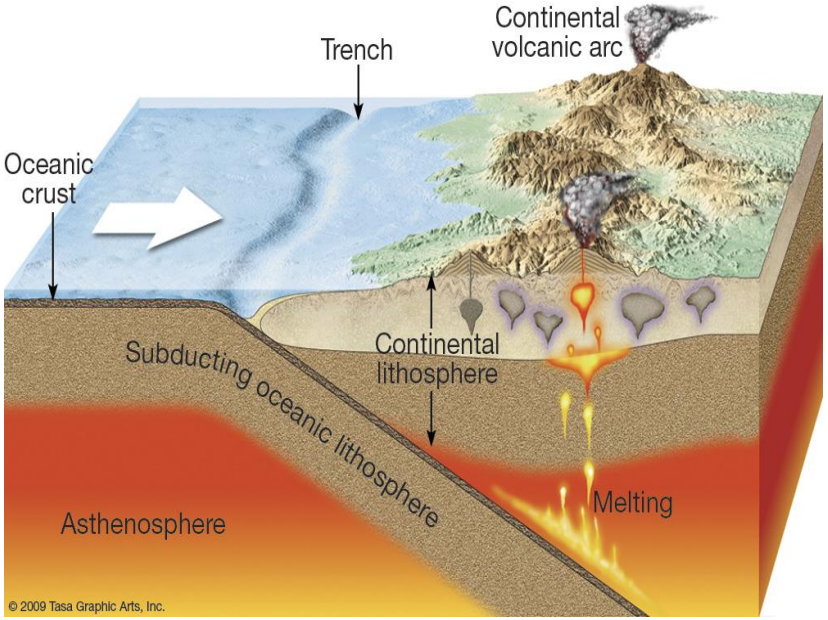
Volcanic island arcs (near trenches)

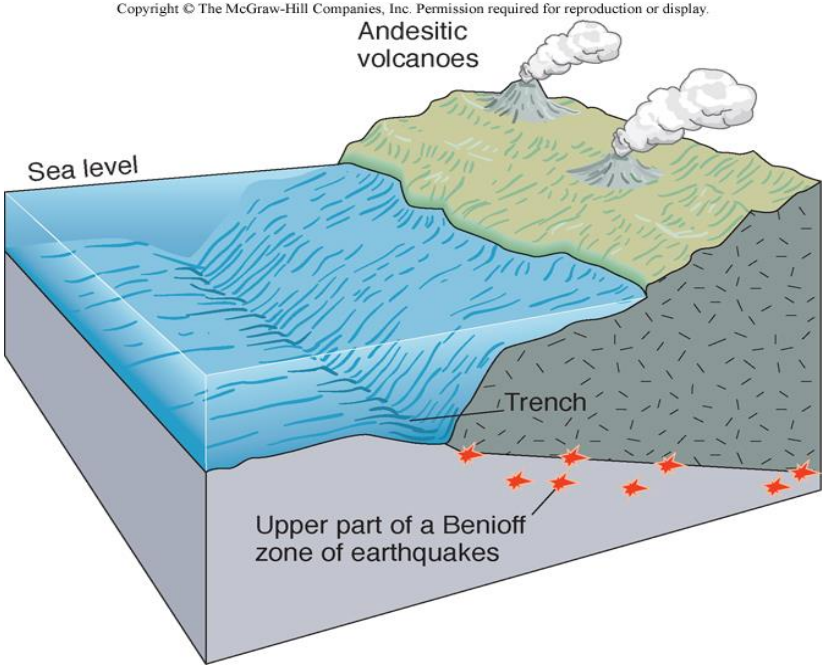


e.g., Aleutian island chain



Active Continental Margin





Convergent plate boundary

-compressive forces

-reverse & thrust faults

-recycling of lithosphere

-Arc volcanoes

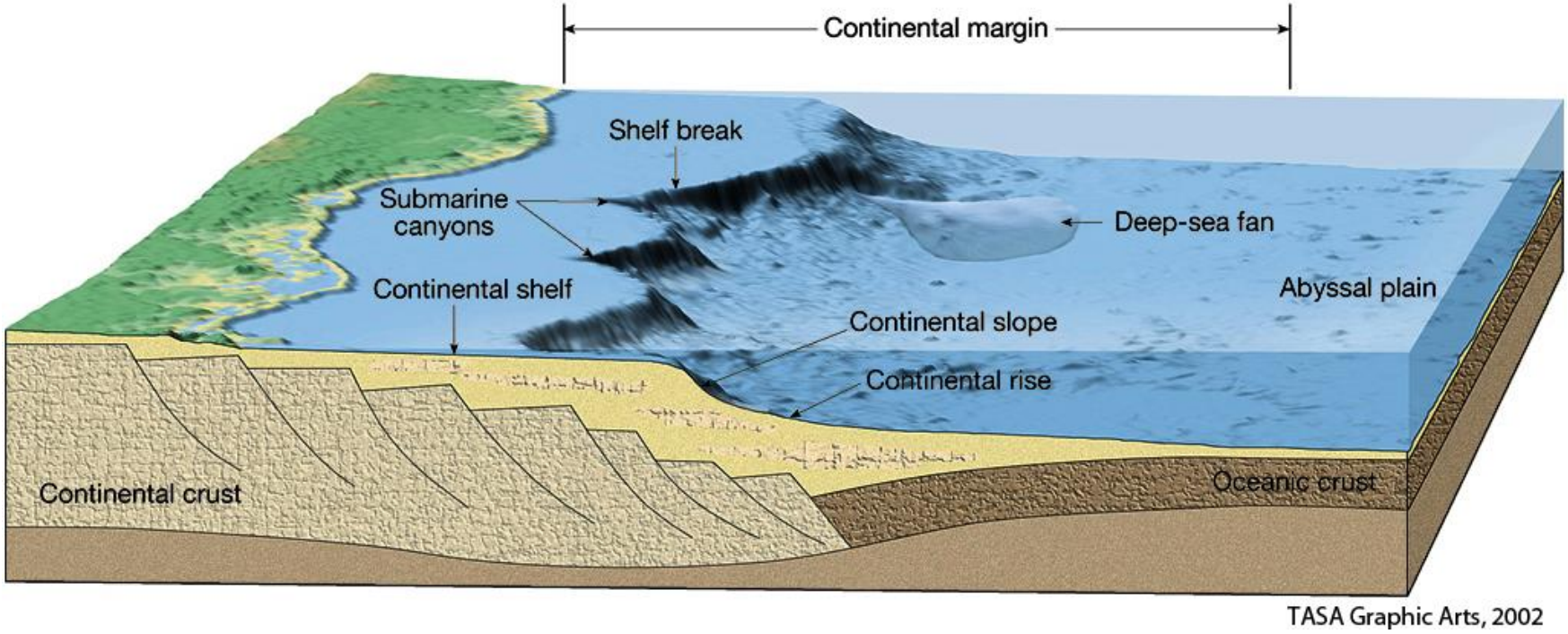
-Trench marks the subduction zone

-Shallow to deep earthquakes

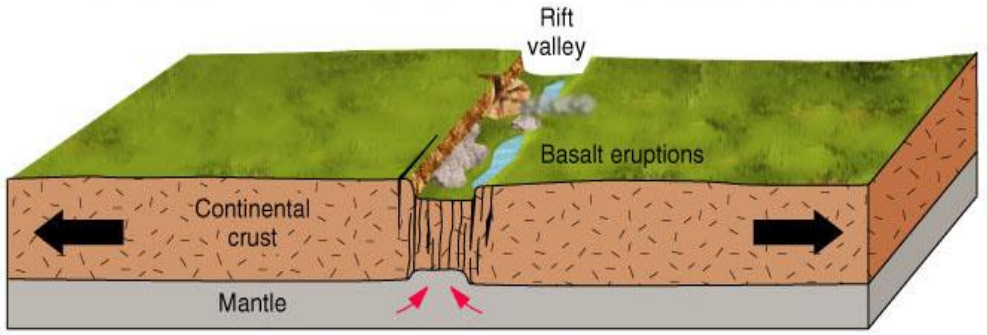
(Wadati-Benioff zone)

