Volcanic Rockin’ ‘n’ Rollin’ in the Cascade-Siskiyou National Monument, Southwest Oregon

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Basic outline of the talk: (note: information on these slides leads progressively to subsequent slides)

There will be a lot of geologic jargon and concepts in this presentation. However, the presentation is being recorded. If you are a masochist, you will be able to see this lecture again and study the illustrations in more details on the Friends' website (www.cascadesiskiyou.org)

1. What are the dominant rock types to be found in the Cascade-Siskiyou National Monument (**CSNM**)?

2. How were they generated in context of geology's overarching "Theory of Evolution": the Plate Tectonic Model?

3. Why do the rocks look so different—and what kinds are found there? What is the difference between diverse types of volcanoes—and what are these things called volcanic "facies"?

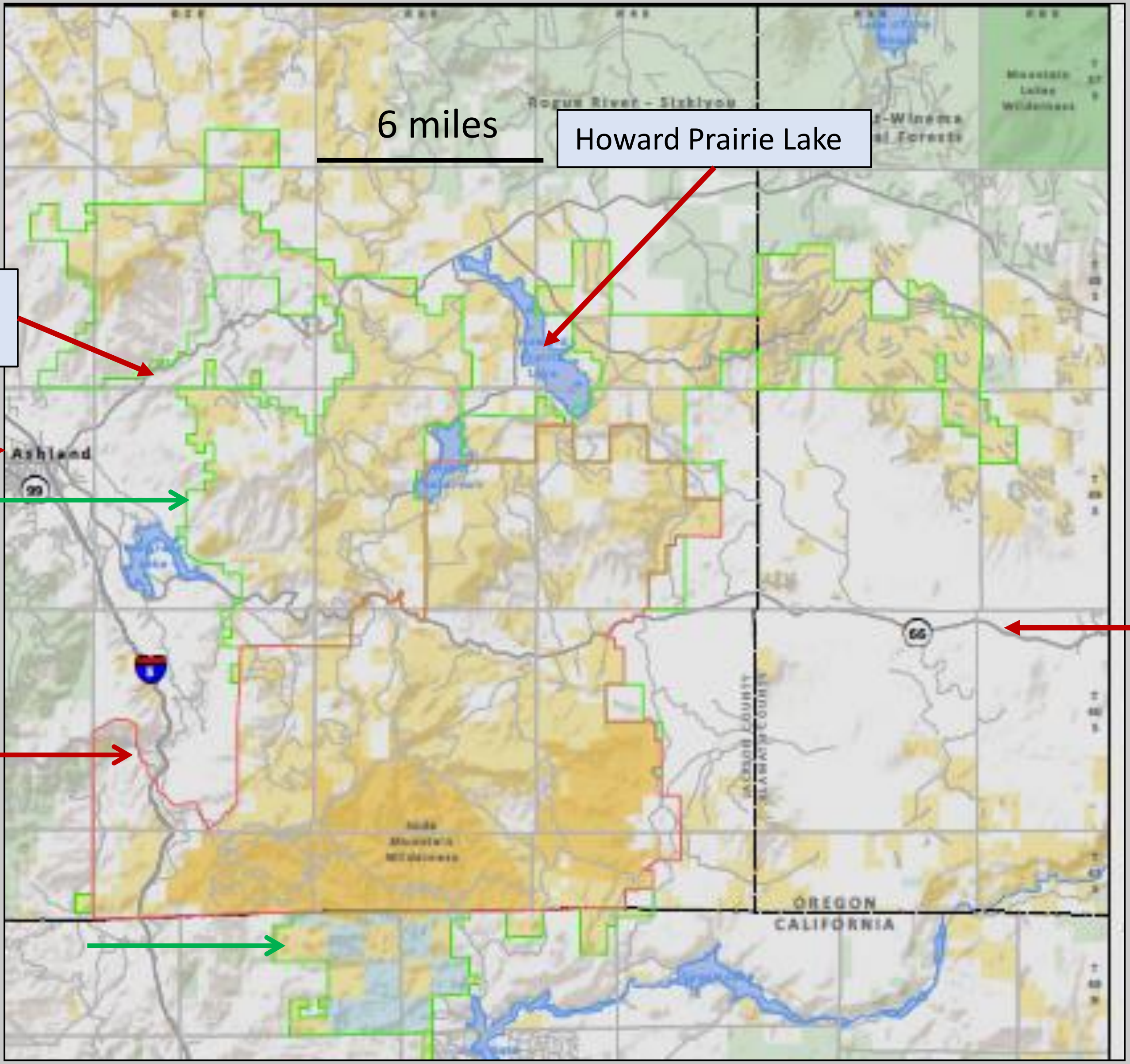
4. Just how old are the rocks—and how do geologists reconstruct the geologic past?

5. Let's look at the type of rocks distributed throughout time within the Monument and basic soil/vegetation differences. For local listeners, I'll briefly list (but won't discuss) where to see these different rock types.

6. Regional tilting and faulting in the Monument; influences on surface and groundwater flow.

7. That's nice… But what does all that geo-blather have to do with biodiversity in the Monument?

Southwest Oregon



6 miles

Howard Prairie Lake

Dead Indian Memorial Highway (**DIM**)

Ashland

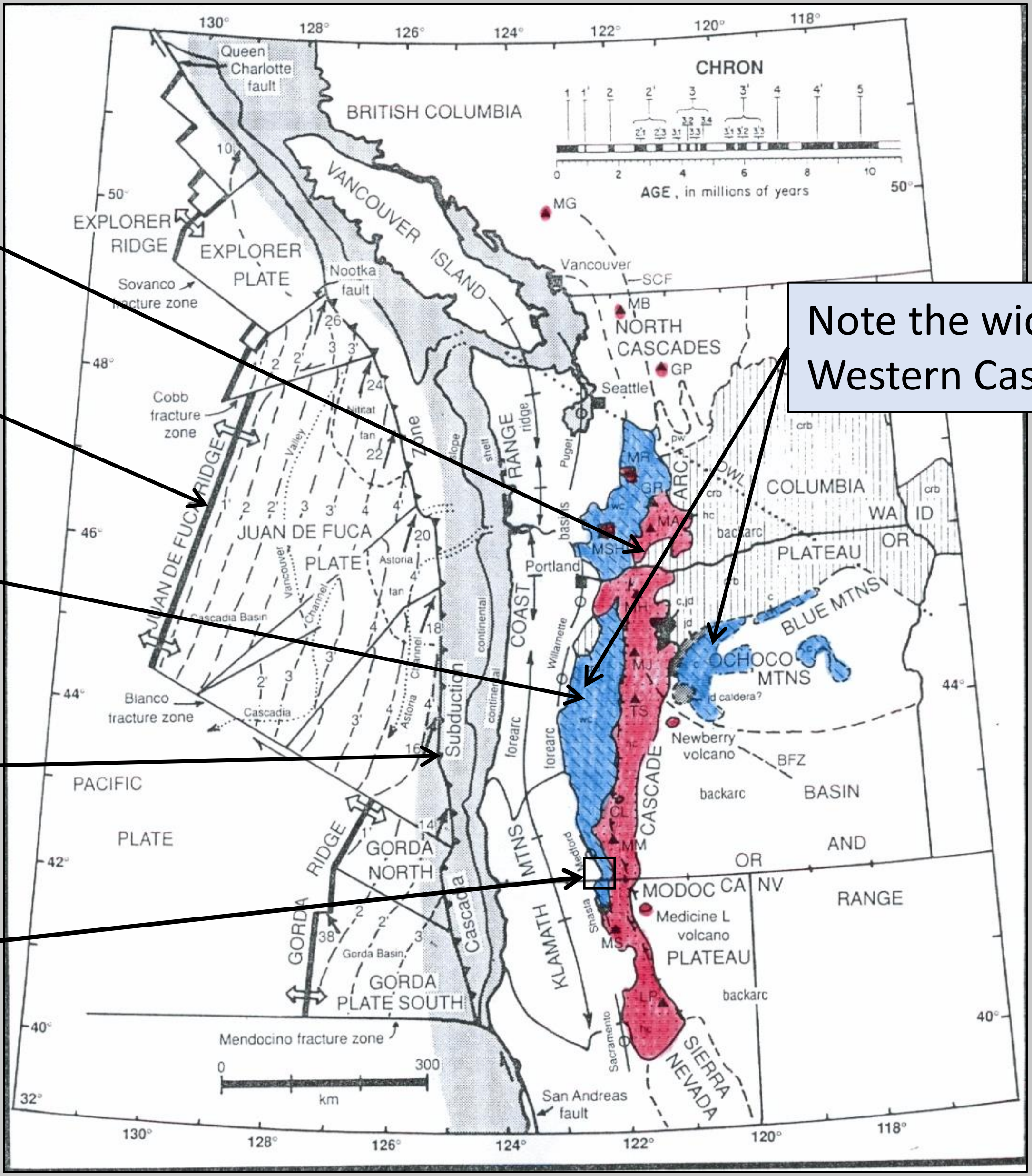
Highway 66

Approximately 114,000 acres of federal lands, and up to 170,410 acres (266 square miles) of Federal, State, and Private Lands.

Clinton’s 2000 original monument (red); Obama’s 2017 Monument expansion (light green).

Regional Setting: Western Cascades, and High Cascades volcanic series

Most of the rocks in the Monument are volcanic



Red: 7 Ma -> Recent High Cascade volcanic rocks

Ridge crest ("oceanic spreading center")

Blue: 47 -> 18 **Ma** (**M**illions of years **a**go) **Western Cascade volcanic** rocks

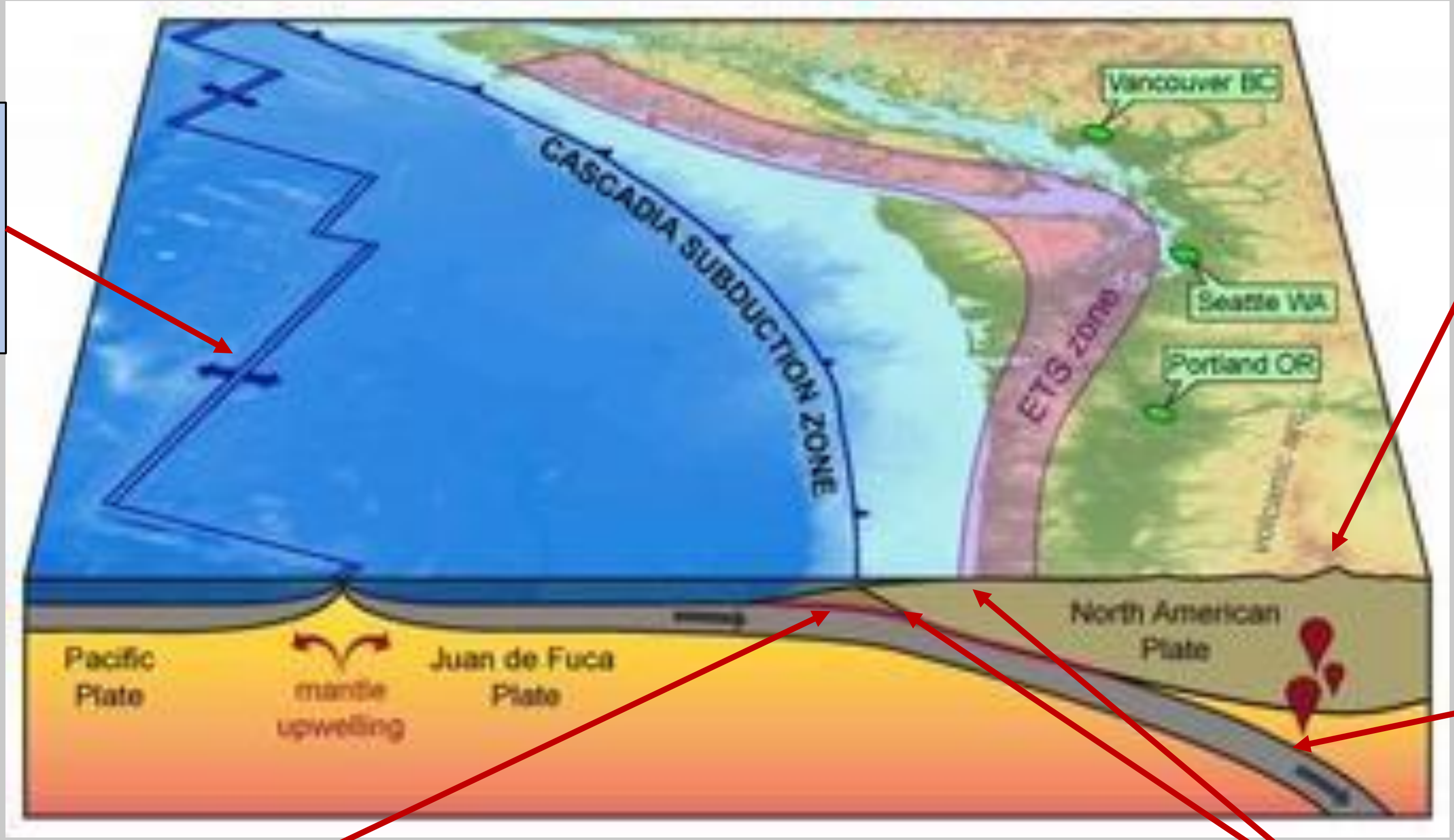
Cascadia Subduction Zone; barbs denote the zone

Cascade-Siskiyou National Monument

Note the wider spread of Western Cascade rocks

Digression: What makes a volcano?

Plate Tectonic basics: creating margin (**ridge crests**), consuming margin (**subduction zones**) and convection (“**mantle drag**”).



New **hot** magma erupts at ridge crest, **pushing** the oceanic plate in both directions.

Less dense magma rises like liquid in a “lava lamp” through denser crust and may erupt at the earth’s surface, producing **volcanoes**.

Magma generation occurs here as the upper mantle is partially melted.

