GEOLOGY 25 - <u>LECTURE 5B</u>

National Parks of the Sierra Nevada: *Yosemite NP*

[Textbook Chs. 18 & 14 (p, 137-141)]

Yosemite National Park

Yosemite NP is on the short list for all Californians to visit. It's full of jaw-dropping scenery and iconic landmarks.

- the mountains reach 13,000' along the eastern boundary of the park along the Sierran crest but are only ~2000' along the western approaches. (reflecting the wedge-shaped geometry of the Sierra tilted fault block)

Yosemite is drained by the westward-flowing Tuolumne and Merced rivers, which originate in the high elevations to the east along the Sierran crest. These river networks cut V-shaped gorges and valleys that formed natural pathways for alpine glaciers to follow.

- the Tuolumne River backs up behind a dam to create Hetch Hetchy reservoir, which is the primary water supply for SF and the Bay Area.

Yosemite National Park is underlain almost entirely by granitic rocks of the Sierran batholith.

The granitic magmas intruded into older Paleozoic and early Mesozoic sedimentary and volcanic rocks, now thoroughly metamorphosed (more on this when we visit Sequoia-Kings Canyon NPs)

- remember that the majority of the granitic magma intruded and solidified between 120 and 80 m.y. ago.
- one of the more distinctive granitic rocks in Yosemite is the Cathedral Peak "granite" - large angular crystals of pink feldspars (2-3" long) float in a salt-and-pepper matrix of quartz and darker minerals. The feldspar crystals are slightly more resistant to erosion than the finer-grained minerals (differential erosion), so they stand out in relief, providing toeholds for climbers.

Landscape Evolution of Yosemite NP

Four important processes/features contribute to the High Sierra / Yosemite / Sequoia / Kings Canyon landscape – **planar jointing**, **exfoliation jointing**, **rockfalls** and **glaciation** – all are somewhat interrelated

Multiple joint sets characterize the granitic rocks of Yosemite/Sequoia/Kings Canyon - they are a natural, planar feature created during uplift of mountains by tectonic stresses.

- joints act as zones of weakness for water to seep into. This water seasonally freezes and thaws (thus expands and contracts), wedging apart the rock along the joint plane.
- some granitic bodies exhibit one parallel set of joints and form imposing, massive cliffs, like El Capitan
- other bodies in the parks exhibit 2 or more intersecting joint sets that form angular, blocky landforms, like Three Brothers and Cathedral Spires
- the same planar jointing occurs throughout the Sierra Nevada, including Sequoia / Kings Canyon NPs

A different type of jointing, called **exfoliation**, forms concentric sheets in granitic rocks, creating an 'onion-skin' appearance to the surface

Intrusive igneous rock (such as the granitic rock that typifies Yosemite) is usually massive and featureless. But as the rocks are uplifted in mountain belts, pressure is released by erosion of overlying rock. This release of confining pressure causes the rock to expand outward, forming thin sheets that flake off (exfoliate). **Exfoliation** is also known as "sheet jointing" or "onion-skin jointing" because of the rounded, sheeted appearance of the granitic surface.

- the fractures between sheets permit the infiltration of water, weakening the rock and setting the stage for slabs to slide away as rockfalls.

Exfoliation is the process that forms **domes** in the High Sierra, including North Dome and Sentinel Dome in Yosemite and several prominent domes in Sequoia/Kings Canyon (e.g., Moro Rock).

How are the vertical cliffs maintained at Yosemite/Kings Canyon/Sequoia?

Some cliff faces in Yosemite (like those of El Capitan, Taft Point and Glacier Point) drop ~3000 vertical feet

Planar joints and exfoliation joints create planes of weakness in rocks that makes them susceptible to detachment from the main mass.

Rockfalls are very common in Yosemite Valley and help to maintain the vertical cliff-faces loved by tourists and rock-climbers.

- 1996, 162,000 tons of rock plummeted 2000', killing one visitor and felling 500 trees
- rockfalls occur as a mass of rock free-falls or bounces down the side of a vertical cliff, exploding into pieces at the base. The debris from rockfalls accumulates as large, angular blocks of rock (called **talus**) at the base of cliffs, a common feature in Yosemite Valley.
- all of the steep cliffs in the valley have talus piles along the base, indicating countless prehistoric and historic rockfalls.

