Introduction to
PLATE TECTONICS

part 3: Plate Boundaries, Hot Spots, and mechanisms

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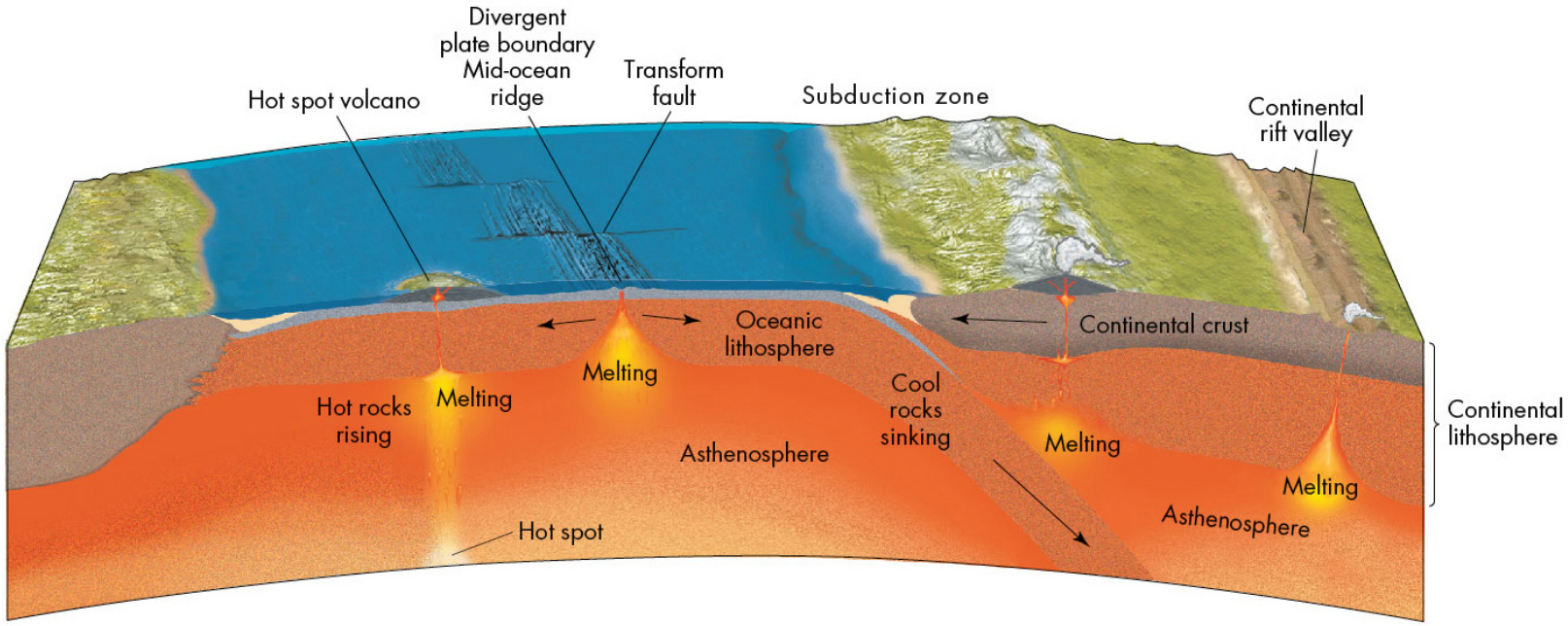
previously…

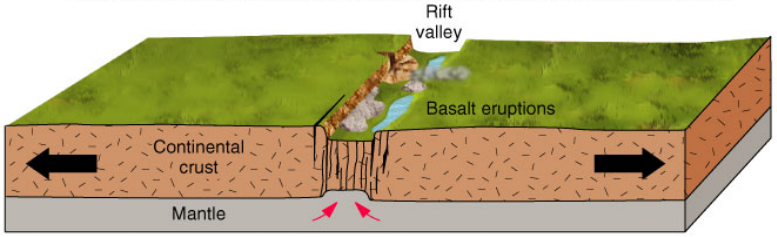
- Plate Tectonics says that Earth's surface is broken down in a series of lithospheric plates, moving around passively, dragged by motion in the asthenosphere
- Plates mostly interact with each other at their edge, or Plate Boundary
- Plate Boundaries can be divergent, transform, and convergent

- *Divergent* boundaries
  - Plates move apart (*spreading*)
  - Magma rises, cools and forms new oceanic crust (basalt)
  - Typically expressed as *mid-ocean ridges (*or *rises)*
  - Both *Volcanic Activity* and *Earthquakes* are present
- *Transform* boundaries
  - Plates slide past one another
  - Fault zones and *Earthquakes* mark boundary, but there is *no Volcanic Activity*
  - Connect segments of the mid-ocean ridge
- *Convergent* boundaries
  - Plates move toward each other
  - Mountain belts and *Volcanoes* common, deepest and strongest *Earthquakes*
  - Oceanic plates may sink into mantle along a *subduction zone*, typically marked by a deep ocean *trench*

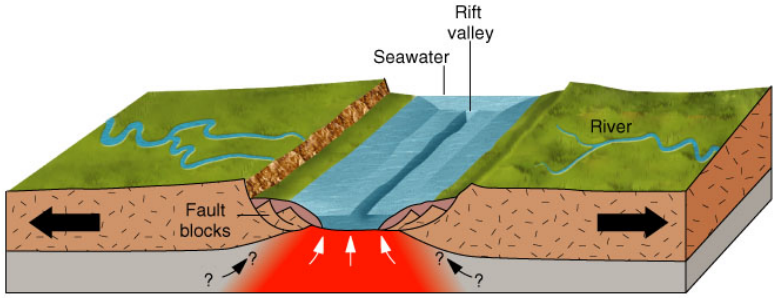
Plate Boundaries



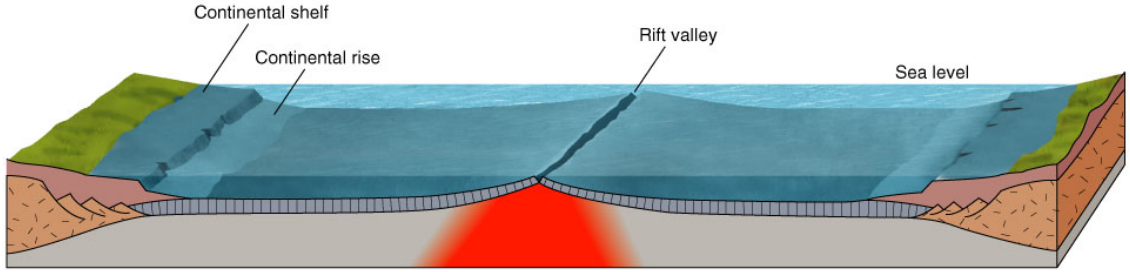
DIVERGENT BOUNDARIES



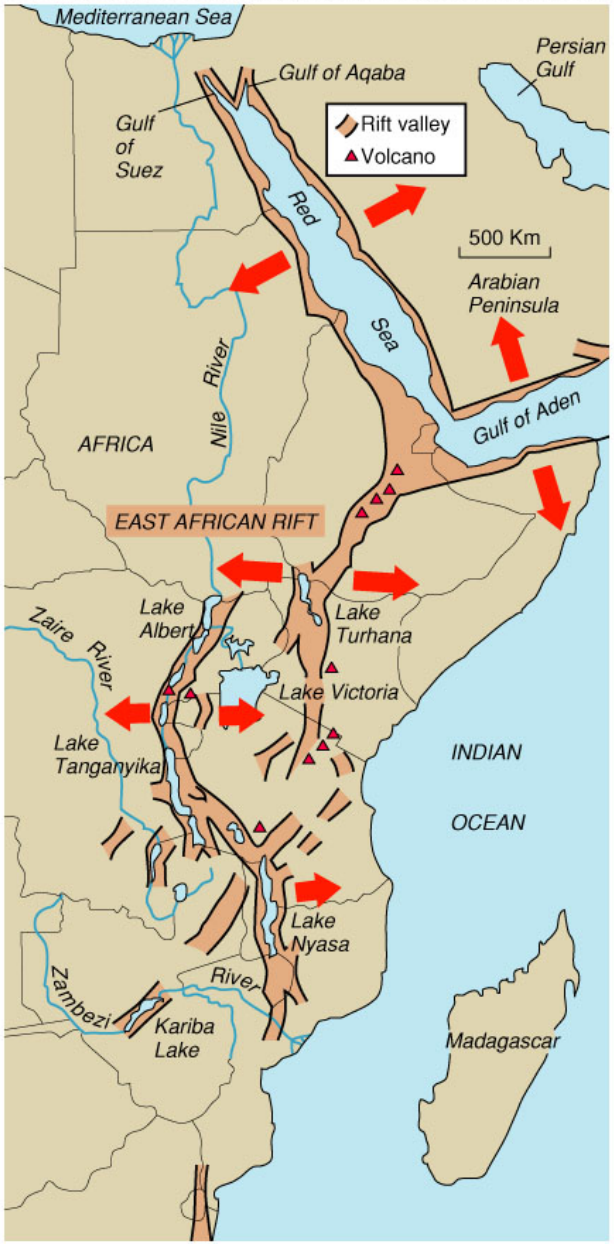
A Continent undergoes extension. The crust is thinned and a rift valley forms (East African Rift Valleys)



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



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



An early rift stage

Death Valley, California

Death Valley is part of the Basin and Range Desert, where the crust is being stretched and thinned. All the characteristic features of a rifting zone found in the East African Rift can also be seen in here, albeit to a smaller scale.

A linear sea stage

The Red Sea

(Egypt to the right, Saudi Arabia to the left)

The Red Sea represents a “linear sea” stage, that is an ocean that is long and narrow.

At this stage, oceanic crust is already present at the bottom of the ocean.

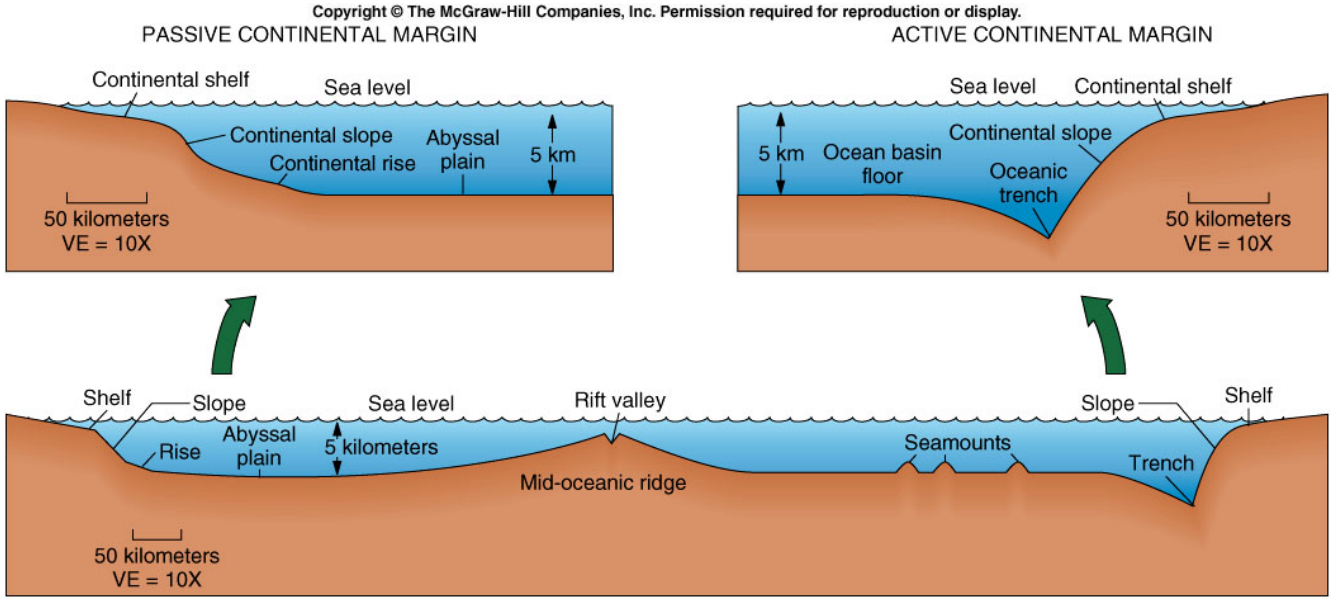
The Atlantic Ocean:
a fully developed ocean

Passive vs. Active Continental Margins

A continental margin is where a continent meets the ocean.

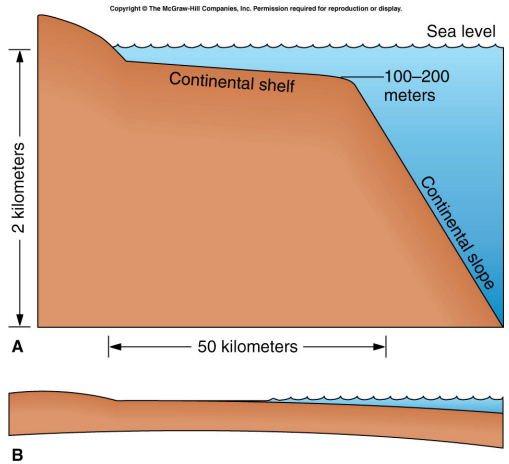
If that coincides with a plate boundary, it is called an **Active Margin** (such as the North American west coast).

