Earth's Changing Surface

Fourth grade scientists are introduced to the scope of geologic time and learn about forces that change our Earth's surface. During their study, students use scientific modeling and research to study the forces that change landscapes over long periods of time through weathering, erosion, and deposition, including the role of glaciers in shaping New England. Students apply their understanding of how landscapes can slowly change through hands-on experiences which culminate in finding evidence of these changes as they explore geologic features in Wellesley during the Geology Field Investigation.

Guiding Question: How did Earth's surface get the shape it has now?

Skills

Students will be able to…

- Design an investigation to determine factors that affect how moving water shapes the Earth's surface
- Model changes made by water and ice (glaciers)
- Test and compare multiple solutions to prevent earthquake damage
- Construct an explanation based on firsthand observations and support their thinking with evidence
- Actively engage in scientific discussions

Knowledge

Students will know…

- Earth has changed over time. Landforms develop and change.
- Water, ice, wind and living things can break down rocks, soils and sediments (weathering) and transport materials elsewhere (erosion).
- Materials can be deposited somewhere else (deposition).
- Glaciers shaped many of the landforms found in Wellesley.
- Volcanoes and earthquakes are rapid events that cause significant damage

Geology Field Investigation

During this field study, students are looking for signs of changes to Earth's surface – evidence of weathering, erosion and deposition.

Imagine this: take a hefty novel, such as *War and Peace*. Cut apart each sentence. Take the slips of paper and toss them up in the air. Remove a significant portion.

Now, try to piece together the story.

This is like the study of geology. As we study the rocks and formations around us, what we see are single sentences from an enormous story. It is up to us to fit the pieces together.

During this field investigation students look for pieces of that story.

Weathering, Erosion & Deposition

Weathering

This is the natural process by which rocks and minerals are dissolved, worn away, or broken into smaller pieces. Weathering can happen in many different ways and usually happens slowly over long periods of time.

There are three major types of weathering: physical, chemical, and biological.

Physical weathering - the mechanical breaking down of rock material. Major sources of physical weathering are:

water - rain, rivers, waves and storms can all wear away rock
wind - pieces of debris can ‘sand’ blast surfaces
ice - water seeps into cracks, expanding as it freezes enlarging the cracks
temperature changes - fluctuations, with hot days and cold nights, can cause rocks to crack

Chemical weathering - when the chemical composition of rocks is changed.

Gasses in the air, such as sulfur dioxide and nitrogen oxides, mix and react with water, oxygen, and other chemicals to form acidic pollutants. When these pollutants fall in the form of precipitation, it is known as acid rain. This weak acid solution dissolves some minerals, causing the rocks to wear away. Some minerals also react with oxygen. Rocks rich in copper can turn green while rocks with a high iron content can actually rust.

Biological weathering – when roots of plants and trees grow in rocks and eventually split them apart.

Erosion

This is the process by which the sediments and rock pieces are *carried away* by water, wind, ice (glaciers), or other natural forces.

Some erosion occurs quickly (such as coastal areas after a major storm), other erosion can take thousands of years (such as a river carving out a canyon or a glacier to wearing away a mountain and leaving a valley behind).

Deposition

Deposition occurs when the sediments, soil and rocks are dropped and left behind – have been *deposited* elsewhere.

Longfellow Pond

Approximate GPS Location: 217 Oakland St, Wellesley

Park at the far end of the parking lot.

You will be following the green arrows.

Before heading up the hill, gather the students:

As you walk up the hill, look at the path. What do you notice about the material in the path? Look at the rocks and stones. What do you notice?

If you have already visited Kelly Field, tell them to note if they see large rocks like the ones bordering the path on the way to Fairy Rock.

Keep walking uphill, following the green arrows.

Stop when you get to the high point (by the cut logs)

Have students look down both sides to note how high up they are and how steep the sides are.

Ask students, **what did you notice about the rocks on the path?**
(answers might include: look very different/lots of different types, very rounded, relatively small, etc.)

What is this evidence of? *(weathering)*

Ask students, **if this whole formation is full of small, rounded rocks and gravel, why is there this high ridge?**

How might it have gotten here?

Students have studied some glacial features during the science unit. Esker formation is not specifically explained in the unit, although in preparation for the trip they have been exposed to how eskers are created. For more information, see the 'Geology Background Information' at the back of this packet.

