GEOLOGY 25 - LECTURE 4A

National Parks of the Cascades: *Mount Rainier NP*

[Textbook Chapters 12, 14 & 1 (p, 5-7, 10-13)

Cascade Range

Cascades extend ~1100 km (700 mi) from Northern Calif., through Oregon and Washington, to southernmost British Columbia

- four national parks and one national monument included within the range: North Cascades NP, Mount Rainier NP, Crater Lake NP, Lassen Volcanic NP & Mt. St. Helens NM

There are two features of the Cascades geologic province that differentiate it from the geology and landscapes of the Colorado Plateau. First, the age of the rocks and the age of the mountainous terrain of the Cascades are both **geologically very young**, related to the fact that **both the rocks and the mountainscape form contemporaneously by the same youthful volcanic processes**. This is in direct contrast to the Colorado Plateau where the rocks are very old, but the erosional landscape is relatively young.

The second feature that distinguishes the national parks and monuments of the Cascades from those of the Colorado Plateau is the presence of **glaciers** and snow crowning the volcanic summits.

Many of the Cascades volcanoes are just a few thousand years old, extremely young by geologic standards, and many are capped by glaciers

- the national parks and monuments of the Cascades geologic province are ideal for introducing the concepts of tectonism, volcanism, and glaciation – all basic geologic processes that you'll hear about constantly over the rest of the course.
- all of the 13 major volcanoes in the chain are active and hazardous, as expressed by the 1980 eruption of Mt. St. Helens in Washington

US Geological Survey volcanologists, along with colleagues from academia and state geologists, have constructed a chronology of volcanic events in the Cascades over the past 4000 years

- involves careful mapping, sample collection, geochemical analysis, and radiometric age-dating to compile the plot (this is what some geologists do)
- of the 13 active volcanoes of the Cascades, 11 have erupted in the past 4000 years.
- Mount St. Helens in southern Washington has been the most consistently active volcano in the recent past, followed closely by Mount Shasta and Mount Rainier.
- both Lassen Peak and Mount St. Helens have erupted within the 20th century.

Plate Tectonics & the Origin of the Cascade Range of Volcanoes

The locations of earthquakes and volcanoes coincide with the margins of **plates** - large, tabular slabs of the Earth's outer surface that are in constant slow motion. When they push together, mountains are built. When they pull apart, ocean basins are created. Earthquakes and volcanoes signify the interaction between plates along their margins.

plate tectonics - the continual creation, motion, and destruction of parts of the planet's active outer surface.

- plate tectonics explains the location of volcanoes and earthquakes as well as the origin of mountain ranges and ocean basins.
- **plates** are about 100-150 km thick (a relatively thin part of the outer Earth considering the planet has a radius of 6371 km)
- plates may consist of only oceanic rock (like the Pacific plate) or they may consist of both oceanic rock and continental rock (like the South American plate) (The rock composing the ocean basins is fundamentally different from the rock composing the continents. The details don't necessarily matter for this course.)
- **tectonics** refers to the large-scale, long-term, slow motion of slabs of Earth's outer surface

The surface of the Earth is in continual motion. New crust is being formed today on the ocean floor. Old crust is being destroyed. All the surface of the planet is in constant slow motion.

Plate motion is driven by the internal heat of the Earth, left over from its original creation, plus heat generated by natural radioactivity in rocks of the Earth.

Hot, weak rock in the mantle slowly flows like a plastic material within **convection currents** at rates of 2 to 15 cm/yr (~100 km/m.y.) dragging along the overlying rigid tectonic plates

Plates can either move away from each other at **divergent** plate boundaries, or they can push together at **convergent** plate boundaries, or they can grind laterally past one another along **transform** plate boundaries.

For most of this course we'll focus on convergent plate boundaries because these are the ones that influenced most of our national parks. We won't discuss divergent boundaries because they don't really impact many of our national parks. We'll talk about transform boundaries when we get to parks along the San Andreas fault toward the end of the course.

The **Andes Mountains** of South America can be used as an analog to illustrate the origin of the Cascade volcanic chain. The Andes are the longest mountain chain on the continents.

