Floods and Flows: Exploring Mars Geology on Earth

http://en.wikipedia.org/wiki/Image:Dry_Falls.jpg

13-19 July 2008

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OVERVIEW

OBJECTIVES

- Investigate geographic features related to lakes, glacial activity, and flowing water
- Build an understanding of the geologic processes that result in these features
- Compare and contrast these features with similar features on Mars and understand the implications of their presence in terms of geologic processes and planetary history
- Be able to bring content and hands-on inquiry based, standards-aligned activities into the classrooms in ways that are appropriate for the grade level being taught

CONTENTS

APPENDICES

QUESTIONS TO PONDER

- What information does each field stop contribute to the overall story of Glacial Lake Missoula?
- What is the evidence for the existence and location of ice sheets in the region?
- What evidence is there for the presence of Glacial Lake Missoula?
- What is the *depositional* evidence for catastrophic outflow of water from Lake Missoula?
- What is the *erosional* evidence for catastrophic outflow of water from Lake Missoula?
- What evidence exists for multiple flooding events?
- Why was the explanation of a “catastrophic” event as the cause of the features we observe not immediately accepted by the geologic community?
- Are there alternative explanations for the features that we observe? What is the role of individual observations / interpretations versus compiled observations?
- How do the features we observe inform our understanding of the geologic history of Mars?

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SAFETY

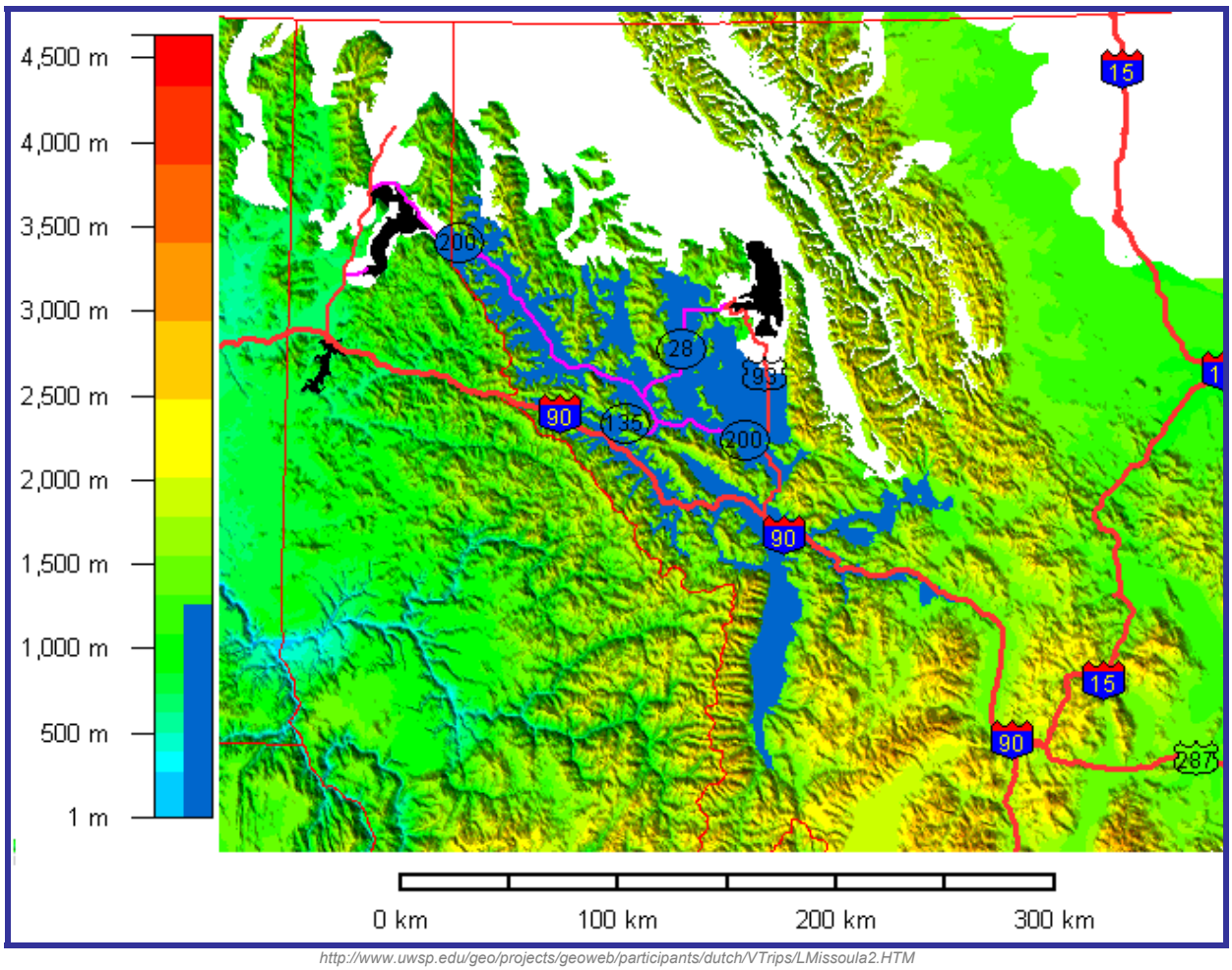
- Remember that an injury is not a pleasant thing to endure and it could end the field trip for everyone. BE CAREFUL - SAFETY FIRST! Explore in pairs.
- Stay healthy to enjoy your day. Wear sunscreen, hats, sunglasses to protect yourself. Wear hiking boots or sturdy tennis shoes.
- Drink lots of water. Drink lots of water. Drink lots of water.
- Do not put yourself into a situation in which you are uncomfortable with respect to your own safety.
- Often the bus will be parked close to the road. Use caution when exiting or entering.
- Often there is a barrier (fence or stone wall) between you and a cliff. DO NOT CROSS THESE BARRIERS – even just to "sit" on the other side.
- When outcrops are close to the road use caution when crossing the road and at the outcrop. Do not wander into the road. Be aware that passing cars and trucks a) go fast and b) may send rocks in the road flying at you.
- Don't climb the rocks unless the ground is stable and climbing is necessary to get to the geology.
- Dislodged rocks fall down (=gravity in action). Do not climb on rocks above other field trippers. Let those beneath you know when rocks are dislodged.
- Rock hammers expose fresh surfaces and provide samples. When you chip away at a rock, be aware of those around you and note that chips fly - protect your eyes!
- Keep an eye out for snakes, large hairy spiders, and other things that can give you a nasty bite. If you find them give them a wide berth and, please, show them respect - do not poke at them with sticks, throw rocks, etc.
- Be aware of the trip schedule and be prompt about returning to the vehicle at the designated meeting time; times will be announced at each stop. The days are long without adding extra waiting time because of one or two people.
- No sampling is allowed in State and National Parks. Please don't! Take pictures instead.

Times in this guide book are estimates. Because of extended or shortened group discussions, weather, field conditions, road conditions, etc., we may alter the time spent at a stop, change the order of the stops, add stops or delete stops. Be flexible! The days will be fun and informative!

Day 1. Missoula to Flathead Lake Region and Back … The Lake

Objective: Examine deposits and features associated with ancient Glacial Lake Missoula and build an understanding of the geologic processes that created them.

8:00	Depart from University Dorms	1:00	**Stop 4 near Niarada** (60 minutes) East on 28 for 15 miles
8:15	**Stop 1 University Hill** (30 minutes) West on 90 for 21 miles	2:15	**Stop 5 near Elmo** (60 minutes) South on 93 for 10 miles
9:15	**Stop 2 Huson, Nine Mile, Alberton** (45 minutes) West on 90 for 42 miles East on 135 for 25 miles North on 382	3:30	**Stop 6 Polson** (30 minutes) South on 93 to Ravalli for 32 miles South on 200 for 27 miles South on 93 for 5 miles East on 90 for 8 miles
11:30	**Stop 3 on 382 Chamis Prairie** (60 minutes) North on 28 for 20 miles Lunch	5:30	Return to University in Missoula



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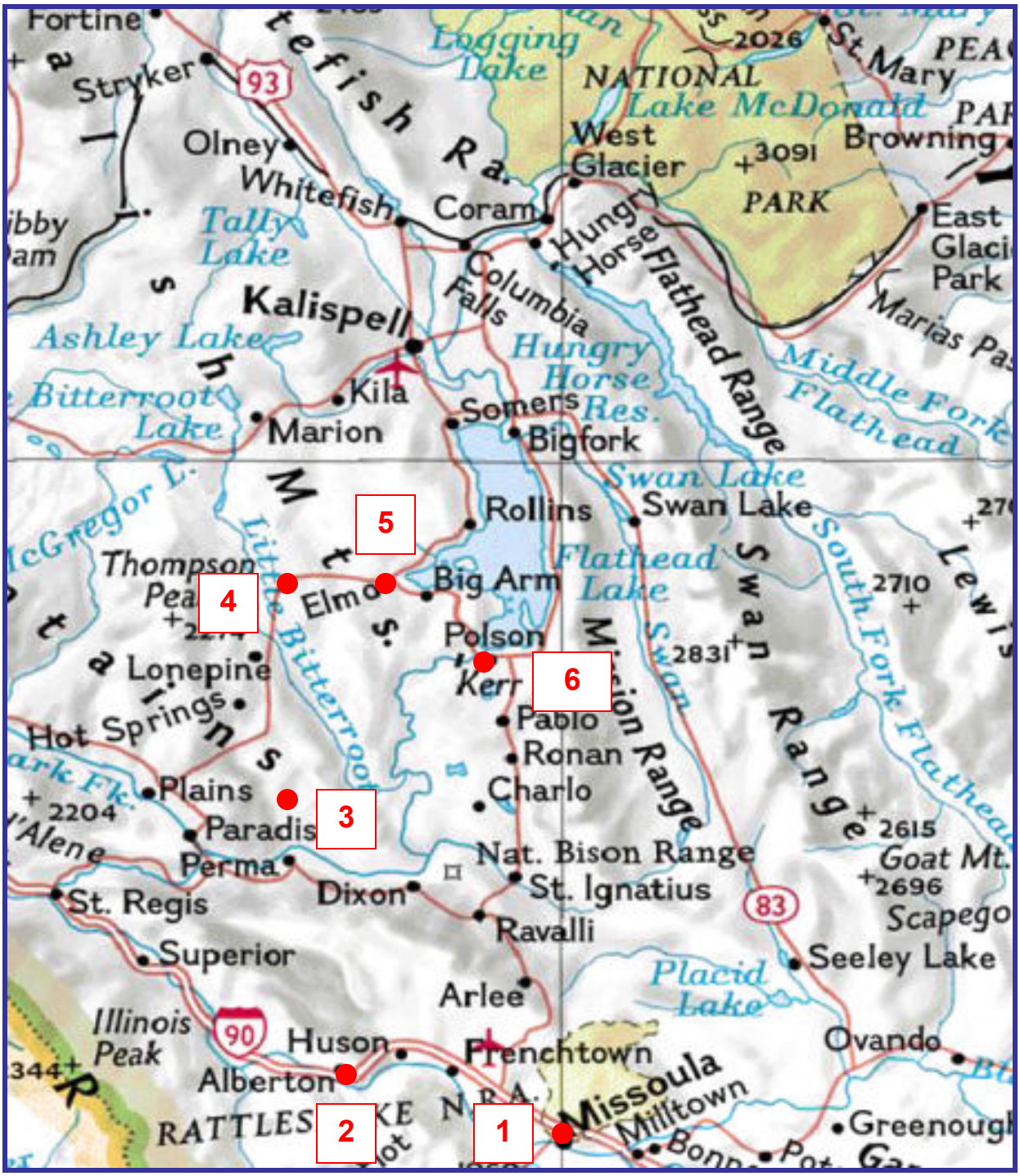

Fortine
Stryker
93
Olney
Whitefish
Tally Lake
Kalispell
Ashley Lake
Bitterroot Lake
Kila
Marion
Logging Lake
NATIONAL
Lake McDonald
West Glacier
Coram
Hungry Horse
Columbia Falls
Hungry Horse Res.
Somers
Bigfork
Flathead Range
St. Mary
Browning
3091
PARK
East Glacier Park
Marias Pass
Middle Fork Flathead
Swan Lake
Rollins
Swan Lake
Flathead Lake
Big Arm
Elmo
Polson
Kerr
Pablo
Ronan
Charlo
Mission Range
Swan Range
South Fork Flathead
2710
2831
2615
Goat Mt.
2696
Scapego
Lonepine
Hot Springs
Plains
Paradise
Perma
Dixon
St. Regis
Superior
Nat. Bison Range
St. Ignatius
Ravalli
83
Seeley Lake
Placid Lake
Arlee
Illinois Peak
90
Huson
Alberton
Frenchtown
Missoula
Milltown
Ovando
Greenough
RATTLESNAKE
2204
Little Bitterroot
McGregor L.
Thompson Peak
1
2
3
4
5
6

Stop 1 Hillsides around the University of Montana

Observations and Illustrations
Observe the hillsides. What features do you see? What is their scale? Is there a pattern to them?

Discussion / Interpretation
What are these features? How did they form? Why are there multiple features? How do they fit into the geologic history of Glacial Lake Missoula? If you observed these features on Mars, how might you interpret them?

Stop 2 Huson, Nine Mile, Alberton

Observations and Illustrations
Describe the sedimentary outcrop from a distance. What is the size of the sediment? Are there any structures that you observe in the outcrop? Is there a pattern to the structures? Examine the outcrop closely. What do you see?

Discussion / Interpretation
What are these features? How did they form? In what depositional environment did they form? What is recorded in this outcrop and how does it relate to the Glacial Lake Missoula? If you observed these deposits on Mars, how might you interpret them?

What kind of fossils might you expect to find and why are they not here?

Stop 3 Chamis Prairie

Observations and Illustrations
Look at the field. What features do you see? What is their scale? Is there an organization to the features?

Discussion / Interpretation
What are these features? How did they form? What was the environment like when they were forming? Are the processes that formed them operating today? If not, then what lines of evidence support your conclusions? Where did the material come from? How do they fit into the geologic history of Glacial Lake Missoula? If you observed these features on Mars, how might you interpret them?

As we head north, past Hot Springs, we will be alongside the Hog Heaven Hills, a Tertiary volcanic complex of light colored quartz latite, latite, andesitic tuff, and basalt. These rocks serve as hosts for copper, silver, and lead ores that have been mined.