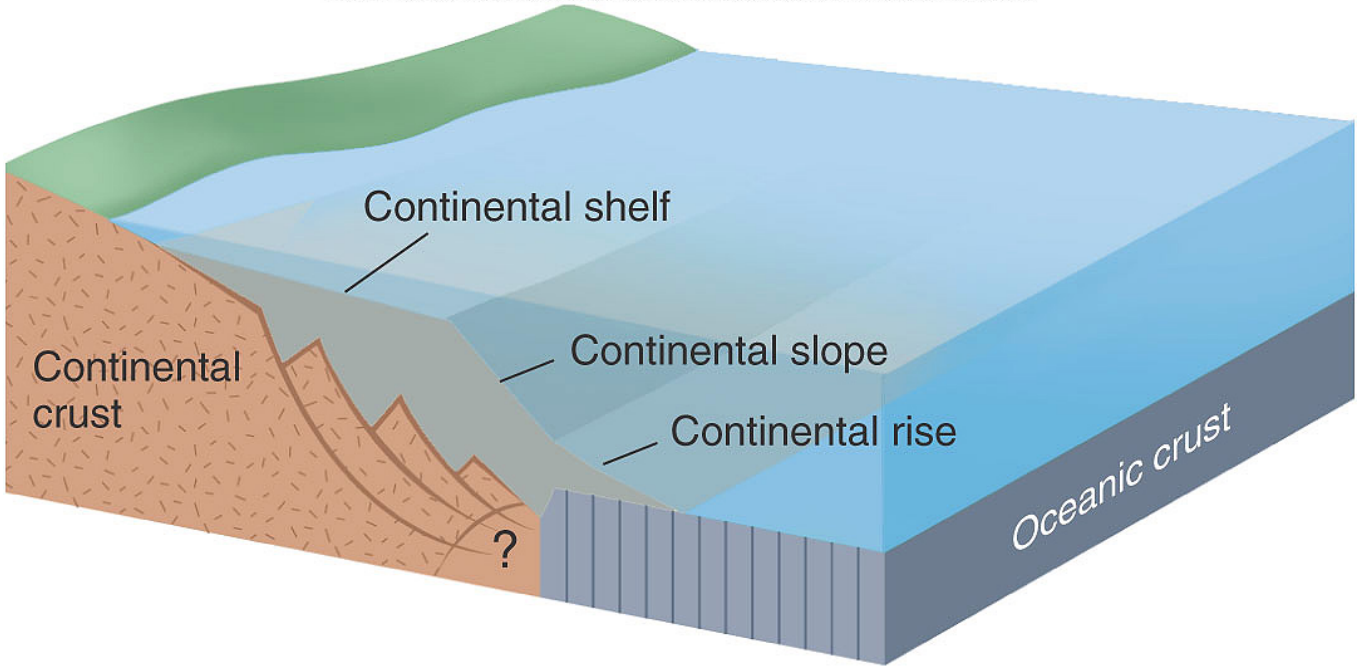
If that does not coincide with a plate boundary, it is called a **Passive Margin** (such as the North American east coast)

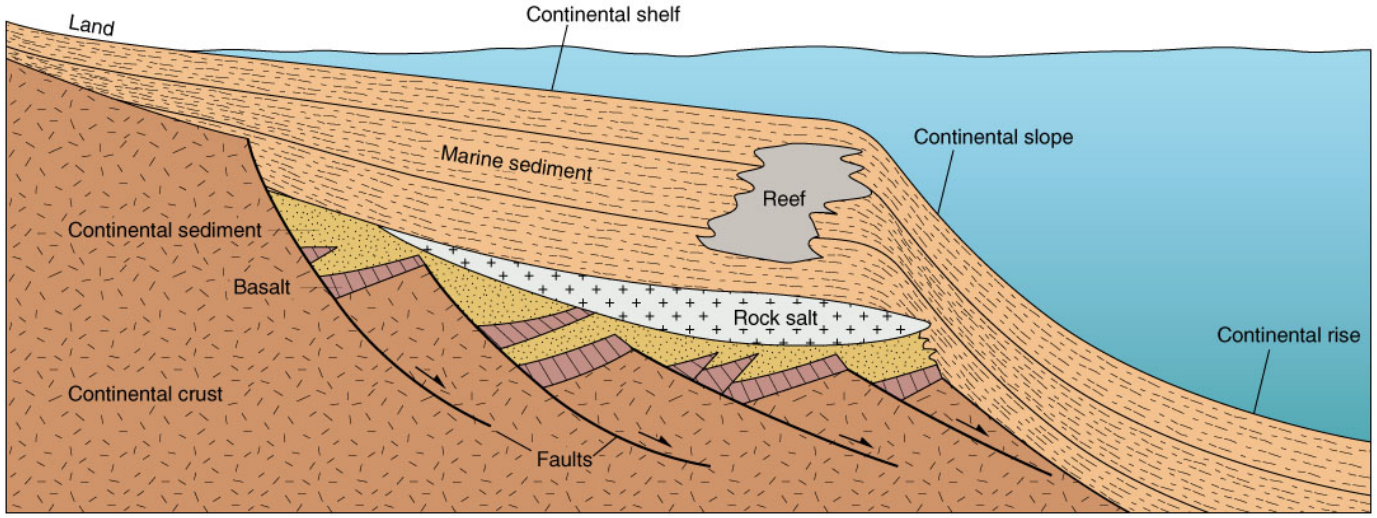


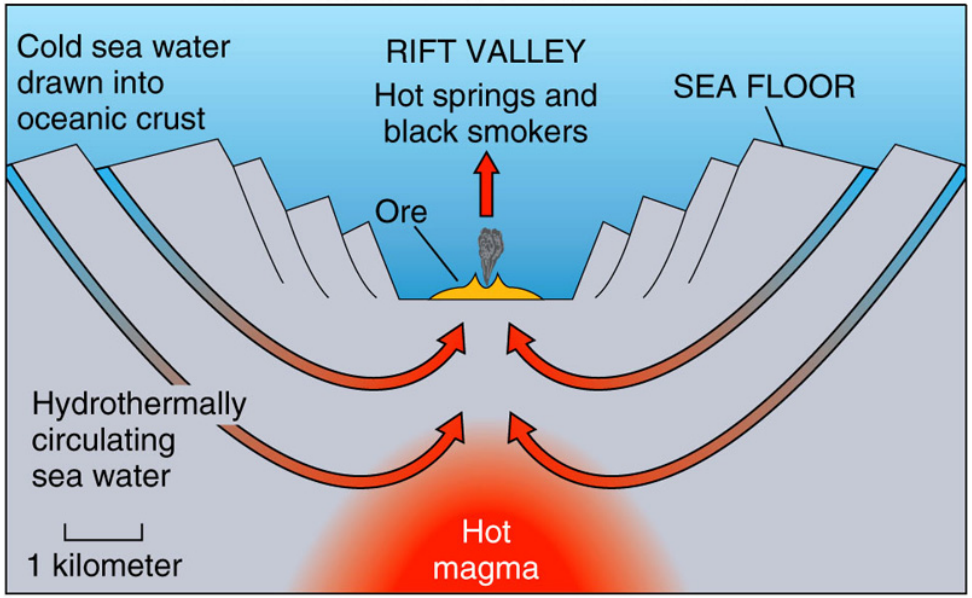
- Continental Shelf
- Slope
- Continental Rise
- Abyssal Plain

- Mid-Ocean Ridge
- Seamounts
- Trench

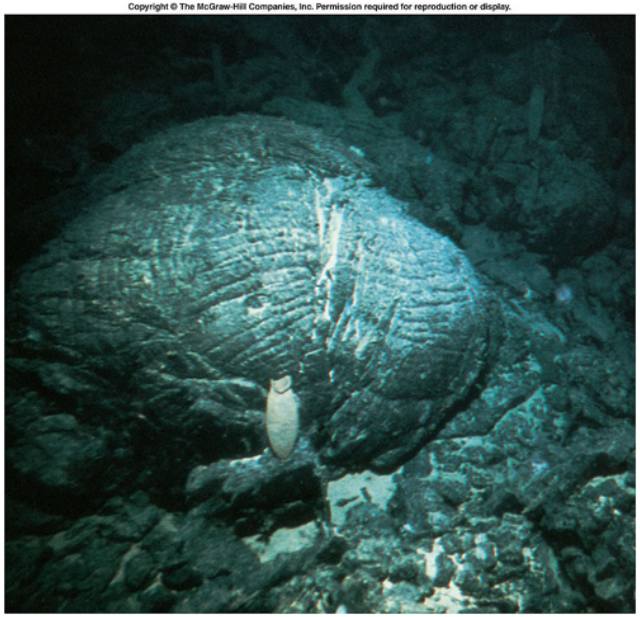




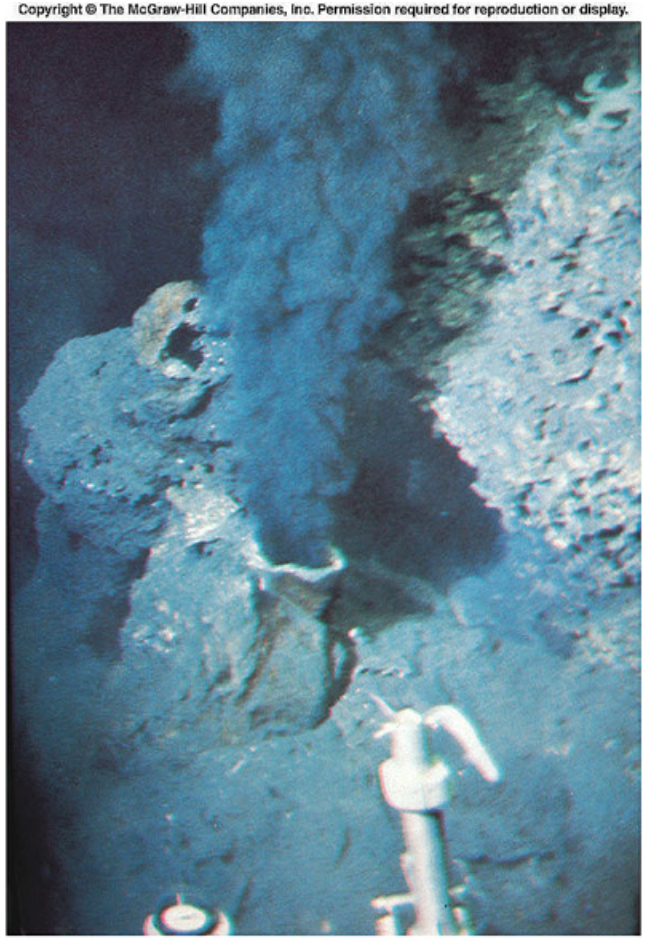




A Mid-Ocean Ridge: the central Rift Valley



Pillow Basalt at a
Mid-Ocean Ridge



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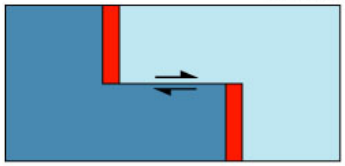
A black smoker in the rift
valley of a Mid-Ocean Ridge

TRANSFORM BOUNDARIES



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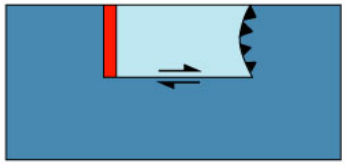

