1. CONTRIBUTOR'S NAME: Johnny MacLean

2. NAME OF INQUIRY: Geologic Framework of Missoula's Ecoregions

3. GOALS AND OBJECTIVES:

a. Inquiry Questions: How does Missoula Valley's geologic history relate to its ecological distribution?

b. Ecological Theme(s): Physical controls on ecological distribution.

c. General Goal: To introduce the role of geologic processes on ecological distribution.

d. Specific Objectives: Students will discover the relationship of rock types, tectonic history, and topography with the ecological distribution in the Missoula Valley. Students will compare and contrast the lithologic (type of rock) and topographic distribution with the Missoula Valley ecoregions. Students will put the geologic and topographic distributions of the Missoula Valley into a tectonic frame of reference. These objectives will be achieved first with the ECOS Guide to the Ecology of the Northern Rockies (http://www.bioed.org/nhguideweb/). An extension to this study will be experiencing the geological and ecological features of the region first-hand.

e. Grade band: 6-8.

f. Duration/Time Required:

→ Prep time: 30 minutes
→ Implementing Exercise During Class: 1.5 hours
→ Assessment: 20 minutes

4. ECOLOGICAL AND SCIENCE CONTEXT:

a. Background (for Teachers): All background information is available on the ECOS Guide and below in the 'background to present to students.'

b. Background (to present to Students): The Missoula Valley is a rich natural setting with numerous ecosystems. The distribution of ecoregions is partly controlled by the physical landscape of the area. The physical landscape is a direct result of earth processes such as plate tectonics, climate changes, glaciation, and erosion. Students should be familiar with these processes, as well as with the concepts involved in ecoregions, before engaging in this inquiry.

The earth processes listed above all contribute to shape our landscape. The General Geologic History of Western Montana section of the Guide outlines the formation of the Northern Rocky Mountains through plate tectonic processes, beginning about 90 million years ago. Tectonic processes are continuing in western Montana even now, as evidenced in the 2005 earthquake near Dillon, MT. In recent geologic history, changes in climate caused glaciation that played an undeniable role in shaping the landscape, from direct glacial erosion and deposition, to indirect processes that contributed to Glacial Lake Missoula and its floods. Finally, erosion continually shapes the landscape through flooding events, avalanches, and landslides.

An understanding of the processes that continue to shape the Northern Rockies is vital to appreciate the diverse ecology in the Missoula Valley. In this inquiry, students not only will discover relationships between rock type, topography, and ecoregions, but will also discover how the landscapes were formed in order to be suitable for their specific ecologies.

5. MOTIVATION AND INCENTIVE FOR LEARNING:

The Missoula Valley is a perfect setting to study relationships between various landscapes and their ecosystems. Students have grown up living in the mountains and valleys, and will be inherently interested in how they formed.

6. VOCABULARY:

- Plate tectonics—the global distribution of geological processes, including earthquakes, volcanism, movement of continents, and mountain building in terms of the interaction of the earth's lithospheric plates.
- Lithology—rock type.

8. MATERIALS LIST (including any handouts or transparency masters):

9. METHODS/PROCEDURE FOR STUDENTS:

a. Pre-investigation work: Review plate tectonics, glaciation, and erosion. Ask students what kinds of plants and animals live in different localities in the Missoula Valley and surrounding areas (Bitterroot Mountains, Bitterroot Valley, Sapphire Mountains, Rattlesnake Mountains, etc.).

b. Investigation work:

1) What evidence (data, samples) do students collect?

Students analyze the Ecoregions of Missoula Valley map, the Geology of Missoula Valley map, and the Topography of Missoula Valley on the Guide. Students equate each ecoregion with its associated lithology and topography. Students determine when and how the mountains formed using the General Geologic History of Western Montana and its associated links. Students then choose one ecoregion-lithology-topography association. They research descriptions of the ecoregion and lithology using the Guide and associated links. They draw connections between the organisms living in these regions and the physical processes that formed the landscapes in which the organisms live.

