THE SHAPING OF THE ARCTIC

Overview:

Permafrost is the foundation of the Arctic landscape. Students will study landscape features and the basic processes by which they are formed.

Objectives:

The student will:

- view images of and identify common permafrost landscape features;
- explain how common permafrost landscape features are formed; and
- make a model of permafrost landscape features and share with classmates.

Targeted Alaska Grade Level Expectations:

[9] SA1.1 The student develops an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[10] SA1.1 The student develops an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[9] SD1.2 The student demonstrates an understanding of geochemical cycles by applying knowledge of the water cycle to explain changes in the Earth's surface.

[10] SD1.2 The student demonstrates an understanding of geochemical cycles by describing their interrelationships (i.e., water cycle, carbon cycle, oxygen cycle).

Vocabulary:

active layer – the layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost

beaded stream – a stream characterized by narrow reaches linking pools or small lakes

continuous permafrost – permafrost occurring everywhere beneath an exposed land surface; mean annual soil surface temperatures are typically below -5° Celsius

debris flow – a sudden and destructive landslide, in which loose material on a slope is liquified and flows down a channel or canyon

discontinuous permafrost – permafrost occurring in some areas beneath the exposed land surface areas that are free of permafrost

drunken forest – trees leaning in random directions caused by thawing permafrost

dry permafrost – permafrost containing neither free water nor ice

frost action – movement due to of alternate freezing and thawing of moisture in soil, rock and other material

frost heave – the upward or outward movement of the ground surface (or objects on, or in, the ground) caused by the formation of ice lenses in the soil

hummock – is a rounded knoll of soil and ice rising above the general level of the land surface

ice lens – a dominantly horizontal, lens-shaped body of ice

ice vein – an ice-filled crack or fissure in the ground

ice wedge – narrow ice mass that is three to four meters wide at the ground surface and extends as much as 10 meters down; cold temperatures cause soil to contract and crack; during the summer these cracks fill with meltwater and sediment then freeze

ice-wedge polygon – polygonal-shaped features often delineated with a furrow or crack; the result of ice wedges; vegetation is frequently concentrated in the furrow and helps emphasize the pattern

massive ice – large masses of ground ice, including wedges, pingo ice, buried ice and large ice lenses

mire – an area of swampy ground that often features a layer of peat over permafrost

needle ice – thin, elongated ice crystals that form perpendicular to the ground surface

non-sorted circle – circular or polygonal-shaped features often delineated with a furrow or crack but without a border of stones; vegetation is frequently concentrated in the furrow and helps emphasize the pattern

palsa – a peaty permafrost mound possessing a core of alternating layers of ice and peat or mineral soil (lithalsa) material

peat – a deposit consisting of decayed or partially decayed humified plant remains

permafrost – ground that remains at or below freezing for two or more consecutive years; ice is not always present (as in the case of bedrock)

permafrost degradation – a naturally or artificially caused decrease in the thickness and/or areal extent of permafrost

pingo – a perennial frost mound consisting of a core of massive ice with soil and vegetation cover

sorted circle – circular or polygonal features defined by a border of stones surrounding a central area of finer material

talik – a layer or body of unfrozen ground occurring in a permafrost area

thaw slump – a slope failure resulting from thawing of ice-rich permafrost

thermokarst lake – a lake occupying a closed depression formed by settlement of the ground following thawing of ice-rich permafrost or the melting of massive ice

Whole Picture:

Permafrost is the foundation of the Arctic landscape. Everything north of the Brooks Range is entirely underlain with frozen ground. Southward, permafrost is still a major factor in ecology and landforms until you reach the coast. Frost action shapes the landscape in dramatic ways. There are too many landforms (above and below ground) to fit into one lesson. This lesson aims to familiarize students with the most common permafrost landforms and help them understand the processes behind their formation.

non-sorted polygons: Stone circles are abundant in the Arctic and range in size from a few decimeters to three meters in diameter. The surface of a non-sorted circle is either flat or slightly domed, and is bordered by vegetation.

sorted polygons: Vegetation circles occur in groups and range in size from 10 centimeters to 10 meters in diameter. The obvious feature is a stone border that forms where the surface has cracked from frost action. Frost heaving from year to year orients the rocks as they move toward the cracks, leaving the smaller particles near the center.