2) Passive Continental Margins

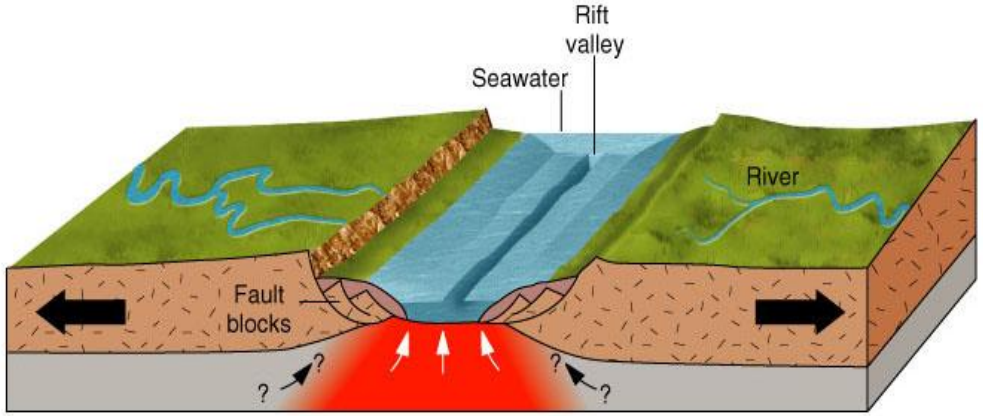
Continental shelf, Continental slope, Continental rise



