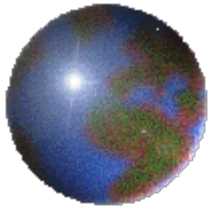
Introduction to Physical Geology



Chapter 20

The Geological Evolution of North America

By Dr. Jia Hui

School of Earth Sciences and Engineering

Xi'an Shiyou University

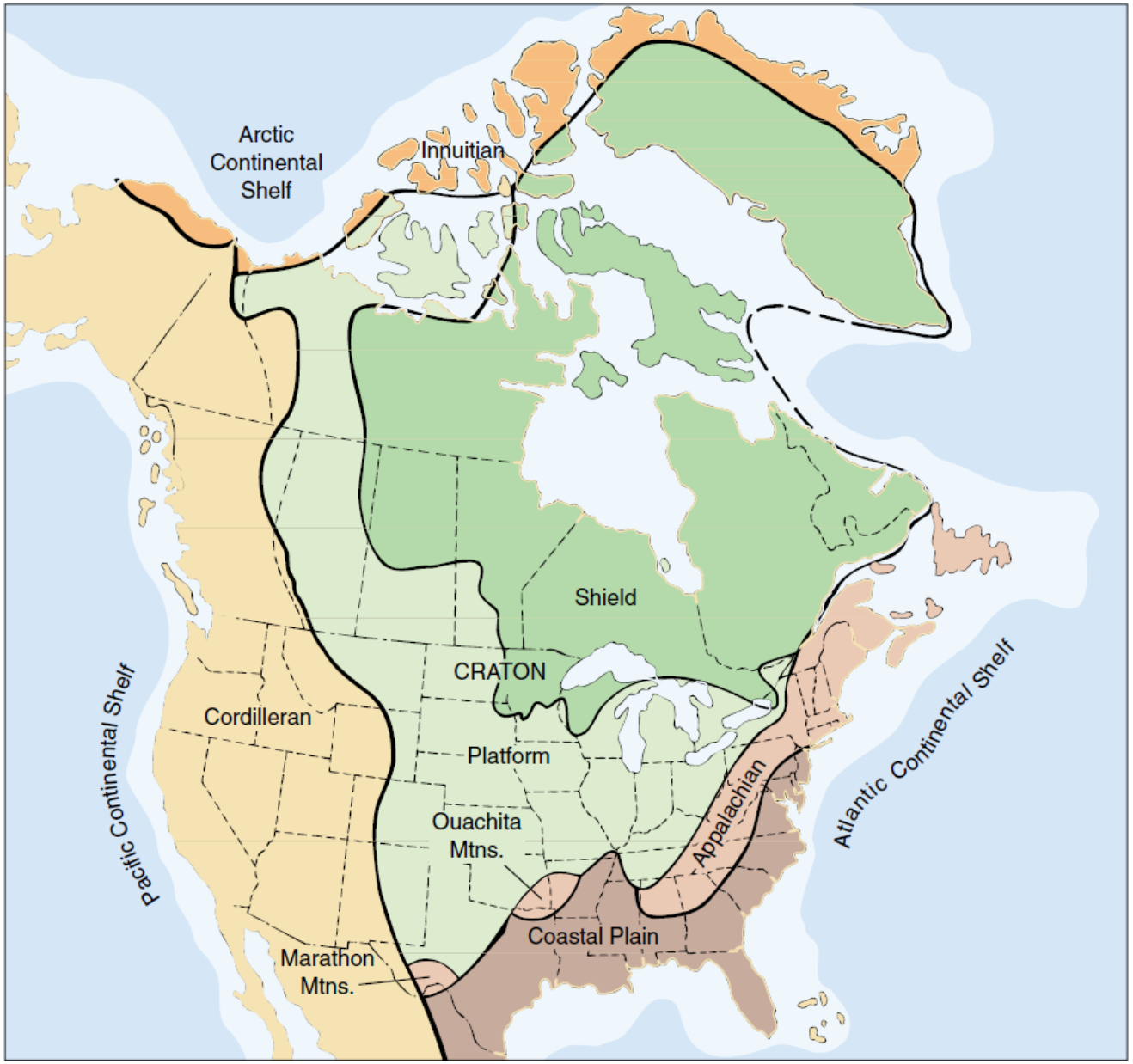
Content

- The oldest known rocks on Earth are those of the 3.96-billion-year-old Arcasta gneiss in Canada's Northwest Territories. Thus, a portion of the North American continent formed early in Earth history.
- Over the past 3.96 billion years, tectonic processes have battered, broken, but ultimately created the North American continent.

20.1 The North American Continent

- Three major geologic regions make up North America today.
  - The **craton** is the continental interior.
  - **Mountain chains** bordering the craton to the east and west, which are young relative to the craton.
  - **Continental shelves** and the **coastal plain**, where young sediments eroded from the continent have accumulated on the continental margin.

20.1 The North American Continent



20.1 The North American Continent

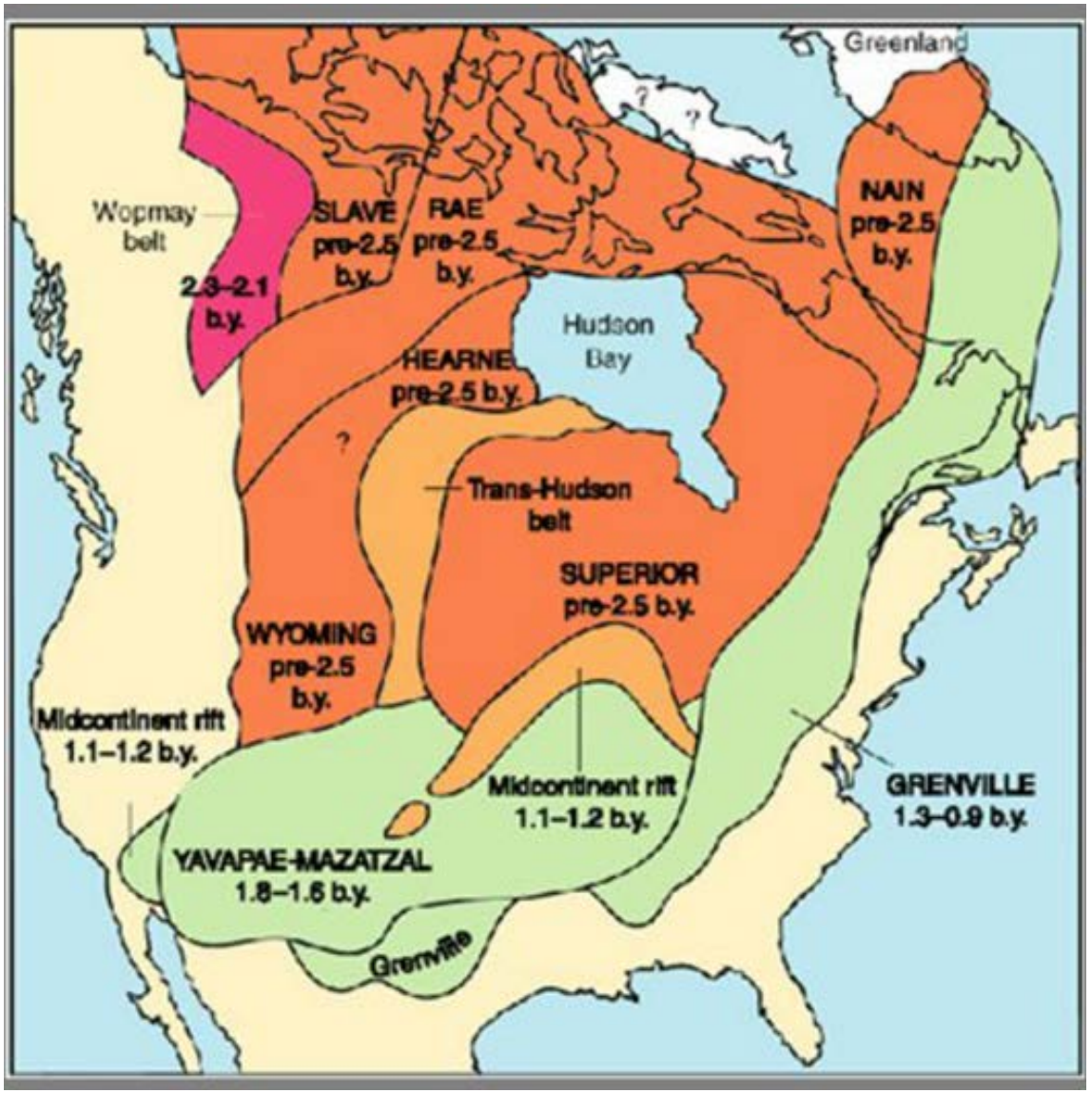
- *Craton* is a tectonically stable region that has seen little or no tectonic activity—no deformation, metamorphism, or magmatic activity—for more than a billion years.
- The craton consists of two subdivisions:
- *Shield*, where very old igneous and metamorphic basement rocks are exposed at the surface.
- *Platform*, where the same types of basement rocks are covered with a veneer of much younger sedimentary rocks.

20.2 The Craton

- The craton consist of several distinct geologic **provinces** that differ from each other in rock type and age.

