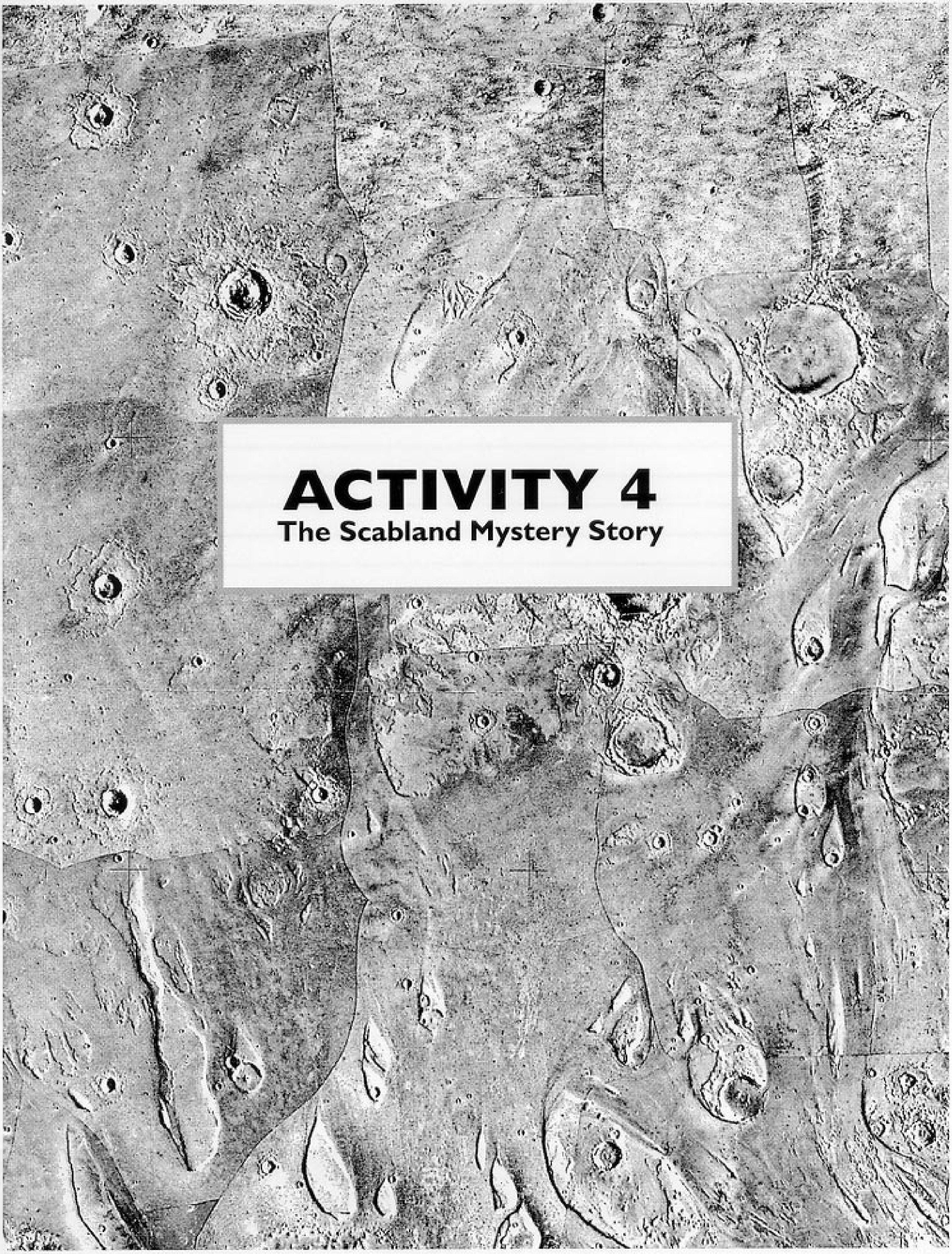
# ACTIVITY 4
## The Scabland Mystery Story



# NOTES

# AT A GLANCE

## Overview
Students read about geologist J. Harlen Bretz's efforts to explain the creation of the Channeled Scablands of eastern Washington State and about some of the evidence he used to support his idea of a cataclysmic flood being responsible for its creation. By examining some of this evidence, students hypothesize about processes that might account for these apparently unrelated features, ultimately creating a hypothesis the entire class can support. Next, students look at images of flood channels on Mars and see if their Scabland hypothesis explains anything about the Martian channels. To draw a sharper comparison, students complete a sheet directly comparing some Scabland and Martian features. Finally, students read an essay describing the outcome of Bretz's work and the gradual acceptance of his ideas.

## Content Goals
- There was a tremendous flood that created the Scabland region in eastern Washington.
- Catastrophic floods leave telltale features such as erratics and huge-scaled ripple marks and gravel bars.
- The Scablands serve as an Earth analog to the Martian flood channels.
- Even when a scientist is right, his or her ideas may be ridiculed.

## Skill Goals
- *Hypothesizing* based on written and visual evidence.
- *Presenting* and, if necessary, *revising* ideas.

