Alleghanian orogeny

- During Late Paleozoic, northwestern Africa collided with southeastern North America, causing the Alleghanian orogeny, and building the Appalachian mountains.
- The orogeny began during Mississippian and continued through Pennsylvanian and Permian.
Alleghanian orogeny

- South America collided with the Gulf Coast region of North America, forming the *Ouachita Mountains*, a southwestern continuation of the Alleghanian orogenic belt.
Plate tectonics model for the continental collisions during Late Paleozoic
By Late Carboniferous, a large continental landmass called Pangea, had formed by the collision of Laurasia (North America plus Europe) with Gondwana (the southern continents of Africa, South America, Australia, Antarctica, and India).
Pangea on the South Pole

• The supercontinent, Pangea, sat over the South Pole. When a continent is over a pole, conditions are right for a glaciation, if the climate is cold and if sufficient moisture is present.
Iapetus Ocean closed

- The Iapetus Ocean (or Proto-Atlantic), completely closed by Late Carboniferous.
- Closure of the Iapetus Ocean disrupted global ocean circulation and caused currents to be diverted from the tropics to more polar areas, contributing to glaciation.
Late Paleozoic Evaporites

- The presence of *evaporites* (E) indicates that the climate was at least locally *dry*.
- This was probably due in part to changes in global oceanic and atmospheric circulation induced by the closure of the Iapetus, as well as by orogeny.
Late Paleozoic Glacial Deposits

- Glacial deposits are present in the southern hemisphere, indicating that a glaciation occurred during Carboniferous and Permian.
Pennsylvanian Paleogeography

- Large landmass in the east, with extensive lowlands (yellow).

- Appalachian Mountains (orange) have formed as a result of the Alleghanian orogeny.
Pennsylvanian Paleogeography

- Sediment eroding from the Appalachian Mountains was transported to the west into the epicontinental sea that covered much of North America during Mississippian.

- These sedimentary deposits have built a broad plain to the west, with alternating non-marine and marine deposits, as the sea transgressed and regressed.
Pennsylvanian Paleogeography

- Coal swamps formed along the western edge of the Appalachian Mountains, in what was basically a tropical rainforest setting.
Pennsylvanian Paleogeography

- Uplifts in the southern and southwestern North America (Uncompahgre Mountains or ancestral Rockies, and others), and the Antler Mountains in the western U.S.
Pennsylvanian Sedimentary Deposits

• The erosion of the Antler Mountains provided detrital sediment that was transported into adjacent basins.

• Thick sequences of Pennsylvanian and Permian shelf sediments accumulated in the area now occupied by the Wasatch and Oquirrh Mountains in Utah.
Pennsylvanian Sedimentary Deposits

- The Absaroka sea began to transgress upon the North American craton near the beginning of Middle Pennsylvanian.

- The rocks in the eastern half of the U.S. are predominantly interbedded marine and nonmarine sediments, indicating the advance and retreat of the sea.

- Each nonmarine-marine sequence is called a cyclothem.
A typical Pennsylvanian cyclothem contains 10 units. The lower half consist of nonmarine sediments, topped by a coal deposit. The coal is overlain by marine deposits, indicating the advance of the sea into the swampy, vegetated area.
Marine and Non-marine deposits

- The repetitious interbedding of non-marine and marine sedimentary deposits indicates either:
  - Episodic regional subsidence and uplift
  - Eustatic (worldwide) sea level changes related to Carboniferous-Permian glaciation in Gondwana.
Coal and Plant Fossils

- Pennsylvanian coal deposits are mined extensively in the Appalachian area, the Illinois basin, and in Europe.
- They are commonly associated with rocks containing plant fossils.
Southwestern North America

- SW part of the North American craton experienced mountain building during Pennsylvanian.

- The highlands are called the Uncompahgre Mountains (or ancestral Rockies) in southwestern Colorado, and the Oklahoma Mountains of western Oklahoma.

- These mountains and related uplifts resulted from movement along large, nearly vertical faults.
Colorado Front Range

- The **Colorado Front Range-Pedernal uplifts** extending north-south through central Colorado formed at this time.

- Precambrian igneous and metamorphic rocks are now exposed in the cores of these eroded mountain ranges.
Pennsylvanian and Permian sandstone deposits

Erosion produced great wedge-shaped deposits of red arkosic sandstone during Pennsylvanian and Permian, some of which is exposed in Colorado as:

- The "flatirons" near Boulder
- The rocks at Red Rocks Amphitheatre near Morrison, west of Denver
- The Garden of the Gods, near Colorado Springs
Deposition of Pennsylvanian clastic sediments in eastern Colorado and New Mexico. Note the accumulation of coarse arkosic sandstones east of the Uncompahgre Mountains.
The Flatirons, near Boulder, Colorado. Steeply dipping red arkosic sandstones, conglomerates, and mudstones of Upper Pennsylvanian and Lower Permian Fountain Formation.

Sediments were derived from the erosion of the ancestral Rocky Mountains to the west.