Think about this: If you dump a bucket full of sand and gravel into a box, then shake the box, the movement forces the sand and gravel to self-sort. In the world of physics, this is known as the "Brazil Nut Problem," or if you like technical terms, vibration-induced granular segregation. Scientists still aren't 100 percent sure what causes this phenomenon of sorting by particle size, though there are many theories, which include the influence of convection, condensation and mass. While the forces involved in shaking are different than those of freezing and thawing, the result is the same. The expansion and contraction that occurs due to frost action in the active layer acts to slowly sort the material.

THE SHAPING OF THE ARCTIC

Materials:

- Internet access on student computers
- Model Magic™ or sculpting clay, brown and white, (enough for each student to complete project)
- 8" x 10" piece of foam core or other sturdy material for model base (one per group)
- toothpicks
- MULTIMEDIA: "How Does Permafrost Shape Earth's Surface?" available on the UNITE US website (uniteusforclimate.org)
- MULTIMEDIA: "Pingos" available on the UNITE US website (uniteusforclimate.org)
- MULTIMEDIA: "Ice-Wedge Polygons" available on the UNITE US website (uniteusforclimate.org)
- VISUAL AID: "This Patterned Landscape"
- STUDENT INFORMATION SHEET: "What's it Called?"
- STUDENT INFORMATION SHEET: "Formerly Frosty Footing Causes Drunken Forests"
- STUDENT WORKSHEET: "Pingos, Wedges and Polygons"
- STUDENT WORKSHEET: "Ready, Set, Frost Action!"

Extension Materials:

- STUDENT WORKSHEET: "Flip It!"

NOTE: This activity could also be accomplished with sticky notes, if available. Students can use a stack of sticky notes to draw their permafrost landscape choice. (Be sure to remind them to orient the sticky edge toward the side that will be held!)

Activity Preparation:

Review the lesson to determine if Activity Procedure Part One will be handled as a review or as a more in-depth study. Review permafrost process to enable discussion.

Activity Procedure:

Use Activity Procedure (Part One) as a review, or go further in depth as you encounter unfamiliar subject matter. NOTE: By now students should be familiar with permafrost features such as ice-wedge polygons, thermokarst lakes, thaw slumps, pingos, and drunken forests.

Part One

1. Hand out STUDENT INFORMATION SHEET: "What's it Called?" so that students can refer to it while reviewing permafrost landform features. Display page one of VISUAL AID: "This Patterned Landscape," which shows false-color satellite images of the northern Alaska landscape. Ask students to identify what permafrost feature is visible in the images. (*thermokarst lakes*) (Student can use STUDENT INFORMATION SHEET: "What's it called?" to help identify the images.) Ask students:
   a. Do you notice anything about the way the lakes are positioned in the upper image? *(Thermokarst lakes on the North Slope often elongate in the same direction.)*
   b. What might be the cause of this patterning? *(Explain while permafrost action is what forms thermokarst lakes, satellite imagery and aerial photography indicate wind and erosion patterns cause lakes to become elongated in the same direction.)*
2. Show students page two of the visual aid, which shows ice-wedge polygons. Ask students: What is this patterning called? What causes it to form? (*Ice-wedge polygons form when the ground freezes and contracts, forming cracks. These cracks fill with melt water in summer and the cycle repeats, enlarging the cracks.)* Explain lakes that form in this terrain are called thermokarst lakes.
3. Show students page three of the visual aid, which shows pingos. Ask students: What is this permafrost landscape feature called? How could you distinguish a pingo from a hill that was not formed from

permafrost action? *(Pingos often occur in isolation in the tundra and have a distinctive shape, however it is possible for a pingo to be undetected if the active layer is deep enough for vegetation to mask the clues. As a pingo matures, it develops a distinctive split and may ultimately thaw and collapse.)*