2) How do students present the evidence (data)?

Students present their data on the worksheet attached.

3) What conclusions are drawn from the evidence students collect?

Certain types of organisms live in certain types of landscapes. These landscapes are formed through earth processes. Geologic and ecologic processes are intricately related.

10. ASSESSMENT:

Worksheet should be correctly and thoroughly completed.

11. EXTENSION IDEAS:

Fieldtrip to any of the mountain ranges or valleys around Missoula.

12. SCALABILITY:

This could be scaled up to high school very easily.

13. REFERENCES:

ECOS Guide : http://www.bioed.org/nhguideweb/
Glacial Lake Missoula Website: http://www.glaciallakemissoula.org/
Web Geologic Time Machine: http://www.ucmp.berkeley.edu/help/timeform.html
Visualization Geology Website:
http://www.geology.sdsu.edu/visualgeology/geology101/index.htm

Name ____________________________________ Date _____________

Using the ECOS Guide to the Ecology of the Northern Rockies, list the types of Ecoregions in the Missoula Valley area, and provide a one-sentence description of each.

1. ____
____
____

2. ____
____
____

3. ____
____
____

4. ____
____
____

List the major rock types in the area.

1. _____________________________________

2. _____________________________________

3. _____________________________________

4. _____________________________________

Instructions: Notice that ecosystems and rock types are spatially related, and these relations also correspond to topography. Pick one type of ecoregion-rock type-topography association. Research what types of organisms live in your chosen region. Using the Guide and any other resources available, research the tectonic and erosional processes that formed the landscape of your chosen region. Also research when these processes took place in Montana's history. Fill out the chart on the following page.

Ecoregion	Major Rock Type	General Topography

Types of organisms within ecoregion:	
Tectonic processes that formed landscape:	
When in earth's history did these processes take place?	
Erosional (water and/or ice) processes that formed landscape:	
When in earth's history did these processes take place?	

General Geologic History of Western Montana

3.8 – 2.5 billion years ago (Archean Eon)

Montana's history began with the formation of the continental crust. While the earth is about 4.5 billion years old, the oldest rocks in Montana are about 3.2 billion years old, and most of the very ancient rocks are about 2.7 billion years old. These very ancient rocks are commonly called 'basement rocks' because they make up the entire continental crust beneath the thin sedimentary veneer. Basement rocks are generally of granitic composition. The locations of basement rocks can be seen on this map. A more detailed description of the basement rocks can be found here.

2.5 billion – 543 million years ago (Proterozoic Eon)

During the ~billion years between 1.5 Ga and 600 Ma, an intracratonic sea formed. Huge amounts of sediment were deposited in this sea. The sediments subsequently lithified into the red and green sandstone, mudstone, and limestone that are called the Belt formations (because they were first studied in the Belt Mountains). The Belt formations contain remnants of algal life, but animals had not yet evolved. The Belt formations are very abundant in western Montana; their localities are shown on this map. A more detailed description of the Belt formations can be found here.

California and western Idaho had not formed by this time in Earth's history. North America was part of a larger 'supercontinent' called Rodinia, and western Montana was attached to some landmass that is now part of a different continent. Towards the end of the Proterozoic Eon, the 'supercontinent' Rodinia broke apart. Current research suggests that Siberia could be the landmass that was once connected to Montana. The Udzha basin of Siberia might be the western half of Montana's Belt basin. Click here for a description of the Siberian Connection.

543 – 248 million years ago (Paleozoic Era)

Western Montana was not a mountainous region during the Paleozoic Era. In fact, Montana was beneath a shallow sea for much of the time. Sediment was deposited in the shallow sea, burying the Belt formations. These younger sediments preserved the first plant and animal fossils.

Just before the end of the Paleozoic Era, plate tectonic processes caused most of the continents to join together, forming another 'supercontinent' called Pangea. Eastern North America was involved in this event, but it would ultimately affect western Montana.