The beds were tilted during the orogeny that produced the modern Rocky Mountains.
Other Uplifts

- Other uplifts also formed, including the Zuni-Fort Defiance uplift, the Amarillo mountains, and the Oklahoma mountains (represented today by the Arbuckle and Wichita mountains).

- The origin of these mountains may be related to the collision of Gondwana along the southern edge of the North American craton in the Ouachita orogenic belt.
Other Uplifts

Crustal adjustments to relieve stress may have resulted in the deformation that produced the highlands and associated basins (such as the Early Pennsylvanian Paradox basin, which contains evaporites and petroleum deposits).
The Paradox basin lies southwest of the Uncompahgre mountains.

Clastic sediments from the mountains were deposited along the northeastern side of the basin.
Paradox Basin

- The Paradox basin was flooded by the Absaroka sea during Early Pennsylvanian.
- Shales were deposited over Mississippian limestone.
- The basin became restricted and thick beds of evaporites (salt, gypsum and anhydrite) were deposited.
Paradox Basin

- Reef-like algal mounds, associated with fossiliferous and oolitic limestones, developed along the western rim of the basin.
- The reefs serve as petroleum reservoirs.
- Near the end of Pennsylvanian, the basin filled with arkosic sediments eroded from the Uncompahgre highlands.
Regression of the Absaroka sea

• The **Absaroka sea**, which began its transgression at the beginning of Pennsylvanian, **began a slow and irregular regression** before the end of Pennsylvanian, which continued into Permian.
Permian Paleogeography

- During Permian, the continents collided and joined to form the supercontinent, **Pangea**.
- Pangea was surrounded by a huge ocean called **Panthalassa**.
- The oceanic area east of Pangea, and between Africa and Europe was called the **Tethys Sea**.
Permian Paleogeography

- Continental collision was accompanied by orogeny, and the Appalachian mountain chain reached its peak during the Alleghanian orogeny.
Permian Paleogeography

- Late Permian was a time of widespread regression of the seas.
- The global map above indicates that sea levels were low worldwide.
- The vast epicontinental seas that once covered North America and parts of other continents were gone.
Permian Paleogeography

- The Gondwana part of Pangea continued to sit atop the South Pole, and glaciation continued into Permian.
Permian Paleoclimatic Indicators

Red circles are coal deposits (humid climates during interglacial periods, possibly associated with glacial meltwaters). Blue triangles are glacial tillites. Irregular green areas are evaporites (arid climates).
Permian Glaciation

Distribution of glaciers can be determined from Permian glacial tillites, or striations on bedrock, caused by the movement of the glaciers.

Glacial deposits are white. Arrows indicate direction of glacial movement as determined from glacial striations on the bedrock.
Permian Evaporites

Cold air holds less moisture than warm air, and the climate became arid during Permian.

Evaporite deposits (gypsum and salt) accumulated in the green areas on the map. There are more Permian salt deposits than any other age.
End of the Coal Swamps

- Drying of climates at low latitudes led to contraction of coal swamps and extinctions among spore-bearing plants and amphibians that required moist conditions.

- Because of the drying, gymnosperms (seed plants, including conifers) replaced many spore-bearing plants, which require moist conditions.
Orogeny and climate

• Orogenies probably also affected the climate.

• Locations of mountains can affect climate and control precipitation (rain-shadow effect).

• Deserts form on the downwind side of mountain ranges.
Permian Paleogeography

- The eastern 2/3 of North America consisted of lowlands, undergoing erosion.

- Continental red beds were deposited locally.
Permian Paleogeography

- Appalachian mountains in the east.
- Ouachita mountains in the southeast.
- Farther west are the "Ancestral Rockies."
- Antler Mountains have been eroded, and are called uplands.
- Subduction and volcanism continue in the far west.
Permian Sedimentary Deposits

• The **Absaroka sea** continued its regression during Permian.

• **Fossiliferous limestones** were deposited in the Absaroka sea, overlain in places by shales, red beds, and evaporites.

• The **Kaibab Limestone**, which forms the cliffs along the rim of the Grand Canyon, is a Permian carbonate deposit.
Phosphate Deposits in NW U.S.

- Deep marine basin in the Wyoming, Montana, and Idaho area filled with cherts, sandstones, and mudstones of the Phosphoria Formation.
- Formation named for layers of dark phosphatic sediments and phosphorites.
- **Phosphorite** = dark gray variety of calcium phosphate. May have formed by upwelling of phosphorus-rich sea water from deeper parts of basin.
- Phosphate is mined for fertilizers and other products.
• Note phosphate deposits
• Carbonates and evaporites were deposited in marine basins in the western U.S., as Permian seas withdrew, and basins became restricted.
• Extensive salt beds were deposited in Kansas.
Permian basins in west Texas and New Mexico

• Several irregularly subsiding basins (such as the Delaware basin) developed between shallow submerged carbonate platforms.
Permian basins in west Texas and New Mexico

- Reefs formed along the basin edges (Capitan Limestone).
- The ancient reef forms the steep El Capitan promontory in the Guadalupe Mountains.
Permian basins in west Texas and New Mexico

- In the shallow water lagoons behind the reefs, thin limestones, evaporites, and red beds were deposited.
Paleozoic review