GEOLOGY 25 - LECTURE 8

Yellowstone NP- Supervolcano

Textbook Ch. 31

Yellowstone National Park

Located in the northwestern corner of Wyoming, with edges in Idaho and Montana.
- situated along the northwesterly trend of the Central Rocky Mountains (but geologically distinct from the Rockies)
- the broad banana-shaped plain to the southwest of Yellowstone is the **Snake River Plain**, that cuts across the north-south grain of the Rocky Mountain topography
- oldest NP, established in 1872. originally overseen by the Army until the National Park Service was established in 1916.

Continental divide extends through the park. Rainwater and snowmelt on the east side of the divide drains through the Yellowstone River (and Madison & Gallatin rivers) northward and eastward where it merges with the Missouri River in Montana. The Missouri River eventually drains into the Mississippi near St. Louis, which then empties into the Gulf of Mexico/Atlantic Ocean.
- rainwater and snowmelt on the west side of the divide in the park drains into the Snake River that eventually winds its way toward the Columbia River and into the Pacific Ocean.

Yellowstone occupies a broad, high **plateau** (~8000' avg. elevation) surrounded by high mountains of the Central Rockies (up to almost 14,000'). But Yellowstone is very different geologically from the rest of the Rocky Mountain province.
- plateau slopes toward southwest onto the Snake River Plain in southern Idaho
- Grand Teton NP to south, enormous Absaroka Range to the east
- Madison, Gallatin, and Beartooths to the west and north

Yellowstone "Supervolcano"

The Yellowstone "volcano" occupies a broad oval basin left behind by gargantuan eruptions - a **caldera**. You were introduced to caldera eruptions at Crater Lake NP, so you might want to review those notes.
- Yellowstone's volcanism is concentrated over a huge caldera with dimensions of about 30x45 miles. (Crater Lake caldera is about 5 miles across, for comparison)
- the Yellowstone caldera is considered an **active** volcano because of the large magma chamber that underlies the region, even though there hasn't been an eruption for the past 70,000 years.

The volcanic system that underlies Yellowstone NP meets the criteria for a **supervolcano**: defined as a volcano that has had eruptions that are orders of magnitude greater than any volcano in historic times. This kind of eruption is typically large enough to cause a long-lasting change to climate and cover huge areas with lava and ash.
- the Yellowstone volcano is active and capable of a mega-eruption, but caldera eruptions are rare, typically occurring on the order of every few hundred thousand years

Calderas are huge downdropped basins formed after large eruptions that empty part of the underlying magma chamber. A **caldera eruption** occurs after the gas-pressurized magma creates a bulge in the overlying crust enough to form a ring-shaped set of vertical fractures that extend to the surface. Magma surges up through these new cracks, eventually forming a ring of erupting vents. As the magma chamber empties itself through **pyroclastic eruptions**, the remnant, overlying crown of the volcano collapses down into the void created by the vacated magma, forming the down-dropped caldera basin.

- the erupted pyroclastic debris and younger lava flows partly fill and smooth the caldera floor
- the caldera rim can be located in some places in the park, but most of the outline of the caldera margins has been obscured by glacial erosion and forests.

Ancient and modern volcanic activity at Yellowstone is powered by two large **magma chambers** located between 5-12 km beneath the surface. (you should remember magma chambers from our discussion of the Sierra Nevada batholith)

- below the stacked magma chambers is a huge column of hot rock that slowly rises up through the mantle (called a mantle plume, we won't have time to talk about these)

Three recent volcanic episodes are recognized on the Yellowstone Plateau, all within the last 2.1 million years (very recent volcanism, considering geologic time spans).

- the oldest eruption occurred 2.1 m.y.a., a second at 1.3 m.y.a., and the most recent at 630,000 years ago (which produced the present Yellowstone caldera).
- the eruptions might have only lasted a few days to a few years each but were extremely violent based on the wide distribution and total volume of pyroclastic debris and lava produced during each eruption.

The following information on pyroclastic volcanism was addressed in the earlier classes on Cascades volcanoes. If any of the terms below seems unfamiliar, re-visit the relevant Cascades notes.