4. Show students page four of the visual aid, which shows sorted and non-sorted circles. Ask students: What is your first thought when you see patterned ground like this? How can underground permafrost form such features on the surface? What are these features called? *(See Whole Picture for details.)*
5. Show students page five of the visual aid, which shows a sinkhole and a thaw slump. Ask students to speculate what could have happened. *(The sinkhole is mostly likely the result of the melting of an ice lens [massive ice] that left an underground cavern, which then collapsed. On a larger scale, the Selawik Slump, an area on the Selawik River, is experiencing a major thaw. The hill looks like a giant ice cream scoop removed the hillside because the thawing land has collapsed. Both the sinkhole and the slump are a result of thawing permafrost and melting ice due to a warming climate.)*
6. Show students page six of the visual aid, which shows a beaded stream, a drunken forest, and permafrost hummocks, three more landforms associated with permafrost. Ask students:
    a. What might cause a series of individual lakes to eventually join and become a beaded stream? *(Drainage channels form between lakes and ponds mainly at the intersection of melting ice wedges. Such streams are often found in conjunction with thaw lakes. This beaded stream is on the North Slope.)*
    b. What is happening to the ground under the forest that would cause the trees to lean and fall? *(The permafrost underneath is thawing, making the ground very wet, muddy, and unstable. The ground can shift, slump, sink and move in many ways. The tree roots are shallow and no longer have firm footing.)*
    c. How do you think a hummock is formed? *(The basic process is similar to what causes a road to get frost heaves. The freezing and thawing of moisture causes the ground to heave and lift. There are many different kinds of hummocks, all with slightly different influencing factors, such as moisture content, soil type, etc. The latest theory put forth by Shur, et. al. 2008 is that hummocks evolve from non-sorted circles.)*

Part Two

7. Explain now that students can recognize many of the most common landforms resulting from frost action, they are going to focus on a few of them to learn more about the processes that shape the Arctic landscape.
8. Ask students to access MULTIMEDIA: "How Does Permafrost Shape Earth's Surface?" on the UNITE US website (uniteusforclimate.org). This multimedia activity will show the formation of ice wedges, ice-wedge polygons, thermokarst lakes, and pingos. (Hint: The slider must be dragged slowly to see the progression properly.)
9. Ask students to access MULTIMEDIA: "Pingos" and "Ice-Wedge Polygons" on the UNITE US website (uniteusforclimate.org). (NOTE: This activity has students view a comic book representation of these two processes.)
10. Divide the class into small groups. Hand out STUDENT INFORMATION SHEET: "Formerly Frosty Footing Causes Drunken Forests" and STUDENT WORKSHEET: "Ready, Set, Frost Action!" Ask students to read the article on drunken forests, and the two excerpts on the worksheet, then complete the questions.
11. Explain small groups will create a small model of permafrost landscape features using a sturdy base and Model Magic™ or sculpting clay. Each group should choose at least three landscape features to model. Toothpicks can be used to carve and to represent trees, if a drunken forest is created. White clay can be used to represent an ice lens, ice wedge, etc. It could also be mixed with the brown to create a distinctive layer beneath the active layer. Students may choose to do a cut-away model, if desired.
12. Ask students to rotate around the room to view the models created by other groups. As a class, discuss the permafrost landscape features explored in the lesson. Use the following questions as discussion starters as needed:
    a. What do you think is the most common permafrost landscape feature in the Arctic?
    b. What do you think is the most interesting permafrost landscape feature?
    c. What is the process that forms the polygon features seen today?

d. What is happening to the ground to cause the phenomenon of the "drunken forest?"
e. If the permafrost under a thermokarst lake were to thaw, what do you think would happen to the water in the lake?

Ideas for Filming:

Students will complete a short film about permafrost for the final project associated with this UNITE US unit. Each lesson leading to the final project contains ideas about what students might film as they compile clips. Students are not limited to the list and are encouraged to use their imagination and creativity when filming.

- Students can film the construction and final model of permafrost features, narrating while they film to explain the landform and the process that forms it.
- Ask students to film as students complete STUDENT WORKSHEET: "Flip It!" in Extension Materials or simply film the finished product in motion!

Extension Idea(s):

Enter the term "Tunnel Man Videos" into an Internet search engine and view Tunnel Man videos that describe how various permafrost features are formed.

Answers:

STUDENT WORKSHEET: "Pingos, Wedges and Polygons"