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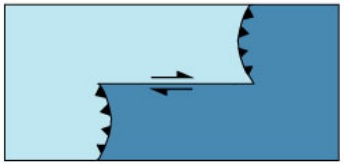
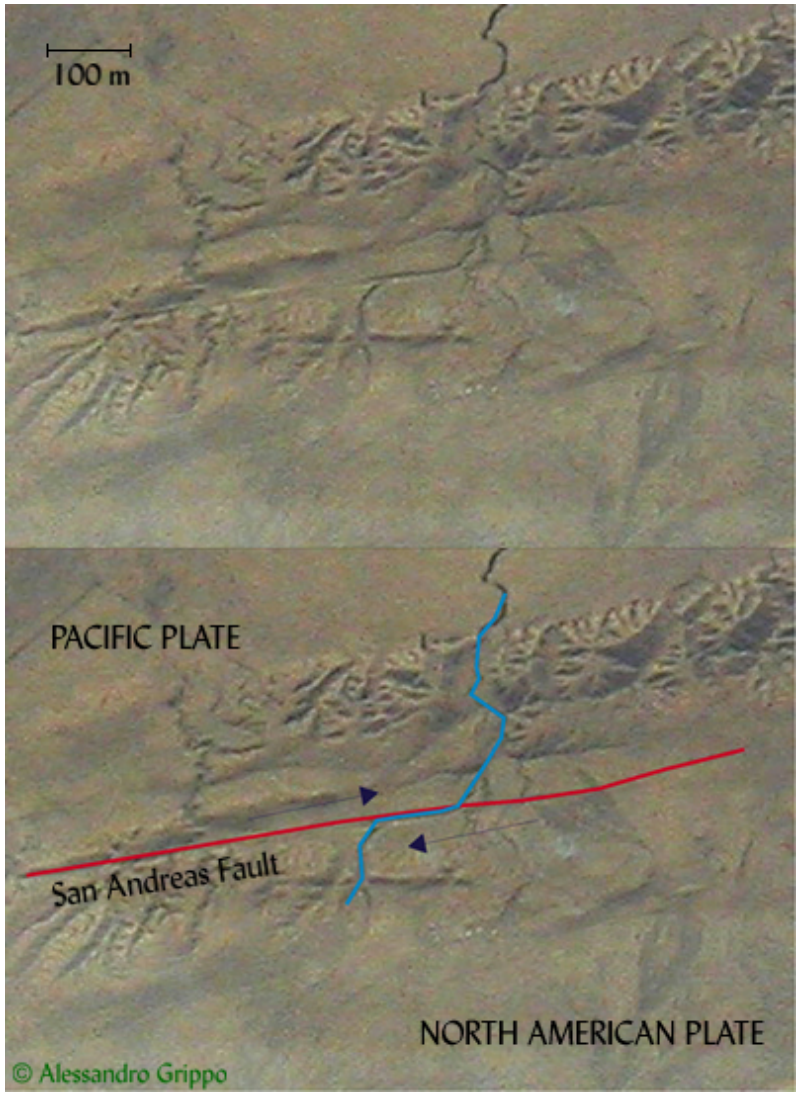
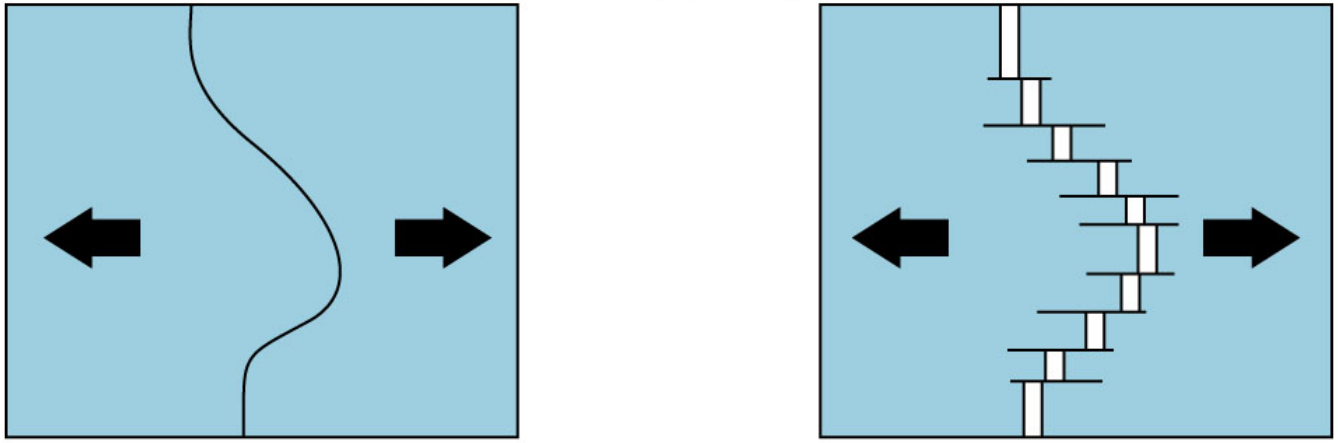


C

D

The San Andreas Fault in the field:
Wallace Creek (San Luis Obispo County)





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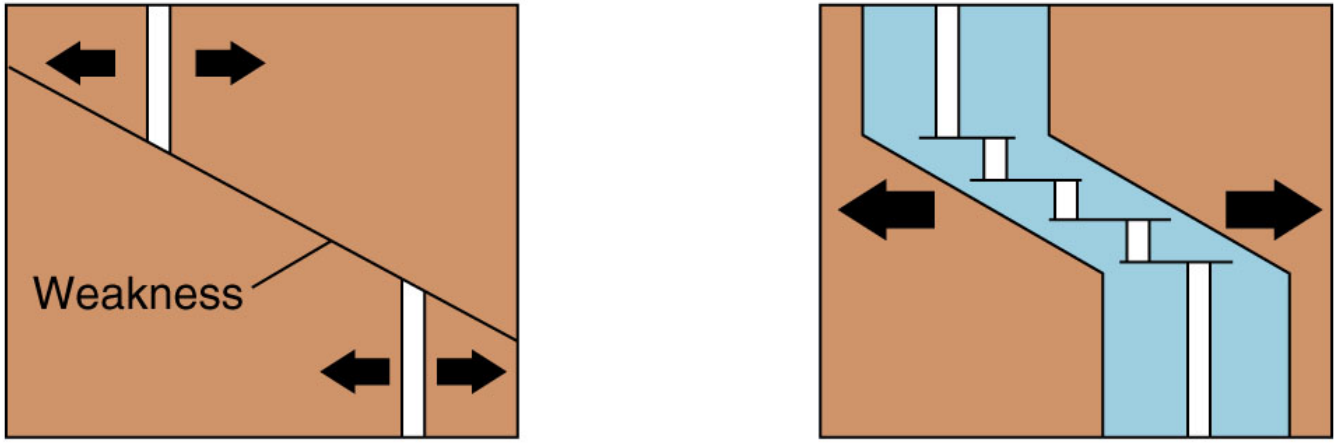
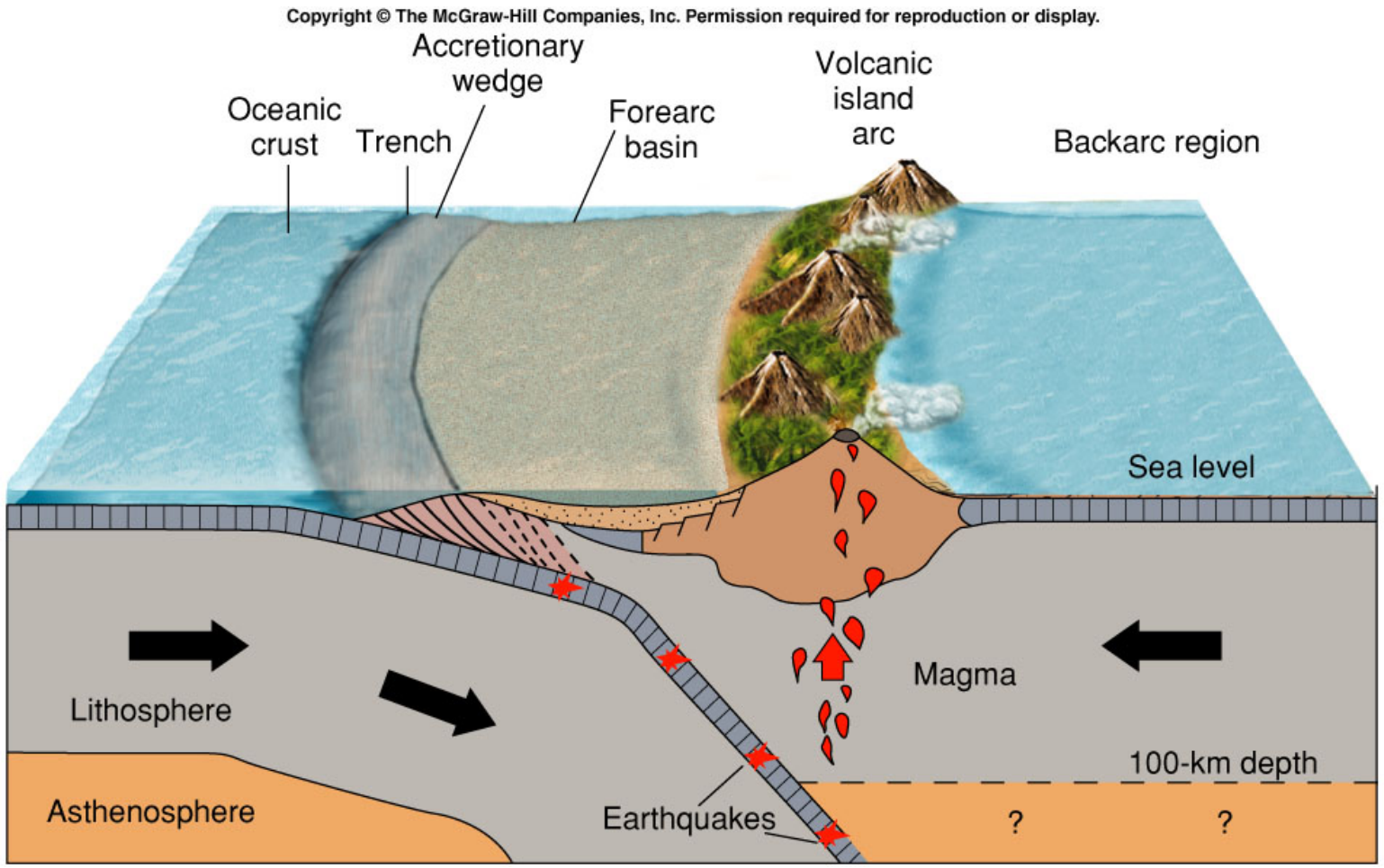


B

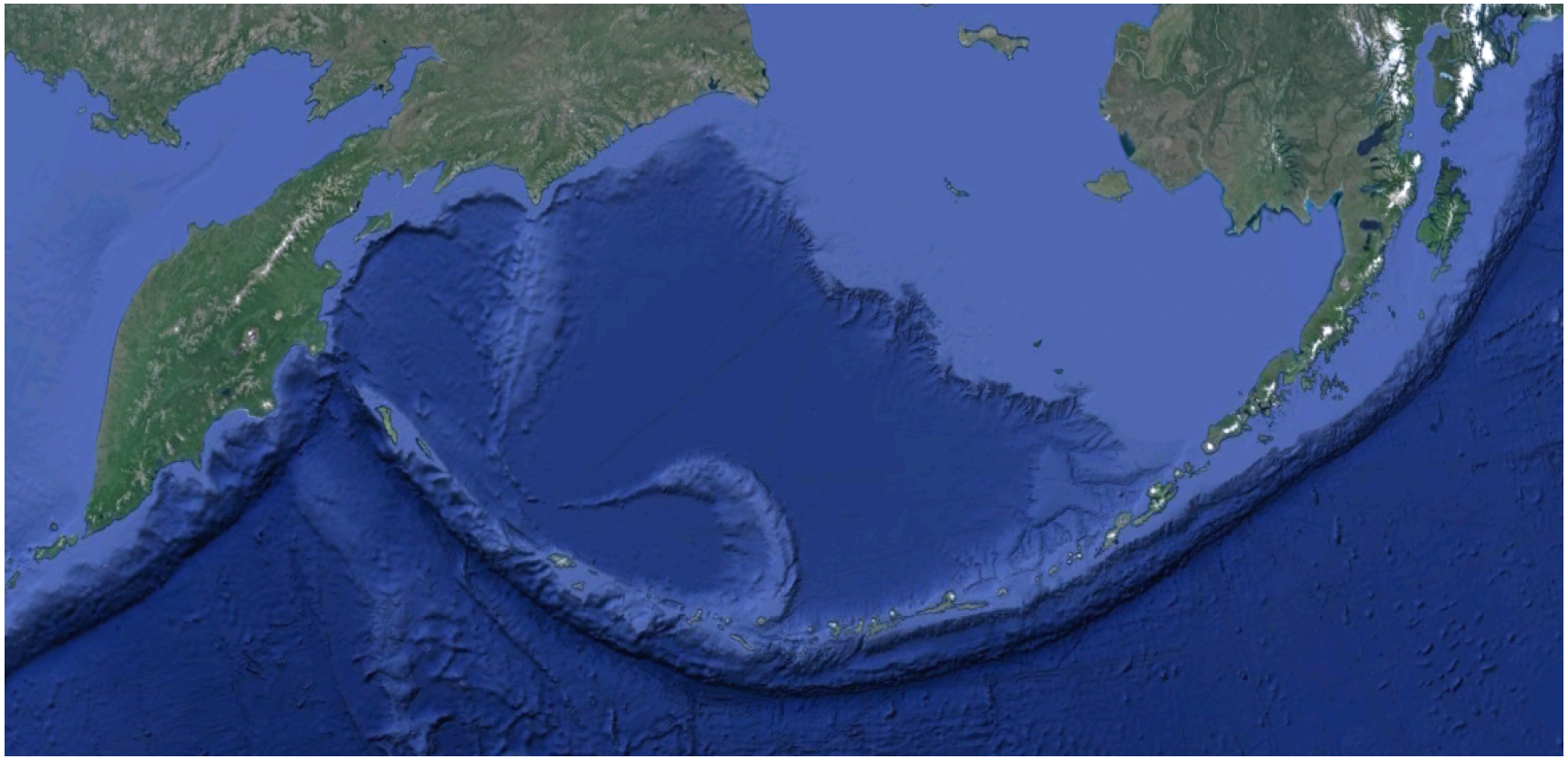
CONVERGENT BOUNDARIES

- Three distinct cases of convergence:
  - Oceanic Crust / Oceanic Crust
    - Subduction, Island Volcanic Arc, Earthquakes
  - Oceanic Crust / Continental Crust
    - Subduction, Island Volcanic Arc, Earthquakes
  - Continental Crust / Continental Crust
    - No subduction, Mountain Building (No Volcanoes), Earthquakes