Stop 4 Niarada and the Big Draw

Observations and Illustrations
Look at the field. What features do you see? What is their scale? Is there an organization to the features? Examine one of the features in cross section along the road. What do you observe about the size of the sediment? Other structures in the feature?

Discussion / Interpretation
What are these features? How did they form? How do they fit into the geologic history of the region?

Stop 5 Elmo

Observations and Illustrations
What do you observe about the size of the sediment? Other structures? What is the overall shape of the feature? What other features are associated with it?

Discussion / Interpretation
What is this feature? How did it form? How does it fit into the geologic history of Glacial lake Missoula? If you observed this feature on Mars, how might you interpret it?

Stop 6 Polson

Observations and Illustrations
Make observations about the region as we drive to this stop. What features do you observe? What does the landscape look like? What are the characteristics of the features (shape, scale, relative location)?

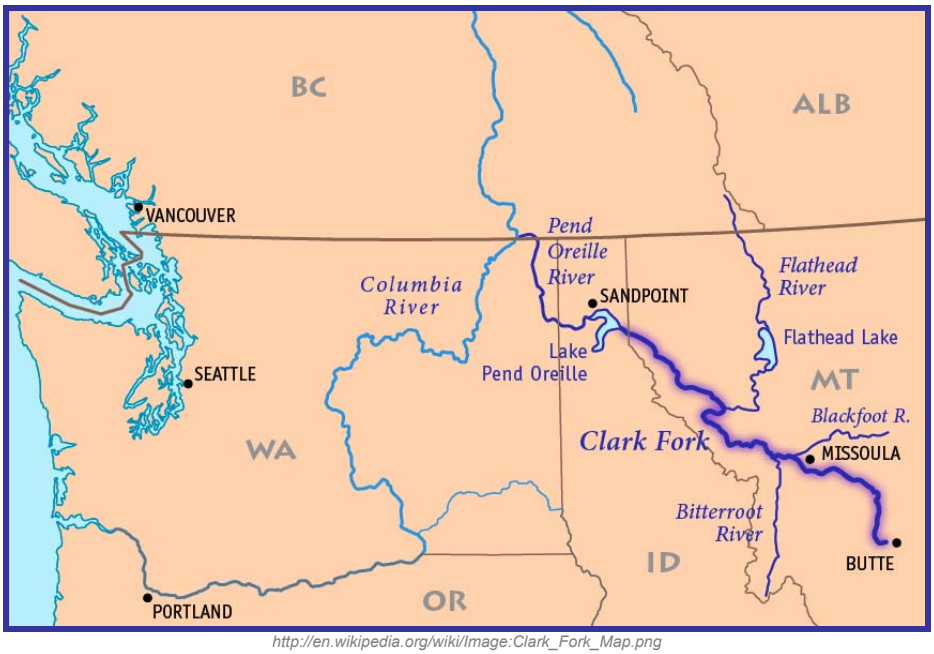
Discussion / Interpretation
What are the features observed? How did they form? How do they fit into the geologic history of the region?

Day 2. Missoula to Central Washington … Breakout!

Objective: Trace Glacial Lake Missoula to the Purcell Lobe Ice Dam and examine the effects of the flood near the breakout.

7:30 Depart University to Wenatchee West on 90 71 miles East on 135 12 miles West on 200 to Clark Fork 100 miles	Farragut State Park Visitor Center - fee Continue to Willow Day-Use / Sunrise Day-Use areas (4 miles) Proceed to beach area
12:00 **Stop 7 Cabinet Gorge Dam** (60 minutes) Orientation, Lunch West on 200 toward Hope/East Hope Turn off at Stephen's Road (paved) and head south for ~2-3 miles	3:30 **Stop 10 Farragut State Park Lake Missoula Break Out Area** (60 minutes) West on 54 Slow past Ramsey Road
1:30 **Stop 8 Powerline Pit** (30 minutes) North on Stephen's Road ~2-3 miles West on 200 toward Hope/East Hope ~12 miles Pullout for between milepost 44 and 45; alternative pull out at hwy sign past Hope	**5:00 Stop 11 Spirit Lake Current Ripples** South on 53 (41) 25 miles **Drive Through of Rathdrum Prairie** West on 95 to Spokane 13 miles Dinner in Spokane West on 2 toward Oronodo ~135 miles South on 97/2 toward Wenatchee 18 miles South on 28 to 80 9th Street, East Wenatchee
2:30 **Stop 9 Lake Pend Oreille Overlook** (30 minutes) West on 200 toward Sand Point 15 miles South on 95 26 miles	9:00 Arrive Wenatchee Staying at Ceders Inn, Wenatchee 80 9th Street, East Wenatchee Dinner at fast-food places

As we are traveling along route 200, we are in Glacial Lake Missoula. When the ice dam broke, the water in this valley was released and began to flow downstream at approximately 45 miles per hour!



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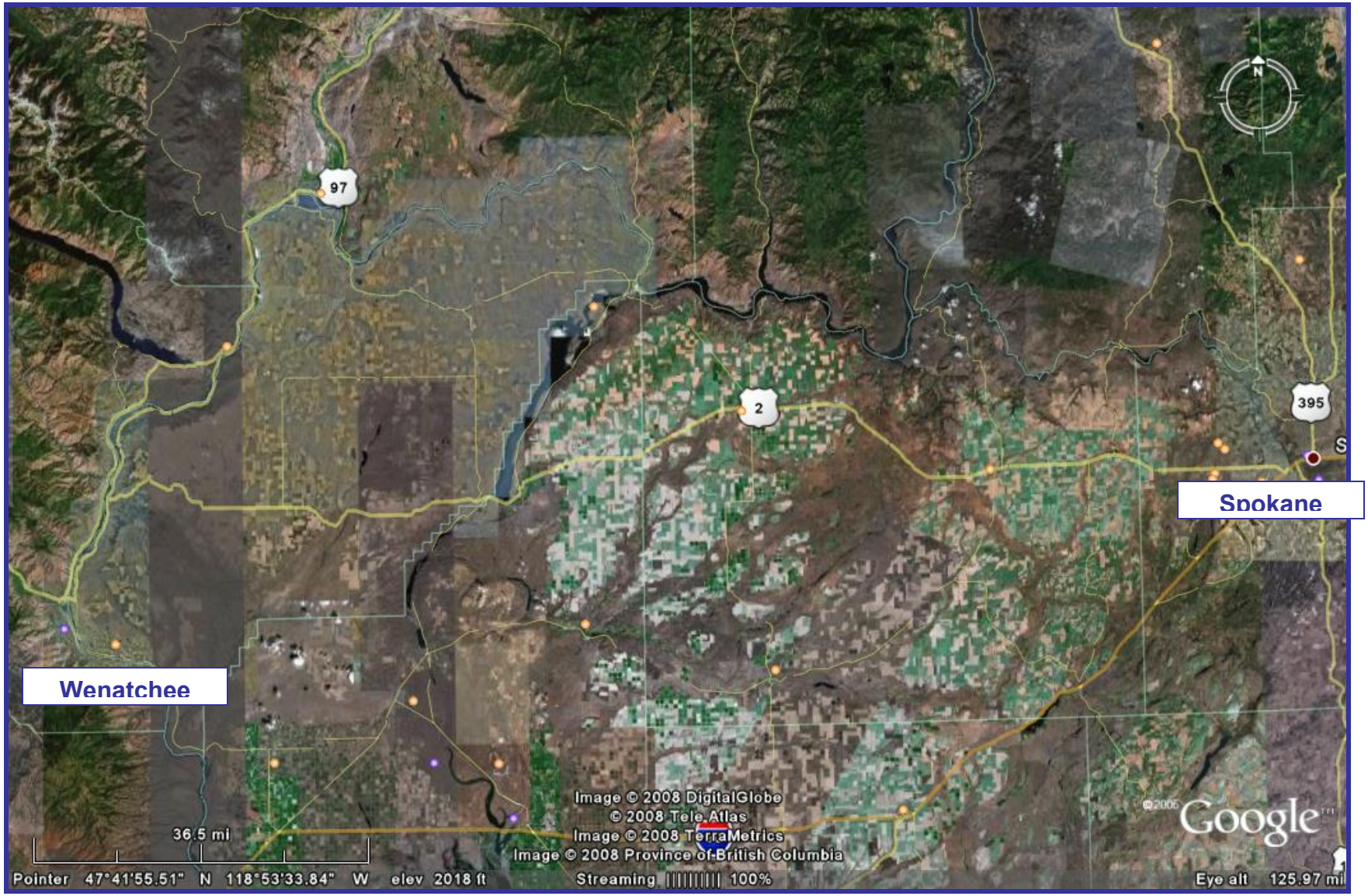
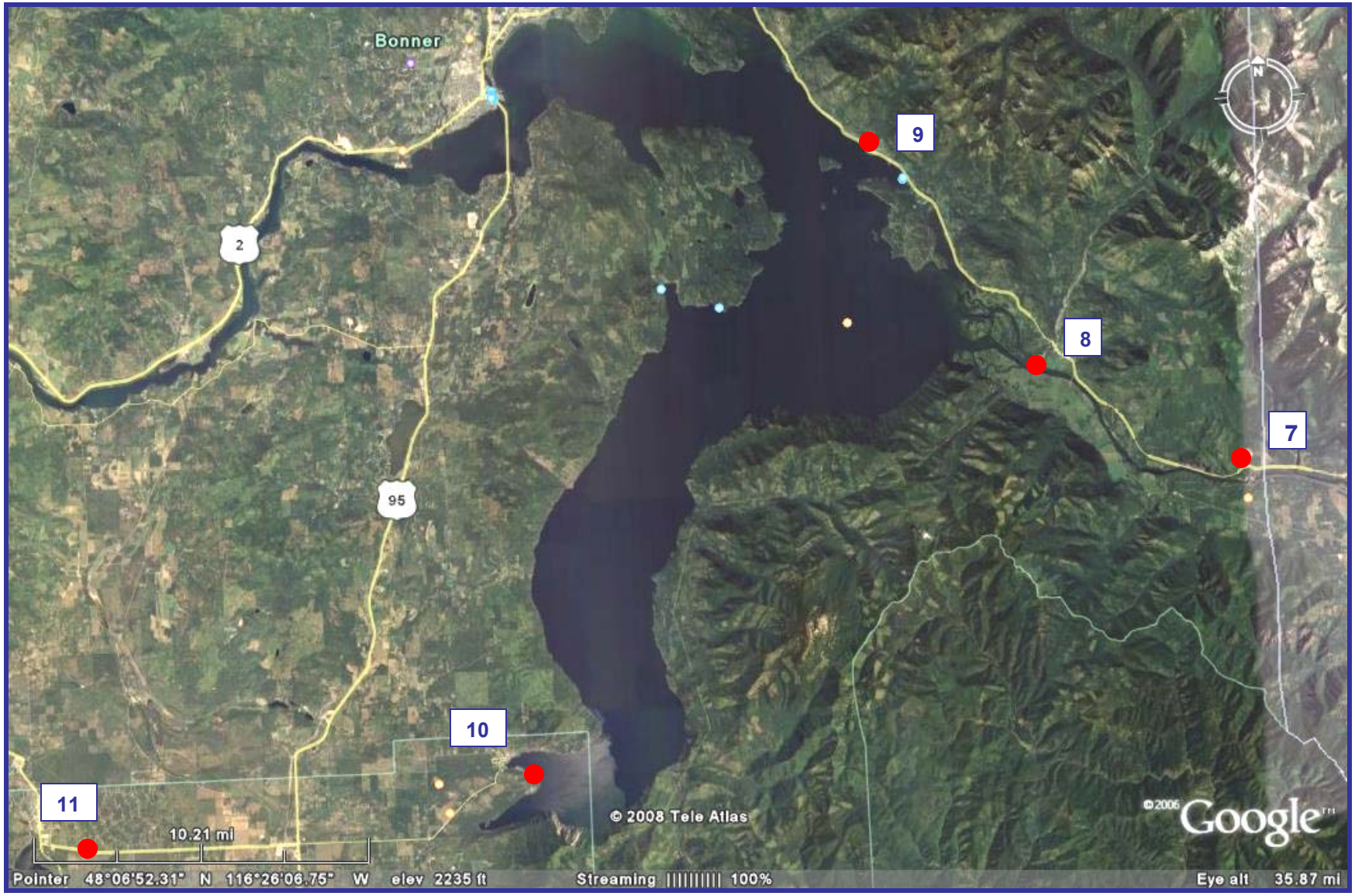
Missoula to Lake Pend Oreille, Montana.

