GEOLOGY 25 - LECTURE 2B

COLORADO PLATEAU: Bryce Canyon NP

(Textbook: Ch 5, p. 62-68)

Bryce Canyon NP

Bryce is different from Zion in that Zion was cut by a river and you look *upward* at steep, massive canyon walls - in Bryce you stand on the rim of a high plateau and look *downward* into "amphitheaters" of irregular cliffs of ornately sculpted hoodoos

- there is a small canyon in the park called Bryce Canyon, but in reality the central feature of the park is not a canyon at all but rather a panorama of erosional pillars (hoodoos) viewed from the rim of a plateau. So the name of the park is somewhat misleading.

Bryce about 1000' higher in elevation than Zion, so cooler and moister (8500 to >9000')

hoodoos are ornate pillars of rock formed by weathering and erosion of bedded sedimentary rock. They are the erosional remnants left behind from a once-continuous, broad sheet of sedimentary rock that currently underlies the adjacent pine-covered Paunsaugunt Plateau.

The elongate park is carved into the eastern edge of the Paunsaugunt Plateau, forming an irregular escarpment of exposed rock called the Pink Cliffs (even though the rocks are more orange than pink). Particles of sediment derived from the eroded edge of the Plateau are transported into the Paria River drainage basin to the southeast, which eventually flows into the Colorado River in the upper Grand Canyon.

- the rock that forms the hoodoos underlies the forested Paunsaugunt Plateau and is exposed along the Pink Cliffs escarpment at the edge of the plateau. Down in the Paria River drainage, the entire formation is eroded away.
- snowmelt and rainwater flow off the gently tilted plateau then downward through small channels and gullies toward the Paria River to the east
- as the water flows over the edge of the plateau it weathers and erodes the rock there, so the Pink Cliffs escarpment continually retreats westward, creating hoodoos in the process (more on this below)

Rocks composing the Bryce landscape

The scenery at Bryce is cut into the horizontally bedded **Claron Formation**, a **Cenozoic** age (~50 m.y. old) layered unit up to 1000' thick composed of alternating thin beds of mudstone, sandstone, limestone, shale and volcanic ash.

- so the rocks of the Grand Canyon are PC and Paleozoic, the rocks of Zion are Mesozoic, and the rocks at Bryce are Cenozoic, the youngest of all
- the Claron Fm is an intact layer beneath the Paunsaugunt Plateau, but weathers and erodes into hoodoos where it is exposed along the edge of the plateau within Bryce Canyon NP

The American West about 50 m.y. ago was a continental setting, much higher in elevation than the Paleozoic and Mesozoic near-sea-level depositional environments of the rocks in the Grand Canyon and Zion.

- the entire Colorado Plateau region was lifted upward by geologic forces over several tens of millions of years during the late Mesozoic and early Cenozoic. What was once a coastal setting through the Paleozoic and Mesozoic became a highland about 3000-6000 ft (1-2 km) in elevation during the Cenozoic. (more on this later)
- the environmental setting during the deposition of the Claron sediments was of a high-elevation plateau surrounded by mountains that drained water into a large lake situated on the plateau
- a modern analog of the Colorado Plateau during the early Cenozoic is the Altiplano Plateau of the Andes Mountains of South America. The Altiplano is a high-elevation plateau with lakes, surrounded by higher mountains of the Andes.

Claron Fm. sedimentary rocks were deposited in a large inland lake that covered thousands of square miles, about the size of modern Lake Erie. The lake was surrounded by ancestral mountains, now eroded away. These mountains eroded to supply the sediment that was deposited as the Claron Formation.

- each stacked bed of differing rock types represents varying environmental conditions as the lake changed shape and depth through time - a shale/mudstone might represent deposition of clays in the deepest part of the lake, whereas a sandstone might represent an ancient lake shoreline washed by waves. limestones represent times when freshwater shellfish and calcite-secreting algae lived and died in the lake, with their debris accumulating on the lake bottom. Volcanoes in nearby mountains erupted volcanic ash that spread across the Claron lake, slowly settling to the bottom.
- different types of sediments were deposited one atop the other as the level of the lake varied with climate through time. The shoreline of the lake transgressed and regressed, with the lake environments shifting in tune with the shoreline.
  - e.g., what was once a sandy shoreline beach may become a deeper water lake bottom accumulating clay as the lake level rises and the shoreline expands outward
- the continental setting of the Claron was in contact with the atmosphere and was thus well-oxygenated. Tiny amounts of iron in the sediments combined with oxygen in the atmosphere and rainwater to create a pinkish tint to the sediments/rock.
- variable shades of pink, orange, white, tan and red coloring the Claron (exposed as the Pink Cliffs) are caused by variable amounts of iron oxides (and manganese oxides) in the original sediments as they were deposited
- rocks of the Claron Fm are relatively 'soft' and more easily eroded than rocks of Grand Canyon or Zion, mostly because they haven't been buried as deeply by younger rocks.