## Possible Misconceptions
- If an idea is correct, people will recognize its correctness and embrace it
  *Ask: How long did it take for people to accept that Earth is not the center of the universe? That the world is made up of atoms? The Earth is round?*
- Even the worst floods just make a mess and are an inconvenience.
  *Ask: How much can a flood affect the land? What's the biggest flood you know about?*

*For activities that deal with misconceptions about water pressure and the carrying capacity of ice, see extension activities 4A, 4B and 4C.*

## Materials
Image set and the two reproducible student sheets in the Teacher Handbook.

## Preparation
Make copies of "Introduction to the Scabland Mystery" and "The Rest of the Scabland Story" for each student.

## Time
1-2 class periods. The Extensions will add 1-2 class periods.

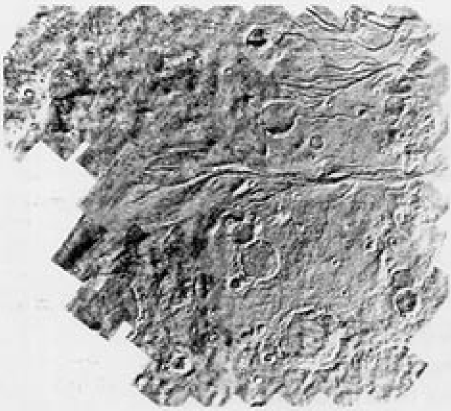


Fig. 4.1
*A dendritic drainage pattern on Mars.*

Even though it is a dry planet, Mars seems to have had water flowing across its surface at some time during its history. Etched into its surface, one can observe what appear to be channels and tributaries similar in pattern to the dendritic (branching) drainage patterns of river systems on Earth (Fig. 4.1). Refer to Mike Caplinger's essay after Activity 1 for additional images and details. There are also features that suggest cataclysmic flooding, an important theme in this module and the focus of Activity 4.

*Cataclysmic floods* release immense amounts of fluid over a brief period of time (Fig. 4.2). We know about many of the features associated with cataclysmic flooding thanks to the work of J. Harlen Bretz, a geologist who studied the Scablands of eastern Washington State starting in the 1920's. Taking a position that ran counter to the ideas of the time, he proposed that 12,000-16,000 years ago, colossal floods flowed from the Washington-Idaho border to the sea. These floods, it turned out, were fed by a lake nearly 600 m (2,000 ft) deep and 320 km (200 mi) long, Lake Missoula. Lake Missoula contained over 2000 $km^3$ (500 $mi^3$) of water – more water than would fill both Lake Ontario and Lake Erie and ten times the annual flow of all the world's rivers combined. When the glacial dam impounding Lake Missoula gave way, this water took only a week to race across Washington State to the sea, traveling as fast as 60 miles per hour in rivers more than 100 meters (325 ft) deep. Today's Scablands cover 34,000 $km^2$ (13,000 $mi^2$).

Fig. 4.2
*Artist's sketch of a flood sweeping down the Columbia River.*

The flood waters stripped the land of its soil – 60 m (200 ft) thick in places – and exposed the layers of black volcanic rock of eastern Washington. Thirty-foot chunks of these layers were easily plucked out by the flood waters, giving the landscape a pockmarked look and giving rise to the area's name, Scablands (Fig. 4.3). Bretz wrote, "Like great scars marring the otherwise fair face of the plateau are these elongated tracts of bare, or nearly bare, black rock. The popular name is an expressive metaphor. The Scablands are wounds only partially healed in the epidermis of soil." In its wake, the flood (and there may have been as many as 100) created other geological oddities: gravel bars hundreds of feet tall, enormous potholes, huge canyons gouged where today almost no water runs, basalt plains stripped bare of soil, erratics and sandbars perched on hillsides hundreds of feet above valley floors, and ripple marks so tall and long that they can only be recognized as ripple marks when viewed from the air. These features are so huge that no one until Bretz recognized them as products of flowing water.

Fig 4.3
*Compare the pockmarked Scablands on the left to the hills of loess (wind deposited soil) on the right.*