Rockfall from El Capitan, Sept. 28, 2017 – two rockfalls in two days. The first was relatively small but killed a man below (measured 130'x65' & 1300 tons). The second was much larger but didn't kill or hurt anyone because the Park Service cleared everyone out of the area.

Rockfalls may be triggered by intense rainfall or small earthquakes.

- there are also many examples of "spontaneous" rockfalls, without any apparent trigger. Measurable evidence suggests that the temperature extremes between day and night along cliff faces may cause thin outer layer of rock to expand and contract as much as a centimeter per day. This daily "breathing" of the rock along joints may enhance the loosening of slabs of rock from the main face along joint planes, causing rockfalls without any clear trigger

On average, about 80 rockfalls happen each year in Yosemite, most occurring along the cliffs of the Valley. Over the years, 15 deaths and at least 85 injuries have been attributed to rockfalls. The Park Service has mapped over 900 distinct rockfalls and has developed a master plan for reducing the risk as much as feasible to protect visitors as well as infrastructure.

How did glaciers modify the modern Yosemite landscape . . . .

The rugged topography of the modern Sierra, including Yosemite/Sequoia/Kings Canyon, was carved by **alpine glaciers** (aka "mountain glaciers") over the past **2.6 m.y.** during the **Ice Ages**.

- alpine glaciers flowed like solid rivers of ice downslope through the canyons of the Tuolumne and Merced rivers and through all smaller stream valleys. In the park the glaciers flowed from east to west, down the western slope of the Sierra.

The last 2.6 m.y. of Earth history are formally called the **Pleistocene Ice Ages**.

The end of the Pleistocene occurred about 12,000 years ago when the planet entered a phase of natural global warming called the **Holocene**. We currently live in the Holocene interglacial warm phase of Earth history. (Our current human-induced global warming is superimposed on the Holocene warming and is occurring much much faster than the natural warming prior to the Industrial Revolution.)

- during the Pleistocene Ice Ages, thick **continental ice sheets** extended from high northern latitudes down to the latitudes of Nebraska and Illinois. The ice sheets were as thick as 2-4 kilometers (up to 2.5 miles thick).
- continental ice sheets exist today on Greenland and Antarctica – they are much much more massive than alpine glaciers

Vast continental ice sheets advanced and retreated >20 times over the past 2 m.y., with cold **glacial phases** alternating with warmer **interglacial phases**

- evidence comes from certain glacial landforms on the continents, sediment cores from the oceans, and ice cores from Greenland and Antarctica
- the periodic changes in global temperatures, shifting over 6 - 10°C (~10-17°F) from global cold to global warmth, are controlled by periodic changes in Earth's orbit and the tilt of its axis

The most recent glacial phase peaked around 20,000 years ago and is called the **Last Glacial Maximum**

- alpine glaciers advanced and retreated in sync with the continental ice sheets, responding to the periodic changes in global temperatures
- the climate of western North America was much wetter during the transition from glacial to interglacial phases as the ice melted. Large lakes formed throughout the west, filling what are now desert valleys (including a lake in Death Valley that was ~300' deep)

In high mountain ranges like the Sierra, Ice Age glaciers took the form of elongate **alpine glaciers** rather than vast continental ice sheets

- alpine glaciers extended downslope eastward and westward from an **ice cap** that covered the crest of the Sierra. (Ice caps are smaller than continental ice sheets and usually crown the highest elevations in mountain ranges worldwide. Alpine glaciers originate from the margins of ice caps, flowing downslope away from the cap.)
- alpine glaciers migrated back and forth across Yosemite's terrain multiple times during the Ice Ages, eroding and modifying the landscape.

The heads of the glaciers of the Last Glacial Maximum began along the Sierran crest that marks the east side of the park. Enormous volumes of snowfall accumulated in the highlands during the cold climate, fed by storm fronts from the Pacific that rose up the western flank of the Sierra. Over centuries to millennia, the snows transformed into dense ice in the harsh glacial conditions, eventually becoming massive enough to flow as a plastic solid downslope under the force of gravity. Individual alpine glaciers coalesced in the high country (around Tuolumne Meadows) to form a continuous sheet of ice that reached over 600 meters (2000') in thickness. The grinding action of sedimentary debris in the ice carved the terrain into a jagged expanse of exposed granitic bedrock.

