Laurentia in the Paleozoic (non-tectonics)

Lecture Goals:
A) Eastern Laurentia (pre-orogenic deposition)
B) Central North America (Depositional sequences)
C) The Grand Canyon


A) Eastern Laurentia (Pre-Orogenic Deposition)
I did my masters research in western Newfoundland, an island off the coast of Canada on rocks that were Ordovician in age (the red area on the simplified geology map to the left from http://instruct.uwo.ca/earth-sci/200a-001/16obduct.htm. I loved my stay on this remote island. It was rustic, wet, rugged and populated by the friendliest people on the planet (with the possible exception of the New Zealanders). The friendliness of the Newfoundlanders was highlighted during the unfortunate events of Sept 11, 2001. When the airspace of the United States was closed to all aircraft, dozens were forced to land in small towns in Newfoundland and other parts of eastern Canada. Thousands of Americans were suddenly stuck in Newfoundland (this is pretty scary when you first look out the airplane window at Gander!). In some cases, there were as many stranded passengers as there were residents in towns like Gander (see image to right from www.airliners.net), but almost all of the passengers reported the most heartwarming experiences. These strangers were welcomed into private homes and treated like long-lost relatives. The stranded passengers were impressed. Many cried when they left Newfoundland. Many said that they would return to the island under happier
circumstances and many (this is really impressive) have kept in touch with their “Newfie” hosts. When interviewed by American reporters after the fact, most Newfoundlanders expressed surprise that their generosity was so surprising to the rest of the world. One person said, “we didn’t so anything special. We would treat anyone in trouble this way”. This is true. I was adopted when I was a student in western Newfoundland. I had people feed me, wine me (my favorite Newfies!), fix flat tires on my trailer (this was a very interesting story – ask me to tell you about it one day; you may cry), and let me shower in their house (this was nice; I had been showering in the campground that I was staying at). All in all, I recommend you visit this pleasant little island.

Did I mention fantastic geology? Newfoundland is the birthplace of the Wilson Cycle which we previously discussed during a lecture on Proterozoic tectonics). Now let me tell you about the rocks that I was looking at for my Masters thesis. They were all deposited well before the birth of the Appalachian Mountains.

The rocks I was looking at were Ordovician in age (specifically Lower Ordovician). They were mostly limestones and dolostones of the St. George Group; all of which were deposited in shallow marine (occasionally evaporative) environments (see diagram 1). They contained all manner of fossils. Stromatolites, gastropods, corals, trilobites, ichnofossils; you name it, they were there. All of these rocks were deposited in a passive continental margin. Remember this term? It is the “boring” type of non-tectonically active shoreline that we have right here along the Gulf Coast. The only difference is that the St. George Group was deposited in a tropical semi-arid carbonate environment rather than our temperate wet siliciclastic environment. But as you go up sequence (i.e., into younger rocks) the shallow marine limestones and dolostones are rather suddenly replaced by deeper marine rocks (limestone and shale) Obviously a transgression occurred, but it was relatively local and was not due to a simple increase in sea level. This was a tectonic change. The sudden deepening was associated with compressive tectonics east of the passive margin. The bottom literally fell out of the passive continental margin, and this was the onset of the first mountain building (orogenic) episode in eastern North America since the Grenville Orogeny around 1 billion years ago. That is the subject of tomorrows lecture.
The rocks of the St. George Group are very similar to rocks of the same age down here in Alabama (see sketch to right). There isn’t really a continuous belt of rocks from there to here, but the environments were very similar. The reason is that in the early Paleozoic, North America was oriented along the equator.