What evidence is there of weathering, erosion or deposition?

Any evidence of changes that are happening now?

St Mary's Cemetery

Approximate GPS Location: 36 Hunnewell St, Wellesley

Entering the Cemetery from Hunnewell Street, park alongside the rock. Remind students of proper decorum in a cemetery. We will be looking at the top of the rock, but students must remain respectful and in control!

Have students observe the rock surface.

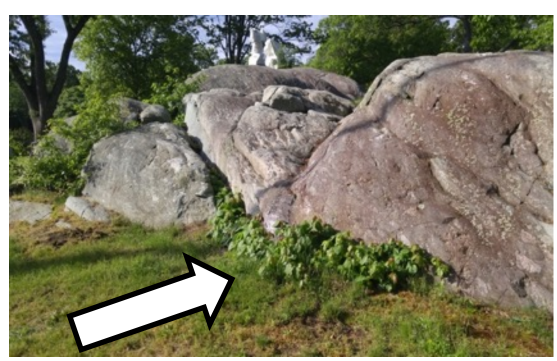
By looking at the shape and surface of the front of the rock, and comparing it to the shape and surface on the backside, geologists can tell what direction the glacier travelled.

What do you notice about the surface of the rock in the "front" versus the backside?

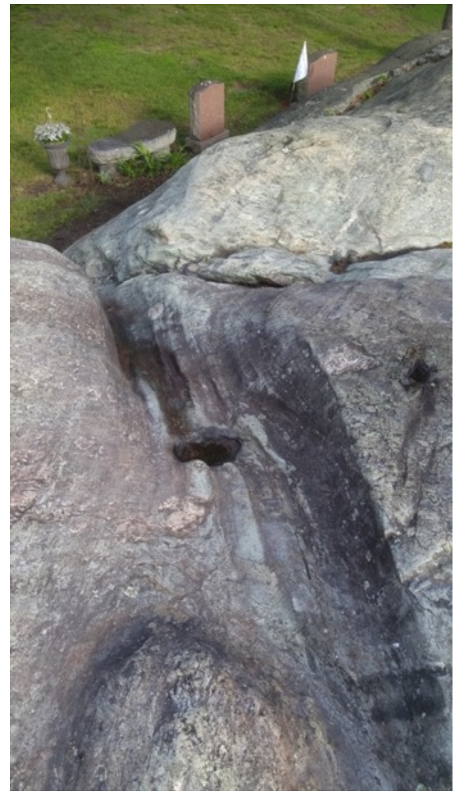
front side (smooth and rounded)

backside (rough and jagged)

Caution! There is **poison ivy** growing around the back edge of the rock as you walk around to the left.

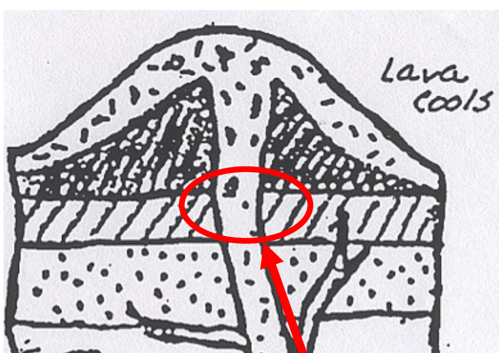


From the backside, have students carefully climb to the top of the rock (remind them to be careful of the statuary on the top of the rock).



What could have caused the rock to look like this?

The rock is called volcanic breccia and it formed as part of a volcano.



This is the part of the volcano we see now. Everything above this has eroded away.

During a volcanic eruption, lava flows to the surface. Pieces of the surrounding rock get broken off and carried in the lava flow. The lava is hot (1300 °F to 2400 °F) – not hot enough to melt the pieces, but hot enough to soften and stretch them. The pieces you see in the rock show signs of being stretched.

The rock we see now did not make it to the surface during the eruption. It cooled deep below ground and has now been exposed due to weathering and erosion of the original volcano.

If this rock cooled below the surface, how is it possible we are seeing it now?

What happened to the volcano?

What evidence is there of weathering, erosion or deposition?

Any evidence of changes that are happening now?

Note: while at St Mary's, point out the radio towers in Needham. The tallest radio tower is a little over 1300 ft tall. A glacier could be up to a mile high – 4 x the height of the radio tower. Imagine a sheet of ice that thick!