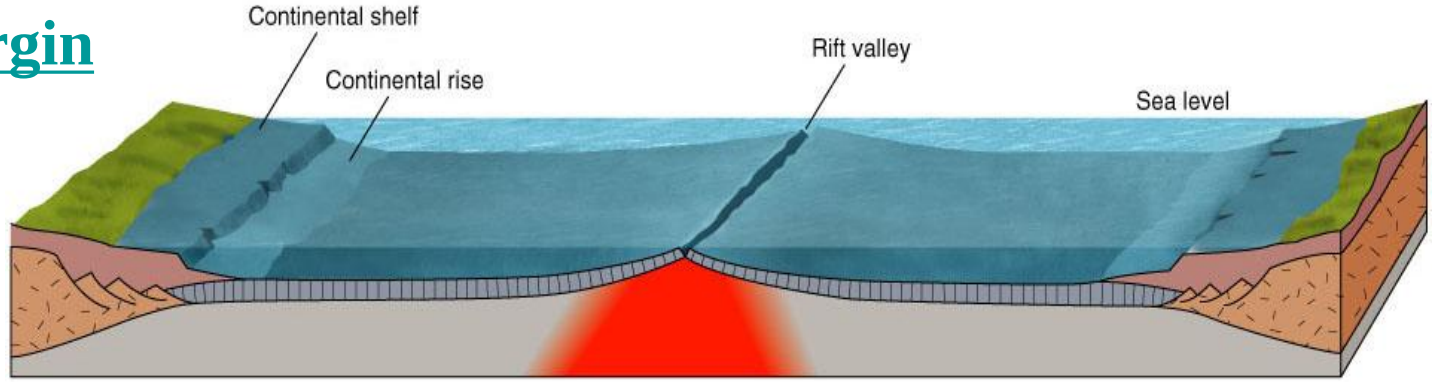
a) Continental rift



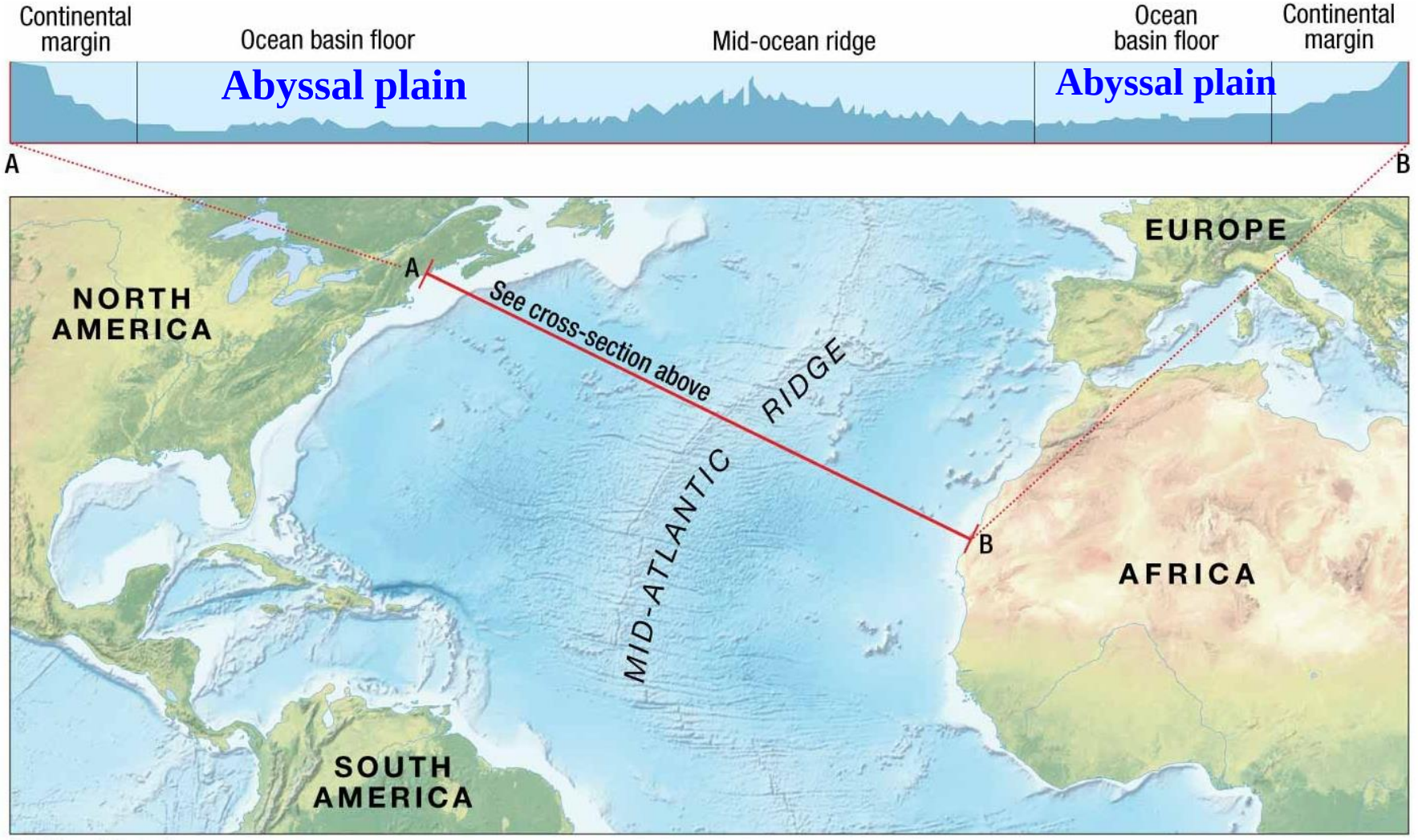
b) Small sea stage



c)MOR & Passive Continental margin

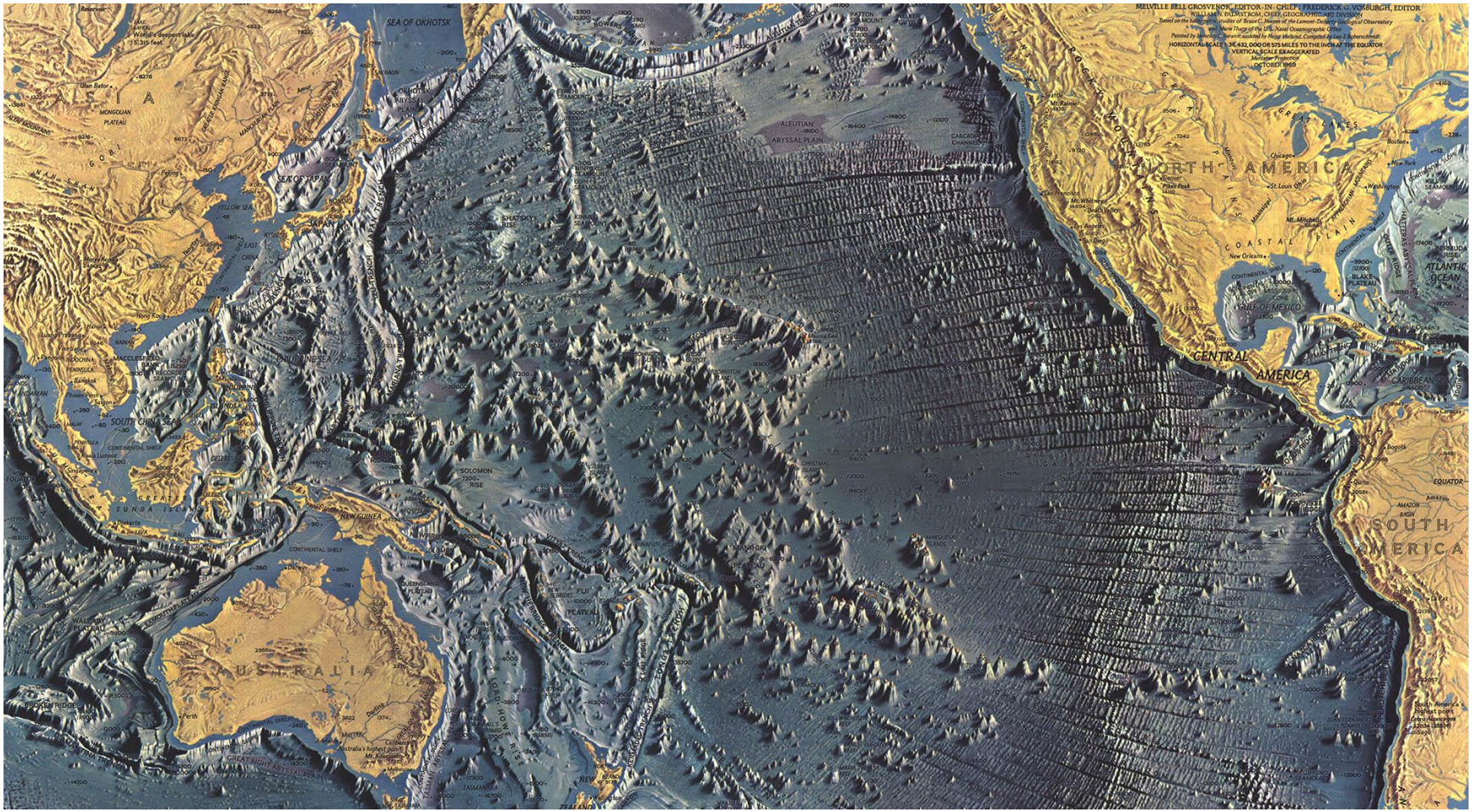


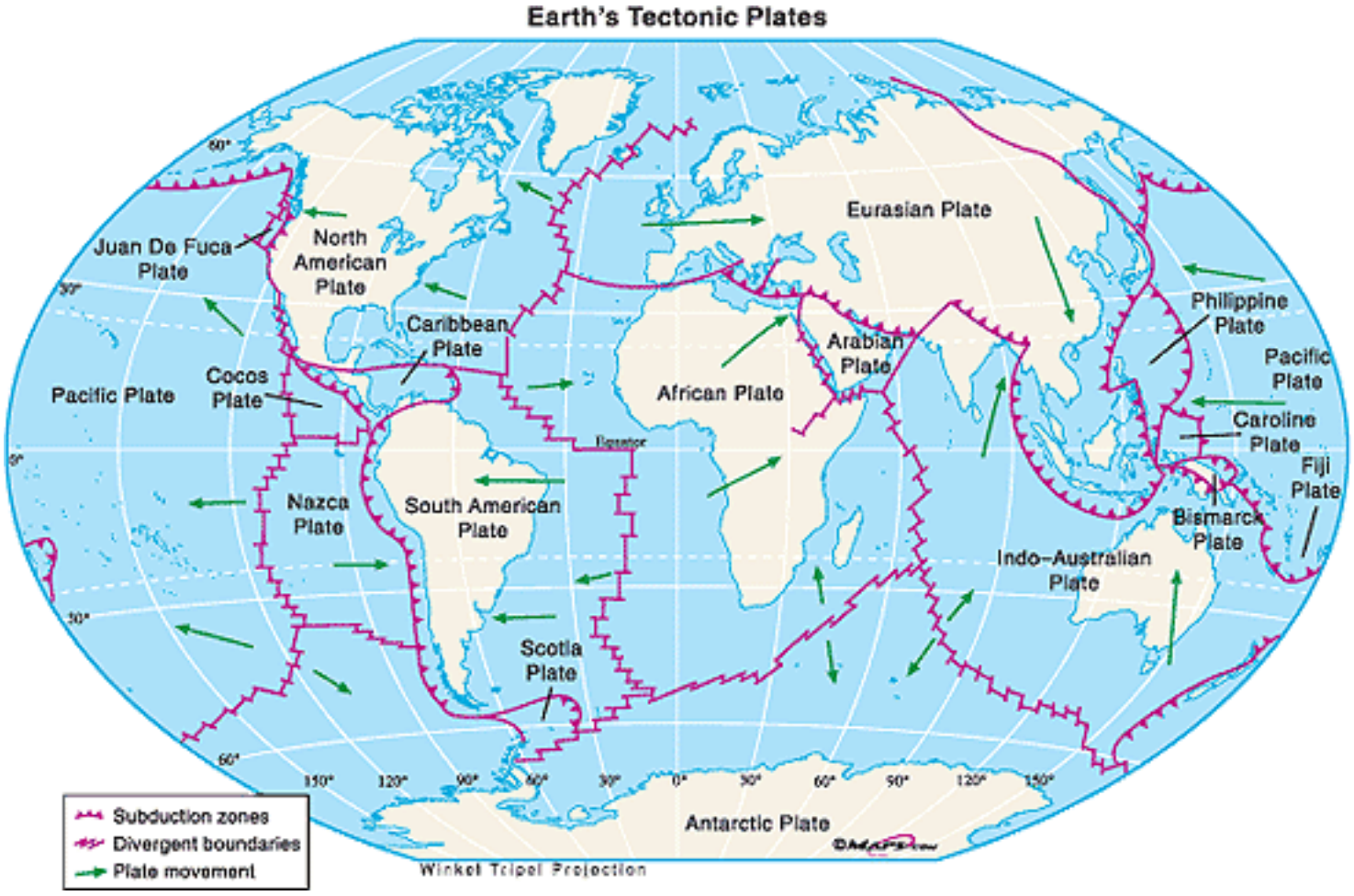
Passive continental margins

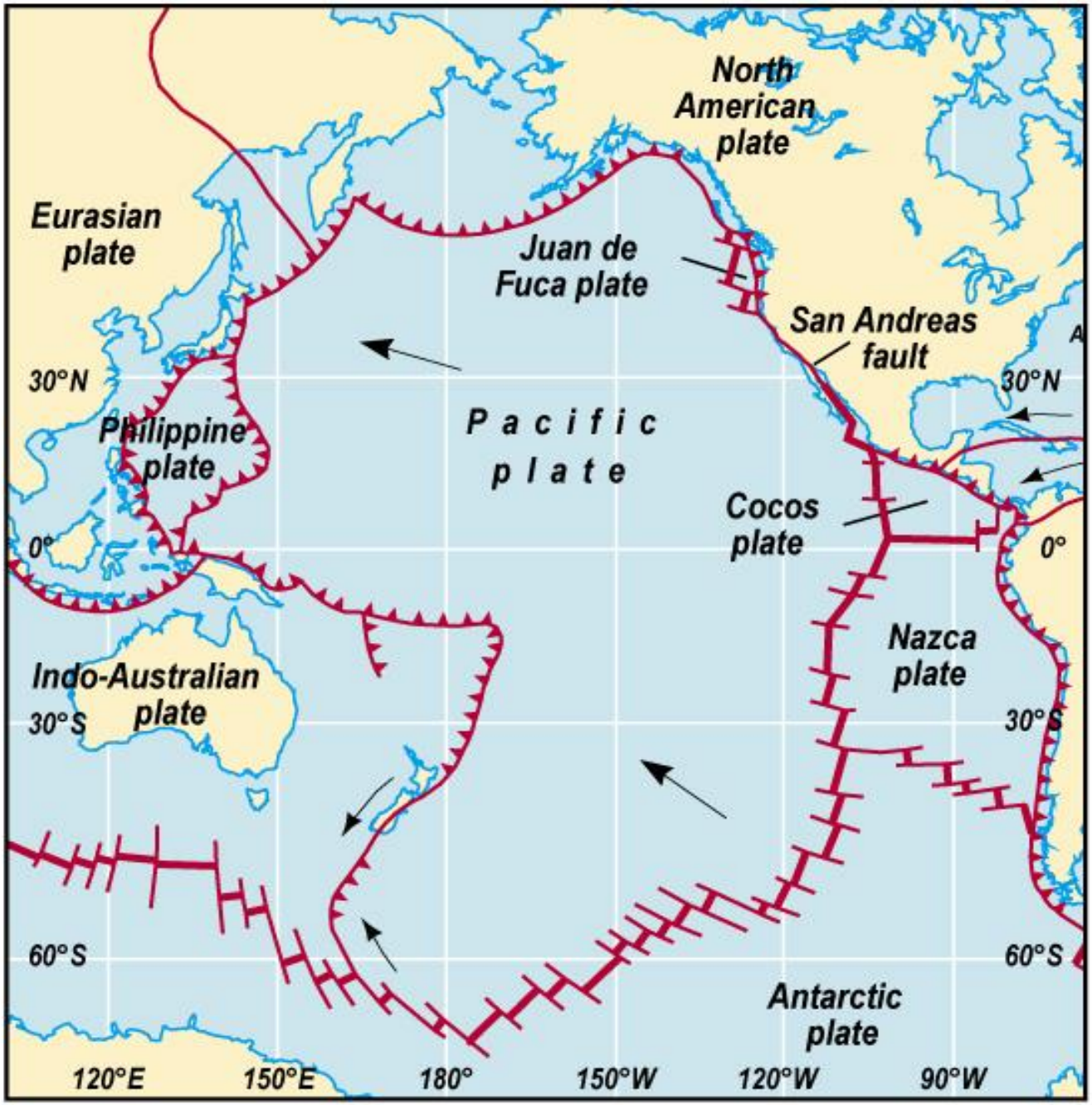


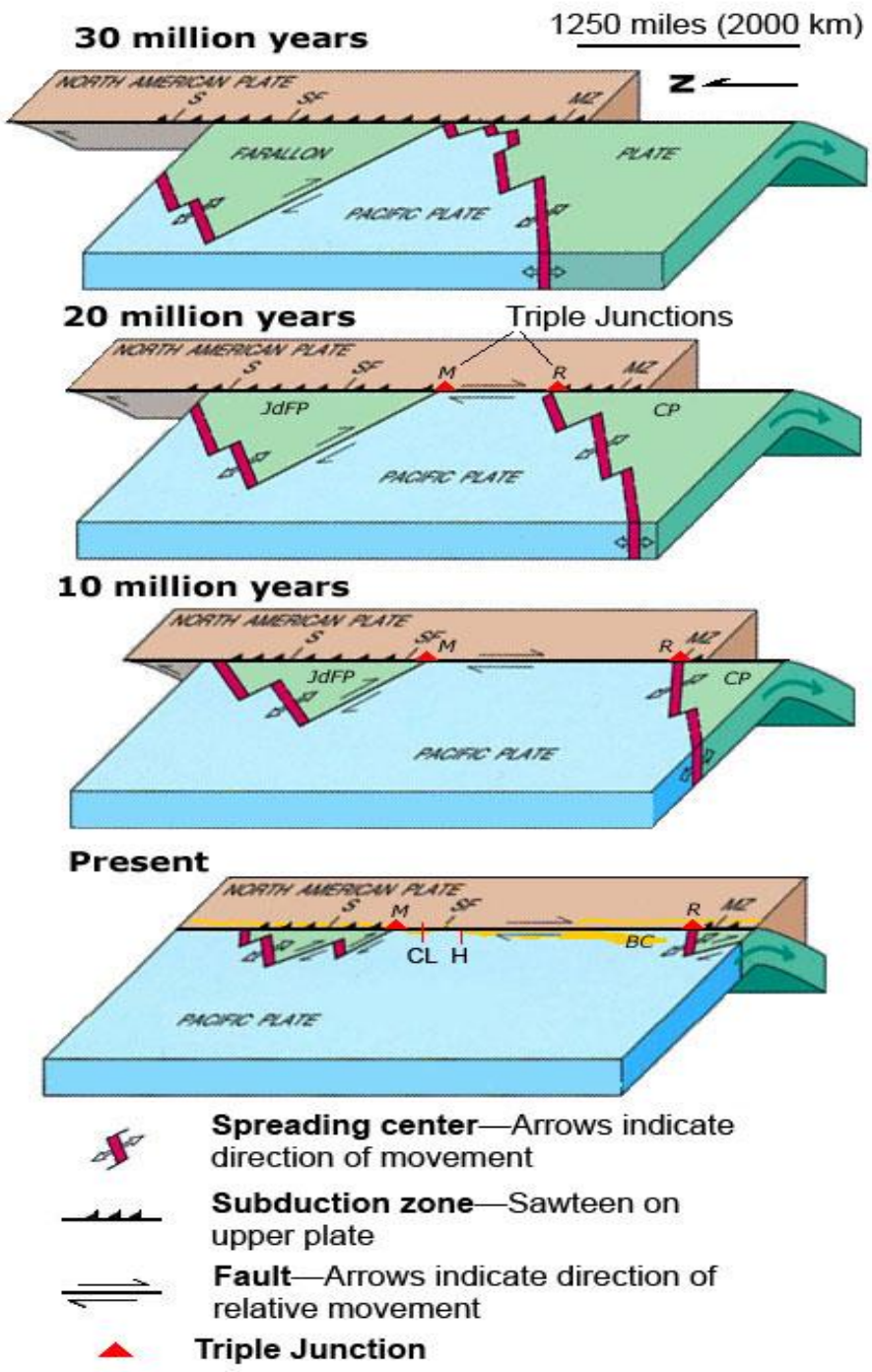
Atlantic Ocean Floor and Passive Continental Margins

Pacific Ocean Floor and Active continental margins




Earth's Tectonic Plates
Juan De Fuca Plate
North American Plate
Eurasian Plate
Philippine Plate
Pacific Plate
Caribbean Plate
Arabian Plate
Cocos Plate
Pacific Plate
African Plate
Caroline Plate
Fiji Plate
Equator
Nazca Plate
South American Plate
Bismarck Plate
Indo-Australian Plate
Scotia Plate
Antarctic Plate
Subduction zones
Divergent boundaries
Plate movement
Winkel Tripel Projection