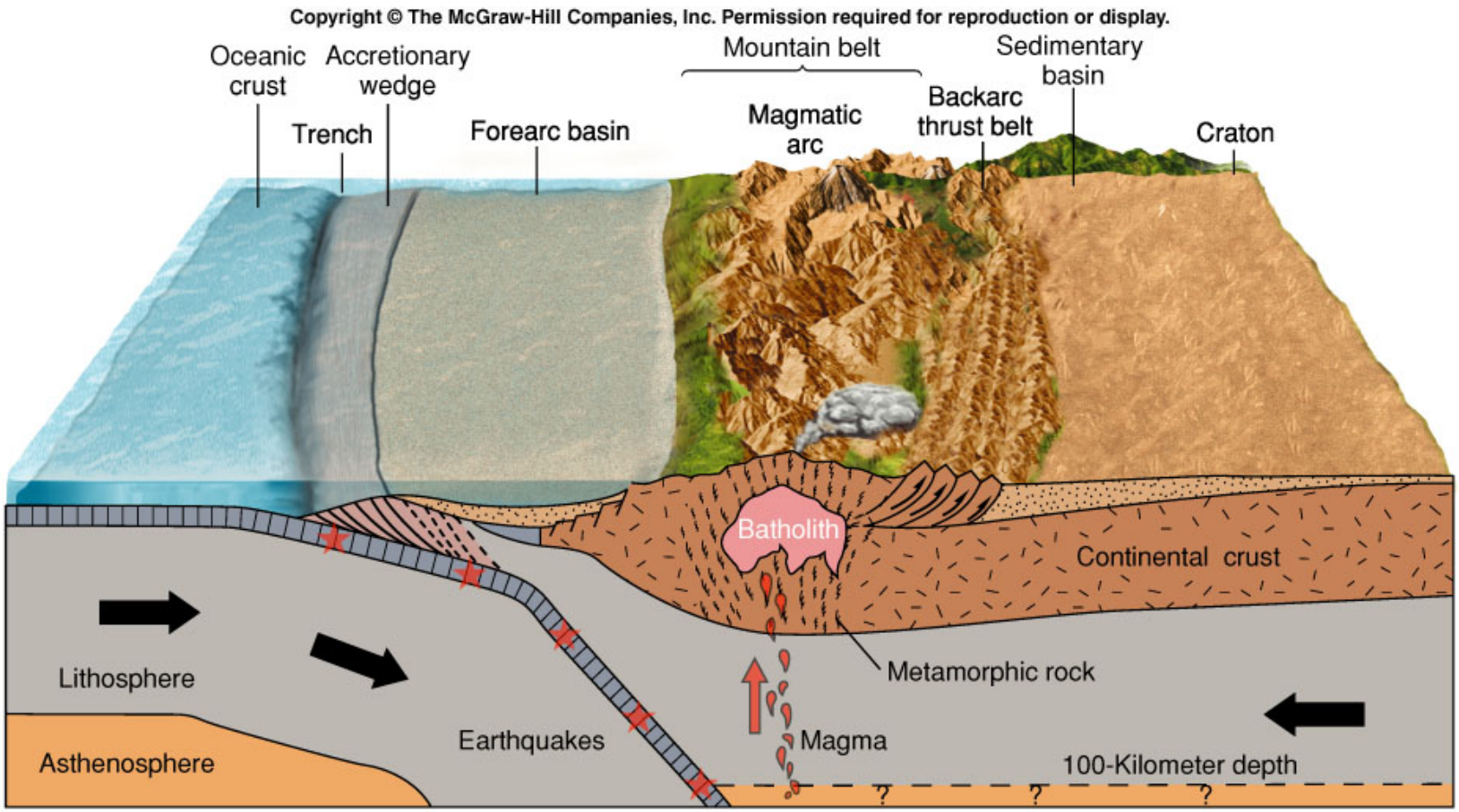
Oceanic Crust / Oceanic Crust Convergence



The Aleutian Islands (Alaska)

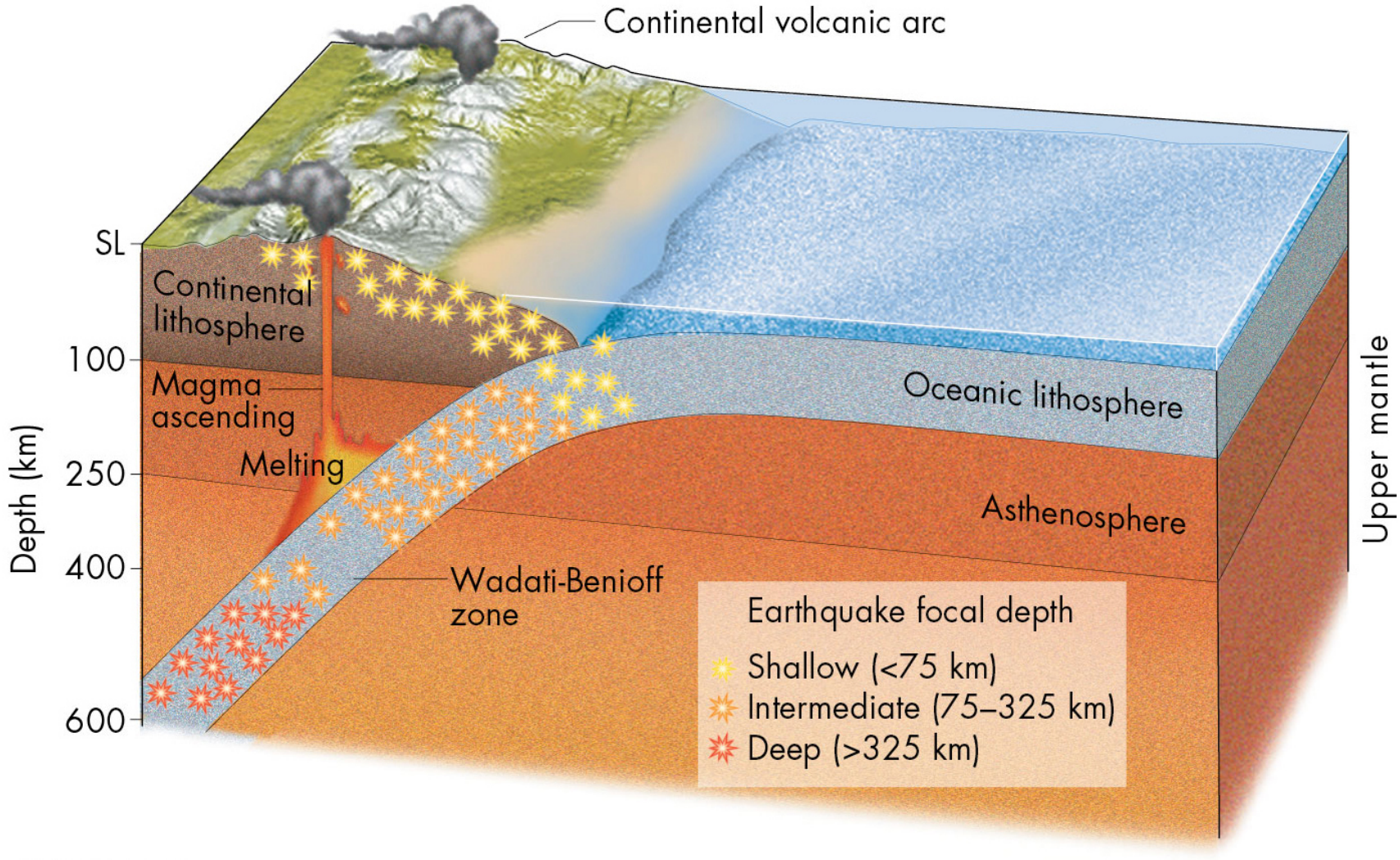


Oceanic Crust / Continental Crust Convergence

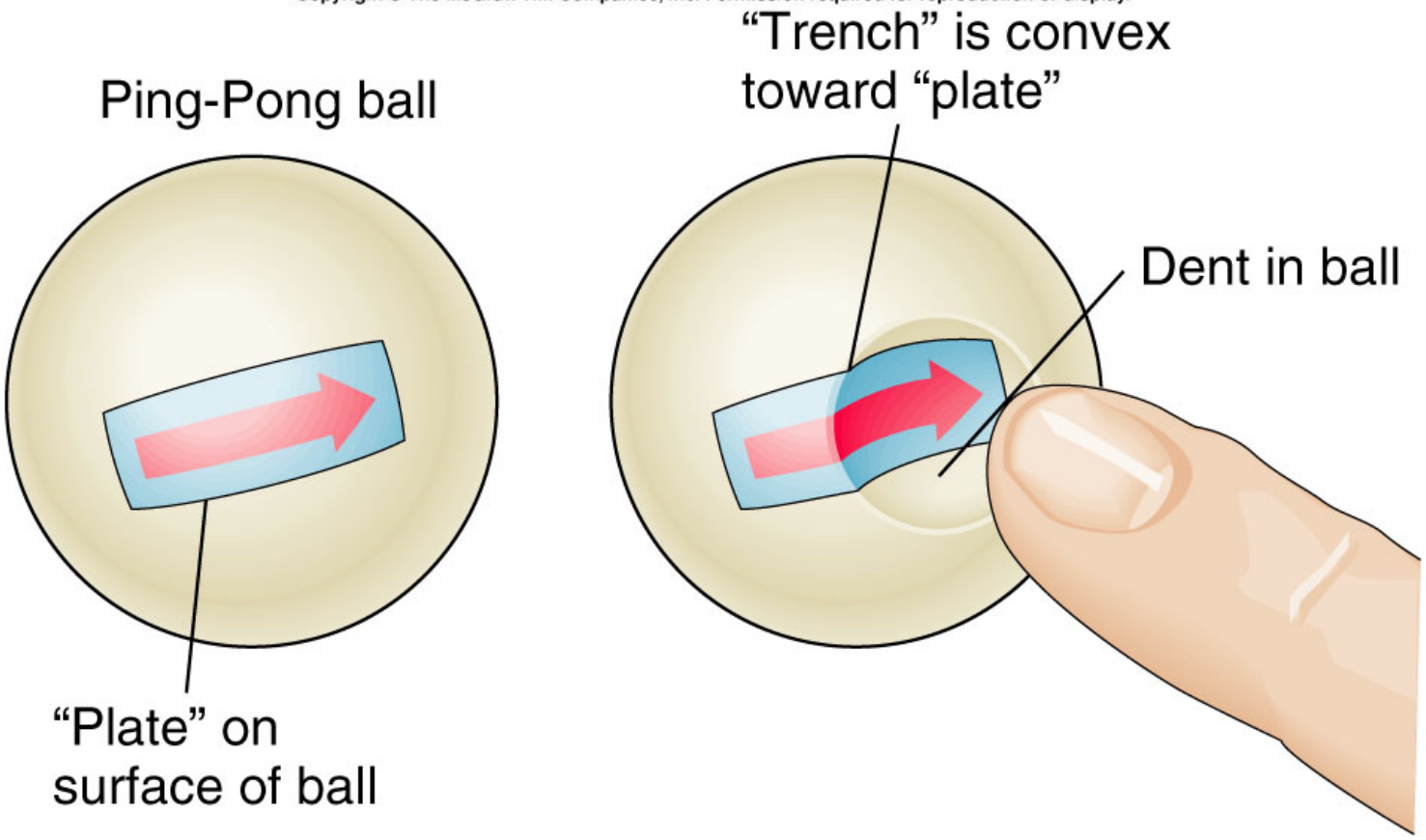


The Cascades: Mt. Shasta, California

part of a volcanic arc formed by ocean / continent collision

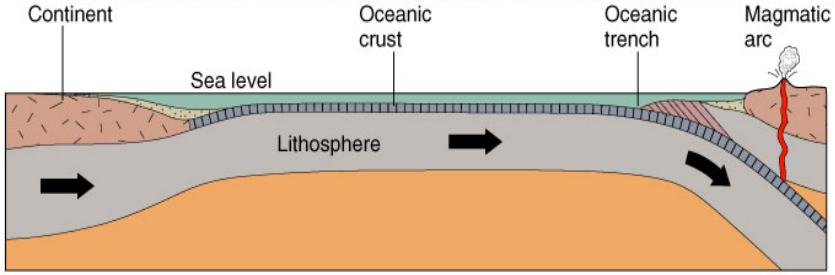

Continental volcanic arc
SL
100
250
400
600
Depth (km)
Continental lithosphere
Magma ascending
Melting
Oceanic lithosphere
Asthenosphere
Upper mantle
Wadati-Benioff zone
Earthquake focal depth
Shallow (<75 km)
Intermediate (75–325 km)
Deep (>325 km)

Why are volcanic arcs (and trenches too!) “arced”?