Hemlock Gorge

Approximate GPS Location: 110 Reservoir St. Needham

Park on the right side of the road by the open space leading to the aqueduct.

Walk on to the bridge – Have students discuss: **How has the river below changed the landscape over time?**

If students are stuck, point out the high ground you came from and on the other side of the bridge. **How is it the water is so much lower than the surrounding land?**

After seeing the bridge, take the path down to the river (now on your right side).

CAUTION! Remind children to stay on the path! There is poison ivy along the sides. They must stay on the dirt path!!!

Take the right fork (you want to head downhill).

Head down the path and cross the wooden bridge.

After crossing the bridge, follow the path to the left to get to the cave.

What do the caves tell us? *(That some of the rock has been carried away - erosion)*

The rock is called Roxbury Puddingstone and it is a sedimentary rock.

Sedimentary rocks form when broken off pieces of rock (sediments) get laid down, layer after layer. Over time the layers get squashed under more and more layers. Given enough time and depth, the pressure on the layers forms solid rock.

What evidence of sediments is there?

Looking closely at the rock, what evidence is there of weathering, erosion and deposition?

Looking around, note any evidence of changes that happened long ago...

Can you find evidence of changes that are happening now?

Devil’s Slide

Approximate GPS Location: 8 Greenwood Rd., Wellesley

Gather students on the path by the stone wall.

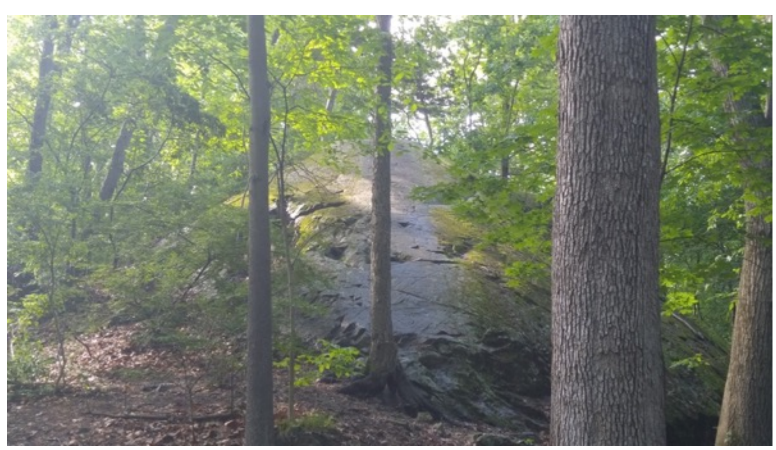
Does this look like a natural or human-made feature?

Why would people take the time and effort to make a wall like this?

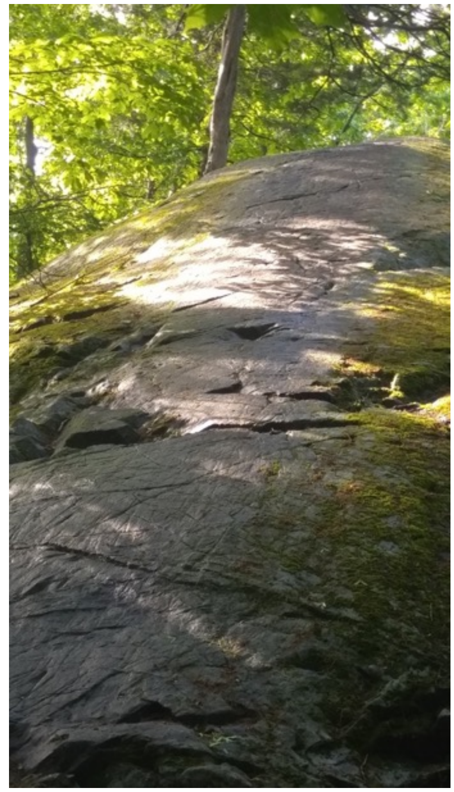
Note the tree growing out of the rock wall.

What is this going to do to the wall over time?