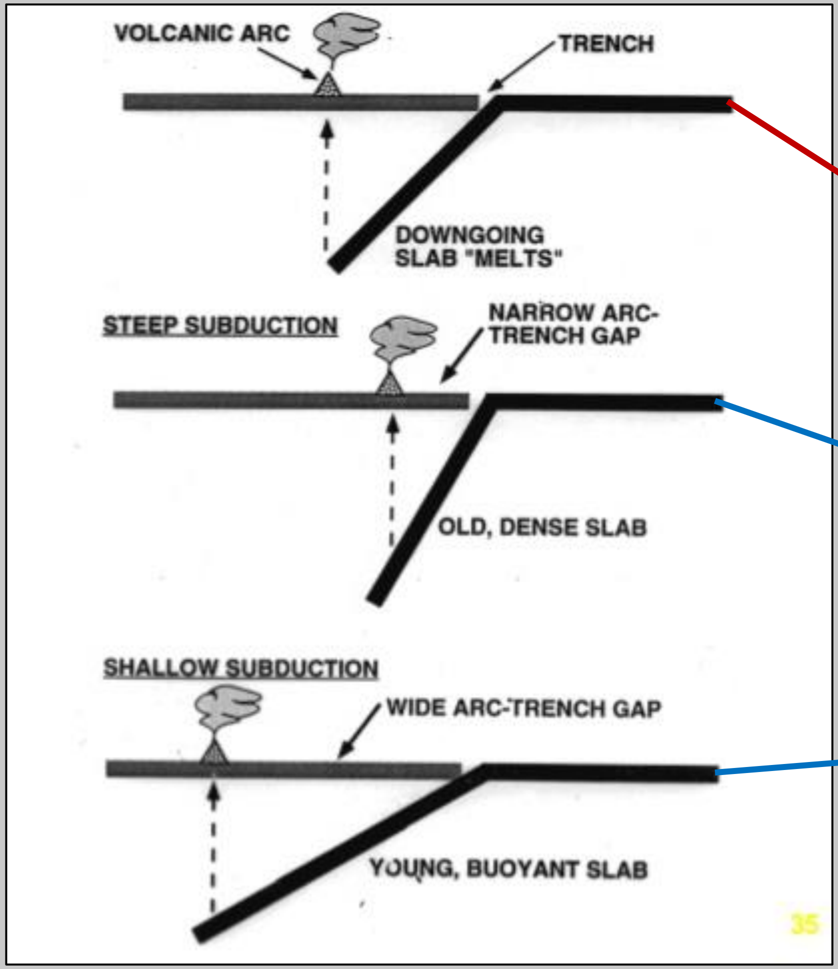
Denser **cold** oceanic crust is **pulled** beneath less dense continental crust at the subduction zone.

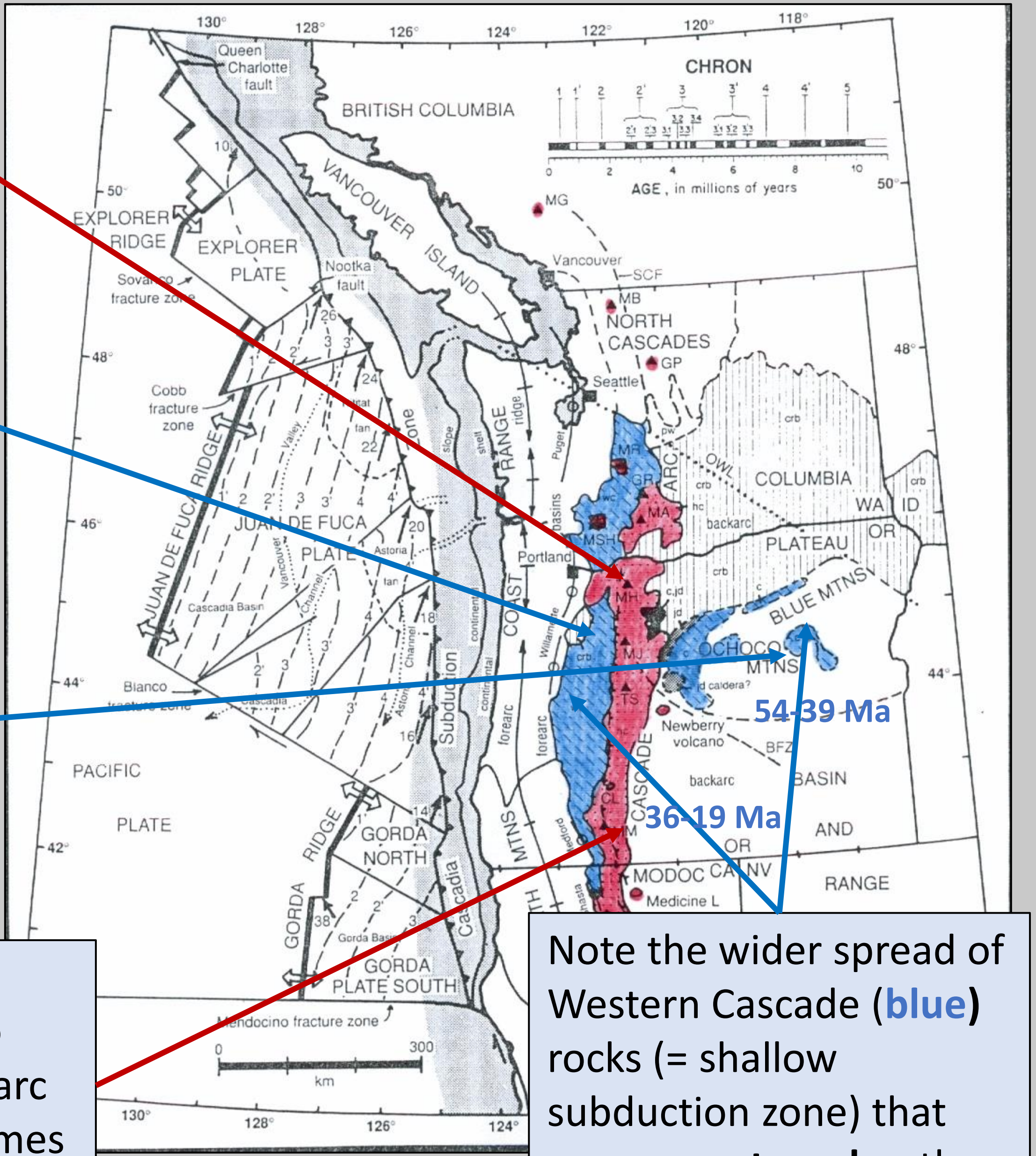
Earthquakes occur here as cool and brittle oceanic crust slides beneath cool and brittle continental crust.

Inclination of the down-going oceanic slab determines how far the volcanic chain lies from the subduction zone.

Melting occurs at ~ 100-150 km depth.

Flip this diagram 180° so that the subduction zone is inclined to the east.





Movement of High Cascade volcanic arc (red) at ~9 Ma to east of the western Cascade arc as the subduction zone becomes less steep.

Note the wider spread of Western Cascade (**blue**) rocks (= shallow subduction zone) that moves **westward** as the rocks become younger).

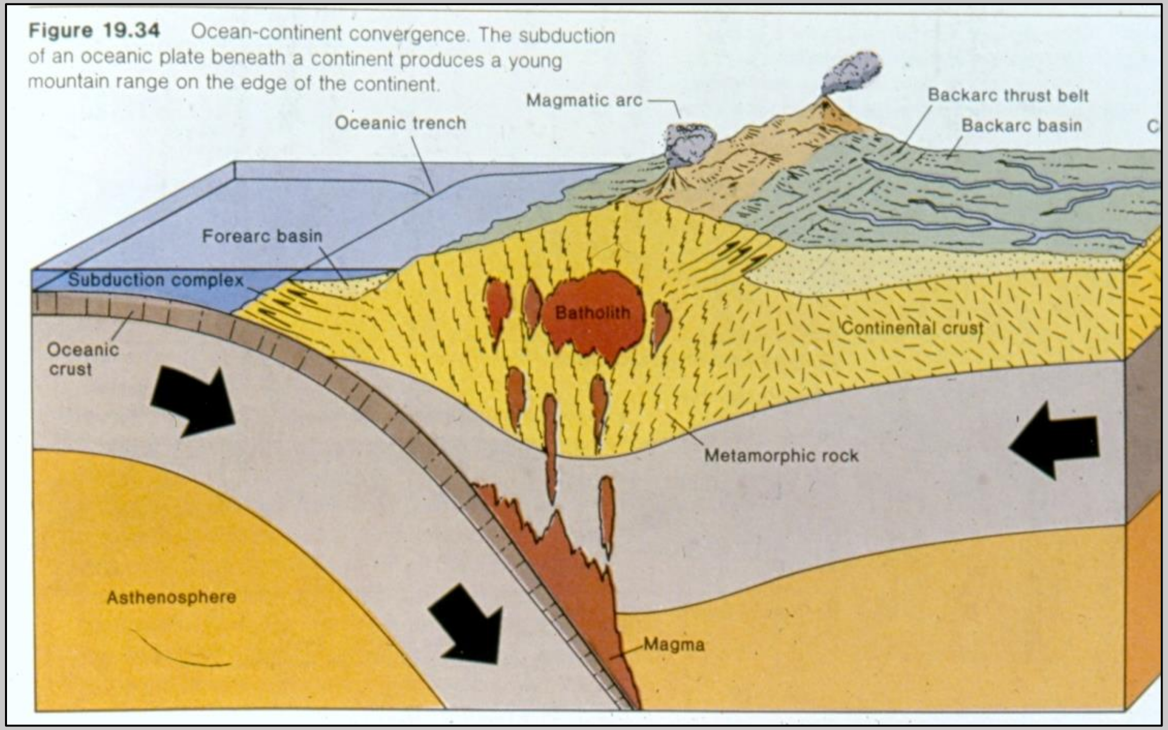


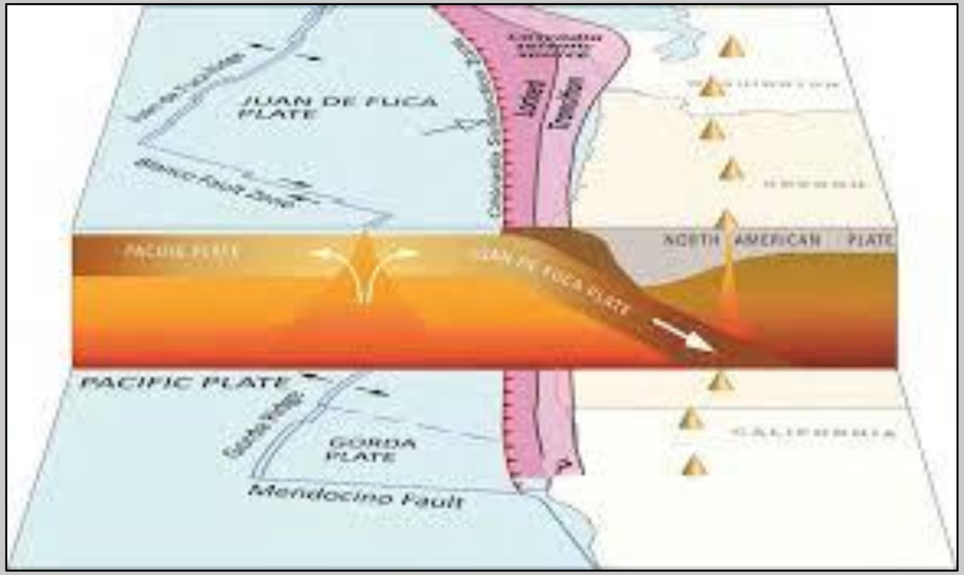
Figure 19.34 Ocean-continent convergence. The subduction of an oceanic plate beneath a continent produces a young mountain range on the edge of the continent.

Dehydration reactions in the down-going oceanic slab release water into the overlying hot mantle causing **partial melting** of the mantle at about 100-150 km depth. Only the lower melting point (and less dense) minerals melt, making the new magma **less dense** than the surrounding mantle rock.

The less dense magma rises toward the surface.

- If the magma rises **"rapidly"**, it is higher in iron (the rock has a darker color and contains few crystals);

- If the magma rises **"slowly"** or the rise is **interrupted**, the magma begins to crystallize and becomes less iron-rich (the color of the rock isn't as dark) and is filled with significantly more abundant crystals.



What do the rocks look like if they rise **rapidly** to the Earth's surface?

- Darker color (lots of iron-bearing minerals) and heavier (denser) as in "basalt";
- Few large minerals (magma rises too rapidly for minerals to form and grow to large sizes).

What do the rocks look like if they rise **slowly** to the Earth's surface?

- lighter color (fewer iron-bearing minerals; lots of light colored minerals) and lighter (less dense) as in "andesite".

- Many large minerals (the greater the number of minerals, the longer the time the magma has stayed beneath the earth's surface).

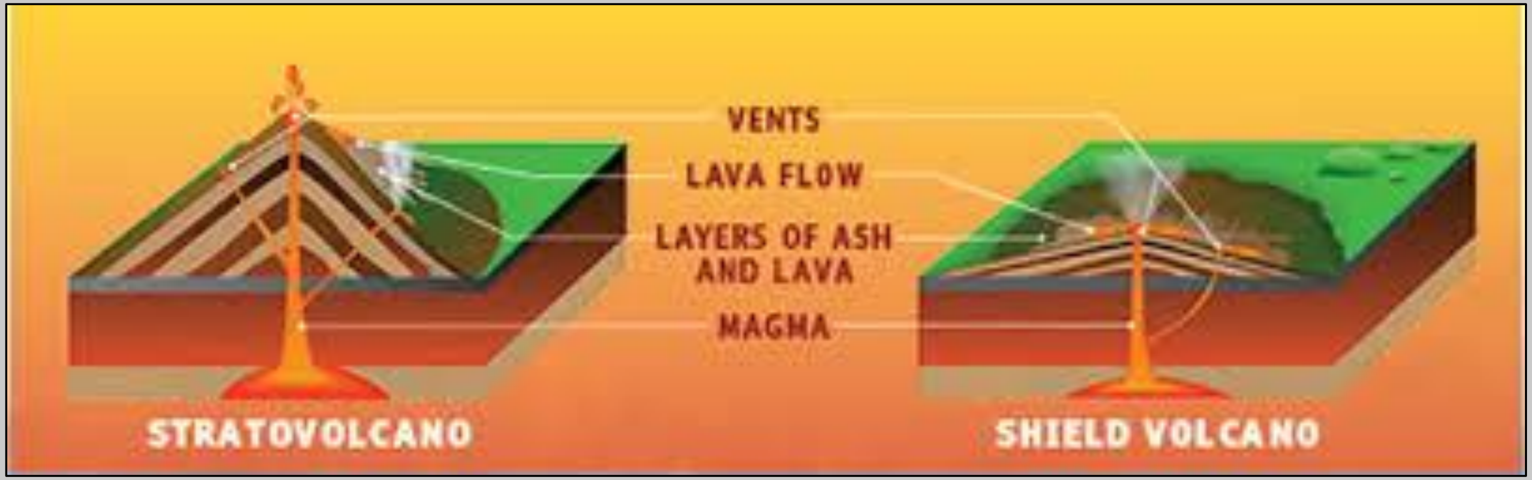
Basic types of volcanoes in the Monument