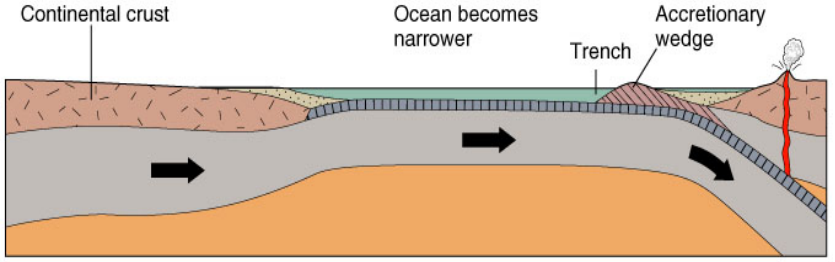


Continental Crust / Continental Crust Convergence

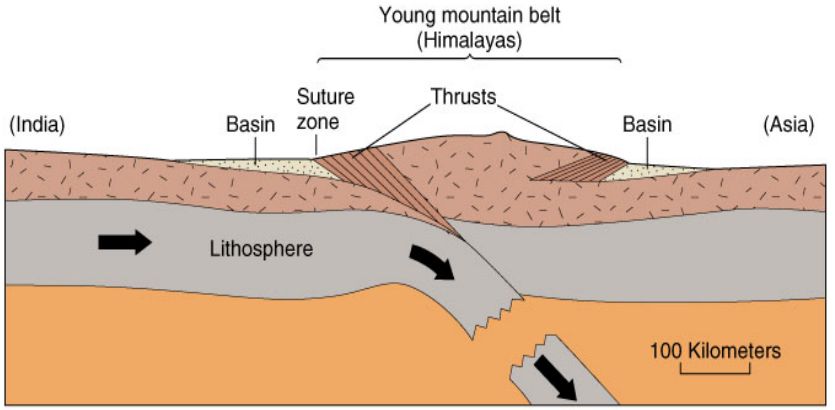
- Continental crust has a SG of 2.7, compared to oceanic crust at SG = 3
- Continental Crust is too buoyant to sink back into the asthenosphere
- There is no subduction
- There is no partial melting
- There is mountain building with no volcanic activity
- Doubling of the Continental Crust (Himalayas)



A Ocean-continent convergence



B Ocean-continent convergence



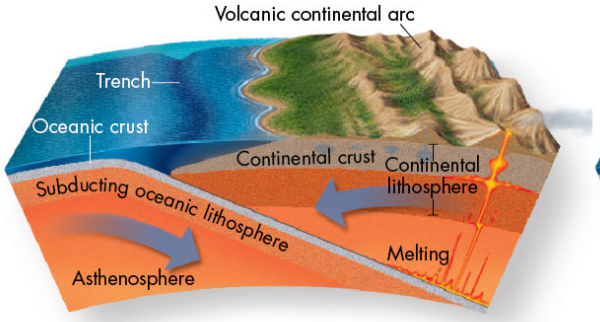
C Continent-continent collision

The Alps

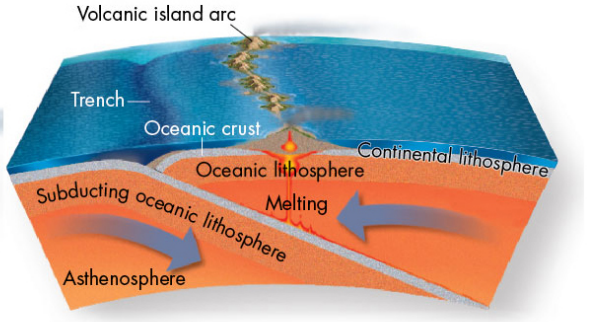
a mountain chain formed by continent/continent collision

The Alps:
Monte Bianco (Mont Blanc), Italy

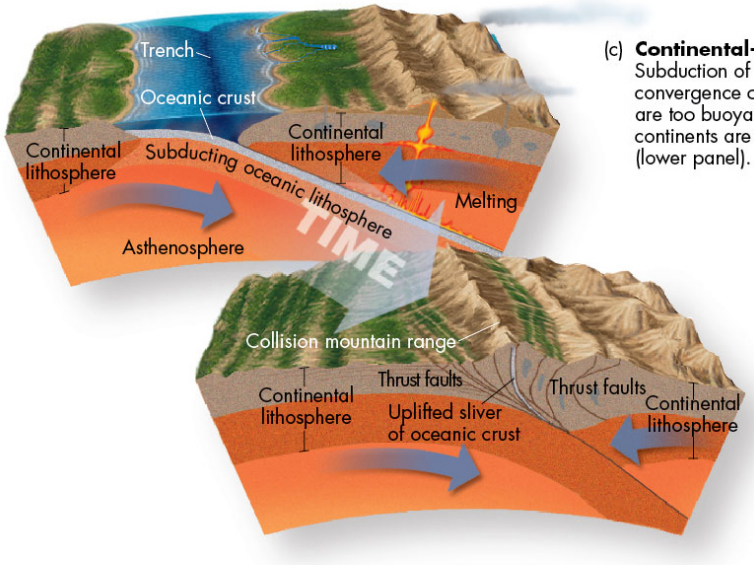
CONVERGENT BOUNDARIES: a summary



(a) **Oceanic-Continental Boundary**
When oceanic and continental plates converge, the oceanic plate must subduct beneath the continental plate because the density of thick continental crust is too low to permit it to sink into the asthenosphere.



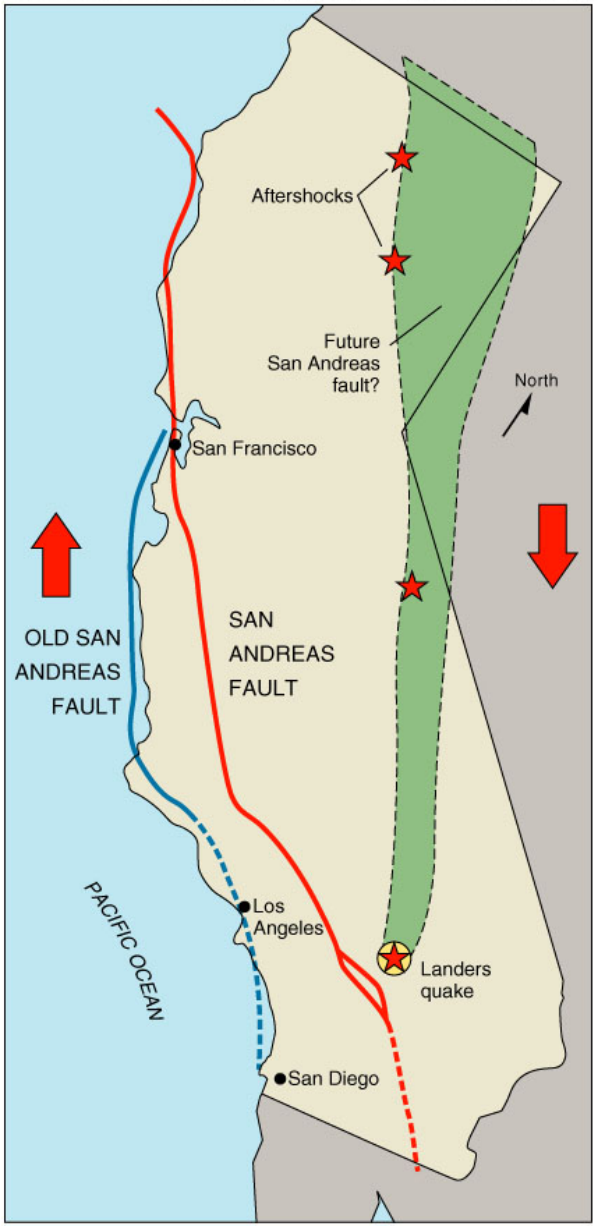
(b) **Oceanic-Oceanic Boundary**
When a convergent boundary forms between plates of oceanic lithosphere, the plate that is older, thicker, and denser subducts the less dense plate.



(c) **Continental-Continental Boundary**
Subduction of ocean lithosphere inevitably leads to convergence of continents (upper panel). Because continents are too buoyant to subduct, high mountains develop as the continents are forced upwards in the collision zone (lower panel).

Western North America: A future divergent boundary?

- Convergence between the North American Plate and the Pacific Plate put the Pacific Rise (ridge) in subduction: the ridge disappears by the Salton Sea and reappears north of Cape Mendocino, connected by the San Andreas Fault.
- The ridge is an area of high heat flow so it will not really subduct, but rather "slide" almost horizontally underneath North America, while keeping on expanding at depth.
- As a consequence the Colorado Plateau has been uplifted and the Basin and Range desert has been "stretched"
- The Basin and Range covers eastern California, Nevada and western Utah. California's Death Valley is an example of a tectonic rift caused by expansion, and presents all the characteristic of an early rifting stage



