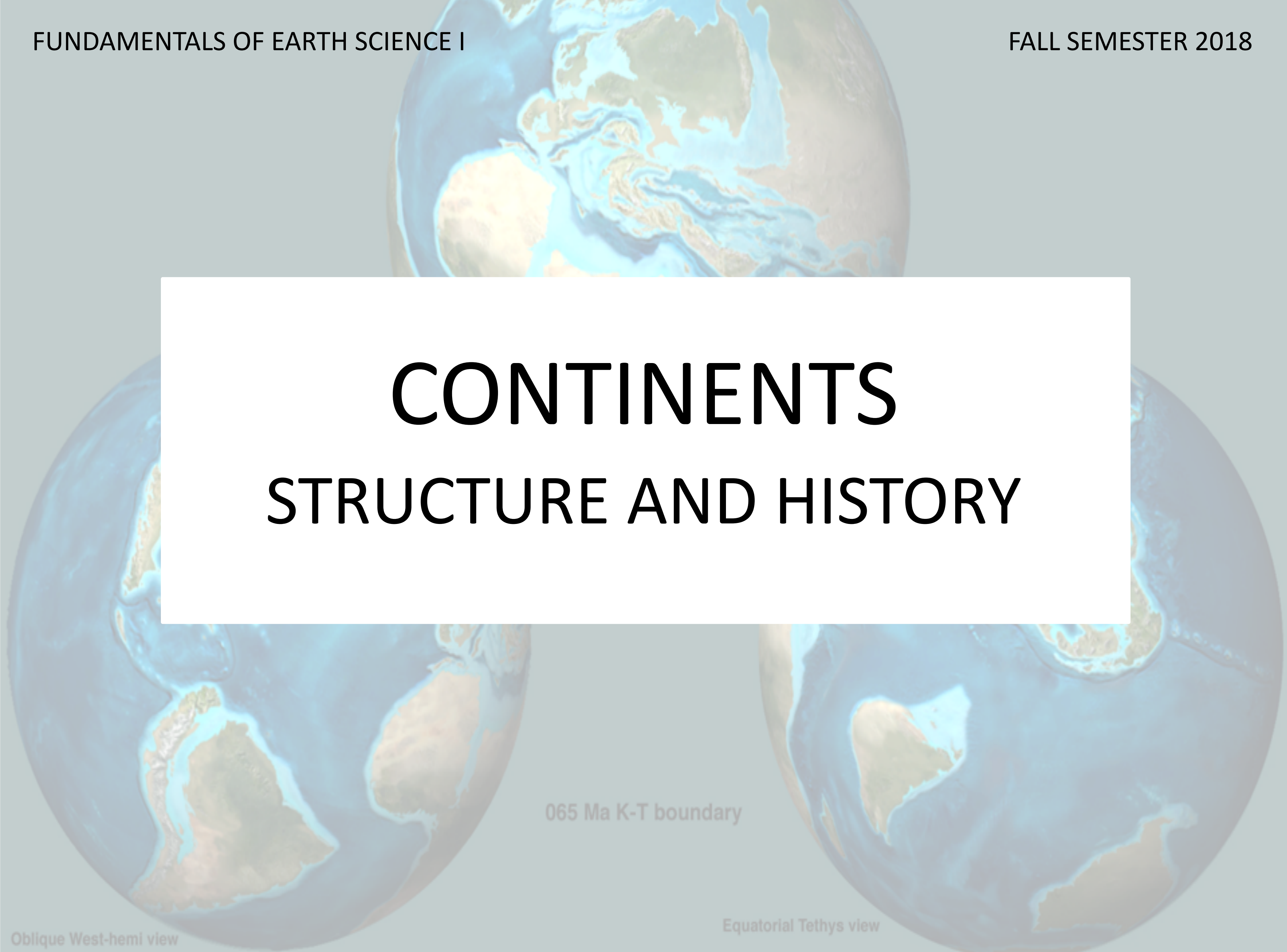
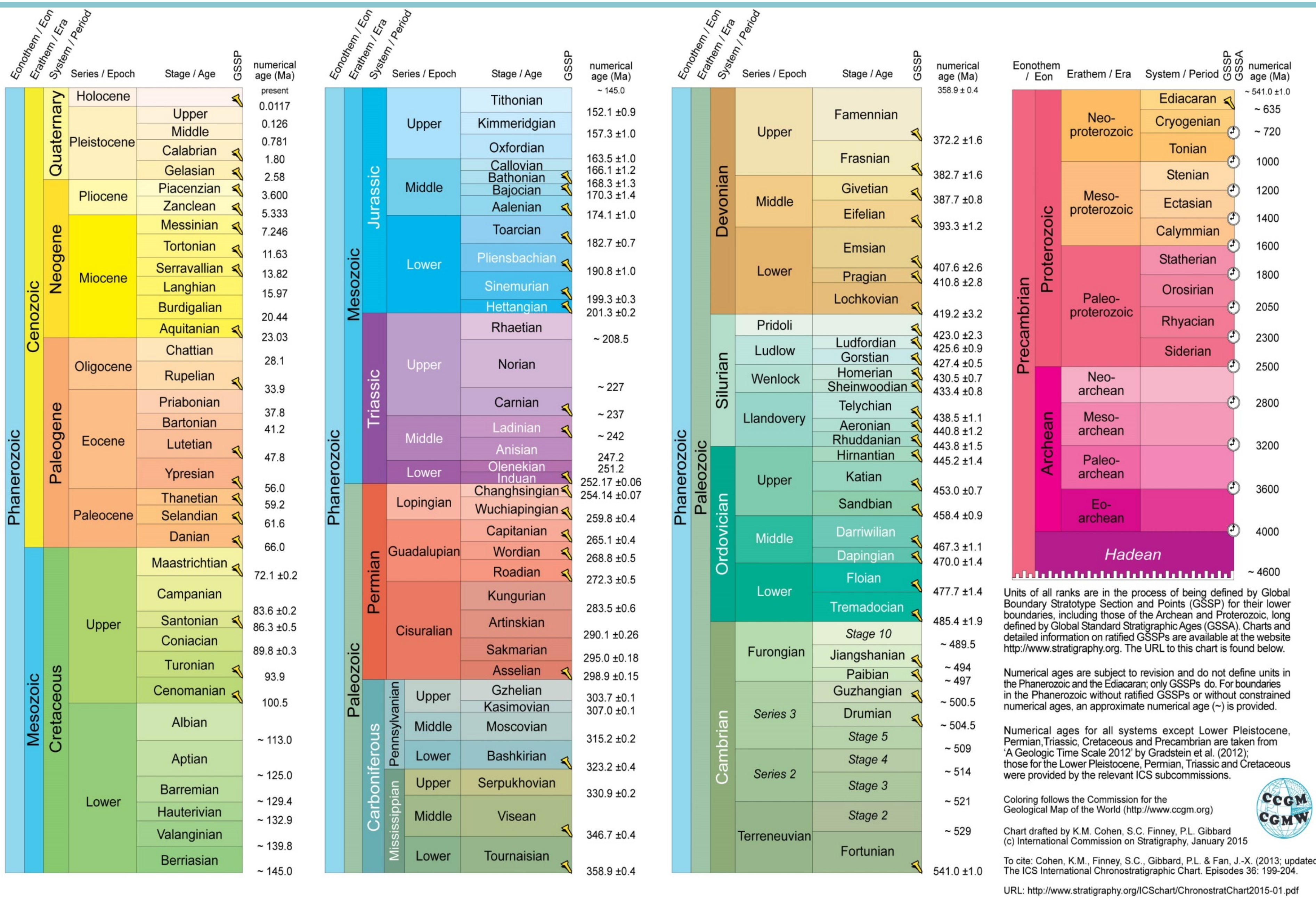


CONTINENTS

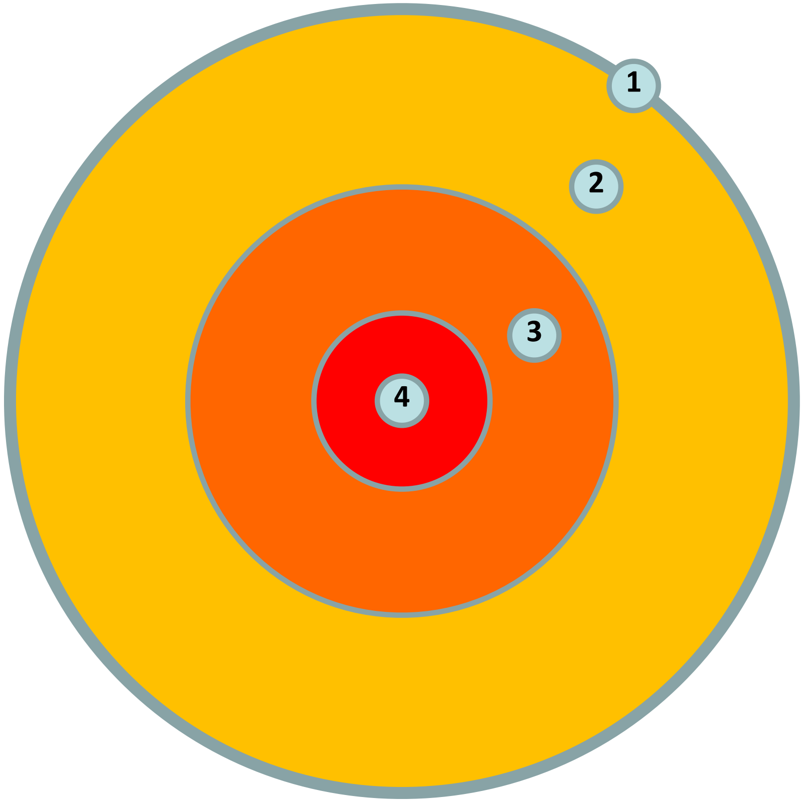
STRUCTURE AND HISTORY

https://www.researchgate.net/figure/Paleogeographic-view-of-the-Earth-at-the-K-T-transition-Courtesy-Ron-Blakey-Department_fig33_251124882

✶ **Review**: Geologic time scale



✶ **Review**: Earth's layered structure



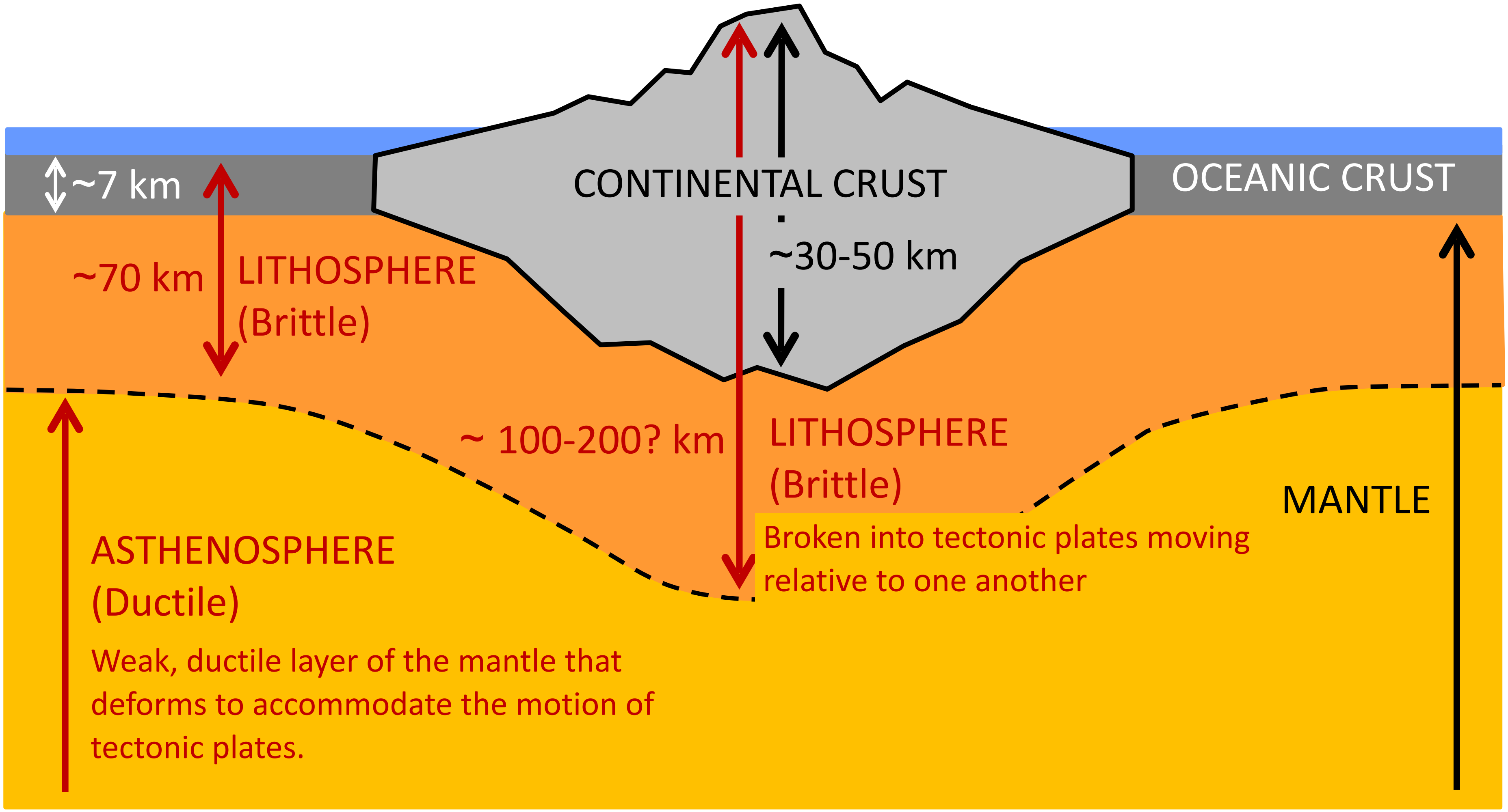
1 CRUST (0-~75 km)

2 MANTLE

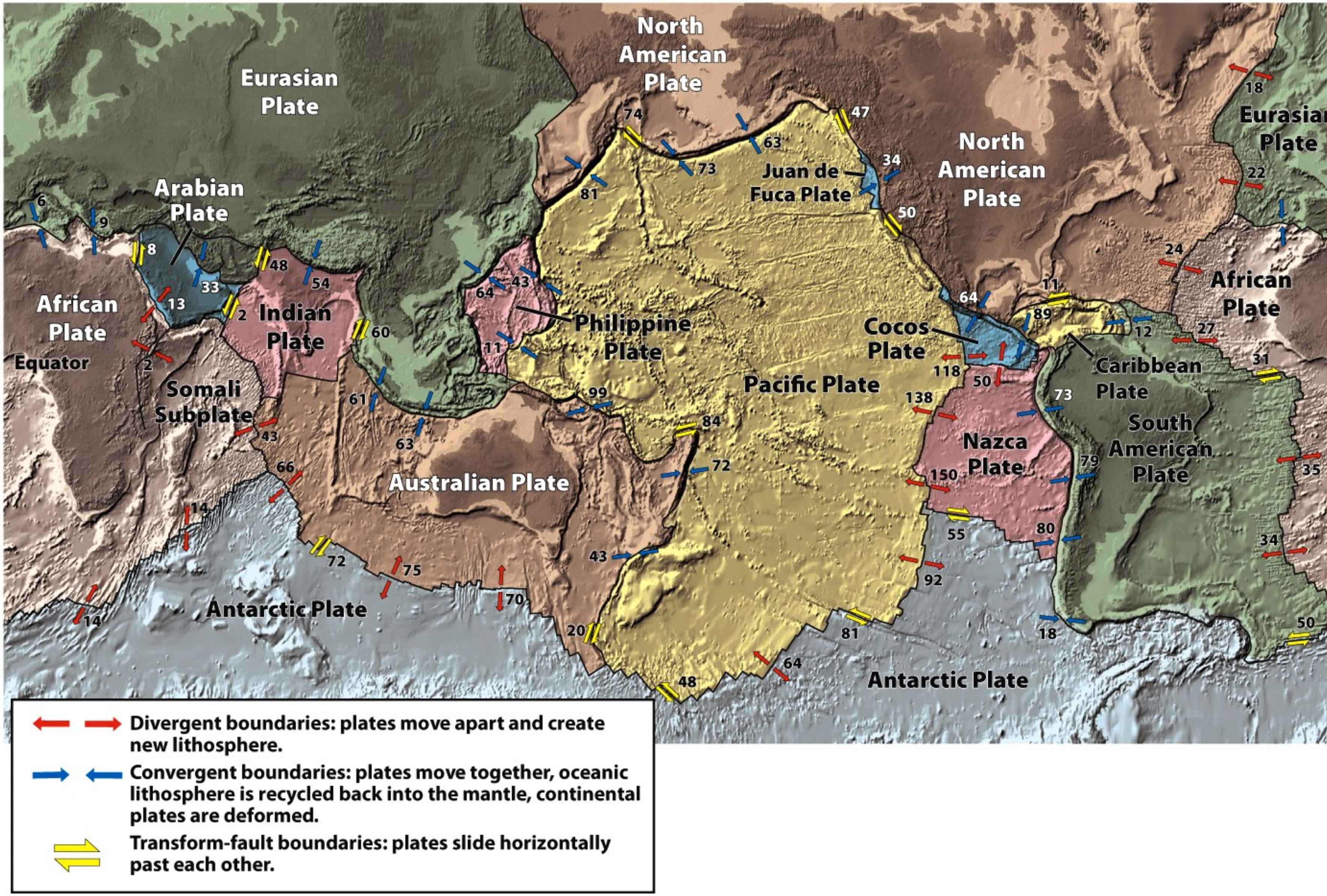
3 OUTER CORE (~3000-5000 km)

4 INNER CORE (~5000-6000 km)

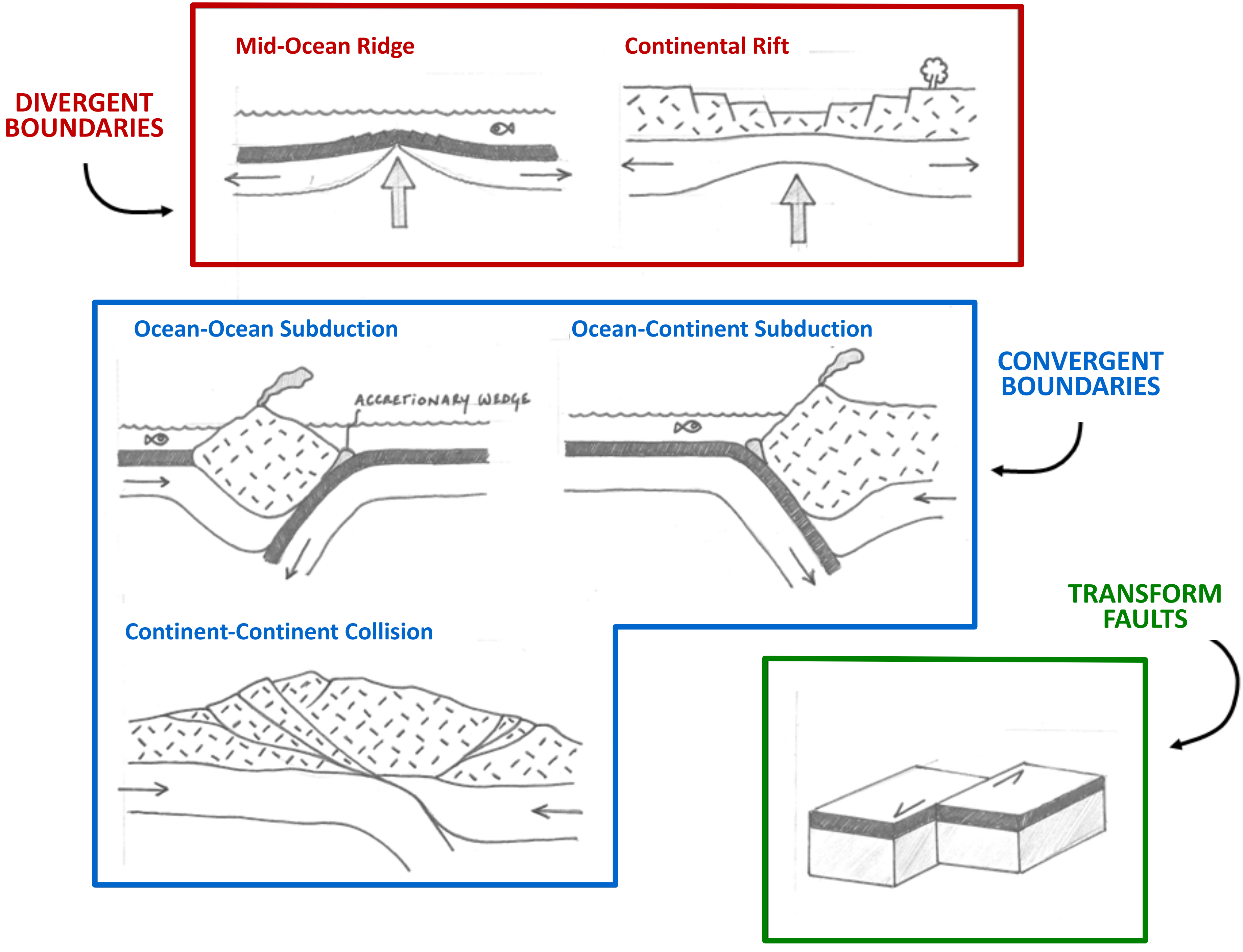
✶ **Review**: Crust, Mantle, Lithosphere and asthenosphere



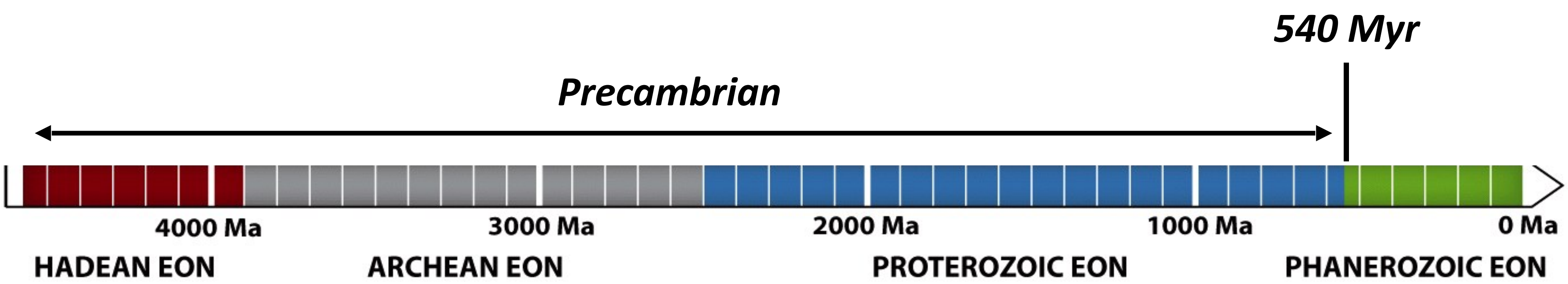
✶ **Review**: Plate boundaries



Understanding Earth 6th Ed.