Stratovolcano

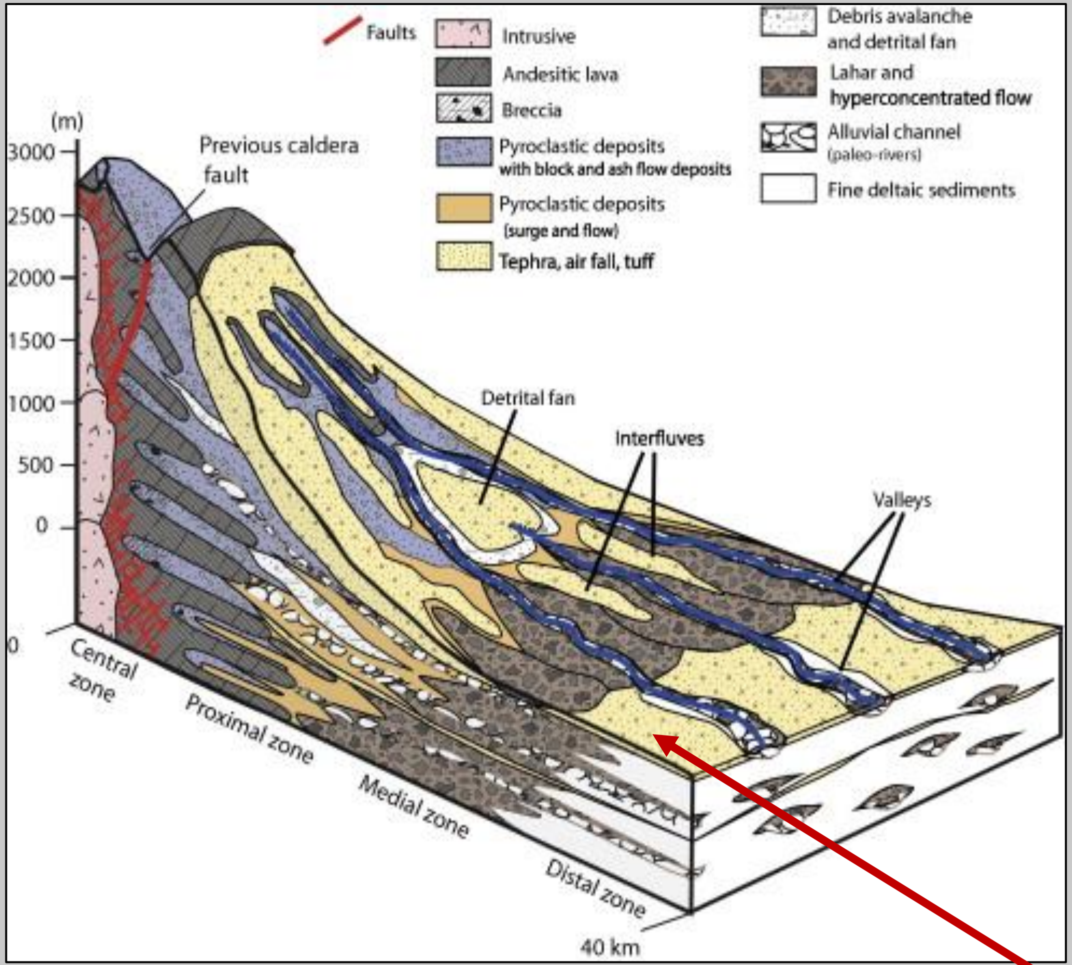
(= composite volcano) such as Mt. McLoughlin, showing a **steep profile**, with both “*sticky*” lower iron (“andesitic”) lava flows and **volcaniclastic** rocks (broken volcanic debris, sandstone, and volcanic ash).

Shield volcano

such as Brown Mountain dominantly comprised of *fluid* iron-rich (“basaltic”) lava which creates a **lower profile.**



Volcanic “facies” (lateral change in rock types with respect to proximity of the vent).



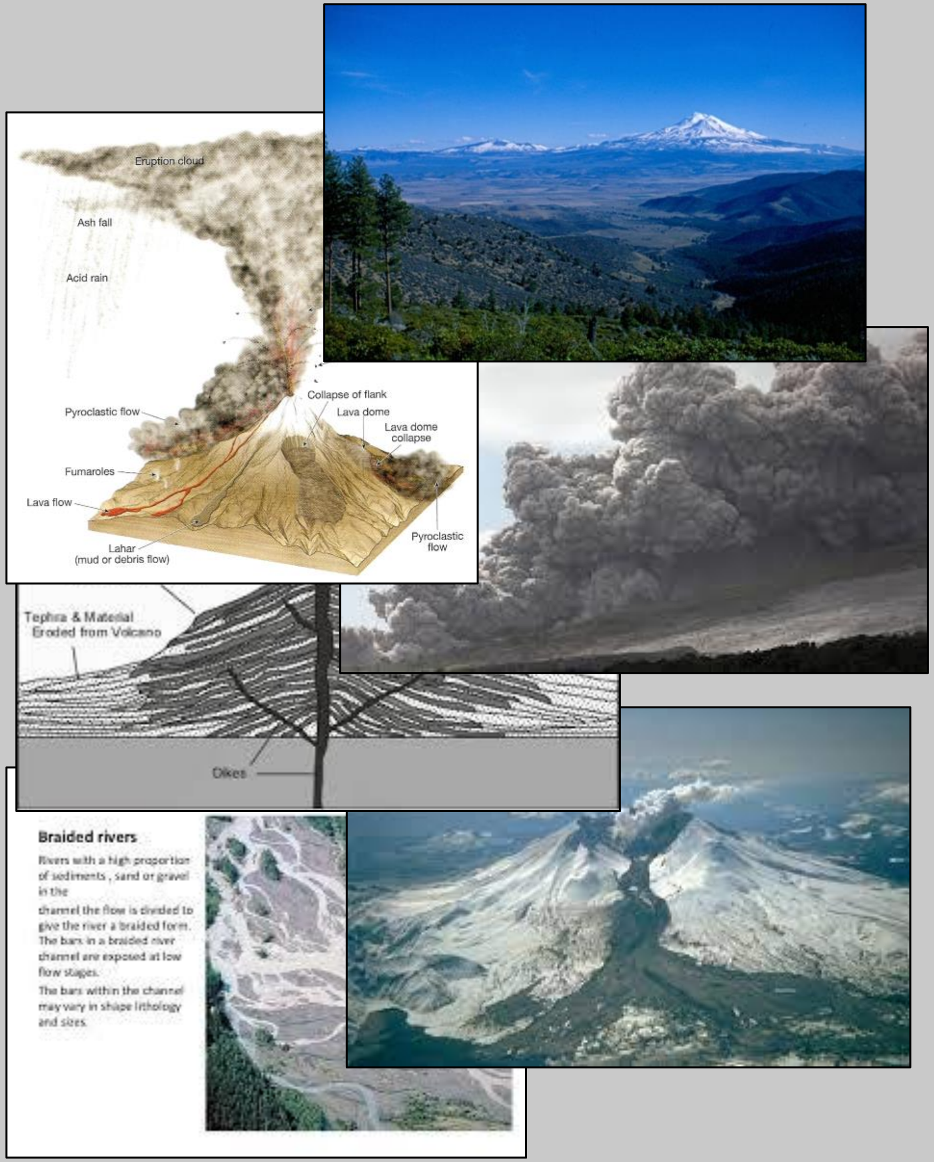
Schematic showing that the farther from the volcanic center, there are fewer lava flows and intrusions and additional deposits of finer-grained rocks (debris flows and sandstones) relative to thin lava flows.

These relations are very useful in **reconstructing ancient geologic features** in terrain that is tilted, faulted, deeply eroded, and covered by that bothersome green stuff.

Alluvial fan and river deposits.

What does this all mean for the distribution and types of volcanic rocks in the Monument?

General reconstruction of the Monument as determined by radiometric dating of rocks: *A Walk Through Time.*



Braided rivers

Rivers with a high proportion of sediments , sand or gravel in the

channel the flow is divided to give the river a braided form. The bars in a braided river channel are exposed at low flow stages.

The bars within the channel may vary in shape lithology and sizes.

~6.5 Ma to recent: High Cascade shield and stratovolcanoes erupt; their lava covers older rocks, burying part of Western Cascade geologic history.

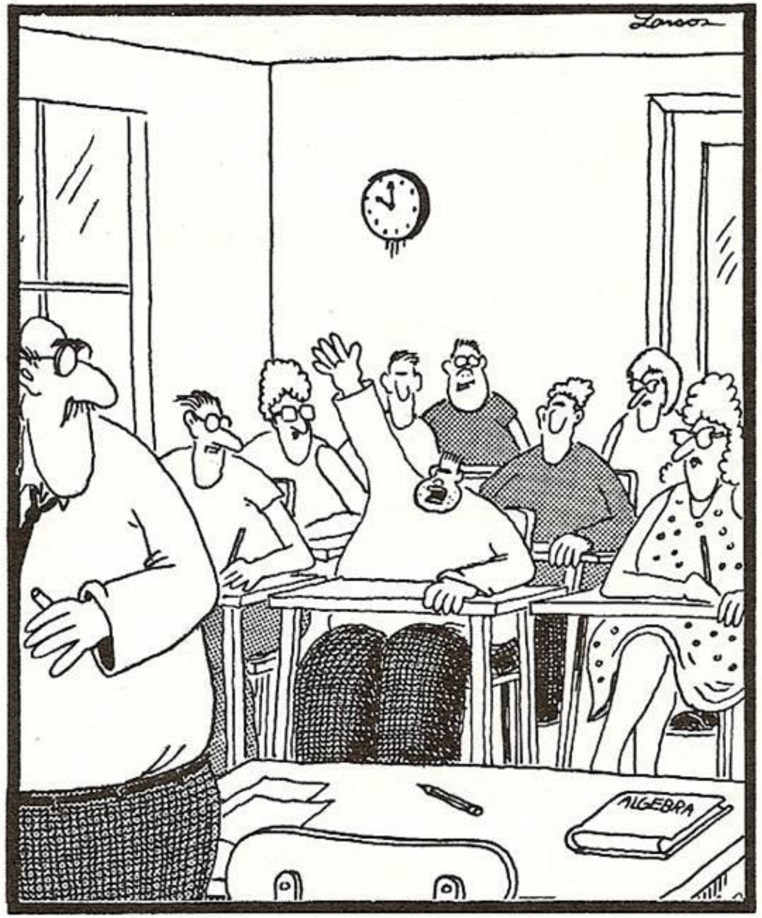
~21-19 Ma: return to large shield and stratovolcanoes.

~24-21 Ma: violent ash eruptions mingle with lava from other volcanoes.

~27-25 Ma: large shield and stratovolcanoes build.

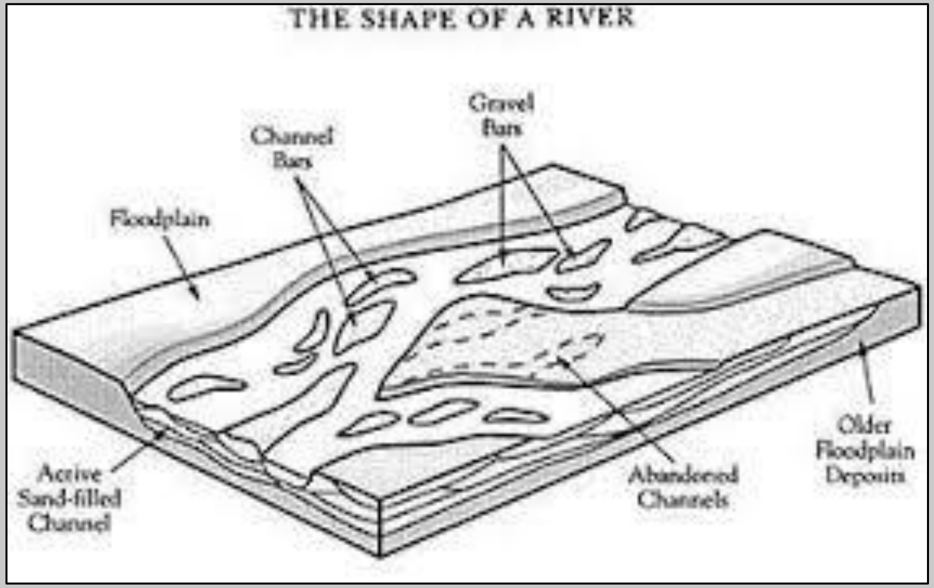
~35-27 Ma: volcanic ash and alluvial fan deposits; few lava flows.

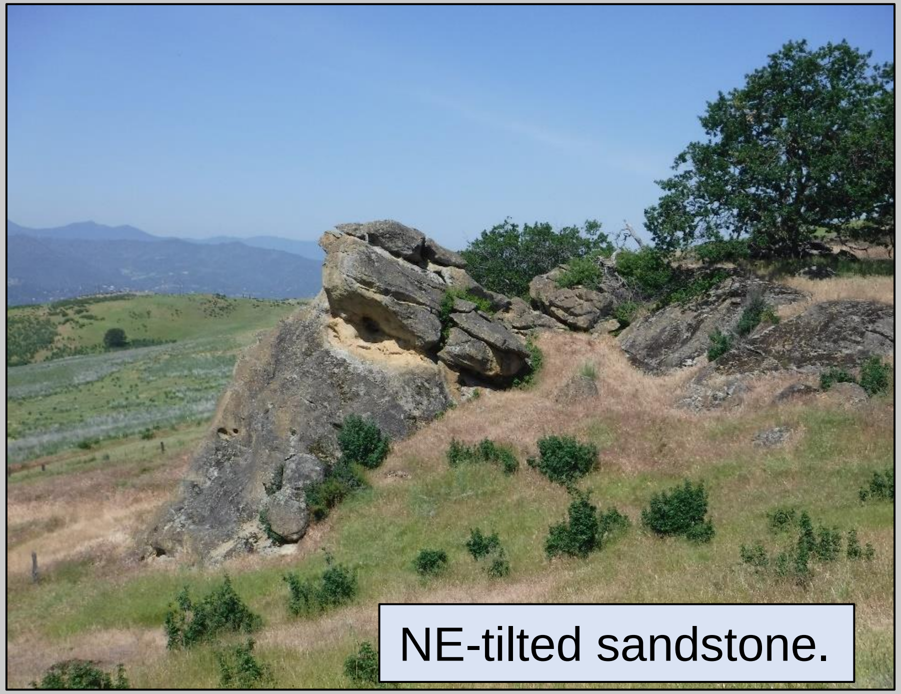
~43-35 Ma: braided stream deposits eroded from the continental interior.