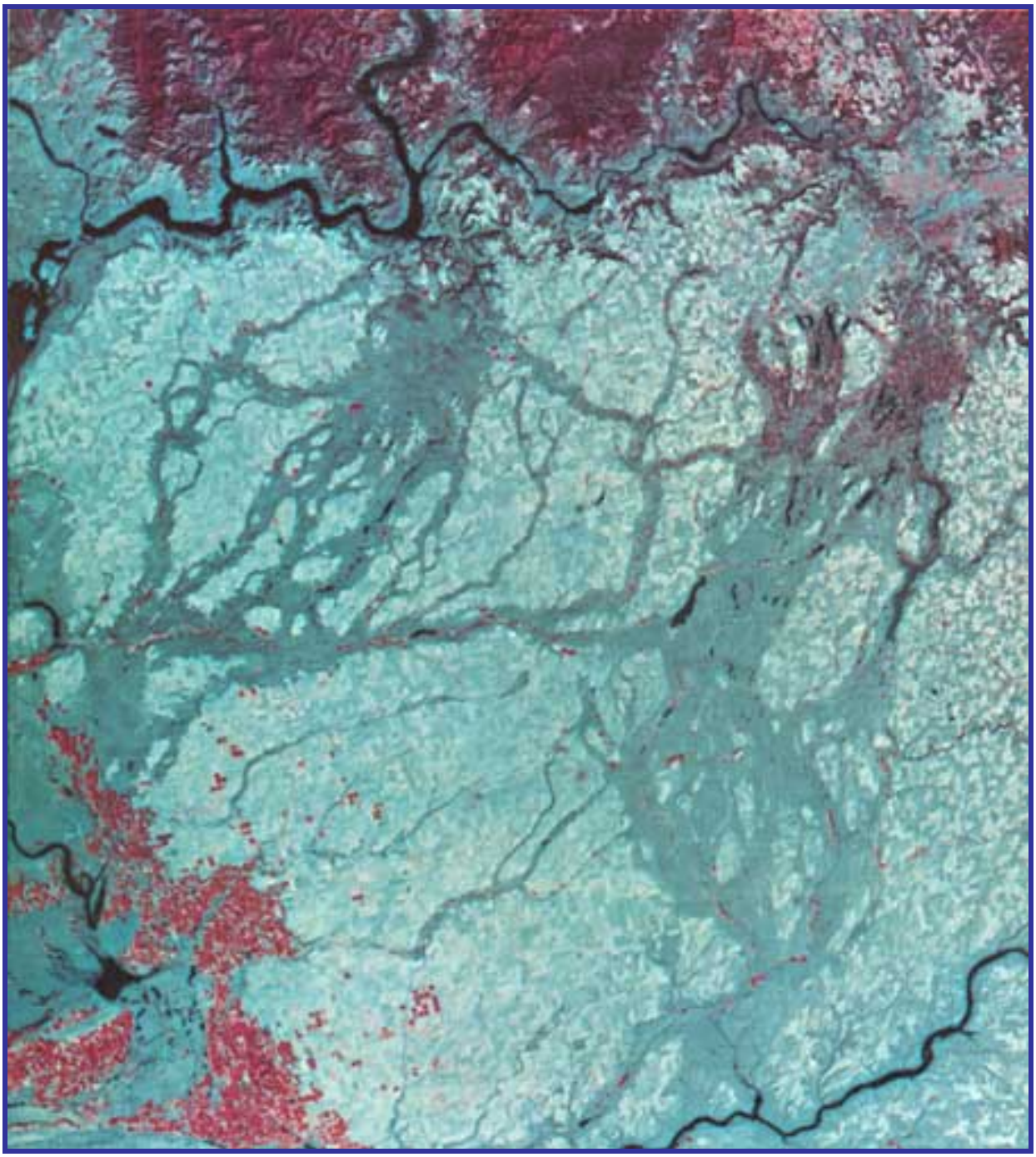
Lake Pend Oreille, Montana to Spokane, Washington.



Spokane to Wenatchee, Washington.



Pend Oreille Region.



NASA Landsat Image of Channeled Scablands from an altitude of 569 miles.

The dark "braided" pattern clearly depicts the channelways of the Great Spokane Flood—the areas where vigorous stream erosion stripped away the "frosting" of loess to expose underlying dark basalt. A large part of the region is planted in wheat as the checkered appearance of the terrain denotes. The clusters of small red circles at the lower left are fields irrigated with rotating sprinklers as part of the Columbia Basin Reclamation Project. The dark red area north of the Columbia and Spokane Rivers is the densely timbered region called the Okanogan Highlands. Grand Coulee and Grand Coulee Dam are visible at the upper left.

This color "photograph" was prepared from a set of three Earth images recorded in the green, red, and infrared bands of the spectrum by the Landsat Multi-spectral Scanner. The electronic data were transmitted to a ground station and processed. The three images were combined, using appropriate color filters, to make this "false" color composite. Green vegetation appears red on this composite mainly because of the strong response of the infrared band to chlorophyll.

Stop 7 Cabinet Gorge Dam

Overview
Cabinet Gorge Dam was completed in 1952. It is 600 feel (83 meters) across and 200 feet (63 meters) high. It sits in Precambrian Belt Supergroup rocks that formed about 1.4 billion years ago.

Imagine standing in this location 15,000 years ago. The dam marks the approximate site of one edge of the Purcell Trench Lobe, an ice lobe that flowed from the north and covered Pend Oreille Lake. To the east, upstream, Glacial Lake Missoula occupied the landscape.

Observation / Illustration
Describe the features you observe at this stop.

Discussion / Interpretation
Why do geologists suggest that “normal” river flow did not carve this gorge?

How high was the water level? What evidence might you use to determine this?

What evidence would you expect to support the interpretation that a glacier once flowed in this vicinity? Can you observe any such evidence?

Stop 8 Powerline Pit

Observations and Illustrations
Describe the outcrop. What structures do you see? What is the grain size of the sediment? Composition? Sorting?

Discussion / Interpretation
What is this feature? How did it form? Describe the environment of deposition. How does this outcrop fit into the geologic history of Glacial Lake Missoula?

Stop 9 Lake Pend Oreille Overlook

Overview
Lake Pend Oreille was occupied multiple times by the Purcell Ice Lobe. With each advance to the southern end of the lake, the Clark Fork River was dammed and Glacial Lake Missoula formed.

The lake is the deepest in the region and has a U-shaped profile; while its origin is debated, glaciers certainly scoured the basin. It contains at least 75 meters of sediment.

Can you identify where the Clark Fork River enters? The Purcell trench?

Pend Oreille Paddler?
Yes, Pend Oreille has its own legend. Watch for it!

Stop 10 Farragut State Park Lake - Missoula Break Out Area

Overview
This was the place of failure of the Purcell Ice Lobe. This lobe of ice repeatedly moved across Pend Oreille, damming the Clark Fork River and causing a lake to form behind the dam. The exact number of times this occurred is debated, but geologists have constrained the timing of events to between 17,000 and 12,000 years ago.

Observation / Illustration
Describe the features and sediment you observe at this stop.

Discussion / Interpretation
How did the ice dam fail? When the dam broke, where did the water go? What is the evidence that we have seen for multiple lake-building events?

Stop 11 Spirit Lake / Rathdrum Prairie

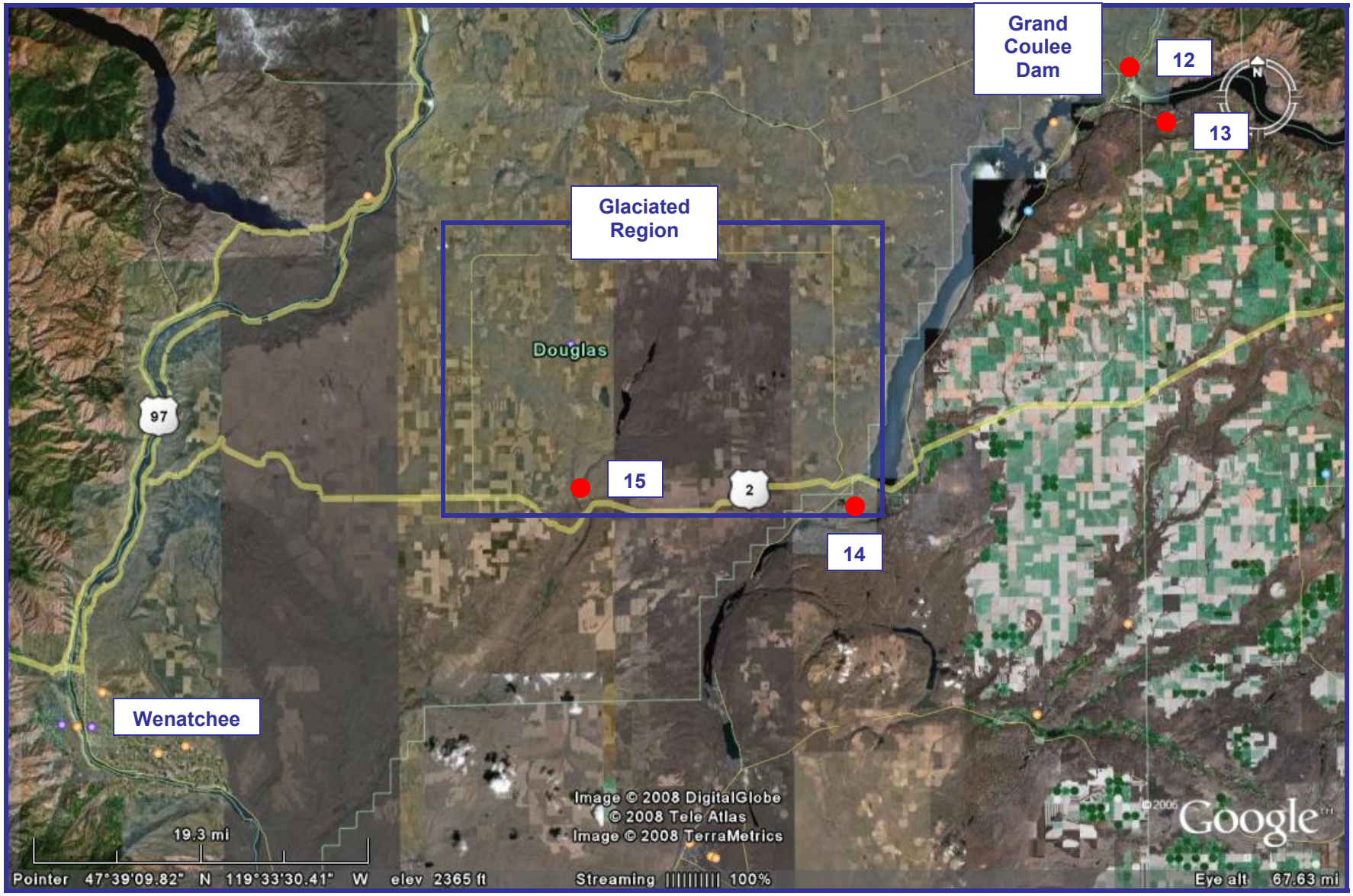
Observations and Illustrations
What features do you observe? What does the landscape look like? What are the characteristics of the features (shape, scale, relative location)? If we can observe the sediment comprising the features, describe the sediment characteristics. How do they compare to features we have observed previously?

Discussion / Interpretation
What are these features? How did they form? Where do they occur relative to the ice dam? How are they related to Glacial Lake Missoula?

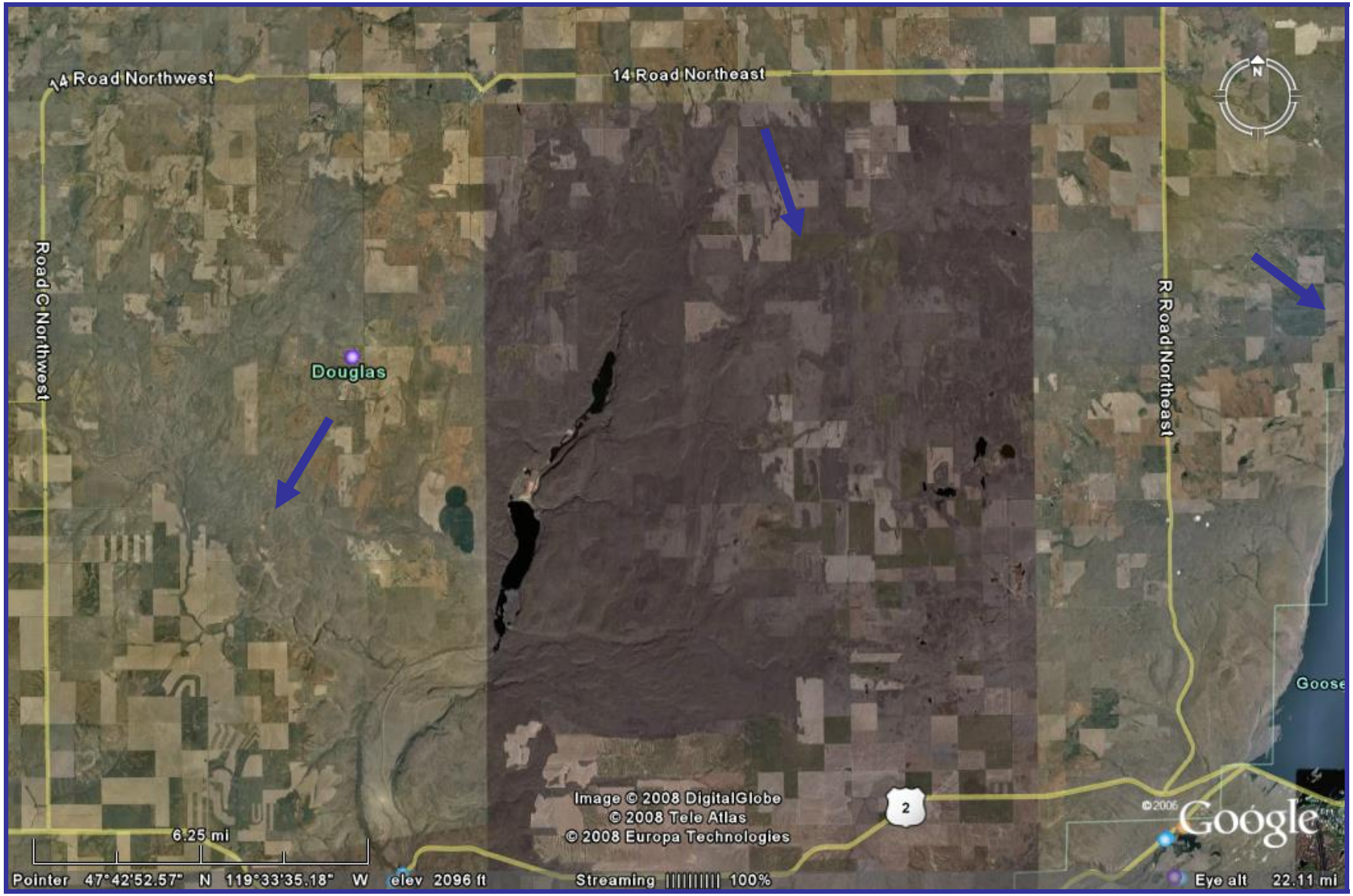
Day 3. Wenatchee Region … Scour

Objective: Examine the flow path of Glacial Lake Missoula – and other – flood waters. Observe the associated erosional features and build an understanding of the geologic processes that created them.