Proceed down the path to Devil’s Slide

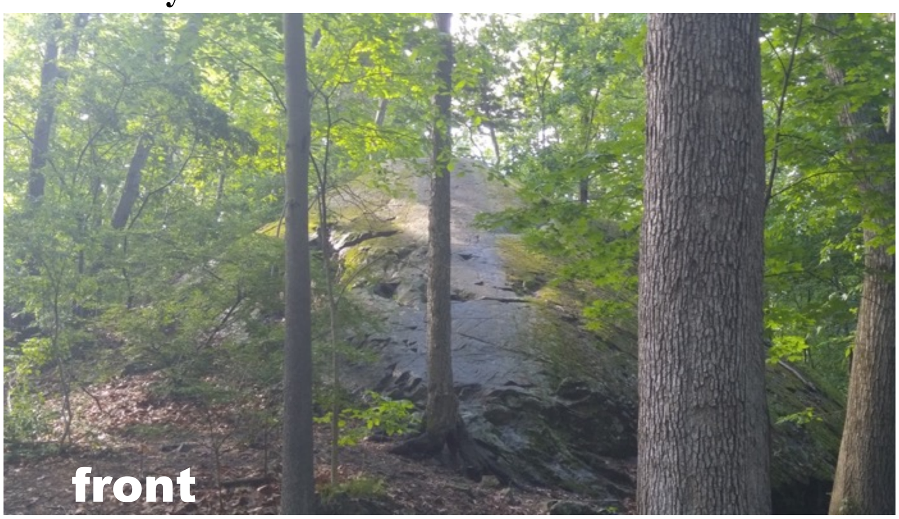


Draw students' attention to the surface: **What do you notice?**



By looking at the shape and surface of the front of the rock, and comparing it to the shape and surface on the backside, geologists can tell what direction the glacier moved.

What do you notice about the surface of the rock in the "front" versus the backside?



For more information on how the glaciers changed the landscape, including **abrasion and plucking** (what we see here at Devil's Slide), go to the Geology Background Information in the back of this packet.

If you decide to go to the top of the rock, return to where you started and take the path that runs along the left side of the formation.

Follow the path to the right then climb to the top.

Remember! Students are not allowed to slide down the rock during the field investigation.

On the top of the rock students should look for evidence of weathering, erosion and deposition.

What evidence is there of weathering, erosion or deposition?

Any evidence of changes that are happening now?

Kelly Field

Approximate GPS Location: 51 Elmwood Rd, Wellesley

From the parking area, head up the trail to the left as you face the woods.

Part way up the path, pause to look at the rocks along the trail. Note the large rock on right side of the path.

There are lots of big rocks sitting around here. As you look at the one on the right – how might a scientist figure out if it is a glacial erratic (a rock carried and dropped by a glacier) or bedrock (the Earth's crust exposed at the surface)?

(Encourage students to think through possible ways scientists might figure this out).

At Fairy Rock:

Have students walk around the rock to compare the appearance of the surface.

Tell students, **this rock is a glacial erratic. It broke off from another area and was carried here by a glacier.**

How does the rock look different in different spots? What factors might cause different parts of a single rock to look very different?

If students are struggling, draw their attention to

the surface of the rock facing you when you first approach

as compared to the surface at the bottom of the slope.

Why might these two surfaces (of the exact same rock) look so different?

What evidence is there of weathering, erosion or deposition?

Any evidence of changes that are happening now?

Kelly Field

Return to the parking area and head to the right (the kettle hole).

First have students state what they see.

(Answers might include *it's flat; there are trees in the water; the land around it is higher*, etc.)

Have students discuss what they think happened here.

Ask students to share what they know about kettle holes. (For more information on kettle holes, see the 'Geology Background Information' in the back of this packet).

Geology Background Information

Every rock tells a story – how it formed and what has happened to it since. Our field investigation is focused on the latter: the processes of weathering, erosion and deposition, along with looking at landforms created by glaciers. The information on this page will provide you with some background on the former, how rocks are formed in the first place.

All the rocks we see on the Geology Field Investigation were formed a long time ago. Similar processes are at work now. New rocks are continually being formed deep below the surface. On the surface, rocks are being weathered, eroded, and otherwise changed.

Bedrock

The crust of the earth is solid rock called bedrock. Bedrock is usually covered by forests, meadows, houses, oceans, ponds, lakes, etc., but it is always there. Sometimes bedrock sticks up where we can see it. When it does we call it mountains or ledge. In Wellesley, the bedrock is very close to the surface and we often see it poking up through the soil.