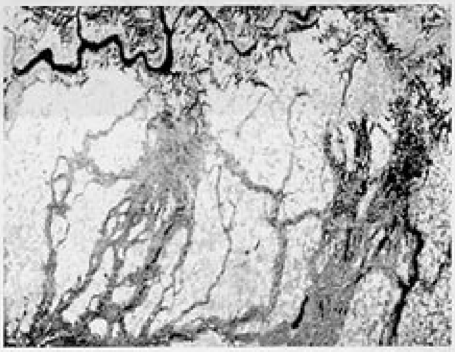


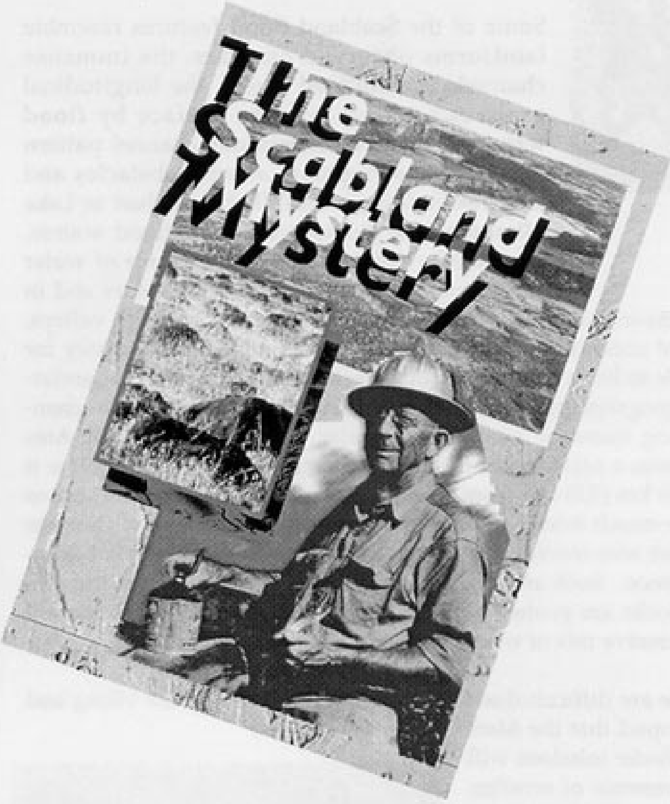
**Fig. 4.4**
*Satellite image of the Scablands.*

Some of the Scabland flood features resemble landforms observed on Mars: the immense channels, streamlined mesas, the longitudinal grooves scoured into the surface by flood waters, and the *anastomosising* channel pattern (channels that separate around obstacles and later rejoin downstream) (Fig. 4.4). Just as Lake Missoula was the source for the flood waters, the chaotic terrain is the likely source of water for the outflow channels. Both on Mars and in the Scablands, the channels cut pre-existing surface features, and there are hanging valleys, testifying to dramatically different conditions before and after the floods. The tendency for the Scabland and Martian channels to be straight rather than meandering is a feature associated with flood waters. The large geographical area of the flood and the great size of the channels support the idea of there being immense quantities of water. Both flow downhill: Ares Vallis flows 1,800 km (1,125 mi) from a plateau to a basin approximately 3 km (2 mi) below it and the Scablands flows about 680 km (425 mi) from an elevation of 1.3 km (4,200 feet) to sea level. Both sets of channels are much wider than they are deep. One major difference between the two floods is that there was considerably more ice present in the flows on Mars – ice that was broken up by turbulence. Such an ice-water mix considerably increases the erosive power of the flow. As ice blocks are pushed along, they drag and shear the bank's soil and rocks. The result is a highly erosive mix of water, ice blocks, soil and rocks.

The comparisons at a smaller scale are difficult due to the limited resolution of the *Viking* and *Mariner* cameras (Fig 4.5). It is hoped that the *Mars Global Surveyor* and the *Mars Pathfinder* missions will provide information about the presence of erratics, ripple marks, sand and gravel bars, scabland topography, and scour marks near flow obstacles. In addition, these missions may shed light on whether there are depositional features such as deltas and large-scale fans at the terminus of the channels. However, because the Martian gravity is 4/10 that of Earth's, features commonly associated with sediment deposition on Earth are likely quite different on Mars. It may be that sediments of all sizes were kept in suspension long enough to deposit themselves fairly evenly over much of the Chryse Planitia without forming a delta.

**Fig. 4.5**
*The mouth of Ares Vallis where it terminates in the Chryse Planitia. Image Set image #3.*

# PROCEDURE




1. Have students read the "Introduction to the Scabland Mystery."
   *An interesting point following up the discussion of catastrophism and uniformitarianism can be made. Today, scientists increasingly accept a blend of the two ideas where events such as meteor impacts and volcanic explosions are part of the normal patterns on Earth.*

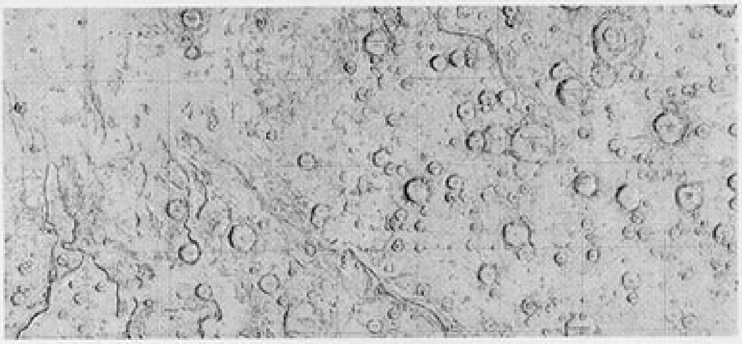
2. Let them look at Image 8 that shows some of the Scabland features.

3. Ask student groups to create hypotheses explaining these apparently unrelated features.

4. Conduct a class discussion to synthesize the thinking of each group and develop a hypothesis the entire class can support.