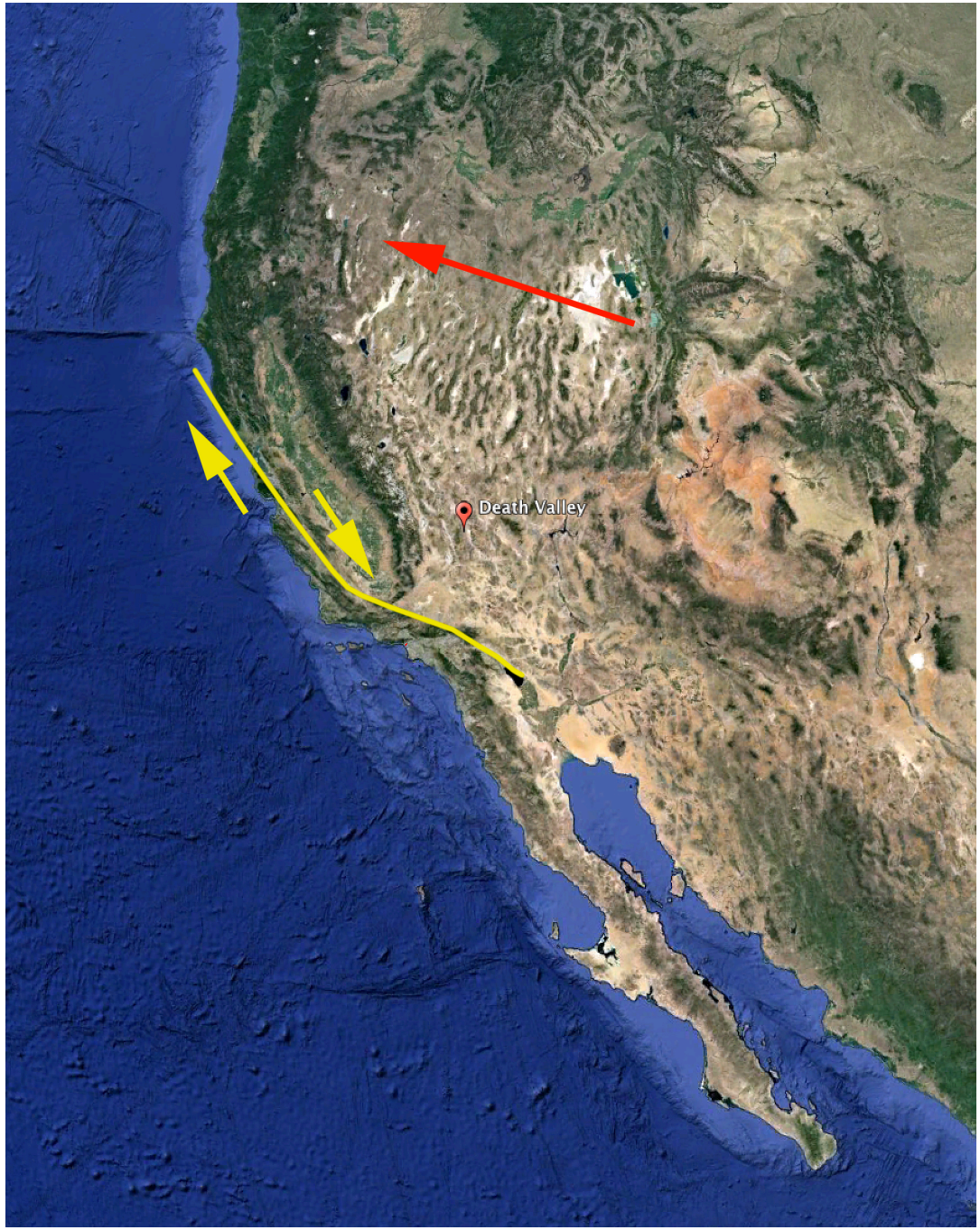
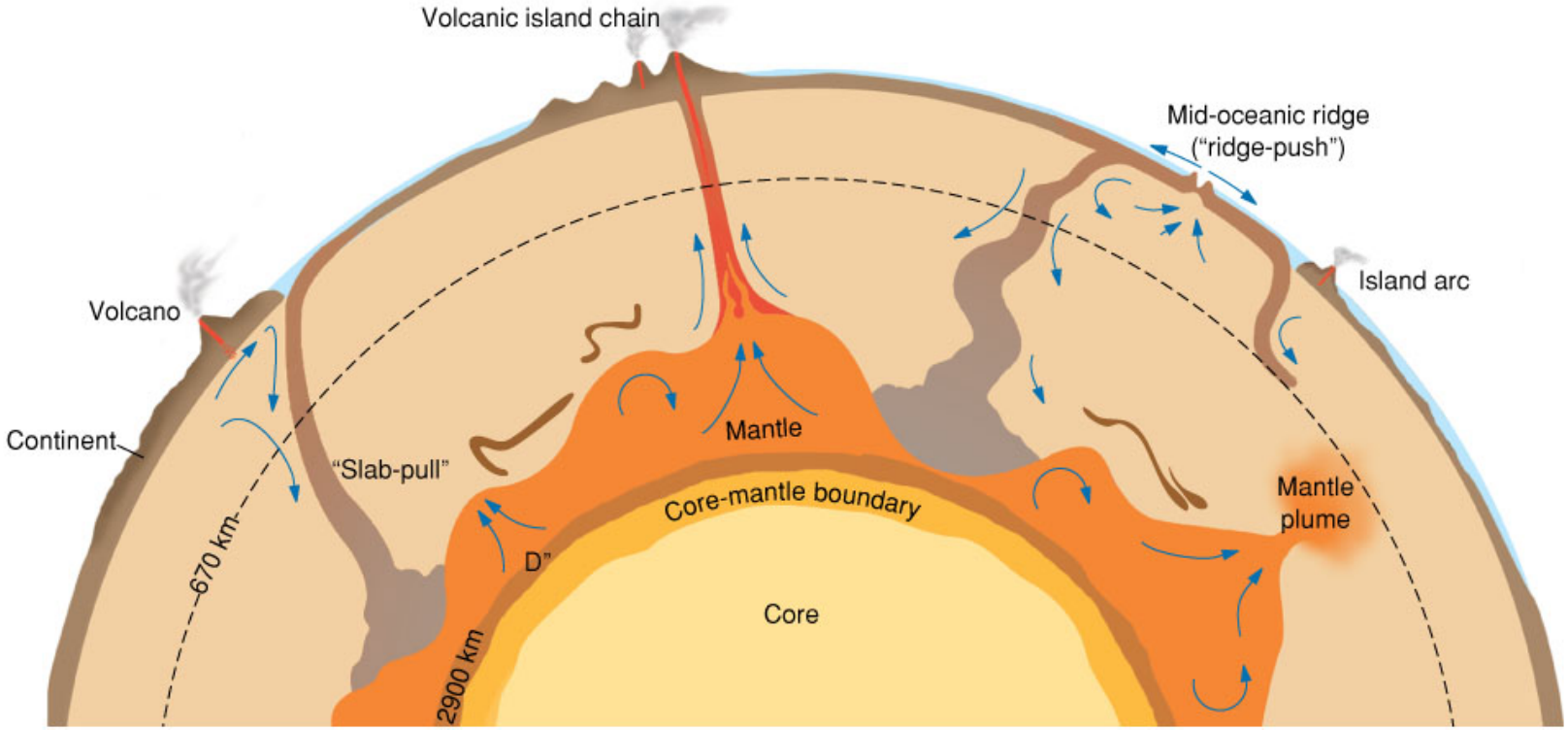

Death Valley

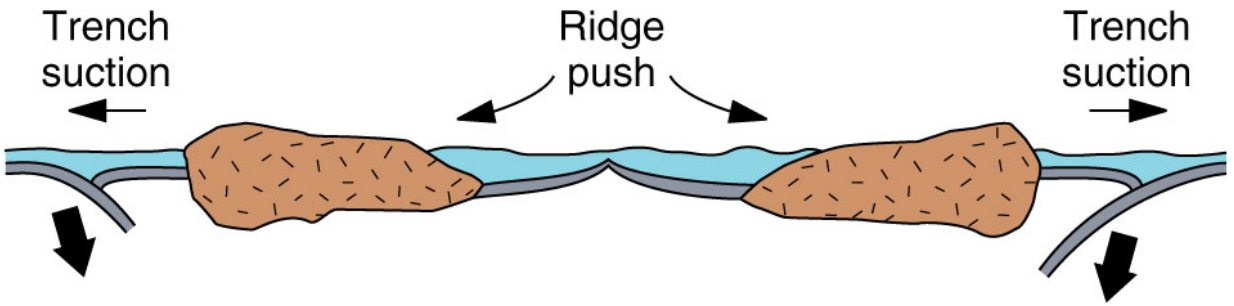
PLATE BOUNDARIES: a summary

TABLE 2.1 Types of Plate Boundaries: Dynamics, Results, and Examples

Plate Boundary	Plates Involved	Dynamics	Results	Examples	Natural Hazards
Divergent	Usually ocean	Spreading. The two plates move away from each other and molten rock rises up to fill the gap.	Mid-ocean ridge forms and new oceanic lithosphere is created and added to each plate.	Mid-Atlantic Ridge, which defines the African and North American plate boundary (Figure 2.8)	Light to moderate earthquakes and nonexplosive volcanic eruptions
Convergent (subduction)	Ocean–continent	Oceanic plate sinks beneath continental plate.	A volcanic continental arc and deep trench are formed. Earthquakes and volcanic activity are found here.	Andes Mountains, a continental volcanic chain formed at the Nazca and South American plate boundary (Figure 2.4a)	Great earthquakes; explosive volcanic eruptions; tsunamis, flooding, mass wasting, and subsidence
Convergent (subduction)	Ocean–ocean	Older, denser, oceanic plate sinks beneath younger, less dense oceanic plate.	A volcanic island arc and deep trench is formed. Earthquakes and volcanic activity are found here.	Caribbean Islands, an ocean island arc formed at the boundary between the Caribbean and South American plates (Figure 2.4a)	Great earthquakes; explosive volcanic eruptions; tsunamis, flooding, mass wasting, and subsidence
Convergent (collision)	Continent–continent	Neither plate is dense enough to sink into the asthenosphere; compression results.	A large, high mountain chain is formed, and earthquakes are common.	Himalayan Mountains, the result of collision and shortening between the Indo-Australian and Eurasian plates (Figure 2.4a)	Major earthquakes, flooding, and mass wasting
Transform	Ocean–ocean or continent–continent	The plates slide past one another.	Earthquakes are common and may result in some topographic changes.	San Andreas fault, which defines the boundary between the North American and Pacific plates (Figure 2.11)	Strong to major earthquakes

What causes plate motions? Convection!

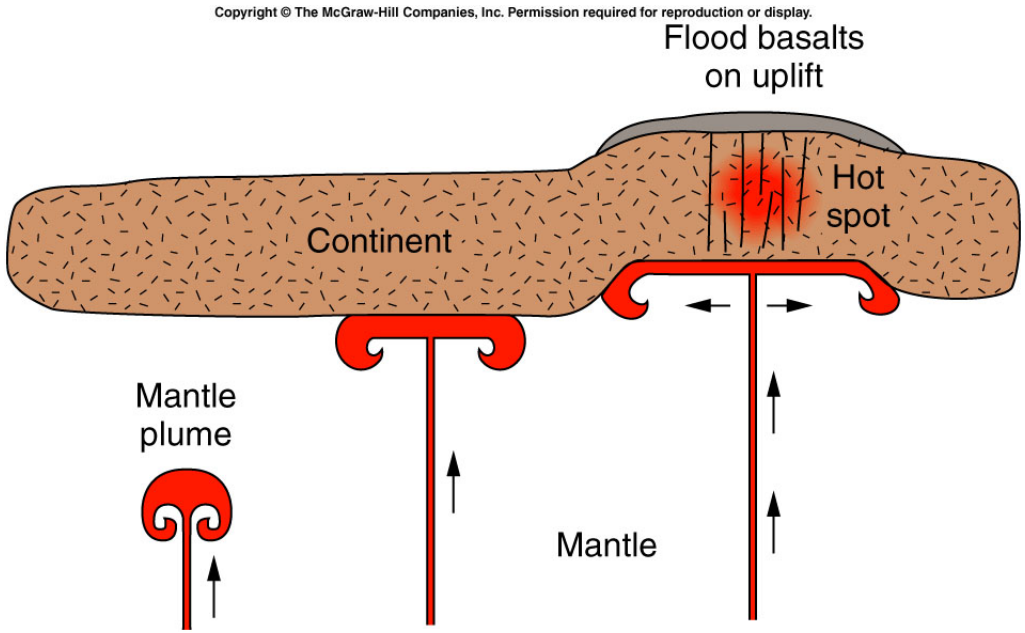




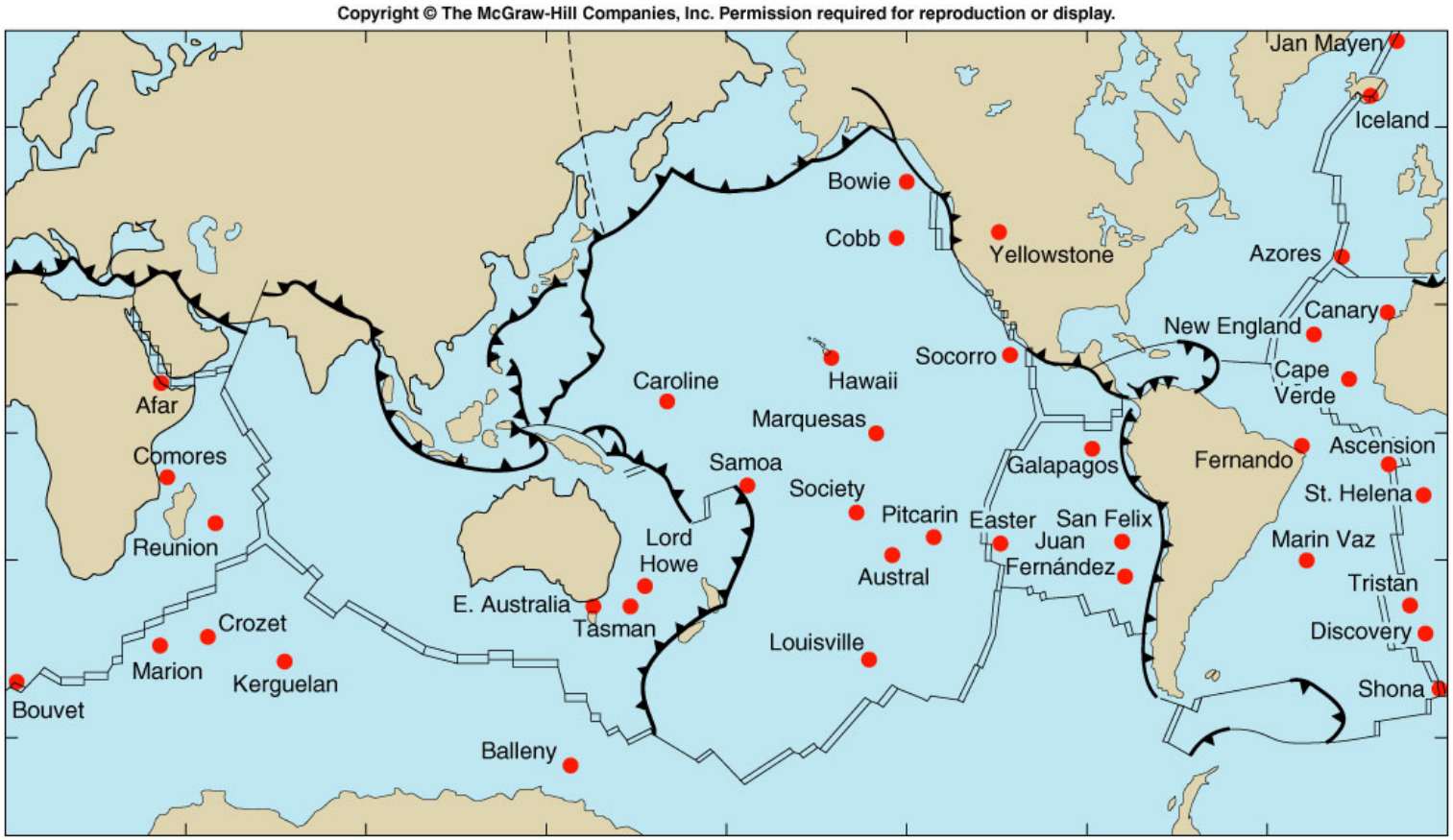
MANTLE PLUMES and HOT SPOTS

- *Mantle plumes* are narrow columns of of hot mantle rock that rise through the mantle itself