DIVERGENT BOUNDARIES
Mid-Ocean Ridge
Continental Rift
CONVERGENT BOUNDARIES
Ocean-Ocean Subduction
ACCRETIONARY WEDGE
Ocean-Continent Subduction
Continent-Continent Collision
TRANSFORM FAULTS

✶ How to reconstruct the history of the Earth's crust?

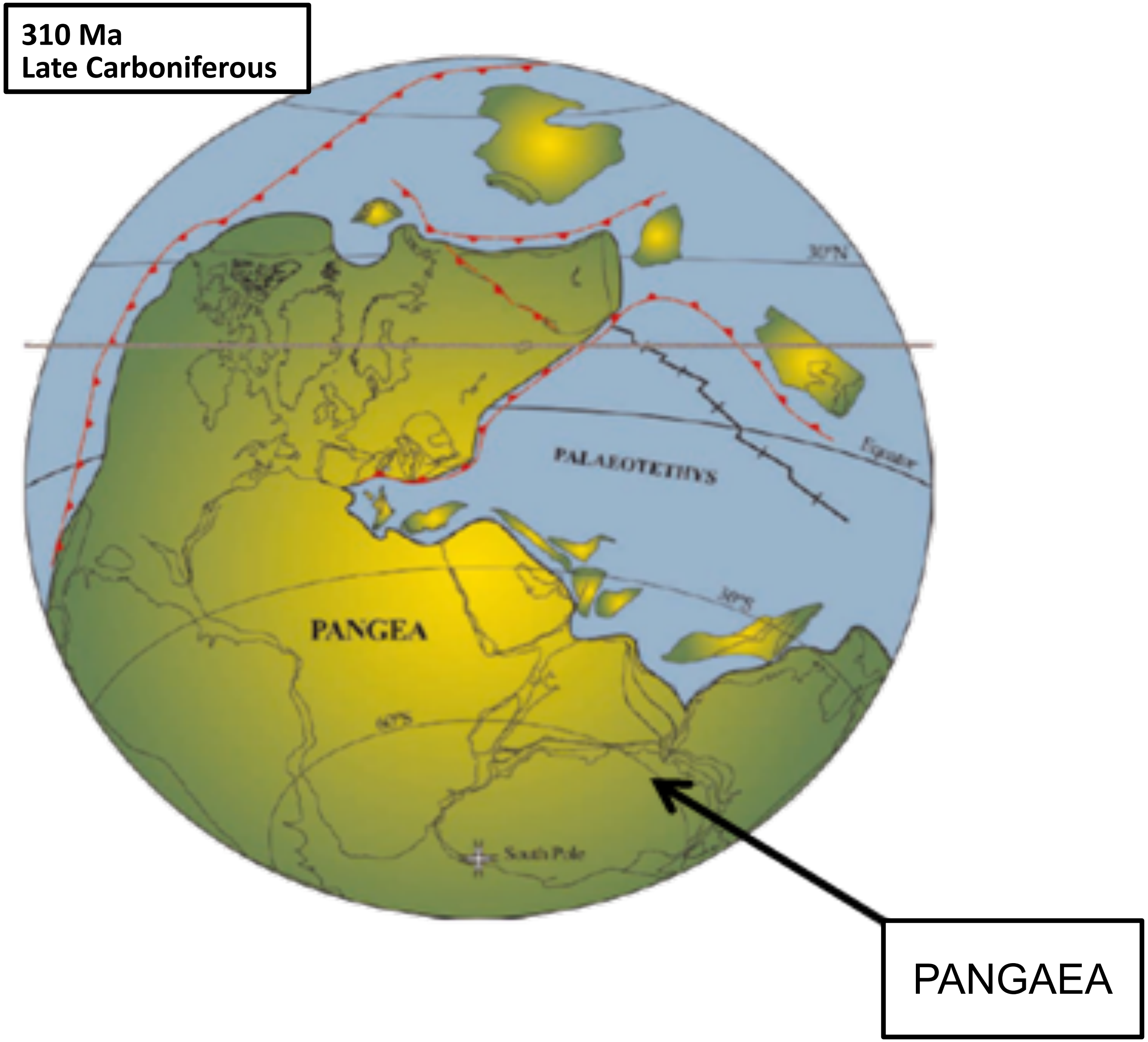


Understanding Earth

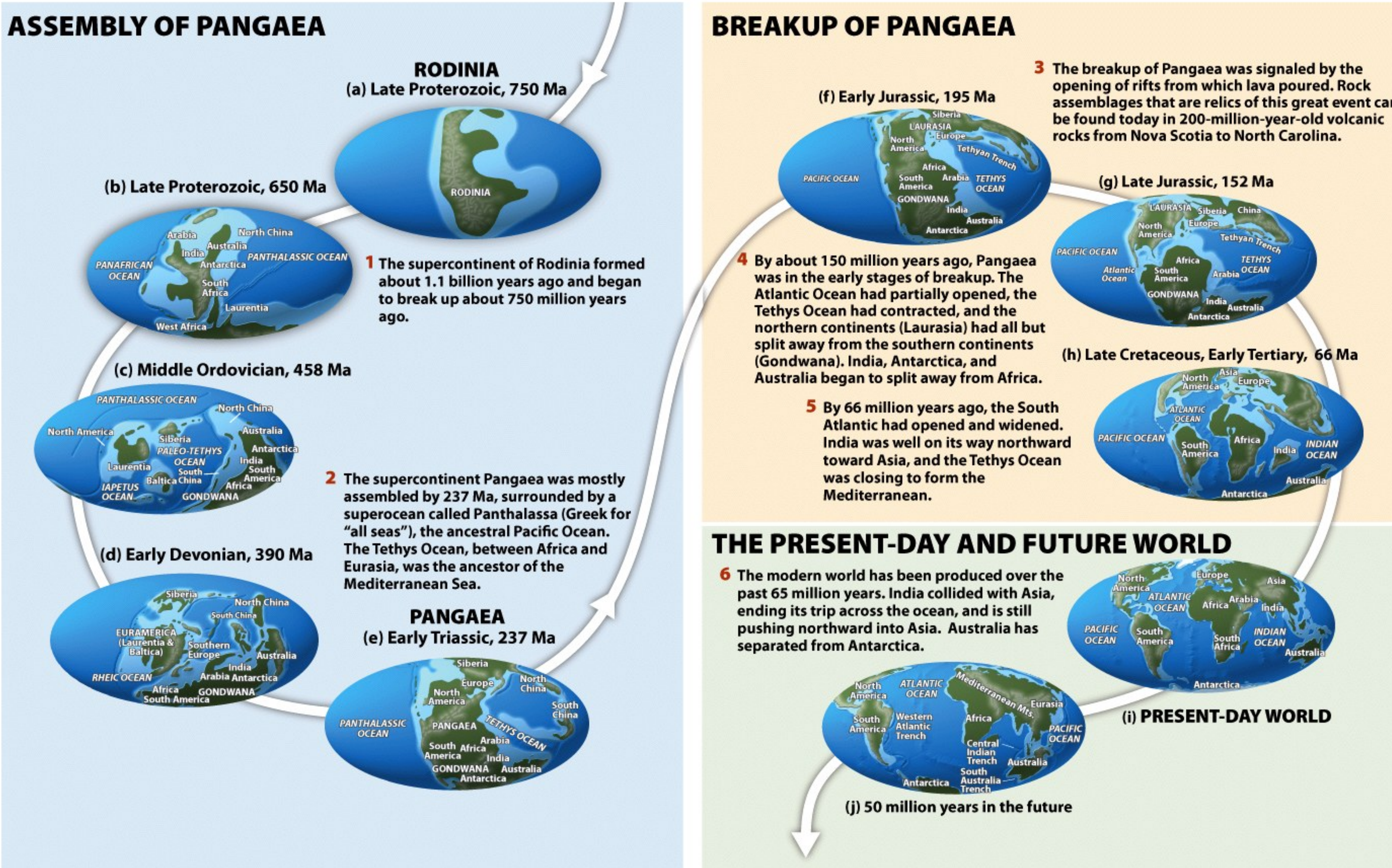
- The Earth is 4.6 billion years old.
- The oldest oceanic crust is "only" 200 million years old.
- The oldest uncontroversial age of a rock from the continental crust is 4 billion years (the Acasta Gneiss from northwestern Canada).

→ Information on the distant past of our planet is locked in rocks composing the continents

✶ **Review**: Supercontinents

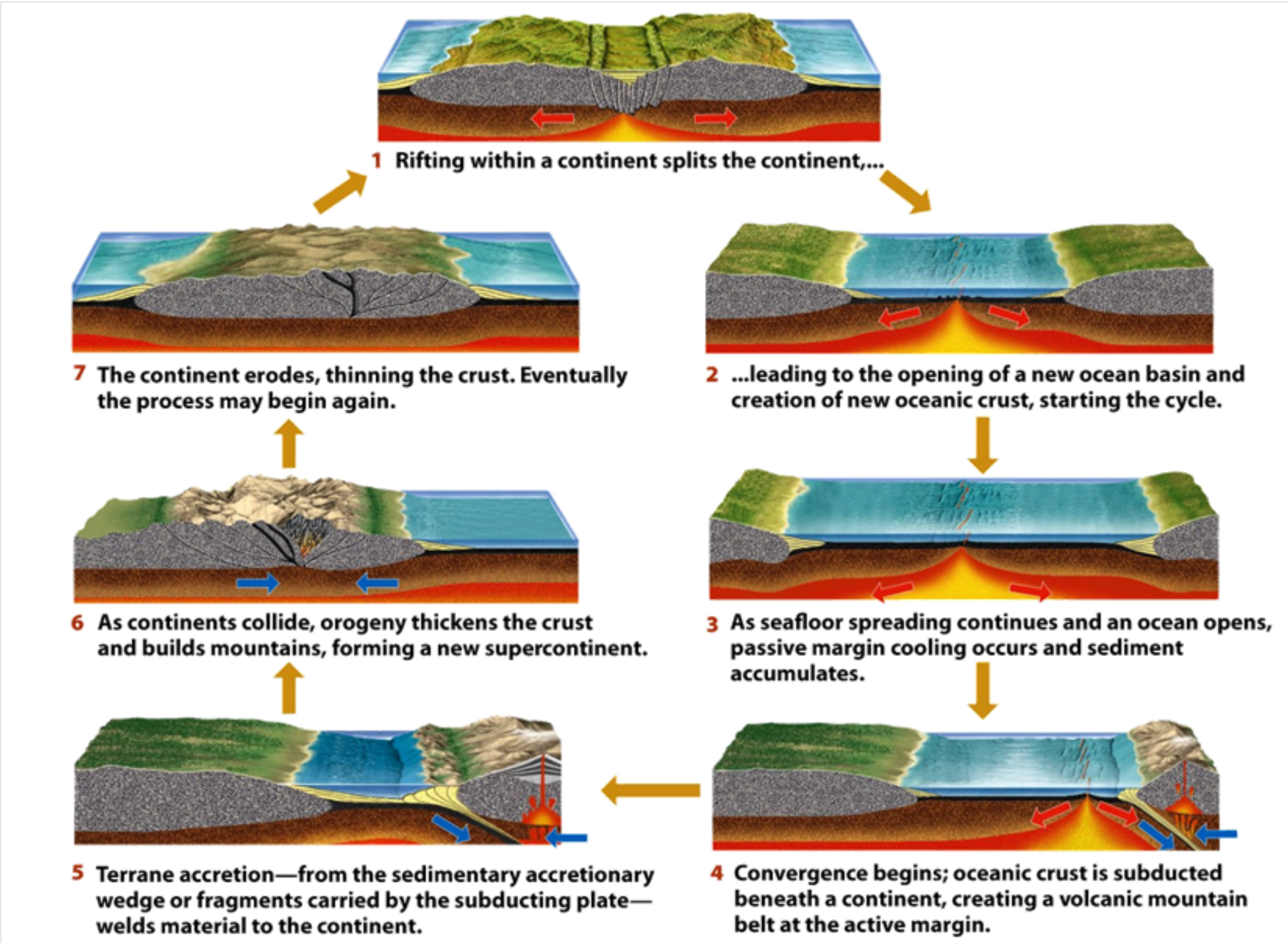


Cocks and Torsvisk (2006)

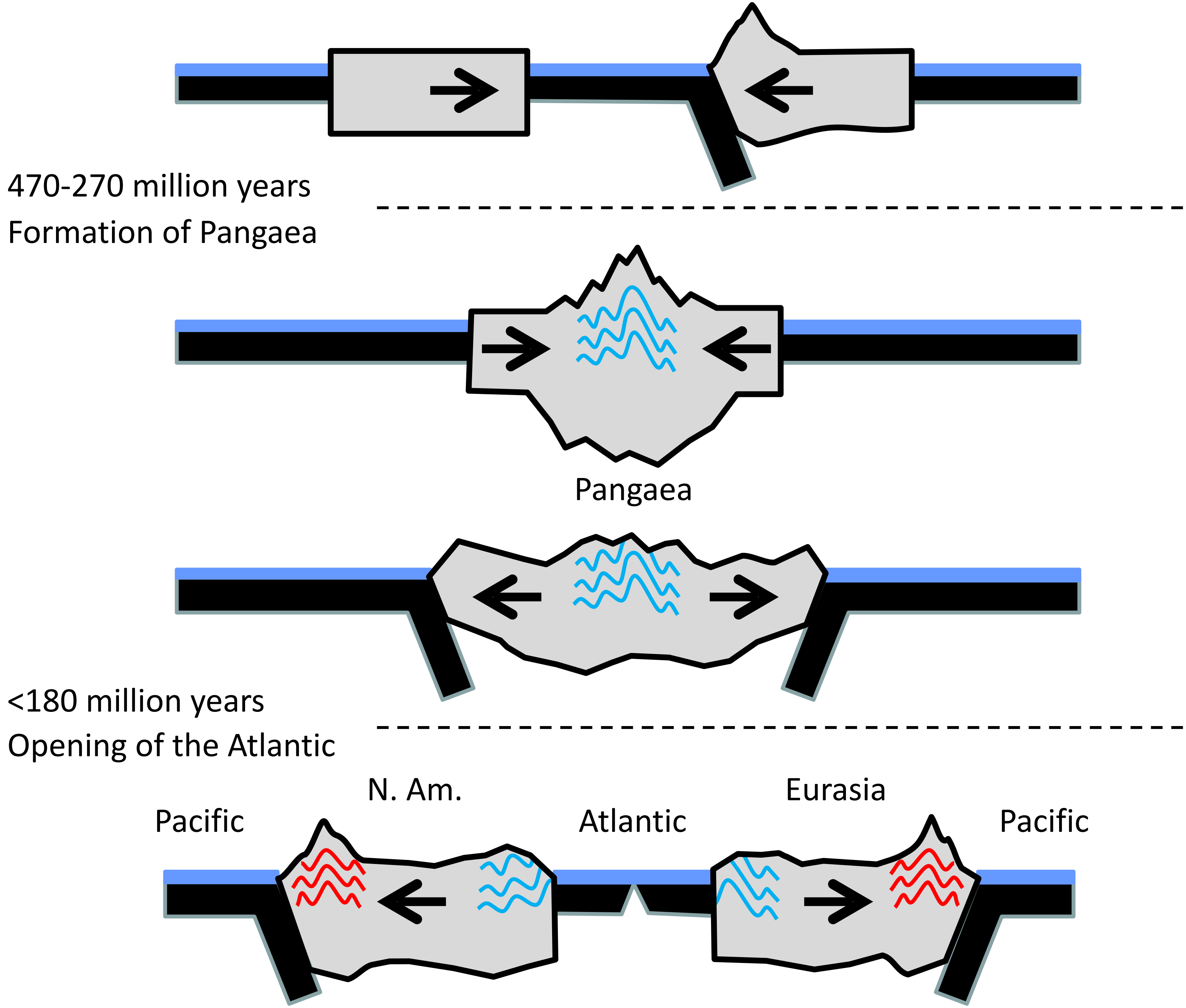


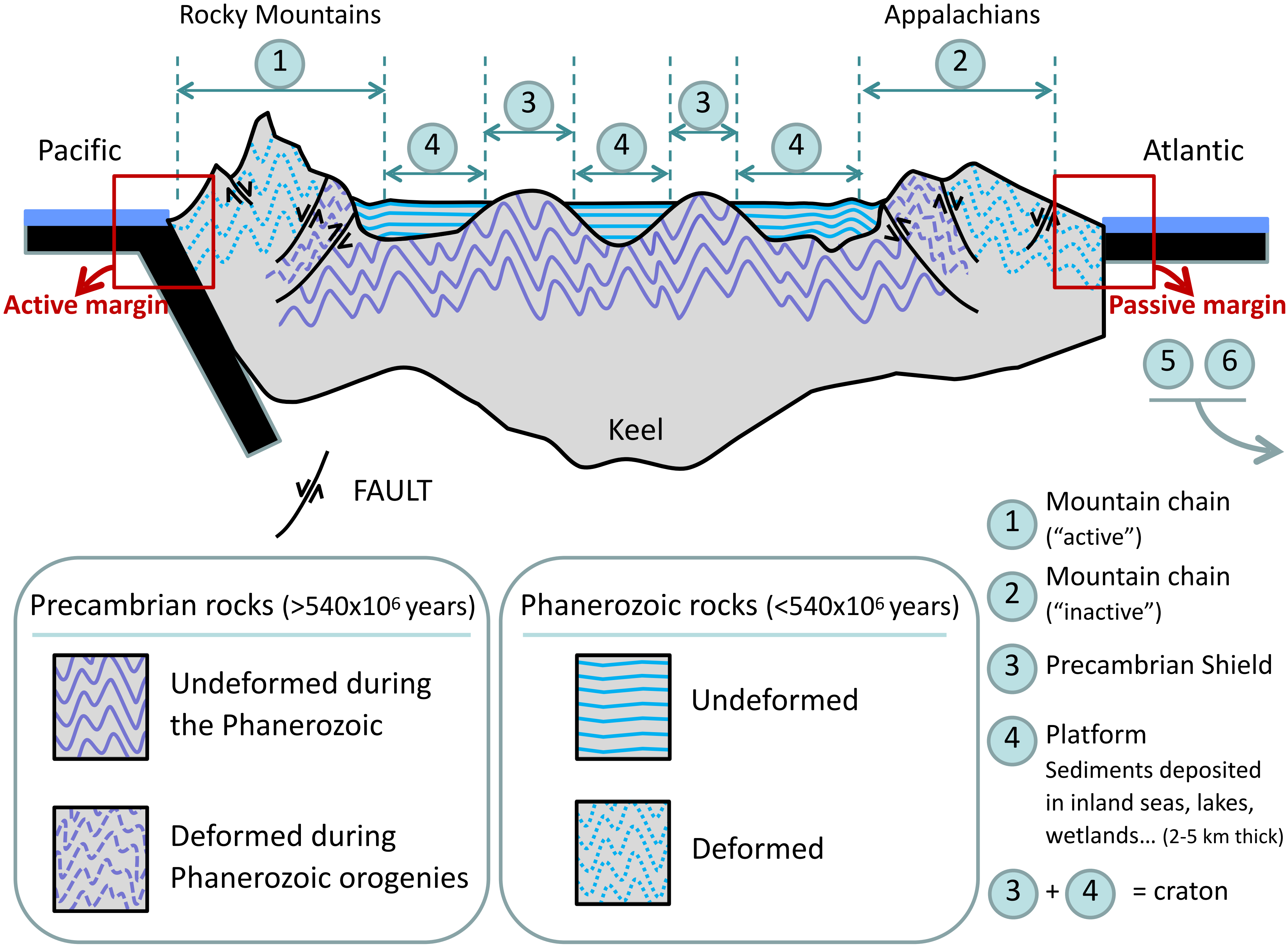
Understanding Earth 6th Ed.