8:00	Depart Wenatchee North on 28 North on 97/2 toward Orondo 18 miles East on 2 toward Dry Falls 23 miles North on 172 to Withrow and beyond 14 miles **Drive-by of Pro-Glacial to Glacial Terrain in Withrow Region** (May stop at large boulder) East on 172 to Mansfield 21 miles North on 17 8 miles East on 174 to Grand Coulee 21 miles
11:00	**Stop 12 Grand Coulee** (150 minutes) Tour and Lunch **Grand Coulee Overlook** Continue east on 174 toward Wilber ~ 5 miles
2:00	**Stop 13 Rock Structures** (30 minutes) Return west on 174 toward ~5 miles (between mileposts 29 and 30; asphalt pullout)
	South on 155 toward Coulee City 26 miles West on 2 to Orondo 6 miles South on 17 to Dry Falls Park ~2 miles
3:30	**Stop 14 Dry Falls** (90 minutes) Visitor Center Overlook North on 17 ~ 2 miles West on 2 ~15 miles
5:15	**Stop 15 Moses Coulee** (30 minutes) Possible sampling stop between milepost 167 and 168 West on 2 toward Oronodo ~33 miles South on 97/2 toward Wenatchee 18 miles South on 28 to 80 9th Street, East Wenatchee
6:30	Arrive Wenatchee



Regional setting of Dry Falls and Grand Coulee. Box marks boundaries of next figure.



Glacial flow directions in Withrow region.

Scour features associated with Dry Falls region.

Stop 12 Grand Coulee

Grand Coulee Dam is a hydroelectric [gravity dam] on the Columbia River in the U.S. state of Washington. In the United States, it is the largest electric power producing facility and the largest concrete structure. It is the fourth largest producer of hydroelectricity in the world. The Grand Coulee Dam is almost a mile long at 5223 feet (1586 m). The spillway is as long as 5.5 American football fields. At 550 feet (168 m), it is taller than the Great Pyramid of Giza; all the pyramids at Giza could fit within its base. Its hydraulic height of 380 feet (115 m) is more than twice that of Niagara Falls. There is enough concrete to build a four-foot wide, four-inch deep sidewalk twice around the equator. The dam was built as part of the Columbia Basin Project for irrigation of desert areas of the Pacific Northwest and for the production of electricity. The U.S. Bureau of Reclamation was created in 1902 to aid development of arid western states. Central Washington's Columbia Basin was a prime candidate -- a semi-desert with fertile loess soil and the Columbia River passing through. …. From Wikipedia, of course!

Grand Coulee Overlook

Observations and Illustrations
Describe the features that you observe and their scale.

Discussion / Interpretation
What processes formed this landscape?

Stop 13 Rock Structures

Observations and Illustrations
Describe the rocks you observe. Are there any structures?

Discussion / Interpretation
What kind of rocks are these? What is their origin? In what environment did they form?

Approximately how old are these rocks? What was the environment of Washington like these rocks formed? How are they related to the geologic history of Glacial Lake Missoula?

Stop 14 Dry Falls

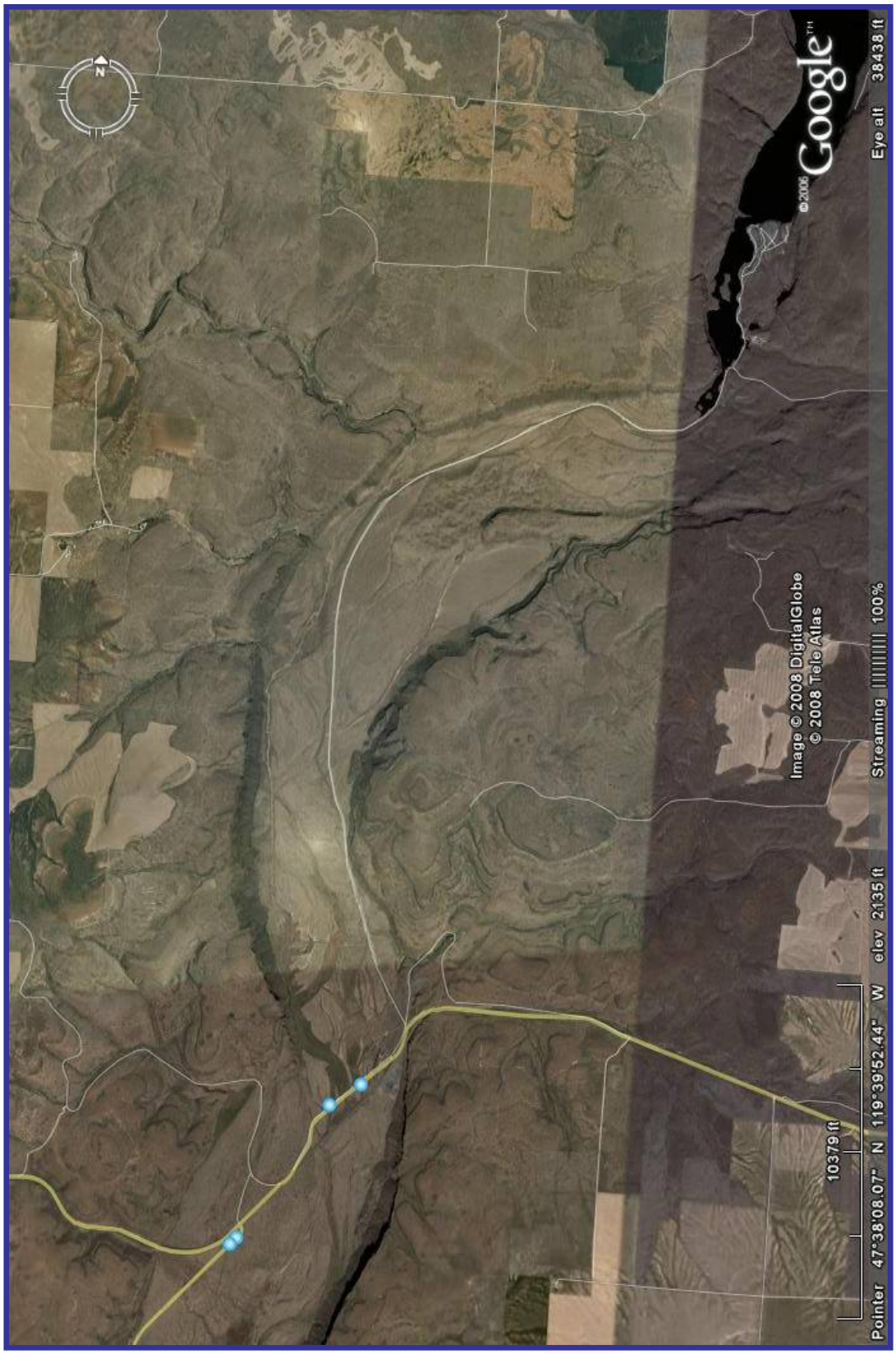
Observations and Illustrations
What features do you observe? What does the landscape look like? What are the characteristics of the features (shape, scale, relative location)?

Discussion / Interpretation
How did these features form? Are the same processes occurring at the same scale today? If not, then what lines of evidence support your conclusions? How are the features related to Glacial Lake Missoula? If you observed similar features on Mars, what would you conclude?

Stop 15 Moses Coulee

Observations and Illustrations
What does the landscape look like? What features do you observe? What are the characteristics of the features (shape, scale, relative location)? What rock types do you observe?

Discussion / Interpretation
What is a coulee? How did the features you observe form? Are the processes that formed them occurring today? If not, then what lines of evidence support your conclusions? How are the features related to Glacial Lake Missoula? If you observed similar features on Mars, what would you conclude?

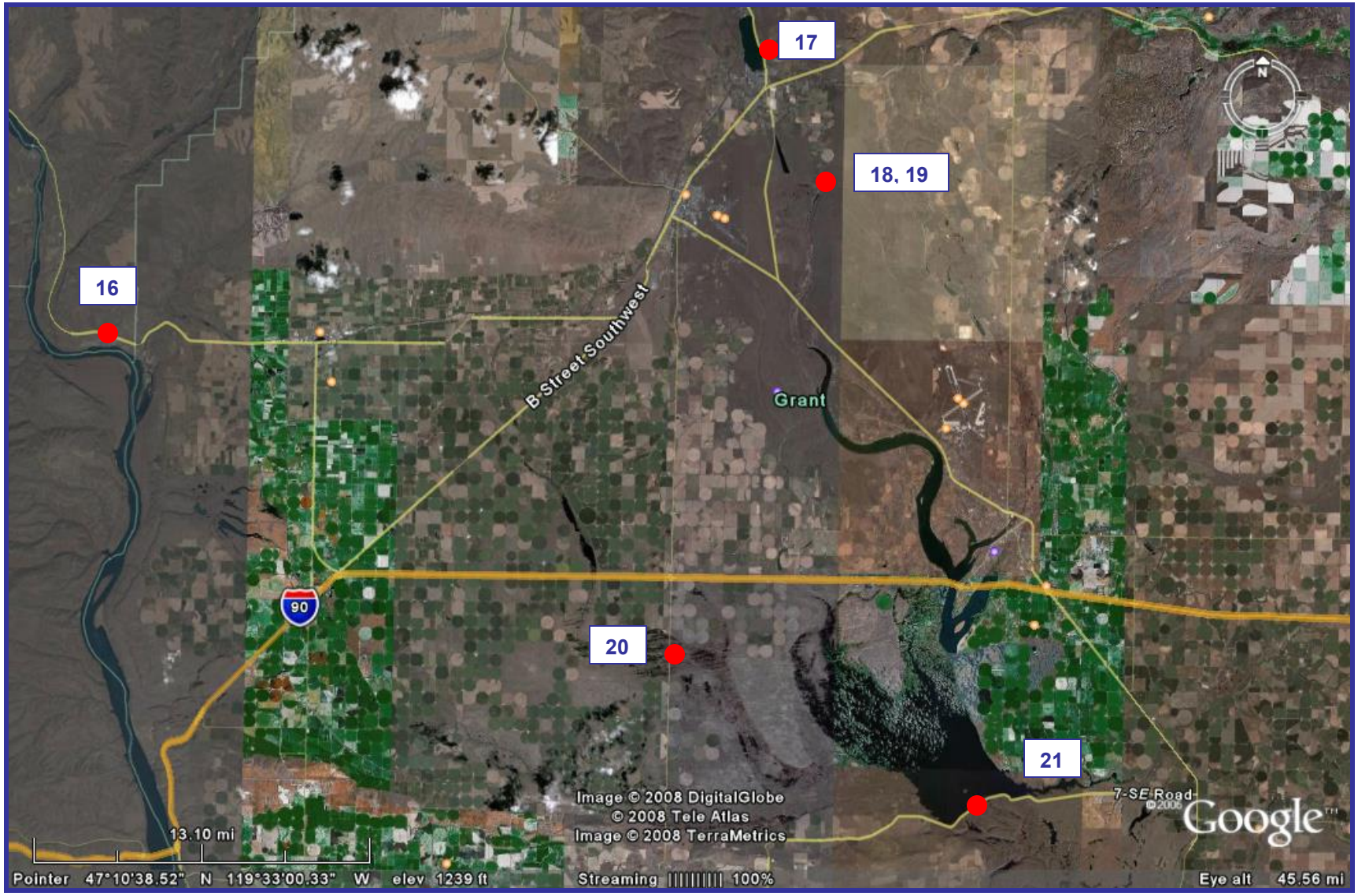


Moses Coulee. Road at bottom is Route 2.

Day 4. Wenatchee Region to Missoula … Deposition (and some erosion)

Objective: Continue to follow the flow of Glacial Lake Missoula flood waters farther downstream. Explore several depositional features and build an understanding of the geologic processes that created them.

8:00	Depart Wenatchee South on 28 toward Quincy 30 miles Turn right on Crescent Bar Road Bus should park at top of hill on hard gravel overlook	11:45	**Stop 19 Ephrata Fan Deposits** (30 minutes) Return to Ephrata South on Dodson Road ~20 miles
8:45	**Stop 16 River Overlook** (30 minutes) West on 28 12 miles North on 28 11 miles North on 17 past Soap Lake 6 miles Locate turn-around		**Stop 20 Overlook of Basalt Dunes** Continue south on Dodson Road (paved) ~15 miles East on 262 O'Sullivan Dam ~12 miles
10:00	**Stop 17 Soap Lake** (30 minutes) Continue south on 17 ~10 miles Make a left (east) onto Fish Hatchery Road *(gravel)*	1:30	Lunch in a pretty place around the dam
11:00	**Stop 18 Giant Boulder Field** (30 minutes) Proceed along Fish Hatchery Road to the Hatchery (turn-around at hatchery)	2:15	**Stop 21 Overlook of Drumheller Channels** Continue east on 262 ~10 miles North on 17 11 miles East on 90 toward Ritzville 40 miles East to Spokane 60 East to Cour d Alene 33 miles East to Missoula 170 miles Food somewhere in here.
		8:00	Arrive University of Montana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13.10 mi
Pointer 47°10'38.52" N 119°33'00.33" W elev 1239 ft
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Stop 16 River Overlook

Observations and Illustrations
What features do you observe? What are the characteristics of the features (shape, scale, relative location)? How are they related to the landscape overall?

Discussion / Interpretation
How did these features form? Are they similar to features we have observed? Are the same processes occurring at the same scale today? If not, then what lines of evidence support your conclusions? How are the features related to Glacial Lake Missoula? If you observed similar features on Mars, what would you conclude?

Stop 17 Soap Lake

Observations and Illustrations
What features do you observe? Describe the landscape.

Discussion / Interpretation
What happened at this site in relation to Glacial Lake Missoula? What do you expect to find south of Soap Lake?

Soap Lake gets its name from its alkalinity; the primary salt in the lake is Na_2CO_3

Stop 18 Giant Boulder Field (aka “Monsters of Rock”)

Observations and Illustrations
Describe the landscape. What features and objects do you see? No need to characterize the livestock. Where are we in relation to the Soap Lake stop with respect to the flow of flood waters?

Discussion / Interpretation
How did the boulders get here? What is the feature that you are standing on and how did it form? How does this relate to the geologic history of Glacial Lake Missoula?

