GEOLOGY 25 - <u>LECTURE 1 - A</u>

COLORADO PLATEAU: GRAND CANYON – part 1

(Textbook: Chapter 2 (p. 32-35), Chapter 3 (p. 36-40), Chapter 1 (p. 18-20)

*Selectively read/browse the parts of the textbook that directly relate to what is in these notes and what we talk about in class. I suggest that you browse/read the book **after** you've had a few classes on the material. Browse strategically and don't get bogged down in unnecessary details that we don't have time to discuss during class. Pay particular attention to the images & captions in the text.*

The Grand Canyon (Notes 1A & 1B) takes the first few class periods so don't get overwhelmed by trying to read the assigned reading all at once. Stretch it out over the first week or two of classes.

Colorado Plateau province

North America is divided into several **geologic provinces** based on similarities in the geology and physical landscapes of a region.

Colorado Plateau centered around the Four Corners region of southern Utah, northern Arizona, western Colorado and the northwest corner of New Mexico.
- Colorado Plateau includes 8 National Parks (NP) and several National Monuments (NM).
- we'll visit Grand Canyon, Zion, Bryce, Arches & Canyonlands

The **Colorado Plateau** is characterized by high elevation plateaus (5000-10,000'), deeply incised canyons (like the Grand Canyon and Zion canyon), flat-lying horizontally layered rocks with reddish colors, elongate escarpments, flat-topped mesas, and semi-arid climate. Commonly called "redrock country".
- a **plateau** is a broad region characterized by a relatively level upper surface, commonly at high elevations
- an **escarpment** is a steep cliff face that extends across a long distance
- the Colorado Plateau is not really composed of 'mountains' even though it's high in elevation and rugged. Rather, it's a broad plateau that has been deeply eroded, mostly by running water. What we see on the surface are the products of constant, ongoing **erosion**. Much more on this with time . . .

Called the Colorado Plateau because of the **Colorado River** that drains it on its path from Rocky Mountain NP in Colorado to the ocean in the Gulf of California east of Baja.
- the Colorado River **drainage basin** (aka **watershed**) is the geographic region where all runoff from rain and snowmelt flows through tributary streams and rivers into the main Colorado River
- rainwater or snowmelt that flows into tributary streams and rivers and then into the main Colorado River ends up in the Gulf of California (the elongate sea between Baja California and mainland Mexico)
- any rainwater or snowmelt that occurs *outside* the watershed flows into a different drainage basin and may end up in the Gulf of Mexico or the Pacific.
- study this map closely to understand the Colorado River watershed

The Colorado River and its countless tributaries are the major agents of erosion by flowing water and are the primary factor in sculpting the landscapes of the Colorado Plateau

Modern Grand Canyon

Grand Canyon, in northern Arizona, is the most famous and most visited NP on the Colorado Plateau

Grand Canyon characterized by a high-elevation plateau, elongate escarpments, horizontally layered sedimentary rocks, a 'stairstep' cliff-slope topography along steep canyon walls, and a deeply incised river canyon. (all classic Colo Plat characteristics)

- established as a national monument in 1908 and a national park in 1919
- located in the northwest corner of Arizona, the Grand Canyon was carved by the Colorado River that flows roughly east to west through the region
- Colorado River flows through the Grand Canyon in a circuitous, meandering east-to-west direction
- multiple tributary rivers and streams cut downward into the Plateau as they flow into the main Colorado River, widening the canyon interior
- the numerous tributaries that feed rainwater or snowmelt into the main trunk of the Colorado contribute to **canyon widening** and the **incision of smaller side canyons** that connect with the main Colorado River canyon
- much of the south rim of the park is owned by Native Americans (Hualapai & Havasupai & Navajo)

Colorado River no longer runs freely through the Canyon. Since 1966, flows are regulated by **Glen Canyon Dam**, upriver near the Arizona-Utah border. *The dam acts as a tourniquet on the river, restricting its flow.* Water backs up behind the dam to form the reservoir of **Lake Powell**, which also acts as a trap for all sediment carried along by the Colorado River on its journey through Colorado and Utah.

- the accumulation of water to form Lake Powell flooded Glen Canyon, a deep, narrow, redrock canyon now submerged beneath several hundred feet of water
- like most dams, Glen Canyon Dam generates hydroelectric power, regulates flow downstream to prevent flooding, and provides a reservoir for recreation. But it also flooded a fantastically beautiful canyon upriver and reduced sediment replenishment for sandbars downriver.

The Colorado River drains much of the red-rock country, incorporating the eroded red sediment into the river flow, so before the dam the river water was cloudy with sediment. Today that sediment gets trapped behind Glen Canyon Dam within Lake Powell so the river runs much clearer downstream through Grand Canyon. But it also means that not enough sediment travels through Grand Canyon to replenish sandbars along the banks, which are eroding away. This has greatly affected the riverside ecology of the canyon.

At the west end of Grand Canyon NP, the Colorado River flows into Lake Mead, the reservoir created by water backing up behind **Hoover Dam** (1935).