Archean = orange

Proterozoic = green



Archean Plate Tectonics

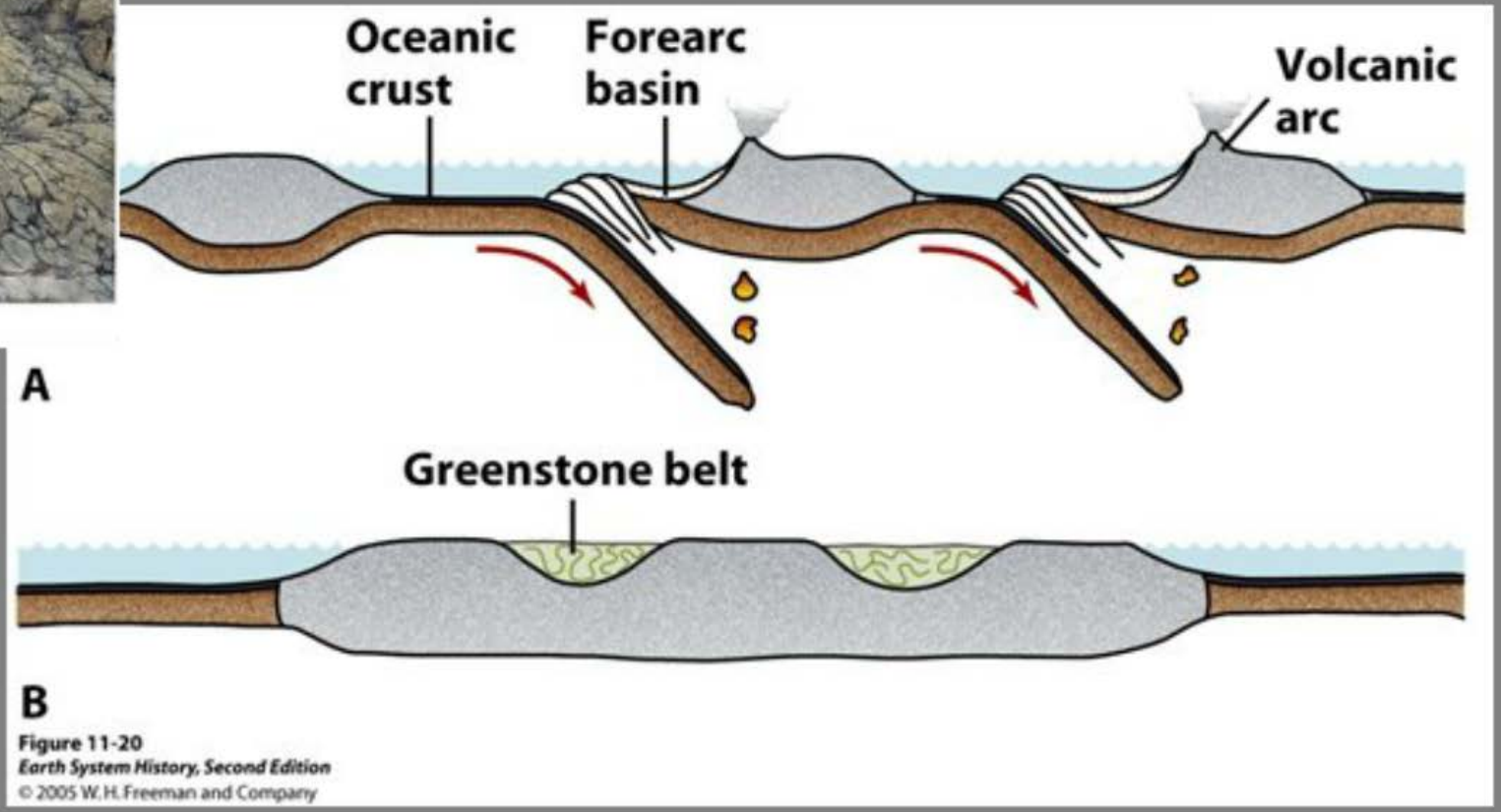


Figure 11-20
Earth System History, Second Edition

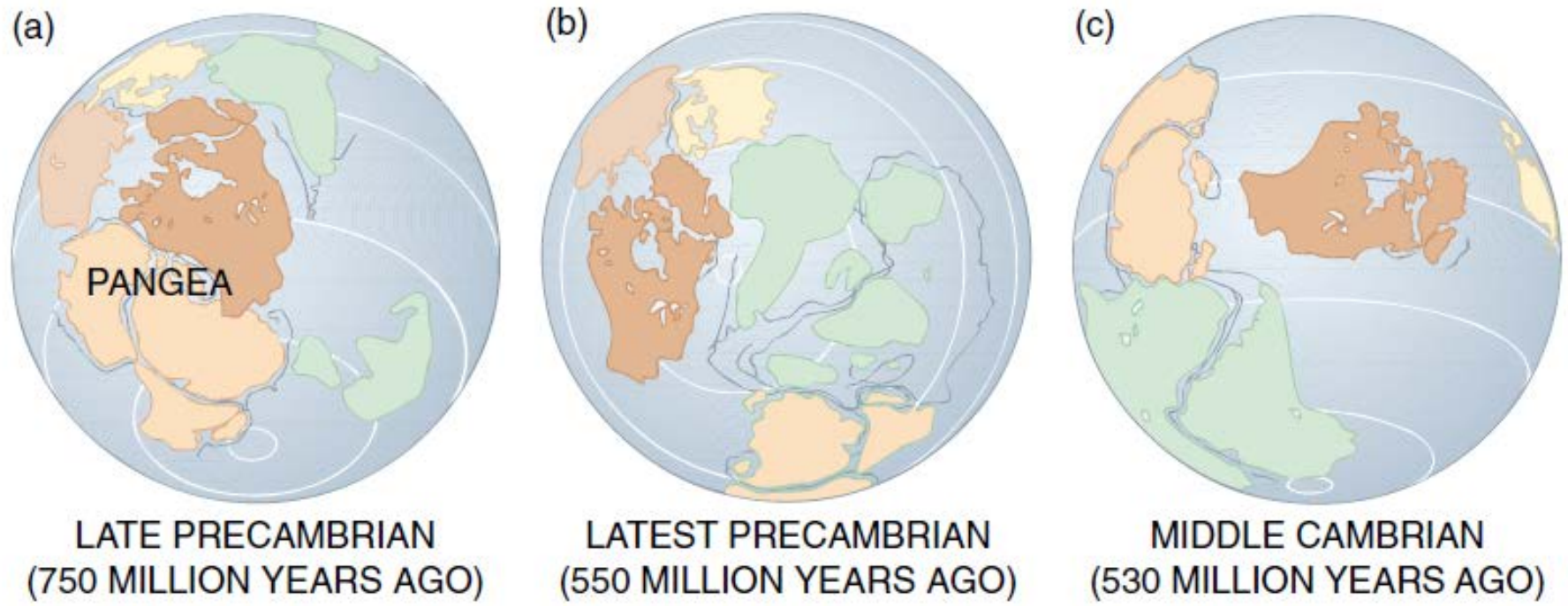
20.3 North America: 2 Billion Years Ago

- Prior to 2 billion years ago, hundreds of small masses of continental crust and island arcs dotted a global ocean basin.
- Between 2 billion and 1.8 billion years ago, tectonic plate movements swept these microcontinents together, forming the first supercontinent, which we call ***Pangea I***.
  - The North American craton was part of Pangea I.
  - The discontinuities between the provinces of the North American craton are ancient boundaries between the microcontinents.
- 1.3 billion years ago, Pangea I broke into several large continental masses, While the provinces of the North American craton remained welded together.

20.4 North America: 1 Billion Years Ago

- 1.0 billion years ago, the fragments of continental crust reassembled again, forming a second supercontinent called ***Pangea II*** (Rodinia).
- 750 million years ago, Pangea II broke apart in late Precambrian time.
  - Australia and Antarctica rifted away from western North America, leaving a shoreline at the western margin of North America.
- 550 million years ago, Northern Europe and South America also had rifted away from North America, as an ocean basin opened along North America's eastern margin.
  - North America had become isolated from other continents and was surrounded by oceans.

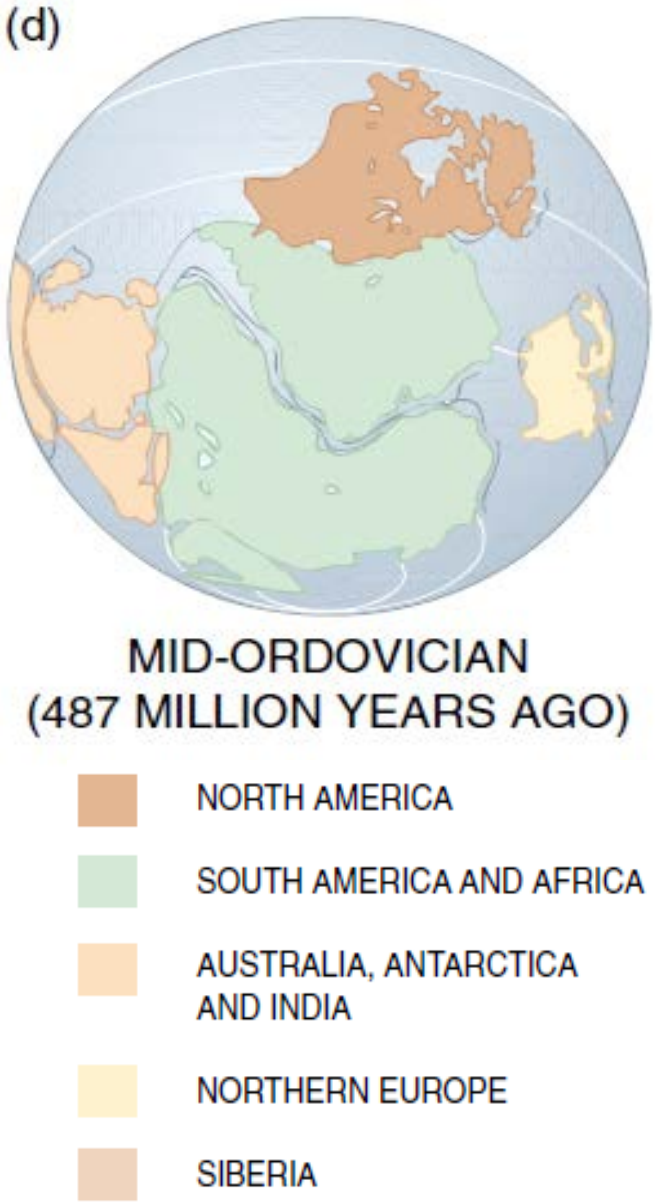
20.4 North America: 1 Billion Years Ago



- From 1 billion to 750 million years ago, western North America was joined to Australia and Antarctica. South America and northern Europe were adjacent to eastern North America at the same time.
- Eastern North America continued to separate from South America as the intervening ocean widened through Middle Cambrian.