North American plate
Eurasian plate
Juan de Fuca plate
San Andreas fault
30°N
Philippine plate
Pacific plate
Cocos plate
0°
Nazca plate
Indo-Australian plate
30°S
60°S
Antarctic plate
120°E
150°E
180°
150°W
120°W
90°W



Farallon Plate

→Juan de Fuca Plate
+ Cocos Plate

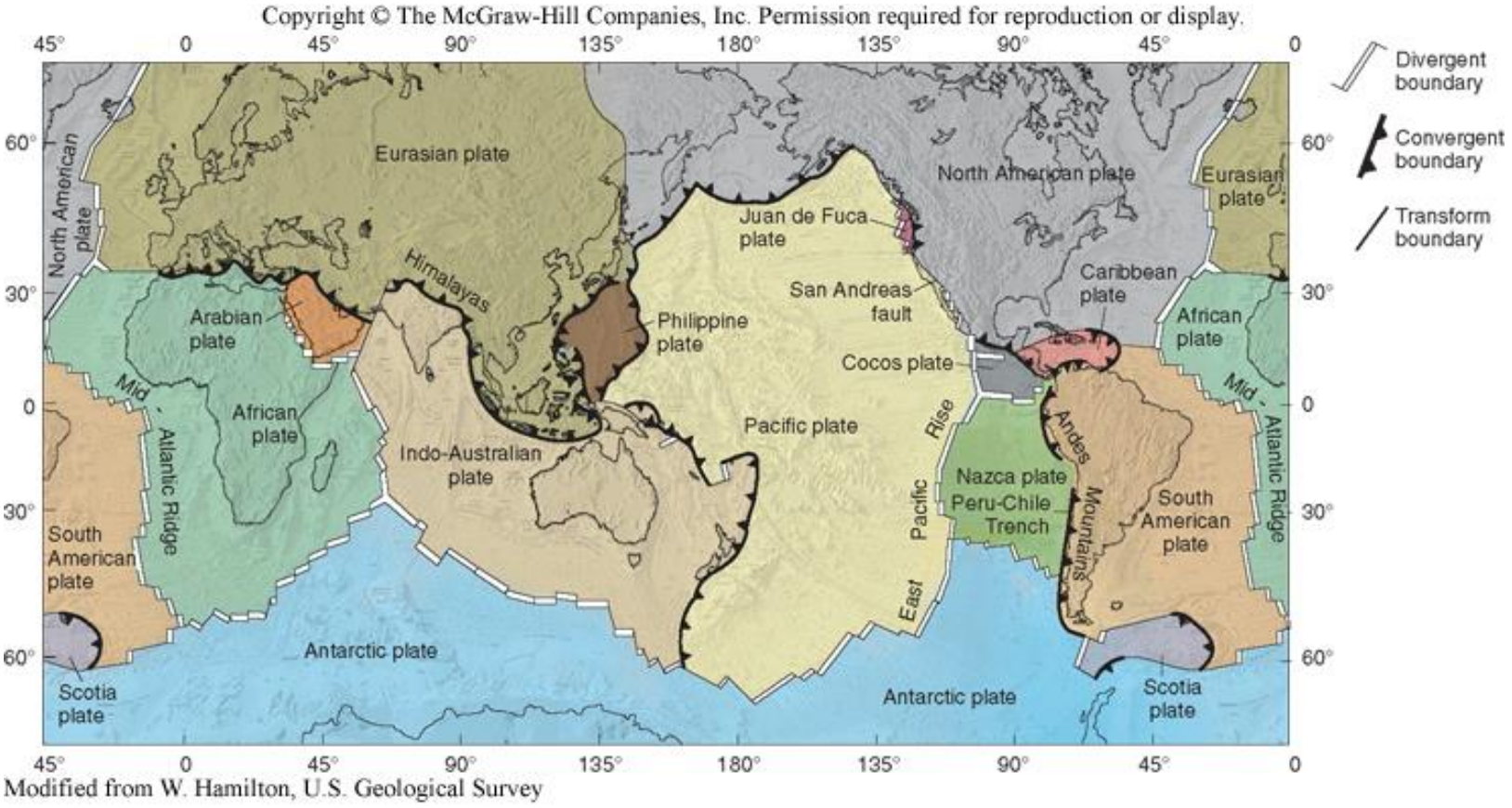
+ San Andreas Fault

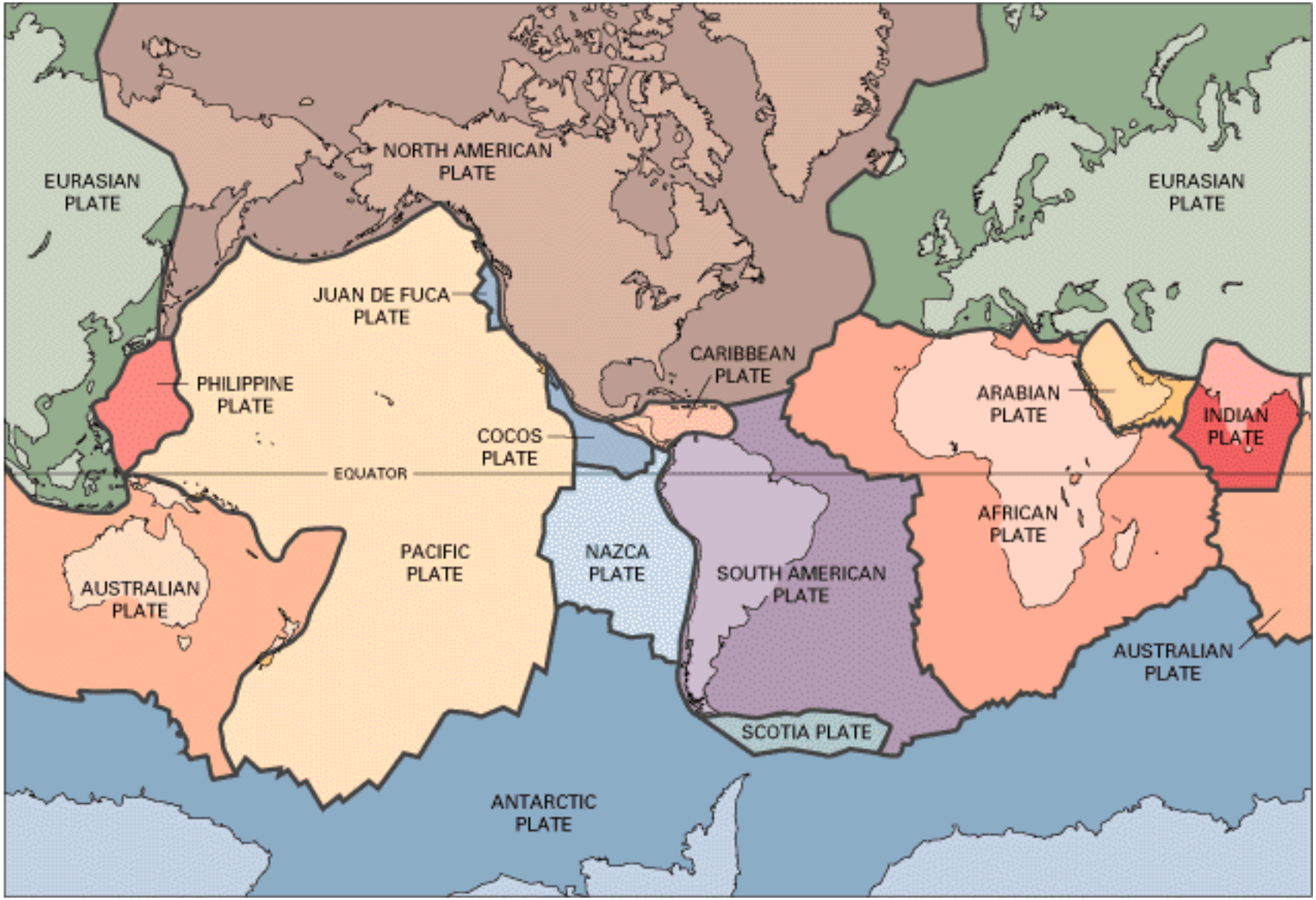
Plates can change in size

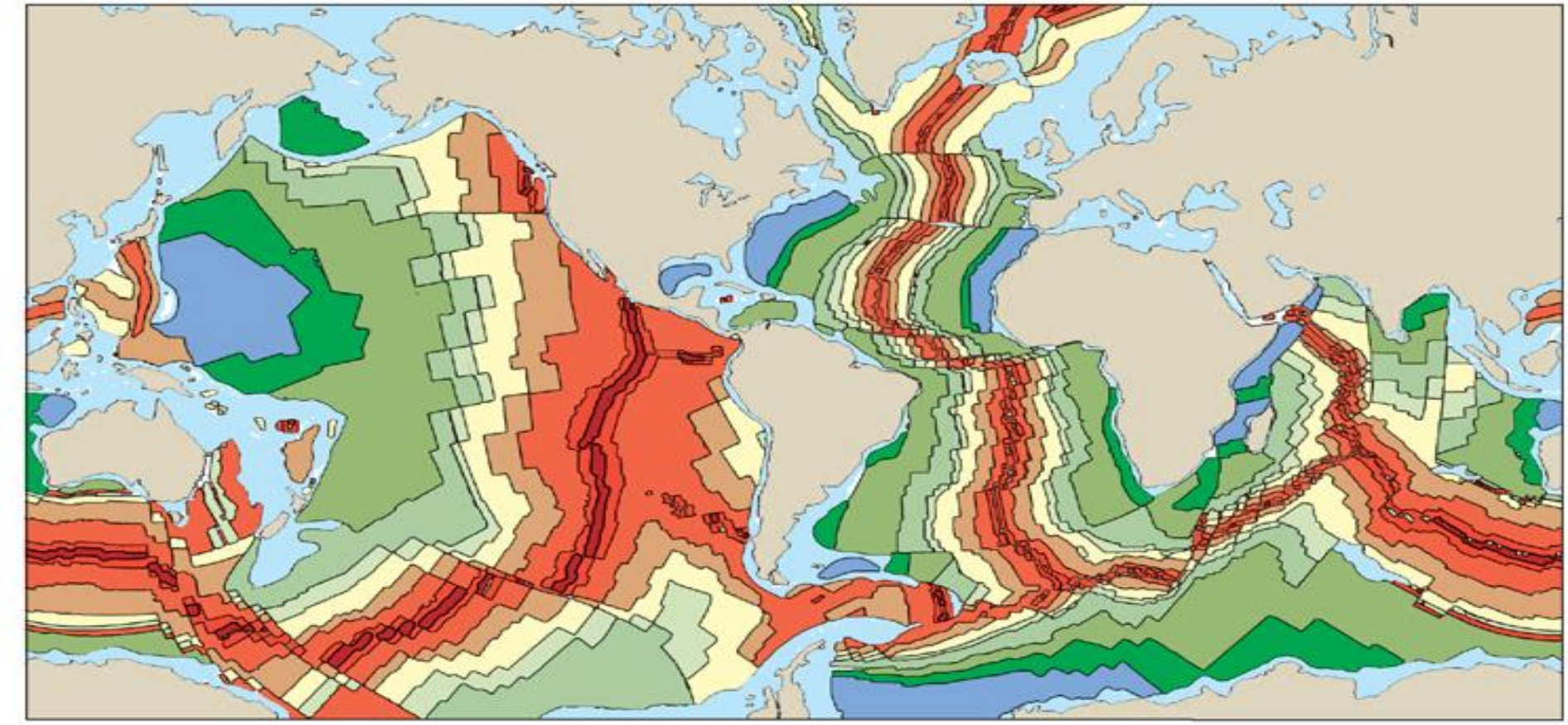
e.g.,

N. America plate: growing in size