- the Andes occur along a **convergent plate boundary** where two plates converge against each other to produce high-elevation, volcanic mountain chains
- the oceanic Nazca plate is denser than the South American continental plate and descends beneath in a process called **subduction** (the entire region is called a **subduction zone**)
- during subduction, the oceanic plate is pulled down along its contact with the adjacent continental plate to form a **deep ocean trench** on the seafloor, up to 8-11 km deep (the average ocean depth is 4 km)
- the deep ocean trench marks the actual convergent boundary between the two plates
- as the oceanic plate subducts, overlying rock of the mantle will melt when it attains a certain depth and temperature (commonly around 100-150 km) (melting of the overlying plate occurs primarily because of the release of water from the wet oceanic sediments along the surface of the downgoing slab of rock)
- this molten rock (i.e., **magma**) is buoyant and rises toward the surface where it may either crystallize in place to form a large body of rock, or it may find a way to the surface and erupt from a volcano
- the most explosive and dangerous volcanic eruptions are associated with subduction zones

This example from the Andes is important to remember since it is not only analogous to the modern Cascades, but it also is an actualistic analog for the ancestral Sierra Nevada that we'll talk about soon.

Tectonics & Volcanoes of the Cascades:

The Cascades exist due to a **convergent plate boundary** where the oceanic Juan de Fuca plate (and two smaller plates) converge against the continental North American plate along a subduction zone to produce a volcanic mountain chain

- convergence along Cascades margin occurs at a rate of about 4 cm/yr
- region collectively called "**Cascadia**" - geologically active area at risk from volcanic eruptions, earthquakes, and tsunami
- the small oceanic plates are denser than the North American continental plate and thus subduct down into the mantle
- each of the Cascade volcanoes has its own magma chemistry and history of development, even though they all originated by the same general tectonic process of subduction

Volcanoes may erupt molten rock as **lava flows** (red eruptions) or they may erupt particles of **volcanic ash and larger blocks of rock** (gray eruptions). Or they may erupt both in their lifetimes.

Volcanoes created along subduction zones typically take the form of steep-sided, conical edifices called **stratovolcanoes**, which have the classic "inverted cone" shape that we typically associate with volcanoes.

- conical shape produced by the accumulation of alternating layers of volcanic ash and solidified lava flows. Most (but not all) volcanoes of the Cascades are stratovolcanoes. The vertical upbuilding of volcanic deposits determines the conical shape.
- the layers composing a stratovolcano may represent hundreds of discrete eruptive events occurring over tens of thousands of years
- both the landscape of a volcanic mountain and the rock composing the volcano are created at the same time during eruptions

Stratovolcanoes commonly erupt violently in **pyroclastic eruptions** that form a vertical column of ash and volcanic debris that reaches tens of km into the atmosphere.

- gas pressure (from H_2O, CO_2, NO_2, SO_2 and other gases dissolved in the magma) within the magma chamber provides the energy for the upthrust of molten rock that crystallizes into small particles of rock and glass (i.e., ash) during the eruption
- **pyroclastic debris** (the solidified particles of magma) ranges across a variety of sizes, from tiny grains of volcanic ash to boulder-sized blocks

volcanic ash is composed of dust-sized particles of rock and tiny shards of glass that form instantaneously from the abrupt cooling of magma during the explosive eruption.

- much of the ash falls directly back down onto the volcano and surrounding region, but winds transport much of the solid pyroclastic particles across great distances before they eventually fall out across the landscape, covering everything in a blanket of ash

Mount Rainier National Park

Located in Washington, southeast of Seattle, Mt. Rainier is the highest mountain in the Cascades (14,411’) and second highest in the coterminous U.S.

- established as the 5th national park in 1899

Mount Rainier is a stratovolcano formed from hundreds of individual **lava flows** that occurred over the last 500,000 years – it punched its way upward through older volcanic rocks of the Cascades

- the most recent major eruptive phase culminated in a massive explosion about 5700 yrs ago that blew off the summit and much of the upper eastern flank
- subsequent smaller eruptions over the past few thousand years have smoothed and modified the mountain and active glaciation has resculpted the volcanic terrain
- although there are no documented historical eruptions on Mt. Rainier, it probably had some minor eruptions during the 19th century

Many stratovolcanoes will erupt both lava and pyroclastic debris at different points in their history. Rainier differs from all other Cascades volcanoes in that about 90% of its eruptions are lava flows. All other Cascades volcanoes have a much higher pyroclastic component.

- much of the bulk of the Rainier stratovolcano is composed of solidified lava flows that have erupted over the past several tens of thousands of years
- crest of the mountain is capped by perennial snow and ice, which partially obscure two summit craters

Alpine glaciers on Rainier

25 named glaciers radiate downslope from the crest of Mt. Rainier.