*You will probably find that as groups present and detail their ideas, new ideas will spring up and a lively discussion will ensue. In addition, a discussion enables you to probe into the weak aspects of a hypothesis. Once students are aware of gaps or contradictions in their arguments, they will be motivated to search for additional evidence to reinforce their hypothesis or they will have to revise their hypothesis. The goal is not necessarily to get the correct answer right away, but to stitch together solid arguments based on evidence and leaps of intuition. Students must remember that before an idea can take final shape, many earlier ideas should be considered. The trick to moving ahead is learning to recognize what is good in an idea and what needs to be discarded.*

# APPLYING THE MODEL TO MARS



*Shaded Relief Map of Ares Vallis. Image Set image #1.*

1. Have students look at the Image set, especially those images showing the outflow channels. Ask students:

   - Do any features remind you of things you saw in the Scabland images?
     *Both have large channels; the Scabland teardrop-shaped gravel bars look similar to the streamlined features at the mouth of the channels; and, the channel pattern shown in the satellite image of the Scablands is reminiscent of the pattern of the channels that flow into the Chryse basin.*

   - What seems to be the source of the fluids that excavated the Martian channels?
     *Chaotic terrain.*

   - What seems to be the source of the fluids that excavated the Scabland channels?
     *Cannot tell, though they seem to originate east of the Scablands.*

   - Estimate the length of the Scablands and compare them to the length of several of the flood channels on Mars. *Channel lengths, widths, and depths could be estimated and flood volumes calculated as a product of the three numbers.*

2. Does the class hypothesis explaining the Scablands seem to explain anything about the Martian channels?

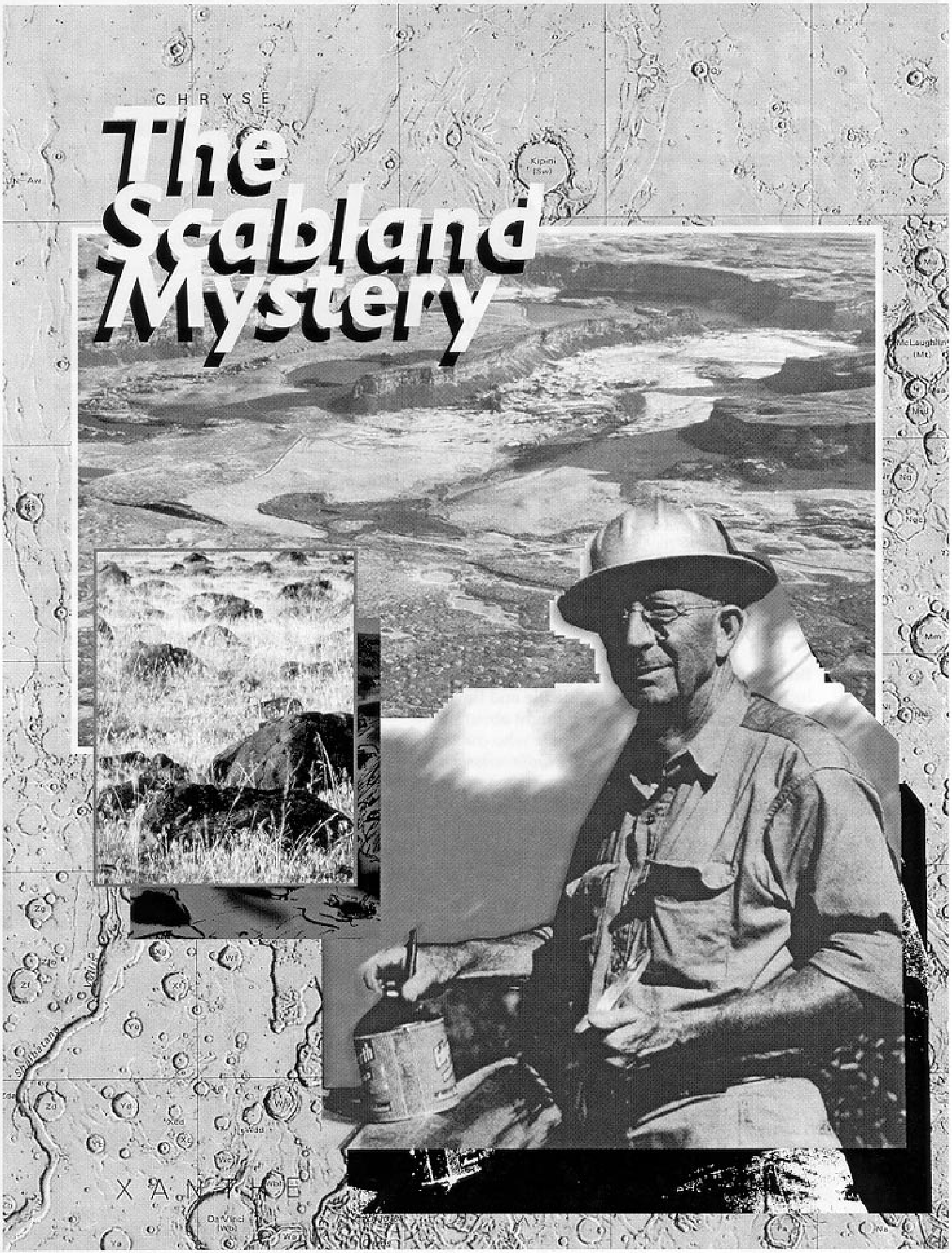
3. View the *Great Floods, Cataclysms of the Ice Age* video. If unavailable, have students read "The Rest of the Scabland Story."