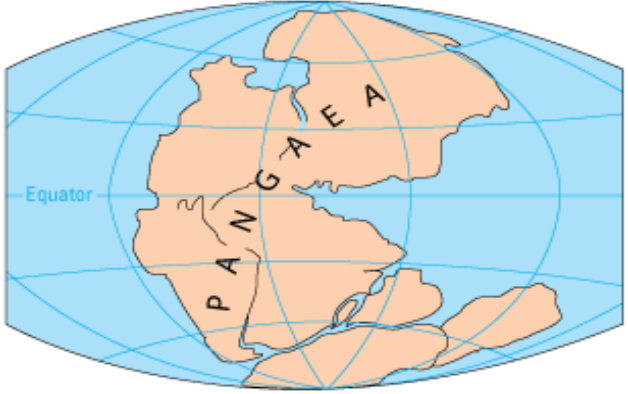
Nazca plate: getting smaller




EURASIAN PLATE
NORTH AMERICAN PLATE
EURASIAN PLATE
JUAN DE FUCA PLATE
CARIBBEAN PLATE
PHILIPPINE PLATE
ARABIAN PLATE
INDIAN PLATE
COCOS PLATE
EQUATOR
AFRICAN PLATE
PACIFIC PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
AUSTRALIAN PLATE
AUSTRALIAN PLATE
SCOTIA PLATE
ANTARCTIC PLATE

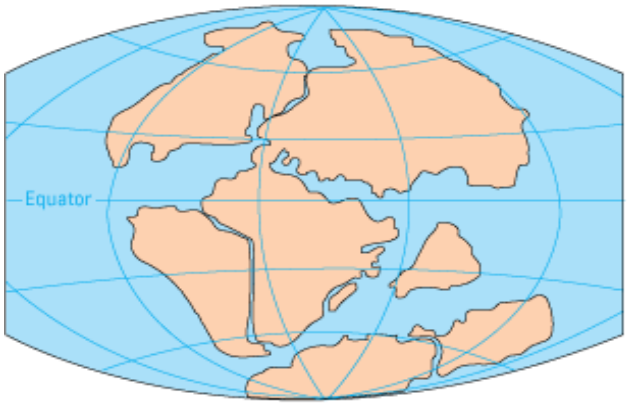


After The Bedrock Geology of the World by R. L. Larson, W. C. Pitman, III, et al., W. H. Freeman