✶ The Wilson Cycle

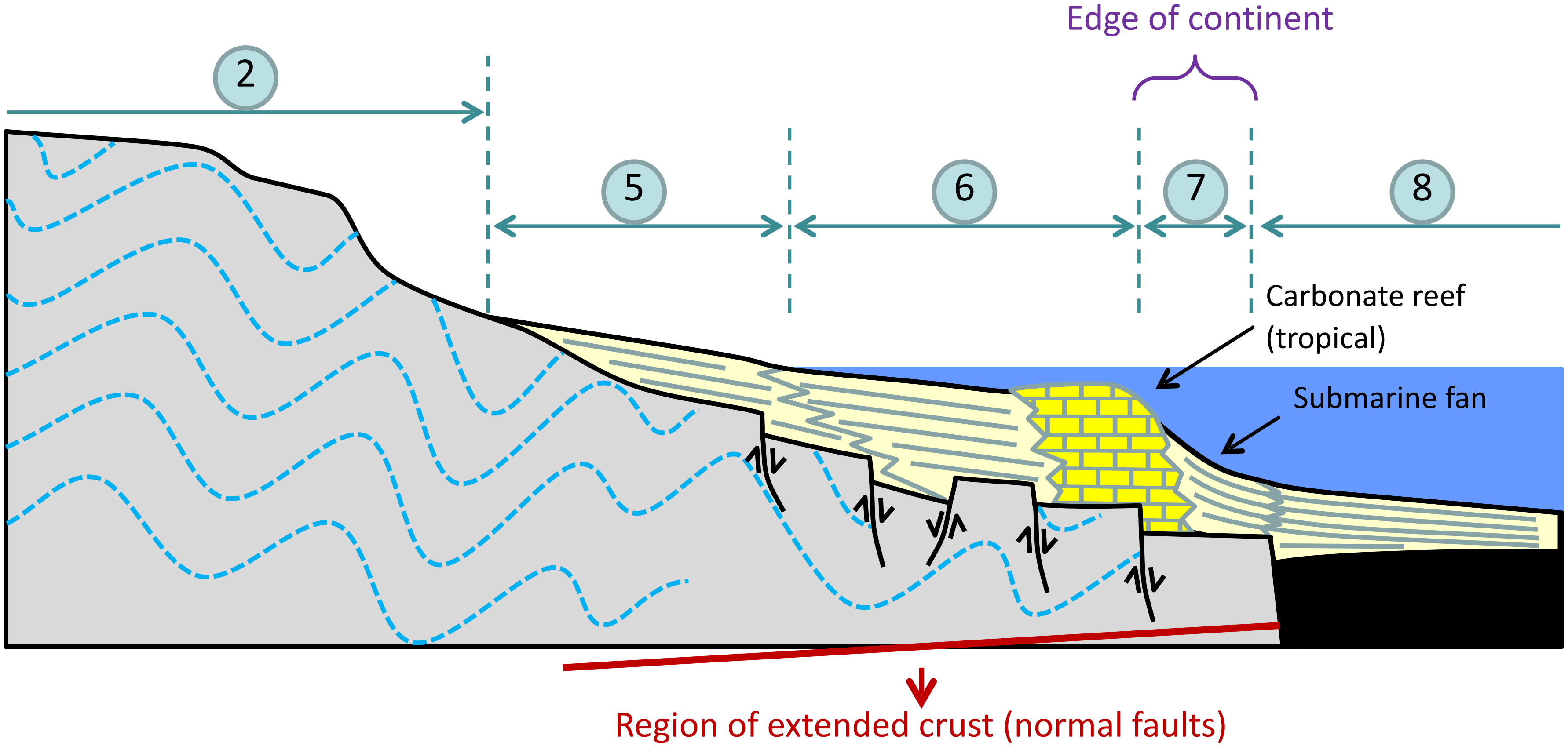


Understanding Earth 6th Ed.


470-270 million years
Formation of Pangaea
Pangaea
<180 million years
Opening of the Atlantic
N. Am.
Eurasia
Pacific
Atlantic
Pacific


Rocky Mountains
Appalachians
1
2
3
3
4
4
4
Pacific
Atlantic
Active margin
Passive margin
5
6
Keel
FAULT
Precambrian rocks (>540x10⁶ years)
Undeformed during the Phanerozoic
Deformed during Phanerozoic orogenies
Phanerozoic rocks (<540x10⁶ years)
Undeformed
Deformed
1 Mountain chain ("active")
2 Mountain chain ("inactive")
3 Precambrian Shield
4 Platform
Sediments deposited in inland seas, lakes, wetlands… (2-5 km thick)
3 + 4 = craton

Passive margin

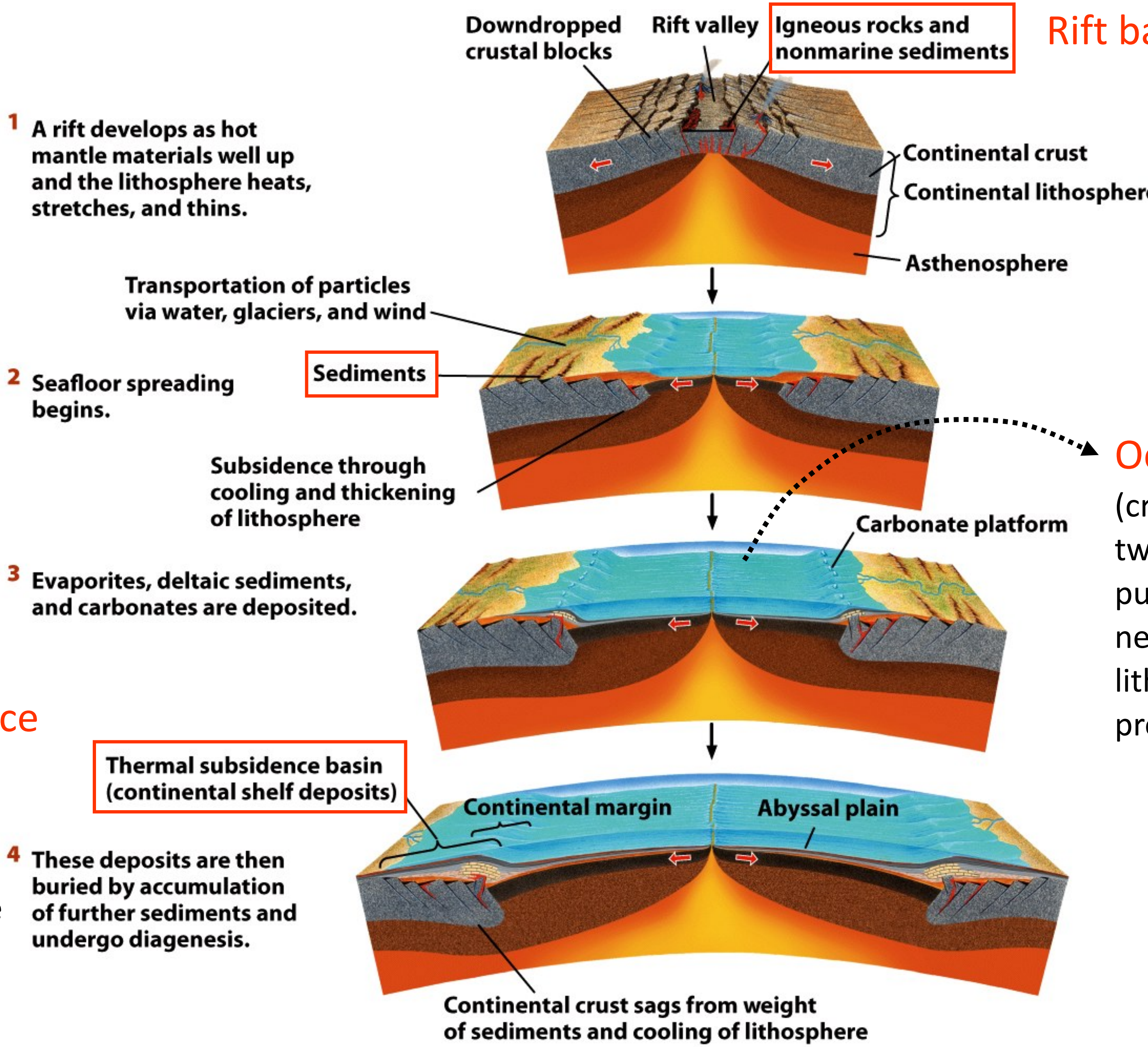


5 **Coastal Plain**
Sediments transported by rivers and deposited in the coastal area.

6 **Continental Shelf**
Region near the edge of continents below sea level that is subsiding and where thick piles of sediments can accumulate.

7 **Continental slope**

8 **Abyssal Plain**



Rift basin

(created as continental lithosphere is stretched and breaks up)

Ocean basin

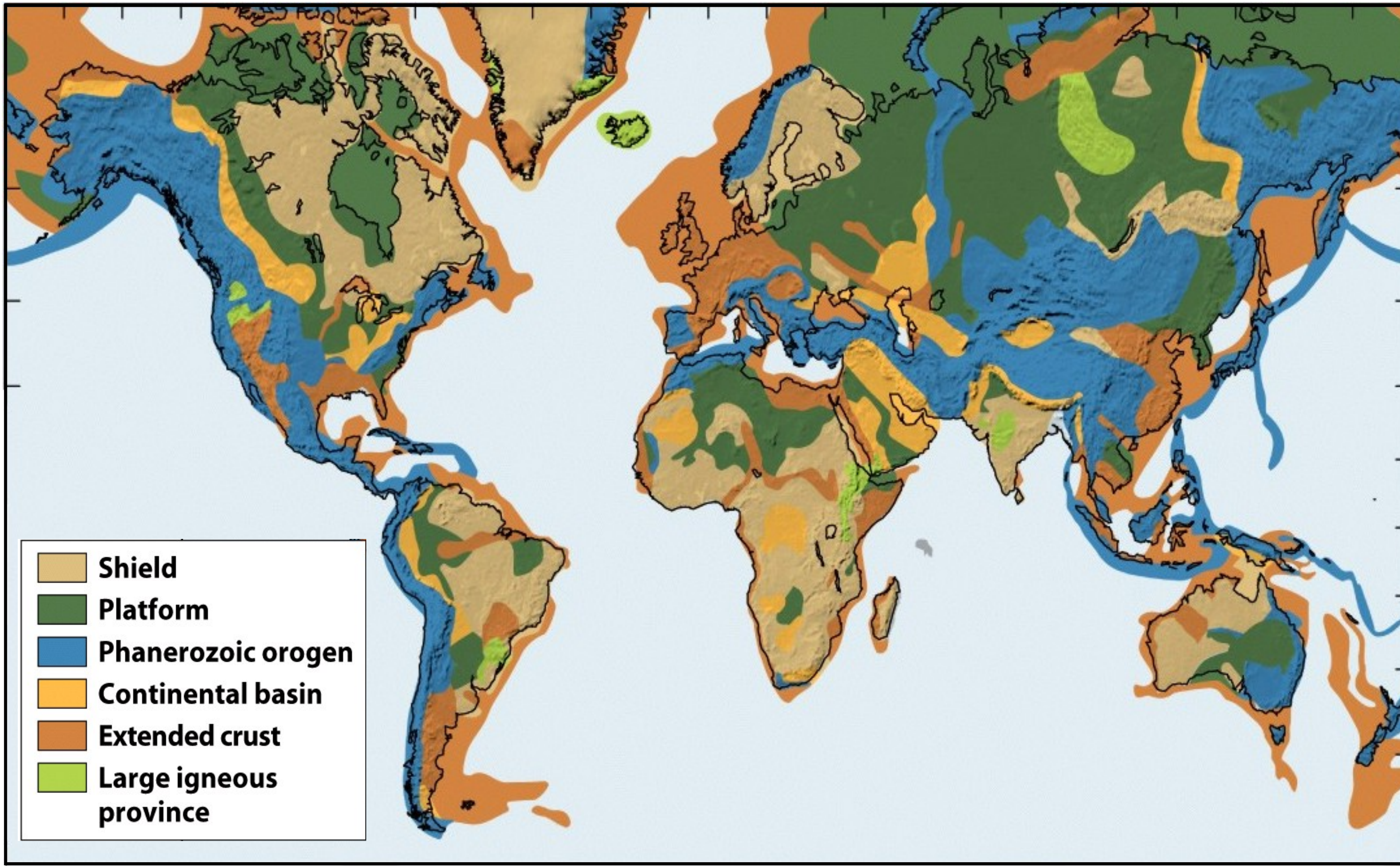
(created as the two plates are pulled apart and new oceanic lithosphere is produced)

Thermal subsidence basin

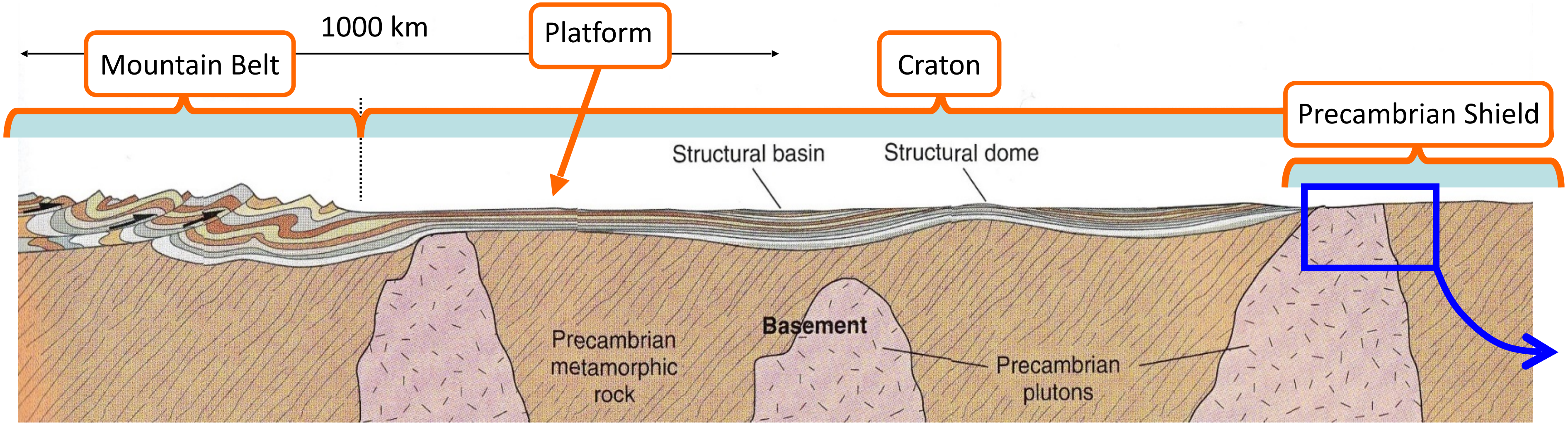
(created as the lithosphere cools and contracts)

Understanding Earth 6th Ed.

✶ Tectonic provinces of the continents



Understanding Earth 6th Ed.



Physical Geology (9th ed.)

★ Shield

- Uplifted Precambrian rocks exposed to the surface.
- Undeformed during the Phanerozoic.

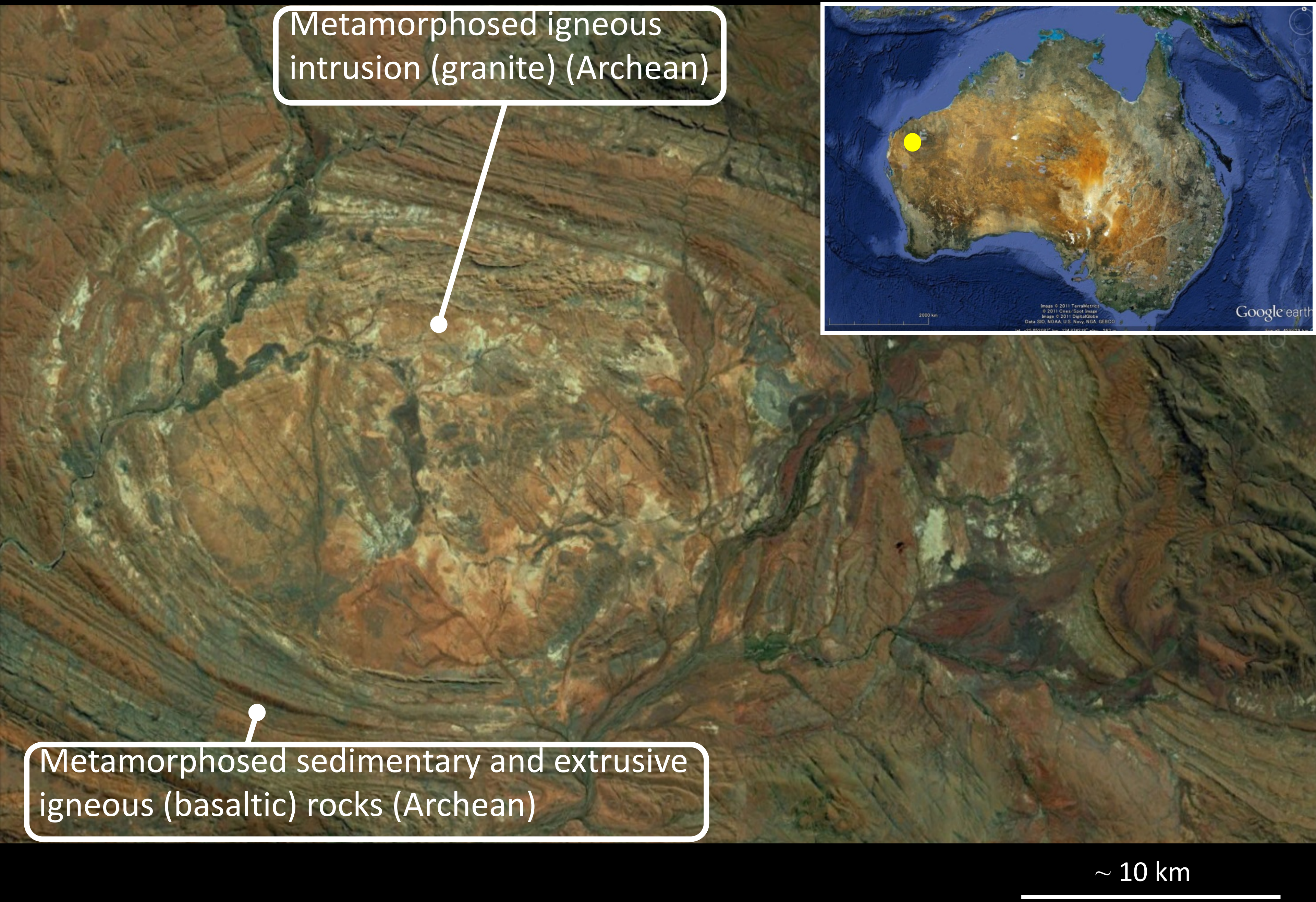
★ Platform

- Flat-lying sediments covering the Precambrian basement rocks.
- Undeformed

Shield + Platform = **Craton**

A craton is the **oldest** and **most stable** part of continents (→ relatively unaffected by Phanerozoic orogenies)

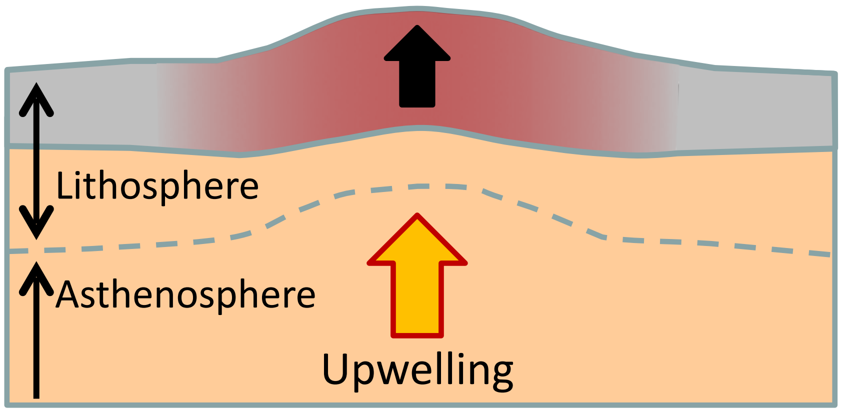
Understanding Earth 6th Ed.