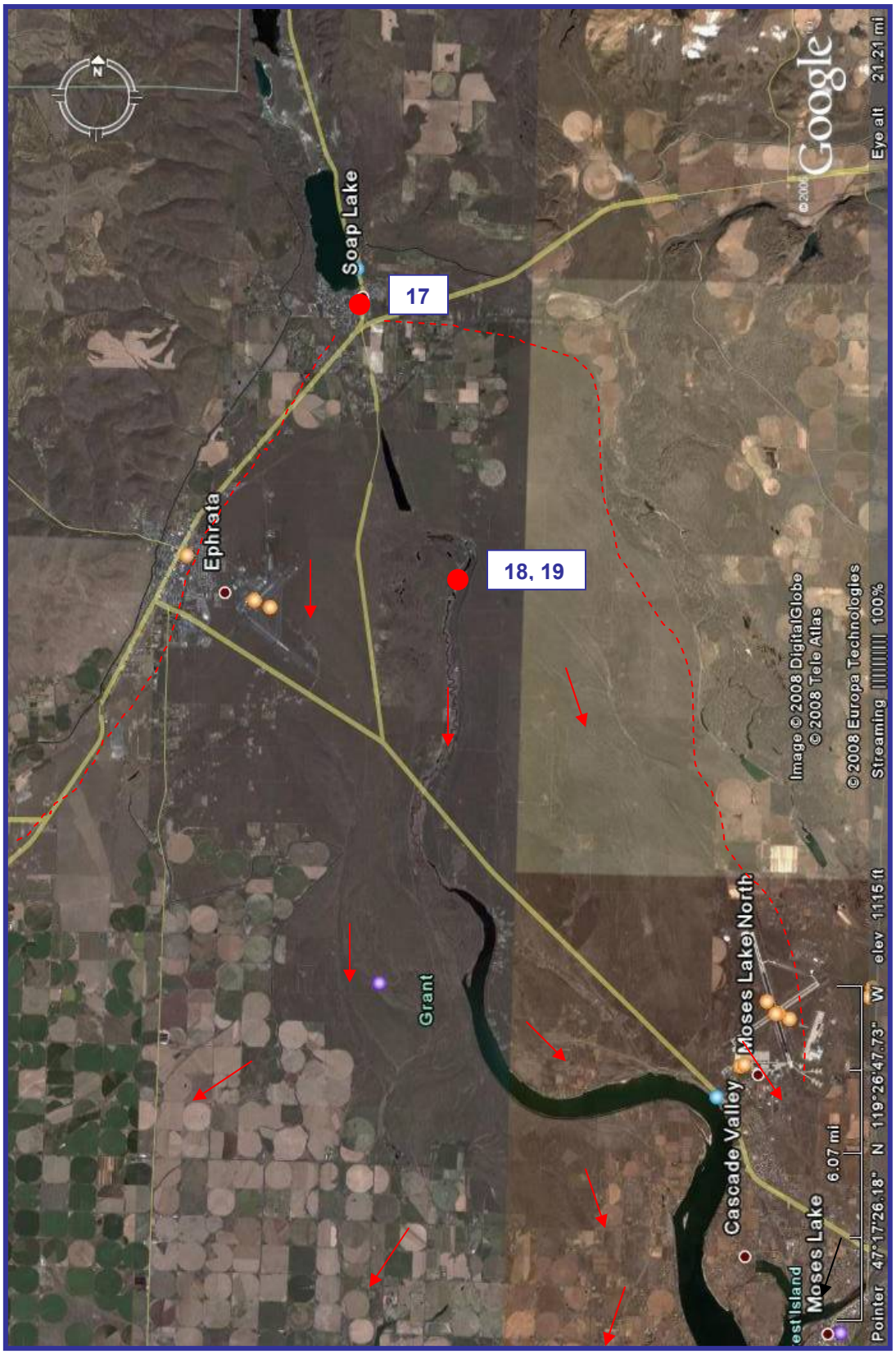
Immediately south of Soap Lake we crossed a rich farming area. This was the site of Lake Bretz. After the Missoula floods subsided, a lake formed; fine-grained sediment covered the lake floor, burying the giant boulders that we observe at the Monsters of Rock Site.

Stop 19 Ephrata Fan Deposits

Observations and Illustrations
If we can get to the outcrop … describe the sediment and sedimentary structures that you observe. What does the surrounding landscape look like?

Discussion / Interpretation
To what kind of depositional feature does this outcrop belong? What do the sediment grain sizes and structures tell you about the environment of deposition? How is this outcrop related to the surrounding features? Where did this material originate?

How are the features we observed at this and the last two stops related to Glacial Lake Missoula? If you observed similar features on Mars, what would you conclude?



Very approximate boundaries of the Ephrata Fan Deposits and even more approximate directions of flow.

Stop 20 Overlook of Basalt Dunes (if time permits)

As we drive south, note how the sediment of the Ephrata Fan changes.

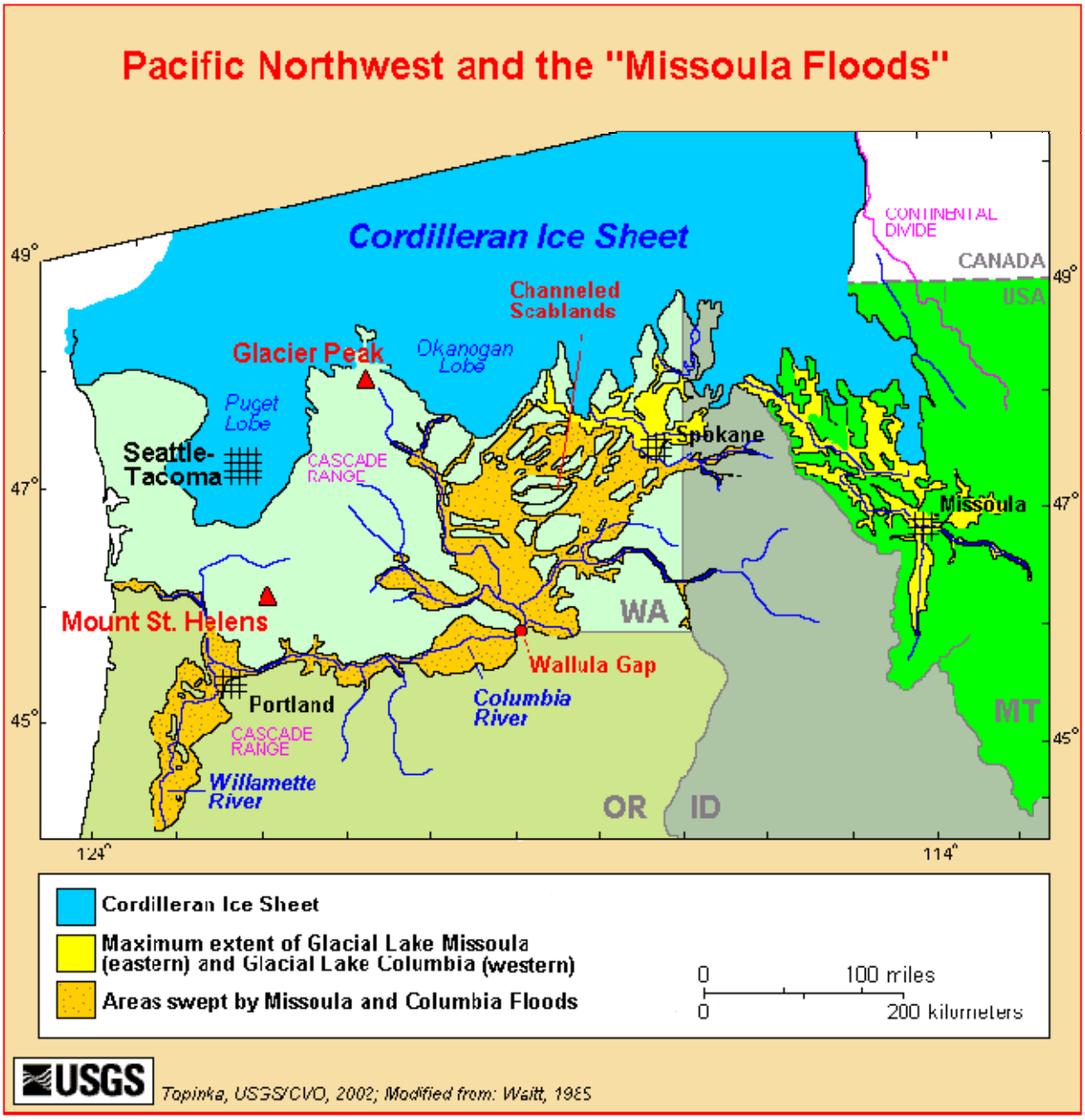
Observations and Illustrations
What features do you observe? What does the landscape look like? What are the characteristics of the features (shape, scale, relative location, composition)?

Discussion / Interpretation
What are these features? How did they form? How is the composition different from what you typically might find composing such features … and why? How are the features related to Glacial Lake Missoula? If you observed similar features on Mars, what would you conclude?

Stop 21 Overlook of Drumheller Channels (if time permits)

Observations and Illustrations
What features do you observe? What kind of rocks occur here? What does the landscape look like?

Discussion / Interpretation
How did these features form? How are the features related to the geologic history of Glacial Lake Missoula? If you observed similar features on Mars, what would you conclude?



http://vulcan.wr.usgs.gov/Glossary/Glaciers/IceSheets/Maps/map_missoula_floods.html

Volcanic and Geologic Terms

(From Volcano World: http://volcano.und.edu/vwdocs/glossary.html)

'A'a: Hawaiian word used to describe a lava flow whose surface is broken into rough angular fragments.

Accessory: A mineral whose presence in a rock is not essential to the proper classification of the rock.

Accidental: Pyroclastic rocks that are formed from fragments of non-volcanic rocks or from volcanic rocks not related to the erupting volcano.

Accretionary Lava Ball: A rounded mass, ranging in diameter from a few centimeters to several meters, [carried] on the surface of a lava flow (e.g., 'a'a) or on cinder-cone slopes [and formed] by the molding of viscous lava around a core of already solidified lava.

Acid: A descriptive term applied to igneous rocks with more than 60% silica (SiO_2).

Active Volcano: A volcano that is erupting. Also, a volcano that is not presently erupting, but that has erupted within historical time and is considered likely to do so in the future.

Agglutinate: A pyroclastic deposit consisting of an accumulation of originally plastic ejecta and formed by the coherence of the fragments upon solidification.

Alkalic: Rocks which contain above average amounts of sodium and/or potassium for the group of rocks for which it belongs. For example, the basalts of the capping stage of Hawaiian volcanoes are alkalic. They contain more sodium and/or potassium than the shield-building basalts that make the bulk of the volcano.

Andesite: Volcanic rock (or lava) characteristically medium dark in color and containing 54 to 62 percent silica and moderate amounts of iron and magnesium.

Ash: Fine particles of pulverized rock blown from an explosion vent. Measuring less than 1/10 inch in diameter, ash may be either solid or molten when first erupted. By far the most common variety is vitric ash (glassy particles formed by gas bubbles bursting through liquid magma).

Ashfall (Airfall): Volcanic ash that has fallen through the air from an eruption cloud. A deposit so formed is usually well sorted and layered.

Ash Flow: A turbulent mixture of gas and rock fragments, most of which are ash-sized particles, ejected violently from a crater or fissure. The mass of pyroclastics is normally of very high temperature and moves rapidly down the slopes or even along a level surface.

Asthenosphere: The shell within the earth, some tens of kilometers below the surface and of undefined thickness, which is a shell of weakness where plastic movements take place to permit pressure adjustments.

Aquifer: A body of rock that contains significant quantities of water that can be tapped by wells or springs.

Avalanche: A large mass of material or mixtures of material falling or sliding rapidly under the force of gravity. Avalanches often are classified by their content, such as snow, ice, soil, or rock avalanches. A mixture of these materials is a debris avalanche.

Basalt: Volcanic rock (or lava) that characteristically is dark in color, contains 45% to 54% silica, and generally is rich in iron and magnesium.

Basement: The undifferentiated rocks that underlie the rocks of interest in an area.

Basic: A descriptive term applied to igneous rocks (basalt and gabbro) with silica (SiO_2) between 44% and 52%.

Bench: The unstable, newly-formed front of a lava delta.

Blister: A swelling of the crust of a lava flow formed by the puffing-up of gas or vapor beneath the flow. Blisters are about 1 meter in diameter and hollow.

Block: Angular chunk of solid rock ejected during an eruption.

Bomb: Fragment of molten or semi-molten rock, 2 1/2 inches to many feet in diameter, which is blown out during an eruption. Because of their plastic condition, bombs are often modified in shape during their flight or upon impact.

Caldera: The Spanish word for cauldron, a basin-shaped volcanic depression; by definition, at least a mile in diameter. Such large depressions are typically formed by the subsidence of volcanoes. Crater Lake occupies the best-known caldera in the Cascades.

Capping Stage: Refers to a stage in the evolution of a typical Hawaiian volcano during which alkalic, basalt, and related rocks build a steeply, sloping cap on the main shield of the volcano. Eruptions are less frequent, but more explosive. The summit caldera may be buried.

Central Vent: A central vent is an opening at the Earth's surface of a volcanic conduit of cylindrical or pipe-like form.

Central Volcano: A volcano constructed by the ejection of debris and lava flows from a central point, forming a more or less symmetrical volcano.

Cinder Cone: A volcanic cone built entirely of loose fragmented material (pyroclastics.)

Cirque: A steep-walled horseshoe-shaped recess high on a mountain that is formed by glacial erosion.

Cleavage: The breaking of a mineral along crystallographic planes, that reflects a crystal structure.

Composite Volcano: A steep volcanic cone built by both lava flows and pyroclastic eruptions.

Compound Volcano: A volcano that consists of a complex of two or more vents, or a volcano that has an associated volcanic dome, either in its crater or on its flanks. Examples are Vesuvius and Mont Pelee.

Compression Waves: Earthquake waves that move like a slinky. As the wave moves to the left, for example, it expands and compresses in the same direction as it moves.

Conduit: A passage followed by magma in a volcano.

Continental Crust: Solid, outer layers of the earth, including the rocks of the continents.

Continental Drift: The theory that horizontal movement of the earth's surface causes slow, relative movements of the continents toward or away from one another.

Country Rocks: The rock intruded by and surrounding an igneous intrusion.

Crater: A steep-sided, usually circular depression formed by either explosion or collapse at a volcanic vent.

Craton: A part of the earth's crust that has attained stability and has been little deformed for a prolonged period.

Curtain of Fire: A row of coalescing lava fountains along a fissure; a typical feature of a Hawaiian-type eruption.

Dacite: Volcanic rock (or lava) that characteristically is light in color and contains 62% to 69% silica and moderate a mounts of sodium and potassium.