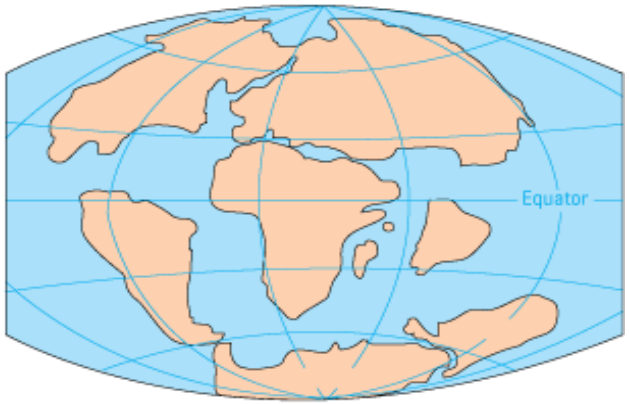


PERMIAN
225 million years ago

TRIASSIC
200 million years ago



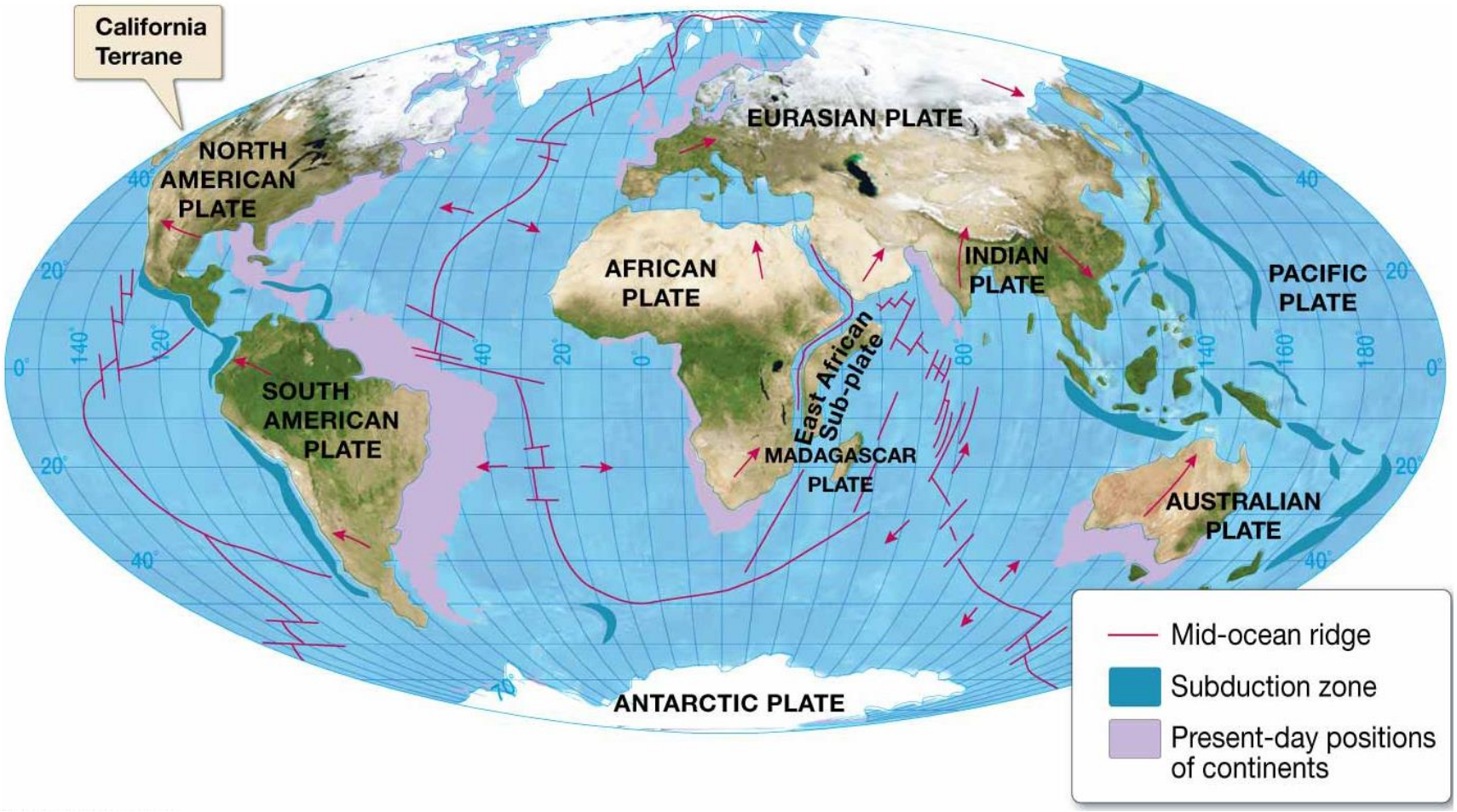
JURASSIC
150 million years ago



CRETACEOUS
65 million years ago

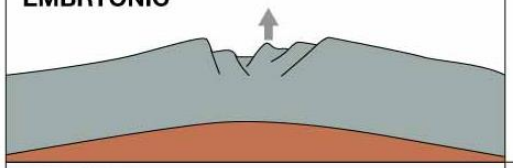
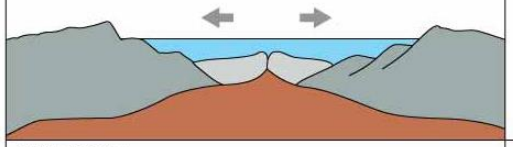
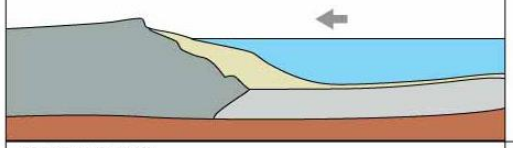
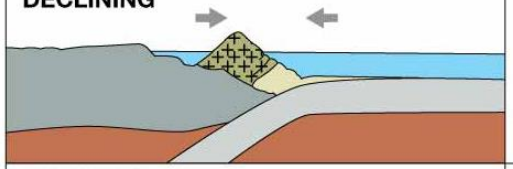
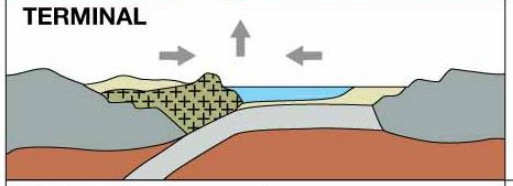
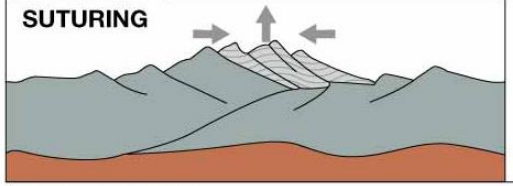
PRESENT DAY