Plate Movement and the Pangaea Supercontinent (for Hemlock Gorge)

The crust of the earth is made of large continental plates. These hard plates move because of changes beneath them. In some places the plates are moving apart. In other places, they are moving toward each other. Earthquakes and volcanoes tend to occur where the plates meet.

Over 200 million years ago the seven continents we have on Earth today were connected in one giant super-continent called Pangaea. The east coast of North America, where we are, was connected to the northwest coast of Africa. Scientists believe at one point these two plates moved apart and then collided again. When they split apart for the final time, they split in a different place, leaving part of what was once Africa connected to northeastern North America. The Roxbury puddingstone at Hemlock Gorge also exists in Africa. To have the exact same rock type on two continents is proof that the land we are on was once part of what is now Africa.

How rocks are made:

New rocks can be created in different ways. There are three types of rock: igneous, sedimentary, metamorphic.

Igneous Rocks are formed from molten materials hardening into rocks as they cool, both deep underground and as volcanic eruptions at the surface. The longer the molten material takes to cool, the larger the crystals in the rock. Rocks cooled under the earth's surface cool slowly. As a result, they have crystals we can see. Different minerals cool at different temperatures. The last mineral to cool fills the remaining spaces. The type of rock depends on what minerals are in it.

When minerals from the magma move rapidly to the surface and cool above ground, they cool so quickly that there are no visible crystals – these are called lava rocks.

Igneous rocks in Wellesley:

- granite – pinkish color: made of feldspar, mica, quartz
- diorite – dark blackish gray: made of feldspar, hornblende
- volcanic breccia – hardened molten material from a volcano, but cooled below the surface

Sedimentary Rocks are formed when surface rocks are weathered and eroded into smaller particles and are moved (primarily by water). The rock particles are rounded by wind and water and are laid down in layers of sediment in lakes or oceans. Sedimentary layers are always flat and parallel. The pressure of the top layers compresses the layers below and it hardens into solid rock. The type of rock depends on what minerals were present and the size of the particles.

Sedimentary rocks in Wellesley:

- Roxbury Puddingstone – conglomerate rock: made of sandstone with larger rocks cemented into it

Metamorphic Rocks are formed when existing rocks are changed by extreme heat and pressure. Marble and slate are examples of metamorphic rock. We do not have any natural metamorphic rock formations in Wellesley (only marble statues or tombstones).

Glaciers in New England

Earth's climate has always undergone changes. Around 2 million years ago, the Earth's climate cooled off enough that huge ice sheets, known as continental glaciers, formed in northern Canada. Because it was cooler, the ice sheets did not melt back during the summer. Each winter the ice sheets got bigger and thicker. Finally, the ice at the bottom of the ice sheets started to flow south. In a time span ranging from 2 million years ago to about 16,000 ago, these glaciers advanced and retreated repeatedly over New England. The peak of the ice age here was around 22,000-25,000 years ago when the ice reached its maximum extent. By about 16,000 years ago, our area was finally free of glacial ice.

As glaciers advanced, all loose material on the surface was either moved or frozen into the ice sheets. Later, as the ice melted, hundreds of tons of debris was left behind in the deep valleys created by the glaciers, along with deposits on the surface. Many of the hills of New England are simply piles of gravel and sand left behind by these ice sheets. Enormous meltwater rivers, loaded with glacial clays, muds and sands, flowed away and created new landforms, such as drumlins, eskers and kettle holes.

Glaciers could be up to a mile high. Geologists estimate that the sheets covering New England were, at a minimum, several thousand feet high. Imagine the weight of all that ice pressing down on the landscape. Consider also the quantity of soil, rocks, and other debris that was frozen into this slowly moving sheet of ice then left behind as the ice began to melt.

This led to many of the features we see here in Wellesley.