- eventually the Colorado winds its way southward, forming the Arizona-California border, before crossing into Mexico and emptying into the Gulf of California

River Incision of the Grand Canyon

Flowing rivers have tremendous erosive power, especially during flood stages.

- before the dams, for millions of years the Colorado River cut down (in a process called **incision**) into the multi-colored, layered rocks of the plateau, exposing them to view.
- the water itself does little to erode the surrounding rock. Rather, the sand, gravel and boulders carried along by the river, especially during fast-flowing, turbulent flood stages, did the bulk of the erosion. Rock smashing against rock is a much more effective tool than water against rock. Since the dams were built several decades ago, erosion has slowed considerably since there are no floods or coarse debris to rage down the canyon.

By reason, the rocks of the Grand Canyon had to have been there as broad continuous layers *before* the river could cut down into them

- the layers of a cake (analogous to layers of rock) had to have been formed before the knife (analogous to the river) could slice downward into it. **The cake layers were once continuous sheets, just like the rocks were once continuous sheet-like layers. They extend under the plateau surface for wide distances, out of sight beneath the ground.**
- the slice removed from the cake is analogous to the canyon left behind after rock was eroded away and transported as sediment to the northern Gulf of California.

The age of the rocks in the Grand Canyon range from **2 billion years** at the very bottom to **~250 million years** at the very top

- downcutting by the Colorado and its tributaries began around **5 to 6 m.y.a**. (m.y.a. = million years ago) (i.e., the river 'knife' incised into the layercake much more recently in time)
- i.e., the Colorado River near the Grand Canyon originated about 5-6 m.y. ago and has been incising downward into the much older rocks since then

Don't worry too much about these ages at this point. Soon enough we'll discuss geologic time and how we know the age of the rocks. At this point, it's enough to know that Earth is billions of years old, and that many of the rocks we'll discuss are hundreds of millions of years old. And that the canyon itself is a relatively young feature, cut into the much older rocks.

So, even though the rocks that compose the canyon are quite old, ranging from ~250 million years (m.y.) at the top to about 2 billion years (b.y.) at the bottom, the canyon itself is very young, geologically - the river cut the canyon through the old rocks only over the last 5 to 6 m.y.

This is a basic concept you'll need to understand for all the parks we discuss: *The modern landscape is always younger than the rocks that compose the landscape.* In other words, the rocks were created long ago, whereas erosion formed the landscape fairly recently in geologic time.

- as an aside, the *landscape* of any area is just the surficial topography of deeply cut canyons, rugged mountains, or dry desert valleys. Rocks form the underlying foundation on which the landscape forms. The rock extends deep beneath the surface, whereas the landscape is merely the uppermost topography sculpted into the rock.
- so when we talk about where the rocks in the upper Grand Canyon came from, think of them as continuous horizontal sheets stacked one on top of the other like a layer cake and try to mentally get rid of the river and canyon

Geologic history recorded in the rocks: How did the rocks of the upper Grand Canyon get there? - Sedimentation and sedimentary rocks

There are two main 'packages" of rock in the Grand Canyon:

1) an "upper" interval of colorful, layered sedimentary rocks (analogous to the layers of a cake)
2) a "lower" interval of dark, complex rocks of the "basement" (analogous to the solid platter on which the cake is built)

The most distinguishing characteristic of sedimentary rock is **layering** - these horizontal layers are called **beds** or **strata** (stacks of horizontal sedimentary layers are sometimes called "layercake strata" due to their similarity)

Individual layers, tens to hundreds of feet thick, exhibit distinct characteristics and have been labeled with formal names into discrete units called **formations** or **groups** (e.g., Tapeats Sandstone, Coconino Formation, Supai Group)

- formations are composed of individual beds of rock (aka 'strata')
- the layers we see on the canyon walls extend back underground and are continuous across much of the American West (more on this later)

The upper Grand Canyon is composed of several distinct formations and groups of sedimentary rock

They range in age from the Tapeats Sandstone (~500 my old) to the Kaibab Limestone (~250 my old), all underlain by much older rocks about 2 billion years old.

(no need to memorize these formation/group names, of course)

Superposition: fundamental principle illustrated in the layered rocks of the canyon: *the layered rocks on the bottom are oldest and become progressively younger as you move upward through the stack toward the top*

- Superposition is a basic, logical way of relating the ages of rock to one another. The layers on the bottom are older than the layers above and the layers on top are younger than the layers below.

So where did the sedimentary rocks of the Grand Canyon come from?

Nature wants to wear down the rocks in high, exposed, mountainous areas of the continents and use the eroded debris ("sediment") to fill in low areas of Earth's surface. Weathering and erosion act to wear away the rock comprising mountainous regions.

- **weathering** is the in-place breakdown of solid rock into smaller particles by water, wind, and glacial ice
- these smaller particles and grains (gravel, sand, silt, clay) are called **sediment**
- **erosion** is the removal of those smaller particles of sediment downslope by gravity into nearby streams and rivers

The loose sediment is transported downslope by gravity, wind, running water, or ice (glaciers).