Debris Avalanche: A rapid and unusually sudden sliding or flowage of unsorted masses of rock and other material. As applied to the major avalanche involved in the eruption of Mount St. Helens, a rapid mass movement that included fragmented cold and hot volcanic rock, water, snow, glacier ice, trees, and some hot pyroclastic material. Most of the May 18, 1980 deposits in the upper valley of the North Fork Toutle River and in the vicinity of Spirit Lake are from the debris avalanche.

Debris Flow: A mixture of water-saturated rock debris that flows downslope under the force of gravity (also called lahar or mudflow).

Detachment Plane: The surface along which a landslide disconnects from its original position.

Devonian: A period of time in the Paleozoic Era that covered the time span between 400 and 345 million years.

Diatreme: A breccia filled volcanic pipe that was formed by a gaseous explosion.

Dike: A sheetlike body of igneous rock that cuts across layering or contacts in the rock into which it intrudes.

Dome: A steep-sided mass of viscous (doughy) lava extruded from a volcanic vent (often circular in plane view) and spiny, rounded, or flat on top. Its surface is often rough and blocky as a result of fragmentation of the cooler, outer crust during growth of the dome.

Dormant Volcano: Literally, "sleeping." The term is used to describe a volcano which is presently inactive but which may erupt again. Most of the major Cascade volcanoes are believed to be dormant rather than extinct.

Drainage Basin: The area of land drained by a river system.

Echelon: Set of geologic features that are in an overlapping or a staggered arrangement (e.g., faults). Each is relatively short, but collectively they form a linear zone in which the strike of the individual features is oblique to that of the zone as a whole.

Ejecta: Material that is thrown out by a volcano, including pyroclastic material (tephra) and lava bombs.

Episode: An episode is a volcanic event that is distinguished by its duration or style.

Eruption: The process by which solid, liquid, and gaseous materials are ejected into the earth's atmosphere and onto the earth's surface by volcanic activity. Eruptions range from the quiet overflow of liquid rock to the tremendously violent expulsion of pyroclastics.

Eruption Cloud: The column of gases, ash, and larger rock fragments rising from a crater or other vent. If it is of sufficient volume and velocity, this gaseous column may reach many miles into the stratosphere, where high winds will carry it long distances.

Eruptive Vent: The opening through which volcanic material is emitted.

Evacuate: Temporarily move people away from possible danger.

Extinct Volcano: A volcano that is not presently erupting and is not likely to do so for a very long time in the future.

Extrusion: The emission of magmatic material at the earth's surface. Also, the structure or form produced by the process (e.g., a lava flow, volcanic dome, or certain pyroclastic rocks).

Fault: A crack or fracture in the earth's surface. Movement along the fault can cause earthquakes or--in the process of mountain-building--can release underlying magma and permit it to rise to the surface.

Fault Scarp A steep slope or cliff formed directly by movement along a fault and representing the exposed surface of the fault before modification by erosion and weathering.

Felsic: An igneous rock having abundant light-colored minerals.

Fire fountain: See also: lava fountain

Fissures: Elongated fractures or cracks on the slopes of a volcano. Fissure eruptions typically produce liquid flows, but pyroclastics may also be ejected.

Flank Eruption: An eruption from the side of a volcano (in contrast to a summit eruption.)

Flood basalt A plateau basalt extending many kilometers in flat, layered flows originating in fissure eruptions.

Fluvial: Produced by the action of flowing water.

Formation: A body of rock identified by lithic characteristics and stratigraphic position and is mappable at the earth's surface or traceable in the subsurface.

Fracture: The manner of breaking due to intense folding or faulting.

Fumarole: A vent or opening through which issue steam, hydrogen sulfide, or other gases. The craters of many dormant volcanoes contain active fumaroles.

Geothermal Energy: Energy derived from the internal heat of the earth.

Geothermal Power: Power generated by using the heat energy of the earth.

Graben: An elongate crustal block that is relatively depressed (downdropped) between two fault systems.

Guyot: A type of seamount that has a platform top. Named for a nineteenth-century Swiss-American geologist.

Hardness: The resistance of a mineral to scratching.

Harmonic Tremor: A continuous release of seismic energy typically associated with the underground movement of magma. It contrasts distinctly with the sudden release and rapid decrease of seismic energy associated with the more common type of earthquake caused by slippage along a fault.

Heat transfer: Movement of heat from one place to another.

Heterolithologic: Material is made up of a heterogeneous mix of different rock types. Instead of being composed on one rock type, it is composed of fragments of many different rocks.

Holocene: The time period from 10,000 years ago to the present. Also, the rocks and deposits of that age.

Horizontal Blast: An explosive eruption in which the resultant cloud of hot ash and other material moves laterally rather than upward.

Horst: A block of the earth's crust, generally long compared to its width, that has been uplifted along faults relative to the rocks on either side.

Hot Spot: A volcanic center, 60 to 120 miles (100 to 200 km) across and persistent for at least a few tens of million of years, that is thought to be the surface expression of a persistent rising plume of hot mantle material. Hot spots are not linked to arcs and may not be associated with ocean ridges.

Hot-spot Volcanoes: Volcanoes related to a persistent heat source in the mantle.

Hyaloclastite: A deposit formed by the flowing or intrusion of lava or magma into water, ice, or water-saturated sediment and its consequent granulation or shattering into small angular fragments.

Hydrothermal Reservoir: An underground zone of porous rock containing hot water.

Hypabyssal: A shallow intrusion of magma or the resulting solidified rock.

Hypocenter: The place on a buried fault where an earthquake occurs. Usage of **hypocenter**.

Ignimbrite: The rock formed by the widespread deposition and consolidation of ash flows and Nuees Ardentes. The term was originally applied only to densely welded deposits but now includes non-welded deposits.

Intensity: A measure of the effects of an earthquake at a particular place. Intensity depends not only on the magnitude of the earthquake, but also on the distance from the epicenter and the local geology.

Intermediate: A descriptive term applied to igneous rocks that are transitional between basic and acidic with silica (SiO2) between 54% and 65%.

Intrusion: The process of emplacement of magma in pre-existing rock. Also, the term refers to igneous rock mass so formed within the surrounding rock.

Joint: A surface of fracture in a rock.

Juvenile: Pyroclastic material derived directly from magma reaching the surface.

Kipuka: An area surrounded by a lava flow.

Laccolith: A body of igneous rocks with a flat bottom and domed top. It is parallel to the layers above and below it.

Lahar: A torrential flow of water-saturated volcanic debris down the slope of a volcano in response to gravity. A type of mudflow.

Landsat: A series of unmanned satellites orbiting at about 706 km (438 miles) above the surface of the earth. The satellites carry cameras similar to video cameras and take images or pictures showing features as small as 30 m or 80 m wide, depending on which camera is used.

Lapilli: Literally, "little stones." Round to angular rock fragments, measuring 1/10 inch to 2 1/2 inches in diameter, which may be ejected in either a solid or molten state.

Lava: Magma which has reached the surface through a volcanic eruption. The term is most commonly applied to streams of liquid rock that flow from a crater or fissure. It also refers to cooled and solidified rock.

Lava Dome: Mass of lava, created by many individual flows, that has built a dome-shaped pile of lava.

Lava Flow: An outpouring of lava onto the land surface from a vent or fissure. Also, a solidified tongue like or sheet-like body formed by outpouring lava.

Lava Fountain: A rhythmic vertical fountainlike eruption of lava.

Lava Lake (Pond): A lake of molten lava, usually basaltic, contained in a vent, crater, or broad depression of a shield volcano.

Lava Shields: A shield volcano made of basaltic lava.

Lava Tube: A tunnel formed when the surface of a lava flow cools and solidifies while the still-molten interior flows through and drains away.

Limu O Pele (Pele Seaweed): Delicate, translucent sheets of spatter filled with tiny glass bubbles.

Lithic: Of or pertaining to stone.

Lithosphere: The rigid crust and uppermost mantle of the earth. Thickness is on the order of 60 miles (100 km). Stronger than the underlying asthenosphere.

Luster: The reflection of light from the surface of a mineral.

Maar: A volcanic crater that is produced by an explosion in an area of low relief, is generally more or less circular, and often contains a lake, pond, or marsh.

Mafic: An igneous composed chiefly of one or more dark-colored minerals.

Magma: Molten rock beneath the surface of the earth.

Magma Chamber: The subterranean cavity containing the gas-rich liquid magma which feeds a volcano.

Magmatic: Pertaining to magma.

Magnitude: A numerical expression of the amount of energy released by an earthquake, determined by measuring earthquake waves on standardized recording instruments (seismographs.) The number scale for magnitudes is logarithmic rather than arithmetic. Therefore, deflections on a seismograph for a magnitude 5 earthquake, for example, are 10 times greater than those for a magnitude 4 earthquake, 100 times greater than for a magnitude 3 earthquake, and so on.

Mantle: The zone of the earth below the crust and above the core.

Matrix: The solid matter in which a fossil or crystal is embedded. Also, a binding substance (e.g., cement in concrete).

Miocene: An epoch in Earth's history from about 24 to 5 million years ago. Also refers to the rocks that formed in that epoch.

Moho: Also called the Mohorovicic discontinuity. The surface or discontinuity that separates the crust from the mantle. The Moho is at a depth of 5-10 km beneath the ocean floor and about 35 km below the continents (but down to 60 km below mountains). Named for Andrija Mohorovicic, a Croatian seismologist.

Monogenetic: A volcano built by a single eruption.

Mudflow: A flowage of water-saturated earth material possessing a high degree of fluidity during movement. A less-saturated flowing mass is often called a debris flow. A mudflow originating on the flank of a volcano is properly called a lahar.

Myth: A fictional story to explain the origin of some person, place, or thing.

Nuees Ardentes: A French term applied to a highly heated mass of gas-charged ash which is expelled with explosive force and moves hurricane speed down the mountainside.

Obsidian: A black or dark-colored volcanic glass, usually composed of rhyolite.

Oceanic Crust: The earth's crust where it underlies oceans.

Pahoehoe: A Hawaiian term for lava with a smooth, billowy, or ropy surface.

Pali: Hawaiian word for steep hills or cliffs.

Pele Hair: A natural spun glass formed by blowing-out during quiet fountaining of fluid lava, cascading lava falls, or turbulent flows, sometimes in association with pele tears. A single strand, with a diameter of less than half a millimeter, may be as long as two meters.

Pele Tears: Small, solidified drops of volcanic glass behind which trail pendants of Pele hair. They may be tear-shaped, spherical, or nearly cylindrical.

Peralkaline: Igneous rocks in which the molecular proportion of aluminum oxide is less than that of sodium and potassium oxides combined.

Phenocryst: A conspicuous, usually large, crystal embedded in porphyritic igneous rock.

Phreatic Eruption (Explosion): An explosive volcanic eruption caused when water and heated volcanic rocks interact to produce a violent expulsion of steam and pulverized rocks. Magma is not involved.

Phreatomagmatic: An explosive volcanic eruption that results from the interaction of surface or subsurface water and magma.

Pillow lava: Interconnected, sack-like bodies of lava formed underwater.

Pipe: A vertical conduit through the Earth's crust below a volcano, through which magmatic materials have passed. Commonly filled with volcanic breccia and fragments of older rock.

Pit Crater: A crater formed by sinking in of the surface, not primarily a vent for lava.

Plastic: Capable of being molded into any form, which is retained.

Plate Tectonics: The theory that the earth's crust is broken into about 10 fragments (plates,) which move in relation to one another, shifting continents, forming new ocean crust, and stimulating volcanic eruptions.

Pleistocene: A epoch in Earth history from about 2-5 million years to 10,000 years ago. Also refers to the rocks and sediment deposited in that epoch.

Plinian Eruption: An explosive eruption in which a steady, turbulent stream of fragmented magma and magmatic gases is released at a high velocity from a vent. Large volumes of tephra and tall eruption columns are characteristic.

Plug: Solidified lava that fills the conduit of a volcano. It is usually more resistant to erosion than the material making up the surrounding cone, and may remain standing as a solitary pinnacle when the rest of the original structure has eroded away.

Plug Dome: The steep-sided, rounded mound formed when viscous lava wells up into a crater and is too stiff to flow away. It piles up as a dome-shaped mass, often completely filling the vent from which it emerged.

Pluton: A large igneous intrusion formed at great depth in the crust.

Polygenetic: Originating in various ways or from various sources.

Precambrian: All geologic time from the beginning of Earth history to 570 million years ago. Also refers to the rocks that formed in that epoch.

Pumice: Light-colored, frothy volcanic rock, usually of dacite or rhyolite composition, formed by the expansion of gas in erupting lava. Commonly seen as lumps or fragments of pea-size and larger, but can also occur abundantly as ash-sized particles.

Pyroclastic: Pertaining to fragmented (clastic) rock material formed by a volcanic explosion or ejection from a volcanic vent.

Pyroclastic Flow: Lateral flowage of a turbulent mixture of hot gases and unsorted pyroclastic material (volcanic fragments, crystals, ash, pumice, and glass shards) that can move at high speed (50 to 100 miles an hour.) The term also can refer to the deposit so formed.

Quaternary: The period of Earth's history from about 2 million years ago to the present; also, the rocks and deposits of that age.

Relief: The vertical difference between the summit of a mountain and the adjacent valley or plain.

Renewed Volcanism State: Refers to a state in the evolution of a typical Hawaiian volcano during which --after a long period of quiescence--lava and tephra erupt intermittently. Erosion and reef building continue.

Repose: The interval of time between volcanic eruptions.

Rhyodacite: An extrusive rock intermediate in composition between dacite and rhyolite.

Rhyolite: Volcanic rock (or lava) that characteristically is light in color, contains 69% silica or more, and is rich in potassium and sodium.

Ridge, Oceanic: A major submarine mountain range.

Rift System: The oceanic ridges formed where tectonic plates are separating and a new crust is being created; also, their on-land counterparts such as the East African Rift.

Rift Zone: A zone of volcanic features associated with underlying dikes. The location of the rift is marked by cracks, faults, and vents.

Ring of Fire: The regions of mountain-building earthquakes and volcanoes which surround the Pacific Ocean.

Scoria: A bomb-size (> 64 mm) pyroclast that is irregular in form and generally very vesicular. It is usually heavier, darker, and more crystalline than pumice.