"Mr. Osborne, may I be excused?
My brain is full."

No significant mountain barriers existed during “Eocene Hot Box” time. That time was characterized by intense rainfall, erosion and deposition of sediment from **wide but shallow** sediment-choked (“**braided**”) streams.





NE-tilted sandstone.

The oldest rocks, (“Payne Cliffs Formation”) of ~43-35 Ma, are exposed in the lower hills on NE side of Bear Creek Valley such as Pompadour Bluff and the Payne Cliffs. Characterized by stream deposits of sandstone and conglomerates.

Where to see: Dead Indian Memorial Hwy (**DIM**) beyond the Ashland Airport and bridge over Walker creek.

The oldest [~33-27 Ma] volcanic rocks of the Western Cascade volcanic series.

Outcrop at Siskiyou Summit on Interstate 5 showing channel deposits, volcanic debris flows, and one of two white volcanic ash (“tuff”) deposits with petrified wood. Distal zone, alluvial fan deposits.

Highway 66 exposure. Note easily-weathered volcaniclastic rocks, clay-rich (sicky when wet, cracked when dry) soil, grasses and scattered oaks growing on harder (less clay) rocks.

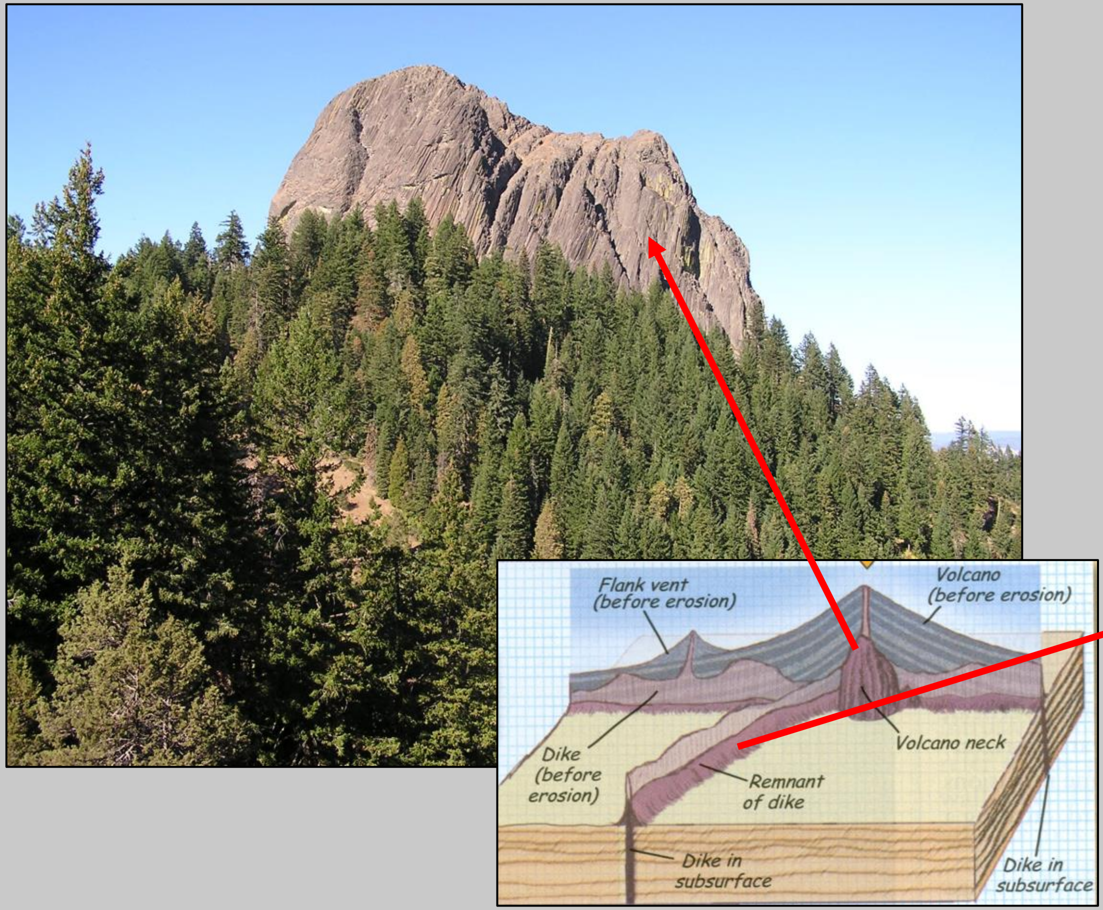
Where to see: DIM beyond Pompadour Bluff to switchback turn; Hwy 66 from east end of Emigrant Lake to Soda Creek; I-5 from Siskiyou Summit to OR-CA border.

~27-23 Ma: large shield and stratovolcanoes build.

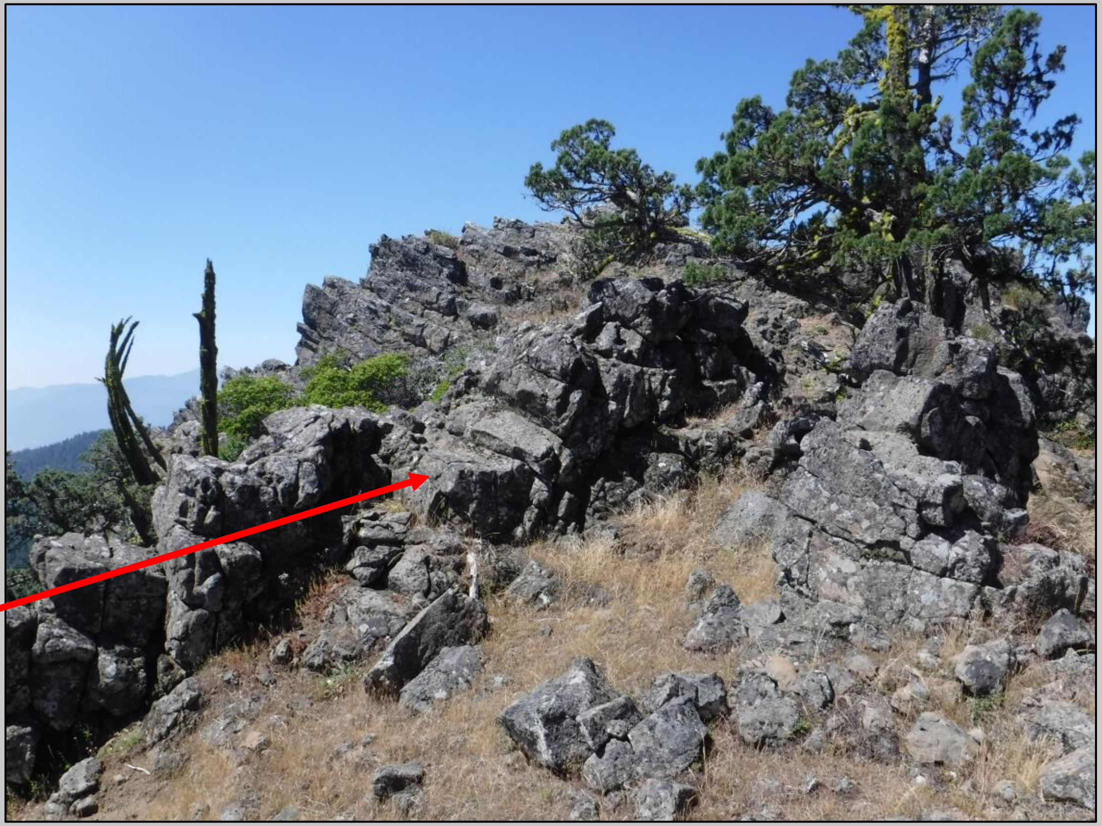
A series of massive lava flows along Hwy 66 showing NE inclination. Change to mostly lava flows occurred as the volcanic arc moved westward through time. Medial and proximal volcanic facies.

Hard (“lithified”) chaotic volcanic debris flows also contribute to the steeper terrain typifying the change to closer proximity to volcanic vents. A few volcanic vents are identified.

Volcanic vents.



Pilot Rock (~25.6 Ma) is the most recognizable vent (all that remains is the “neck”) although there are a few larger and less noticeable vents (such as on Grizzly Peak).



Smaller vents, like this one north of Willow-Witt Ranch (Shale City Road area) dot the landscape. This vent, like Pilot Rock, is tilted to the NE. Notice the dike (a feeder for the vent) in the foreground.

~24-21 Ma: violent ash eruptions creating "tuffs" mingle with lava from less violent volcanoes.

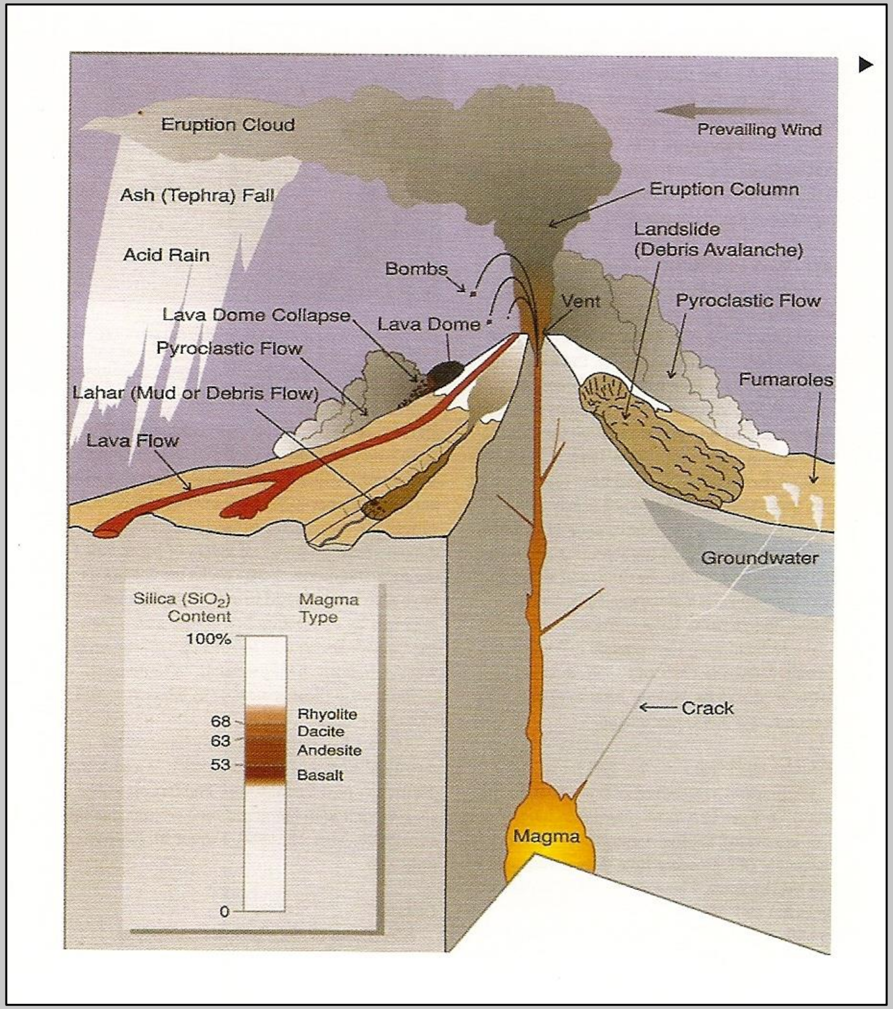
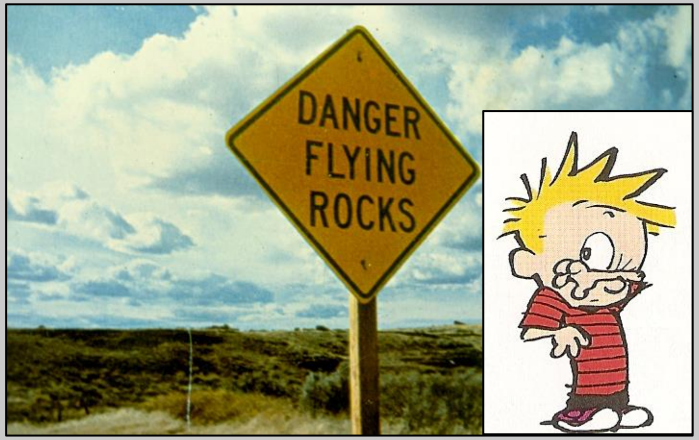


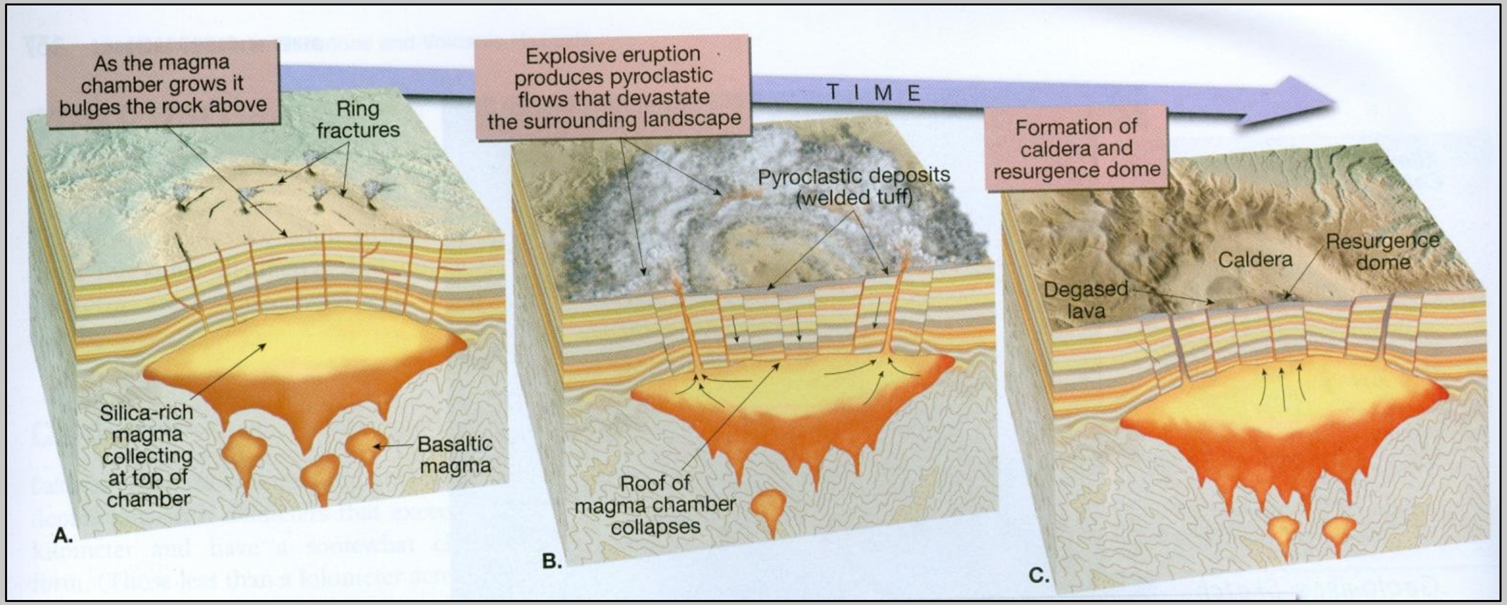
Diagram showing violent eruptions of ash-fall and ash-flow (hot incandescent clouds) from a volcano.