Metamorphosed igneous intrusion (granite) (Archean)
Metamorphosed sedimentary and extrusive igneous (basaltic) rocks (Archean)
Google earth
~ 10 km

★ Intracratonic BASINS and DOMES

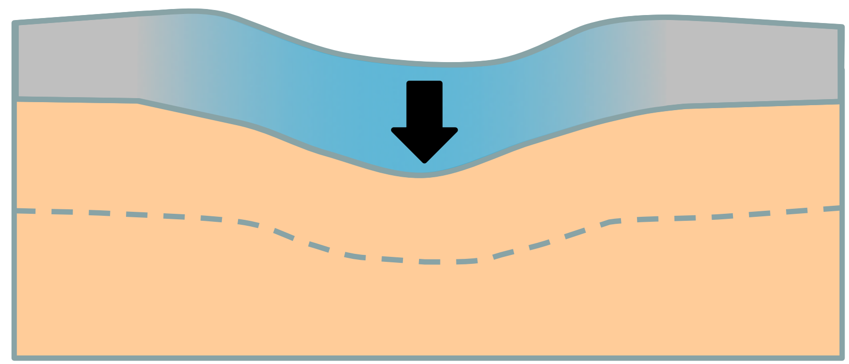
DOME

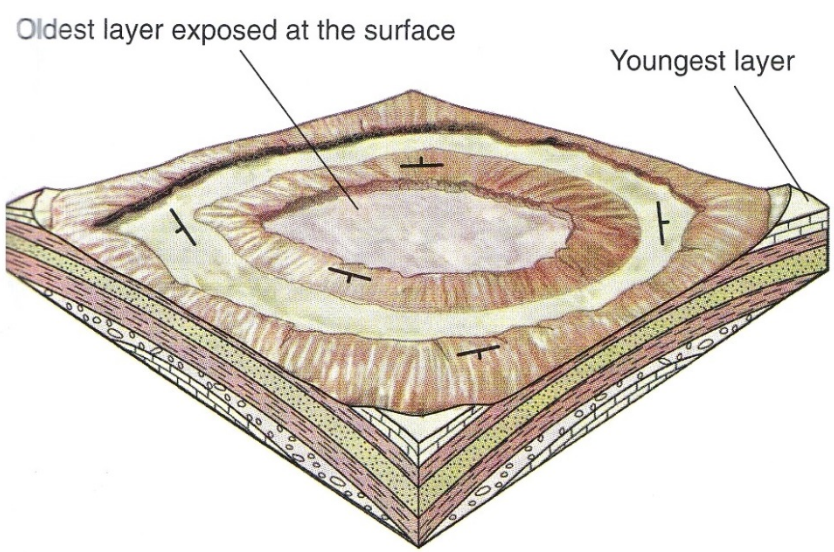
Heating → uplift

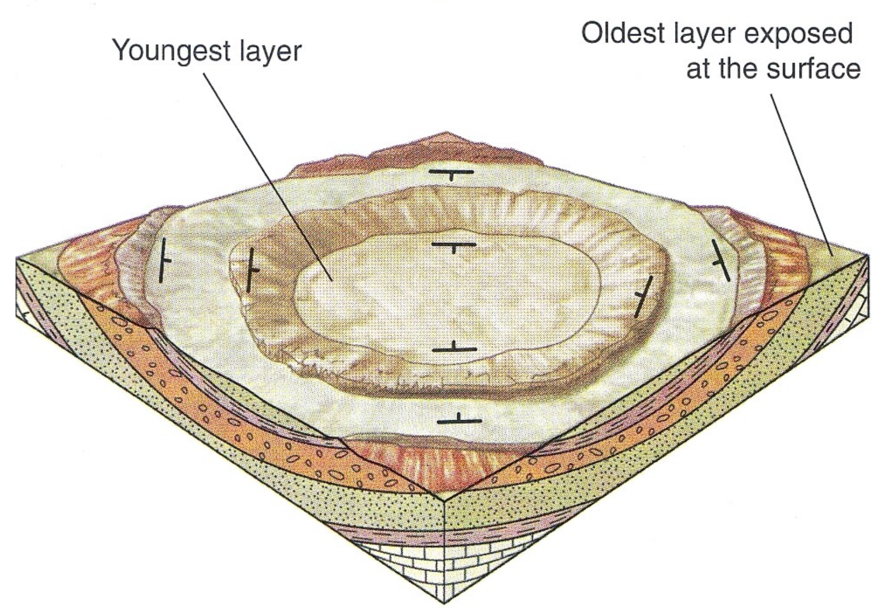


THERMAL SUBSIDENCE BASIN

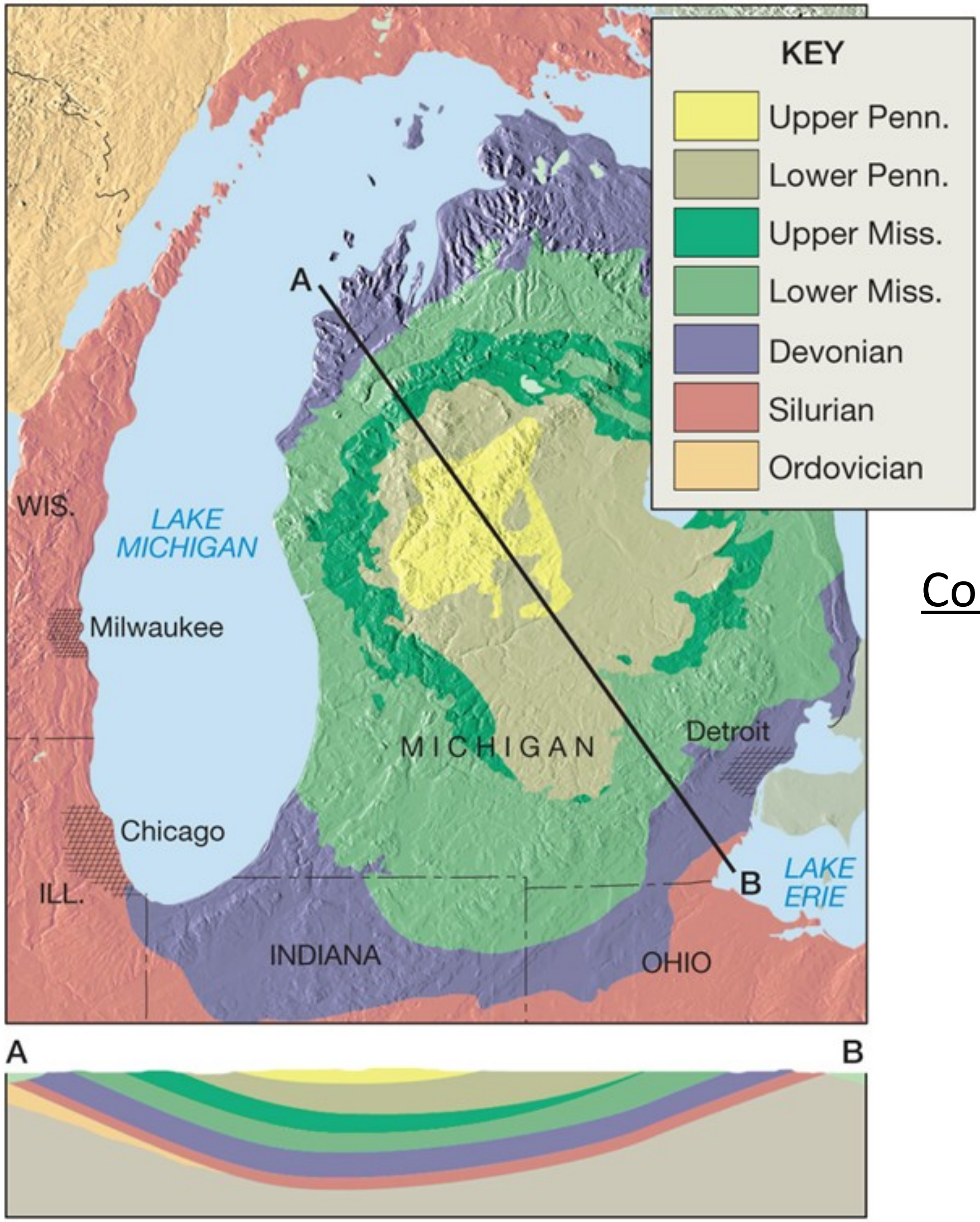
Cooling → subsidence

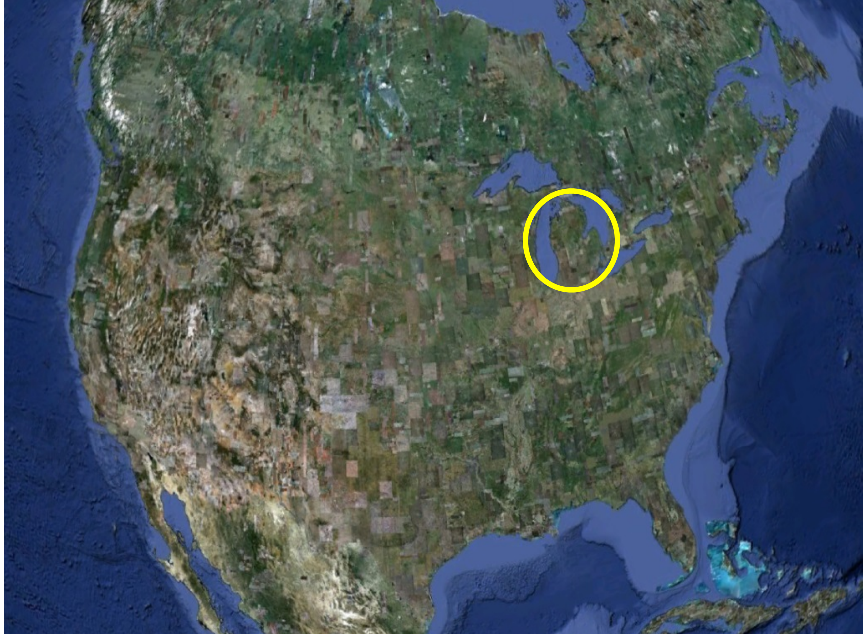






Physical Geology (9th ed.)





Continental Basin

- Region of the continental crust that has subsided and formed a depression where sediments can accumulate.
- Sedimentary layers dip toward the center of the basin.

Example: Michigan Basin (USA)

J.L. Ahern (Univ. of Oklahoma)

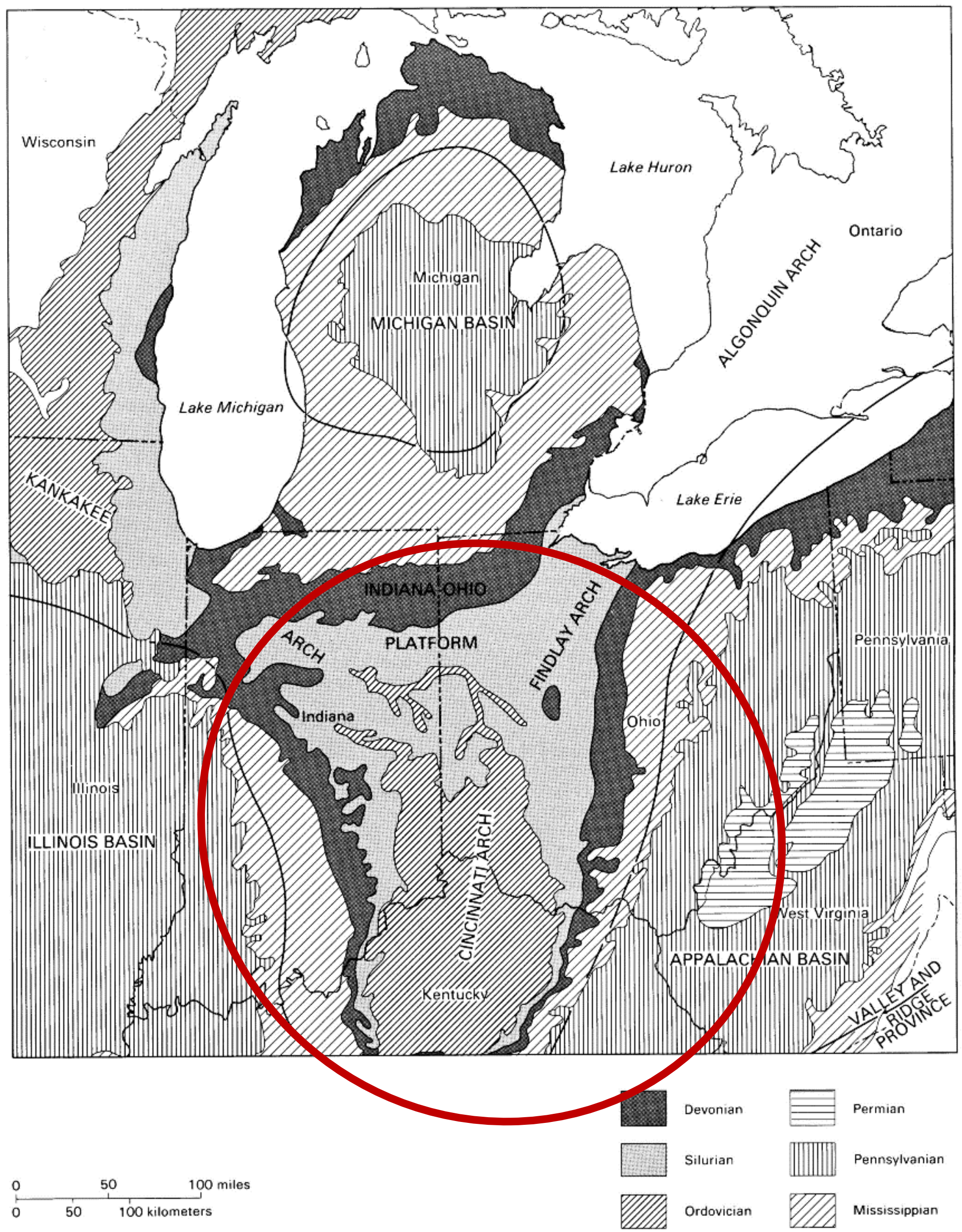
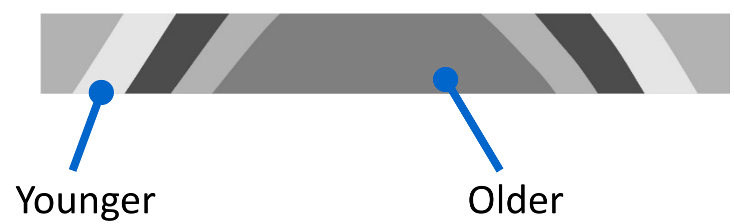


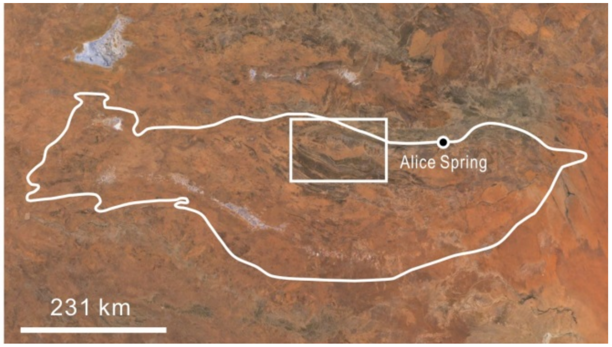
FIGURE 3-4.—Regional geologic structures of Ohio and adjacent states (from Carlson, 1991, fig. 4).

Continental Dome

- Region of the continental crust that has been uplifted, forming a structural dome.
- Sedimentary layers dip away from the center of the basin.

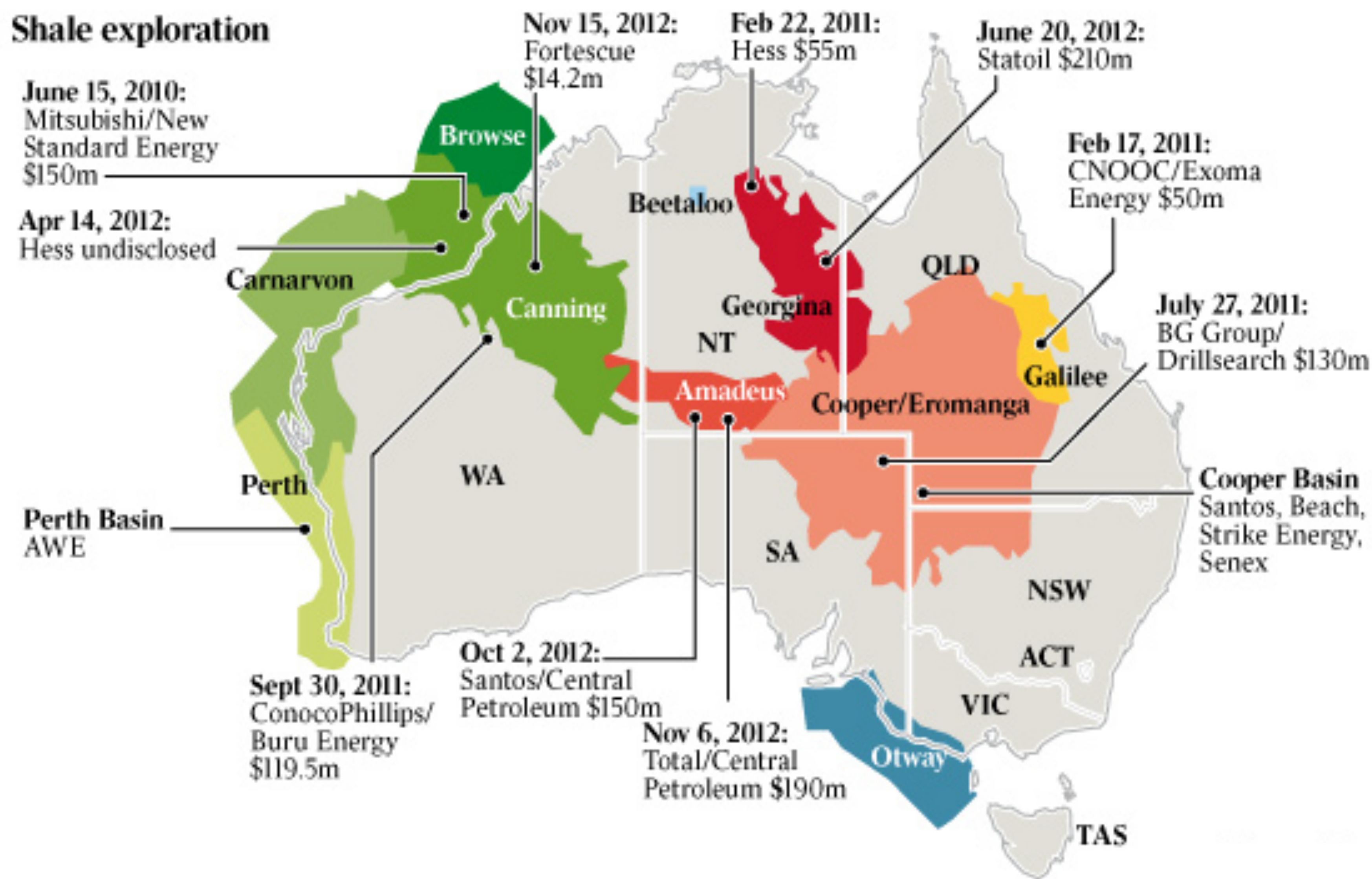
Example: Cincinnati Arch (USA)





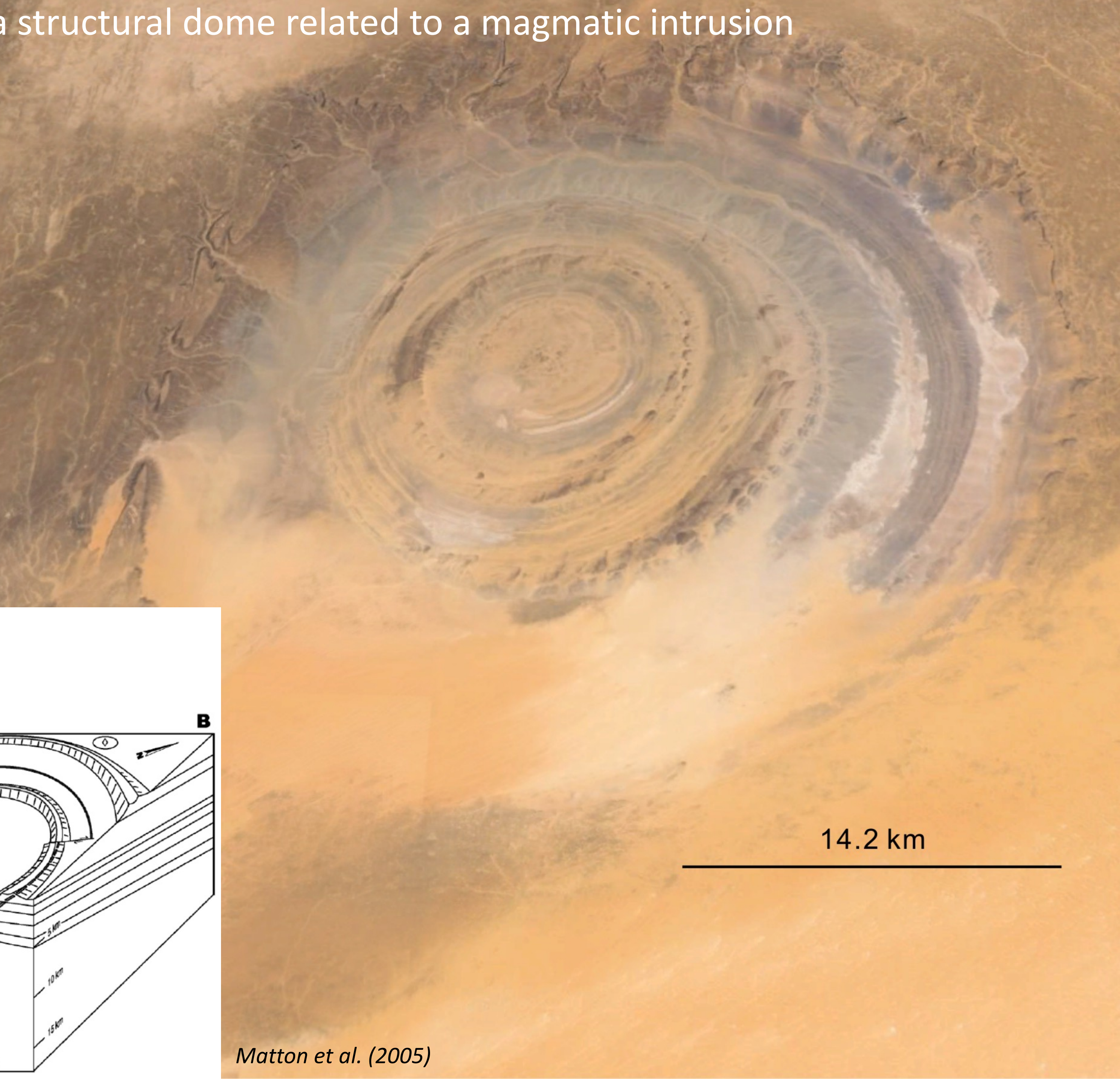
Intracratonic basin with a more complex history:
Example: Amadeus Basin (Australia)