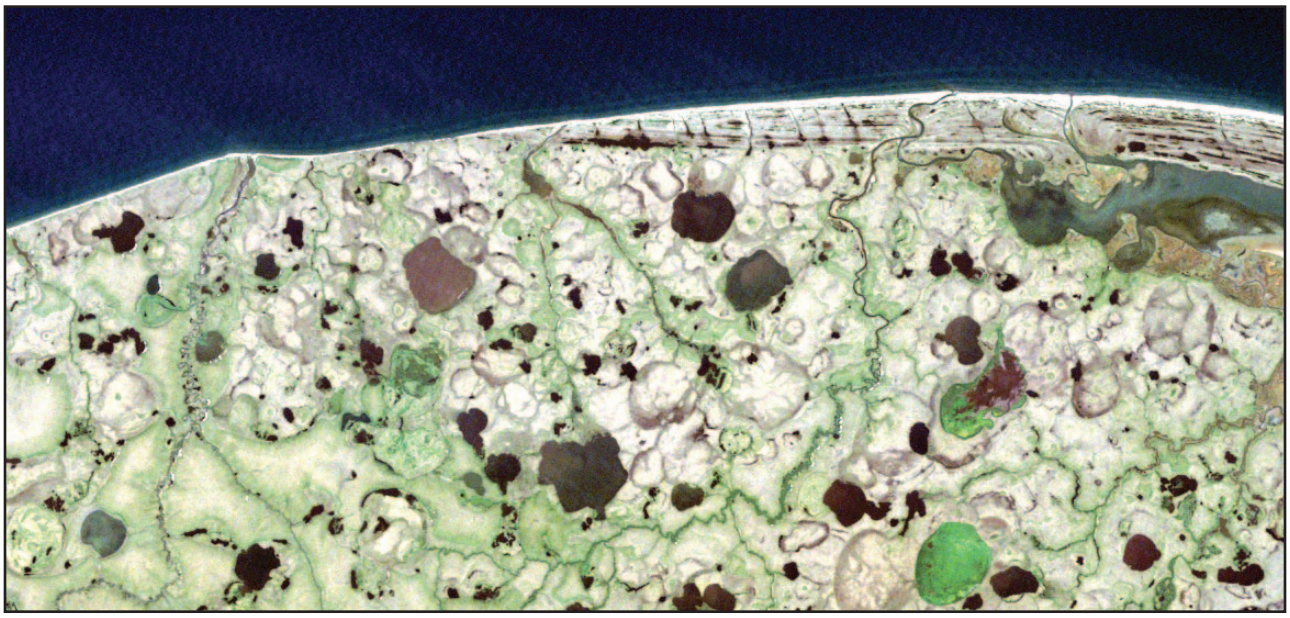
1. active layer
2. ice wedges
3. Winter cold causes the soil to shrink and cracks to form.
4. It can take several thousand years
5. thermokarst
6. pingo
7. open system, closed system
8. Diagrams will vary, but should indicate open-system and closed-system pingos. In open-system pingos, ground water that rises close to the surface and freezes in permafrost ground is pushed up due to expansion. In closed-system pingos, a pocket of water from a drained lake freezes and expands.
9. A pingo will collapse when the ice at its core melts.
10. The ice wedge will melt and the ground will sink and slump.

STUDENT WORKSHEET: Ready, Set, Frost Action!

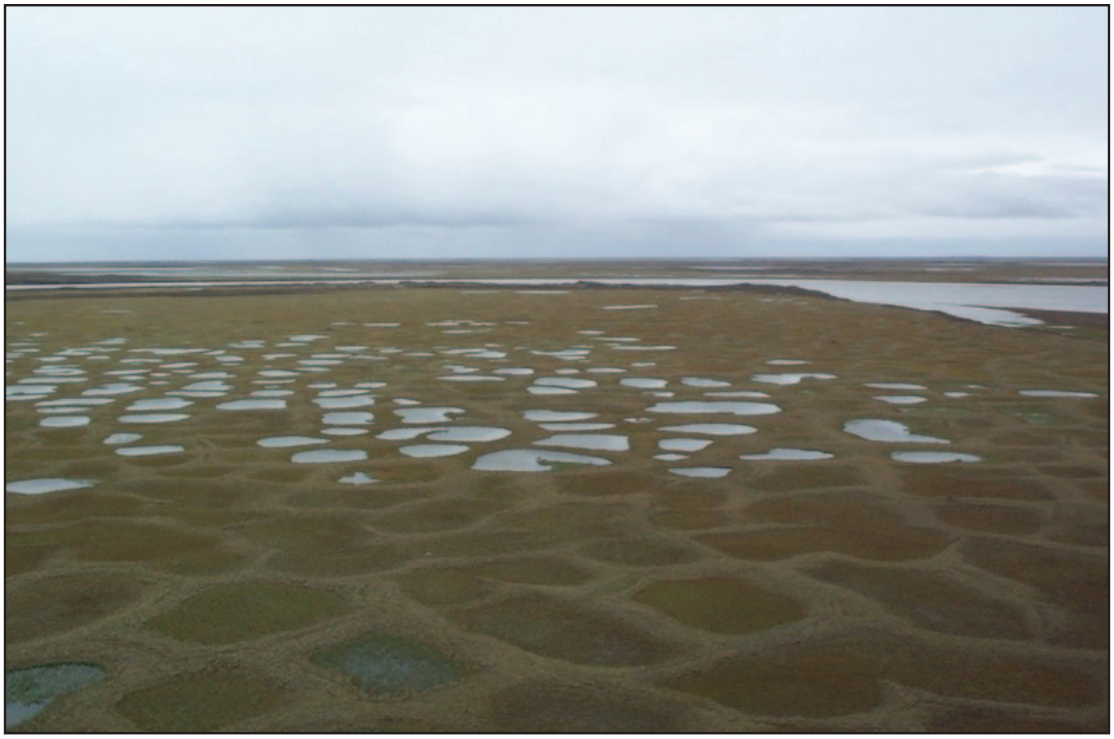
1. Fine-grained soils like clay and silt
2. The freezing of water already in the soil, the freezing of new water that migrates upward from below the frost line
3. The freeze – thaw cycle
4. Alaska and Norwegian islands of Spitsbergen