Abrasion and Plucking

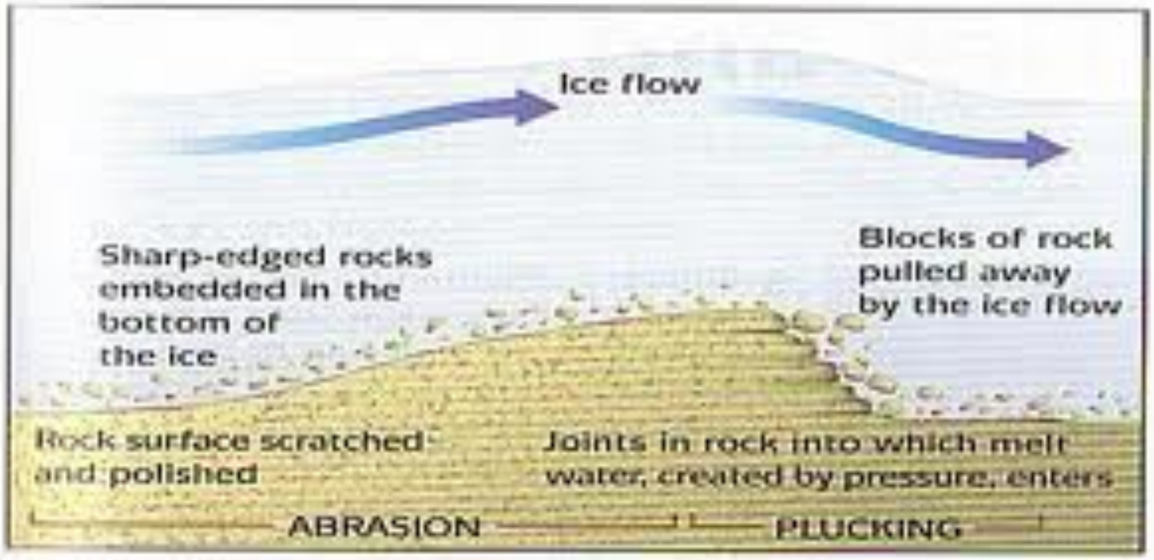


Figure 4 How the rocks below ice are eroded by glacial processes (abrasion and plucking).

As glaciers move, boulders, rocks, pebbles, etc. can get pushed aside. Other rocks become frozen in the ice and carried by the glacier.

A glacier cannot move bedrock, so it passes over it. As the ice passes over the top, the rocks frozen into the bottom of the glacier smooth and polish the bedrock. At the same time, the weight of the glacier pushing down on the sharp rocks frozen into the ice scratches and scrapes the front side of the rock (**abrasion**).

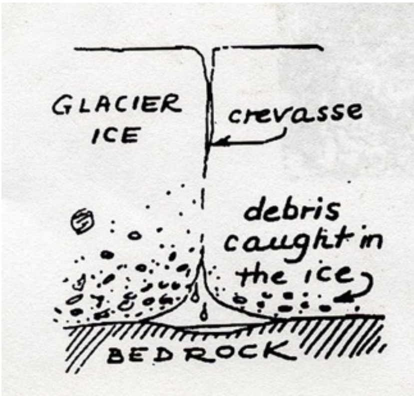
On the back side the ice flow pulls rocks away as it passes over. This is called **plucking**.

This can clearly be seen at Devil's Slide and to some extent at St. Mary's Cemetery. The rock surface on the front is smooth and polished while the back is rough and jagged.

Note: The peak of the last ice age in New England was around 22,000 years ago. The fallen rocks on the back side of Devil's Slide are more likely signs of weathering that has occurred in the last 20,000 years (since the ice age), rather than rocks that were pulled off by the glacier. The rough surface does, however, serve as an excellent model of the effect of plucking.

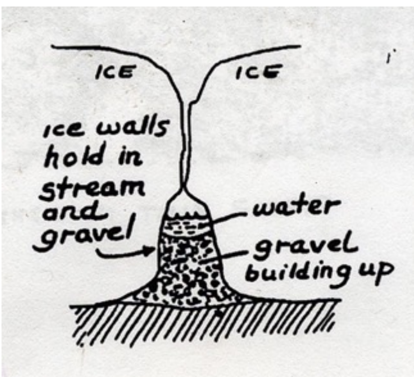
Eskers

Eskers form when streams start flowing underneath the glacier.



A crack forms in the ice and melting water drips down to the ground underneath.

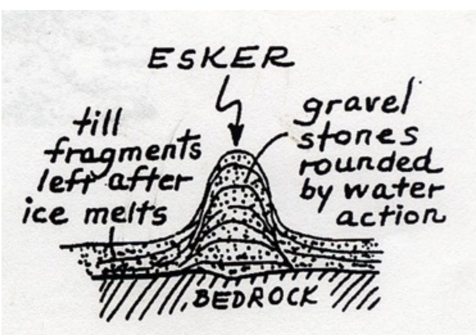
A stream develops and runs under the glacier, melting some ice and forming a tunnel. Rocks of different sizes (and types) get carried along by the running stream.