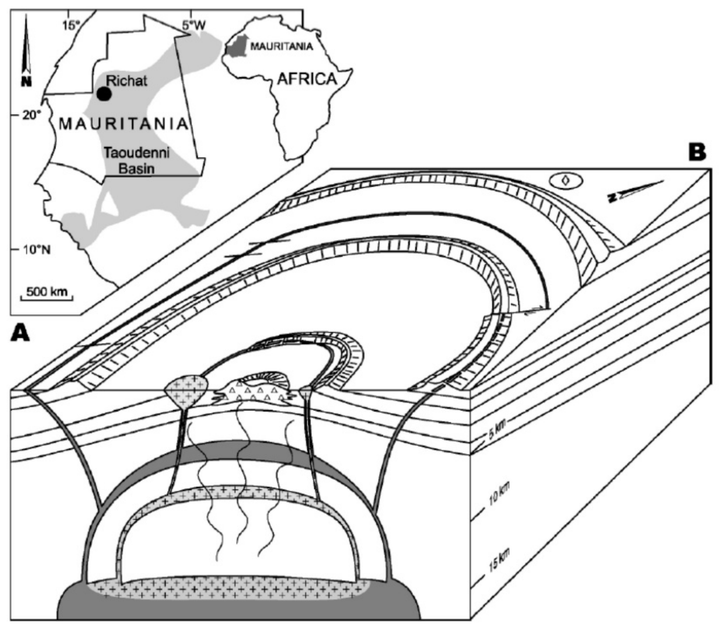
Intracratonic basins: important reservoirs of coal, oil, and natural gas



http://peakenergy.blogspot.com/2013/09/manufacturing-gas-crisis.html 2020/3/6

The Richat dome: a structural dome related to a magmatic intrusion



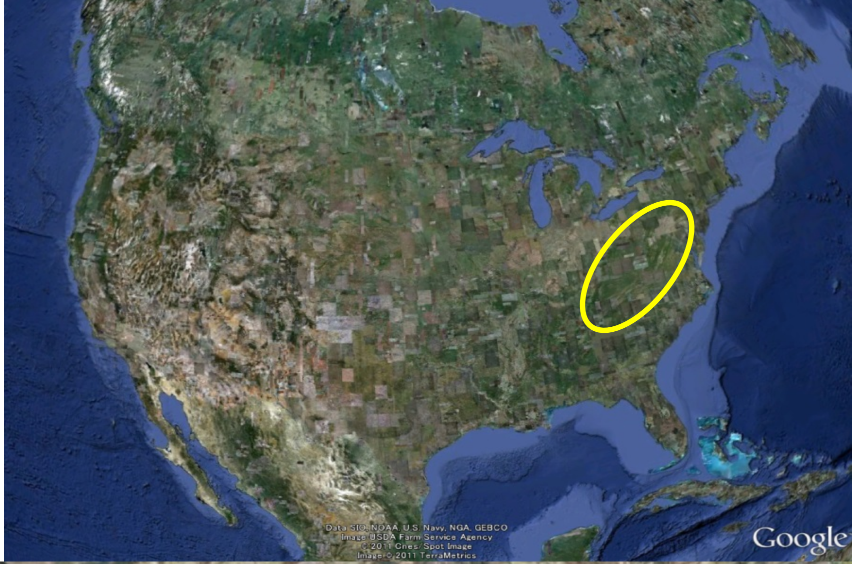


Matton et al. (2005)

★ Phanerozoic orogens (= mountain belts)

- Mountain belts are formed by episodes of compressive deformation where two tectonic plates converge.
- Orogeny refers to the process of mountain building.

Examples: Appalachian Mountains (USA)
Alpine-Himalayan orogenic belt (Eurasia)



The **Appalachian mountains** are marked by two distinct successive episodes of compressive deformation (orogenies):

- **Caledonian orogeny** resulting from the collision of the continents **Laurentia** (part of N America, Greenland), **Baltica** (N-E Europe), and **Avalonia** (part of N-E America, part of W Europe) 450-400 Ma ago.

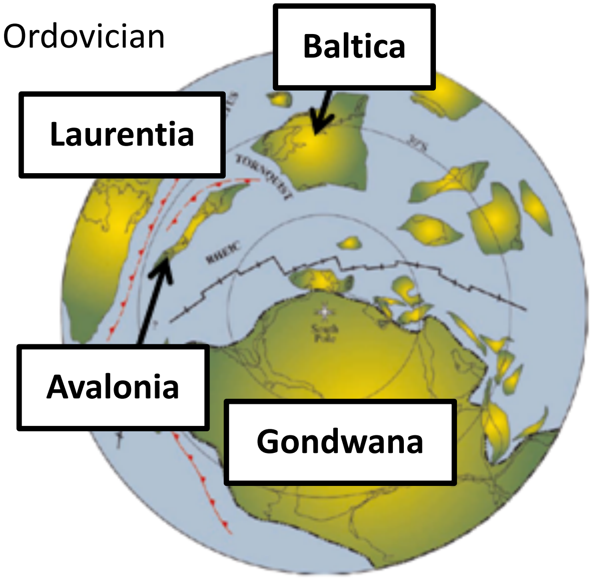
  The collision between Laurentia, Baltica, and Avalonia resulted in the formation of the continent **Laurussia**.

- **Variscan* orogeny** resulting from the collision of the continents **Laurussia** and **Gondwana** (S America, Africa, Madagascar, India, Antarctica, and Australasia) 400-300 Ma ago.

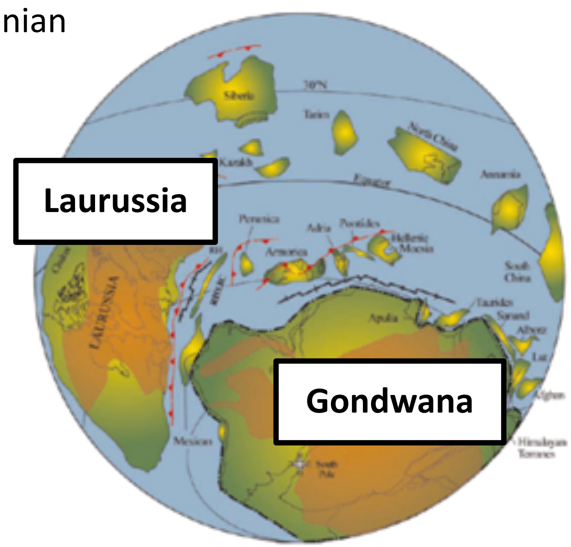
  The collision between Laurussia and Gondwana resulted in the formation of the supercontinent **Pangaea**.

*also referred to as the Hercynian orogeny

460 Ma
Middle Ordovician



400 Ma
Early Devonian



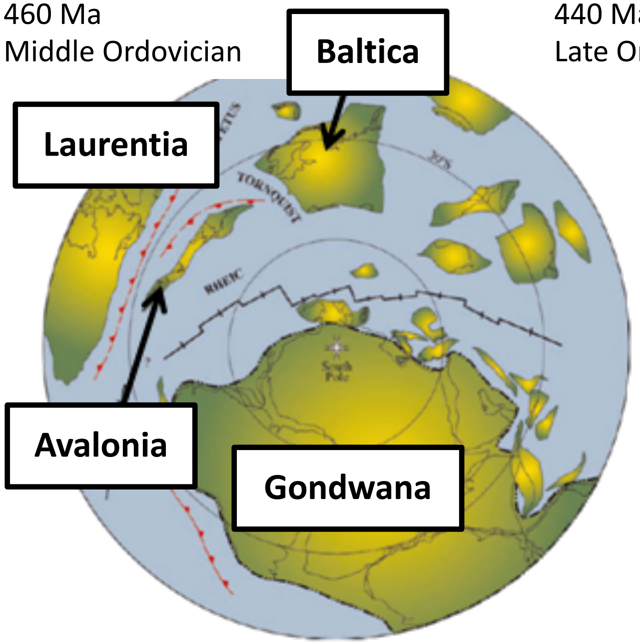
Appalachians-USA

! [?]Wikipec

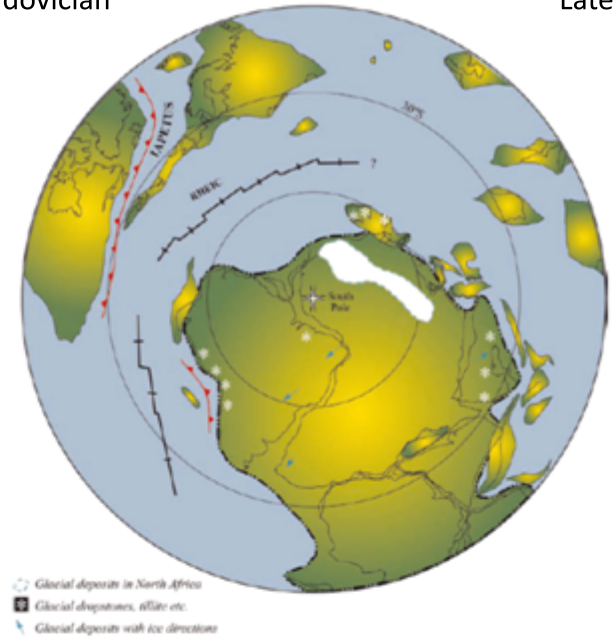
Eifel-Germany

Ardennes-Belgium

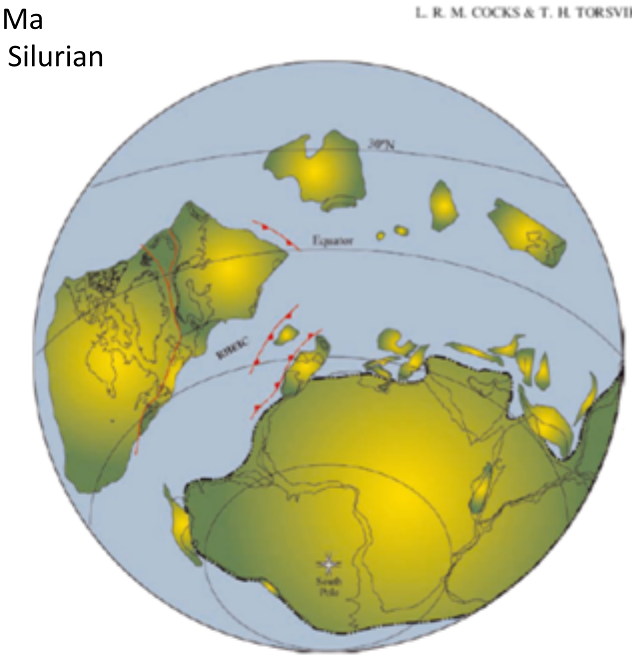
460 Ma
Middle Ordovician



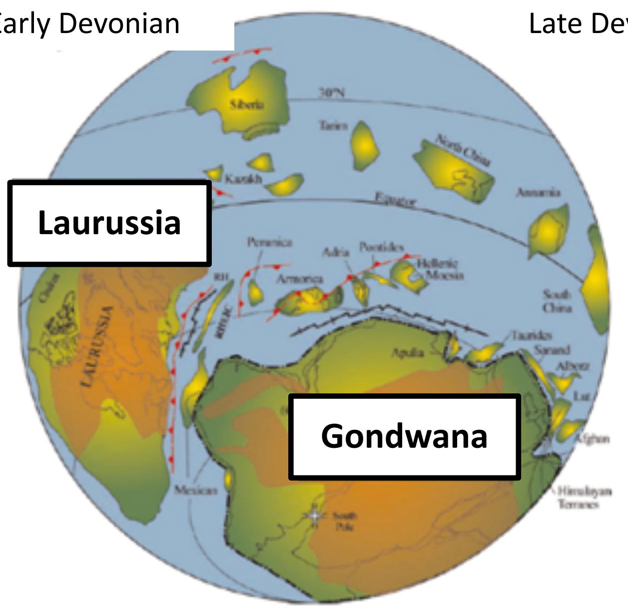
440 Ma
Late Ordovician



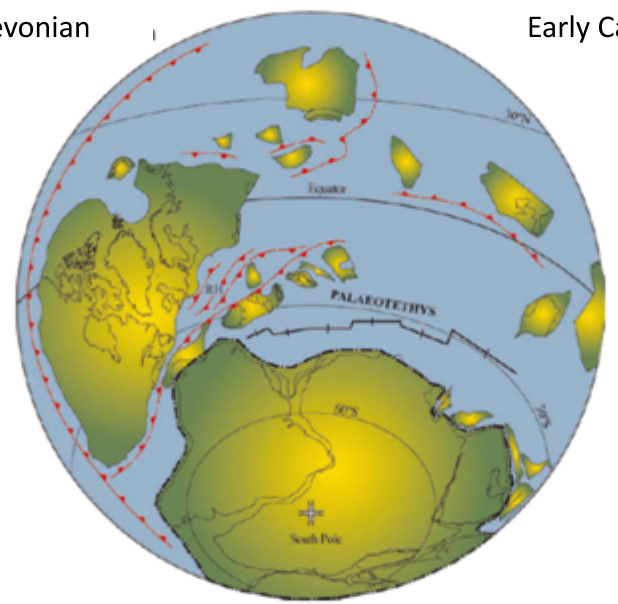
420 Ma
Late Silurian



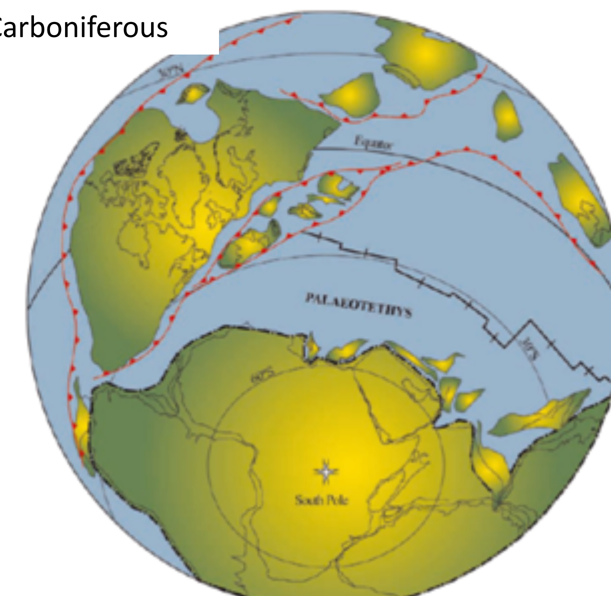
400 Ma
Early Devonian



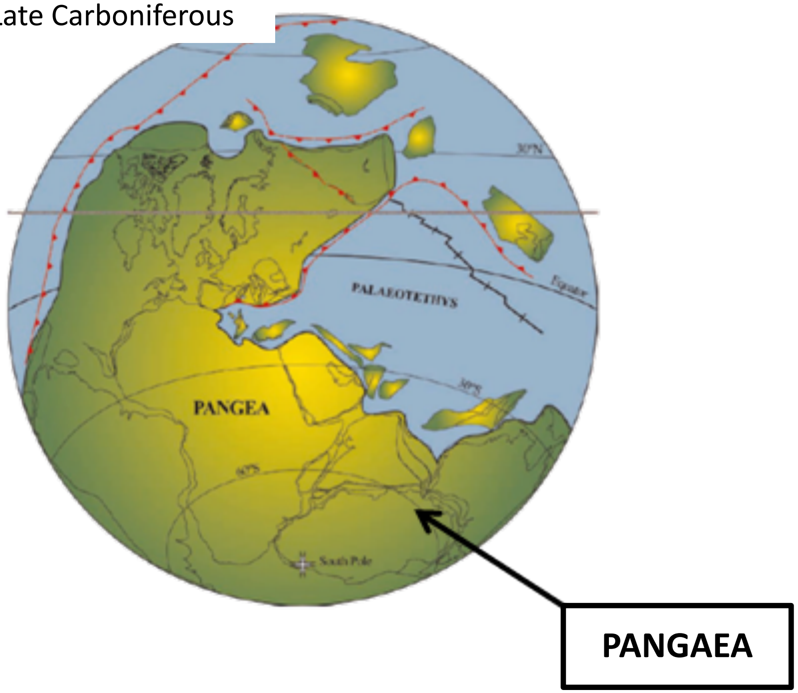
370 Ma
Late Devonian



340 Ma
Early Carboniferous

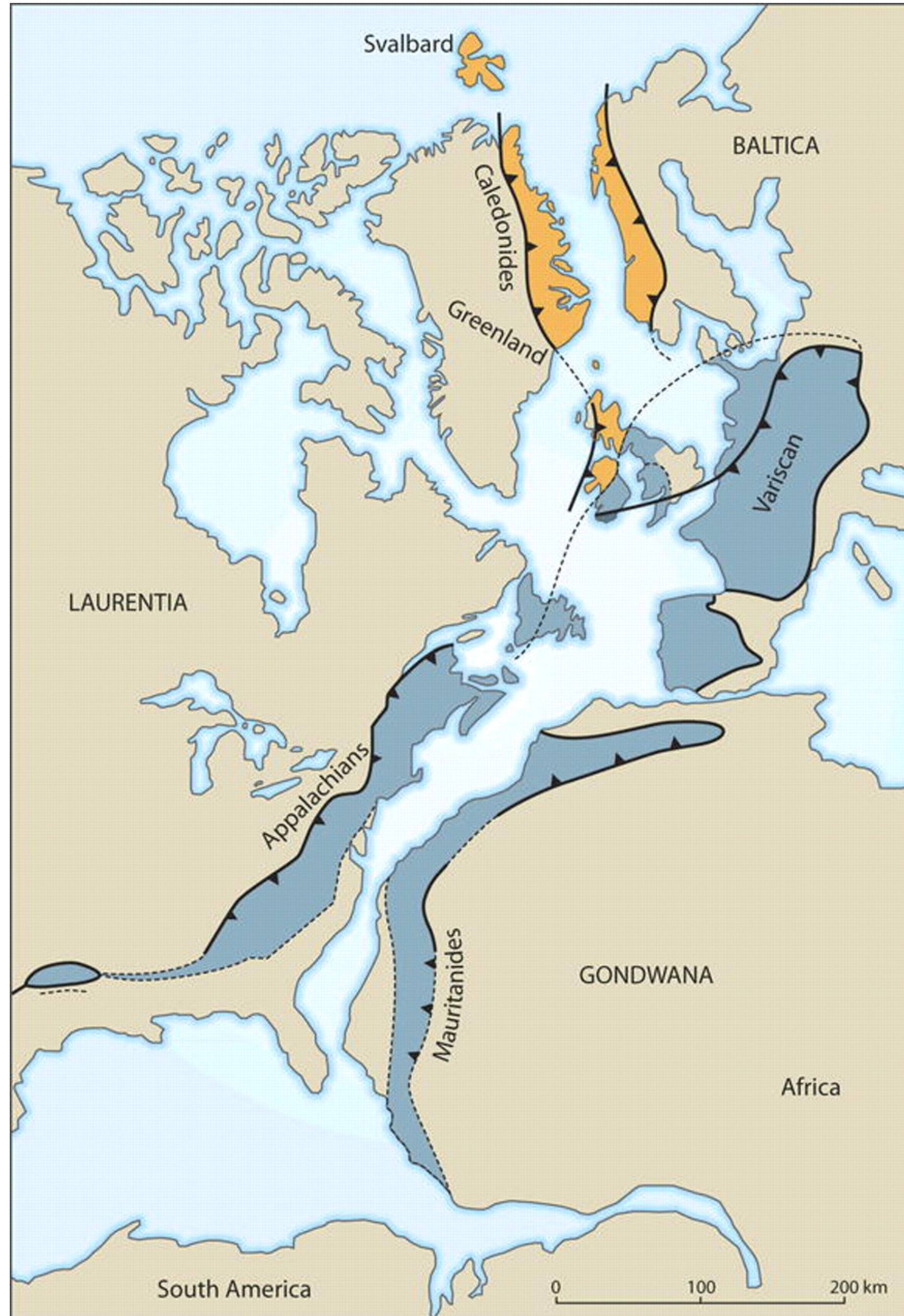


310 Ma
Late Carboniferous



Paleogeographic reconstructions based on:

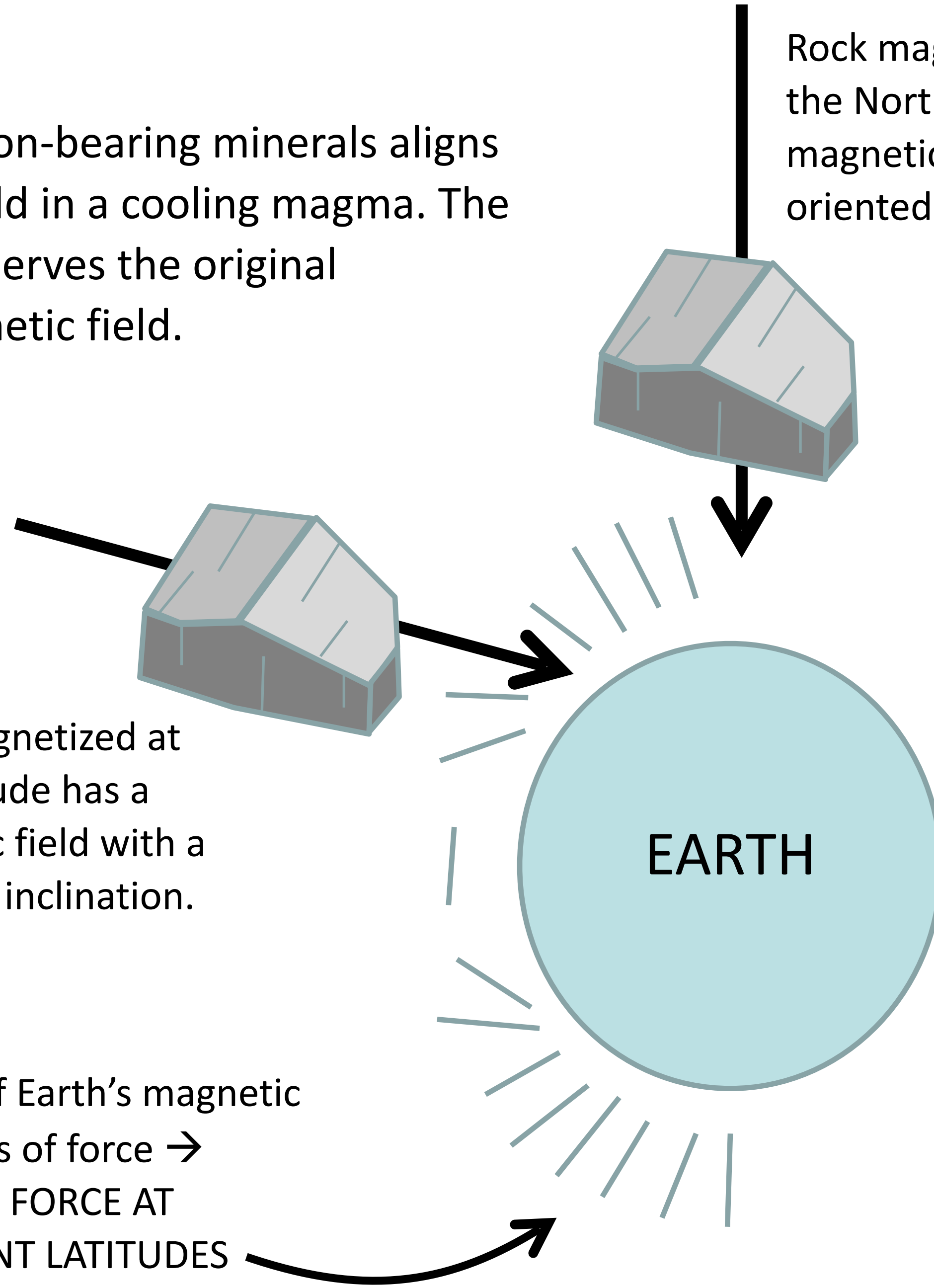
- Mapping rock types and geologic structures
- Fossil distribution
- Rock paleomagnetism
  When lava cools, iron-rich minerals become magnetized in the direction of Earth's magnetic field. By measuring rock magnetization, it is possible to determine the paleolatitude at which the rock formed.