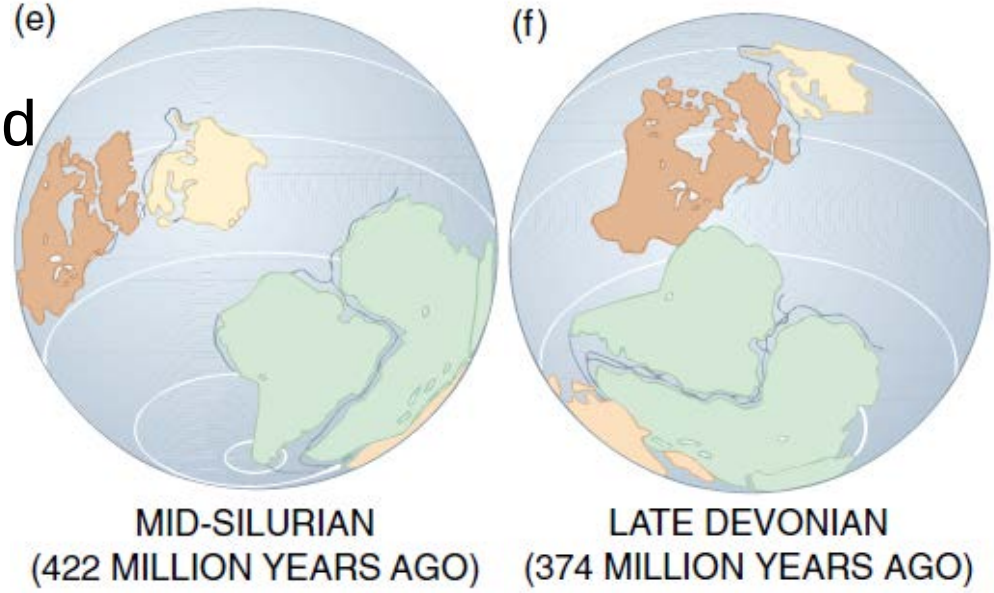
20.5 North America: A Half Billion Years Ago

- In mid-Ordovician, the two continents began converging again and collided, caused subduction of oceanic crust near the east coast of North America.
- This first phase of building of the Appalachian mountain chain is called the ***Taconic orogeny***.
  - ***Orogeny :*** the processes by which mountain ranges are built.



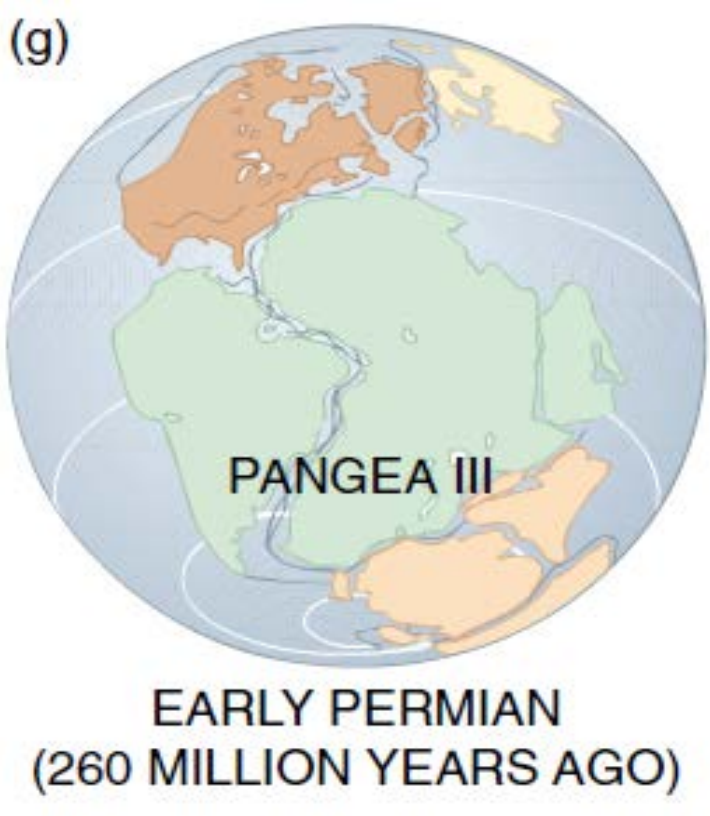
20.5 North America: A Half Billion Years Ago

- In late Devonian time, North America separated from South America second time and then collided with it again.
- The collision shoved sedimentary rocks westward from the continental shelf onto the craton, forming tremendous thrust faults and folds along the east coast.
- This second phase of mountain building in the Appalachians is called the ***Acadian orogeny***.



20.5 North America: A Half Billion Years Ago

- 265 million years ago, North America slid around the upper end of South America and collided with western Africa.
- This collision built the central and southern Appalachians in the ***Allegheny orogeny***.
- All of these events are collectively called the ***Appalachian orogeny***, similar to the events that built Himalayas.



- As the Appalachians rose, all other continents joined the growing landmass. Thus, ***Pangea III*** had assembled by about 265 million years ago.