Ash-flow deposit ("welded tuff") with carbonized wood and re-melted pumice.



Thin air-fall tuff (white) with carbonized wood lying beneath a pebbly debris flow.

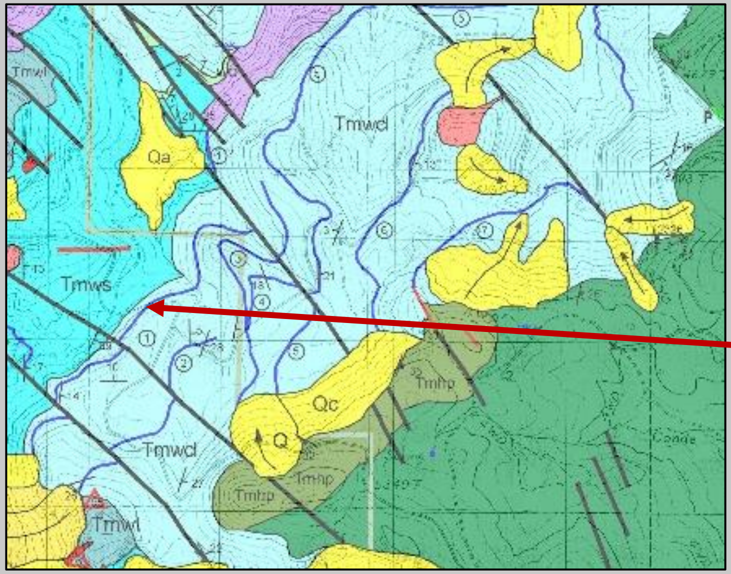
General diagram of caldera formation (far NW part of Monument).

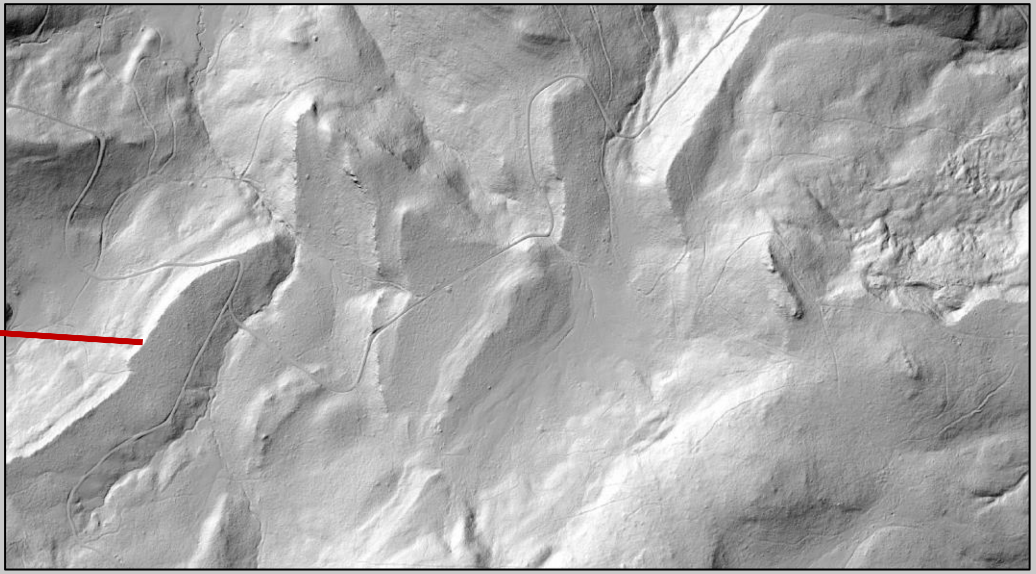


The volcano swells like an engorged pimple then erupts. Sorry for the visual…

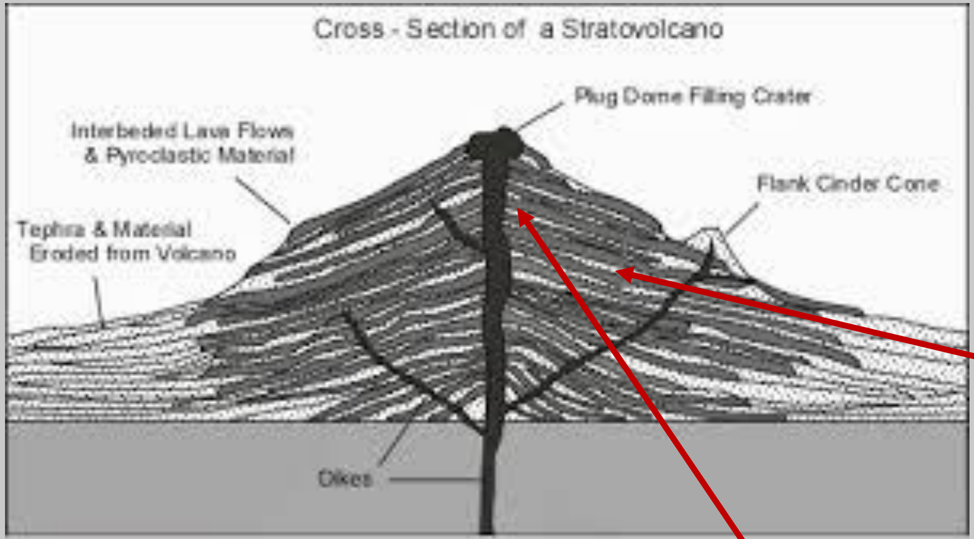
LiDAR image of resistant welded tuff bands separated by less resistant airfall tuffs. Location: east of Willow-Witt Ranch, Shale City road area.

Geologic map of same area showing hard welded tuffs (dark blue) and softer airfall tuffs (light blue).





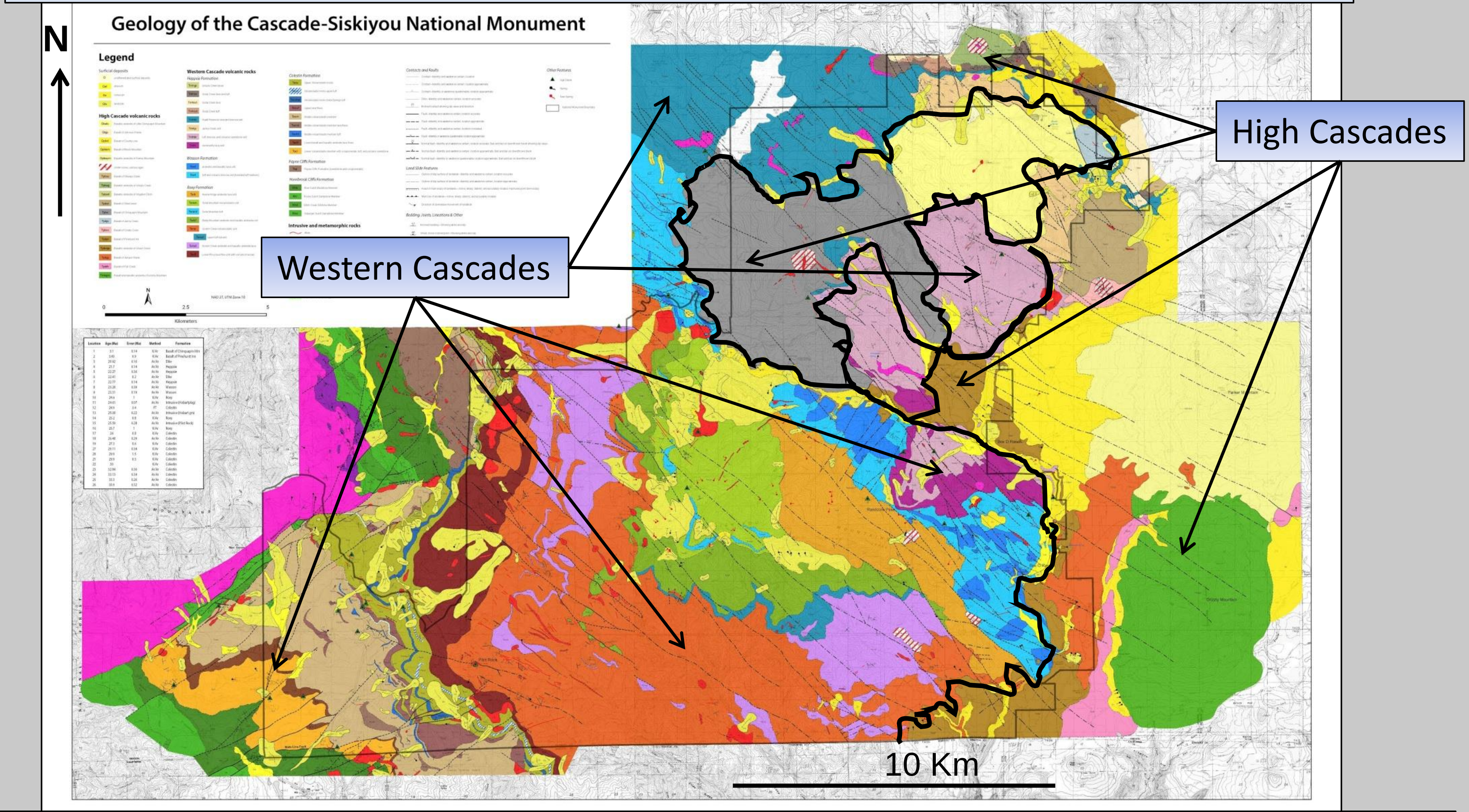
~21-19 Ma: return to large shield and stratovolcanoes.



Martin Harris (UO student supported by a Friends' Research Grant) standing on tilted lava flows.

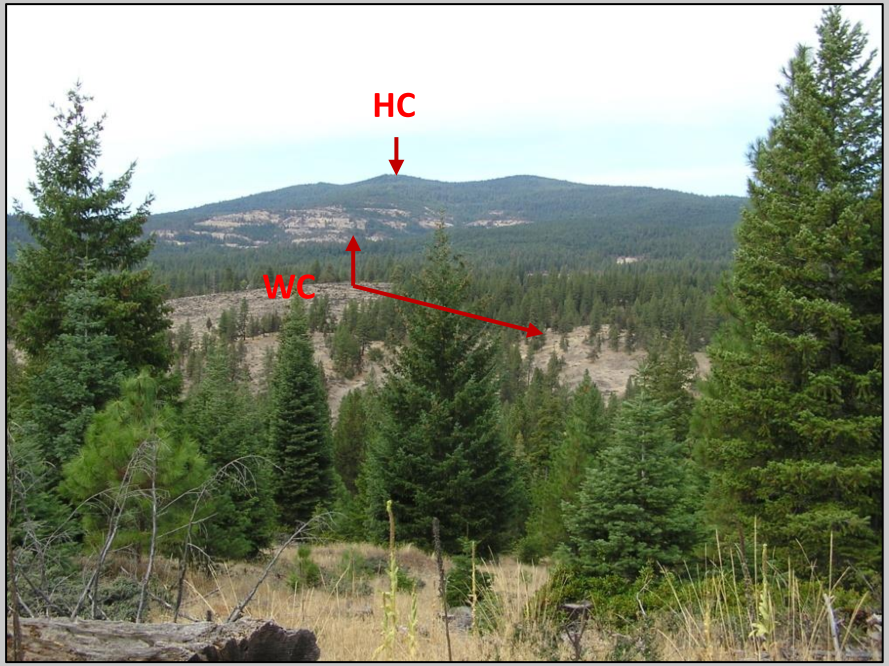
Jenny Creek Falls cutting through resistant (hard) dikes.

~6.5 Ma to recent: High Cascade shield and stratovolcanoes cover older rocks.



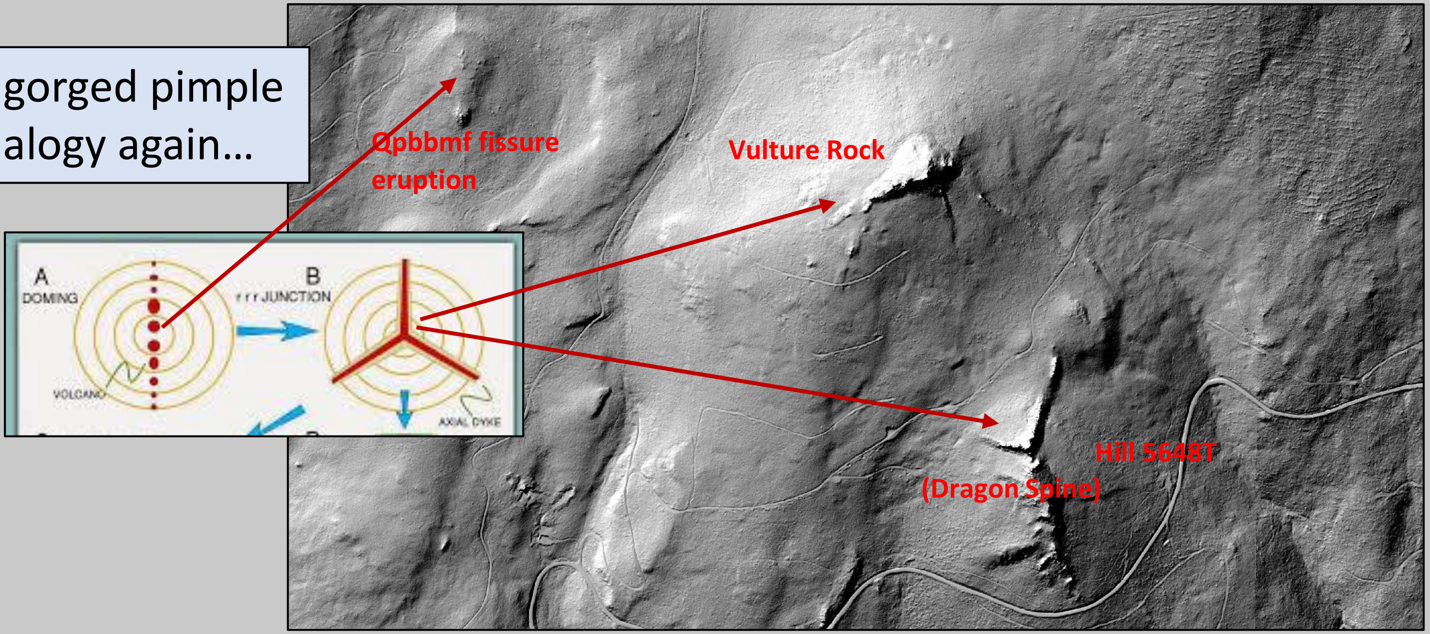
Geologic mapping in the original Monument and the Extended Monument (as of 2016). Western Cascade rocks are older in the east progressing to younger in the west. High Cascade shield volcano rocks lie on the eastern border and overlap Western Cascade rocks.