Seafloor Spreading: The mechanism by which new seafloor crust is created at oceanic ridges and slowly spreads away as plates are separating.

Seamount: A submarine volcano.

Seismograph: An instrument that records seismic waves; that is, vibrations of the earth.

Seismologist: Scientists who study earthquake waves and what they tell us about the inside of the Earth.

Seismometer: An instrument that measures motion of the ground caused by earthquake waves.

Shearing: The motion of surfaces sliding past one another.

Shear Waves: Earthquake waves that move up and down as the wave itself moves. For example, to the left.

Shield Volcano: A gently sloping volcano in the shape of a flattened dome and built almost exclusively of lava flows.

Shoshonite: A trachyandesite composed of olivine and augite phenocrysts in a groundmass of labradorite with alkali feldspar rims, olivine, augite, a small amount of leucite, and some dark-colored glass. Its name is derived from the Shoshone River, Wyoming and given by Iddings in 1895.

Silica: A chemical combination of silicon and oxygen.

Sill: A tabular body of intrusive igneous rock, parallel to the layering of the rocks into which it intrudes.

Skylight: An opening formed by a collapse in the roof of a lava tube.

Solfatara: A type of fumarole, the gases of which are characteristically sulfurous.

Spatter Cone: A low, steep-sided cone of spatter built up on a fissure or vent. It is usually of basaltic material.

Spatter Rampart: A ridge of congealed pyroclastic material (usually basaltic) built up on a fissure or vent.

Specific Gravity: The density of a mineral divided by the density of water.

Spines: Horn-like projections formed upon a lava dome.

Stalactite: A cone shaped deposit of minerals hanging from the roof of a cavern.

Stratigraphic: The study of rock strata, especially of their distribution, deposition, and age.

Stratovolcano: A volcano composed of both lava flows and pyroclastic material.

Streak: The color of a mineral in the powdered form.

Strike-Slip Fault: A nearly vertical fault with side-slipping displacement.

Strombolian Eruption: A type of volcanic eruption characterized by jetting of clots or fountains of fluid basaltic lava from a central crater.

Subduction Zone: The zone of convergence of two tectonic plates, one of which usually overrides the other.

Surge: A ring-shaped cloud of gas and suspended solid debris that moves radially outward at high velocity as a density flow from the base of a vertical eruption column accompanying a volcanic eruption or crater formation.

Talus: A slope formed a the base of a steeper slope, made of fallen and disintegrated materials.

Tephra: Materials of all types and sizes that are erupted from a crater or volcanic vent and deposited from the air.

Tephrochronology: The collection, preparation, petrographic description, and approximate dating of tephra.

Tilt: The angle between the slope of a part of a volcano and some reference. The reference may be the slope of the volcano at some previous time.

Trachyandesite: An extrusive rock intermediate in composition between trachyte and andesite.

Trachybasalt: An extrusive rock intermediate in composition between trachyte and basalt.

Trachyte: A group of fine-grained, generally porphyritic, extrusive igneous rocks having alkali feldspar and minor mafic minerals as the main components, and possibly a small amount of sodic plagioclase.

Tremor: Low amplitude, continuous earthquake activity often associated with magma movement.

Tsunami: A great sea wave produced by a submarine earthquake, volcanic eruption, or large landslide.

Tuff: Rock formed of pyroclastic material.

Tuff Cone: A type of volcanic cone formed by the interaction of basaltic magma and water. Smaller and steeper than a tuff ring.

Tuff Ring: A wide, low-rimmed, well-bedded accumulation of hyalo-clastic debris built around a volcanic vent located in a lake, coastal zone, marsh, or area of abundant ground water.

Tumulus: A doming or small mound on the crest of a lava flow caused by pressure due to the difference in the rate of flow between the cooler crust and the more fluid lava below.

Ultramafic: Igneous rocks made mostly of the mafic minerals hypersthene, augite, and/or olivine.

Unconformity: A substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic sucession, such as an interruption in continuity of a depositional sequence of sedimentary rocks or a break between eroded igneous rocks and younger sedimentary strata. It results from a change that caused deposition to cease for a considerable time, and it normally implies uplift and erosion with loss of the previous formed record.

Vent: The opening at the earth's surface through which volcanic materials issue forth.

Vesicle: A small air pocket or cavity formed in volcanic rock during solidification.

Viscosity: A measure of resistance to flow in a liquid (water has low viscosity while honey has a higher viscosity.)

Volcano: A vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure (usually conical) that is produced by the ejected material.

Volcanic Arc: A generally curved linear belt of volcanoes above a subduction zone, and the volcanic and plutonic rocks formed there.

Volcanic Complex: A persistent volcanic vent area that has built a complex combination of volcanic landforms.

Volcanic Cone: A mound of loose material that was ejected ballistically.

Volcanic Neck: A massive pillar of rock more resistant to erosion than the lavas and pyroclastic rocks of a volcanic cone.

Vulcan: Roman god of fire and the forge after whom volcanoes are named.

Vulcanian: A type of eruption consisting of the explosive ejection of incandescent fragments of new viscous lava, usually on the form of blocks.

Water Table: The surface between where the pore space in rock is filled with water and where it is filled with air.

Xenocrysts: A crystal that resembles a phenocryst in igneous rock, but is a foreign to the body of rock in which it occurs.

Xenoliths: A foreign inclusion in an igneous rock.

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Hydrologic Terms

(From USGS: http://ga.water.usgs.gov/edu/dictionary.html)

acid--a substance that has a pH of less than 7, which is neutral. Specifically, an acid has more free hydrogen ions (H^+) than hydroxyl ions (OH^-).

acre-foot (acre-ft)--the volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot. Equal to 325,851 gallons or 1,233 cubic meters.

alkaline--sometimes water or soils contain an amount of alkali (strongly basic) substances sufficient to raise the pH value above 7.0 and be harmful to the growth of crops.

alkalinity--the capacity of water for neutralizing an acid solution.

alluvium--deposits of clay, silt, sand, gravel, or other particulate material that has been deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain.

appropriation doctrine--the system for allocating water to private individuals used in most Western states. The doctrine of Prior Appropriation was in common use throughout the arid west as early settlers and miners began to develop the land. The prior appropriation doctrine is based on the concept of "First in Time, First in Right." The first person to take a quantity of water and put it to Beneficial Use has a higher priority of right than a subsequent user. Under drought conditions, higher priority users are satisfied before junior users receive water. Appropriative rights can be lost through nonuse; they can also be sold or transferred apart from the land. Contrasts with Riparian Water Rights.

aquaculture--farming of plants and animals that live in water, such as fish, shellfish, and algae.

aqueduct--a pipe, conduit, or channel designed to transport water from a remote source, usually by gravity.

aquifer--a geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.

artesian water--ground water that is under pressure when tapped by a well and is able to rise above the level at which it is first encountered. It may or may not flow out at ground level. The pressure in such an aquifer commonly is called artesian pressure, and the formation containing artesian water is an artesian aquifer or confined aquifer. See *flowing well*

artificial recharge--an process where water is put back into ground-water storage from surface-water supplies such as irrigation, or induced infiltration from streams or wells.

base flow--sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural base flow is sustained largely by ground-water discharges.

base--a substance that has a pH of more than 7, which is neutral. A base has less free hydrogen ions (H^+) than hydroxyl ions (OH^-).

bedrock--the solid rock beneath the soil and superficial rock. A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material.

capillary action--the means by which liquid moves through the porous spaces in a solid, such as soil, plant roots, and the capillary blood vessels in our bodies due to the forces of adhesion, cohesion, and surface tension. Capillary action is essential in carrying substances and nutrients from one place to another in plants and animals.

commercial water use--water used for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Water for commercial uses comes both from public-supplied sources, such as a county water department, and self-supplied sources, such as local wells.

condensation--the process of water vapor in the air turning into liquid water. Water drops on the outside of a cold glass of water are condensed water. Condensation is the opposite process of evaporation.

consumptive use--that part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.

conveyance loss--water that is lost in transit from a pipe, canal, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground-water source and be available for further use.

cubic feet per second (cfs)--a rate of the flow, in streams and rivers, for example. It is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second. One "cfs" is equal to 7.48 gallons of water flowing each second. As an example, if your car's gas tank is 2 feet by 1 foot by 1 foot (2 cubic feet), then gas flowing at a rate of 1 cubic foot/second would fill the tank in two seconds.

desalination--the removal of salts from saline water to provide freshwater. This method is becoming a more popular way of providing freshwater to populations.

discharge--the volume of water that passes a given location within a given period of time. Usually expressed in cubic feet per second.

domestic water use--water used for household purposes, such as drinking, food preparation, bathing, washing clothes, dishes, and dogs, flushing toilets, and watering lawns and gardens. About 85% of domestic water is delivered to homes by a public-supply facility, such as a county water department. About 15% of the Nation's population supply their own water, mainly from wells.

drainage basin--land area where precipitation runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large drainage basins, like the area that drains into the Mississippi River contain thousands of smaller drainage basins. Also called a "watershed."

drip irrigation--a common irrigation method where pipes or tubes filled with water slowly drip onto crops. Drip irrigation is a low-pressure method of irrigation and less water is lost to evaporation than high-pressure spray irrigation.

drawdown--a lowering of the ground-water surface caused by pumping.

effluent--water that flows from a sewage treatment plant after it has been treated.

erosion--the process in which a material is worn away by a stream of liquid (water) or air, often due to the presence of abrasive particles in the stream.

estuary--a place where fresh and salt water mix, such as a bay, salt marsh, or where a river enters an ocean.

evaporation--the process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces. See transpiration

evapotranspiration--the sum of evaporation and transpiration.

flood--An overflow of water onto lands that are used or usable by man and not normally covered by water. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.

flood, 100-year--A 100-year flood does not refer to a flood that occurs once every 100 years, but to a flood level with a 1 percent chance of being equaled or exceeded in any given year.

flood plain--a strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood.

flood stage--The elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

flowing well/spring--a well or spring that taps ground water under pressure so that water rises without pumping. If the water rises above the surface, it is known as a flowing well.

freshwater, freshwater--water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.

gage height--the height of the water surface above the gage datum (zero point). Gage height is often used interchangeably with the more general term, stage, although gage height is more appropriate when used with a gage reading.

gaging station--a site on a stream, lake, reservoir or other body of water where observations and hydrologic data are obtained. The U.S. Geological Survey measures stream discharge at gaging stations.

geyser--a geothermal feature of the Earth where there is an opening in the surface that contains superheated water that periodically erupts in a shower of water and steam.

glacier--a huge mass of ice, formed on land by the compaction and recrystallization of snow, that moves very slowly downslope or outward due to its own weight.

greywater--wastewater from clothes washing machines, showers, bathtubs, hand washing, lavatories and sinks.

ground water--(1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturate zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

ground water, confined--ground water under pressure significantly greater than atmospheric, with its upper limit the bottom of a bed with hydraulic conductivity distinctly lower than that of the material in which the confined water occurs.

ground-water recharge--inflow of water to a ground-water reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.

ground water, unconfined--water in an aquifer that has a water table that is exposed to the atmosphere.

hardness--a water-quality indication of the concentration of alkaline salts in water, mainly calcium and magnesium. If the water you use is "hard" then more soap, detergent or shampoo is necessary to raise a lather.

headwater(s)--(1) the source and upper reaches of a stream; also the upper reaches of a reservoir. (2) the water upstream from a structure or point on a stream. (3) the small streams that come together to form a river. Also may be thought of as any and all parts of a river basin except the mainstream river and main tributaries.

hydroelectric power water use--the use of water in the generation of electricity at plants where the turbine generators are driven by falling water.

hydrologic cycle--the cyclic transfer of water vapor from the Earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, and lakes, and ultimately into the oceans.

impermeable layer--a layer of solid material, such as rock or clay, which does not allow water to pass through.

industrial water use--water used for industrial purposes in such industries as steel, chemical, paper, and petroleum refining. Nationally, water for industrial uses comes mainly (80%) from self-supplied sources, such as a local wells or withdrawal points in a river, but some water comes from public-supplied sources, such as the county/city water department.

infiltration--flow of water from the land surface into the subsurface.

injection well--refers to a well constructed for the purpose of injecting treated wastewater directly into the ground. Wastewater is generally forced (pumped) into the well for dispersal or storage into a designated aquifer. Injection wells are generally drilled into aquifers that don't deliver drinking water, unused aquifers, or below freshwater levels.

irrigation--the controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall.

irrigation water use--water application on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands, such as parks and golf courses.

leaching--the process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

lentic waters--ponds or lakes (standing water).

levee--a natural or manmade earthen barrier along the edge of a stream, lake, or river. Land alongside rivers can be protected from flooding by levees.

livestock water use--water used for livestock watering, feed lots, dairy operations, fish farming, and other on-farm needs.

lotic waters--flowing waters, as in streams and rivers.

maximum contaminant level (MCL)--the designation given by the U.S. Environmental Protection Agency (EPA) to water-quality standards promulgated under the Safe Drinking Water Act. The MCL is the greatest amount of a contaminant that can be present in drinking water without causing a risk to human health.

milligram (mg)--One-thousandth of a gram.

milligrams per liter (mg/l)--a unit of the concentration of a constituent in water or wastewater. It represents 0.001 gram of a constituent in 1 liter of water. It is approximately equal to one part per million (PPM).

million gallons per day (Mgd)--a rate of flow of water equal to 133,680.56 cubic feet per day, or 1.5472 cubic feet per second, or 3.0689 acre-feet per day. A flow of one million gallons per day for one year equals 1,120 acre-feet (365 million gallons).

mining water use--water use during quarrying rocks and extracting minerals from the land.

municipal water system--a water system that has at least five service connections or which regularly serves 25 individuals for 60 days; also called a public water system

nephelometric turbidity unit (NTU)--unit of measure for the turbidity of water. Essentially, a measure of the cloudiness of water as measured by a nephelometer. Turbidity is based on the amount of light that is reflected off particles in the water.

NGVD--National Geodetic Vertical Datum. (1) As corrected in 1929, a vertical control measure used as a reference for establishing varying elevations. (2) Elevation datum plane previously used by the Federal Emergency Management Agency (FEMA) for the determination of flood elevations. FEMA current uses the North American Vertical Datum Plane.