You will find Cambrian and Ordovician limestones and other passive continental margin rocks in northern Alabama. Stratigraphically, we refer to these rocks as the **Knox Group** and on maps, they are identified as being **Cambro-Ordovician** in age. All this means is that they consist of a sequence of sedimentary rocks that straddle the Cambrian and Ordovician. We live in an
interesting part of the world as far as rocks of this age are concerned. If you travel up to the Alabama-Tennessee state line (just due north of Athens, AL), you will encounter Ordovician limestones and siliciclastic sedimentary rocks that are almost perfectly flat-

![Cambro-Ordovician limestone of the Knox Group near Centreville Alabama (Cahaba River). Note that these rocks are “deformed”](image)

flat-lying (i.e., horizontal). Here, the Law of Superposition is easy to apply; stuff on the bottom is older than stuff on top. If, however, you look at the same rocks to the southeast of Athens (near Birmingham), you find that they are not flat-lying (see photo above). The Cambro-Ordovician sequences here are folded, faulted and in some areas, metamorphosed. Clearly some of the originally passive continental sedimentary rocks have been deformed while others have not. Alabama is a great place to study geology because we lie at the edge of a mountain belt and can therefore examine both pre- and post-deformation rocks.

As I mentioned, we will deal with the deformations tomorrow. For today, let’s consider the pre-orogenic rocks. As you will see, deposition was not limited to shallow marine environments around Laurentia. Lots of stuff was also being deposited on the craton itself. Depositional sequences were a continent-wide phenomenon

**B) Depositional Sequences**

You already know that orogenies that build mountains, but mountains are produced from rocks that were around before the orogenies occurred. The rocks that I was studying in Newfoundland were deposited and many of the sedimentary rocks that make up the Appalachian Mountains in Alabama were all deposited long before the mountains began to grow. Long ago, before plate tectonics and before radiometric dating, this used to cause scientists a lot of headaches. They would ask, “How could beach rocks and marine shells get up in mountains thousands of feet above sea level?” Some envisioned terribly high sea levels (i.e., like Kevin Costner’s “epic” movie *Water World*). Others thought that this was evidence of a “great flood”. It was neither. The rocks formed at sea level; they just got pushed up to great heights. The other thing to remember is that not all of the rocks deposited during the Paleozoic were deformed by orogenies. Many thick sequences of sedimentary rock deposited on the continent (cratonic sequences) are still pretty much
in the same horizontal disposition today that they were when they were originally deposited. These sequences are usually named. The **Sauk sequence** occurs over much of central south North America and is Pre-Cambrian to Ordovician in age. It is unconformably overlain by the **Tippecanoe Sequence** (Ordovician-Devonian). These two sequences reflect major episodes of transgressions when the craton was flood by sea water. The unconformities that separate them are periods of major regressions. Other cratonic sequences of the Paleozoic include the **Kaskaskia** and the **Absaroka**.

Most geology text books have a series of paleogeographic maps illustrating the types of rocks that were deposited along the continental margins and interior of North America (or **Laurentia** as it was known in the Paleozoic). There is no need to duplicate them all here, but one is probably a good idea. In the lower Paleozoic (Cambrian to Ordovician) a shallow **epicontinental** or **epeiric seaway** covered most of the east-central portion of Laurentia. There were topographic highs at this time, some of which rose above the waters surface. They were ultimately sources of sediment. The highs are called **arches**, **highs** or **domes**. The lows were called **basins**. In the United States, some of the most important Paleozoic basins were the **Michigan Basin**, **Williston Basin** (Montana), **Appalachian Basin** and the **Permian Basin** (West Texas). Most of them are major reservoirs of petroleum, natural gas and/or coal. Sauk deposition took place in the basins
that developed on the craton. Paleozoic topographic highs include the **Black Hills Uplift**, the **Nemaha Ridge**, and the **Ozark Dome**.

Many topographic highs remained above sea-level even during the highest transgressions. These arches/highs/domes are usually sites of fairly major **unconformities**. The diagram at the top of the next page attempts to explain why.