- **pyroclastic debris** consists of ash, rock fragments of all sizes, and many gases - this material is released during violent pyroclastic eruptions.
- **ash** is composed of very fine particles of rock and volcanic glass that form from the instantaneous chilling of molten rock as it is explosively erupted into the atmosphere.
- ash blown vertically into the sky from a volcano eventually falls out of the atmosphere (called **pyroclastic fall** or **ash-fall**) and forms widespread layers on the surface of the landscape
- ash that flows laterally along the flanks of a volcano are called **pyroclastic flows** or **ash-flows**
- when ash settles and solidifies, it forms a volcanic rock called a **tuff**

Most of the rock that you see in the park is relatively young and volcanic, consisting of **ash-fall tuff**, **ash-flow tuff** and lesser **lava flows** from these three latest eruptions

- the buff yellow color of much of the tuff in Yellowstone is caused by hot, acidic groundwater that percolates through the rock, altering its color. Hence, "Yellowstone".

Ash fallout from the 630,000 yr old eruption can be recognized as a single layer (that thins toward its margins) from California to Texas

- the ash-fall tuff from the most recent caldera eruption at Yellowstone (630,000 years) is up to 1600 ft thick near the source to as thin as an inch or two at its most distant reaches

- the 2.1 m.y. eruption was one of the largest volcanic blasts in the history of the Earth: the ash-fall tuff from that event would have buried all of the states west of the Mississippi River two feet deep.
- force of the blast and blanket of ejected material killed all life for hundreds of miles around the region, including Ice Age mammals that roamed about such as camels, giant ground sloths, wooly rhinos, and mammoths.
- deposition of even a millimeter-thick layer of ash on today's world would shut down airports and other transportation networks and dramatically reduce agricultural production – the environmental and health effects would be felt worldwide for decades

Caldera eruptions are far less common than typical single-crater volcanoes - but when they explode, the effects are far more widespread. Short of an impact by an asteroid or comet, caldera eruptions are arguably the most disastrous natural event that can happen to a planet.
- the Yellowstone caldera eruptions were of a magnitude unlike anything known in historic times.

Future eruptions at Yellowstone?
It is impossible to predict when more eruptions will occur at Yellowstone.
Eventually, likely not for several tens to hundreds of thousands of years, but perhaps sooner, a new cycle of Yellowstone volcanism will begin again.
- based on past history of volcanism, length of time between eruptions (~700.000 years), high seismicity, shallow active heat source, and high heat flow, future eruptions are inevitable. It's highly likely that the magma chamber beneath Yellowstone is slowly being replenished with molten rock derived from sources deep in the mantle.

Almost all volcano experts agree that those of us living on the earth today are exceedingly unlikely to experience an active supervolcano. Catastrophic eruptions tend to occur only once every few hundred thousand years.

Hydrothermal activity at Yellowstone . . .

Yellowstone National Park contains the world's largest concentration of geothermal features. In fact, this is the primary reason it was set aside as a National Park in 1872.
- with an estimated 10,000 geysers, hot springs, mud pots, and fumaroles (steam vents), Yellowstone sits on one of the hottest hot spots on Earth.
- most of Yellowstone's geothermal features are clustered into about 120 distinct thermal areas, most barren of vegetation.

Heat flow is simply a measure of the amount of heat emanating from the surface.
- surface heat flow at Yellowstone is 30 times the rest of North America (due to the magma chamber not that far beneath the surface)
- temperatures reach 400°F at depths of 500-600' in drill holes at Yellowstone
- heat is transported to the surface within hydrothermal waters

Water from rain or snowmelt migrates downward through fracture systems (joints, faults) until the water comes in contact with either hot rock or the deep magma chamber. As the water gets

hotter, it expands and becomes buoyant, eventually migrating back toward the surface transporting gases and heat energy.
- results in **hydrothermal** (i.e., hot water) features across the surface: geysers, hot springs, mud pots, and steam vents
- hydrothermal features require: 1) a powerful heat source, such as a magma chamber at depth, 2) a plentiful supply of water, such as abundant rainfall and snowmelt, and 3) a natural "plumbing" system of joints and faults.