The end of the Paleozoic Era is marked by the largest mass extinction ever—the Permian Extinction—in which ~99% of all life was wiped out.

248 – 65 million years ago (Mesozoic Era)

The Mesozoic Era was the Age of Dinosaurs. Montana has a rich dinosaur history, especially east of the Rocky Mountain Front near Choteau.

About 200 million years ago, Pangea broke apart, forming the Atlantic Ocean. Although this didn't directly influence western Montana, it did begin a chain of events that resulted in the formation of the Rocky Mountains.

The opening of the Atlantic Ocean caused the plate bearing the North American continent to collide with the Pacific Ocean floor. Since the rock the makes up ocean floor is denser than that of continental crust, the Pacific floor began to subduct beneath North America. Eventually, starting around 90 million years ago, the collision between North America and the Pacific floor caused thick slices of Belt formations, Paleozoic sediments, and Mesozoic sediments to travel eastward along deep fractures called thrust faults. This thickened the western margin of the continent in an accordion-like manner, creating a broad highland in western Montana.

At the same time of the thrust faulting, the ocean crust that was subducting beneath North America caused the lower continental crust to melt into magma. The magma was granite because granite has the lowest melting temperature. Great volumes of granitic magma rose into the upper continental crust, forming great batholiths such as the Idaho Batholith and the Boulder Batholith. These and other igneous intrusions can be seen on this map.

65 million years ago – Present (Cenozoic Era)

Central and Eastern Montana were beneath sea level through much of the Mesozoic, but by about 55 million years ago, the shallow sea had retreated eastward to North Dakota.

The formation of the Rocky Mountains was basically complete by the beginning of the Cenozoic Era. However, a brief period of igneous activity occurred about 50 million years ago. The Absaroka and Gallatin ranges, as well as several small areas in central Montana, contain 50 million year old granitic rocks. There is also an enormous swarm of fractures filled with igneous rock. These dikes are evidence that the crust was stretching apart. In fact, Montana is still a tectonically active region. Earthquakes occur often. Most are not strong enough to notice without instruments, but some are. For example, a 5.6 magnitude earthquake occurred on 7/25/2005 about 23 miles from Dillon, MT. This tectonism is the northern extremity of basin-and-range type extension that is affecting primarily the southwestern U.S. In Montana, extensional deformation has produced pairs of mountain ranges and valleys such as the Bitterroot Mountains and Bitterroot Valley, and the Mission Mountains and Mission Valley.

About 40 million years ago, Montana's climate was very dry, inhibiting the streams' capability to transport sediment. It was so dry that there was probably even more pronounced soil erosion than we have now in Montana. The types of sediment that were deposited in the ancient mountain valleys include gravels, sands, muds, volcanic ashes, limestones, and coal. Some of the valleys contain sediment that is more than 2000 feet thick. These sediments are called the Renova Formation. The Renova Formation is typically pale gray and tan, and it is often soft enough to dig with a shovel. It has a much different character than the Belt formations. The ash beds in the Renova Formation probably came from the Western Cascades in Oregon and Washington.

The dry climate around 40 million years ago is evident in the types of lakes and marshes that were present during the deposition of the Renova Formation. It was probably similar to the climate of the Great Salt Lake region in Utah. Fossils are abundant in the Renova Formation, including petrified wood and fossilized leaves from the Dawn Redwood, a relative of the Sequoia tree. Therefore, the climate must have been dry enough to choke the streams, but wet and warm enough for redwood trees to grow on the surrounding mountains.