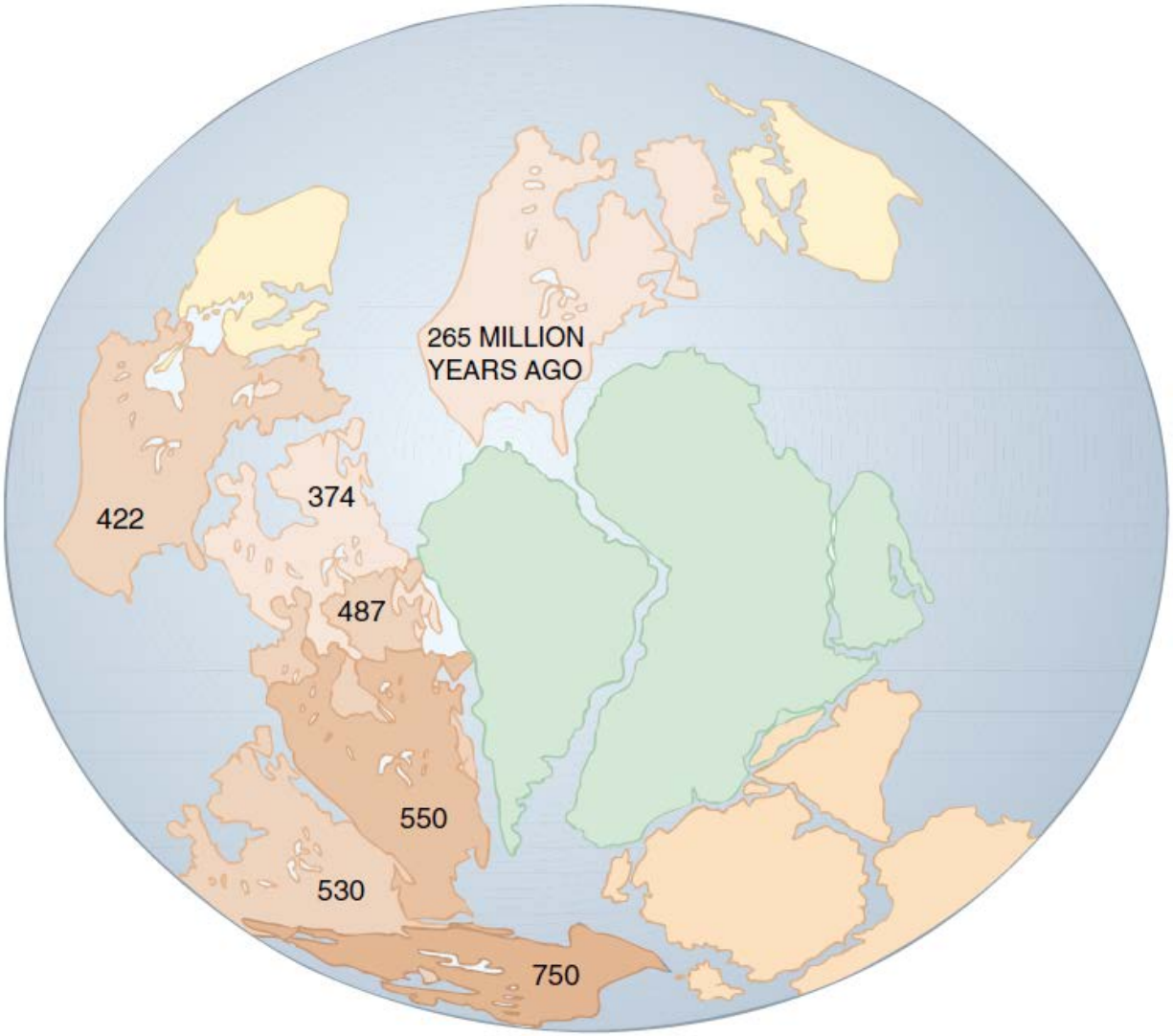
Permian North America Paleogeography

Appalachian -Ouachita Mountain Chain

Joined N. Hem. continents are called Laurentia

Joined S. Hem. continents are called Gondwana

20.5 North America: A Half Billion Years Ago



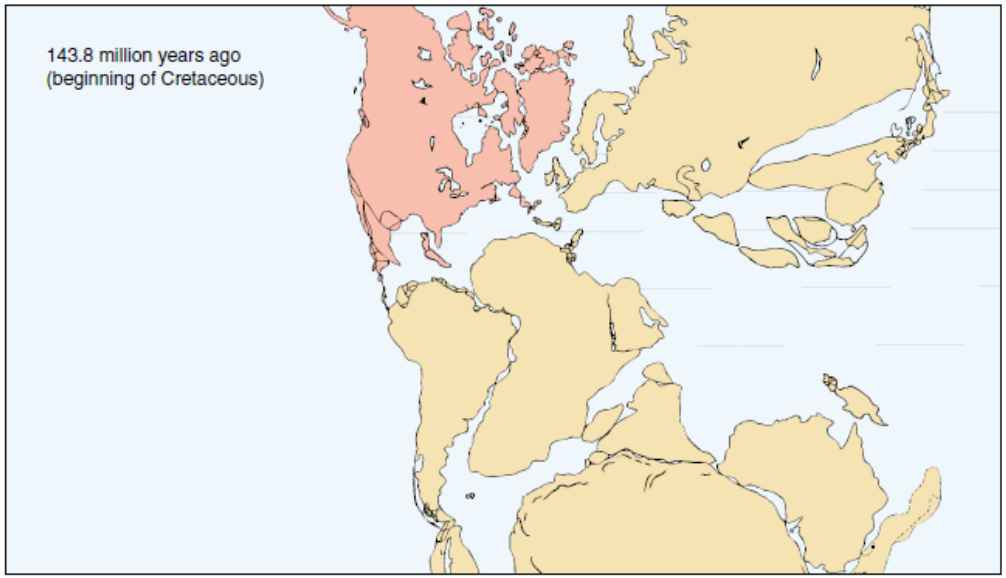
A composite map showing the movements of North America from 750 million years ago to 265 million years ago. The other continents are shown in their positions of 260 million years ago.

20.6 Breakup of Pangea III

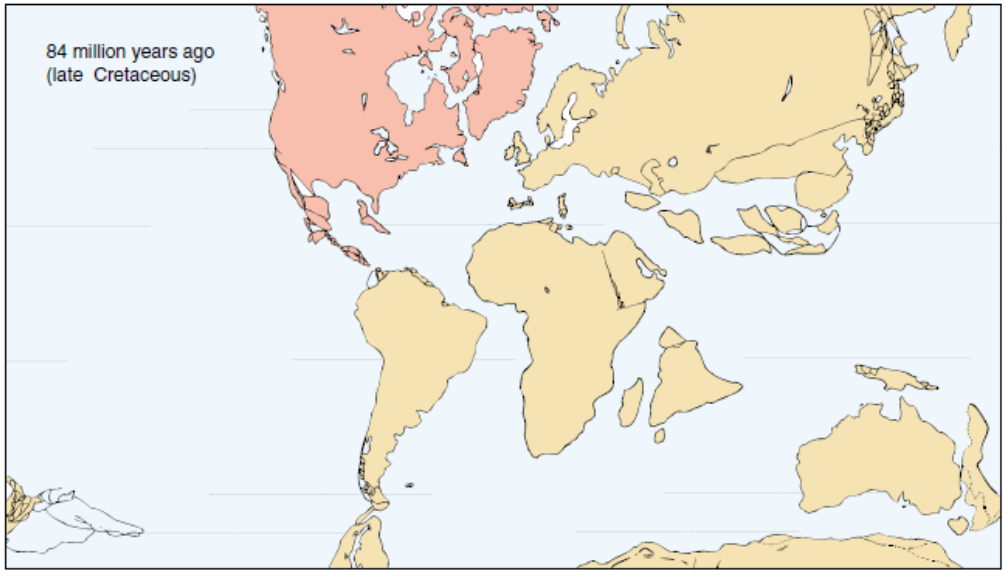
- Pangea III remained intact from about 300 to 180 million years ago and then began to rift apart.
- As North and South America separated from Eurasia and Africa, the modern Atlantic Ocean began to open.
- Passive continental margins developed on both sides of the newly opening ocean basin.
- Tectonic activity on the eastern margin of North America ceased, and the lofty Appalachians began to wear away.

20.6 Breakup of Pangea III

- Pangea began to break up about 180 million years ago.
- The rifting followed the lines of the earlier collision zone that had formed the Appalachians. However, bits and pieces of Africa or Eurasia remained stuck to North America, and fragments of North America went off with Africa and Eurasia.



(a)



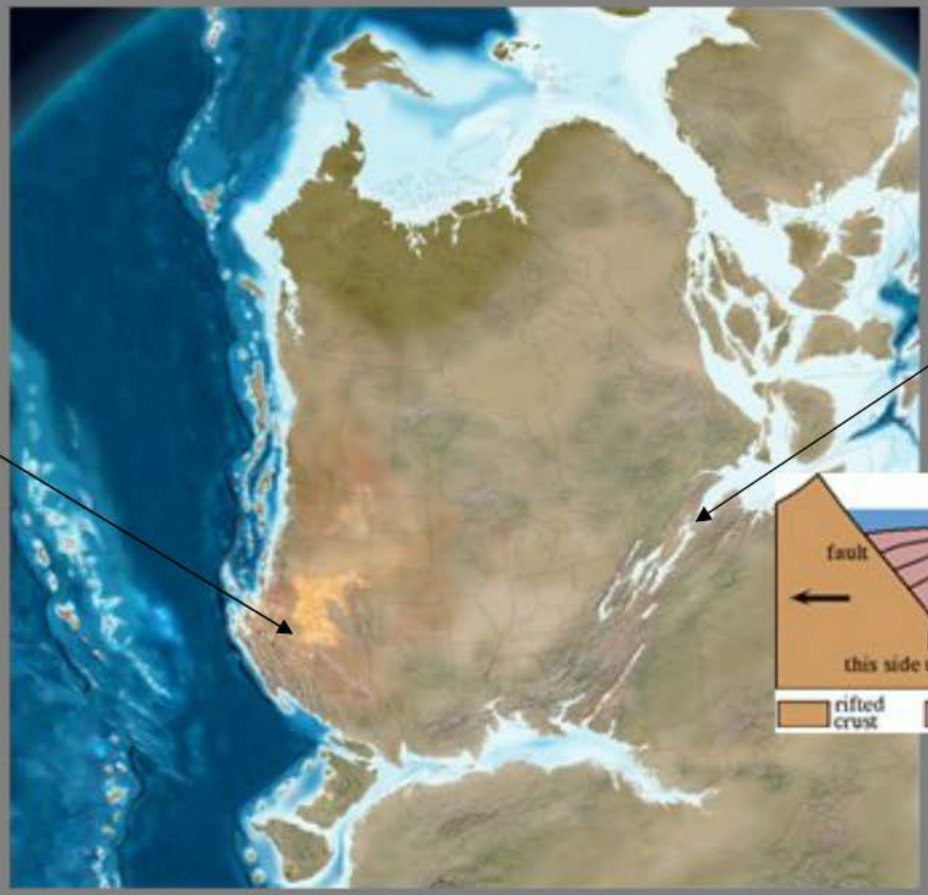
(b)