~7 Ma to recent: High Cascade shield and stratovolcanoes cover older rocks.



Chinquapin Mountain HC shield volcano north of Highway 66 with its lava superimposed like chocolate syrup dripped over WC rocks.

Engorged pimple analogy again…

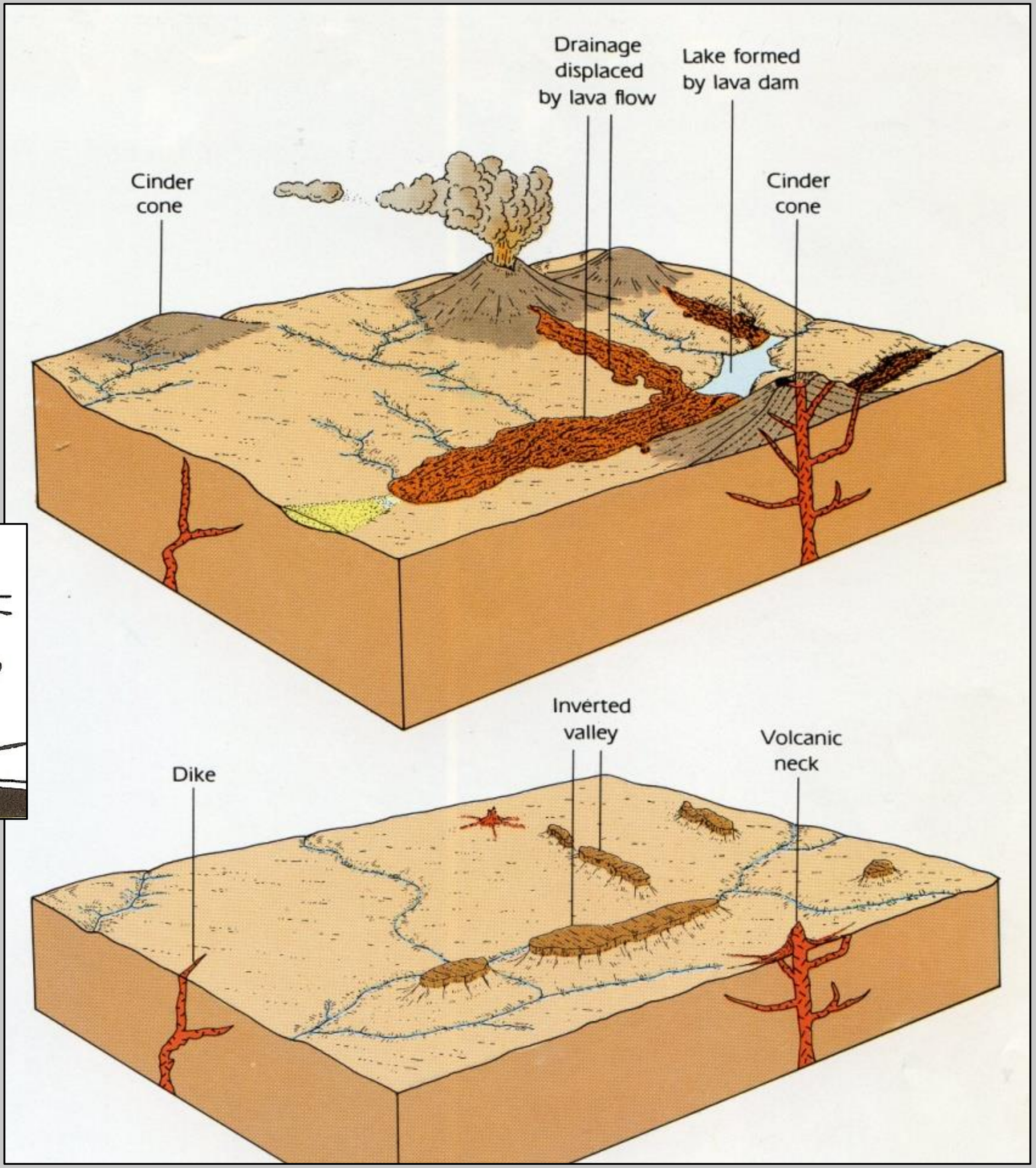


LiDAR image of two High Cascade volcanic vents and a fissure eruption west of Howard Prairie Lake.
Inset shows formation of vent and dikes.

Mt McLoughlin carved by glaciers on its eastern side.

The oldest High Cascade lava in our region is found at the Table Rocks (7 Ma).

"**Inverse topography**", of what was formerly a low area (the ancestral Rogue River as in the upper diagram) filled by lava, is caused by erosion of softer rocks around the lava. That process results in mesas of hard rock (Table Rocks) that are now 600 feet above the current valley floor (lower diagram).



Regional Tilting

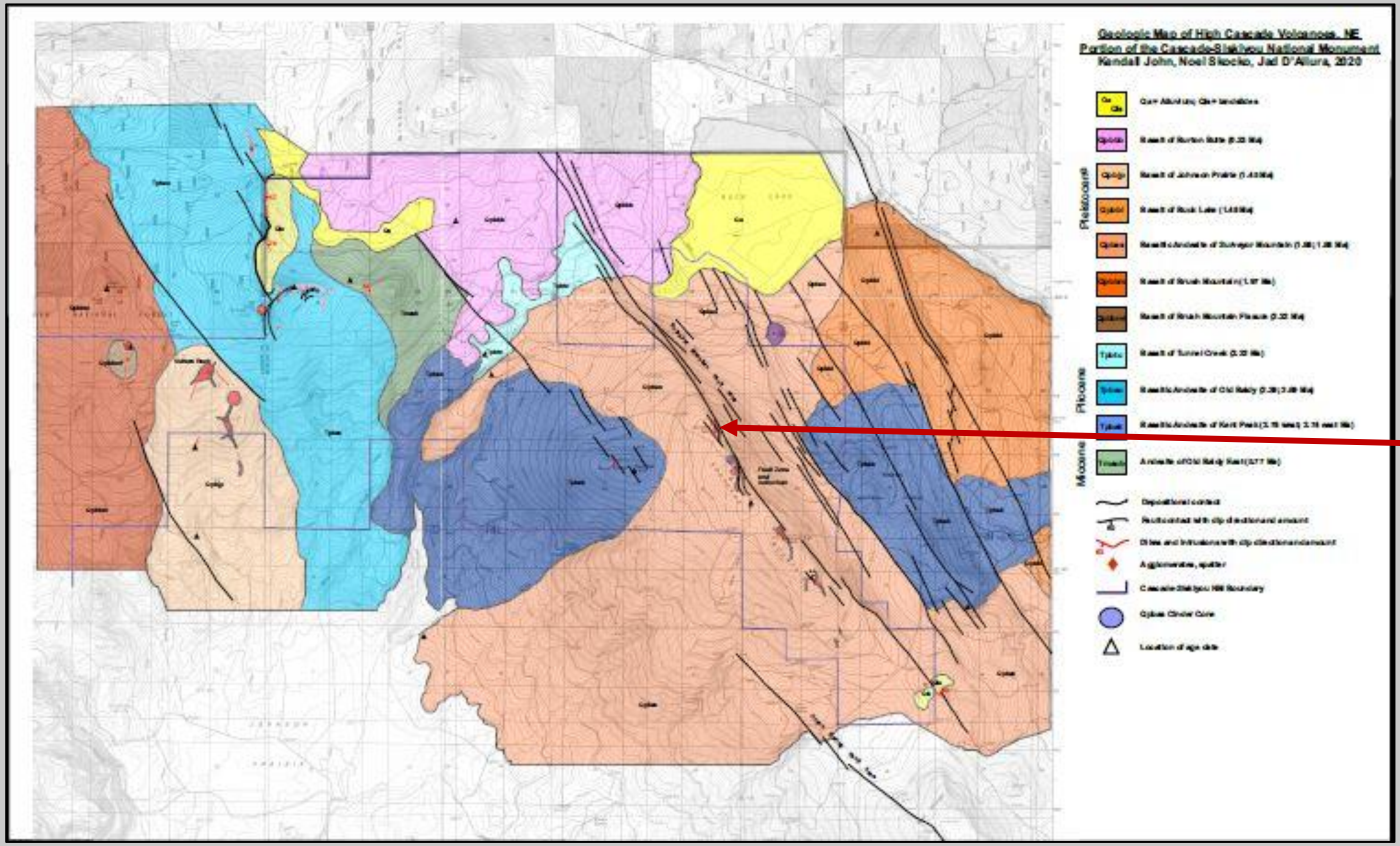
Rocks that originally were tilted slightly to the west are tilted to the NE as a result of the episodic uplifting of the Klamath Mountains. Acting like a teeter totter, uplifting occurred over more than 100 Ma combined with later down-dropping in the Klamath Falls area.

View is looking NE across the Valley from the Ashland Airport.

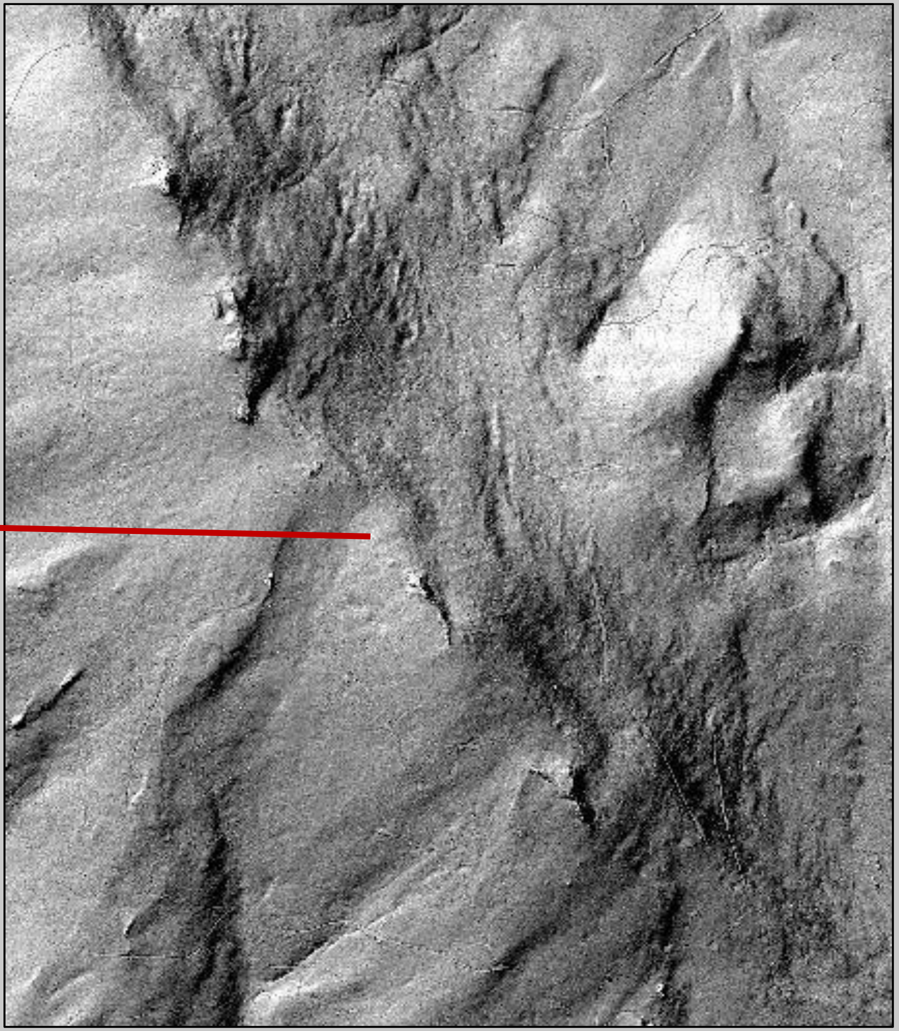
Martin Harris (UO student; recipient of FCSNM grant) standing on tilted lava flows near Jenny Creek.

The amount of tilting decreases toward the east (younger rocks haven't been tilted as much).