50 million Years in Future

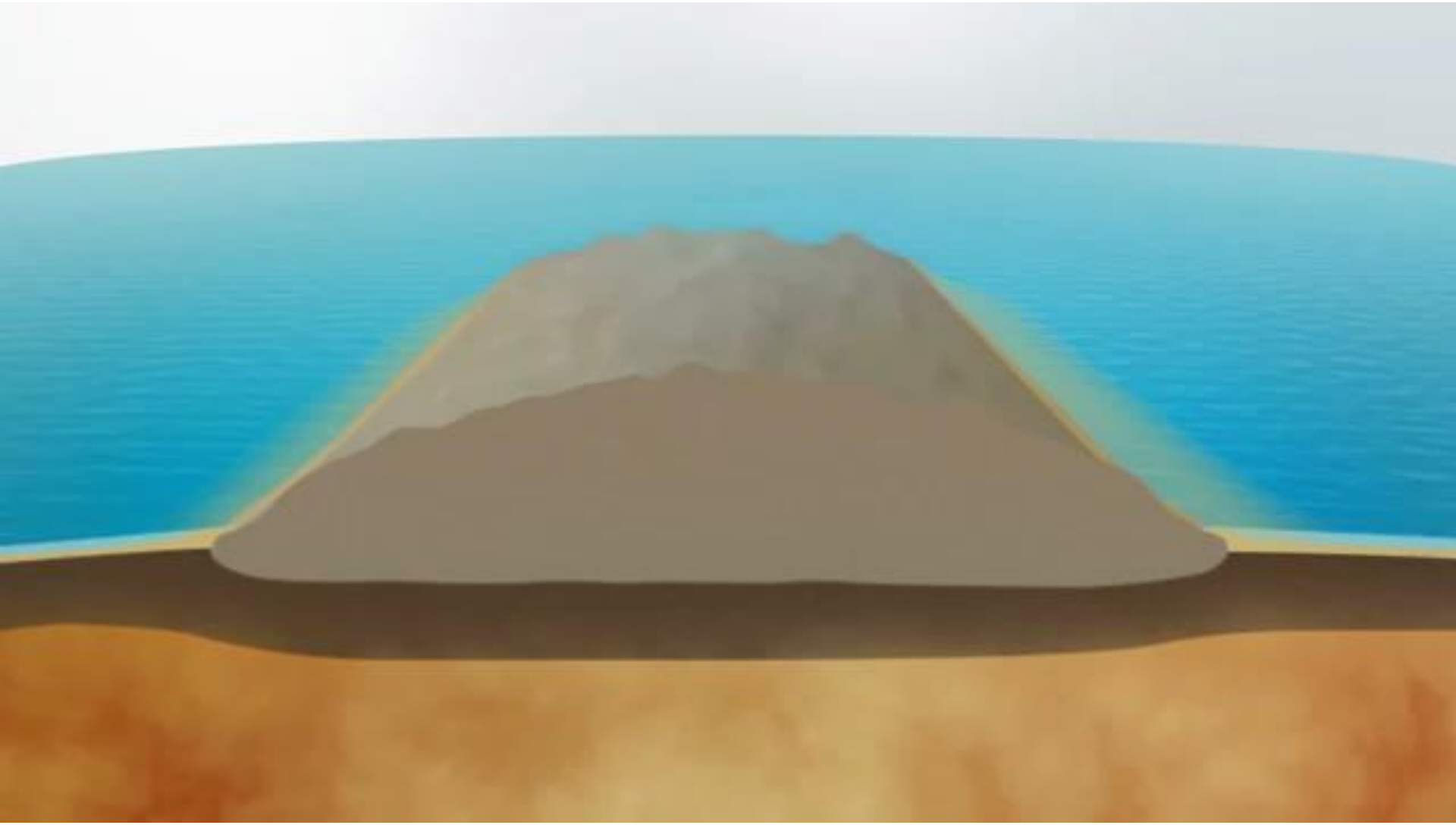


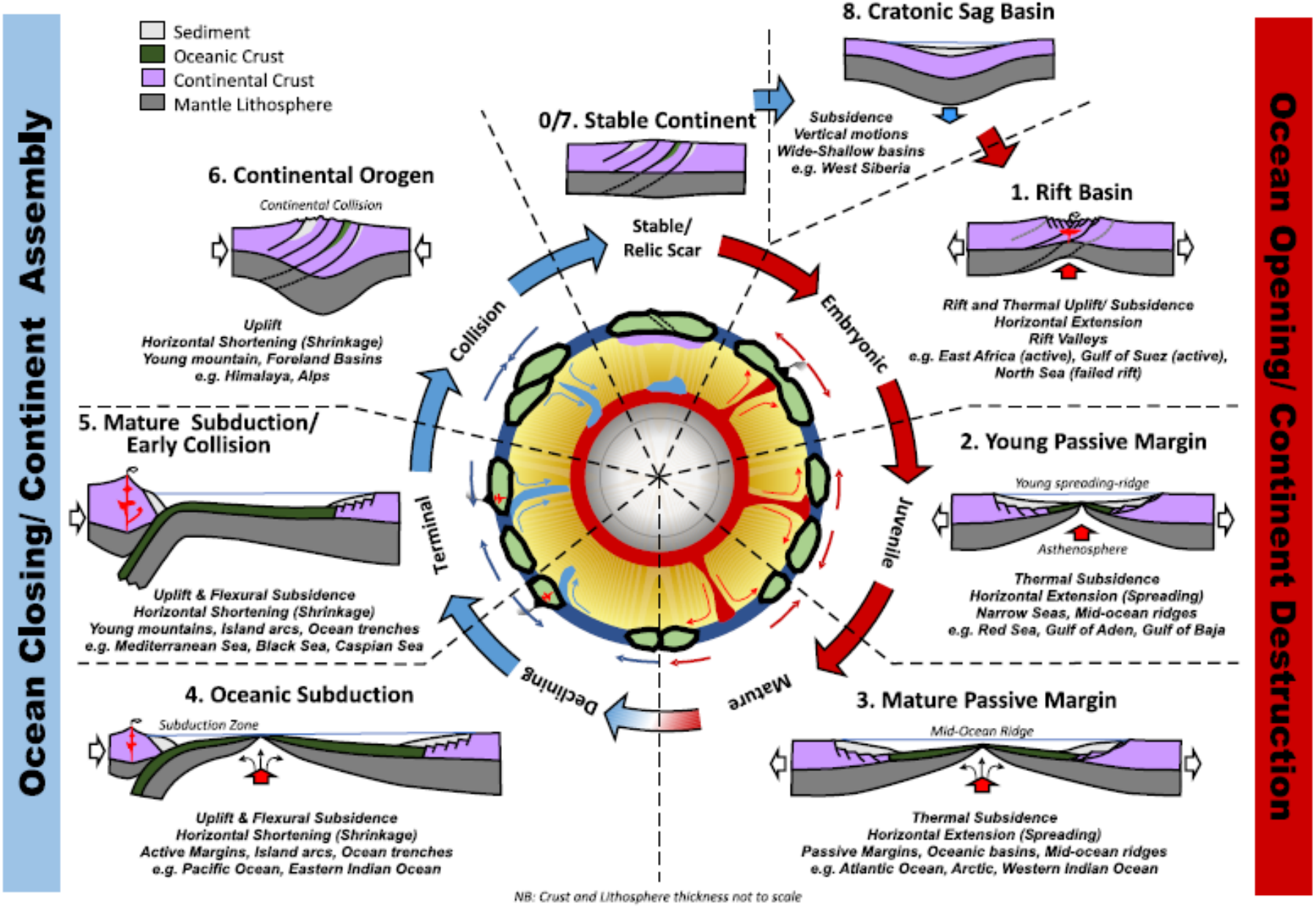
650 million year in 1 minute 20 seconds

Wilson Cycle of Ocean Basins

Stage, showing cross-sectional view	Motion	Physiography	Example
EMBRYONIC 	Uplift	Complex system of linear rift valleys on continent	East Africa rift valleys
JUVENILE 	Divergence (spreading)	Narrow seas with matching coasts	Red Sea
MATURE 	Divergence (spreading)	Ocean basin with continental margins	Atlantic and Arctic Oceans
DECLINING 	Convergence (subduction)	Island arcs and trenches around basin edge	Pacific Ocean
TERMINAL 	Convergence (collision) and uplift	Narrow, irregular seas with young mountains	Mediterranean Sea
SUTURING 	Convergence and uplift	Young to mature mountain belts	Himalaya Mountains

Wilson Cycle




Ocean Closing/ Continent Assembly
Ocean Opening/ Continent Destruction
Sediment
Oceanic Crust
Continental Crust
Mantle Lithosphere
8. Cratonic Sag Basin
Subsidence
Vertical motions
Wide-Shallow basins
e.g. West Siberia
0/7. Stable Continent
1. Rift Basin
Rift and Thermal Uplift/ Subsidence
Horizontal Extension
Rift Valleys
e.g. East Africa (active), Gulf of Suez (active), North Sea (failed rift)
6. Continental Orogen
Continental Collision
Uplift
Horizontal Shortening (Shrinkage)
Young mountain, Foreland Basins
e.g. Himalaya, Alps
Stable/ Relic Scar
Embryonic
Collision
Juvenile
Terminal
Mature
Declining
2. Young Passive Margin
Young spreading-ridge
Asthenosphere
Thermal Subsidence
Horizontal Extension (Spreading)
Narrow Seas, Mid-ocean ridges
e.g. Red Sea, Gulf of Aden, Gulf of Baja
5. Mature Subduction/ Early Collision
Uplift & Flexural Subsidence
Horizontal Shortening (Shrinkage)
Young mountains, Island arcs, Ocean trenches
e.g. Mediterranean Sea, Black Sea, Caspian Sea
3. Mature Passive Margin
Mid-Ocean Ridge
Thermal Subsidence
Horizontal Extension (Spreading)
Passive Margins, Oceanic basins, Mid-ocean ridges
e.g. Atlantic Ocean, Arctic, Western Indian Ocean
4. Oceanic Subduction
Subduction Zone
Uplift & Flexural Subsidence
Horizontal Shortening (Shrinkage)
Active Margins, Island arcs, Ocean trenches
e.g. Pacific Ocean, Eastern Indian Ocean
NB: Crust and Lithosphere thickness not to scale

1. Typical features of Ocean-Ocean convergence

2. The pros and cons of continental drift

3. If you were Alfred Wegener who was trying to persuade people to believe continental drift, where would you go to find evidence, and what phenomenon would you expect to find?

- **Homework:**
- Please describe the mechanisms (hypotheses), characteristics, and typical fields of Oceanic crust **obduction.**