Breakup of Pangaea

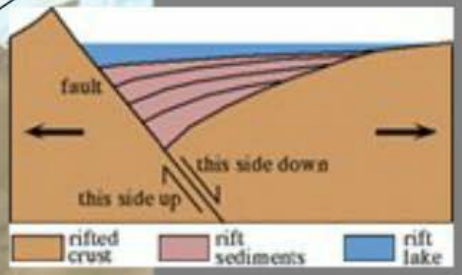
Canyon de Chelly, nw AZ

2 - Triassic Shinarump Conglomerate

1 - Permian de Chelly Sandstone



Rift valleys developing between Africa and N Am



Dinosaur footprints CT rift basin

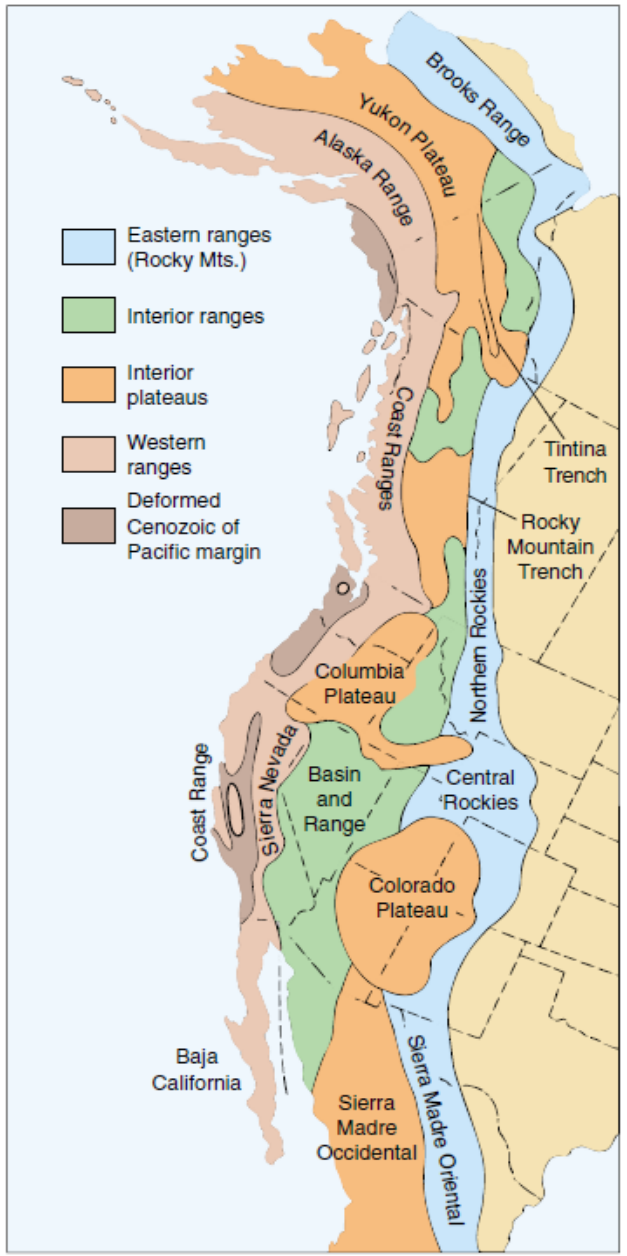
The seas deposited a new sequence of platform sediments. They also flooded the continental margin, depositing sediment on the continental shelf and coastal plain along the eastern and southeastern margins of North America

Cretaceous North America

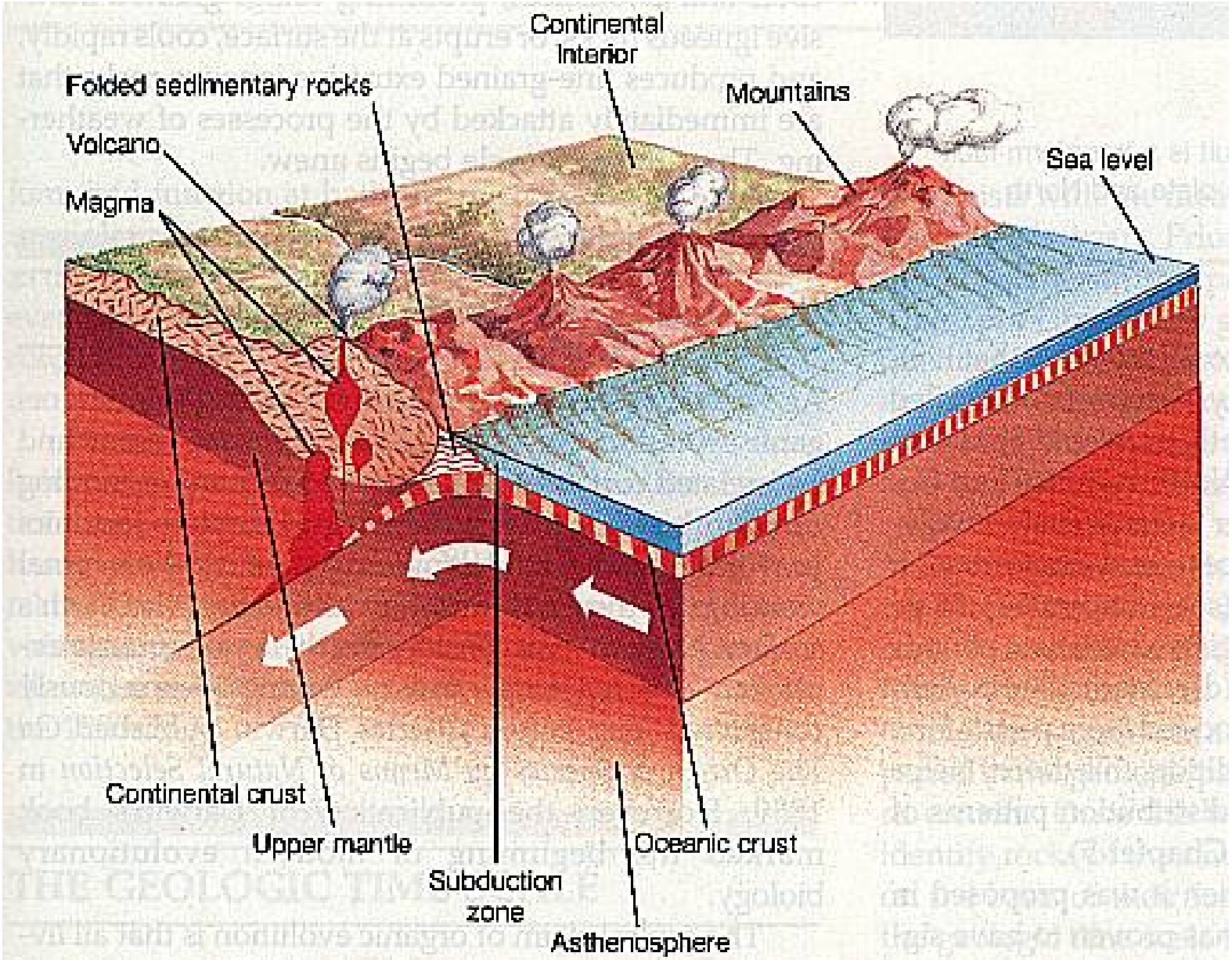
Western Interior Seaway

20.7 Building of The Cordilleran Mountains

- The Cordilleran mountain chain is long, broad mountain chain of western North America.
- The ***Cordillera*** (chain of mountains) formed as Pangea III rifted apart, includes the Rocky Mountains, the Coast Ranges, the Sierra Nevada, and all other mountains and intermountain regions in the western part of North America continent.
- As the Atlantic Ocean opened, the lithospheric plate carrying North America began moving westward, tectonic plates of the Pacific Ocean sank beneath the western edge of the continent, creating a subduction zone and an Andean-type continental margin.