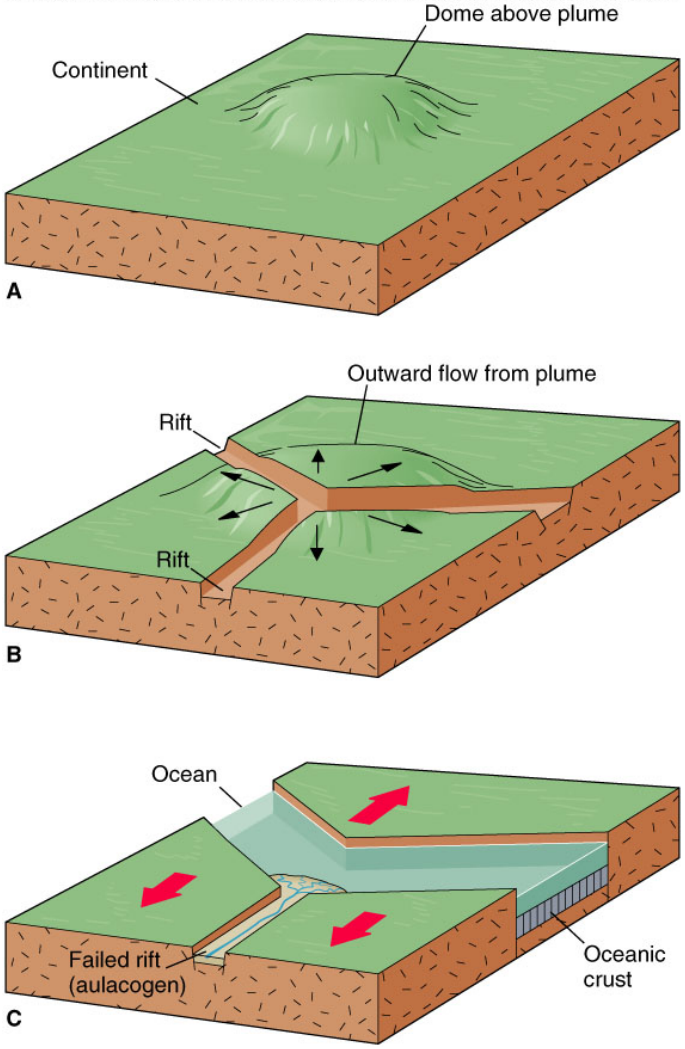
- Plumes form *hot spots* of active volcanisms at Earth's surface