Cocks and Torsvisk (2006) *Henriksen et al. (2008)*

The magnetic field of iron-bearing minerals aligns with Earth magnetic field in a cooling magma. The resulting solid rock preserves the original orientation of the magnetic field.

Rock magnetized at the North Pole bears a magnetic field oriented vertically.

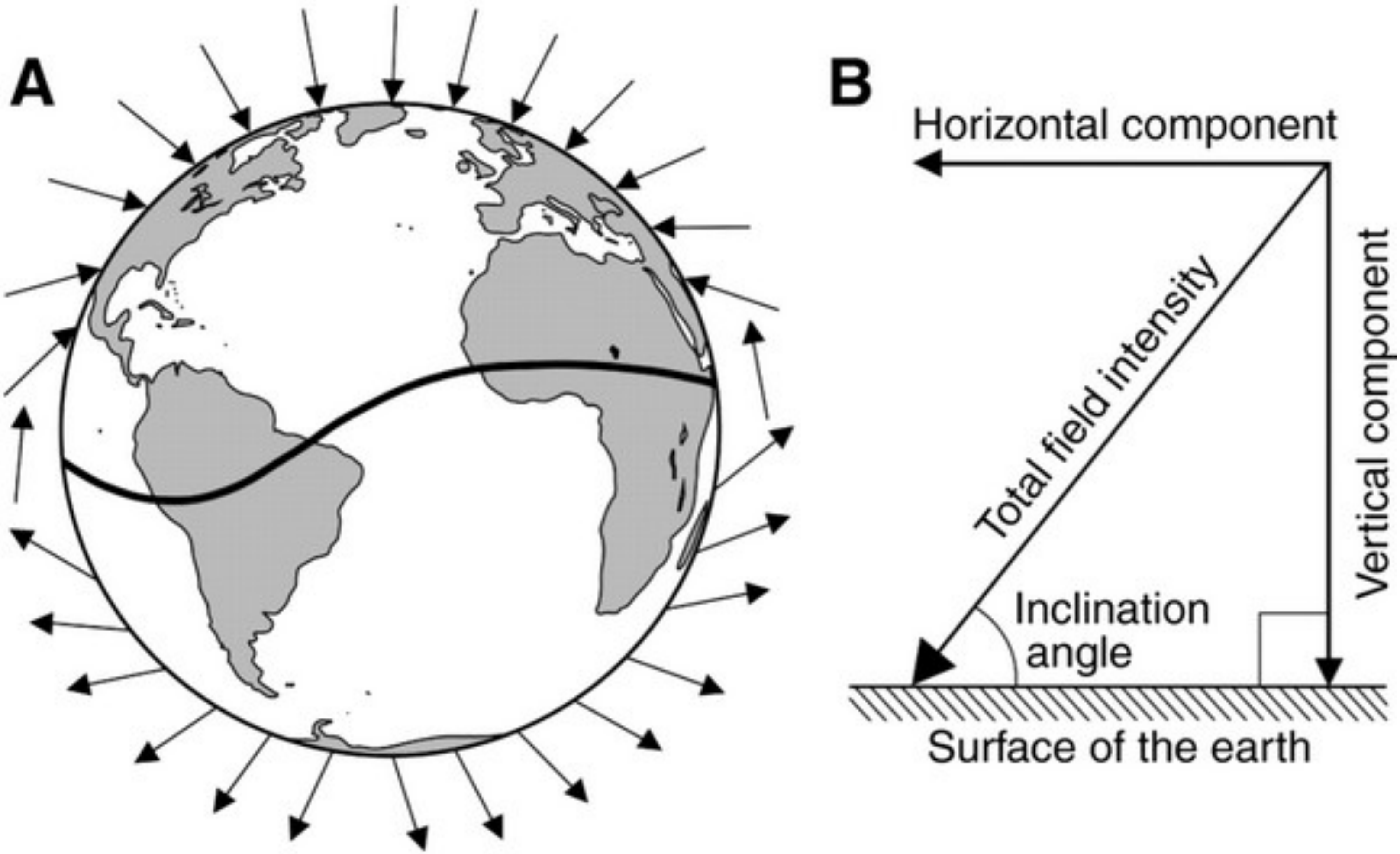


Rock magnetized at this latitude has a magnetic field with a different inclination.

Trends of Earth's magnetic field lines of force → LINES OF FORCE AT DIFFERENT LATITUDES HAVE DIFFERENT INCLINATIONS!

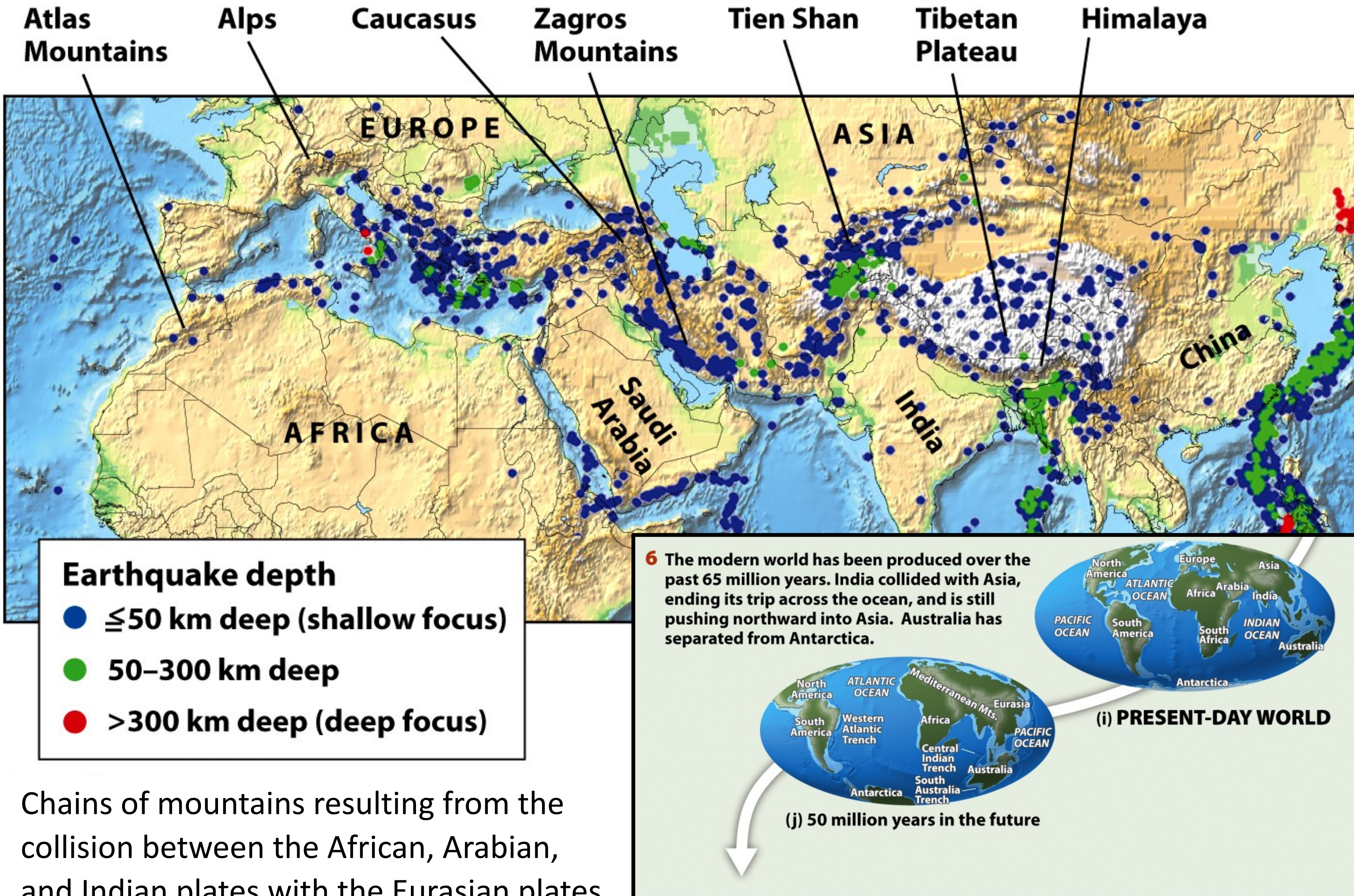
http://www.nature.nps.gov/geology/usgsnps/noca/sb10paleomag.html

Rock paleomagnetism constrains the paleo-latitude of a rock formation but not its paleo-longitude.



http://people.eku.edu/ritchisong/nav_orient.htm

Alpine-Himalayan orogenic belt (still active)



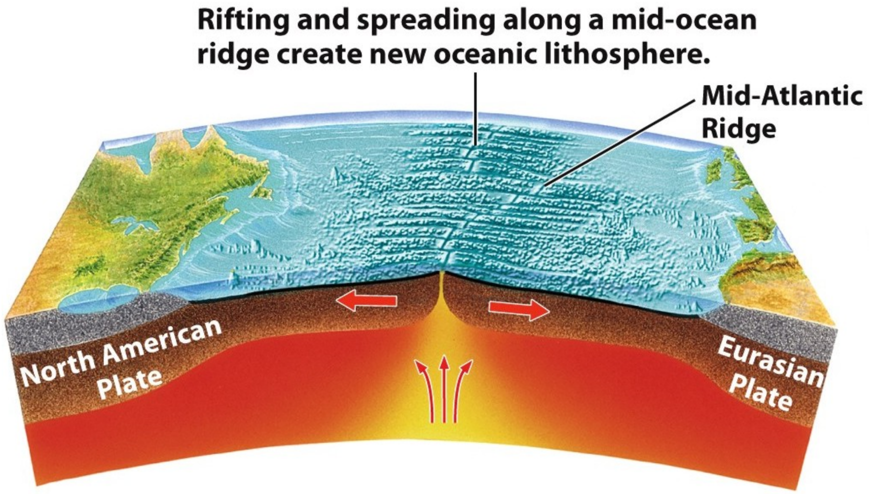
Chains of mountains resulting from the collision between the African, Arabian, and Indian plates with the Eurasian plates.

Understanding Earth 6th Ed.

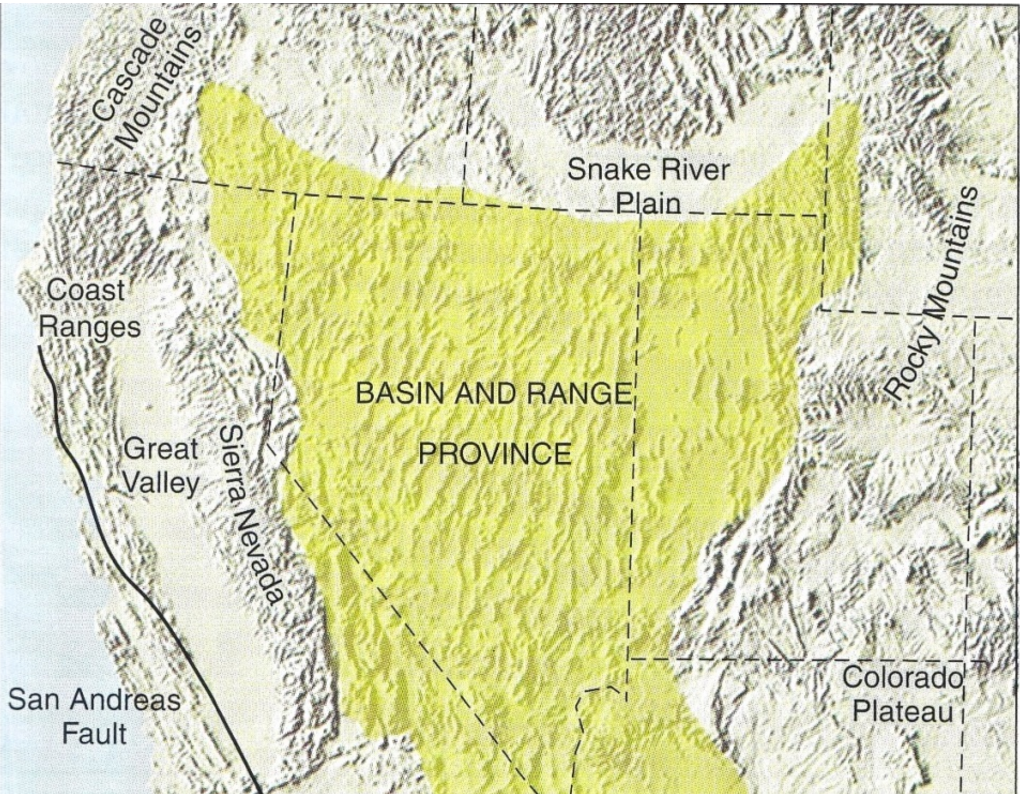
Extended crust

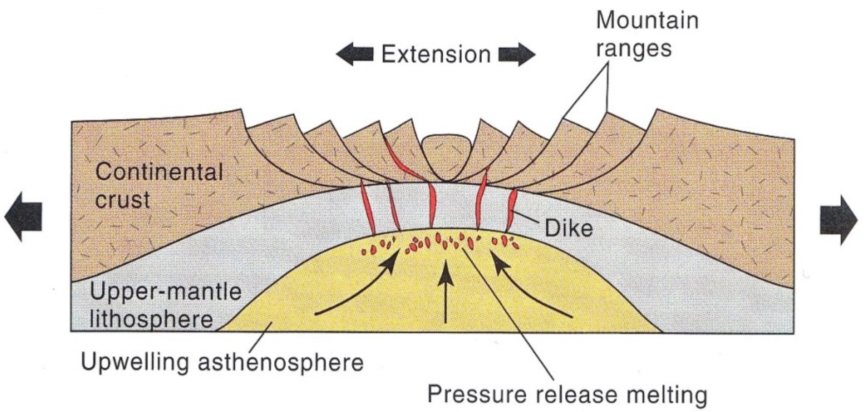
- Region of the crust where the most recent deformation has involved large-scale crustal extension.

e.g. Atlantic coastal plain
Basin and Range Province (USA)



Extension resulting from the opening of the Atlantic Ocean beginning 180 million years ago.

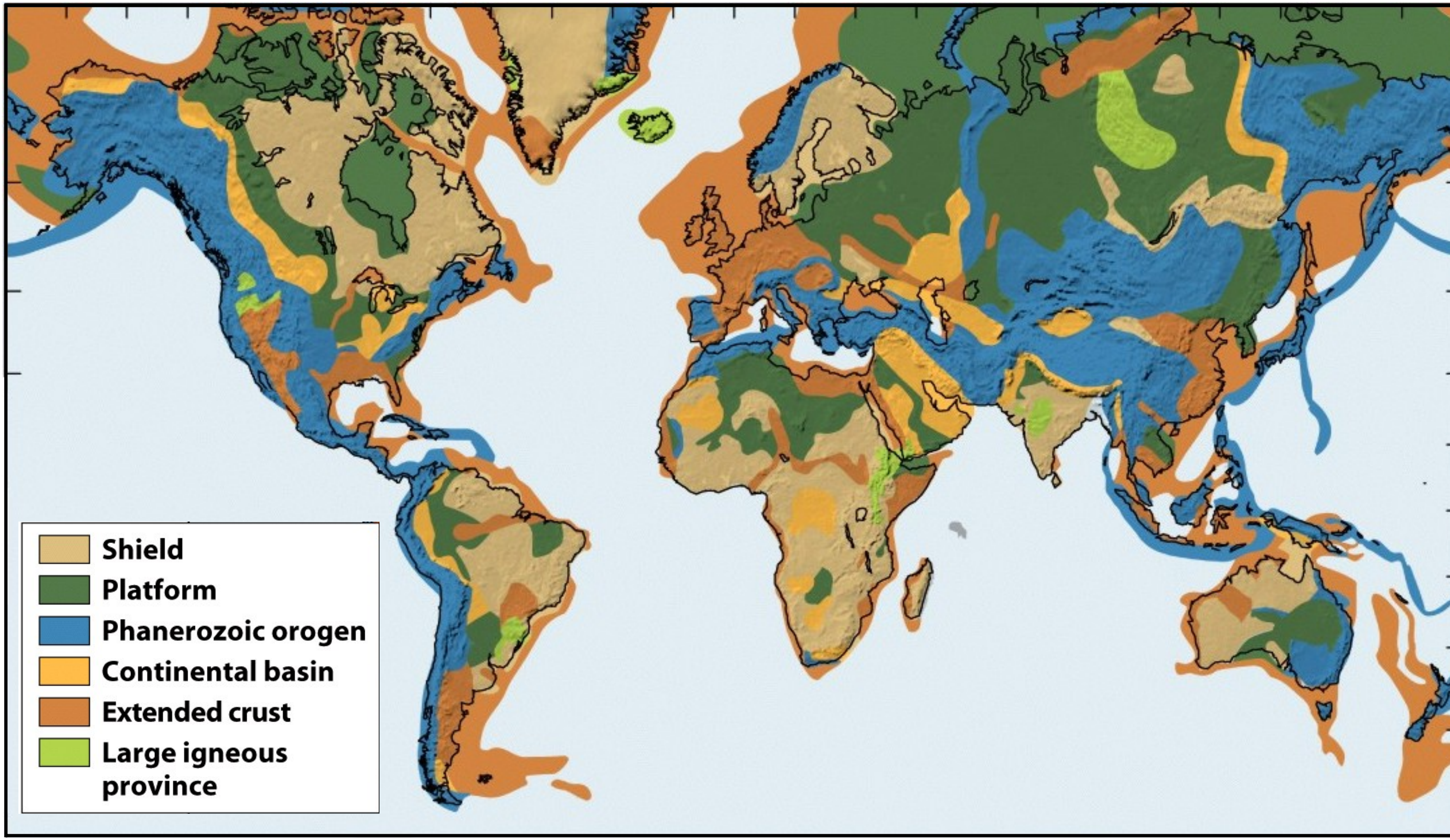




Extension resulting from upwelling convection currents in the mantle.