- the mountain glaciers of Mt. Rainier comprise the largest single-peak glacial system in the contiguous U.S. – the total volume of glacial ice on Rainier is greater than all other Cascades volcanoes combined.

Rainier glaciers are elongate rivers of ice called **alpine glaciers**, (sometimes referred to as “mountain” glaciers or even “valley” glaciers).

- alpine glaciers flow downslope under their own weight, driven by gravity
- glaciers move slowly, with the ice literally flowing like a thick plastic within the body of the glacier. They may also flow due to sliding along the underlying soil or bedrock, sometimes with the aid of a basal layer of liquid water.

How alpine glaciers work

A balance exists between the **zone of accumulation** at the upslope ‘head’ of the glacier and the **zone of ablation** at the downslope ‘toe’ of the glacier

- **accumulation** occurs as snow is transformed to denser ice by compaction from the weight and pressure of overlying snow, accompanied by the removal of air from between snow crystals
- **ablation** is the removal of ice near the toe of glaciers, typically by melting, sublimation (the evaporation of ice directly into water vapor), and ‘calving’ of icebergs into water

- if the rate of accumulation exceeds the rate of ablation, the glacier advances downslope; if the rate of ablation exceeds the rate of accumulation, the glacier retreats upslope by loss of ice at its toe. (The glacier doesn't actually move upslope, it just appears to move that way due to melting and loss of ice at the toe.)
- warming climates promote faster rates of ablation and slower rates of accumulation – thus glaciers typically recede during warming climate phases. Conversely, glaciers grow during cooler phases of global climate.
- in today's warming climate, the glaciers on Rainier are rapidly retreating

The Carbon Glacier is not only the largest glacier in the park, but is the thickest and most massive glacier in the coterminous U.S.
- 200 meters thick, the Carbon Glacier reaches over 9 kilometers from head to toe – the longest glacier on Rainier.

As glaciers move downslope, they scrap away at the underlying rock and soil, eroding it to form distinct features on the landscape - we'll discuss glacial landforms in greater detail as the course progresses . . . .

Volcanic mudflows (lahars)

The crown of glacial ice and snow on Mt. Rainier (and all other Cascades volcanoes) contributes greatly to the overall hazard during an eruption because glaciers and snow supply meltwater that creates **lahars** - volcanic mudflows consisting of rapidly moving masses of volcanic ash and debris mixed with hot water
- the heat of an eruption can cause glacial ice or snow to rapidly melt. The slurry of volcanic ash, larger debris, and water race rapidly down the flank of the volcano as a lahar. They've been timed as moving at 80 kph (50 mph)
- lahars commonly follow the path of river valleys that radiate outward from volcanic cones and can travel far downstream - composed of melted ice, muddy ash, boulders, and uprooted trees
- when the slurry comes to a rest, it sets, somewhat like concrete, so that anything underneath or within becomes trapped
- 60 individual debris-rich, muddy deposits from lahars (spanning the last 10,000 yrs) have been mapped around Rainier – they extend for several tens of miles outward from their source (moved at >25 mph) and reach thicknesses of several tens of meters

The longest and thickest lahar deposit extends 70 miles to the northwest, reaching Puget Sound – this lahar was likely triggered during the massive eruption that blew off much of the summit and upper eastern flank about 5700 yrs ago
- several communities are built along ancient (and future) paths of lahars. - more than 100,000 people now live directly on top of mudflow deposits (and in the path of future volcanic mudflows from Rainier).

Mount Rainier is considered one of the most dangerous volcanoes in North America, partly because of the inevitability of future eruptions and partly because of its proximity to the Seattle-Tacoma metropolitan area (2.5 million people).
- Rainier is one of the most heavily monitored volcanoes in the world

- Mount Rainier is in a temporary state of repose and will almost certainly enter a renewed phase of active volcanism sometime in the near future

Lahar video
https://www.youtube.com/watch?v=bt05FIIZPgM

Great hikes in Mt. Rainier NP: https://embracesomeplace.com/best-hikes-mt-rainier-national-park/

A few websites with relevant material in lieu of using the textbook
USGS & NPS on plate tectonics
https://pubs.usgs.gov/gip/dynamic/understanding.html
https://www.nps.gov/subjects/geology/plate-tectonics-subduction-zones.htm
National Park Service – Geology of Mt. Rainier NP
https://www.nps.gov/mora/learn/nature/glaciers.htm
https://www.nps.gov/mora/learn/nature/volcanoes.htm
Wikipedia – Geology of Mt. Rainier NP
http://en.wikipedia.org/wiki/Mount_Rainier