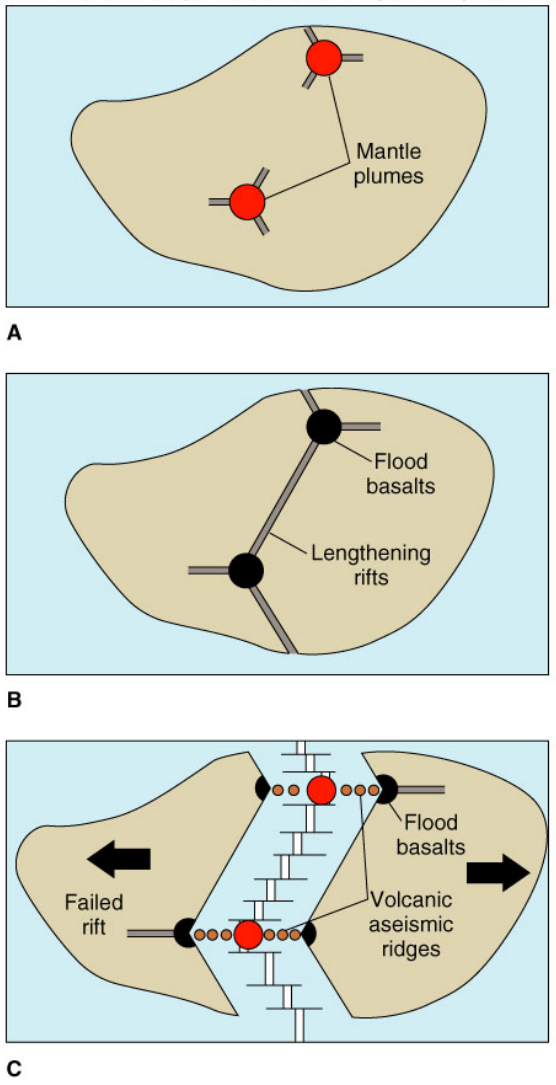


Most Hot Spots are located in volcanic regions

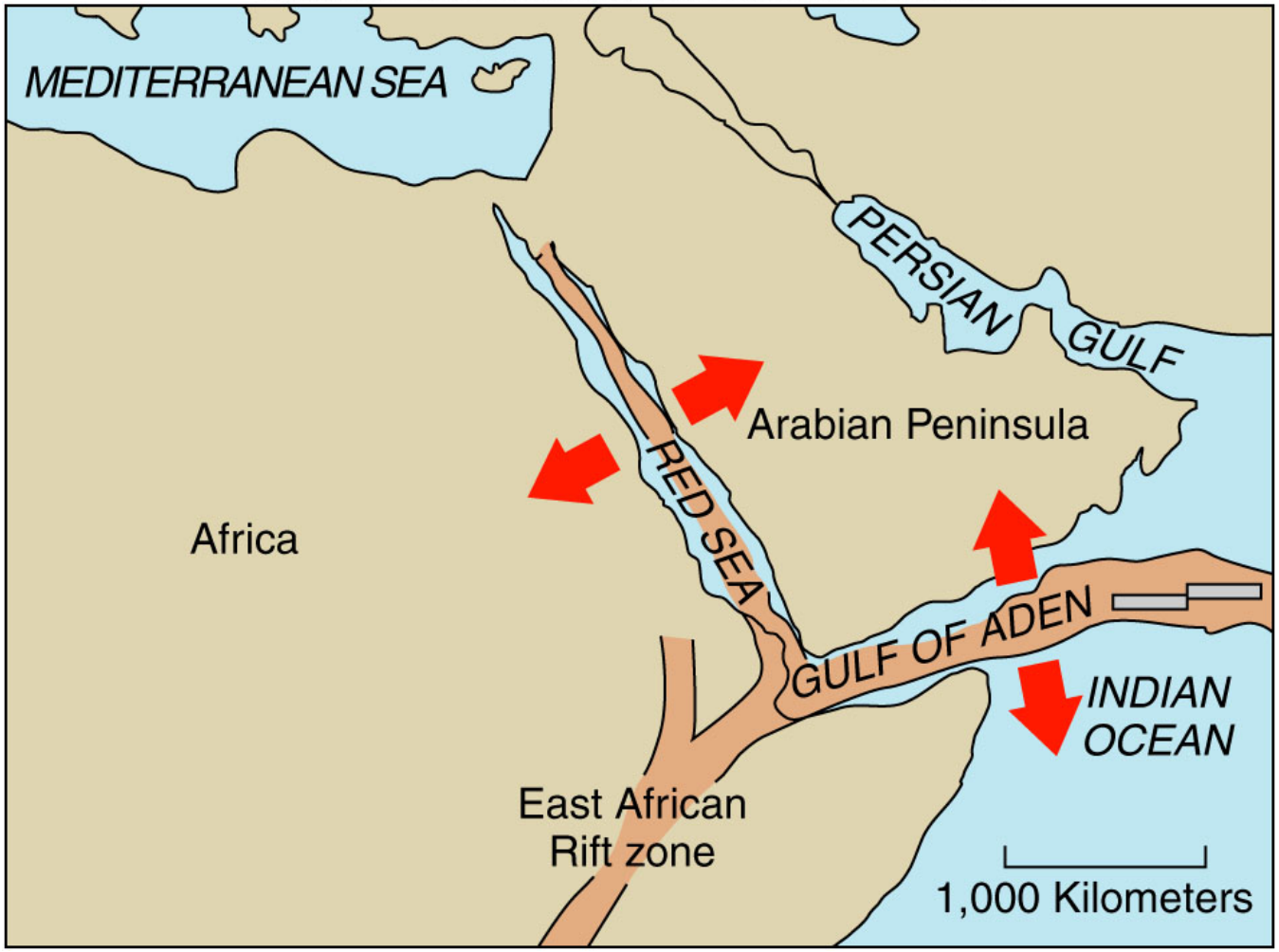


The role of hot spots in breaking up continental crust



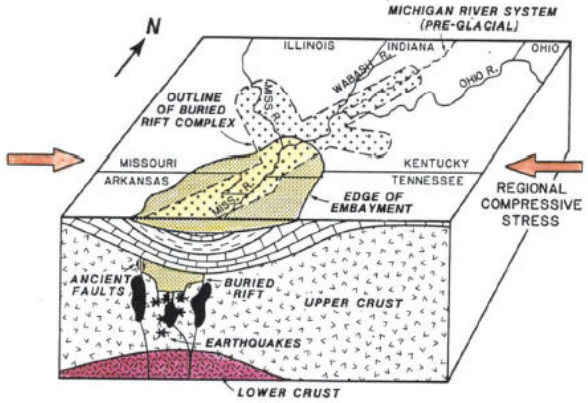


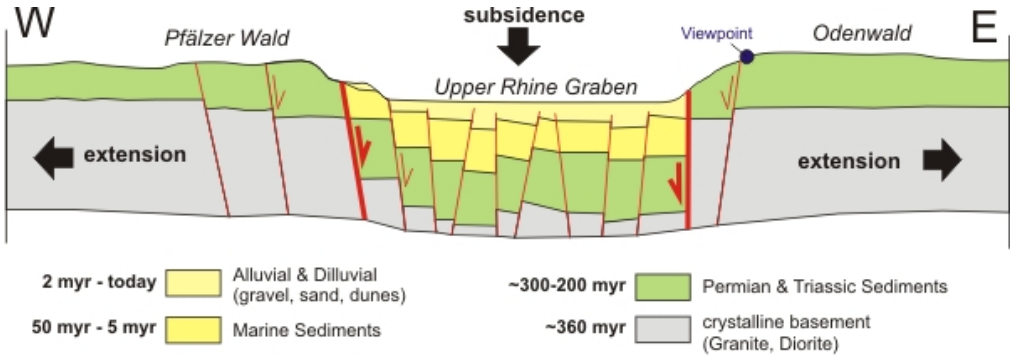
Aulacogens, or Failed Rifts

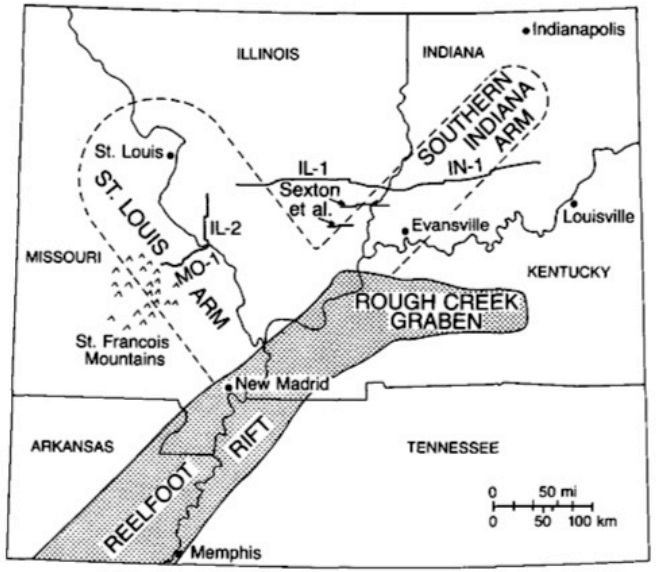


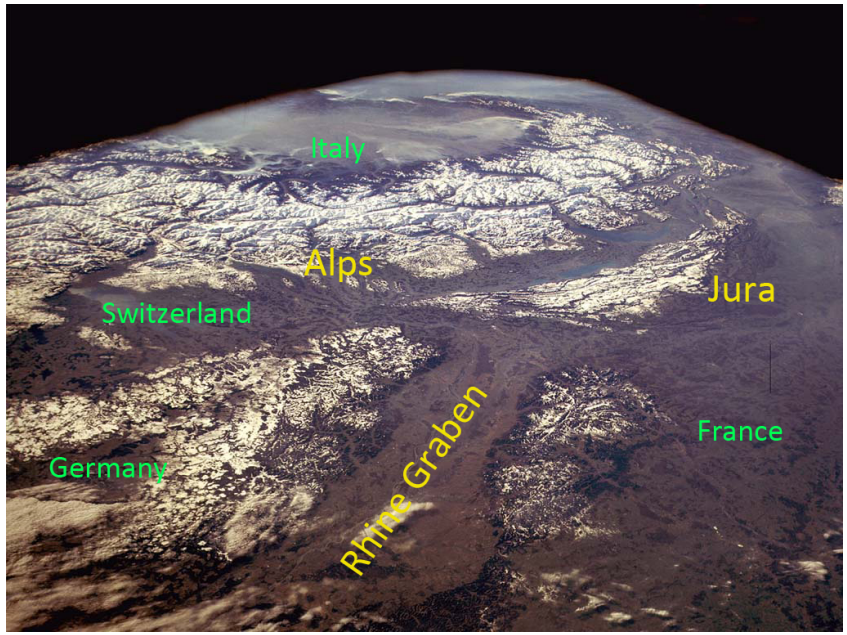
Aulacogens in North America and Europe

the Mississippi River (left) and Rhine River (right) valleys



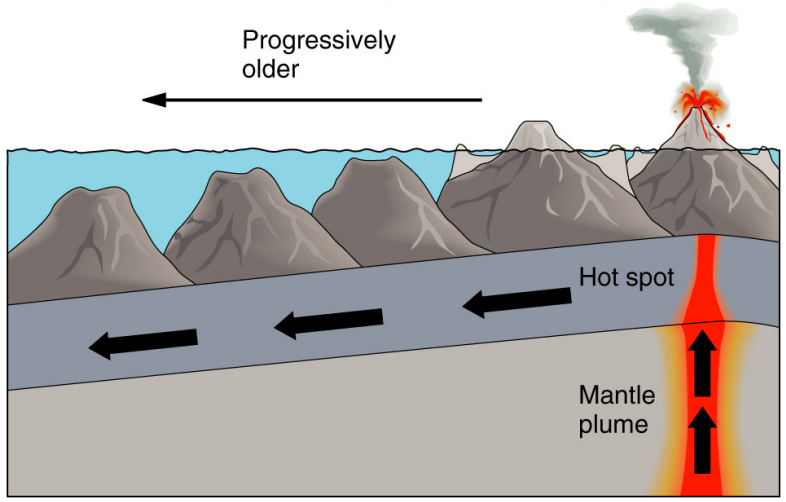


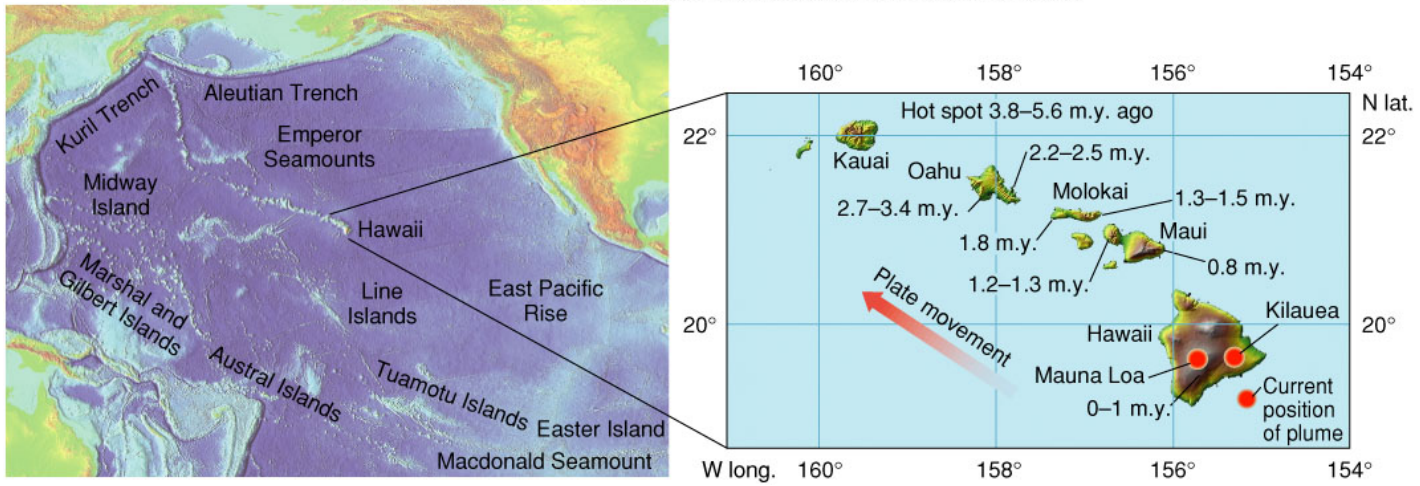


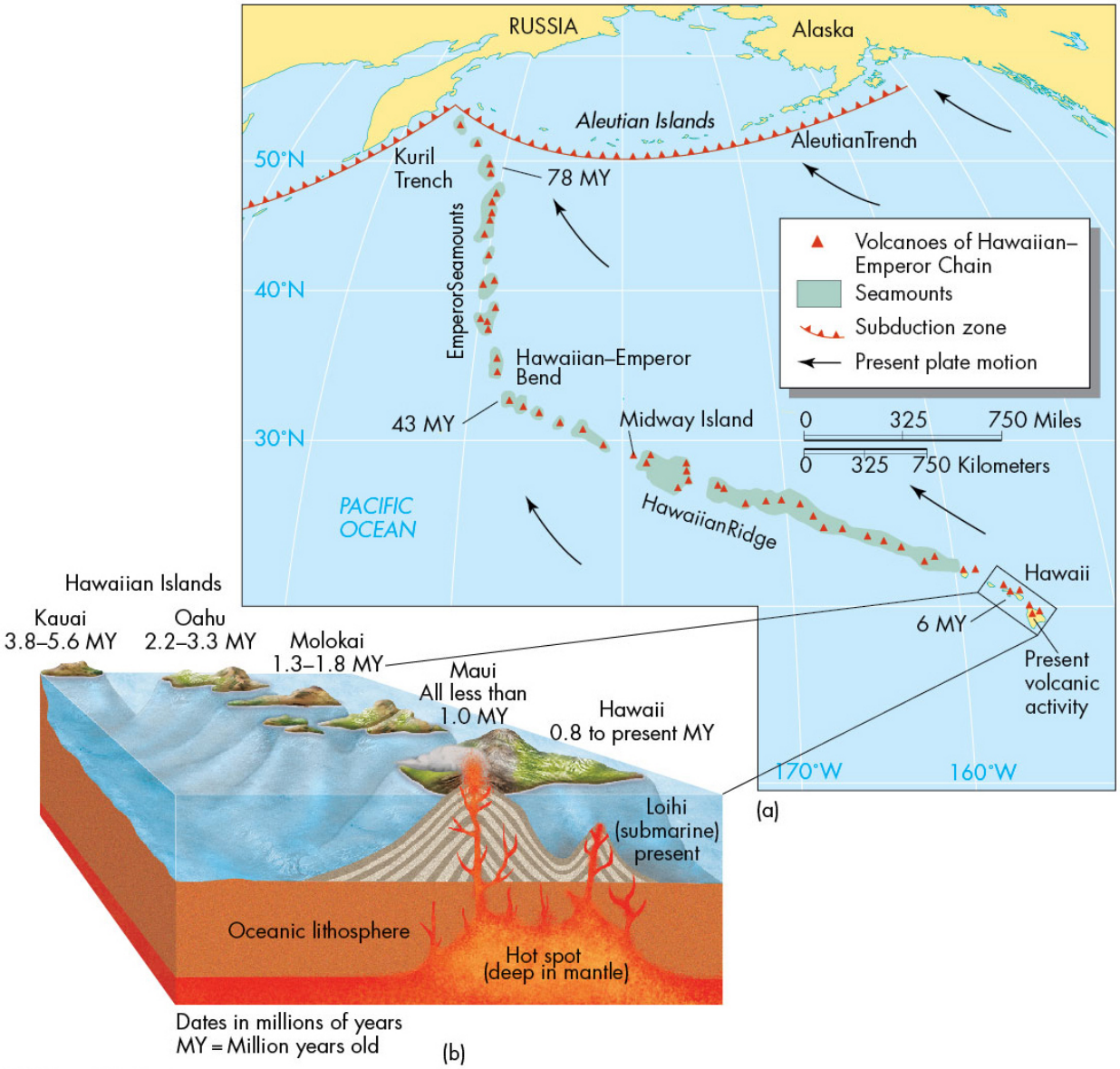


Hot spots that are fixed and plates that are moving

Through oceanic crust: Hawai'i

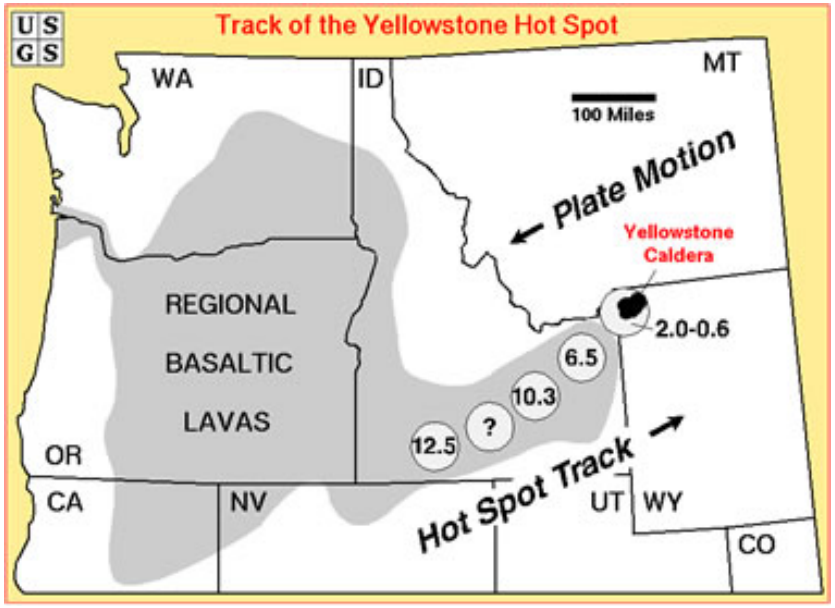





RUSSIA
Alaska
Aleutian Islands
AleutianTrench
50°N
Kuril
Trench
78 MY
EmperorSeamounts
40°N
Hawaiian–Emperor
Bend
43 MY
Midway Island
30°N
PACIFIC
OCEAN
HawaiianRidge
Hawaii
6 MY
Present
volcanic
activity
Volcanoes of Hawaiian–
Emperor Chain
Seamounts
Subduction zone
Present plate motion
0 325 750 Miles
0 325 750 Kilometers
170°W
160°W
(a)
Hawaiian Islands
Kauai
3.8–5.6 MY
Oahu
2.2–3.3 MY
Molokai
1.3–1.8 MY
Maui
All less than
1.0 MY
Hawaii
0.8 to present MY
Loihi
(submarine)
present
Oceanic lithosphere
Hot spot
(deep in mantle)
Dates in millions of years
MY = Million years old
(b)

Hot spots that are fixed and plates that are moving

Through continental crust: Yellowstone



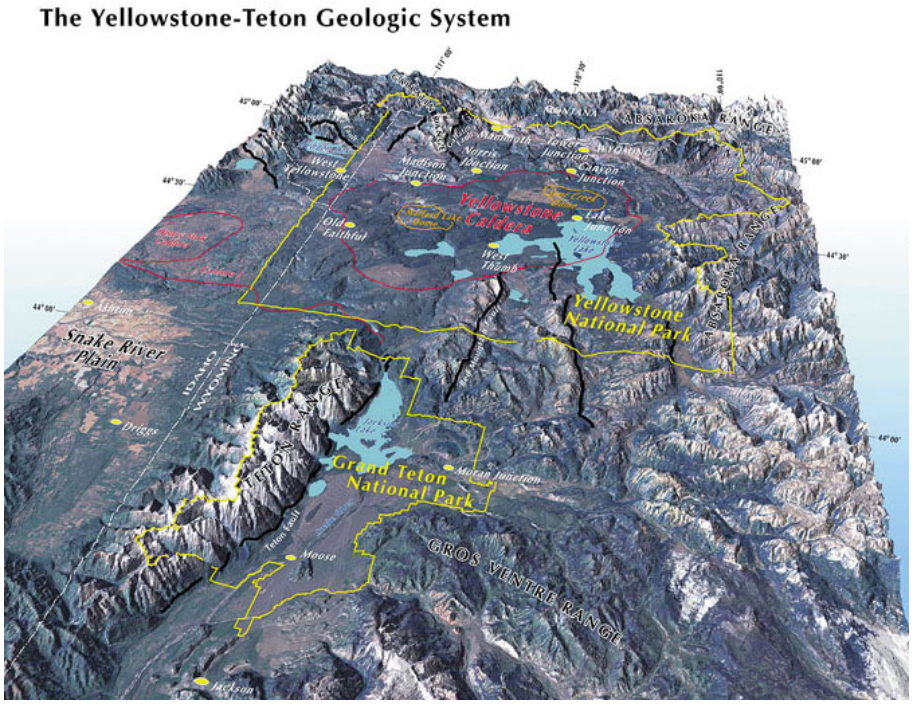


Plate Tectonics

end