4. Now that immense, cataclysmic floods have been identified as the cause of the Scabland features, have students complete the sheet comparing the Scabland and Martian channels to features known to be associated with immense floods.

5. If they have not already done so in Step 3, have students read, "The Rest of the Scabland Story."

6. Have students make lists of additional evidence they would like to have in order to argue for or against the idea that the surface of Mars experienced cataclysmic flooding.

# The Scabland Mystery



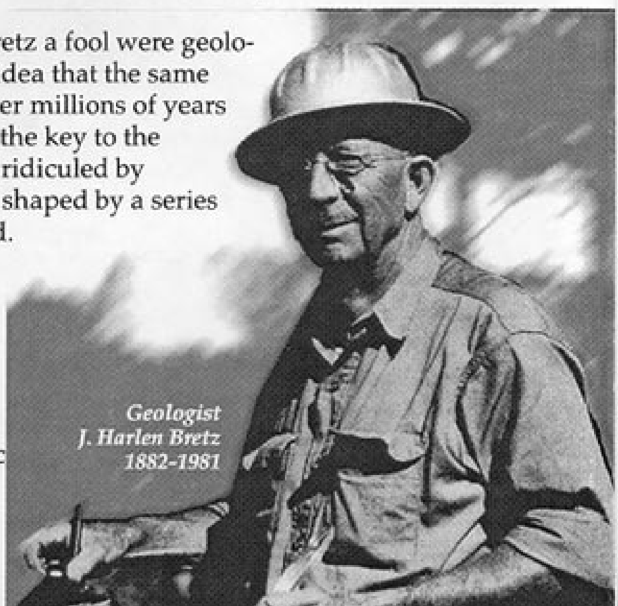
# The Scabland Mystery

*Dry Falls in the Channeled Scablands of Eastern Washington.*

## What did the first visitors think when they saw this barren, desolate land?

Did they think an angry god had cursed this land and punished the creatures living there? Did they call it the land of the dead and stay far away? The barren landscape is filled with gigantic canyons, tall cliffs, deep gorges, big pits, odd knobby protuberances and immense, empty channels that look like channels for some invisible river. Thousands of years after these early explorers by-passed this forsaken land, farmers avoided it and even ranchers turned their backs on it. In most of its 34,000 $km^2$ (13,000 $mi^2$), the thin or non-existent soil can scarcely grow enough grass to keep a flock of sheep going. This area is known as the Scablands, and it is located in eastern Washington State near the Oregon and Idaho borders. However, even odd places have their admirers. This activity describes the work of one of these admirers, a young geologist named J. Harlen Bretz.

Bretz never intended it to happen, but he was a revolutionary. And he paid the price many revolutionaries pay – ostracism, ridicule and the rejection of his ideas. However, Bretz had an idea he believed in, and the more he thought about it, the more he believed in it. The people who considered Bretz a fool were geologists who supported the idea of *uniformitarianism,* an idea that the same geologic processes we see today worked gradually over millions of years to produce the present-day landscape – the present is the key to the past. Not so long before, uniformitarianists had been ridiculed by *catastrophists*, people who thought that the Earth was shaped by a series of sudden, violent upheavals, events like Noah's flood.



*Geologist J. Harlen Bretz 1882-1981*

Catastrophism was the conventional mindset in the mid-1800s, and uniformitarianists worked hard to convince geologists of their new idea. Eventually, uniformitarianism came to dominate geologic thinking. Having won such a long and hard-fought battle, uniformitarianists were reluctant to view any geologic event as being caused suddenly and did not look kindly on people challenging their ideas.

Bretz began his career teaching high school in Seattle, Washington. Soon, however, his geologic passion prompted him to obtain an advanced degree in geology. After graduating, Bretz began examining the Columbia River Gorge and the Quincy Basin in Washington state and developing a huge base of factual information. The landforms reminded Bretz of channels and ripples left behind after a seasonal creek dried up. Yet, they were so enormous that they were only recognizable as sandbars, ripple marks, pot holes and gravel bars when they were viewed from an airplane. A further complicating factor was that the features he was seeing are associated with flowing water, yet there was virtually no nearby water. Puzzled by size, shape and origin of these features, Bretz returned again and again with his family to study the features of the Channeled Scablands.

*Ripple-like hills 11m (35 ft) high and 3 km (2 mi) long spaced 110m (350 ft) apart.*

*A gravel bar totally out of scale with the Columbia River (to the left).*

What impressed Bretz was the great number of *erratics* (rocks that do not match any nearby formations) located high on hillsides where they had no business being. A small erratic can be picked up by a person. A big one can weigh more than 150 tons and be the size of a small house. Bretz found many erratics perched on hillsides hundreds of feet above the valley floor. Scientists had no explanation for these boulders that were hundreds of miles from their parent rock and that were lifted to high elevations. What could move rocks weighing 200 tons far from their original locations? How could matching rocks be scattered over thousands of square miles? Bretz kept on looking and taking precise notes of his observations.

In 1922, Bretz presented a paper that outraged geologists. They tried to discredit and ignore him. But the more time he spent in the Scablands, the more convinced he became of the correctness of his idea. What was the idea that so upset his colleagues? What could he see that no one else could see? Why couldn't he convince anyone else of his idea? This activity invites you to take a look at some of the evidence Bretz saw and to draw your own conclusions.