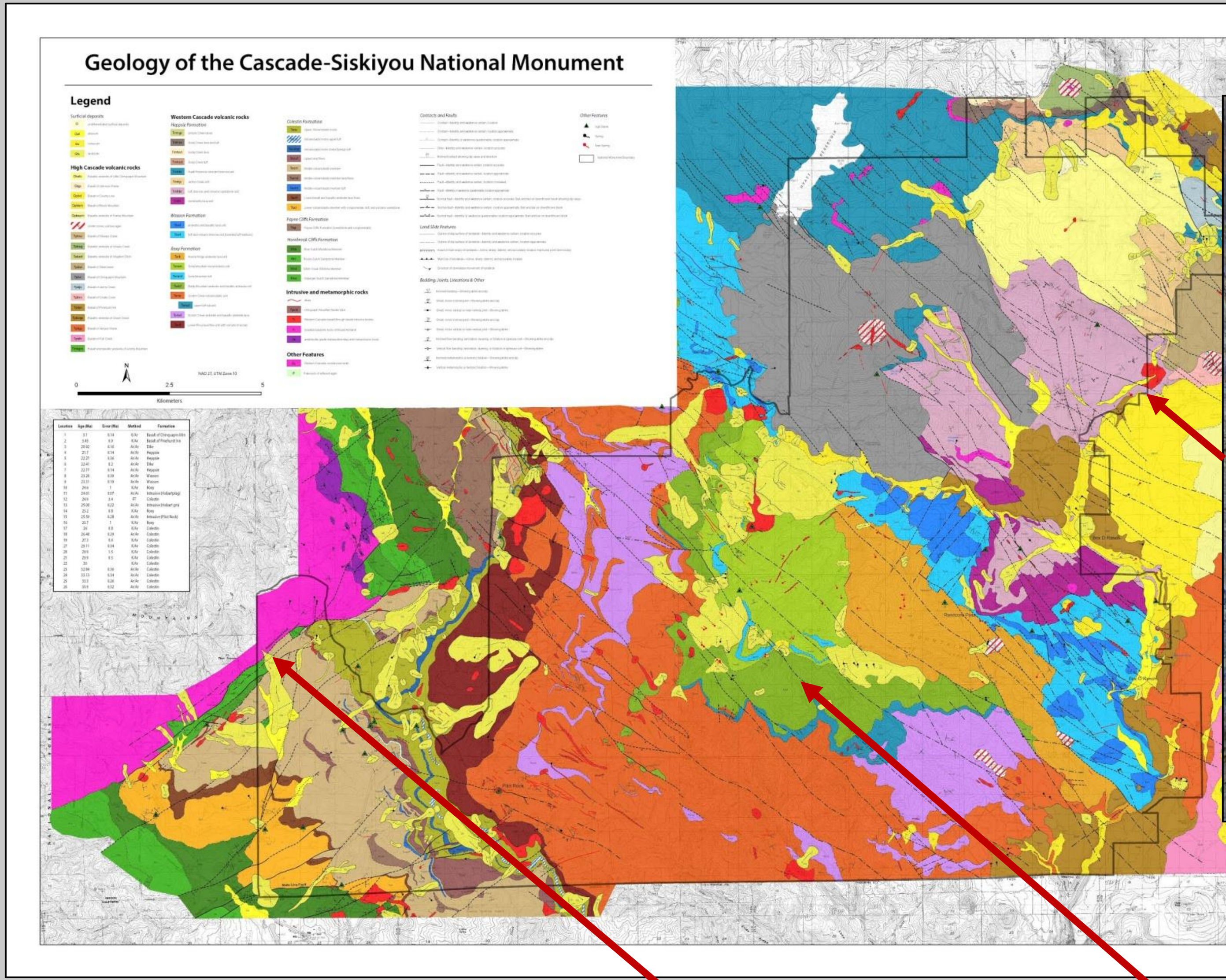
Faulting and fracturing



Geologic map of the far NE portion of the CSNM showing NW-trending faults (black lines) and different High Cascade rock units erupted from a series of different vents.



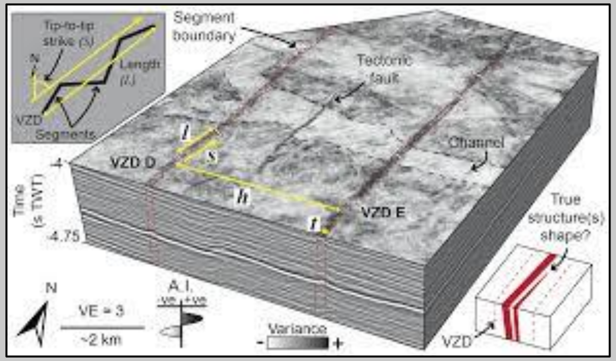
LiDAR “bare earth” image of the Surveyor Mountain fault zone. Notice isolated vents along the fault trend.



Steep faults near the old Pinehurst Inn, highway 66 (Greensprings hwy).

Geologic map showing early NE-trending faults and later NW-trending faults.

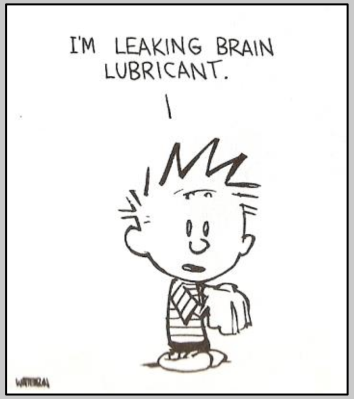
Dikes and dike swarms

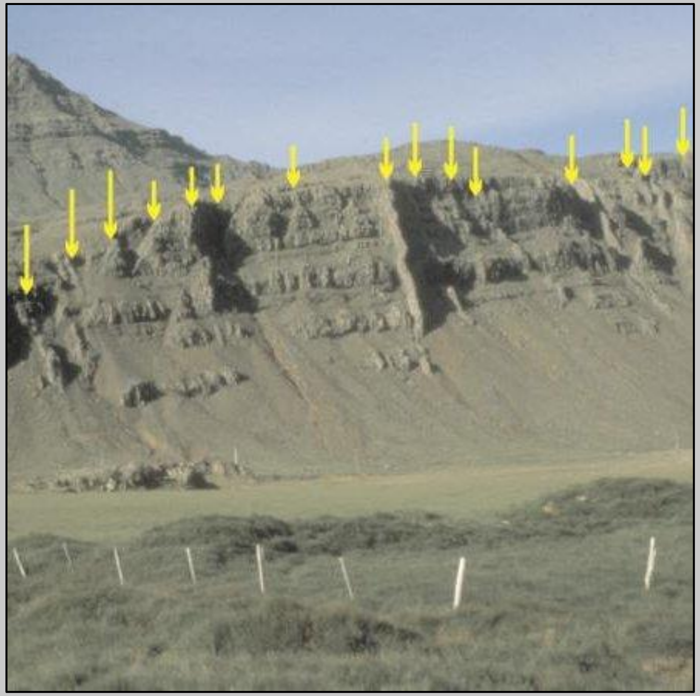


Dike swarm filling zones of weakness such as faults or fractures. They can generate earthquakes as they intrude.

Sam Cooke (UO student) standing beside prominent “dinosaur sail” dike.

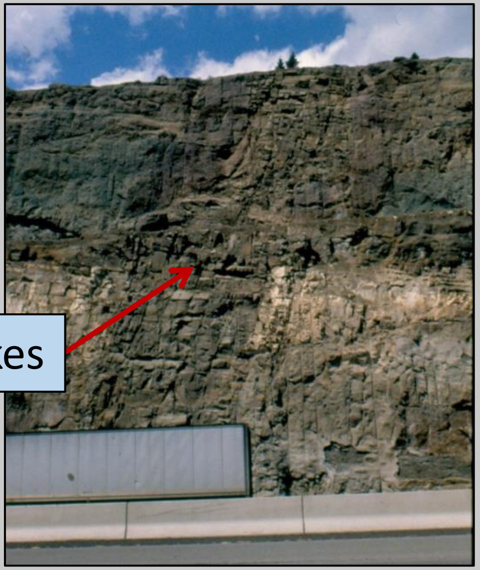
Dikes normally are harder than the rocks they intrude so they form ridges as erosion occurs.





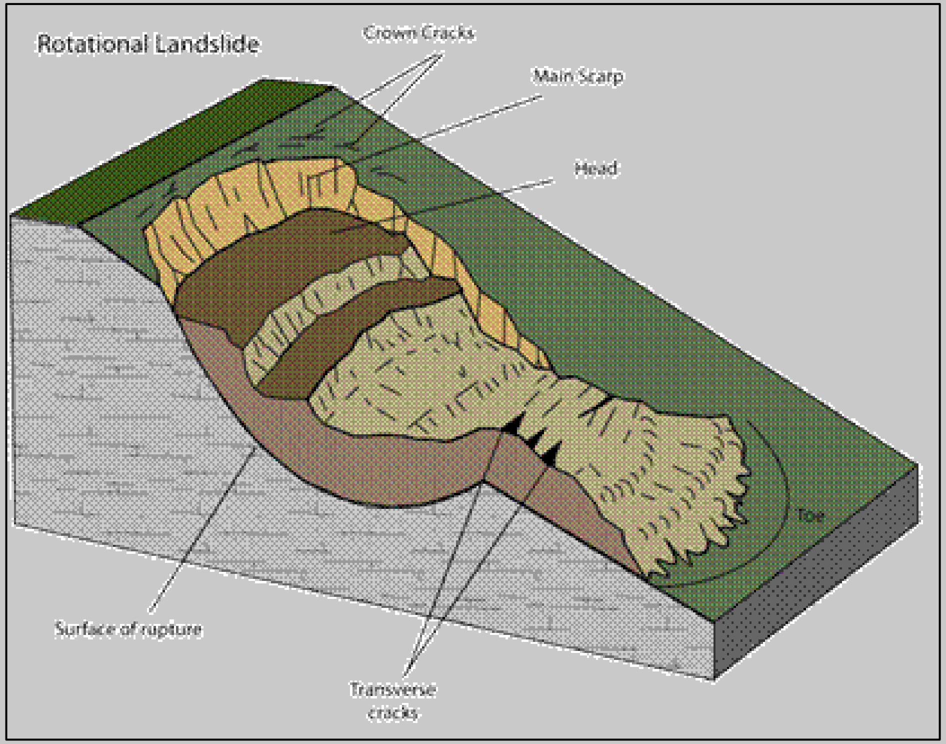
Right: Dike as part of a swarm SE of Pilot rock.

Far right: dike seen at south end of Siskiyou Summit.

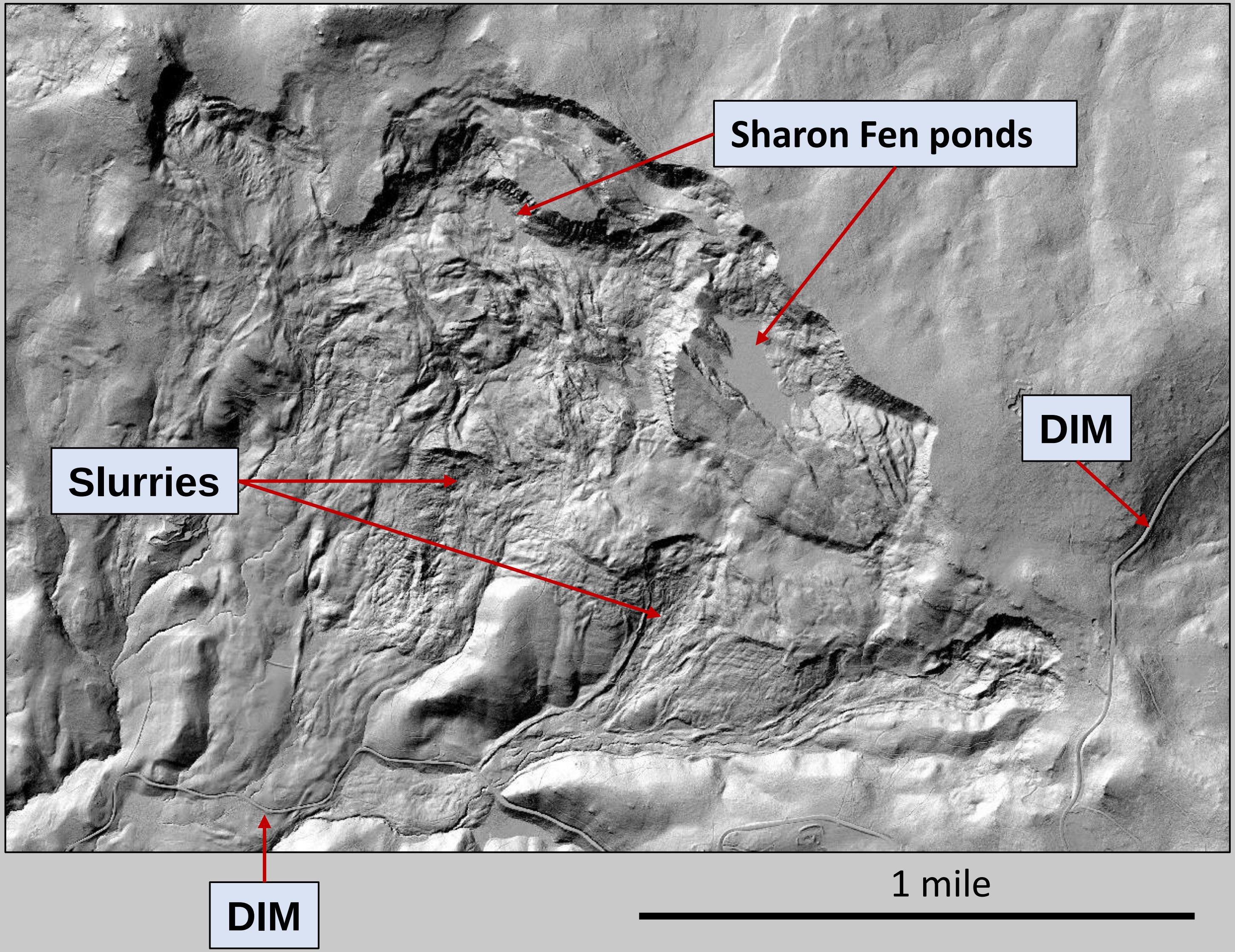


Dikes

Landslides

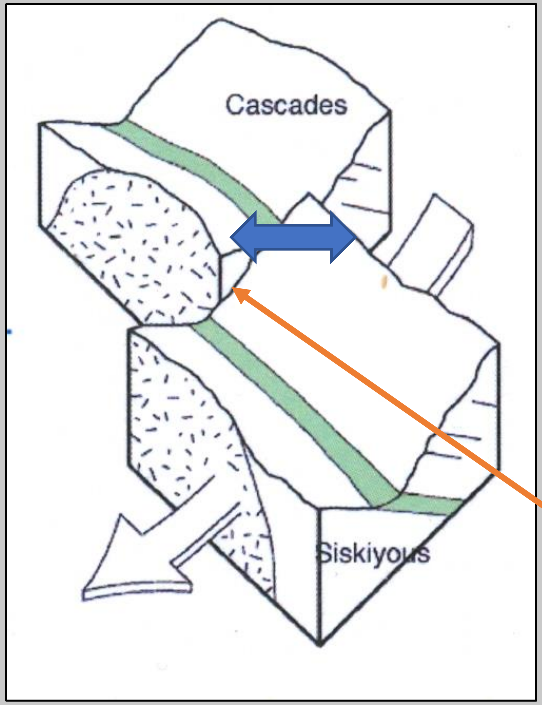


Landslides occur where groundwater saturates clay-rich soil, usually on steep slopes. Failure may result in slurries of muddy debris or as large rotated blocks.