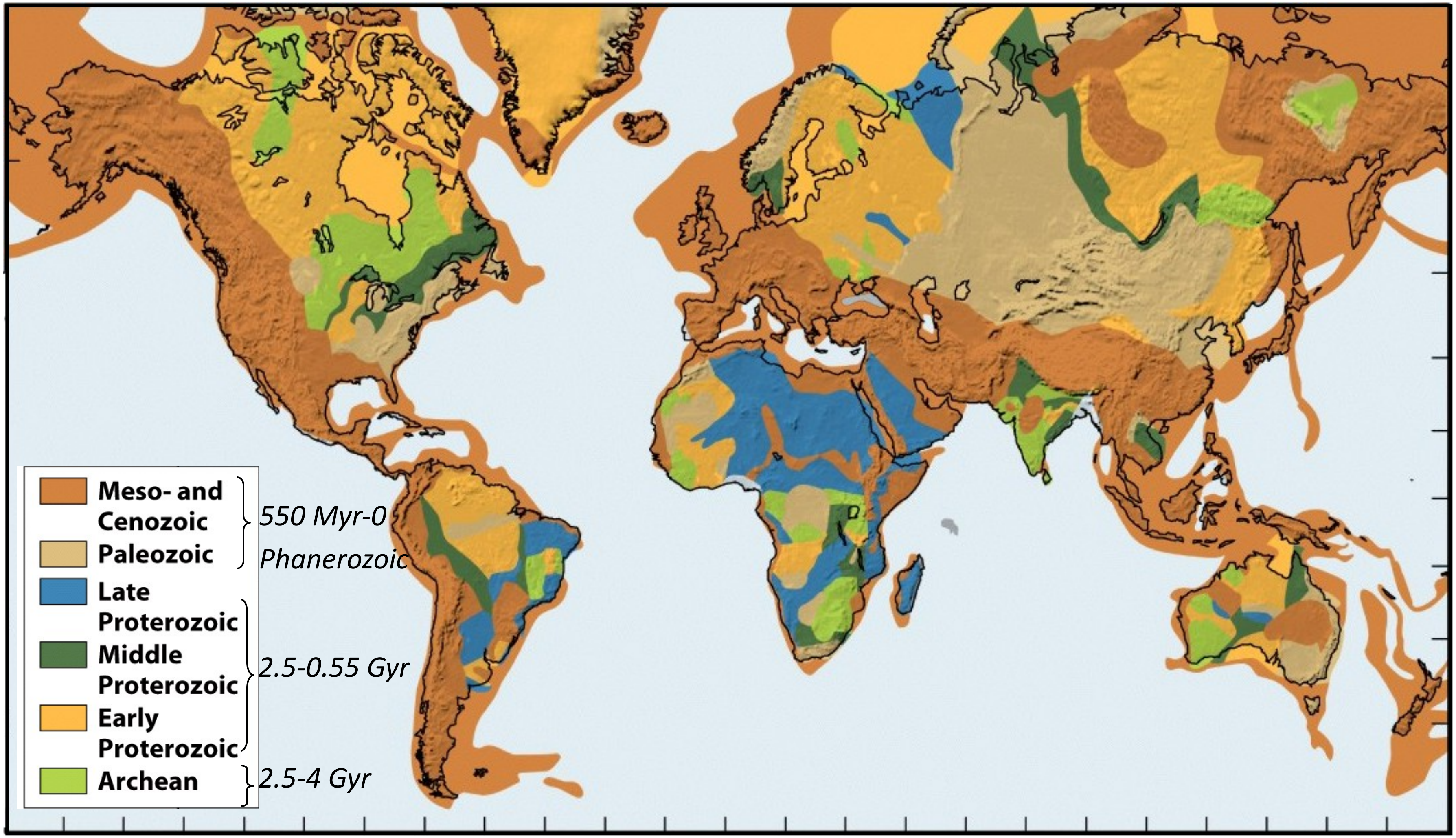
Physical Geology (9th ed.)

✶ Tectonic provinces vs. tectonic ages



Understanding Earth 6th Ed.

Tectonic age = time of the last major episode of crustal deformation

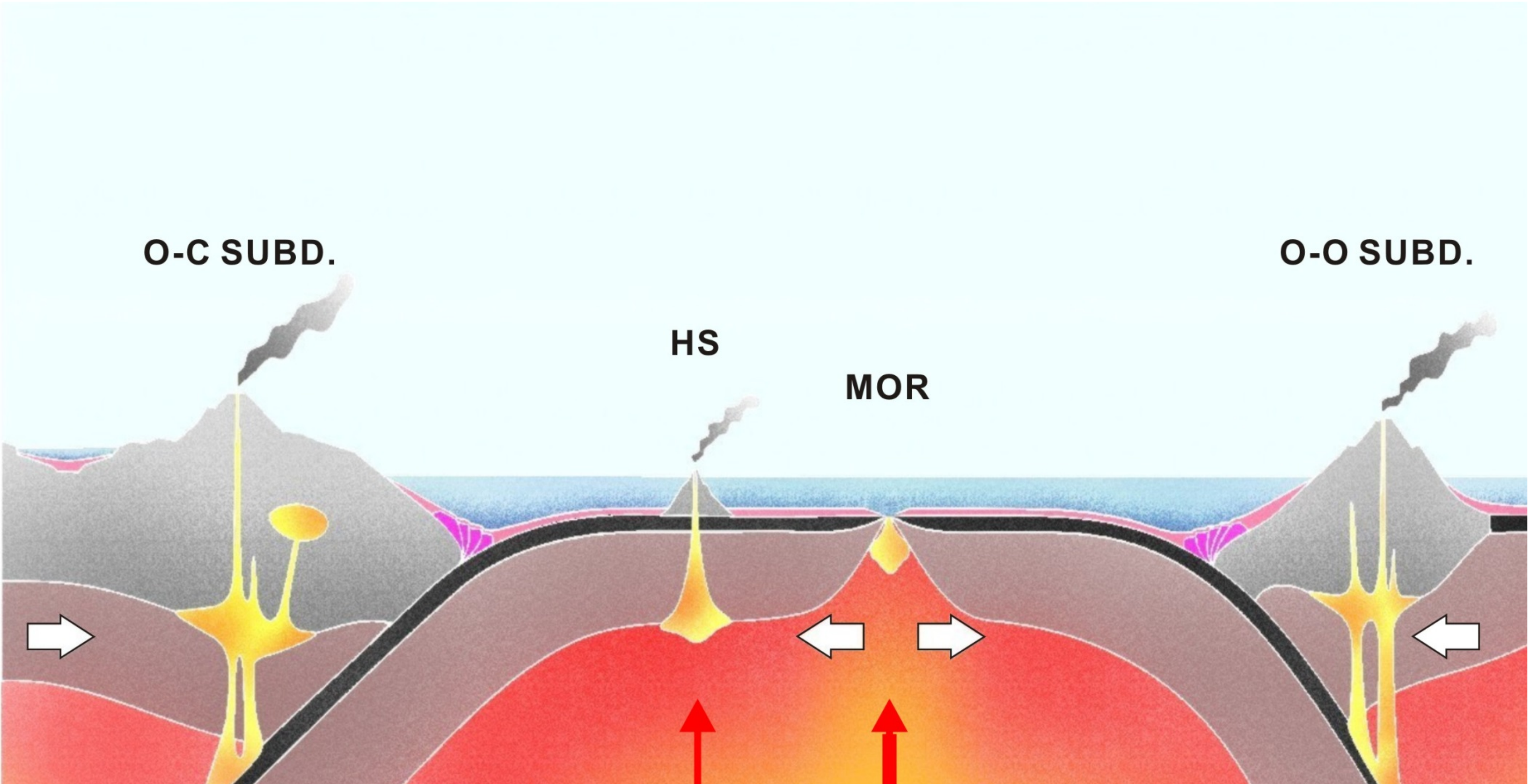


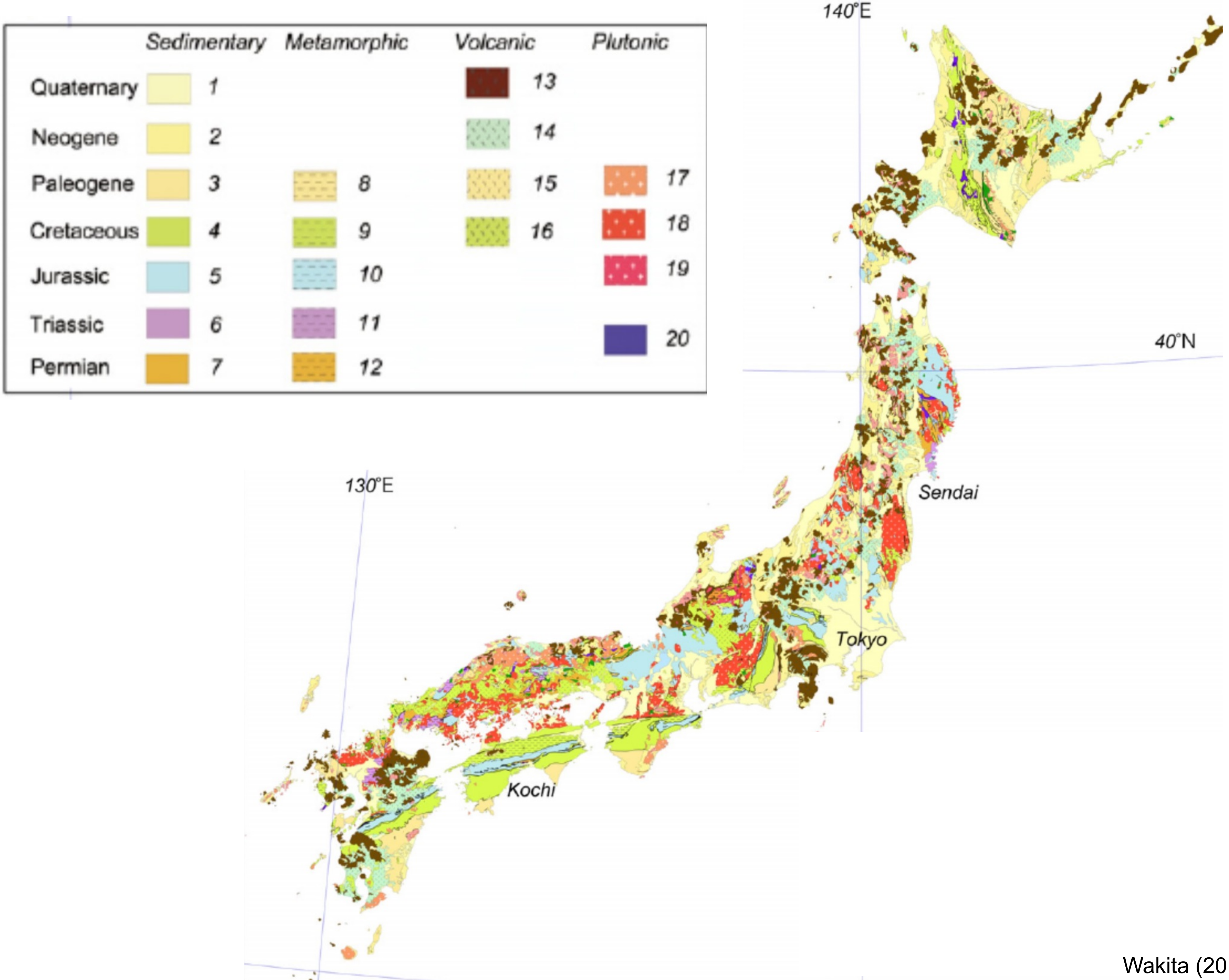
Understanding Earth 6th Ed.

✶ The growth of continents

★ Magmatic addition

- Direct addition of magma in subduction zones
  (water-induced melting, various igneous rocks produced)

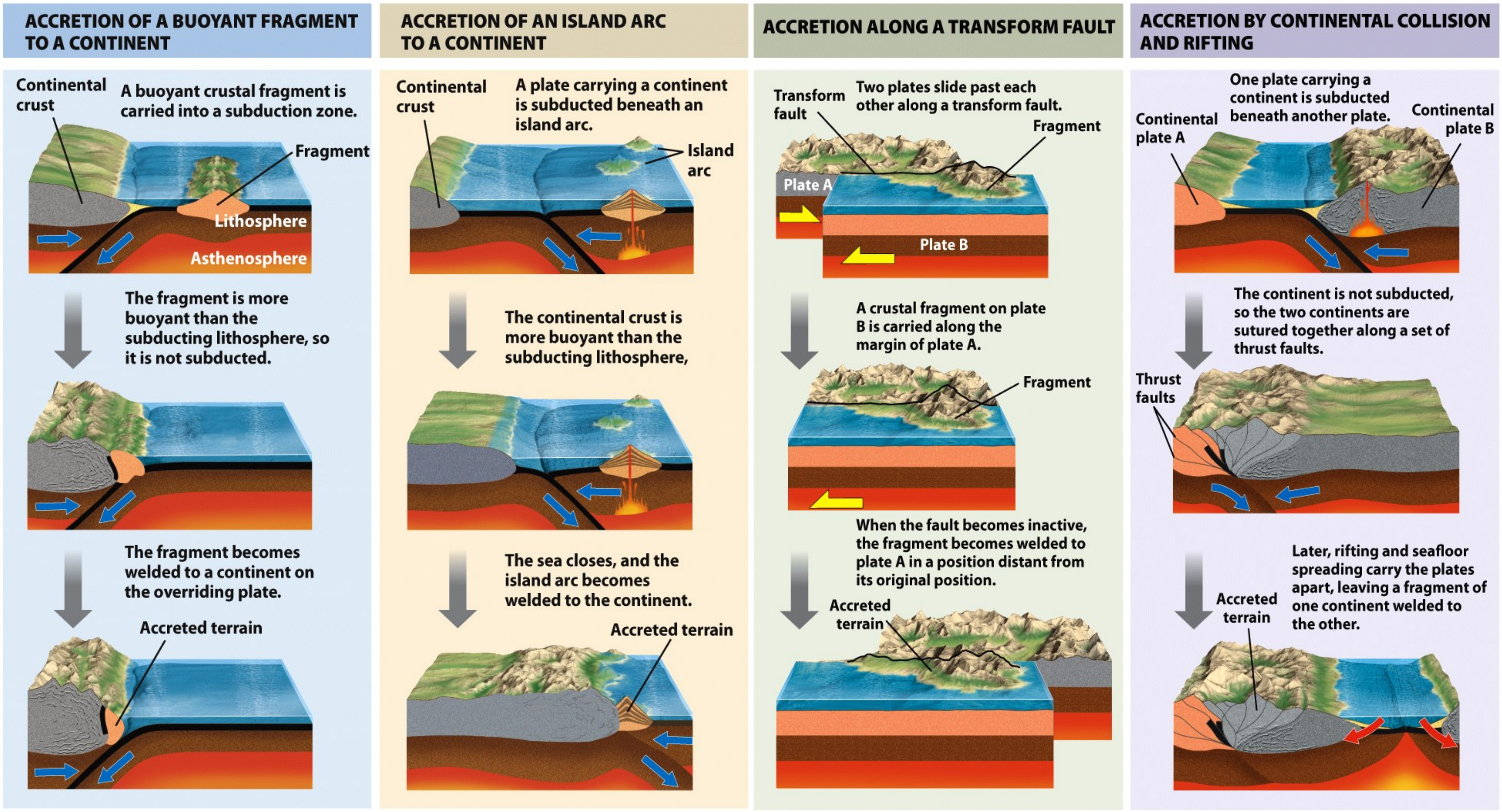



Sedimentary
Metamorphic
Volcanic
Plutonic
Quaternary 1 13
Neogene 2 14
Paleogene 3 8 15 17
Cretaceous 4 9 16 18
Jurassic 5 10 19
Triassic 6 11 20
Permian 7 12
140°E
40°N
130°E
Sendai
Tokyo
Kochi

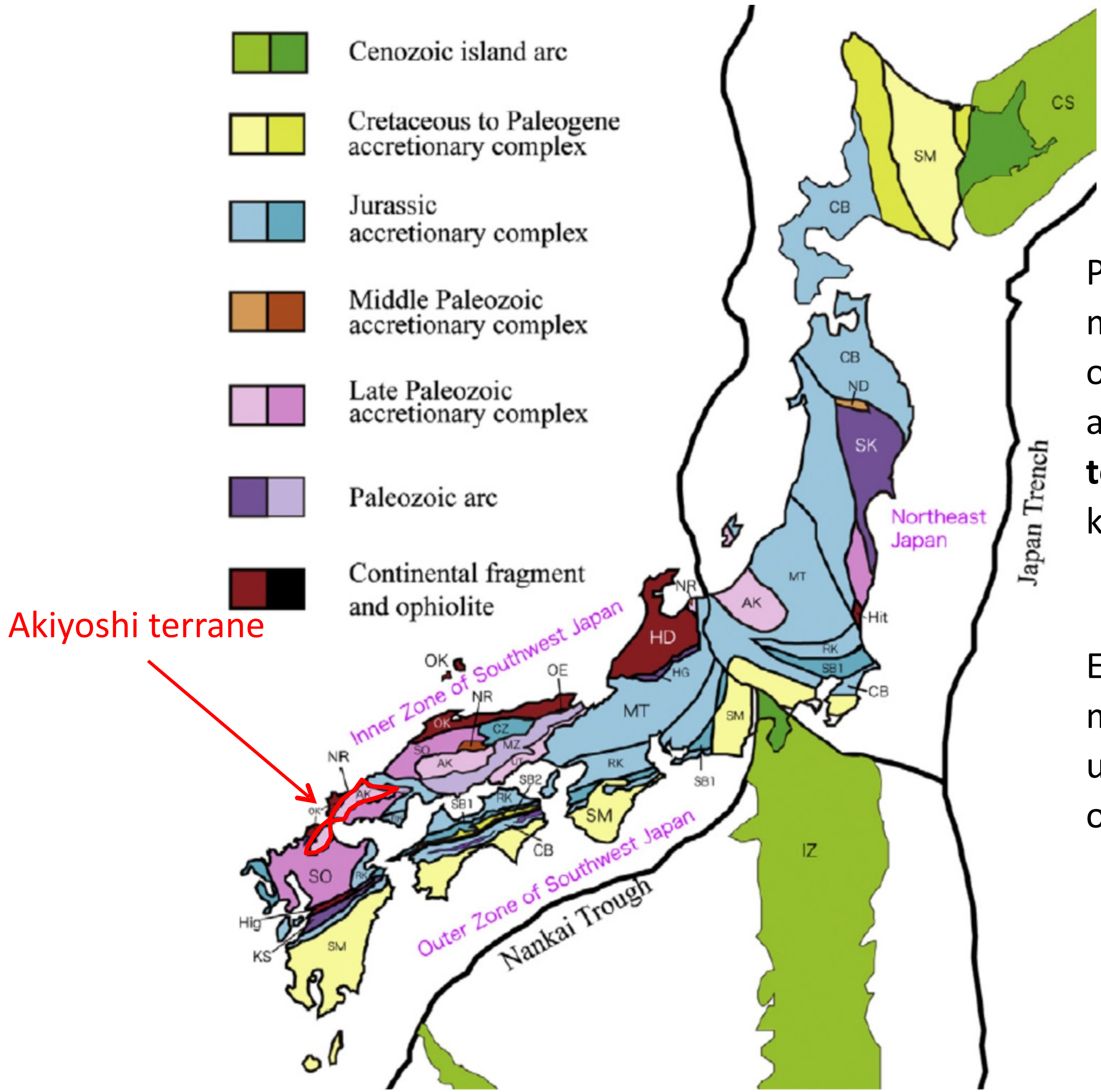
Wakita (2012)

Accretion

- Tectonic plates carry crustal material that can be incorporated to existing continental masses.



Understanding Earth 6th Ed.



Pieces of buoyant, light material plastered onto other continental masses are called **accreted terranes** (10s to 100s of km in width).

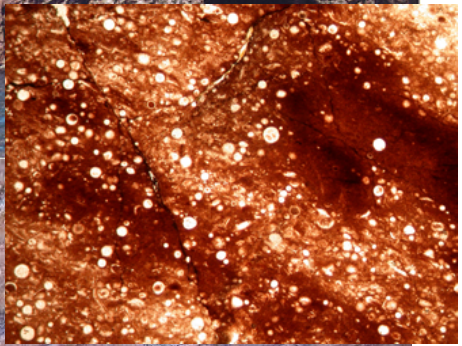
Examples of accreted material: islands, underwater volcanoes, ocean floor sediments.