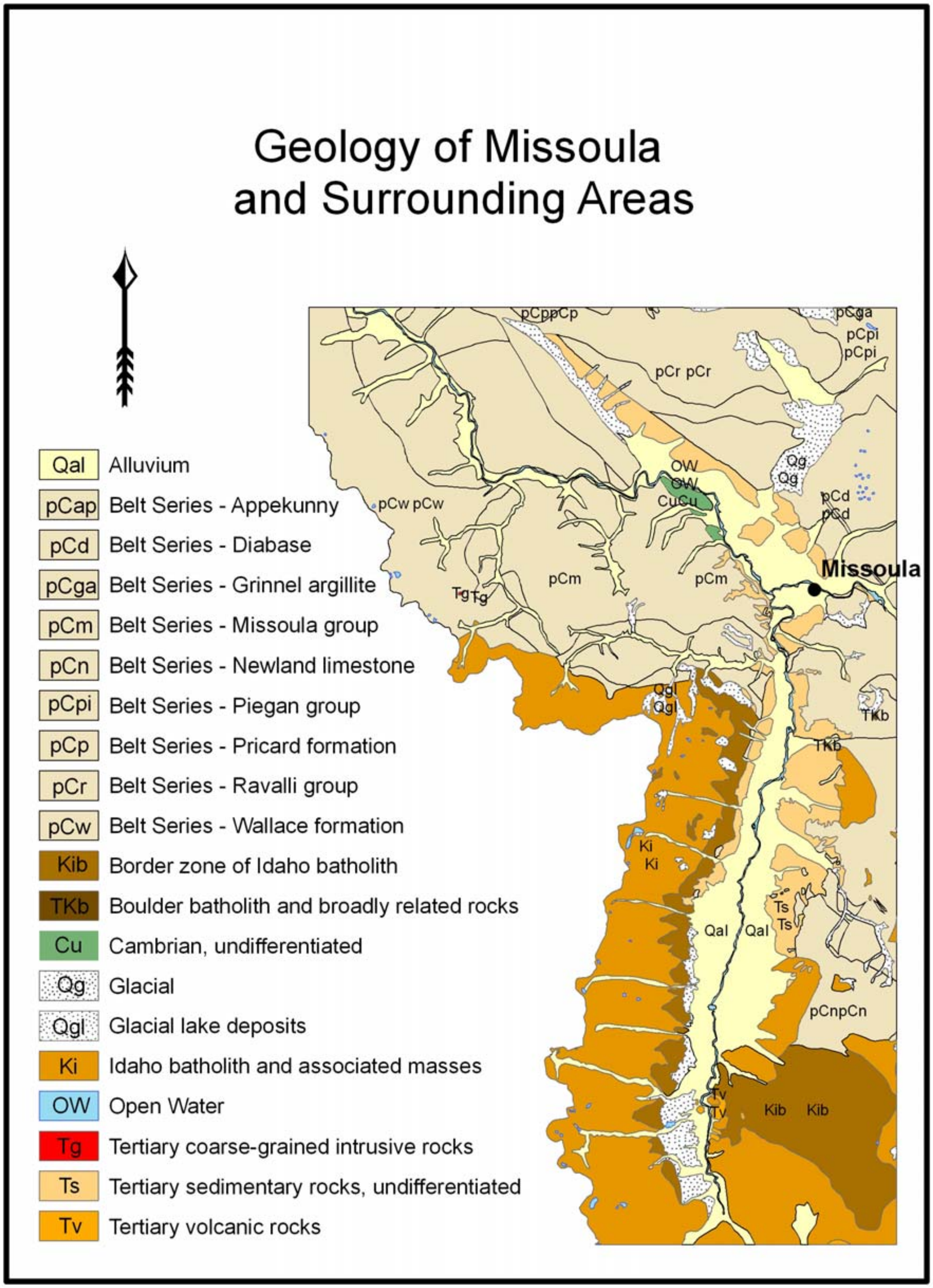
From 20 million years ago to 10 million years ago, Montana had a tropical climate similar to the present Caribbean. The red soil that lies on top of the Renova Formation has the chemical and mineral composition of modern laterites, or tropical soils. The tropical climate coincided with the huge lava flows that built the Columbia Plateau. Some of the lava flows dammed rivers, forming lakes. Laterites deposited in these lakes are sandwiched between black basalt and contain perfectly preserved fossils of tropical leaves similar to those found in Florida and the Caribbean. Streams began to flow during the tropical period.

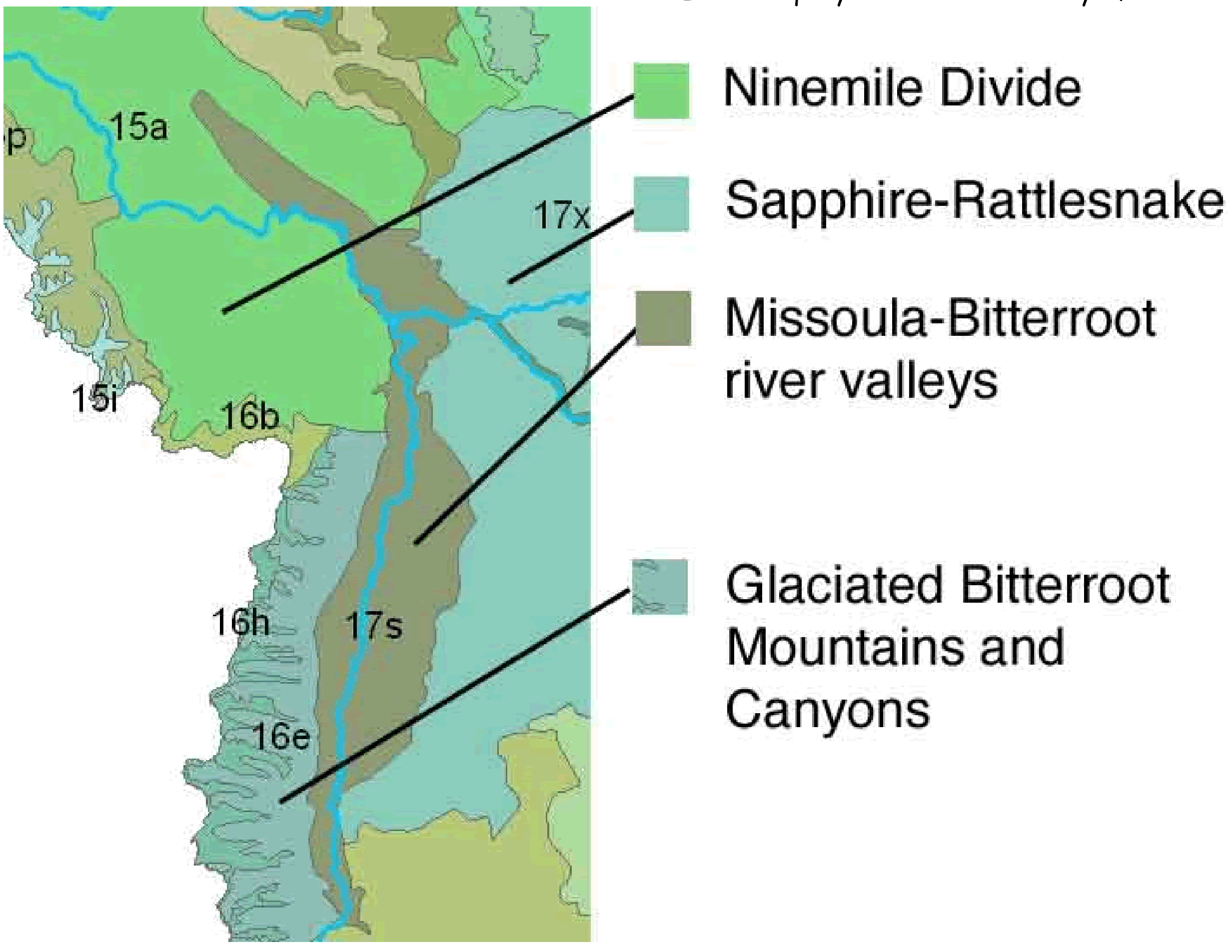
About 10 million years ago, the tropical climate changed to a desert even drier than the first dry spell. Montana's climate from 10 to 2.5 million years ago was similar to today's Death Valley. The brown gravels with layers of sand and mud that were deposited in the mountain valleys during the second dry spell make up the Six Mile Creek Formation. The Six Mile Creek Formation typically rests on the red tropical laterites or on the Renova Formation. It does not typically contain plant fossils, as the climate was too dry to support much plant life. However, the sparse vegetation in desert regions is very nutritious, so there were some large mammals that grazed in the region during this time. Occasional fossils of early horses and camels are found.

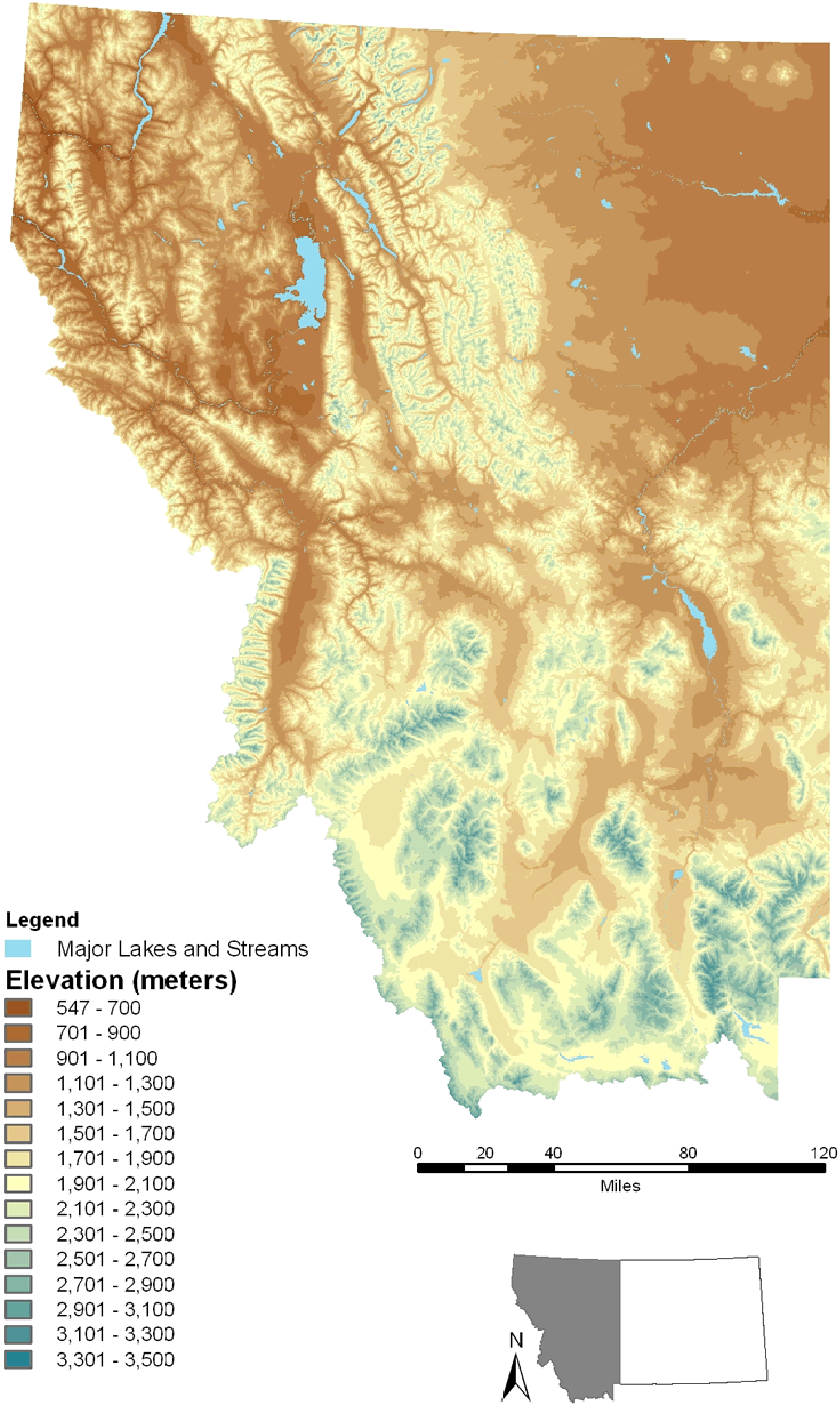
At about 2.5 million years ago, the climate became wetter again. Streams began to flow once more, and green plants returned to Montana. Accompanying this climate change was the last developmental phase of Montana's landscape: the beginning of the great ice ages. Ice ages are periods in Earth's history when the global climate was a bit wetter and a few degrees cooler. Each year in the mountains and at the high latitudes, more ice accumulated than melted. The ice eventually advanced to cover all of Canada and parts of the northern United States. Montana's landscape shows ample evidence of such events, such as glacially carved mountains, glacial sediment and moraines, glacial outwash, etc.

In Montana, we find evidence of two major ice ages. The Bull Lake glaciation occurred sometime between 13,000 and 70,000 years ago. The Pinedale glaciation occurred from about 15,000 to about 10,000 years ago. The Pinedale glaciation is formed Glacial Lake Missoula, a lake bigger than any of the Great Lakes that periodically drained in catastrophic floods.

The Yellowstone volcano is one of the largest and most active volcanoes in the world, hundreds of times more violent than Mount St. Helens. It has erupted three times at 600,000 year intervals, and the most recent eruption was 600,000 years ago. When it erupts again, the consequences will be more extreme than ever recorded by humans. The Yellowstone volcano is a resurgent caldera. When it erupts, it collapses into a huge crater. The crater then fills up with new volcanic rocks. It then erupts again. The type of volcanic rock in Yellowstone is rhyolite. Rhyolite has the same composition as granite, and it forms very explosive eruptions because rhyolitic magma is more viscous than basalt (like honey compared to water), so it builds up lots of pressure before its eruption.


Geology of Missoula and Surrounding Areas
Qal Alluvium
pCap Belt Series - Appekunny
pCd Belt Series - Diabase
pCga Belt Series - Grinnel argillite
pCm Belt Series - Missoula group
pCn Belt Series - Newland limestone
pCpi Belt Series - Piegan group
pCp Belt Series - Pricard formation
pCr Belt Series - Ravalli group
pCw Belt Series - Wallace formation
Kib Border zone of Idaho batholith
TKb Boulder batholith and broadly related rocks
Cu Cambrian, undifferentiated
Qg Glacial
Qgl Glacial lake deposits
Ki Idaho batholith and associated masses
OW Open Water
Tg Tertiary coarse-grained intrusive rocks
Ts Tertiary sedimentary rocks, undifferentiated
Tv Tertiary volcanic rocks
Missoula
pCr pCr
pCw pCw
pCm
Qal Qal
Kib Kib
pCnpCn


15a
15i
16b
17x
16h
17s
16e
Ninemile Divide
Sapphire-Rattlesnake
Missoula-Bitterroot river valleys
Glaciated Bitterroot Mountains and Canyons


Legend
Major Lakes and Streams
Elevation (meters)
547 - 700
701 - 900
901 - 1,100
1,101 - 1,300
1,301 - 1,500
1,501 - 1,700
1,701 - 1,900
1,901 - 2,100
2,101 - 2,300
2,301 - 2,500
2,501 - 2,700
2,701 - 2,900
2,901 - 3,100
3,101 - 3,300
3,301 - 3,500
0 20 40 80 120
Miles
N