Evolution of the modern landscape at Bryce Canyon NP

Remember that the Claron was once a laterally continuous wedge of sedimentary rock that extended across Utah and over into northwest Colorado. Relatively recently in time (~5-6 m.y. ago), it's been uplifted as part of the Colorado Plateau, then erosionally sculpted into the landscape we see today.

Dominant scenery-forming processes at Bryce are **weathering** and **erosion** by flowing water.

- **weathering** is the decomposition of rocks, soils and their minerals through direct contact with the atmosphere. Weathering occurs *in situ* ("with no movement") by contact with liquid water and ice.
- weathering is the first step that leads to **erosion**, which is the process that involves the movement of loose, weathered sediment by water, ice, wind, and gravity.
- both processes are commonly used in tandem, as in "weathering and erosion," since they are so closely related

Weathering and erosion preferentially occur along **joints** - sets of near-parallel, planar fractures in the rock
- sets of joints commonly form in perpendicular orientations to one another, partitioning the body of rock into blocks
- sets of joints may form as rocks are squeezed or stretched by large-scale geologic stresses (tectonism) at some point in their history. They may form during uplift of a large regional block of crust (e.g., uplift of Colorado Plateau)
- uplift occurs slowly, taking a few million years to raise rocks upward by a kilometer or more (a lot more on this later)
- two near-vertical joint sets meet at right angles in Bryce Canyon NP, contributing to the columnar shapes of hoodoos on the landscape

During the warmer daytime, water from rainfall or snowmelt seeps in along the joint planes. At night, the water freezes and expands (increasing in volume by as much as 9%), physically pushing apart the rock a tiny bit along the joint plane. It melts again the next day, perhaps washing away a few grains of loosened sand. This **freeze-thaw cycling** (aka "ice-wedging") through long periods of time wears away the rock adjacent to the joint, widening the joints and creating separation between the remaining rock walls.
- plant roots also find their way into joints where water may accumulate; the organic acids from the roots and the physical growth of the roots act to widen the joint planes.

How does the Pink Cliffs escarpment retreat, creating hoodoos in the process?

Headward erosion (one particular type of erosion) occurs at the head of a gully or rivulet (the '**head'** of a stream is its upslope point of origin, while the downstream end where the river empties into a lake or sea or another stream is its '**mouth'**).
- as water from rainfall or snowmelt flows off the edge of the plateau into the head of a gully (at the margin of the Paunsagunt Plateau), the flow picks up velocity at the steep edge. The water accelerating over the edge wears away at the rock at the highest tip of the channel near the plateau edge. The rock at the highest tip of the gully breaks down by weathering and falls apart, creating sediment. The weathered grains of sediment are carried off by rain and snowmelt into small gullies and rivulets draining the uppermost slope above the head of the stream. These gullies and rivulets act to extend the head of the stream upslope (i.e., 'headward') as the weathered debris drains into a stream after intense rains or heavy snowmelt. (none of this description makes any sense without looking at the appropriate image)
- at Bryce, headward erosion is concentrated along the break at the edge of the plateau where it drops off into the drainage network of the Paria River below

- as the edge of the Paunsaugunt Plateau is weathered and eroded, it retreats toward the west as the stream network migrates headward. Rock layers of the Claron Formation are progressively exposed by headward erosion. In time, the layers erode to form isolated hoodoos of remnant rock.

