Cambrian Sedimentary Deposits - The Sauk Sequence

• During Cambrian, there were no vascular plants on the land, so the landscape was barren. Erosion was active and severe without plant roots to hold the soil.

• After Neoproterozoic glaciation, the sea transgressed onto the craton.

• Shoreline (beach) deposition produced a vast apron of clean quartz sand.

• Carbonate deposition occurred farther from land.
Cambrian Deposits of the Grand Canyon Region

In the Grand Canyon region, the Lower Cambrian Tapeats Sandstone is an example of the sandy beach deposits unconformably overlying Precambrian rocks.
The Tapeats is a massive cliff-forming unit of brown sandstone. Much of the sand is very coarse-grained, often pea-sized or larger, and some grains are beautifully colored—students call this the M&M conglomerate. The Tapeats Sandstone represents near-shore beach and sand bar deposits.

The base of the Tapeats contains a conglomerate member (part of the Tapeats), called the Hotauta Conglomerate. This was a pebble beach formed as the Tonto Sea encroached and tore up the Vishnu, so the Hotauta contains schist and granite pebbles.
Tapeats Sandstone is overlain by Bright Angel Shale, an offshore deposit. Bright Angel Shale is overlain by Muav Limestone, deposited farther from land. These rocks form a transgressive sequence.
These sedimentary units are **diachronous** (i.e., they cut across time lines). In each case, the sedimentary units are older in the west than in the east. The red lines are trilobite zones, which approximate time lines.
Left: *Glossopleura gigantea* 5.3" Trilobite, Spence Shale Formation, Hansen Canyon, Cambrian, Wellsville Mountains, Box Elder Co., Utah. Right: *Glossopleura bion* 3.9" Trilobite with bite mark, Spence Shale Formation, Cambrian, Miners Hollow, Wellsville Mountains, Box Elder Co., Utah
Left: Nevada Cambrian Trilobite *Olenellus gilberti*, a beautifully preserved specimen of this widespread species that is found in Nevada and California. The genus is restricted to the early Cambrian (540-520 million years ago), making them good index fossils. They have a most distinctive large cephalon containing crescentic eyes, making them quite attractive to collectors. Most are only found as a preserved cephalon, making those from the famous Pioche Shale highly desirable. Right: *Olenellus fowleri*, This is a particularly well preserved specimen of Olenellus fowleri. It has very good color and presence. All the spines and the delicate opistothorax are preserved. There is some damage to the glabella. The species has been recently described in 1998. It is one of the rarer species found at this location. The genus is restricted to the early Cambrian (540-520 million years ago), making them good index fossils. They have a most distinctive large cephalon containing crescentic eyes, and most are only found as a preserved cephalon.
The three facies (sandstone, shale, and limestone) coexisted and migrated laterally as sea level rose. The Bright Angel Shale is Lower Cambrian in the west, and Middle Cambrian in the east.
Near the end of Early Ordovician, the seas regressed (due to glaciation). The Muav Limestone was exposed to subaerial erosion and a widespread unconformity developed.
Ordovician Paleogeography

Note the mountains and volcanoes in the Appalachian region.

Volcanic ash deposits are found in Ordovician rocks throughout the eastern U.S. (Now altered to a clay called bentonite).
Ordovician orogenies

The Taconic Orogenic Belt lay between Laurentia (North America) and Baltica (Europe and western Russia) during Ordovician.
Plate tectonic cross-section showing forces that caused the Taconic Orogeny.
A - Eastern North America during Cambrian and Early Ordovician, following the breakup of Rodinia.
B - Large volcanic island arc nears eastern North America.
C - Volcanic island arc collides with eastern North America causing Taconic orogeny.
Volcanic Island Arc Collides with Eastern North America

- As the Iapetus Ocean narrowed, a volcanic island arc approached and collided with the North American craton, causing folding, faulting, metamorphism, and mountain building.