Wakita (2012)

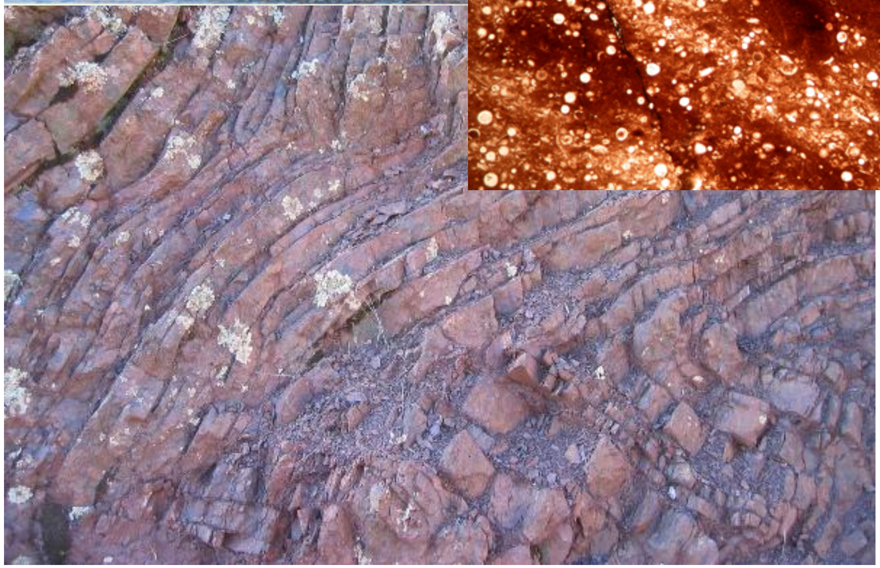
Examples of accreted material from the subducting plate in Japan

Radiolarian chert

Geological Survey of Japan



University of Edinburgh



http://www.geocaching.com

Fossil atoll reefs (Akiyoshidai, Carboniferous-Permian)

http://www.pref.yamaguchi.lg.jp

http://www.geol.sci.hiroshima-u.ac.jp

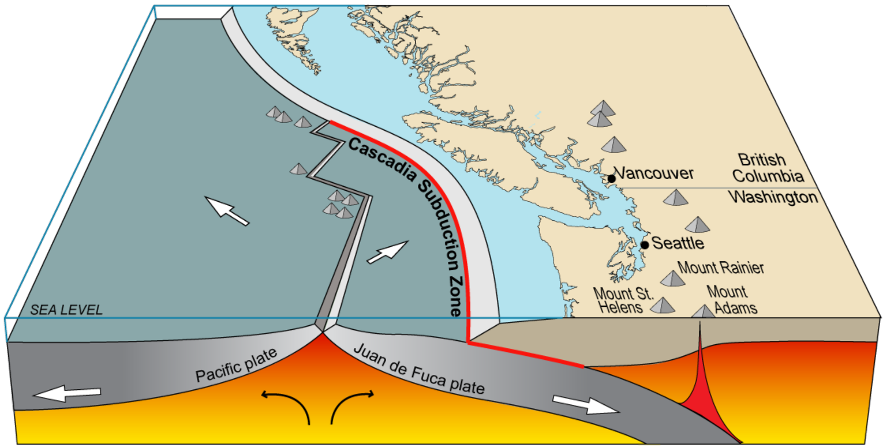
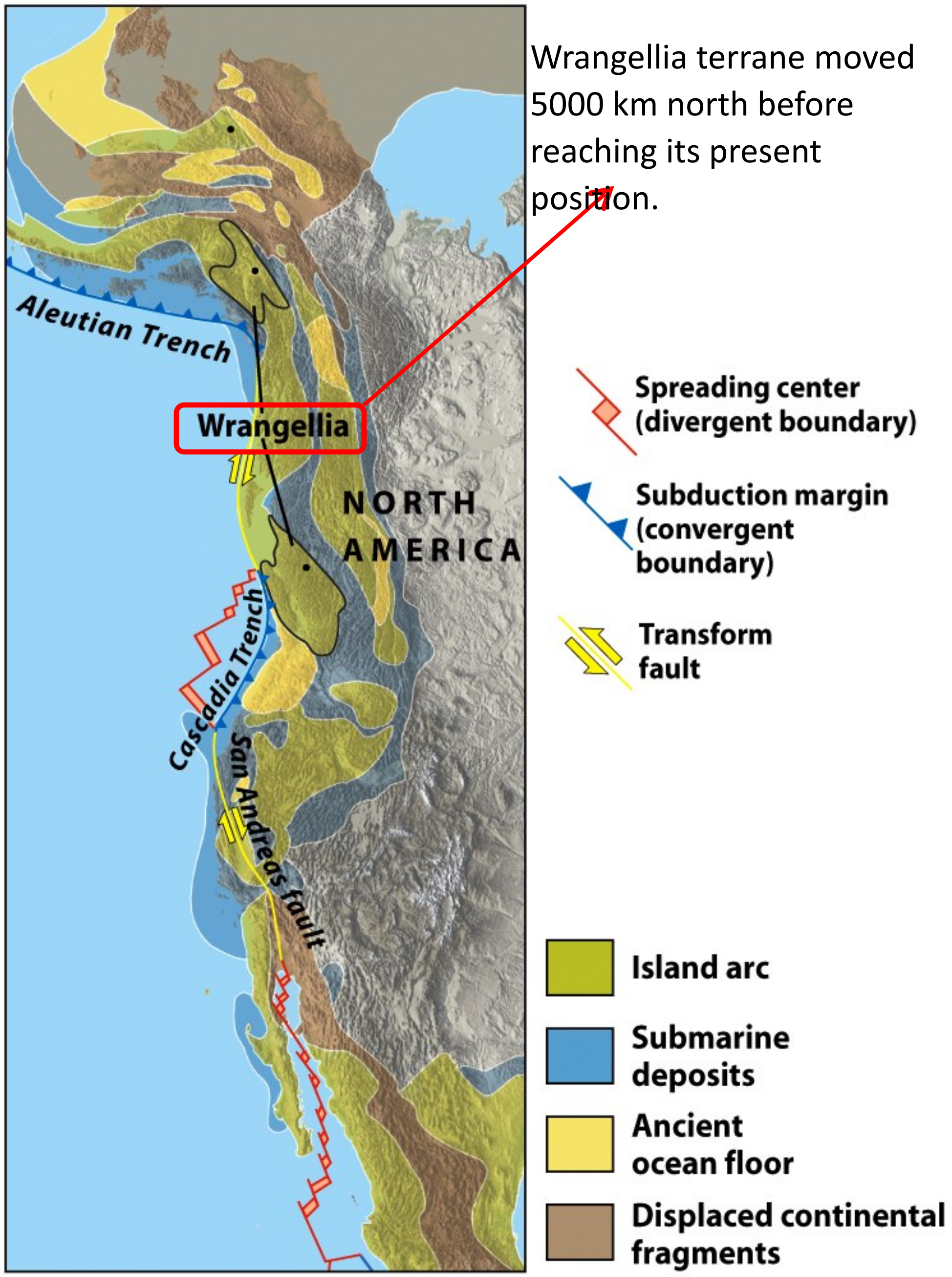


*figure modified from USGS Cascadia earthquake graphics at http://geomaps.wr.usgs.gov/pacnw/pacnweq/index.html



Wrangellia terrane moved 5000 km north before reaching its present position.

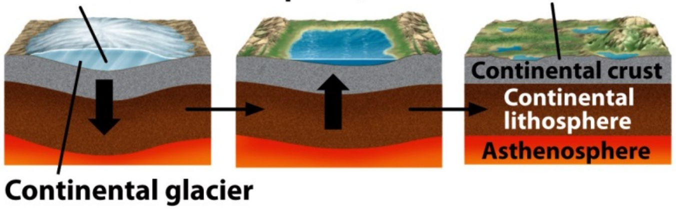
The west coast of North America is mainly composed of “small” crustal blocks incorporated to the continental mass over the past 200 million years.

http://www.dnr.wa.gov/ *Understanding Earth 6th Ed.*

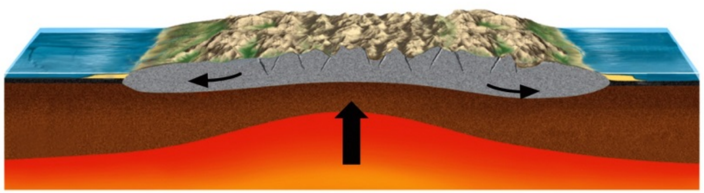
✶ Epeirogeny

GLACIAL REBOUND

The weight of glacial ice downwarps the continental lithosphere,… **…which rebounds once the ice is removed.**



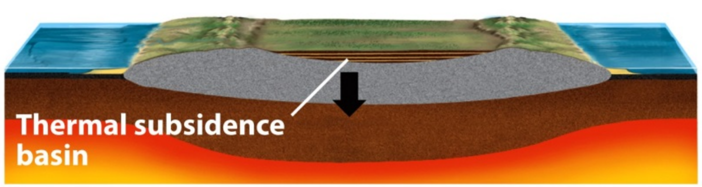
HEATING OF LITHOSPHERE *(expansion of litho.)*



Upwelling of mantle material causes uplift and thinning of the continental lithosphere.

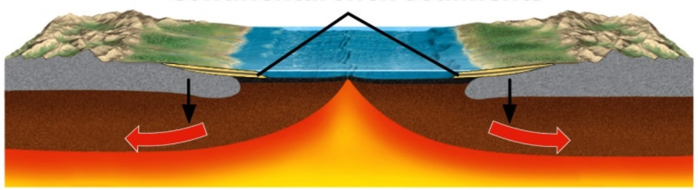
Heating → lower density → lithosphere "floats"
Expansion higher on asthenosphere

COOLING OF LITHOSPHERE IN CONTINENTAL INTERIOR



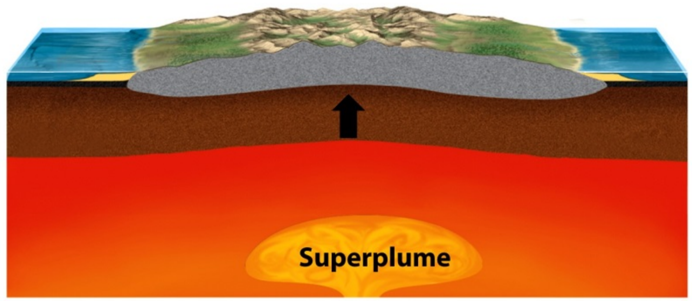
As the lithosphere cools and contracts, it subsides to form a basin within the continent.

COOLING OF LITHOSPHERE ON CONTINENTAL MARGIN



When seafloor spreading splits a continent apart, the edges subside as they cool, accumulating thick sediments.

HEATING OF DEEP MANTLE *(Mantle material pushes the lithosphere)*



A superplume rising from the deep mantle heats the lithosphere and raises the base of the continent, upwarping the surface over a broad area.

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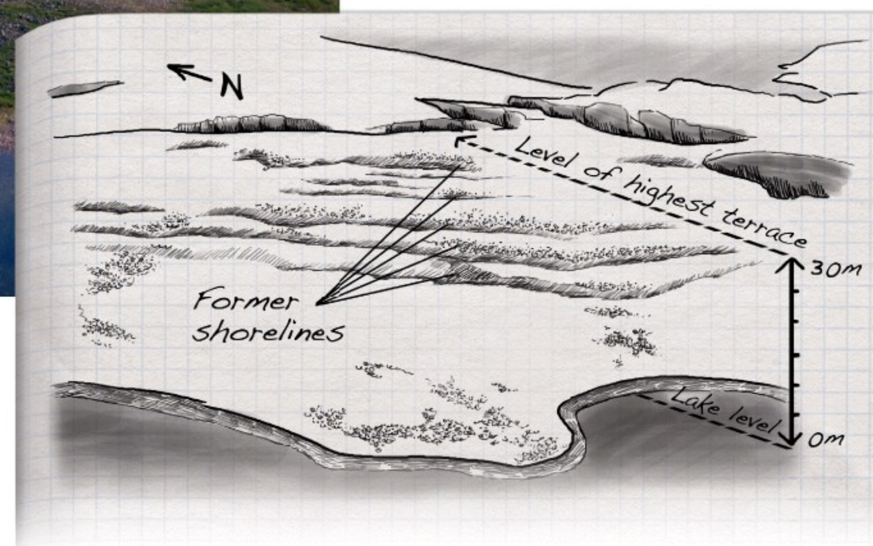
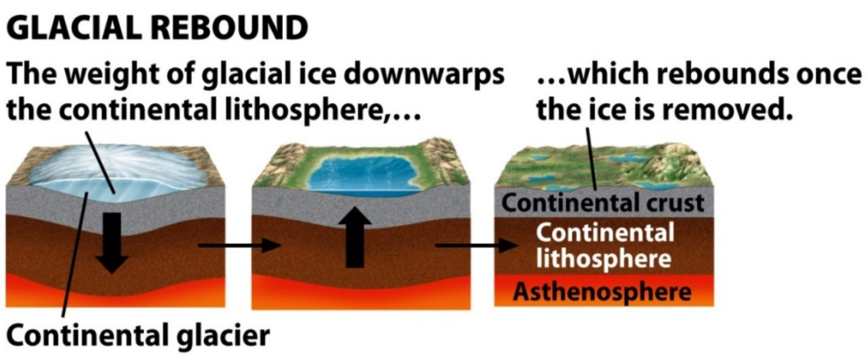
Example of glacial rebound: raised beaches resulting from the melting of the ice cap after the last glacial maximum 20,000 years ago. The land that was once covered with ice is progressively raised after the ice melted (ice unloading)

Land raised

↓

Relative drop of water level!





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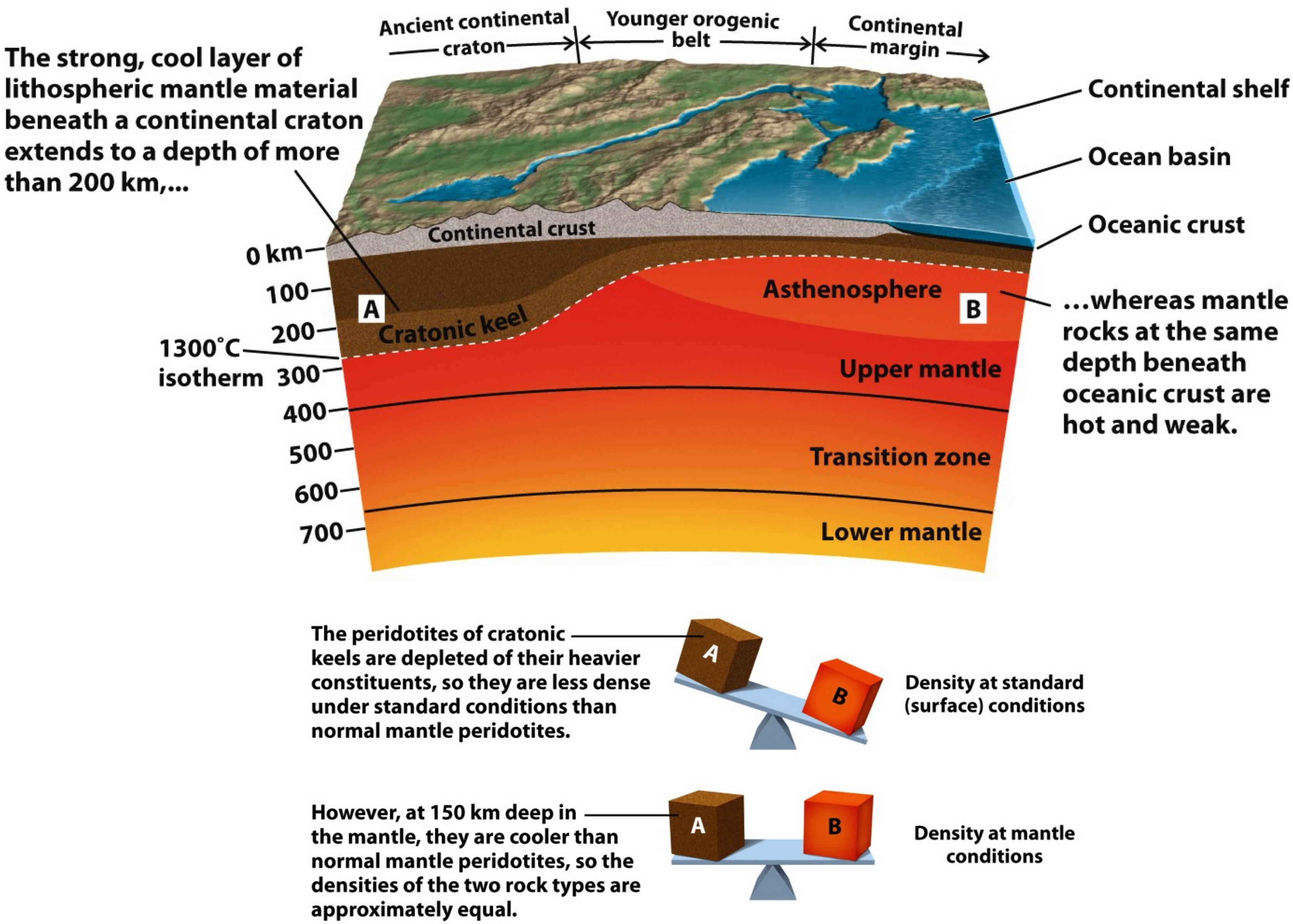
✶ What explains the long-term stability of cratons?



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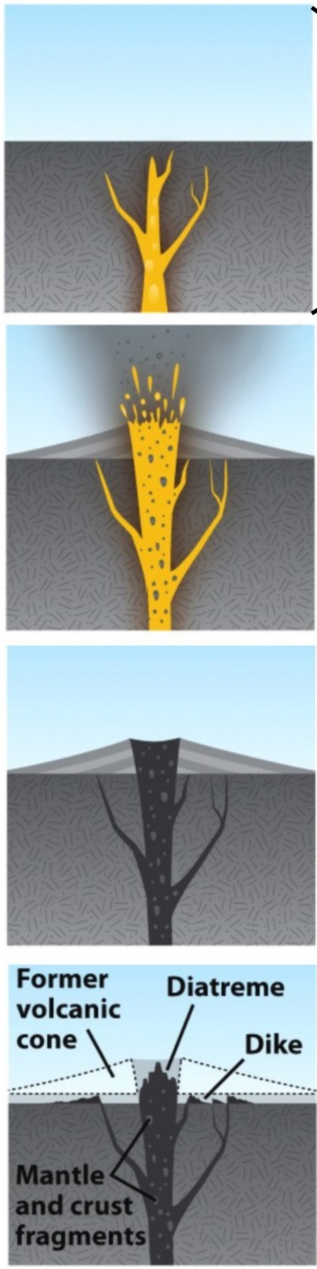
Diatreme

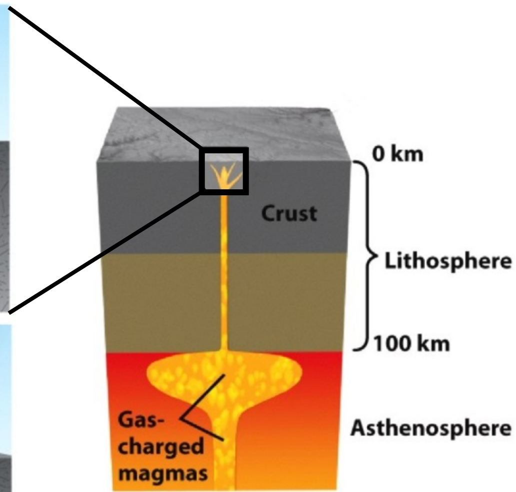
1.

2.

3.

4.





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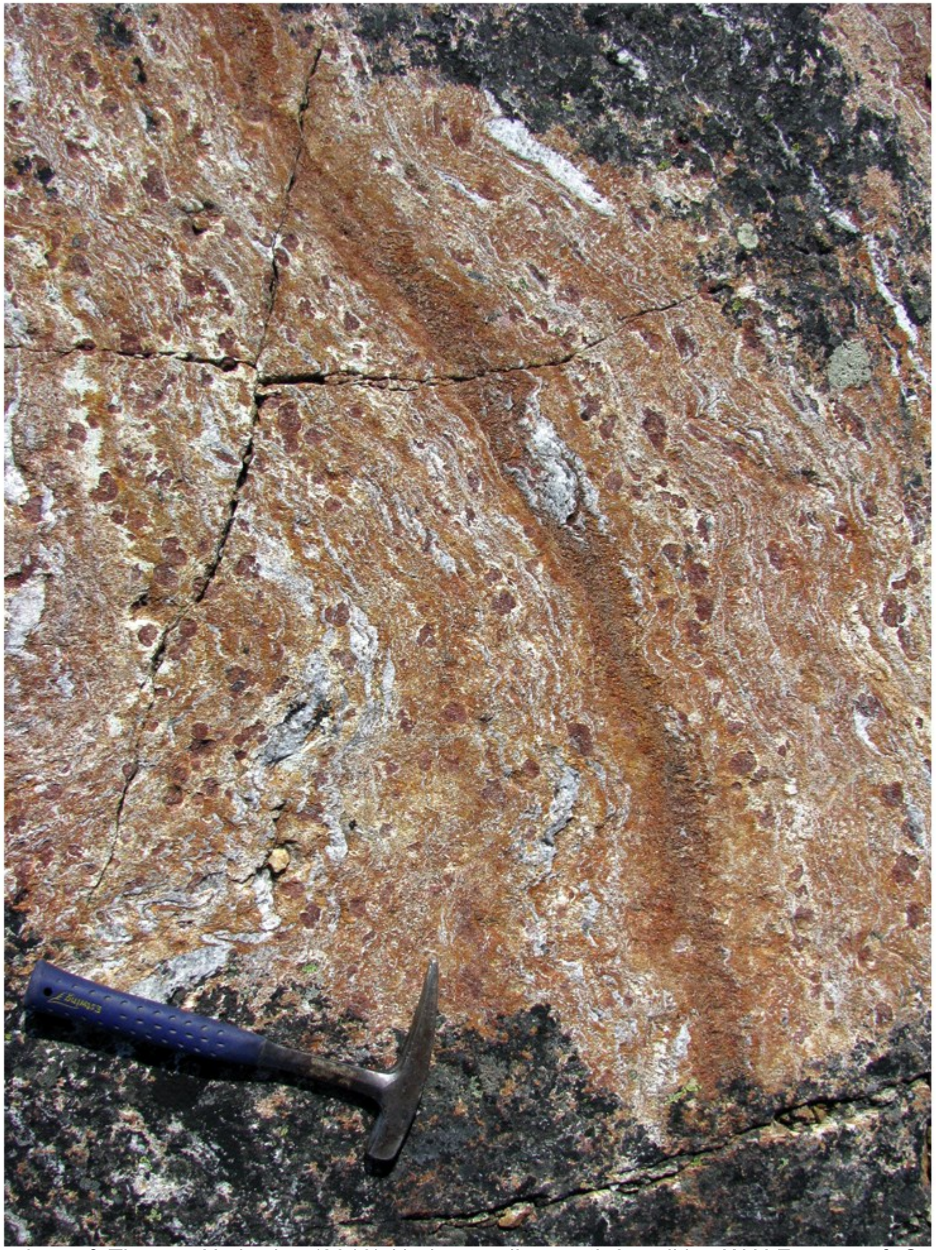
Kimberlite

Acasta Gneiss
(Canadian Shield, 4.0 Ga)



John Grotzinger & Thomas H. Jordan (2010) *Understanding earth* 6th edition W H Freeman & Co

Amphibole-bearing rock
(Canadian Shield, 4.28 Ga)