20.7 Building of The Cordilleran Mountains

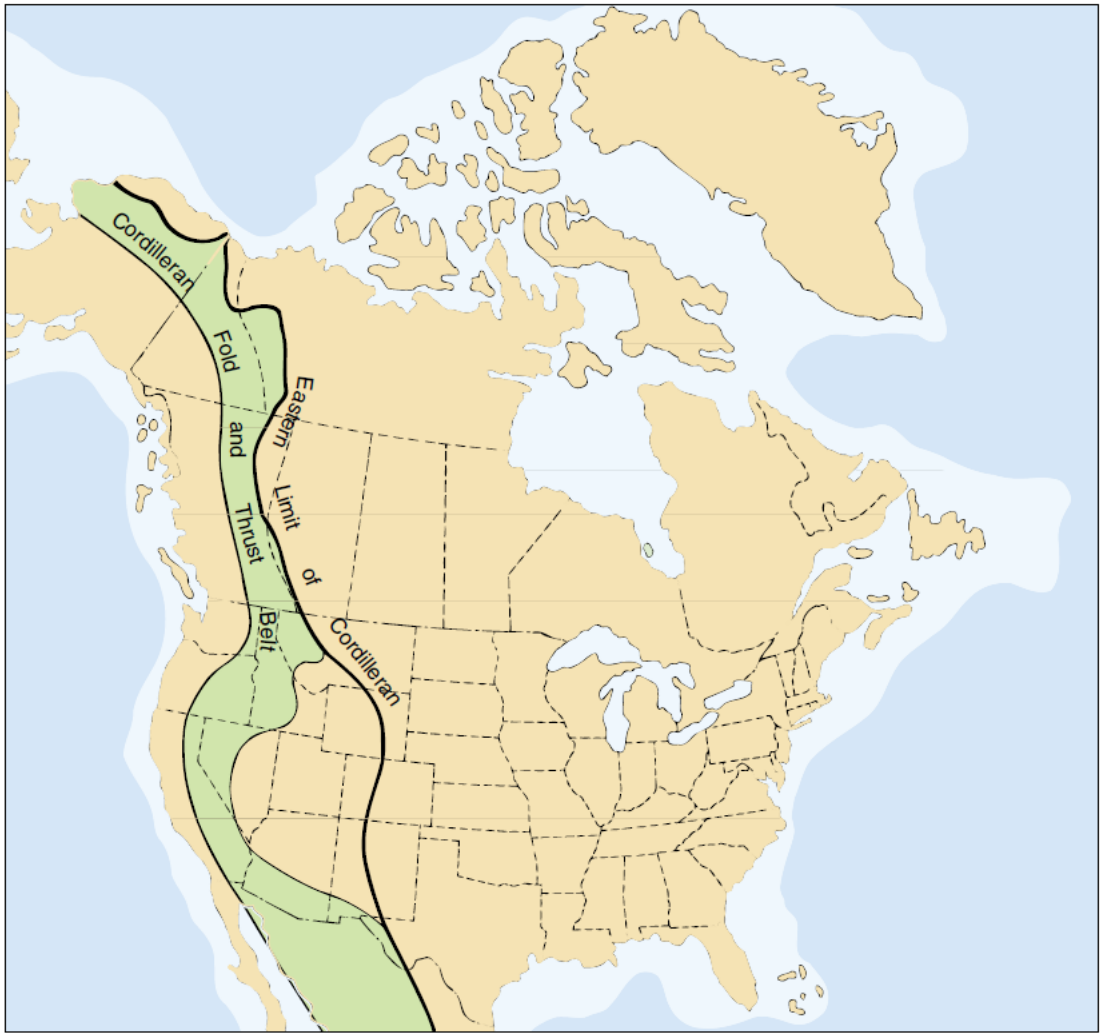


20.7 Building of The Cordilleran Mountains

- After Pangea III broke up, numerous island arcs and microcontinents dotted at the subduction zone in the Pacific Ocean, as the tectonic plates of the Pacific sank beneath western North America.
- Because they were too buoyant to sink into the mantle, they collided with the western margin of the continent and became parts of the continent------ ***docking.***
- In this way, North America grew westward from about 180 to 80 million years ago. About 40 accreted island arcs and microcontinents, called ***accreted terrains***, have identified in the Cordillera.

20.7 Building of The Cordilleran Mountains

- As terrains crashed into the continent, they created compressive forces like those of a continent–continent collision. The resulting zone of folded and thrust-faulted rocks is called the ***Cordilleran fold and thrust belt***



20.7 Building of The Cordilleran Mountains

The first tectonic forces change:

- Western margin of the continent was compressed and docking of the accreted terrains continued at high speed.
- However, the rate of convergence suddenly slowed about 45 million years ago, the compressive forces weakened and the warm, thick crust of the Cordillera began to spread out.
- The upper crust was cold and brittle. It fractured and faulted as the spreading deeper rocks pulled it apart.
- Plutonic and volcanic rocks formed during the last 45 million years are abundant in western North America.

20.7 Building of The Cordilleran Mountains

The second tectonic forces change:

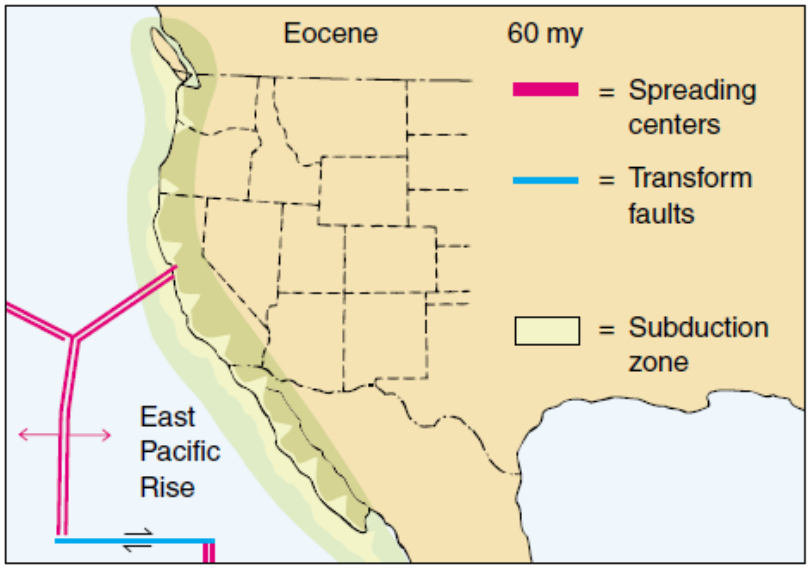
- As North America moved westward, the west coast drew closer to a portion of the mid-oceanic ridge called the ***East Pacific rise.***
- By 30 million years ago, the Pacific plate was moving northwest—nearly parallel to the westward movement of North America. Since these two plates were moving in nearly the same direction, subduction stopped where California touched the Pacific plate.

20.7 Building of The Cordilleran Mountains

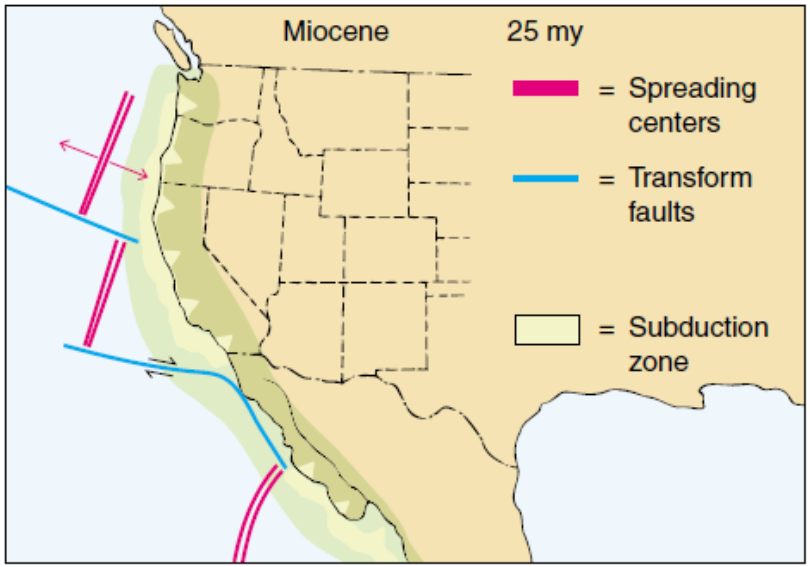
The second tectonic forces change:

- But the Pacific plate was moving in a slightly different direction from the continent. The Pacific plate began sliding northwestward against the California coast along the new strike-slip (transform) fault. The new fault was the beginning of the San Andreas fault.
- As North America continued to move westward and reached greater lengths of the East Pacific rise, the San Andreas fault grew longer and migrated inland.

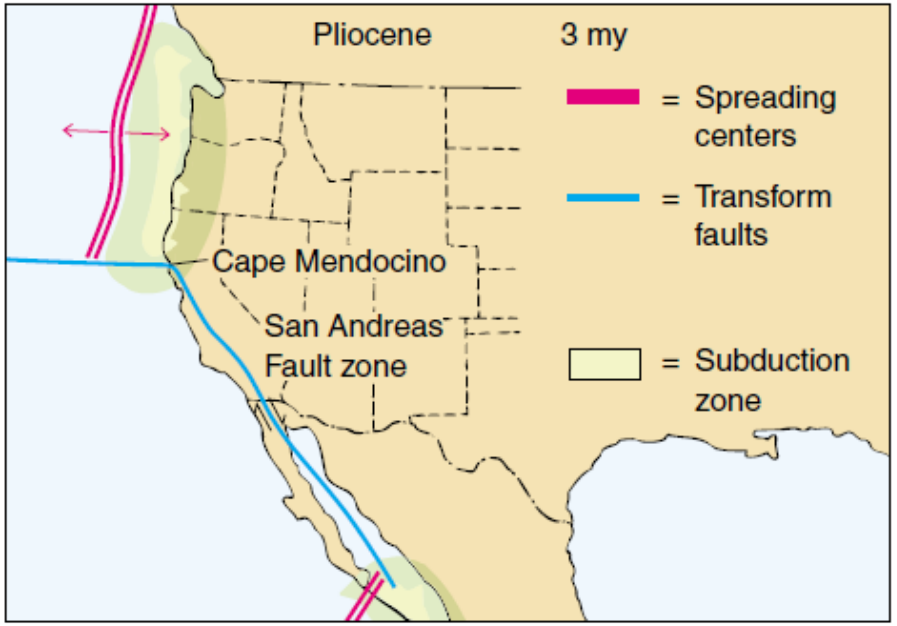
20.7 Building of The Cordilleran Mountains



(a)



(b)



(c)

Figure 20–14 The San Andreas fault developed where western North America overran the East Pacific rise, beginning 30 million years ago. The fault has grown longer as more of California has hit the rise. The subduction zone, shown in light green, once extended the entire length of the coast, but it has become inactive in the region of the San Andreas fault.