- This mountain-building event in the Appalachian region is called the Taconic orogeny (480 - 460 m.y. ago).
Upper Ordovician Sedimentary Deposits

As the Taconic mountain belt eroded, Upper Ordovician to Lower Silurian red sandstones and shales were deposited to the west in huge delta systems.
Ordovician shales, New York
Ordovician graptolites
Ordovician graptolites
Ordovician graptolite facies

Graptolite facies (graywackes, siliceous shales, and volcanics)
Eurypterids were impressively size arthropods that crawled out on land and could reach 10 feet.
Caledonian Orogenic Belt

The **Caledonian orogenic belt** (which extends along the northwestern edge of Europe) is part of the same trend as the Taconic orogenic belt.

The Caledonian orogeny reached its climax slightly later, during Late Silurian to Early Devonian.

The Caledonian event is recognized in the Canadian Maritime Provinces, northeastern Greenland, northwestern Great Britain, and Norway.
Silurian global conditions

- Silurian sea levels were high worldwide.

- In Laurentia (North America), much of the craton was flooded, indicating melting of Late Ordovician glaciers.

- This was the second major transgression during Paleozoic, which deposited the Tippecanoe Sequence.
Silurian Paleogeography

Mountains in eastern N. America are eroding.

Sandstone & conglomerate deposits.

Widespread carbonate deposition.

Deep marine deposits in NW and SE U.S.

Reefs and evaporites.
Silurian Sedimentary Deposits

- As the Tippecanoe Sea flooded North America, deposition began with nearshore sands.

- These include the famous St. Peter Sandstone, an unusually pure, well sorted, well rounded quartz sandstone.

- Silurian Tuscarora Sandstone was deposited in the central Appalachian region.
Silurian Sedimentary Deposits

- Sandstone is overlain by extensive limestone deposits, locally replaced by dolomite.
- In eastern U.S., limestones are overlain by and interbedded with shales along the periphery of the Queenston delta. **Niagara Falls** is a classic locality where these rocks are exposed.
Silurian Michigan Basin Evaporites

- Near the end of the Tippecanoe sequence, reef-fringed basins developed, such as the Michigan Basin.
- Evaporation led to the precipitation of immense quantities of rock salt and gypsum within the basin, indicating an arid paleoclimate.
- Evaporite minerals total over 2500 ft (750 m) thick in the Michigan Basin.
Isopach map shows thickness in feet of late Silurian evaporite basins. The Michigan Basin is one of the greatest areas of rock salt (and other evaporites like gypsum) in the world, and these sediments have been the basis of major chemical and plasterboard industries in Michigan.
The rate of subsidence within the Michigan Basin then increased markedly, and a series of coral reefs developed along the Kankakee Arch and in the shallow waters along the western and southern margins of the basin. Some of these reefs can be seen today on the south side of Chicago, and I-94 crosses over a giant quarry into one of them. But the genial climates of the Silurian came to an end. The close of the Silurian was a long time of aridity in which the seas became so salty that living creatures swam to a more suitable home. The conditions were roughly analogous to the present-day Mediterranean Sea where water from the Atlantic flows in over the rather shallow restriction at the Straits of Gibraltar. The arid climate in the region evaporates the sea water and concentrates the salt. The heavier, highly saline water sinks to the bottom and cannot escape and therefore tends to accumulate. Great salt beds (named the Salina Salt Beds) were deposited in the basin. In the central part of the basin 2300 feet of alternating salt, shale, and limestone beds have been penetrated in the Salina, with 1600 feet of rock salt.
Silurian Iron Ore

- Economically important sedimentary iron ore deposits accumulated during Silurian in the southern Appalachians, particularly around Birmingham, Alabama.
- Steel was produced for many years in Birmingham from this iron ore.
- Fuel was supplied by nearby Late Paleozoic coal deposits.
- Limestone, also found nearby, was used as flux in the blast furnace.
Silurian Orogenic Activity

• Orogenic activity (mountain building) was more or less continuous at one place or another during Silurian and Devonian.

• The **Caledonian orogeny** was most intense in Norway, as the Iapetus Ocean closed.

• The folded rocks of the Caledonians end in Ireland, but can be traced to NE Greenland, Newfoundland, and Nova Scotia, Canada.
Jasper National Park, Alberta with lower Paleozoic sedimentary rocks in the distance.
Paleozoic review