*Erratics (rocks that do not match any nearby rocks) scattered in a field in Washington State.*

# The Rest of the Scabland Story

*Erratics (rocks that do not match any nearby rocks) littering a field in Washington State.*

Bretz focused his attention on the erratics. They were too big to be shot from volcanoes. Water couldn't lift them to the tops of hills. If erratics had been frozen into small icebergs, maybe they could have floated here. But how would one collect enough water to float icebergs big enough to carry them? And how could erratics have been left at such high elevations? But something had moved huge erratics onto hill tops, had carved gigantic channels and waterfalls, and had piled up immense gravel hills. In fact, the hills of gravel lay precisely where one would expect gravel bars to form if enough water could be made to flow. And Bretz could think of no other answer than a flood of mind-boggling proportions. A cataclysmic flood would be the one thing that could explain all the oddities seen in the Channeled Scablands.

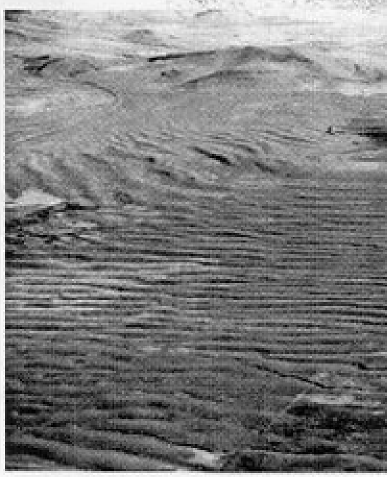
In 1922 and 1923, Bretz presented papers listing the evidence which compelled him to conclude that 12,000 - 16,000 years ago, 34,000 $km^2$ (13,000 $mi^2$) of Washington's Columbia Plateau were swept repeatedly by glacial floods of an unimaginable magnitude to create the Scablands. "I could conceive of no geologic process of erosion to make this topography except huge, violent rivers of glacial melt water." He was painfully aware that he had discovered no source for the immense volume of water, but he felt he had to present his hypothesis, nonetheless. In 1928, Bretz wrote: "Ideas without precedent are generally looked upon with disfavor and men are shocked if their conceptions of an orderly world are challenged."

As he expected, his work was met with ridicule. First of all, opponents of his ideas simply could not condone any *catastrophic* idea when they had worked so hard to formulate their *uniformitarian* position. Secondly, Bretz's inability to produce a source for so much water gave his critics ample reason to doubt his flood idea, and they explained the odd landforms in other ways.

*Streamlined, teardrop-shaped gravel bar deposited during the flood.*

*During the flood, water filled Wallula Gap to the top and stripped the soil from the basalt on both sides. Water flowing gently over millennia would produce a V-shaped valley rather then these steep-sided cliffs.*

In 1940, the American Association for the Advancement of Science met in Seattle. Joseph Pardee was a presenter with an unassuming topic: "Unusual Currents in Lake Missoula." The geologists all knew that as the Ice Age ended there had been a series of glacial lakes – lakes that form behind ice dams. Lake Missoula was one such glacial lake, a lake nearly 600 m (2,000 ft) deep and 320 km (200 mi) long containing over 2000 $km^3$ (500 $mi^3$) of water – more water than would fill both Lake Ontario and Lake Erie. Pardee described some ripple marks he had found in the floor sediments of former Lake Missoula. These parallel ripple marks were large – 15 m (50 ft) tall with wavelengths between 60-150 m (200 - 500 ft). Ripple marks of this size could have been formed only by a vast pouring of waters over a slope, which would have happened only if the ice dam failed suddenly. Pardee suggested that this is precisely what happened, and that it probably failed in less than a day. His calculations showed that in each hour after a sudden failure, nearly 40 $km^3$ (10 $mi^3$) of water would flow at close to 100 km (60 mi) per hour through the narrow gap in the glacial dam for several days. The huge ripple marks he observed provided evidence for the idea that the ice dam failed catastrophically, and that Lake Missoula drained within days. The only outlet for the water was at the Clark Fork river which opened onto Bretz's Channeled Scabland. Here was Bretz's water source! The audience remained silent at the end of Pardee's presentation as the news sunk in, but soon it rose to its feet in a standing ovation. It still took meetings and debate, but before his death J. Harlen Bretz was awarded geology's highest honor: the Penrose Medal.