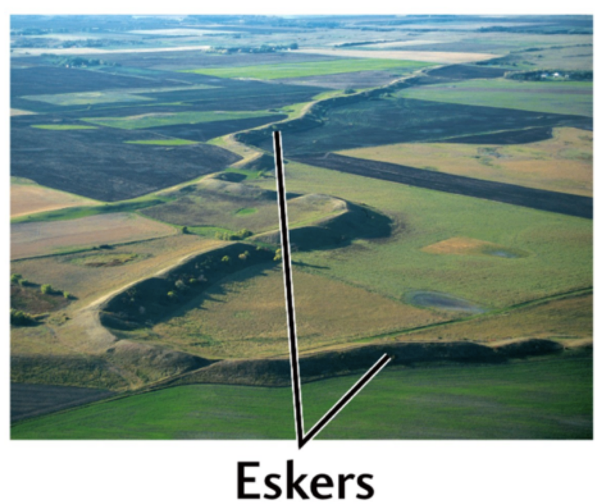
Over the thousands of years ice ages last, temperatures could change from day to day and year to year. Some years were colder and the stream froze. Other years were warmer causing the ice to melt a bit and the stream to start flowing again.

As the stream thaws the rocks settle, creating a new stream bed on top of the old one. More rocks are carried along or dropped in the streambed. Water flows on top of the deposited rocks and the tunnel forming under the ice gets higher.

Eventually layer after layer of gravel builds up in the cavity under the ice.

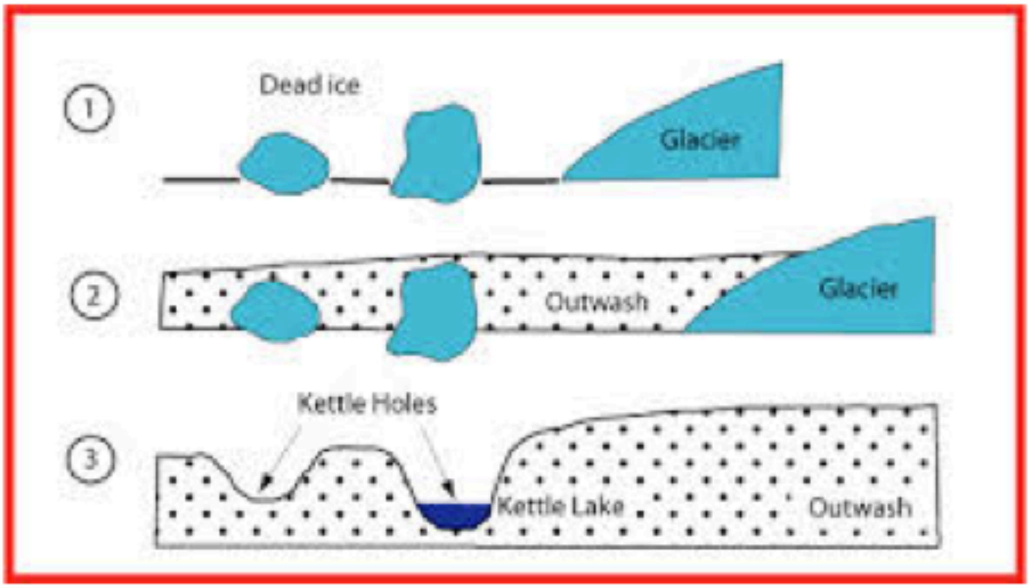


In time, the glacier melts above the tunnel. Then the sides melt. The rocks dropped by the stream are left in the form of a giant ridge that meanders across the landscape, just the way a stream might meander.



https://www.pinterest.com/pin/512988832322208889

Kettle Holes



Blocks of ice break off from the glacier.

As the glacier melts, the melted water carries sand, gravel and rocks (outwash) that flows and settles around the ice block.

The block of ice can get covered with sand and debris. Eventually the ice block melts and the debris settles into the hollow.

Kettle Holes can be as big as lakes, or just small hollows that fill with water only after a very snowy winter.