GEOLOGY 25 - LECTURE 6

National Parks of the Rocky Mountains: *Glacier National Park*

Textbook Chs. 20 & 22

Rocky Mountain Province

The **Rocky Mountains** are a linear chain of mountain ranges that extend from northern New Mexico, through Colorado, Wyoming, Idaho, and Montana, then northward into Canada.
- the Rockies rise abruptly above the Great Plains to the east
- Rocky Mountain NP in Colorado is located in the southern Rockies, whereas Glacier NP in Montana is located in the northern Rockies

The Rockies compose the eastern flank of the wide and extensive **North American Cordillera**, the complex set of mountain belts that dominate the western part of the continent
- the N.A. Cordillera includes the Rockies, the Colorado Plateau, the mountains within the Basin & Range province, the Sierra Nevada, the Cascades, and the Coast Ranges of the Pacific rim.
- the north-south orientation of mountain ranges in the Cordillera relates to east-west tectonic stress

The Rockies are a result of **compressive forces** where the orientations of tectonic stress are directed toward each other
- rocks caught in the vise between converging stress fields (tectonically driven) tend to be squeezed and crumpled into **folds** or broken along specific types of faults called **thrust faults** *(more on these below)*
- the compressional stresses that formed the Rockies are related to the convergent, Andean-style plate boundary that bordered the continent to the west throughout the Mesozoic and well into the Cenozoic. (i.e., subduction of the Farallon plate beneath western North America) *(see Lecture notes 5 and information below)*
- the other major process that controls the topography and landscape of the Rockies is Ice Age glaciation

Glacier National Park

Glacier NP is the southern half of Waterton-Glacier International Peace Park that straddles the U.S.-Canadian border in northern Montana.
- located along the easternmost front of the Rockies
- the **continental divide** snakes northward through the park into Canada (a 'divide' is a drainage boundary that separates watersheds – in this case the continental divide separates rivers that drain to the Atlantic Ocean from rivers that drain to the Pacific)
– a raindrop on one side of the continental divide will end up in the Pacific Ocean whereas a raindrop on the other side of the divide will end up in the Atlantic

Over 7000' of relief w/ six mountains over 10,000' in elevation
- **relief** is the difference in elevation in any one area; in Glacier, the lowest elevations are around 3000' whereas the highest are just over 10,000'
- weather changes rapidly in the park, with snowfall occurring in any month. Some high elevation regions receive 400" per year.

- grizzly bear, wolves, lynx, mountain lions, moose, elk, bighorn sheep, and ubiquitous mountain goats

One main road traverses the park east-west: Going-to-the-Sun Road

Rocks composing Glacier NP . . .

The primary rocks composing the park are **Precambrian** age **sedimentary** rocks, about 1600 to 800 million years old.
- the rocks attain a thickness of >18,000' in the park area (but they're not neatly stacked like at the Grand Canyon. Instead, they're bent into folds and broken by faults.)
- the rocks are mildly metamorphosed, but retain many of their original sedimentary features that indicate accumulation in a shallow tropical seaway when the paleogeographic position of northern Montana was in an equatorial position (interpretations partly based on actualism)
- the main rock types are limestones, sandstones, and shales, some of which were mildly metamorphosed during episodes of mountain-building
- features in the rocks like **mudcracks** indicate periodically dry conditions on tidal flats, whereas **ripplemarks** on rock surfaces indicate shallow, moving water over a sandy substrate, perhaps on a beach or shallow tidal flat

The only fossils are domal mounds called **stromatolites** - organic structures built by primitive **cyanobacteria** as they photosynthesized in shallow tropical waters near the tidal zone
- the cyanobacterial colony would form a sticky layer of green slime as they photosynthesized. The tide would come in and bury the layer of slime with a layer of lime sediment. The cyanobacteria would send filaments upward through the sediment and recolonize the surface. This process repeated itself through time, building upward into a domal outer structure and a thinly laminated inner structure.
- stromatolites are very common in Precambrian sedimentary rocks since photosynthesizing bacteria dominated, with no multi-cellular organisms evolving till very late in the Precambrian (i.e., in the Precambrian, marine invertebrates like corals, clams, oysters, and other calcite-secreting animals had not yet evolved.)
- stromatolites were the first contributors of oxygen to our atmosphere. These 'mats of slime' released enormous amounts of oxygen as a waste product of photosynthesis.
- the cyanobacteria that formed stromatolites also were able to precipitate calcite from seawater, so the rocks they form are limestones
- because cyanobacteria are photosynthetic and therefore needed to live where the sunlight was the strongest, stromatolites provide evidence for warm, shallow tropical waters bathing that part of western N.A. during this portion of the Precambrian. (The rocks were laid down as sediments in very shallow tropical seas during the PC. They were deeply buried to become layers of limestone, then subsequently lifted up to their current height as the Rockies rose.)