LiDAR imagery showing **Sharon Fen ponds** north of Dead Indian Memorial **(DIM)** Highway lie behind rotated landslide blocks. The **Parsnip Lakes** south of Hwy 66 are created in a similar manner.

So? What does all this have to do with the biodiversity for which the Monument was designated?



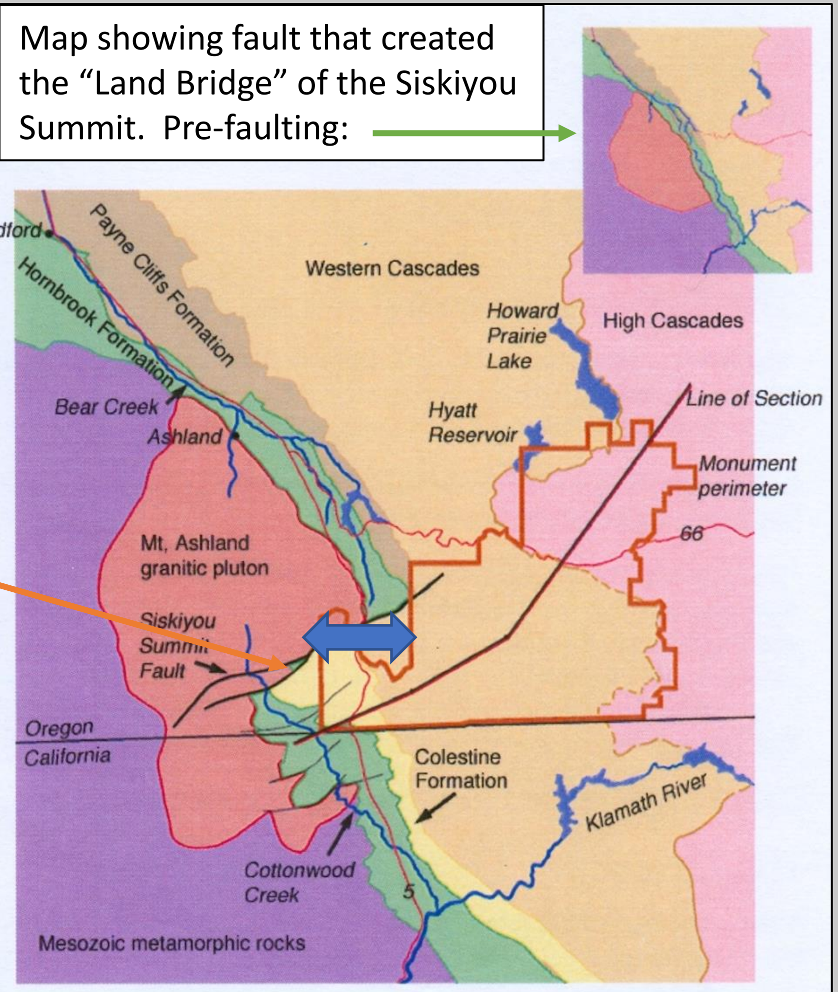
Diagrams by Len Eisenberg for the CSNM

Migration along the **land bridge** is shown by blue double arrows on both diagrams.

Post-faulting

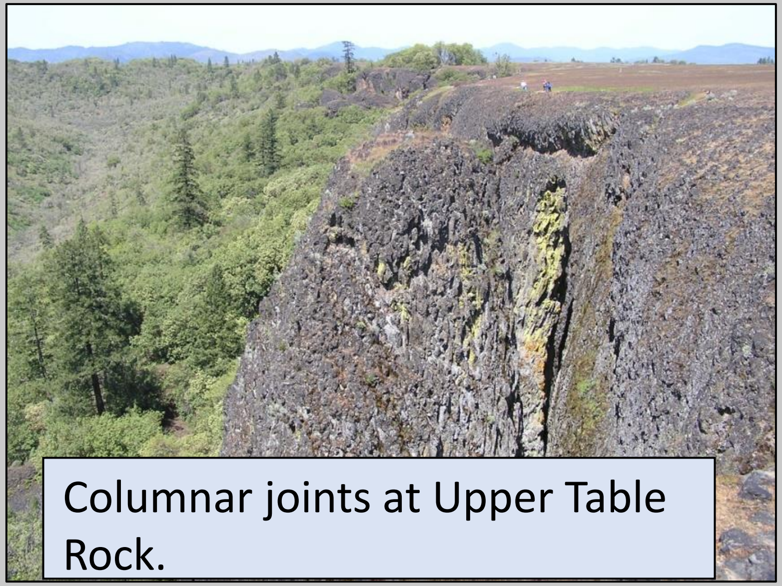
So what physical factors allowed the CSNM to become such a biologically diverse region? One answer lies in the geology. A large fault, the **Siskiyou Summit Fault**, offset the Bear Creek and Cottonwood Creek (Colestin) valleys bringing hard granitic rocks against hard volcanic rocks. The resulting topographically high area formed the **"land bridge"** between the Siskiyous, Cascades, and Great Basin. The fault became inactive ~27 million years ago.

Map showing fault that created the "Land Bridge" of the Siskiyou Summit. Pre-faulting:

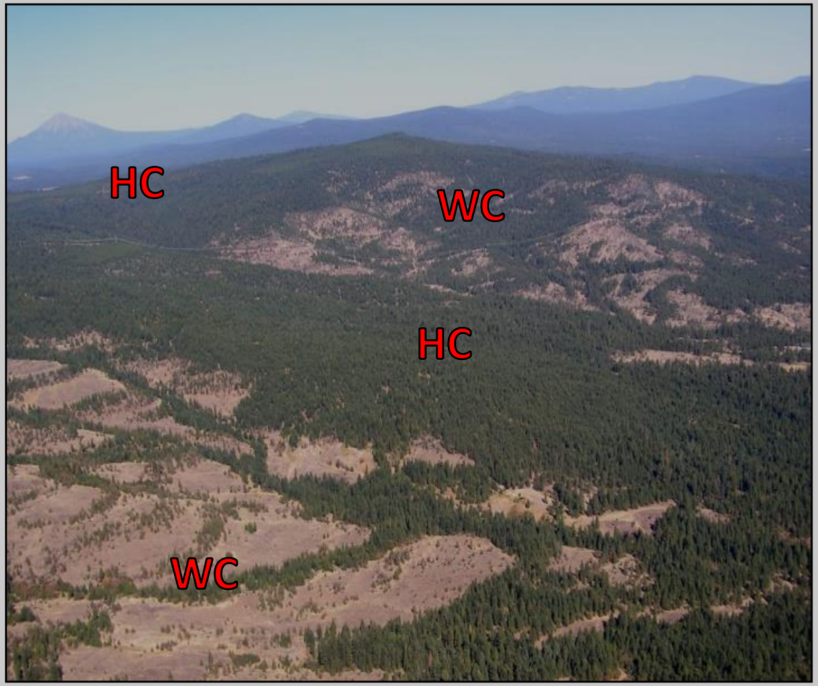


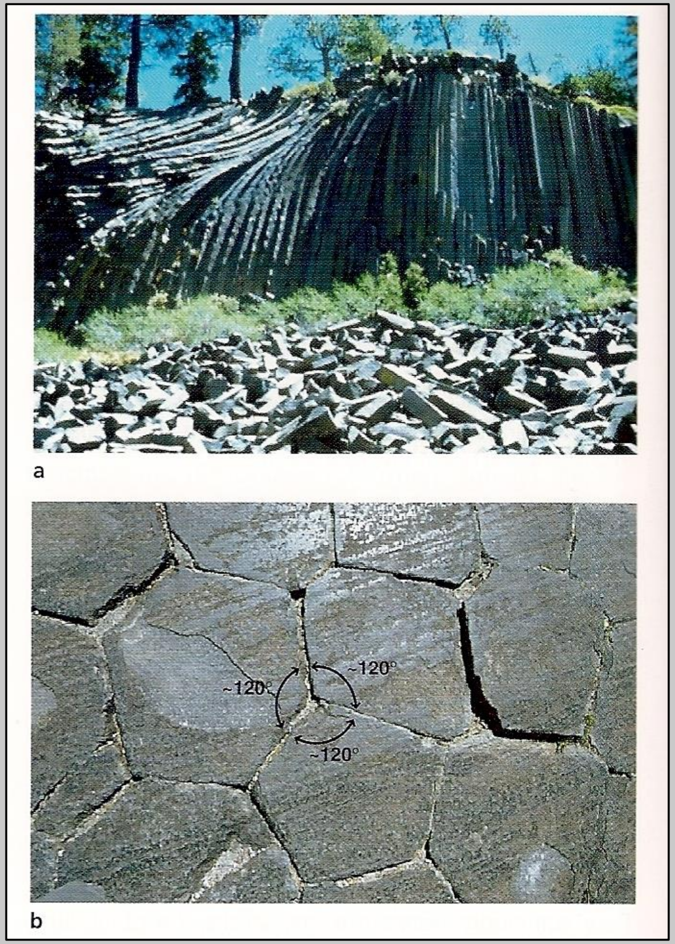
Geologic Map of Cascade-Siskiyou Area

Major geologic formations, faults and cultural features are summarized on this simplified map. The most prominent feature is the offset of geologic formations along Siskiyou Summit Fault. The small inset map shows how the same features would appear without the fault.



Columnar joints at Upper Table Rock.





Columnar joints formed by cooling and shrinking of lava provide conduits for and reservoirs of water.

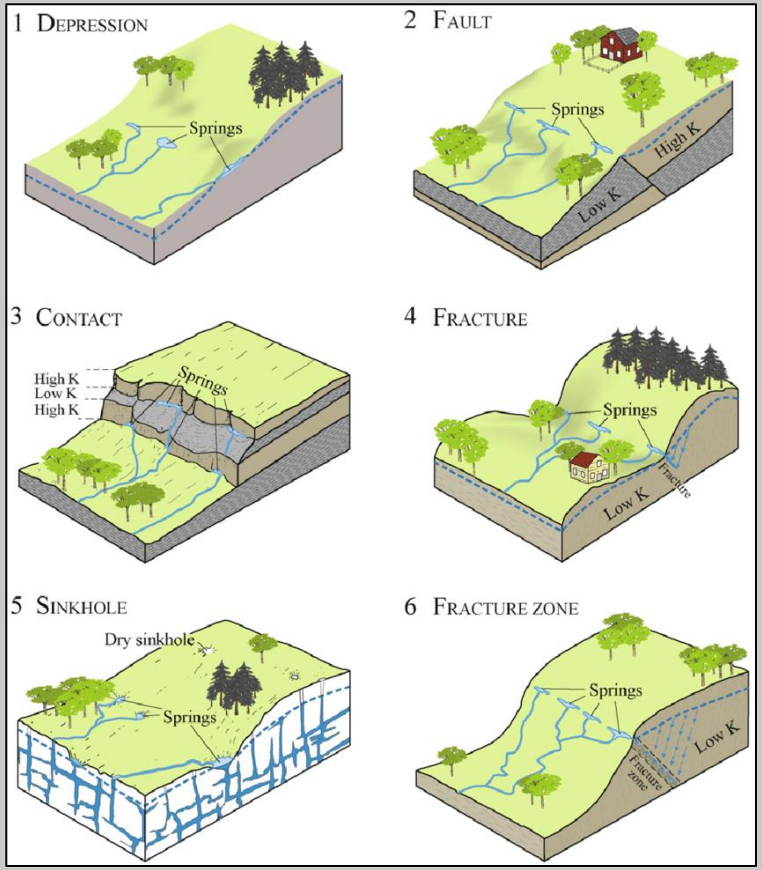
<u>Effect of different rock types on vegetation</u>: low permeability and clay soils developed on **WC** (foreground, middle ground); trees developed on permeable **HC** lava.

Different soils are derived from different rock types; clay-rich soils, fractured rock reservoirs; and topographically sheltered areas.

Clay rich soils developed on volcaniclastic rocks **aren't as permeable** as **lava flows** (which **contract upon cooling** creating conduits which store water through the dry summer). Clay rich soils support shallow rooted vegetation (grasses, poison oak) while more permeable rock supports deeper rooted trees and brush.

Topography caused by different rock types creates **sheltered areas**. Such areas include north slopes of ridges and places on south-facing slopes where moisture can not only collect through drainage but be sheltered and retained longer than on open south-facing slopes.

Effects of geology surface and ground water characteristics.



Rocks and soils that have different permeabilities not only affect surface **run-off during storms** but have different capabilities with respect to **storage of ground water** that can be released to streams during dry summer months .

Shoat Spring forming at the base of a permeable lava flow. Picture taken in August, 2018.

Contacts between permeable (upper rocks) and impermeable (lower rocks) can create springs at their interface; **all natural springs have an underlying geologic cause**.

Fractures and faults can break rocks creating reservoirs for moisture to collect which, in turn, supports different kinds of vegetation.

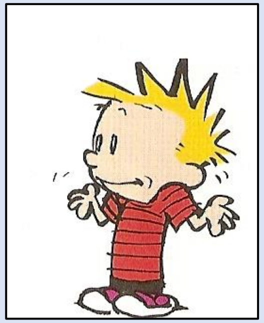
So, why is it important to know about the geology in the CSNM?

General understanding of the landscape around us, what caused it, why are there different rock types, why are they there, how old are they, and the beauty and satisfaction of knowing more about your environment. Analogy: turning paintings from facing the wall to facing the public.

Too, there's always an appreciation of some unique geologic features of the CSNM such as:

- Pilot Rock: what is it and why does it project above the landscape?
- Table Rocks: what caused the flat mesas and where is the source of those lava flows?
- Why is Howard Prairie Lake aligned in a NW direction? [answer: it is caused by erosion of soft tuffaceous rocks that trend NW; that's also why the Bear Creek Valley trends to the NW—erosion of soft ancient mudstone.]
- Why are Highway 66 and DIM so steep then flatten out at Greensprings Inn and Howard Prairie Lake (respectively)? [answer: transition from old softer and easily eroded Western Cascade volcaniclastic rocks to hard lavas of younger High Cascade volcanoes.]
- Gosh! I'm so excited! Where can I learn more?

  Oregon's DOGAMI (Dept of Geology and Mineral Industries)
  Roadside Geology of Oregon (2nd edition)
  Unfortunately, no local geology text exists.



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Questions?