Sequence of events that form the landscape at Bryce:
1 – deposition of the horizontal layers of sediment, followed by burial and cementation
2 – during subsequent uplift many millions of years later, sets of joints form, commonly at sharp angles (joints may have formed during uplift of the Colorado Plateau 5-6 million years ago)
3 - weathering and headward erosion along joints accentuate columns and walls of rock created as the joints widen; the remaining walls or columns of rock are then carved by water and wind into various ornate shapes based on differential erosion of the alternating layers of mudstone, siltstone, sandstone, limestone and volcanic ash
4 – with time and more weathering & erosion, the Pink Cliffs escarpment at the edge of the plateau retreats westward from the headward erosion of streams, with old walls and columns destroyed and new ones created

Joints control the orientation of walls of hoodoos and the linear alignment of hoodoos because weathering and erosion preferentially occur along joints

Why do individual hoodoos have such variable shapes?
- shales, mudstones and volcanic ash tend to erode easily, forming recessed beds, whereas sandstones and limestones are more resistant, forming beds that stand out in relief. Thus the vertical spires, turrets, and scalloped pinnacles (i.e., 'hoodoos') exhibit intricate patterns of parallel grooves and corrugations created by this **differential erosion**

You can follow the Rim Trail along the edge of the Plateau for views down into the hoodoos, but a fun hike at Bryce Canyon is the **Navajo Loop trail** that takes you down among the hoodoos where you walk though narrow canyons.

Grand Staircase-Escalante National Monument

How do the rocks at Zion and Bryce Canyon NPs relate to rocks at Grand Canyon?

North of Grand Canyon and close to Zion and Bryce, numerous smaller plateaus compose part of the Colorado Plateau - called **Grand Staircase-Escalante National Monument**
- this is a huge, undeveloped region popular among those hardy adventurers who like their redrock country empty and remote
- national monuments commonly preserve a unique cultural or natural feature or area and are commonly administered by the Bureau of Land Management rather the National Park Service
- a national monument differs from a national park in that monuments can be created solely by presidential decree, without congressional approval

The Mesozoic rocks of the Grand Staircase are hot hunting grounds for dinosaurs, partly because they lived in abundance in the region prior to its uplift into a plateau and partly because of the modern semi-arid climate and complete exposure of the rocks.

Grand Staircase – Escalante NM is also notable for remote **slot canyons** that lure the prepared adventurer to the backcountry.

Why is the National Monument called the Grand Staircase?

Over a distance of about 150 kilometers, a series of east-west oriented escarpments step northward from the rim of the Grand Canyon to Bryce Canyon in a topographic feature called the **Grand Staircase**. Each escarpment extends laterally for several tens of kilometers and are named for the dominant color of the rock exposed along the steep cliff face (e.g., Chocolate Cliffs, Vermillion Cliffs, White Cliffs, Pink Cliffs).

- the escarpments are erosional remnants left behind as the Mesozoic and early Cenozoic rocks are weathered away through time (uplift of the GC region raised these units upward where they were removed by weathering and erosion, leaving the stepped escarpments as a remnant)

Graphic columns of rock from each park show how the Grand Staircase connects the older rocks of the Grand Canyon with younger rocks in Zion and Bryce (look at this cross-section closely)

- Grand Canyon - Precambrian and Paleozoic rocks
- Zion - Mesozoic rocks with much of the scenery coming from the Navajo Fm.
- Bryce - scenery cut in Cenozoic Claron Fm

Grand Staircase cross-section (look at this diagram closely)

Precambrian and Paleozoic rocks at Grand Canyon underlie Mesozoic rocks at Zion which in turn underlie Cenozoic rocks at Bryce Canyon.

- the Cenozoic rocks at Bryce and the Mesozoic rocks at Zion once extended across the Grand Canyon region, but relentless weathering and erosion by flowing water has since stripped these layers back to the north where they form the stepwise escarpments of the Grand Staircase
- the principles of superposition, lateral continuity, and faunal succession were used to create the cross-section.

Odds & ends . . .

National Monuments can be declared by executive order of the US president without congressional approval. Monuments typically preserve a single unique feature of either cultural or natural significance.

National Parks require an act of Congress for approval; park status is a more challenging process than that for national monuments. National parks preserve scenic and natural regions of global and national significance.

These websites may be useful to those of you who have chosen not to use the textbook.

National Park Service – Geology of Bryce Canyon NP
https://www.nps.gov/brca/learn/nature/geologicformations.htm

Wikipedia – Geology of Bryce Canyon
https://en.wikipedia.org/wiki/Geology_of_the_Bryce_Canyon_area

Wikipedia – Grand Staircase
http://en.wikipedia.org/wiki/Grand_Staircase-Escalante_National_Monument