20.7 Building of The Cordilleran Mountains

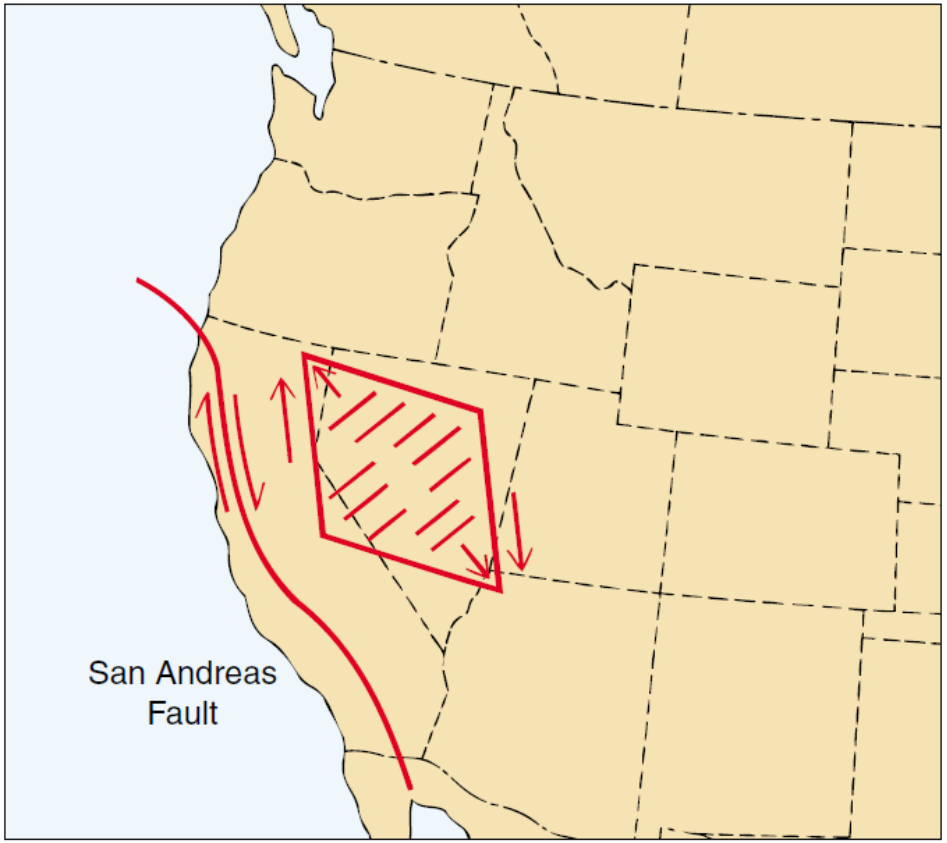
The Modern Cascade Volcanoes:

- San Andreas fault now veers westward in northern California, where it runs out into the Pacific Ocean to connect with the remnants of the East Pacific rise spreading center.
- The Juan de Fuca oceanic plate is sinking beneath the westward-moving continent.
- The subduction creates an active volcanic zone from northern California to southern British Columbia.

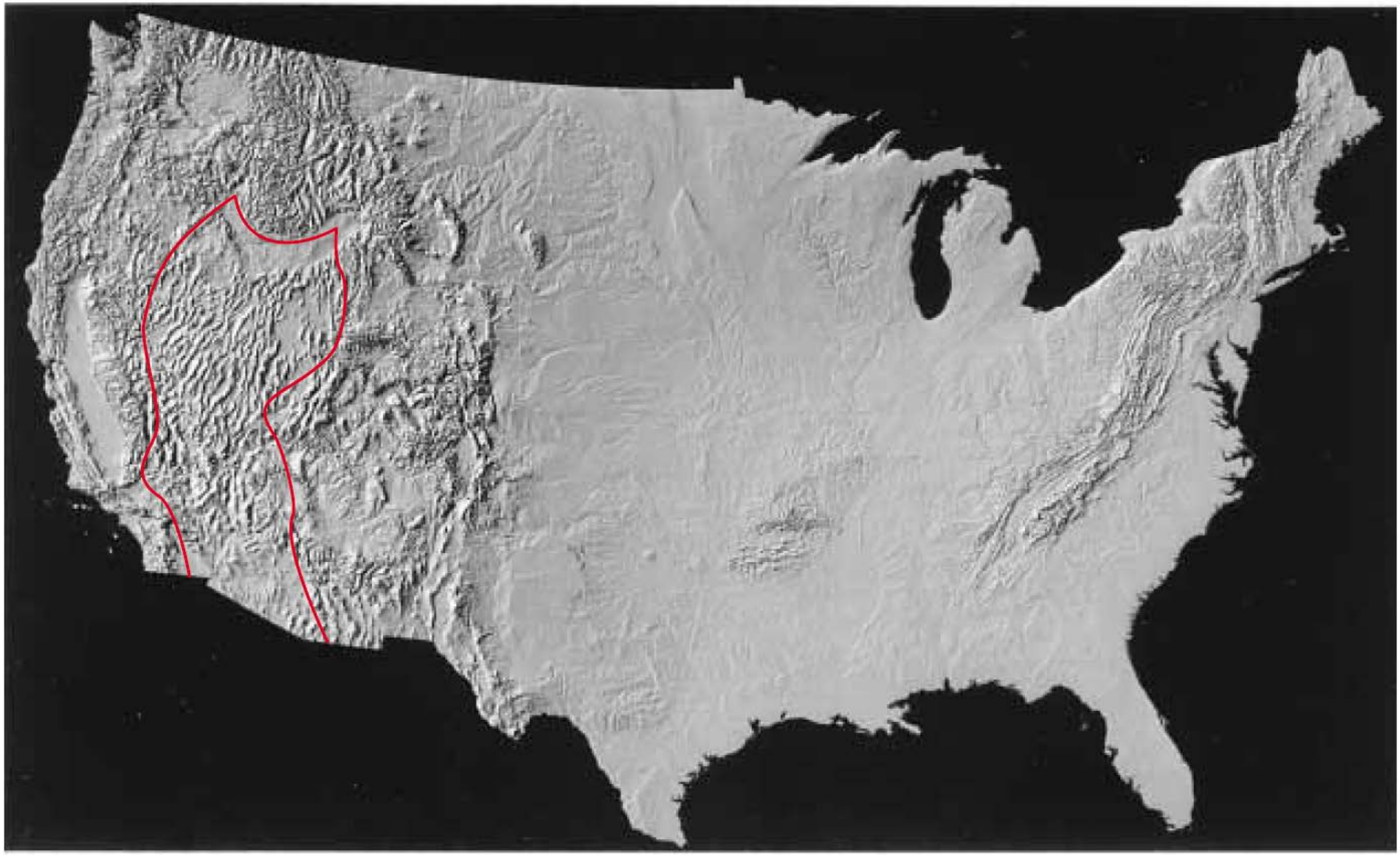
20.7 Building of The Cordilleran Mountains

The Basin and Range Province:

- For the past 30 million years, friction along the San Andreas fault stretches Nevada and nearby regions in a northwest–southeast direction, large blocks of crust have dropped as grabens along the faults, forming normal faults, exist as mountain ranges and valleys in the Basin and Range.



The Basin and Range Province



20.7 Building of The Cordilleran Mountains

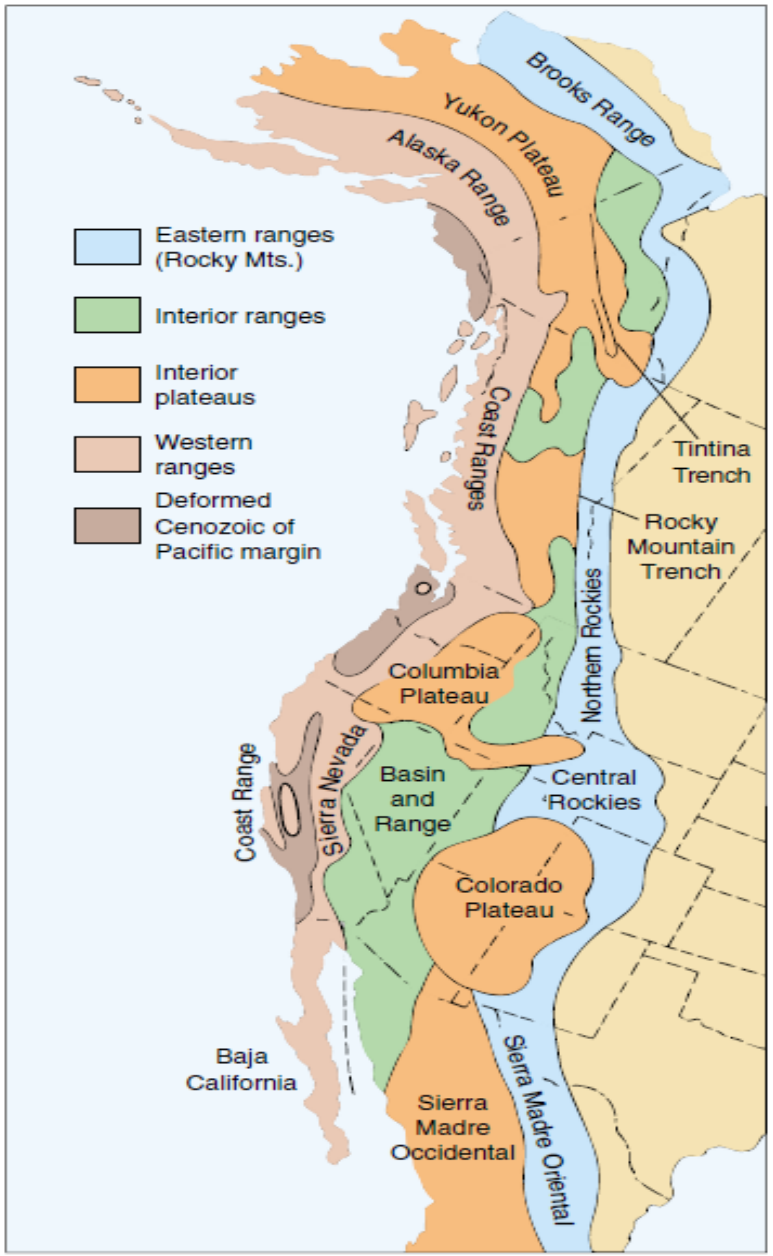
The Colorado Plateau:

- Perhaps because it has a thicker and stronger crust, a large block of western North America remained strangely immune to the faulting and igneous activity---- the Colorado Plateau, although it is surrounded on three sides by the Basin and Range.
- The entire Colorado Plateau simply rotated clockwise in response to the tectonic forces that created the Basin and Range.