All the Precambrian rocks in Glacier NP indicate shallow water deposition near sea level for hundreds of millions of years. As sediment accumulated, the weight of the sediment caused just enough **subsidence** of the underlying crust to keep the surface of deposition in the region close to sea level, maintaining the shallow water conditions for hundreds of millions of years. ("subsidence" was described in lecture notes 1B)

Laramide Mountain-building in Glacier NP

The rocks of the Rocky Mountains in Glacier NP have been squeezed by **compressive forces**, producing folds and thrust faults.
- many of the rocks have been bent into **folds**, a characteristic feature of regions that underwent compression sometime in their history.
- folds are simply bent layers of rock, squeezed into convex and concave shapes

As the rock folds over on itself during continued compression, the rock may break along **thrust faults** where the block of rock on one side of the fault is pushed up and over rocks on the opposite side of the fault plane at a low angle.
- you know from our discussion of rocks in the Colorado Plateau that younger rocks are always deposited above older rocks (law of superposition).
- but in Glacier NP, very old rocks overlie much younger rocks. This occurs long after deposition by thrust faulting resulting from compressive tectonic forces.
- thrust faulting occurs abruptly, one earthquake at a time, a few kilometers underground. The sheet of rock thrust above the younger rock moves in short increments, perhaps just a few meters during each earthquake. So over long periods of geologic time, many earthquakes must have occurred to force one huge block of rock far up and over another.

Thrust faulting due to tectonic compression occurred in the late Mesozoic to early Cenozoic.
- huge sheets of Precambrian and Paleozoic rocks were gradually pushed about 25 km eastward, over and above younger rocks of Mesozoic age.
- the thrust sheets extend far south of Glacier NP as well as northward to the Canadian Rockies – 450 km long, north to south
- many mountain ranges worldwide grow upward by the progressive stacking of thrust sheets one atop another through time
- each thrust sheet might be up to a kilometer thick
- the stack of thrust sheets is continually modified by weathering and erosion to produce the irregular topography of mountain ranges

The mountainous topography of the Rockies near Glacier NP is formed by the resistant Precambrian rocks juxtaposed above the less resistant shales and siltstones of the underlying Mesozoic rocks.

The low-angle thrust faults in Glacier NP were all generated during the **Laramide orogeny**, a compressional mountain-building event that occurred during the late Mesozoic and early Cenozoic throughout the American West.
- an **orogeny** is simply a widespread mountain-building event
- the Laramide event ranged from ~80 m.y. ago to ~40 m.y. ago and was the primary event in uplifting the Rocky Mountains
- during mountain-building events like the Laramide, thrust sheets are typically shingled one atop another at the surface of the Earth, creating high elevation topography
- after Laramide thrusting and uplift ended ~40 Ma, weathering and erosion (especially by glaciers during the Pleistocene Ice Ages) sculpted the landscape we see today

- the stacking of thrust sheets is a form of uplift expressed in many modern mountain chains including the Himalayas and Alps (as well as the ancient Appalachians)

Tectonics of the Laramide Orogeny of the American West

The Rocky Mtns and much of the American West was lifted upward during the Laramide orogeny that began around 80 m.y. ago and ended around 40 m.y. ago. (This included the mountains around Glacier NP, of course. And Rocky Mtn. NP in Colorado, which we have to skip this quarter.)

During the Laramide orogeny, compressional tectonic forces of the Farallon plate were oriented eastward toward the stable, strong interior of the continent, which acted as a buttress against the compressional forces from the west.

- the east-west-oriented compressional stress uplifted north-south-oriented mountain ranges, including the Rockies and highlands in Nevada.

The nearby **Colorado Plateau** also was uplifted into a broad, high-elevation plateau during the Laramide orogeny.