*Giant ripples near Markle Pass, Montana discussed in Joseph Pardee's presentation.*

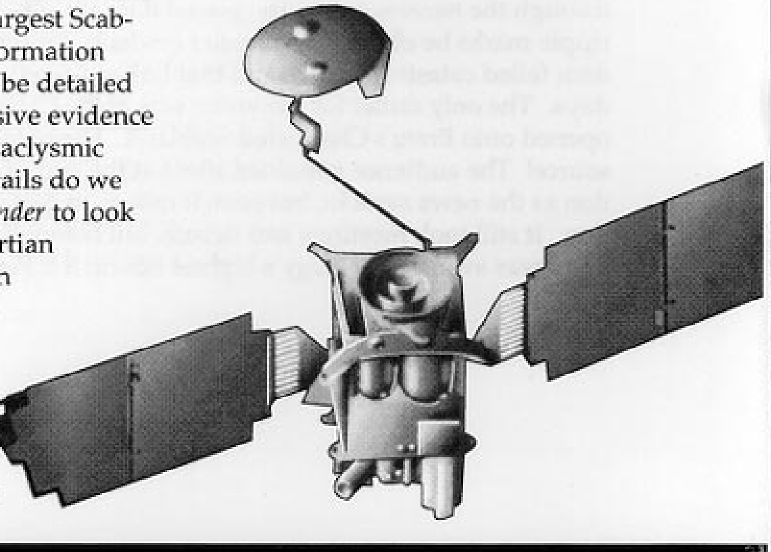
*Artist's sketch of a flood sweeping down the Columbia River.*

## So what is the story we now know?

In the last Ice Age, a lobe of ice from a huge continental glacier moved down the Purcell Trench in Idaho until it was stopped by Montana's Bitterroot Mountains. 12,000-16,000 years ago, the lobe of ice blocked several rivers, creating a lake behind the ice lobe. When the lake level became 9/10th the height of the ice dam, approximately 600 m (2,000 ft), the ice dam floated allowing lake water to flow under the dam and undercut it. Within a day or two, the dam failed and a churning, muddy wall of water hundreds of feet deep raced to the Pacific ripping gaps through constricted places.

The water transported icebergs containing 9 m (30 ft) erratics swiftly across eastern Washington. Some of these icebergs settled on the shores of the temporary lakes. When the waters receded and these icebergs melted, the boulders contained in the icebergs settled high above the now-dry valley floors. In less than a week, the flood waters drained to the ocean by Portland, Oregon, forming a huge delta there. People now think that as many as a 100 floods erupted at regular intervals every 55 to 60 years. It seems that as the ice lobe moved continuously down the Purcell Trench, it created dam after dam as the previous one floated and failed.

In the 1970's, when *Mariner 9* and the *Viking* missions sent images of the Martian channels, geologists were confronted with scenes that resemble, more than anything, Bretz's Channeled Scablands. Soon, *Pathfinder* and *Mars Global Surveyor* are going to Mars. Ares Vallis shows similarities to the largest Scabland features. Will the information from *Mars Global Surveyor* be detailed enough to provide conclusive evidence for whether there were cataclysmic floods on Mars? What details do we want rovers such as *Pathfinder* to look for as they explore the Martian surface? What information would you like to have in order to answer your questions?



*Mars Global Surveyor and Mars Pathfinder will arrive at Mars in 1997.*

# *Were there Cataclysmic Floods on Mars?*

Below are listed a number of features known to occur on Earth in areas that have experienced cataclysmic floods – tremendous volumes of water released over a short period of time. By filling in the boxes with either Yes, No, or Can't Tell, see how the features associated with the Martian channels compare to the features associated with the great Scabland floods.

| Feature Associated with Immense Floods | Scablands | Martian Channels |
|---|---|---|
| Identifiable source areas | | |
| Consistent downhill flow | | |
| Flow for thousands of kilometers | | |
| Flow occurs over a large geographical region | | |
| Clear edge and upper limit to fluid flow | | |
| Sharp break between eroded and non-eroded land | | |
| Wide, shallow channels | | |
| Main channels tend to be straight, not meandering | | |
| Channels separate and then rejoin downstream | | |
| Streamlined landforms in and near the channels | | |
| Bedrock has grooves cut parallel to fluid flow | | |
| Residual uplands separating channels | | |
| Areas where flow has obviously been constricted | | |
| Erratics – rocks far from their point origin | | |
| Giant ripple marks | | |
| Resistant rock layers eroded | | |
| Gravel bars and large-scale sediment deposits | | |
| Channel terminus hard to determine due to the lack of deltas or fan-shaped deposits at the mouth. | | |

# EXTENSION ACTIVITY 4A

**Overview**

A misconception students often have is that water pressure is a function of the amount of water in a container or impounded behind a dam. In fact, water pressure is a function of depth. By measuring the distance water spurts out of holes in containers, students discover and demonstrate that pressure at the base of a can is greater than at the top of the can. Students conclude that water pressure behind dams varies with water depth and not lake length, so dam strength is unaffected by lake surface area or volume.

**Background**

Students learn that at its largest, Lake Missoula was 600 m (2,000 ft) deep at the ice dam, over 320 km (200 mi) long, covered 7,500 $km^2$ (3,000 $mi^2$) and contained 2,000 $km^3$ (500 $mi^3$) of water. They also learn that Lake Missoula eventually breached the ice dam. While students might be impressed at the overall size of Lake Missoula, its depth is the most important factor to consider in terms of breaching the ice dam. Whether a lake is one or a hundred miles long, the pressure on the dam will be the same at the same depth. Lakes on Mars could have been enormously long and contained great volumes of water if they were contained in level beds. Catastrophic flooding could have occurred when dam structures gave way.

**Materials**

Calibrated wallpaper tub, stand to hold the cup at a constant height above tub, ruler, plastic bottles or paper cups of different volumes, something to poke holes, tape.