20.7 Building of The Cordilleran Mountains

The Columbia Plateau:

- One of the largest basalt plateaus in the world.
- It formed by rapid extrusion of flood basalt magma about 15 million years ago.



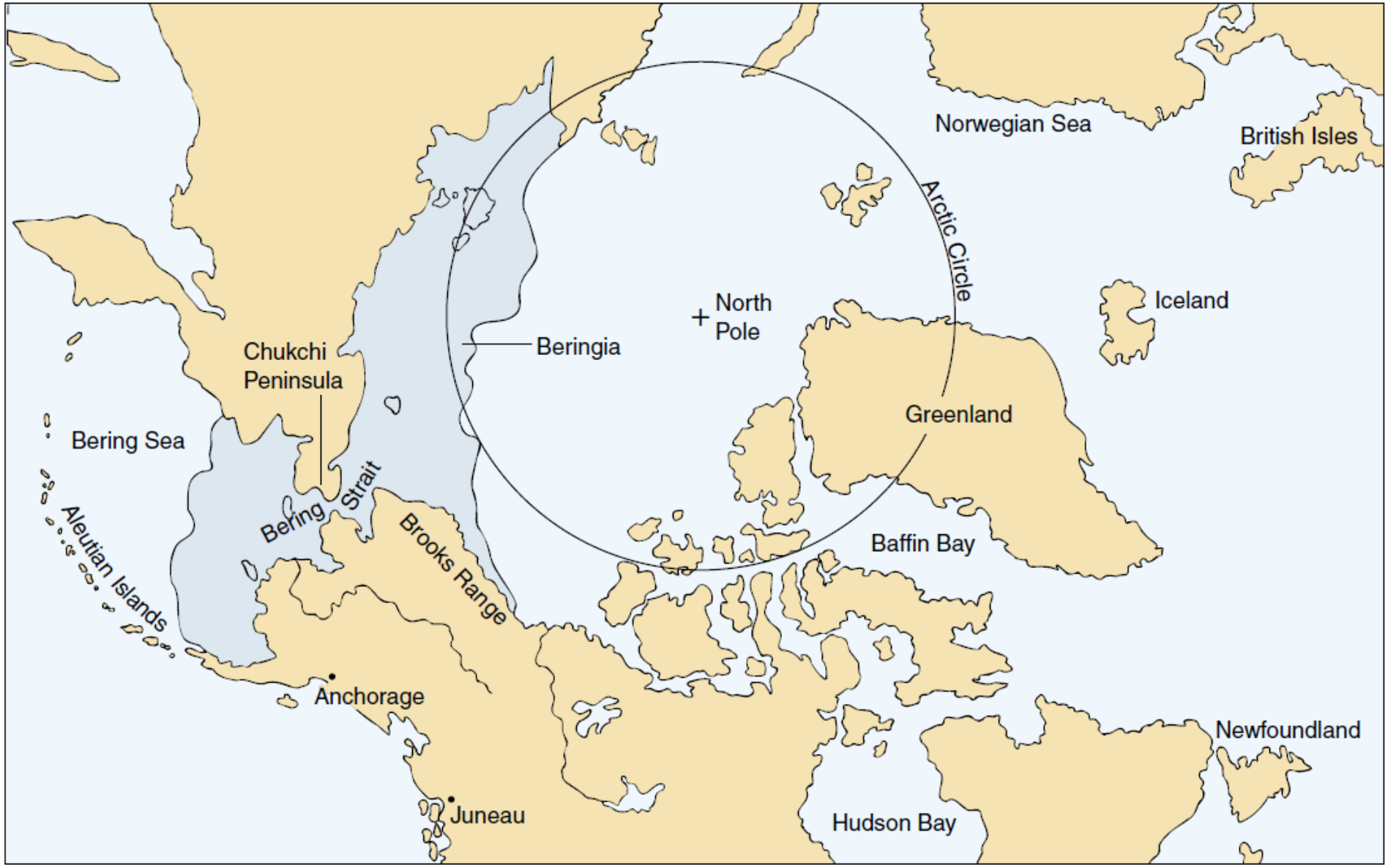
20.8 The Pleistocene Ice Age and The Arrival of Humans In North America

- By 2 million years ago, large ice sheets as much as 3000 meters thick had formed in both the Northern and Southern Hemispheres and were rapidly spreading outward.
- The flowing ice scoured rock and soil from the land, and when the glaciers melted, they deposited huge piles of sand and gravel.
- Thus, glacial erosion and deposition greatly modified the landscape of North America.

20.8 The Pleistocene Ice Age and The Arrival of Humans In North America

- The Bering Strait is part of a shallow-water shelf lying between Alaska and Siberia.
- During the ice age, global sea level fell about 130 meters, the Bering Strait was exposed as a low lying, swampy isthmus connecting Asia to North America----*Beringia*.
- Many animals migrated across Beringia to this continent during Pleistocene time.
- Humans also migrated across Beringia to North America, although it is difficult to determine precisely when they first arrived.

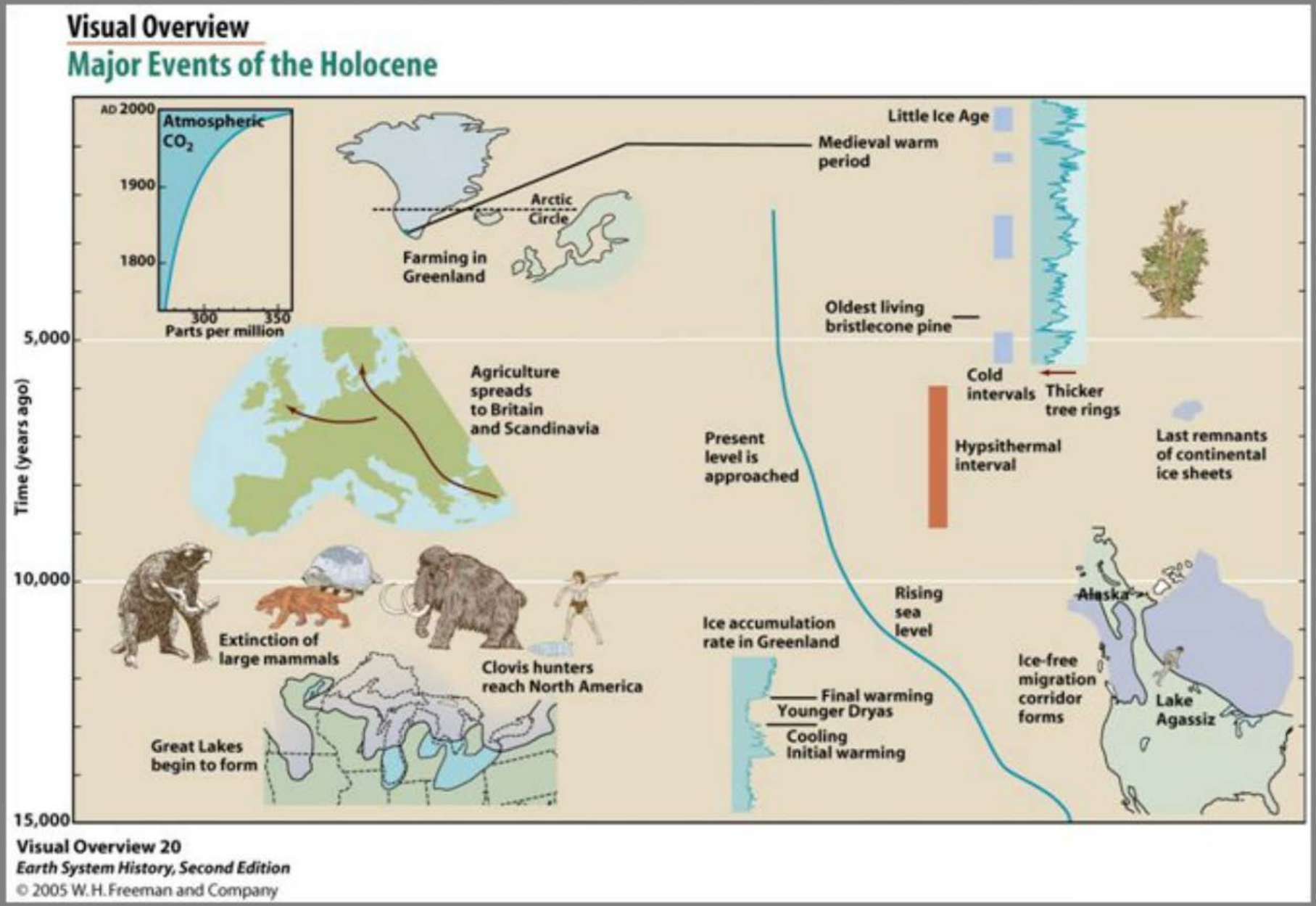
20.8 The Pleistocene Ice Age and The Arrival of Humans In North America



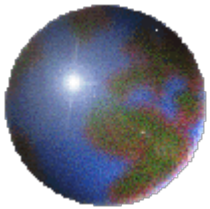
20.8 The Pleistocene Ice Age and The Arrival of Humans In North America

- As they arrived, humans and other animals spread out from the Alaska coast, following several paths.

Holocene Overview



Introduction to Physical Geology



END OF THE COURSE !

AHSANTE!