- the loose sediment is eventually deposited as horizontal layers in low areas in various **depositional environments** *(e.g., lakes, rivers, deltas, deserts, beaches, shallow continental shelves, deep oceanic basins)*

Sedimentary rocks are the solidified products of mud, silt, sand and other loose sediment. The sediment was originally deposited as laterally extensive, horizontal layers in various depositional environments.

All of the information in this section is spelled out in the relevant pages of your textbook for this class. (Chapter 1, p. 18-20)

Sedimentary rocks are formed near Earth's surface by the following sequence:

1) **weathering** and **erosion** of previously existing rocks exposed on land to produce loose sediment (like sand, silt, clay, or gravel)

2) **transport** of loose sediment downslope by water, wind or ice (glaciers)

3) **deposition** of sediment in a topographic depression like a river floodplain, a lake, a delta, or an ocean basin (i.e., a **depositional environment**)

- deposition occurs when the energy of the transporting system (e.g., a river) decreases enough for grains to settle out by gravity along a relatively horizontal surface
- the finer silts and clays will settle out in quiet water environments (floodplains, lagoons, the deep ocean), whereas the coarser sand will be washed by currents and waves to accumulate in higher energy environments (beaches, sandbars, river channels)
- during deposition, sediments are deposited as horizontal layers because gravity causes particles of sediment to fall to their lowest possible position.

4) **burial**, **compaction** and **cementation**: over long periods of time, as loose sediment becomes buried by more sediment on top, it compacts, squeezing water out from between the grains

- with time, groundwater charged with ions in solution (e.g., calcium, iron, silica and many others) percolates through the tiny pores between grains. When the solution become concentrated enough in pores, a natural cement precipitates (of iron oxide, calcite or silica) that binds grains together into solid rock. (remember from high-school chemistry that "precipitation" is nothing more than the formation of a solid from a saturated solution)
- perhaps a kilometer or two beneath the surface, sandy sediment becomes cemented together over time to form ***sandstone*** (perhaps representing ancient deposition of sandy sediment on a beach or in a desert)
- silty sediment (finer grains than sand) hardens into ***siltstone*** (perhaps representing deposition on a floodplain or delta of a river)
- clay-rich sediment hardens into *claystone* (or *mudstone* or ***shale***) (perhaps deposition occurring somewhere where the energy level was low enough for clay particles to settle, like a lake bottom or seafloor)
- mixtures of clay, sand, pebbles and cobbles harden into **conglomerate** (perhaps deposition occurring somewhere where the energy level was temporarily high enough to move large heavy pieces of sediment as well as tiny particles, such as a raging river in flood)

In the **upper** sedimentary Grand Canyon, all the horizontal, multicolored layers represent a quarter-billion years of changing environments such as shallow oceans, meandering rivers and floodplains, and migrating deserts where thick deposits of eroded sediment came to rest over broad regions of western N.A.

All of these interpretations of depositional environments represented by rocks are based on the principle of **actualism** - what we can actually see occurring in today's world is likely what occurred in the past *(i.e., The present is the key to the past)*

- sediments being deposited today in lakes, rivers and their floodplains, deltas, ocean basins, etc., are modern analogs for ancient processes and environments
- if you want to study rocks formed within rivers, visit modern rivers; rocks deposited in deserts on sand dunes, visit modern deserts; volcanic rocks, study modern volcanoes

Easy-to-read resources other than the textbook:

Geology of Grand Canyon NP
https://www.nps.gov/grca/learn/nature/grca-geology.htm

Wikipedia – Geology of the Grand Canyon
https://en.wikipedia.org/wiki/Geology_of_the_Grand_Canyon_area

Wikipedia – Colorado Plateau
https://en.wikipedia.org/wiki/Colorado_Plateau

odds and ends: *(for your own info, not for an exam)*

- Grand Canyon is roughly a mile deep and averages about 10 miles across (from 9-18 mi wide)
- 277 circuitous miles of river within the park
- it takes a 380 km (235 mile) drive to see the canyon from the opposite rim
- the south rim (where most tourists go) has elevations between 5750-7400', whereas the north rim (more remote and difficult to get to) has elevations between 7450-9000'
- certain animals on the separate rims have evolved into separate species
- the average temperature range from river (hot) to rim (cooler) is about 20°F

- *Suggestion for studying for quizzes and exams in this class: Study these lecture notes by relating them directly with the images I provide, available in Files on Canvas. Visualizing the ideas and concepts in these notes using the images is a much easier way to understand them rather than just memorizing the words on paper.*
- *Every word in these notes is important so carefully read all of it. The main concepts and principles are of primary importance, with the details adding substance to the bigger picture.*
- *Create an organized digital notebook of these notes and images for efficient access during quizzes.*
- *And be sure to browse the sections of the textbook I suggest to tie everything together.*