NGVD of 1929--National Geodetic Vertical Datum of 1929. A geodetic datum derived from a general adjustment of the first order level nets of the United States and Canada. It was formerly called "Sea Level Datum of 1929" or "mean sea level" in the USGS series of reports. Although the datum was derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts, it does not necessarily represent local mean sea level at any particular place.

non-point source (NPS) pollution--pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land-use activities, which are carried to lakes and streams by surface runoff. Non-point source pollution is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants, such as nutrients and pesticides.

organic matter--plant and animal residues, or substances made by living organisms. All are based upon carbon compounds.

osmosis--the movement of water molecules through a thin membrane. The osmosis process occurs in our bodies and is also one method of desalinating saline water.

outfall--the place where a sewer, drain, or stream discharges; the outlet or structure through which reclaimed water or treated effluent is finally discharged to a receiving water body.

oxygen demand--the need for molecular oxygen to meet the needs of biological and chemical processes in water. Even though very little oxygen will dissolve in water, it is extremely important in biological and chemical processes.

pH--a measure of the relative acidity or alkalinity of water. Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity, while pH levels higher than 7 indicate increasingly basic solutions.
View a diagram about pH.

particle size--the diameter, in millimeters, of suspended sediment or bed material. Particle-size classifications are:
[1] Clay—0.00024-0.004 millimeters (mm); [2] Silt—0.004-0.062 mm; [3] Sand—0.062-2.0 mm; and [4] Gravel—2.0-64.0 mm.

parts per billion--the number of "parts" by weight of a substance per billion parts of water. Used to measure extremely small concentrations.

parts per million--the number of "parts" by weight of a substance per million parts of water. This unit is commonly used to represent pollutant concentrations.

pathogen--a disease-producing agent; usually applied to a living organism. Generally, any viruses, bacteria, or fungi that cause disease.

peak flow--the maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

per capita use--the average amount of water used per person during a standard time period, generally per day.

percolation--(1) The movement of water through the openings in rock or soil. (2) the entrance of a portion of the streamflow into the channel materials to contribute to ground water replenishment.

permeability--the ability of a material to allow the passage of a liquid, such as water through rocks. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas unpermeable material, such as clay, don't allow water to flow freely.

point-source pollution--water pollution coming from a single point, such as a sewage-outflow pipe.

polychlorinated biphenyls (PCBs)--a group of synthetic, toxic industrial chemical compounds once used in making paint and electrical transformers, which are chemically inert and not biodegradable. PCBs were frequently found in industrial wastes, and subsequently found their way into surface and ground waters. As a result of their persistence, they tend to accumulate in the environment. In terms of streams and rivers, PCBs are drawn to sediment, to which they attach and can remain virtually indefinitely. Although virtually banned in 1979 with the passage of the Toxic Substances Control Act, they continue to appear in the flesh of fish and other animals.

porosity--a measure of the water-bearing capacity of subsurface rock. With respect to water movement, it is not just the total magnitude of porosity that is important, but the size of the voids and the extent to which they are interconnected, as the pores in a formation may be open, or interconnected, or closed and isolated. For example, clay may have a very high porosity with respect to potential water content, but it constitutes a poor medium as an aquifer because the pores are usually so small.

potable water--water of a quality suitable for drinking.

precipitation--rain, snow, hail, sleet, dew, and frost.

primary wastewater treatment--the first stage of the wastewater-treatment process where mechanical methods, such as filters and scrapers, are used to remove pollutants. Solid material in sewage also settles out in this process.

prior appropriation doctrine--the system for allocating water to private individuals used in most Western states. The doctrine of Prior Appropriation was in common use throughout the arid West as early settlers and miners began to develop the land. The prior appropriation doctrine is based on the concept of "First in Time, First in Right." The first person to take a quantity of water and put it to beneficial use has a higher priority of right than a subsequent user. The rights can be lost through nonuse; they can also be sold or transferred apart from the land. Contrasts with riparian water rights.

public supply--water withdrawn by public governments and agencies, such as a county water department, and by private companies that is then delivered to users. Public suppliers provide water for domestic, commercial, thermoelectric power, industrial, and public water users. Most people's household water is delivered by a public water supplier. The systems have at least 15 service connections (such as households, businesses, or schools) or regularly serve at least 25 individuals daily for at least 60 days out of the year.

public water use--water supplied from a public-water supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pools.

rating curve--A drawn curve showing the relation between gage height and discharge of a stream at a given gaging station.

recharge--water added to an aquifer. For instance, rainfall that seeps into the ground.

reclaimed wastewater--treated wastewater that can be used for beneficial purposes, such as irrigating certain plants.

recycled water--water that is used more than one time before it passes back into the natural hydrologic system.

reservoir--a pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

return flow--(1) That part of a diverted flow that is not consumptively used and returned to its original source or another body of water. (2) (Irrigation) Drainage water from irrigated farmlands that re-enters the water system to be used further downstream.

returnflow (irrigation)--irrigation water that is applied to an area and which is not consumed in evaporation or transpiration and returns to a surface stream or aquifer.

reverse osmosis--(1) (Desalination) The process of removing salts from water using a membrane. With reverse osmosis, the product water passes through a fine membrane that the salts are unable to pass through, while the salt waste (brine) is removed and disposed. This process differs from electrodialysis, where the salts are extracted from the feedwater by using a membrane with an electrical current to separate the ions. The positive ions go through one membrane, while the negative ions flow through a different membrane, leaving the end product of freshwater. (2) (Water Quality) An advanced method of water or wastewater treatment that relies on a semi-permeable membrane to separate waters from pollutants. An external force is used to reverse the normal osmotic process resulting in the solvent moving from a solution of higher concentration to one of lower concentration.

riparian water rights--the rights of an owner whose land abuts water. They differ from state to state and often depend on whether the water is a river, lake, or ocean. The doctrine of riparian rights is an old one, having its origins in English common law. Specifically, persons who own land adjacent to a stream have the right to make reasonable use of the stream. Riparian users of a stream share the streamflow among themselves, and the concept of priority of use (Prior Appropriation Doctrine) is not applicable. Riparian rights cannot be sold or transferred for use on nonriparian land.

river--A natural stream of water of considerable volume, larger than a brook or creek.

runoff--(1) That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or ground-water runoff. (2) The total discharge described in (1), above, during a specified period of time. (3) Also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.

saline water--water that contains significant amounts of dissolved solids.

Here are our parameters for saline water:
Fresh water - Less than 1,000 parts per million (ppm)
Slightly saline water - From 1,000 ppm to 3,000 ppm
Moderatly saline water - From 3,000 ppm to 10,000 ppm
Highly saline water - From 10,000 ppm to 35,000 ppm

secondary wastewater treatment--treatment (following primary wastewater treatment) involving the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems and which generally removes 80 to 95 percent of the Biochemical Oxygen Demand (BOD) and suspended matter. Secondary wastewater treatment may be accomplished by biological or chemical-physical methods. Activated sludge and trickling filters are two of the most common means of secondary treatment. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. This treatment removes floating and settleable solids and about 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment.

sediment--usually applied to material in suspension in water or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.

sedimentary rock--rock formed of sediment, and specifically: (1) sandstone and shale, formed of fragments of other rock transported from their sources and deposited in water; and (2) rocks formed by or from secretions of organisms, such as most limestone. Many sedimentary rocks show distinct layering, which is the result of different types of sediment being deposited in succession.

sedimentation tanks--wastewater tanks in which floating wastes are skimmed off and settled solids are removed for disposal.

self-supplied water--water withdrawn from a surface- or ground-water source by a user rather than being obtained from a public supply. An example would be homeowners getting their water from their own well.

seepage--(1) The slow movement of water through small cracks, pores, Interstices, etc., of a material into or out of a body of surface or subsurface water. (2) The loss of water by infiltration into the soil from a canal, ditches, laterals, watercourse, reservoir, storage facilities, or other body of water, or from a field.

septic tank--a tank used to detain domestic wastes to allow the settling of solids prior to distribution to a leach field for soil absorption. Septic tanks are used when a sewer line is not available to carry them to a treatment plant. A settling tank in which settled sludge is in immediate contact with sewage flowing through the tank, and wherein solids are decomposed by anaerobic bacterial action.

settling pond (water quality)--an open lagoon into which wastewater contaminated with solid pollutants is placed and allowed to stand. The solid pollutants suspended in the water sink to the bottom of the lagoon and the liquid is allowed to overflow out of the enclosure.

sewage treatment plant--a facility designed to receive the wastewater from domestic sources and to remove materials that damage water quality and threaten public health and safety when discharged into receiving streams or bodies of water. The substances removed are classified into four basic areas:
[1] greases and fats;
[2] solids from human waste and other sources;
[3] dissolved pollutants from human waste and decomposition products; and
[4] dangerous microorganisms.
Most facilities employ a combination of mechanical removal steps and bacterial decomposition to achieve the desired results. Chlorine is often added to discharges from the plants to reduce the danger of spreading disease by the release of pathogenic bacteria.

sewer--a system of underground pipes that collect and deliver wastewater to treatment facilities or streams.

sinkhole--a depression in the Earth's surface caused by dissolving of underlying limestone, salt, or gypsum. Drainage is provided through underground channels that may be enlarged by the collapse of a cavern roof.

solute--a substance that is dissolved in another substance, thus forming a solution.

solution--a mixture of a solvent and a solute. In some solutions, such as sugar water, the substances mix so thoroughly that the solute cannot be seen. But in other solutions, such as water mixed with dye, the solution is visibly changed.

solvent--a substance that dissolves other substances, thus forming a solution. Water dissolves more substances than any other, and is known as the "universal solvent".

specific conductance--a measure of the ability of water to conduct an electrical current as measured using a 1-cm cell and expressed in units of electrical conductance, i.e., Siemens per centimeter at 25 degrees Celsius. Specific conductance can be used for approximating the total dissolved solids content of water by testing its capacity to carry an electrical current. In water quality, specific conductance is used in ground water monitoring

as an indication of the presence of ions of chemical substances that may have been released by a leaking landfill or other waste storage or disposal facility. A higher specific conductance in water drawn from downgradient wells when compared to upgradient wells indicates possible contamination from the facility.

spray irrigation--an common irrigation method where water is shot from high-pressure sprayers onto crops. Because water is shot high into the air onto crops, some water is lost to evaporation.

storm sewer--a sewer that carries only surface runoff, street wash, and snow melt from the land. In a separate sewer system, storm sewers are completely separate from those that carry domestic and commercial wastewater (sanitary sewers).

stream--a general term for a body of flowing water; natural water course containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural channel as distinct from a canal.

streamflow--the water discharge that occurs in a natural channel. A more general term than runoff, streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

subsidence--a dropping of the land surface as a result of ground water being pumped. Cracks and fissures can appear in the land. Subsidence is virtually an irreversible process.

surface tension--the attraction of molecules to each other on a liquid's surface. Thus, a barrier is created between the air and the liquid.

surface water--water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

suspended sediment--very fine soil particles that remain in suspension in water for a considerable period of time without contact with the bottom. Such material remains in suspension due to the upward components of turbulence and currents and/or by suspension.

suspended-sediment concentration--the ratio of the mass of dry sediment in a water-sediment mixture to the mass of the water-sediment mixture. Typically expressed in milligrams of dry sediment per liter of water-sediment mixture.

suspended-sediment discharge--the quantity of suspended sediment passing a point in a stream over a specified period of time. When expressed in tons per day, it is computed by multiplying water discharge (in cubic feet per second) by the suspended-sediment concentration (in milligrams per liter) and by the factor 0.0027.

suspended solids--solids that are not in true solution and that can be removed by filtration. Such suspended solids usually contribute directly to turbidity. Defined in waste management, these are small particles of solid pollutants that resist separation by conventional methods.

thermal pollution--a reduction in water quality caused by increasing its temperature, often due to disposal of waste heat from industrial or power generation processes. Thermally polluted water can harm the environment because plants and animals can have a hard time adapting to it.

thermoelectric power water use--water used in the process of the generation of thermoelectric power. Power plants that burn coal and oil are examples of thermoelectric-power facilities.

transmissibility (ground water)--the capacity of a rock to transmit water under pressure. The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer one foot wide, extending the full saturated height of the aquifer under a hydraulic gradient of 100-percent. A hydraulic gradient of 100-percent means a one foot drop in head in one foot of flow distance.

transpiration--process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores. See evapotranspiration.

Tributary--a smaller river or stream that flows into a larger river or stream. Usually, a number of smaller tributaries merge to form a river.

turbidity--the amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter. Thus, turbidity makes the water cloudy or even opaque in extreme cases. Turbidity is measured in nephelometric turbidity units (NTU).

unsaturated zone--the zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. These zones differ from an aquifer, where the pores are saturated with water.

wastewater--water that has been used in homes, industries, and businesses that is not for reuse unless it is treated.

wastewater-treatment return flow--water returned to the environment by wastewater-treatment facilities.

water cycle--the circuit of water movement from the oceans to the atmosphere and to the Earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation.

water quality--a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

water table--the top of the water surface in the saturated part of an aquifer.

water use--water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human's interaction with and influence on the hydrologic cycle, and includes elements, such as water withdrawal from surface- and ground-water sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and instream uses, such as using water to produce hydroelectric power.

watershed--the land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large watersheds, like the Mississippi River basin contain thousands of smaller watersheds.

watthour (Wh)--an electrical energy unit of measure equal to one watt of power supplied to, or taken from, an electrical circuit steadily for one hour.

well (water)--an artificial excavation put down by any method for the purposes of withdrawing water from the underground aquifers. A bored, drilled, or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.

withdrawal--water removed from a ground- or surface-water source for use.

xeriscaping--a method of landscaping that uses plants that are well adapted to the local area and are drought-resistant. Xeriscaping is becoming more popular as a way of saving water at home.

Place each stop in the context of the question that it addresses and briefly annotate how it addresses that question.

Stops relating to evidence for the existence and location of ice sheets in the region.

Stops relating to evidence for the presence of Glacial Lake Missoula.

Stops relating to depositional evidence for catastrophic outflow of water from Lake Missoula.

Stops relating to erosional evidence for catastrophic outflow of water from Lake Missoula.

Stops relating to evidence exists for multiple flooding events.

Stops relating to informing our understanding of the geologic history of Mars.