We've already talked about hot springs and fumaroles (steam vents) when we discussed Lassen Volcanic NP. Here at Yellowstone we'll focus on the abundant geysers and hot springs.

geysers - intermittent jets of hot water and steam that regularly or irregularly erupt.
- there are only about 1000 active geysers on Earth, with about half in Yellowstone.
- Old Faithful geyser - probably the most popular feature of Yellowstone. Reaches an average height of 130', with each eruption lasting about 4 minutes. Followed by a quiet period of about 70 minutes before it erupts again. (This cycle varies somewhat from month to month and year to year.)
- the hot, acidic waters dissolve silica from the volcanic rocks below the surface. When water blasts outward as a geyser, the silica in the hot water is emitted. As the water runs off the slope of the geyser, the silica is deposited as **sinter** (more below)

How Old Faithful geyser works:

About 23 feet below the surface, a narrow constriction of built-up silica restricts the upper conduit beneath the geyser to only 4 inches across. (acts like a nozzle on a hose)
- hot water backs up beneath the constriction, filling cavities and fractures in the underlying "plumbing system"
- pressure builds within the superheated (400°F) water beneath so that the water begins to vaporize to steam.
- steam pressure builds to a threshold then buoyantly pushes through the constriction above, causing a gurgling of water at the surface. The water beneath the steam follows up through the constriction with tremendous force, causing the water to jet upward as a plume of steam-driven water
- the temperature of water ejected from Yellowstone's geysers averages 95°C (204°F)

hot springs – pool of permanent hot water fed by a continuous supply heated from below and transported upward through fractures. Temperatures may range from just above human body temperature to near boiling.
- the difference between a geyser and a hot spring is that the supply of water is continuous beneath a hot spring, with no constrictions or back-ups
- Grand Prismatic Hot Spring - 200' wide, vividly colored hot spring. Various colors due to different species of microbes that thrive in the superheated waters. Water flows upward into the spring at a rate of 4000 gallons per minute, making it North America's largest hot spring.

The surface of the land around geysers and hot springs is commonly covered in a white crust of silica (SiO_2) called **sinter**. As acidic hot water rises through the silica-rich volcanic rocks beneath the surface, it dissolves silica out of the rocks. When the water either erupts from a geyser or pours

out onto the land near a hot spring, the silica precipitates from the saturated water to form crusts of whitish sinter in the surrounding area. Various bacteria may colonize puddles of hot water on the sinter crust, turning it yellow or orange or other shades.

Influence of the Ice Ages

Over the past 2.6 m.y., **ice caps** and **alpine glaciers** waxed and waned, reaching thicknesses of 3000' in the Yellowstone area.
- many glacial landforms similar to those you've learned from earlier parks
- the surrounding mountains poked out like islands through the ice sheet. Sharp, pyramid-shaped peaks are called **horns**, formed at the intersection of three cirques.
- **glacial erratics** – huge boulders left behind after glaciers receded, are common in the park

As the thick ice caps and alpine glaciers melted during warmer interglacial phases, their meltwaters raged through river valleys, incising deep, narrow canyons and erosionally modifying the landscape. (e.g., Grand Canyon of the Yellowstone River)

The same incision by glacial meltwater happened on the **Colorado Plateau** as well. When glaciers melted in the Colorado Rockies, the water and sedimentary debris released from the glaciers flushed down the Colorado River and its tributaries with tremendous velocity and erosional power. Incised canyons were deepened by the massive floods of glacial meltwater and debris that formed as the glaciers melted during warmer interglacial phases. (Remember that this would have occurred 20-30 times during the 2.6 m.y. of the Ice Ages.)

Best hikes in Yellowstone NP
https://www.tripsavvy.com/the-best-hikes-in-yellowstone-national-park-5212926

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

National Park Service – Geology of Yellowstone NP
http://www.nps.gov/yell/naturescience/geology.htm

National Park Service – Yellowstone geologic history
http://www.nps.gov/yell/learn/nature/volcano.htm

Yellowstone hydrothermal features
http://www.yellowstonenationalpark.com/geology.htm

Wikipedia – Geology of Yellowstone NP
http://en.wikipedia.org/wiki/Yellowstone_National_Park

If you want to be terrified watching a science-based fictional movie on a Yellowstone super-eruption, watch: *http://www.youtube.com/watch?v=4AjQvOWUJ2o*