As you know from the description of alpine glaciers from the Mt. Rainier notes, alpine glaciers are "rivers of ice" that slowly flow downslope under their own weight, scraping and abrading the underlying and adjacent rock.
- glaciers transport huge amounts of sedimentary debris within the ice, on top of the ice, and along the base of the ice
- much of the physical **abrasion** of the underlying rock is done by the sand, pebbles, and grit transported along the base of the glacier
- many landscape features of the High Sierra, including at Yosemite, reveal the former presence of large, mobile alpine glaciers.

*What are some common **glacial landforms** left behind by glacial erosion and deposition?*

U-shaped valleys - characteristic shape of glacially carved valleys, with steep sides and broad bottoms. Alpine glaciers occupied the V-shaped valleys carved by rivers and streams, modifying them through erosion into U-shaped glacial valleys.
- the glacier that filled Yosemite Valley was over 2000' thick and only the highest peaks poked out above the ice

Abrasion by sedimentary debris carried along the base and margins of alpine glaciers is an important process in eroding bedrock along the base and flanks of valleys.

hanging valleys – The massive glaciers filling the main valleys of the Tuolumne and Merced rivers cut much deeper valleys than their smaller tributary glaciers because they have greater erosive power. As the Ice Age glaciers retreated during interglacial warming phases, the tributary glaciers were left "hanging" high on the valley walls. As meltwater streams flowed through these U-shaped hanging valleys, the water plummeted over the edge into the much deeper main valley, creating the famous waterfalls of Yosemite Valley, including Yosemite Falls and Bridalveil Fall.

glacial erratics – alpine glaciers carry enormous amounts of rock and sediment within the body of the ice. When the glaciers begin to melt and recede during warmer interglacial climates, they drop their load of sedimentary debris. Some of the debris left behind are huge boulders called glacial erratics.

striations and **glacial polish** – sand and pebble-sized particles trapped within the ice at the base of the glacier act as a rasp on the underlying bedrock, abrading it as the glacier grinds across the surface. The gritty sediment may score the underlying bedrock with linear grooves and scratches, forming striations oriented in the direction of movement of the glacier.

The abrasive action of silt-sized particles at the base of the glacier may create a shiny, glassy surface known as glacial polish.

A few small active glaciers remain in Yosemite. They are not remnants of the Pleistocene Ice Ages, but rather formed during the **Little Ice Ages** between 1350-1850 AD.

Today, Yosemite glaciers are shrinking rapidly in response to global climatic warming. The Lyell Glacier, once Yosemite's largest, has shrunk 78% since 1883 and will likely be gone in 10-20 years.

As we visit more parks, we'll add more glacial processes and glacial features to our list.

Half Dome is a great example of all four landscape-forming processes working collectively to create the iconic feature . . . .

Half Dome rises ~4700' above the floor of Tenaya Valley, a branch of Yosemite Valley

- Half Dome developed due to both vertical jointing and exfoliation, with help from rockfalls and glacial activity. The smooth, rounded south face is a result of exfoliation. The sheer, vertical north face of Half Dome was originally created by the collapse of huge slabs of rock between parallel vertical joints that were loosened by weathering until they fell away to the floor of the valley as individual earth-shaking rockfalls.
- Half Dome was later modified by glaciers that froze against the lower rock face and "plucked" out large slabs isolated by vertical joint sets. (Tenaya Glacier reached within 500' of the top of Half Dome.)
- the Tenaya Glacier in the valley below Half Dome bulldozed away the talus from the base of the slope

Easy, moderate, and strenuous hikes in Yosemite Valley:
https://www.nps.gov/yose/planyourvisit/valleyhikes.htm

https://www.alltrails.com/parks/us/california/yosemite-national-park

Where to camp near or in Yosemite
https://www.hipcamp.com/en-US/discover/california/yosemite-national-park

To get reservations for a campsite in Yosemite you'll need to create an account at https://www.recreation.gov then search for the park you want to visit.

A few websites with relevant material if you're not using the textbook

National Park Service – Geology of Yosemite NP (and the other links on the page)
    https://www.nps.gov/yose/learn/nature/geology.htm

Wikipedia – Geology of Yosemite NP
    http://en.wikipedia.org/wiki/Geology_of_the_Yosemite_area

Wikipedia - Ice Ages
    https://en.wikipedia.org/wiki/Ice_age

"Climb the mountains and get their good tidings. Nature's peace will flow into you as sunshine flows into trees. The winds will blow their own freshness into you, and the storms their energy, while cares will drop off like autumn leaves."

- John Muir

Getting to Yosemite from Davis: