



**Montana Natural History Center**  
Connecting People with Nature

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# Glacial Lake Missoula

## Nature Discovery Trunk Curriculum

## Glacial Lake Missoula Trunk

### Nature Discovery Trunk Contents List

#### **Articles, Books & Pamphlets:**

Cataclysms of the Columbia  
After the Ice Age  
Glacial Lake Missoula  
Ice Age Mammals of North America  
Northwest Exposures  
Roadside Geology of Montana  
Roadside Geology of Washington

National Geographic Prehistoric Mammals  
Terra Tempo Ice Age Cataclysm  
Woolly Mammoth  
Ice Age Animals: Woolly Mammoths  
The Ice Age Tracker's Guide

#### **Videos**

Ice Age Flood  
Mystery of the Megaflood

#### **Posters**

Extent of Continental Ice  
Ice Age Floods/Floods of Epic Proportions  
Glacial Lake Missoula and the Channeled  
Scablands  
The Americas

#### **Additional Materials**

Prehistoric Mammals Card Game  
Saber Tooth Replica  
Sabertooth Tiger Figure  
Giant Sloth Figure  
Woolly Mammoth Figure  
Prehistoric Mammal Skulls: 8 count  
Sedimentator: 4 Count

**Glacial Lake Missoula  
Nature Discovery Traveling Trunk**

## Background on Glacial Lake Missoula

Between 18,000 and 12,000 years ago the climate was much different from what we see today. Large continental glaciers spread across the top of North America.

During this time, the Purcell lobe of the Cordilleran Ice Sheet (a massive glacier in Canada) would expand periodically and reach down to what is now Sand Point Idaho, blocking the flow of the Clark Fork River. The river water dammed up behind the ice, flooding valleys and creating an enormous glacial lake - Glacial Lake Missoula. At its greatest extent the lake stretched south to Darby, east to Drummond, and filled the Blackfoot and Flathead valleys. Though other glacial lakes developed around the world, Glacial Lake Missoula may have been the largest.

Periodically the ice dam would fail, releasing the waters of Glacial Lake Missoula at a volume ten times all the rivers of the world all at once. The flood waters would rush across eastern Washington, through the Columbia River Gorge, and pour into the Pacific Ocean near Astoria, Oregon. Geologists studying layers of lake sediment believe the lake may have filled and emptied 30-40 times. Today evidence of this major geologic event is still visible in the form of lake shorelines, giant ripple marks, scoured gorges, and much more.

### GEOLOGIC TIME SCALE

RELATIVE GEOLOGIC TIME			TIME
Era	Period	Epoc	In Millions of Years Before Present
CENOZOIC	<i>Quaternary</i>	Holocene	0.011
		Pleistocene	1.6
	<i>Tertiary</i>	Pliocene	5.3
		Miocene	24
		Oligocene	37
		Eocene	58
		Paleocene	65
MESOZOIC	<i>Cretaceous</i>		144
	<i>Jurassic</i>		208
	<i>Triassic</i>		245
PALEOZOIC	<i>Carboniferous</i>	<i>Permian</i>	286
		<i>Pennsylvanian</i>	320
	<i>Mississippian</i>	360	
	<i>Devonian</i>	408	
	<i>Silurian</i>	438	
	<i>Ordovician</i>	505	
	<i>Cambrian</i>	570	
PRECAMBRIAN			

Glacial Lake Missoula Event



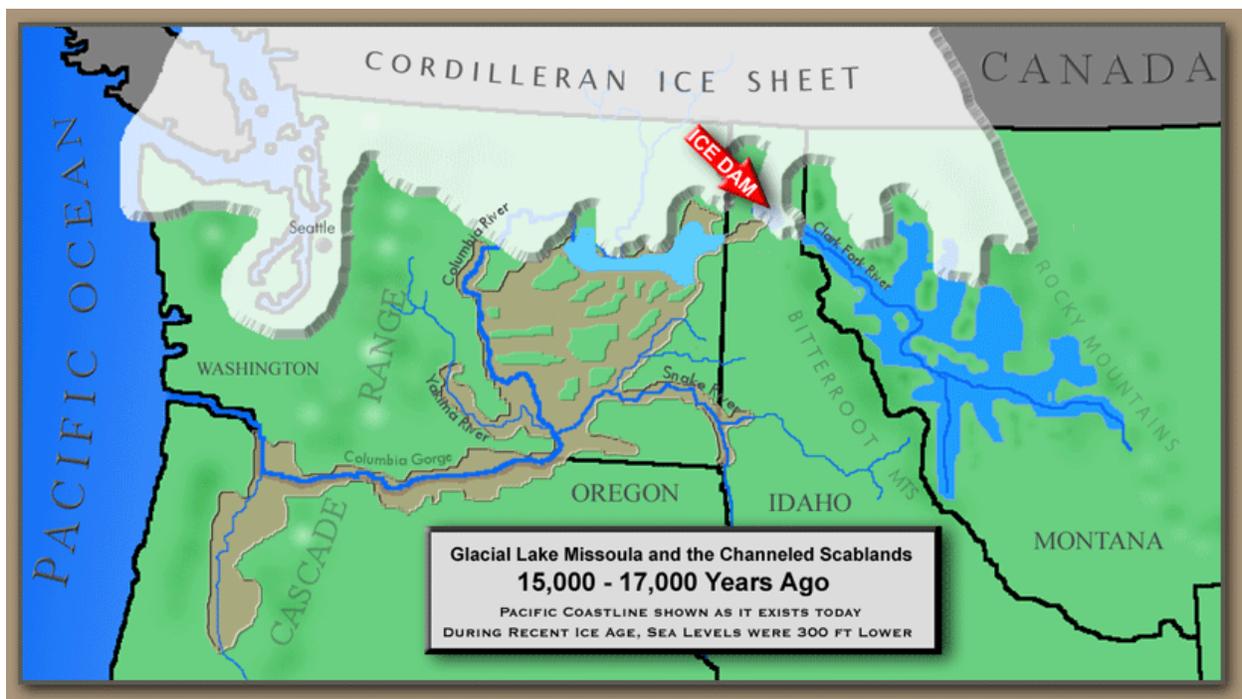
Map compilation and text by David L. Wagner. Graphics by Dinah D. Maldonado. California Geological Survey.

## Lesson 1: Geography and Mapping Glacial Lake Missoula

### Background Information:

During the most recent glacial period, popularly called the Ice Age, a piece of the Cordilleran Ice Sheet moved south damming the Clark Fork River creating Glacial Lake Missoula. The 2,000-foot ice dam blocked the Clark Fork River filling the valleys east of Missoula with water. Once it reached its maximum capacity, (4,200 feet in elevation), Glacial Lake Missoula was the size of Lake Erie and Lake Ontario combined. As the water rose the pressure of the water against the ice dam, caused the ice dam to fail. The water pressure caused the glacier to become buoyant, causing water to escape below the ice dam. The rate of the water flow was 10 times all the world's rivers at once! Meaning that the lake drained in a few days to a week at speeds of 30-50 miles per hour.

The ice dam formed and failed many times throughout history. The outflowing water would rush across Eastern Washington and down the Columbia River drainage into the Pacific Ocean.



**Overview:** During this activity students will work together to create a Master Map of the Ice Age Floods region. Over the course of the unit, they will add photos and information to the map to explore the full scale of the Glacial Lake Missoula and Ice Age Floods events. This activity may take up to 2-3 class periods to complete depending on how much time the students are given to complete the assignment.

### Procedure:

1. Divide students into groups of four.
2. Pass out Lake Missoula Map Handout and a piece of poster board or large paper for each group. Students will work together to create a map that they will use throughout the unit.

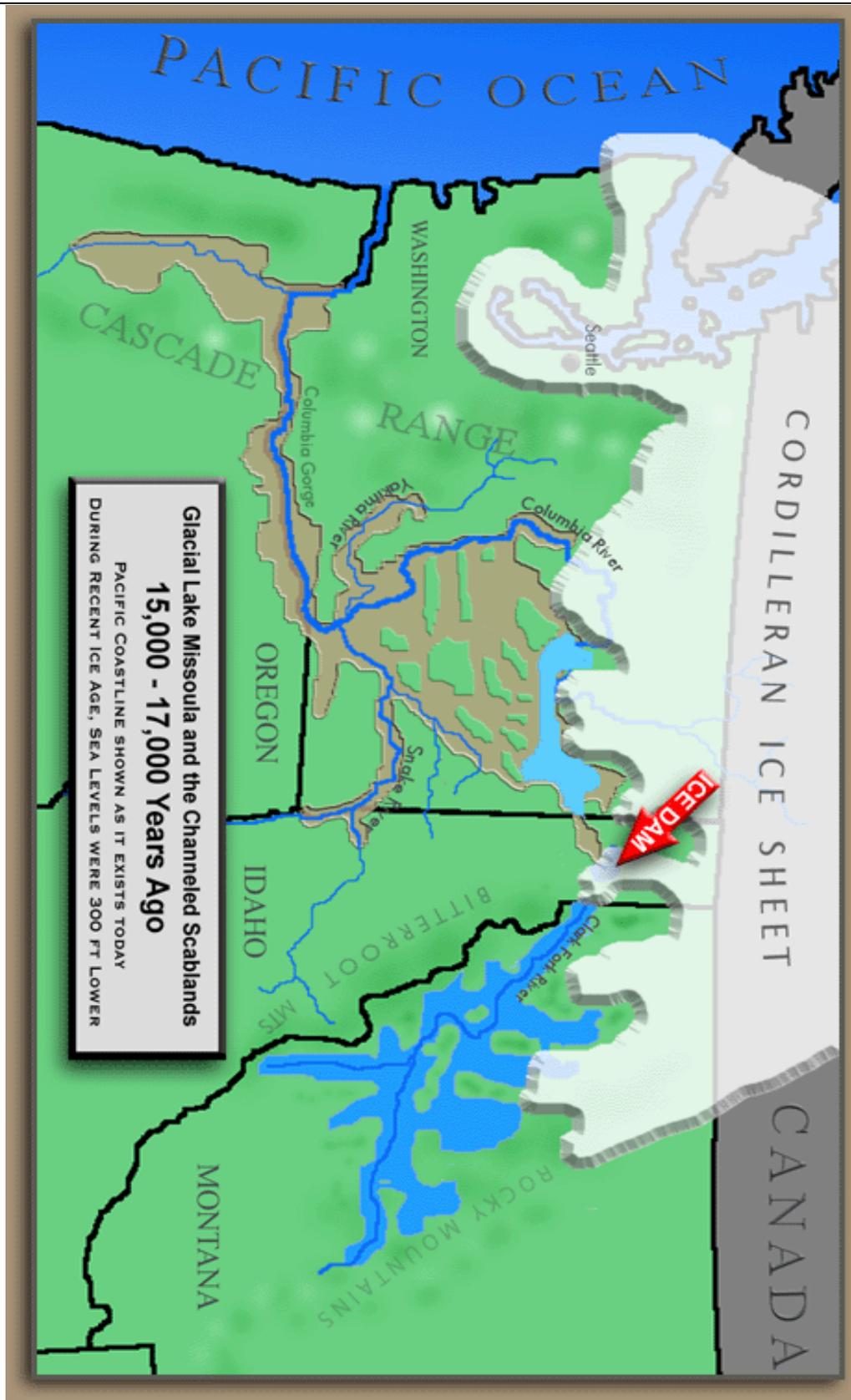
## Glacial Lake Missoula Nature Discovery Traveling Trunk

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Students will need to outline states, showing their interpretation of the lake's location and drainage. You may prefer to project the map on the wall using a computer and the PDF version of this lesson for students to trace.

3. Details to include on Map:
  - Compass: Indicating direction
  - States: Montana, Idaho, Washington, Oregon and Canada
  - Rocky Mountains, Lake Missoula, Clark Fork River, Bitterroot Mountains, Snake River, Cascade Range, Columbia Gorge, Pacific Ocean
  - "The Channeled Scablands"
  - Cordilleran Ice Sheet
  - Ice Dam on Clark Fork River
4. After the students have illustrated the details on their map, they will need to color and include a color key for the items listed above.
5. Students will display maps in classroom for easy reference and addition throughout the unit.
6. Food for thought and discussion post map-making:
  - What does the map tell you right now about the flood?
  - Think about where you live in Missoula and try to place your house on the map.

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## Lesson 2: J. Harlen Bretz and Joseph T. Pardee: Evidence and Discovery

### Background Information:

J. Harlen Bretz spent much of his life studying the geological landscape of Eastern Washington. He published a series of papers in 1923 naming the scarred landscape “The Channeled Scablands” He believed that only moving water could have formed the features of Eastern Washington. His hypothesis was that the features were formed by a large scale flood at a catastrophic proportion. Bretz had no proof of the catastrophic flood. Many people thought his hypothesis to be outrageous. People believed that since no one had ever seen a flood of that proportion then the hypothesis must not be true. Bretz’s idea was quickly dismissed.

The controversy continued until 1942 when Joseph T. Pardee introduced evidence for the possible catastrophic flood. Joseph T. Pardee was from Montana and worked for the United States Geological Survey (USGS). In 1910, he wrote a paper on Glacial Lake Missoula proposing that the lake was formed due to glaciers blocking the Clark Fork River. In his paper he never mentioned what happened to the water that filled the lake.

In 1942, Pardee published Unusual Currents in Glacial Lake Missoula. Pardee discovered that the “giant ripple marks” that are seen in the Camas Prairie, indicating an average height of 15-30 feet and wavelength of 250 feet. The ripple marks are evidence that deep and swift flowing currents passed through this area. Pardee hypothesized that these marks were from the failure of the ice dam. Pardee estimated that Lake Missoula drained at a rate of 9.46 miles an hour.

**Overview:** Students will study, and add to their maps, the clues that Bretz and Pardee discovered. They will make predictions about the Ice Age Flood events as they piece the clues together, similar to how Bretz and Pardee gathered the clues to tell the Ice Age Floods story. Students will do research to confirm the flood events, linking the clues together in the story.

### Procedure:

1. Provide students with images of the Ice Age Flood clues discovered by Bretz and Pardee. Visit <http://www.glaciallakemissoula.org/virtualtour/index.html> for a map on location of clues.
2. As a class, work with students to identify on their maps where each of these clue photos should be added. They can cut the photos out and glue them right to the maps.
3. Thinking like a scientist, have students work in pairs or small groups to make some predictions on why the events would have happened. They should look at all of the different images on their map and try to figure out what story the geology clues are telling them.
4. Students can write their prediction in story or simple time line format.
5. Once they have a theory, have them do the research and confirm. You can encourage them to do research on their own or you can share one of the videos on the Ice Age Floods.
6. Finally, have the students research J. Harlen Bretz and Joseph T. Pardee. Who were these scientists? How did they piece the Ice Age Floods puzzle together?
7. Students can present their research and their learning process.

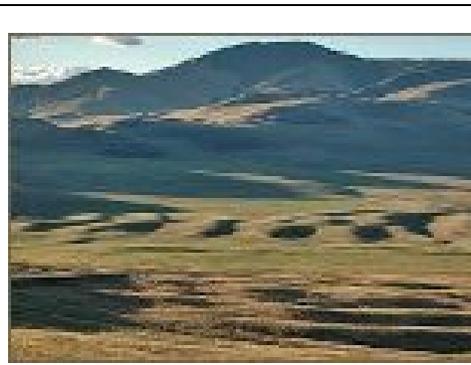
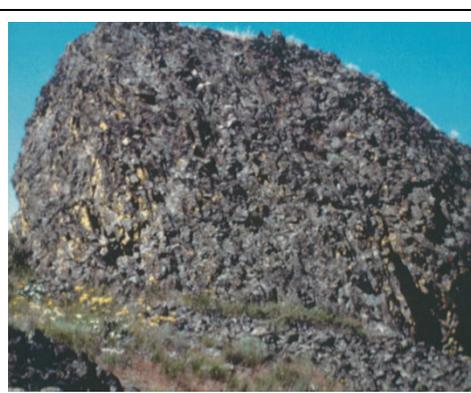
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### **Extension Opportunity:**

Using mystery bags, you can introduce science concept skills of observation and inference before you start the mapping of Ice Age Flood events. Mystery Bags: <http://www.scholastic.com/teachers/top-teaching/2014/01/mystery-bags-develop-observation-and-inference-skills>

## Ice Age Flood Clues

		<p>Beachlines on Mount Sentinel</p>
		<p>Camas Prairie Ripple Marks</p>
		<p>Camas Prairie Ripple Marks</p>
		<p>Glacial Erratic (Giant boulders)</p>

Glacial Lake Missoula  
Nature Discovery Traveling Trunk

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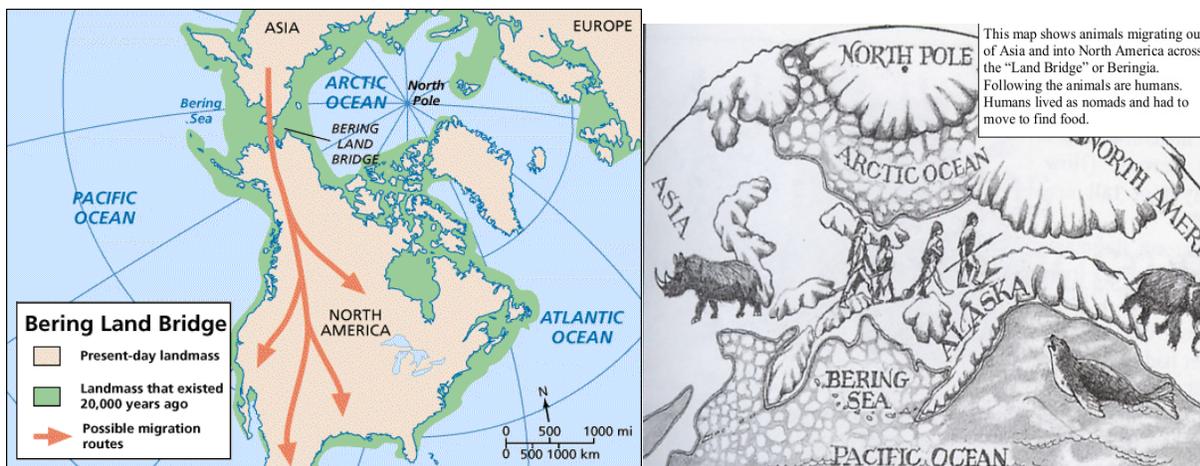
	Glacial Erratic (Giant Boulders)
	Dry Falls
	Palouse Falls
	Channeled Scablands

## Lesson 3: Exploring Animals of the Ice Age

**Background Information:** During the last glacial maximum of the ice age, almost 30% of earth's entire land surface was covered with giant ice sheets. The water was locked in glaciers, lowering the sea level and exposing connections between continents that are under water today. During this time, animals (even people!) migrated from Asia to North America.

While no fossils of ice age mammals have been found in close proximity to the ancient lake, fossils from other locations shows their abundance and distribution across North America during this time.

Interesting Read: <http://www.burkemuseum.org/blog/uncovering-evolutionary-effects-inter-continental-migration>



<http://www.swimswithseals.com/2014/11/people-gotta-move.html> <http://www.slideshare.net/vault415/unit-1-first-americans-26138116>

### Classification of Pleistocene Animals

#### Xenarthra: Sloths and Armadillos

Harlan's Ground Sloth

#### Carnivora: Carnivores

Canines: Dire Wolf

Bears: Short-Faced Bear

Cats: Saber-Toothed Cats

#### Even toed ungulates: Deer, Bison and

#### Camels

Bison Latifrons

Musk Ox

Camelops

#### Elephants

Mastodons

Woolly Mammoth

**Overview:** To put the timing of the Glacial Lake Missoula and Ice Age Floods events into context, students will explore Ice Age Mammals that would have been alive during this time. Students will research one or more of the animals listed and as groups or a full class, they will create a field guide to Ice Age Mammals, showing the information they have learned.

## Glacial Lake Missoula Nature Discovery Traveling Trunk

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### Procedure:

1. Divide students into groups of four.
2. The students can choose one animal to research with their group or groups can be expected to research all animals.
3. The students will gather preliminary information form about their chosen animal.
4. Details to include in final project display:
  - Animal
  - Scientific name
  - Animal's size (height, length and weight)
  - Diet
  - Habitat
  - Behavior
5. After deciding on an Ice Age animal students will create a field guide. This can be a traditional paper book or they can use PowerPoint or a similar program to show the information they have learned.

### Extension Opportunity: Creating a Land Bridge Model

Students will create a land bridge out of salt dough, water, blue food coloring, and ice.

Salt dough recipe:

Ingredients

- 1 cup of salt
- 2 cups of all-purpose flour
- 1 cup of warm water

Directions

1. Mix salt and flour in bowl.
2. Gradually add water. Mix well until it forms dough consistency.
3. Mix blue food coloring and water. You'll need about 1-2 cups of water depending on thickness of land bridge.
4. Make two land masses representing Asia and North America with salt dough. Connect them with a lower elevation bridge of land. Please see map for more accurate sizing of land bridge: [:https://en.wikipedia.org/wiki/Beringia](https://en.wikipedia.org/wiki/Beringia)
5. Mix blue food coloring into the water, then gently pour water into tray until the it is just below the land bridge.
6. Place ice cubes on land to represent glaciers.
7. Now wait and observe what happens to the water levels as the ice melts. This will take several hours so plan on checking in with the landscape throughout the day.



## Extension Opportunity: Make your own fossil

**Background:** Fossils are preserved remains or traces of organic materials from the distant past. The process of fossilization varies. Some fossils are created where minerals replace organic material such as fossilized dinosaur bones. Others can be made by an impression of the organism or material in sand or mud that later hardens (lithifies). This creates a mold which is the type we will make here.

**Overview:** Students will use Ice Age Mammal replicas to simulate the process of making a fossil.

### Procedure:

Fossil Recipe #1

To make dough you will need:

- 1 cup used coffee grounds
- ½ cup cold coffee
- 1 to 2 cups flour (Begin with 1 cup and add more flour if dough is too sticky)
- ½ cup salt
- Mixing bowl
- Wooden spoon
- Small objects such as plastic play animals

1. Measure and mix ingredients together into bowl.
2. Knead dough together with hands. Roll dough into small circles about 3 inches in diameter.
3. Flatten rounds using the palm of your hand. Press plastic animals into fossil dough creating an impression.
4. Allow dough to dry overnight.



## Lesson 4: The Missoula Aquifer

### Background:

The Missoula aquifer is a rock formation made of layered sand, gravel and cobblestones deposited by Glacial Lake Missoula that stores water underground. The aquifer is primarily fed by the Clark Fork River, starting in Hellgate Canyon as water percolates down through the cobbles, and by Rattlesnake Creek. It is not a static reservoir but a flowing body of water moving at a rate of 3-10 feet per day. (Most aquifers' flows are measured in feet per year!) Aquifer water returns to the Clark Fork from Reserve Street to Huson. The water table is an average of 35 feet below the valley floor through Missoula

The Bitterroot aquifers are two aquifers below the Bitterroot Valley—an upper and lower one. The shallow aquifer is separated from the deep aquifer by an impermeable layer of rock. The shallow aquifer contains 628 billion gallons of water, of which humans use barely a fraction.

**Overview:** Students will use gravel, sand, or pea gravel to create an aquifer in a cup. The amount of water that each student aquifer holds will be measured and compared to determine what substrate holds the most water and why.

### Procedure:

1. In Missoula, the bowl of Glacial Lake Missoula, the drinking water comes from an aquifer. If students live in Missoula, ask them if they know where their drinking water comes from. Many people in western Montana obtain their drinking water from a well. Where does the well water come from? Below ground.
2. Ask students what they think the aquifer looks like. Ask what kinds of materials they think make up an aquifer (e.g. rocks, sand, dirt, gravel, etc.). After students generate a list of materials ask them which they think will hold the most water. Take all ideas, but don't give away the answer. They will figure that out with an experiment.
3. Students will use the three materials you've provided—sand, small gravel and large gravel—to create a model of an aquifer that holds as much water as possible. As a class you'll keep track of the results on the following table (draw this on the board now):

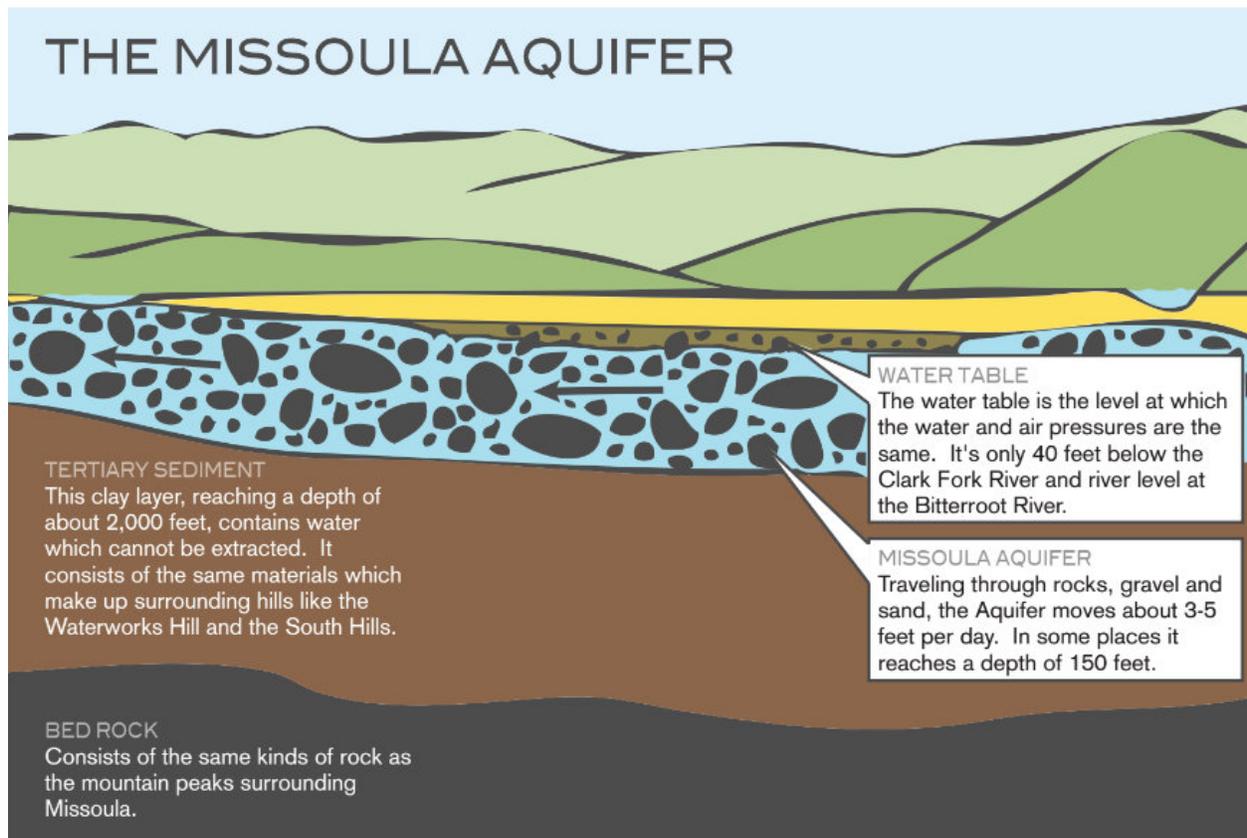
Name	Materials	Amount of Water Held
Jonathan	1 sand, 2 small gravel	3 oz
Sara	3 large gravel	5 oz

4. Explain the procedure before following any of the steps.
5. Students should get into groups of three.
6. Each group will get 3 scoops of material. As a group they should decide what materials they want and in what quantities (i.e. 3 scoops of sand, 1 scoop of each, etc.).
7. One at a time the groups will come up to get their scoops and a clear plastic cup in which to build their aquifer.
8. When all the groups have finished they will come one at a time to the front of the class (or you can go from group to group around the room). You'll then pour water from a measuring cup (so you can tell exactly how much their aquifer holds) slowly into their cup until the aquifer is

## Glacial Lake Missoula Nature Discovery Traveling Trunk

fully saturated (water just barely covering every piece of rock or the barely covering the top of the sand).

9. Then in the table on the board you'll write down one person's name from the group, the materials they used, and how much water the aquifer held.
10. Discussion: which cup aquifers held the most water? The aquifers made of large rocks should hold the most water because there is more space for water between the rocks. (As an interesting side note, given time the sand filled aquifers will expel some of the water they originally absorbed.)
11. Ask students, based on the results of the experiment, what they think Missoula's aquifer is made of. (Big rocks.) Ask how they think those big rocks got there. (flood waters of Glacial Lake Missoula.) Explain, in brief, the story of Glacial Lake Missoula and how it left the big boulders behind that give us such a good aquifer. Explain that since Glacial Lake Missoula only happened about 15,000 years ago there isn't a lot of sediment piled on top of our aquifer. In places around Missoula the aquifer is only 30 feet below the ground. So, whatever we pour on the ground ends up trickling down into our drinking water.



**Glacial Lake Missoula  
Nature Discovery Traveling Trunk**

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## **Lesson 5: Constructing an Aquifer**

**Overview:** Students will construct an aquifer model to observe how water flows from land to the aquifer below.

**Materials not included in the trunk:**

- Pea sized gravel for base
- Soil
- Grass Clippings or leaves
- Plastic cup with small holes in the bottom
- Blue colored water
- Coffee filter
- Rubber band

**Procedure:**

Lesson is adapted from this website: <http://sciencelearn.org.nz/Contexts/H2O-On-the-Go/Teaching-and-Learning-Approaches/Constructing-an-aquifer-model>

1. Share the Sedimentors and ask students to observe how the materials move and settle. They can shake them to disturb the materials and then either hold them still or set them on their desks to observe how they settle. What materials fall to the bottom? What layers do you see?
2. This is similar to how materials in Glacial Lake Missoula would have settled but with much bigger rocks of course! Have students think back to the aquifer cup experiment and imagine the materials settling out in a big lake.
3. Now they will build aquifer models in groups to observe how water falls onto the land and how it filters down into the aquifer.
4. Divide students into groups of four.
5. Place stones in plastic container. Slope to form a depression at one end of the model. This depression will represent a lake.
6. Add a layer of soil on top of the stones. Pat the soil down to minimize erosion.
7. Add a layer of grass to represent vegetation.
8. Hold cup over the model. Pour colored water into cup to simulate rain. Move cup around so that it “rains” over the entire model. Refill the cup as needed until a small lake is formed. (Only a few centimeters deep)
9. Cut a small strip from coffee filter. Use these to cover the bottom of the spray nozzle tube. Secure the filter with a rubber band. The filter prevents fine particles from entering the tube and plugging the spray nozzle. To obtain water from the water table, use the spray pump to represent a municipal well. Work the spray nozzle and “pump” water from the aquifer.
10. Students can pollute their aquifers with food coloring to observe how hazardous materials spilled on land can make their way into the aquifer and drinking water.



**Extension:** Additional activities for how to use the Sedimentors are included in the trunk.

## Glacial Lake Missoula Nature Discovery Traveling Trunk

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### **Symposium Suggestions**

Once the students have completed their maps and projects they will present what they have learned. Have students set up their projects in the classroom and present to the class, other classes or parents about what they learned.

Some good ideas for student presentations:

<https://anethicalisland.wordpress.com/2013/06/27/preparing-students-to-present/>

Have them practice a couple of times before the presentation.

## Glacial Lake Missoula Nature Discovery Traveling Trunk

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### Resources

#### Video Resources

Mystery of the Megaflood: Examining the World's Most Catastrophic Flood  
<http://www.pbs.org/wgbh/nova/megaflood/>

Ice Age Floodscapes Youtube Channel  
<https://www.youtube.com/channel/UCNS9qfD-DQWvRrjKsIIUzvw>

#### Curriculum References

<http://www.dmns.org/science/the-snowmastodon-project/for-families/>

<http://www.education.com/activity/article/fossils/>

<http://www.layers-of-learning.com/land-bridge-model/>

<http://sciencelearn.org.nz/Contexts/H2O-On-the-Go/Teaching-and-Learning-Approaches/Constructing-an-aquifer-model>

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<http://www.pbs.org/wgbh/nova/megaflood/>

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<http://www.burkemuseum.org/blog/uncovering-evolutionary-effects-inter-continental-migration>