- the Colorado Plateau was uplifted as a relatively intact crustal block by tectonic compression during the Laramide. Uplift occurred by thrust faulting along the margins.
- for the most part, the sedimentary rocks of the region maintained their relatively horizontal layering during uplift. (this is sometimes referred to as "mushroom-style" uplift)
- this was the uplift event in the Colorado Plateau that triggered the formation of a highland plateau with a large lake (see notes on Bryce Canyon NP)

A second phase of uplift of the Colorado Plateau occurred during the late Cenozoic beginning 5-6 m.y. ago accompanied by deep incision by rivers and streams of the Colorado River system. *(This later phase of uplift was mentioned in notes 1B on the Grand Canyon, and in notes 2A and 2B on Zion and Bryce & 2C on Canyonlands)*

What was the tectonic setting for the Laramide orogeny?

Previously, between 120-80 m.y. ago subduction of the Farallon plate produced the granitic magma of the Sierra batholith in the ancestral Sierra Nevada. Intrusion of granitic magma ended around 80 m.y. ago at the onset of the Laramide. The supply of magma from the subduction zone ended and a long phase of erosion of the ancestral Sierra Nevada began.

Since the Rocky Mountains were so far inland from the subduction boundary during the Mesozoic/early Cenozoic (700-800 miles), the subducting Farallon oceanic slab is interpreted to have descended at a very shallow angle and was able to transmit compressive stress by 'underplating' far toward the interior of the continent.

- this tectonic model for the Laramide orogeny is called **flat-slab subduction**.
- evidence for flat-slab subduction is the total absence of subduction-related volcanism throughout the American West of late Mesozoic to early Cenozoic age because the subducting Farallon plate never got deep enough (~150 km) to melt overlying rock of the mantle to produce magma that would then rise toward the surface. (Plutonism and intrusion of the granites within the ancestral Sierra Nevada ended around 80 m.y.a. due to the gradual flattening of the subducting plate.)

- so the model for the Laramide orogeny affecting such a broad area of the American West is the flat angle of subduction causing the overlying continental plate to compress (kind of like sliding a piece of plywood beneath a throw rug)

Ice Age landscape modification . . .

As with all of the other high-latitude, high-elevation national parks, Ice Age glaciation created the modern landscape of Glacier NP, sculpting the mountains in much the same manner as at national parks of the Cascades, Yellowstone, Yosemite, Sequoia/Kings Canyon, and Grand Tetons.
- U-shaped valleys, hanging valleys, cirques, arêtes, hundreds of glacial tarns and paternoster lakes, and a variety of other glacial features characterize the landscape
- remember that cirques form at the head of alpine glaciers beneath the zone of accumulation

Many lakes contain "**glacial flour**," fine particles of silt suspended in the water that imparts a milky turquoise color to the waters. The powdery glacial flour is derived from the abrasive action of sand- and gravel-size sediment entrained along the base of glaciers, which produce tiny silt-size particles as they grind over the underlying bedrock. The glacial silt is discharged with meltwater and is fine enough to remain suspended in lakes where it reflects and refracts light to produce the characteristic bluish sparkle.
- some U-shaped valleys are filled with snowmelt to form **elongate glacial lakes**
- Lake McDonald is an example of an elongate glacial lake formed behind a natural dam created by the 'bulldozing' of debris at the front of an advancing mountain glacier, with the debris left behind as the glacier melted and receded. The linear pile of sedimentary debris forms a natural dam that backs up water to form the lake.
- glaciers act like giant rasps due to the sedimentary debris carried along in the basal layers of ice that scrap away at the underlying soil and rock, partly by glacial plucking, partly by glacial abrasion

~25 active glaciers in the park
- Grinnell Glacier, the largest in the park, has retreated significantly over the past several decades, accompanied by the growth of a large meltwater lake.
- unfortunately, climate change is causing glaciers in Glacier NP to recede. It's estimated that Glacier NP will have no glaciers in 30 years.

Best hikes in Glacier NP
https://www.earthtrekkers.com/best-hikes-in-glacier-national-park/

A few websites with relevant material if you're not using the textbook
National Park Service – Geology of Glacier NP
http://www.nps.gov/glac/naturescience/geologicformations.htm
Wikipedia – Geology of Glacier NP
http://en.wikipedia.org/wiki/Glacier_National_Park_(U.S.)