Let’s return to the idea of depositional sequences in view of the unconformity cartoon pictured above. Major transgression result in very high sea-levels which may produce a thick blanket of sedimentary rock. The longer sea-level stays high, the longer sedimentation occurs and the thicker the depositional sequence becomes. But there is more to this than just high sea level. Some sediment (e.g., tropical limestone) can be deposited very quickly, so fast in fact, that it could reach an elevated sea-level within a few decades (or less). Were this to occur, no further marine sedimentation would happen. It is clear, however, that some depositional sequences contain a lot more marine sedimentary rocks than could have been deposited due exclusively to a sea-level rise. The basin must also have sunk during deposition, a process referred to as **subsidence**.
space that you have to deposit sediment is a combination of sea level rise and subsidence. Sedimentologists refer to this as total **accommodation space**.

I don’t want to leave you with the idea that only marine sedimentary rocks comprise depositional sequences like the Sauk and Tippecanoe. There are lots of non-marine rocks too. It’s just that marine rocks give us good base-level information. If marine limestone covers non-marine lithic sandstone, we know that a transgression (or local subsidence) has occurred. If non-marine lithic sandstone overlies non-marine red shale, it is a tad more difficult to resolve any possible sea level-induced reasons for the shift. It might just have been a shift in depositional environments (e.g., a meandering channel crossing a flood plain). Non-marine depositional sequences are very important in one area though. They allow you to determine when **uplift** (this is when the basement rises rather than sinks) is starting to affect an area. Uplift, which is tectonically-induced (e.g., orogenies), elevates a region. If the area was initially marine, uplift would result in a regressive depositional sequence (e.g., marine limestone to beach quartz arenite to river lithic...
sandstone etc.). If uplift continues and you ultimately make a mountain range, the river lithic sandstone might pass upward into a conglomerate then an arkose then a breccia. The latter rocks are of course associated with alluvial fans. Alluvial fans flank mountains. A depositional sequence that progresses from marine rocks to breccias implies that major uplift associated with some sort of orogenic event has occurred.

One of the most impressive examples of these orogenically-induced depositional sequences occurs in the middle Paleozoic (mostly the Devonian) in the northeastern United States. The **Catskill Clastic Wedge** complex is a thick sequence of non-marine and marine sedimentary rocks that thins westward across New York state, Pennsylvania etc. It is wedge-shaped in section (see cartoon below) and is composed of siliciclastic detritus that was being shed from the Appalachian Mountains *as they were forming*. Remember. Erosion occurs simultaneously with uplift.

![Catskill Clastic Wedge](image)

**C) The Grand Canyon**

You cannot discuss great depositional sequences without mentioning the geology of the **Grand Canyon**. In fact, it is the geology that makes the canyon “grand”. Oh I know what you are thinking. “The canyon is the deepest hole on the planet” (not quite true), “and this alone makes it a special place”. Special yes, but not necessarily grand. The most impressive thing about the Grand Canyon is that it exposes over 5000 feet of geology. At the bottom of the canyon, you are standing on “shield”-aged crystalline basement rocks (Pre-Cambrian) The rocks are deformed and are about 1.5 billion years old (Mesoproterozoic). These rocks are overlain by Neoproterozoic sedimentary rocks that are also deformed, but not as extensively (mostly faults, dike intrusions etc). Above this, you get flat-lying sedimentary rocks that are classic examples of the Law of Superposition: Cambrian at the base; Quaternary at the top. It is NOT a complete sedimentary record. It contains several major disconformities (e.g., there are no Ordovician or Silurian rocks), but it is still an awe-inspiring site. From the bottom up, you span 1/3 of the entire time span of the Earth. You see evidence of transgressions, climate change, tectonic events, volcanic explosions, evolution…. Everything!

Every person should see the Grand Canyon once in his or her life. Every geology student should walk up the stratigraphy once in their lives. You’ll know that you are geology material if you want to go back and do it again just in case you missed something the first time around.
Important terms/concepts from today’s lecture

**Cratonic Sequences (Depositional Sequences):** Sauk Sequence, Tippecanoe Sequence, Kaskasia Sequence, Absaroka Sequence, Catskill Clastic Wedge Complex

Subsidence, Uplift, Accommodation space, Grand Canyon