**Brief Description**

1. Begin by confronting students' preconceptions. Punch four evenly-spaced holes vertically on the side of a container. Cover the holes with tape and fill the can to the brim with water. Ask students to draw the paths the water will take once you remove the tape. Leave the tape on until the end of the activity.
2. Have students punch a vertical column of small holes in plastic bottles or paper cups, positioning the holes in even increments along the vertical side of each container.
3. Have students place tape over the holes and fill their containers with water.
4. Have them remove the tape from the holes one at a time and measure the water-spurt distance. Refill to original level after every trial.
5. Repeat with a container with a different volume, making sure the hole heights and water depth in the second container are the same as in the first container.
6. Examine variables such as container height, width and volume and water depth.
7. Have students review and, if necessary, revise the predictions they made in Step 1. Remove the tape.
8. Have a contest to see who can make water squirt the farthest. Use hoses or extendible dryer venting attached to a cup to create very tall columns of water. What makes water come out faucets? Why are water tanks on tall legs on hilltops?

# EXTENSION ACTIVITY 4B

**Overview**

After determining how much water is required to float ice, students investigate whether an ice dam impounding water can be floated. This informs their understanding of how the ice dam impounding Lake Missoula may have been breached.

**Background**

As water becomes a solid, it expands one-ninth in volume. Consequently, ice has a mass to volume ratio of nine to ten, and its density is 0.9 grams per cubic centimeters. Since the density of water is 1 gram per cubic centimeter, ice weighs less than water per unit of volume and, therefore, floats in water. This relationship provides the basis for the theory that each time Lake Missoula filled to nine tenths the dam's height, the dam floated. Most people think water would push over an ice dam. It took geologists a long time to understand that the pressure on the bottom of the dam actually floated the ice dam impounding Lake Missoula, causing it to fail.

**Materials**

Ice, beaker, water, large plastic bottles, wallpaper tub, soil, ruler, warm water to shape ice.

**Brief Description**

1. To find how high ice floats, put one or two ice cubes in a clear container. Pour cold water over the ice cubes until they float.
2. Measure the amount of ice above and below the water. *(Ice floats with about 1/10 above and 9/10 below the water level.)*
3. To see if an ice dam will float or be pushed over by the water behind it, freeze about 3 inches of ice in soda bottles to get large chunks. Cut off the top of the bottles and take this ice and shape it so it fits as tightly as possible across the wallpaper tray. *(Dribble hot water along the sides to shape them.)*
4. Because the ice will not make a tight seal with the edges of the wallpaper tub, bank soil around the bottom and sides of the ice, leaving the top free of soil.
5. Fill one side of the tray with water to impound a lake behind the ice dam. Continue to fill until the dam gives way, monitoring the depth of the water.
6. How deep was the water when the dam was breached? Was it pushed over or did it float? *(Sometimes the soil at the side or under the dam gives way allowing a flood to occur around the base and edges of the ice. Other times the base of the dam melts into a concave shape and water floods through just above the soil at the base of the dam. Observe carefully (or use a video camera] because the breaching happens quickly.)*

# EXTENSION ACTIVITY 4C

**Overview**

Students model how boulders can be transported far from their point of origin on ice rafts. They measure how much weight an ice raft can support and model how debris-carrying ice rafts can create erratics.

**Background**

Wind and water sort sediments by particle size and density. When the velocity of a sorting agent decreases, material is laid down selectively with large particles settling out first and fine materials being carried longer distances. Ice is incapable of this kind of sorting, and a characteristic feature of ice deposits is that they are unsorted. This jumble of sediment is called ***glacial till***. Sometimes, chunks of ice containing boulders break off a glacier and float away in water. Eventually, the ice melts and deposits the rock. These isolated rocks are called ***erratics***. Erratics are a common glaciao-fluvial deposit, and they can be found quite far from any glacial till. While students know that large rocks cannot float great distances to new locations, they usually have not thought about a mechanism for transporting rocks and therefore miss the interesting story related to the presence of an erratic. Consider introducing this extension with a lesson on sinking and floating. This would enable you to investigate additional topics such as density, displacement, and the proportional reasoning involved in mass per volume.

**Materials**

Ice, balance, water, deli containers, containers to float the ice, rulers, gravel and other small objects, sandbox, nearby stream or stream table, towels.

**Brief Description**

1. To determine how much an iceberg will carry, use ice cubes or make a hockey puck-sized chunk of ice by freezing water in the bottom of deli containers.
2. Float the ice in water. Measure the amount above and below the water. *(Approximately one-tenth will be above water and nine-tenths will be below the surface.)*
3. Pile bits of gravel on the floating ice until it is just submerged. *(Pucks work best for this.)*
4. Remove the gravel and weigh it. Weigh the clean ice. Have the class determine how much weight an ice raft can carry. *(Ice can support approximately one-tenth its weight.)*
5. Imbed some material in ice. *(Warm the materials or set the ice and materials in the sun.)*
6. Place these icebergs (with erratics embedded) in a flood you create in a sandbox or a nearby stream. Observe how the ice rafts travel and where the erratics land.
7. Students should consider the consequences if ice were denser than water.

# NOTES