THIS PATTERNED LANDSCAPE

False-color satellite images of northern Alaska landscape.



THIS PATTERNED LANDSCAPE

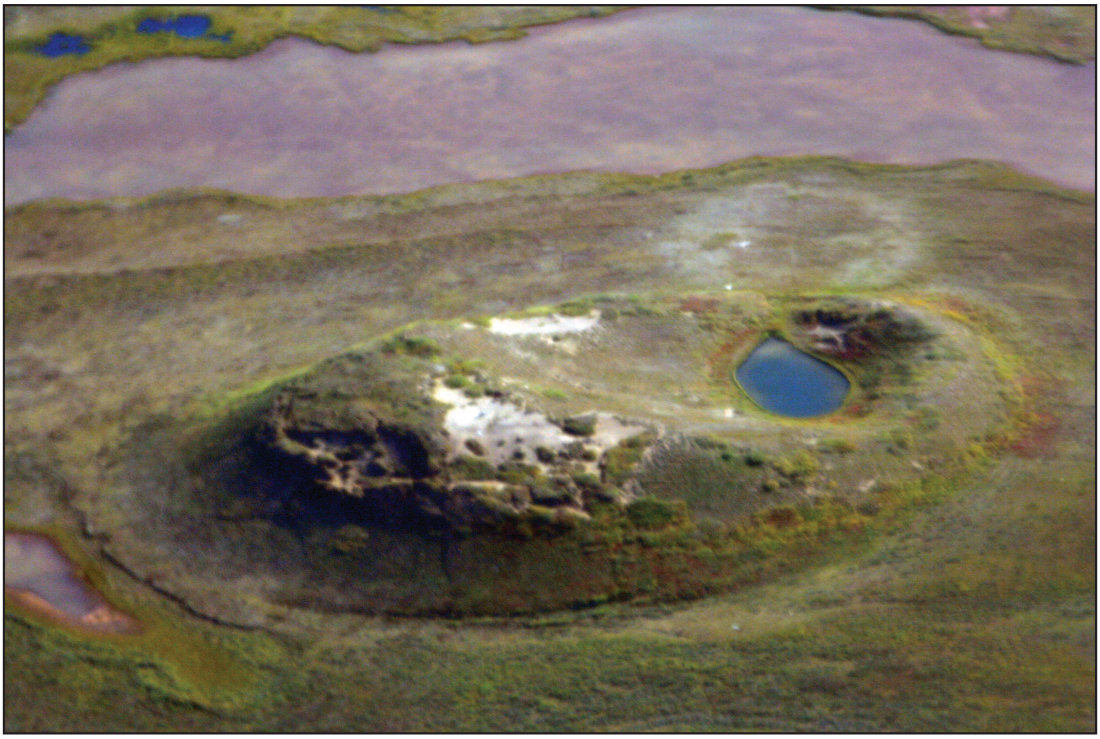


Ice-wedge polygons and thermokarst lakes on the North Slope of Alaska. Photo courtesy of Dr. Vladimir Romanovsky, Geophysical Institute, UAF.

Irregular ice-wedge polygons and not-sorted circles on Howe Island, Alaska. Photo courtesy of Dr. Ronald Daanen, Geophysical Institute, UAF.

THIS PATTERNED LANDSCAPE

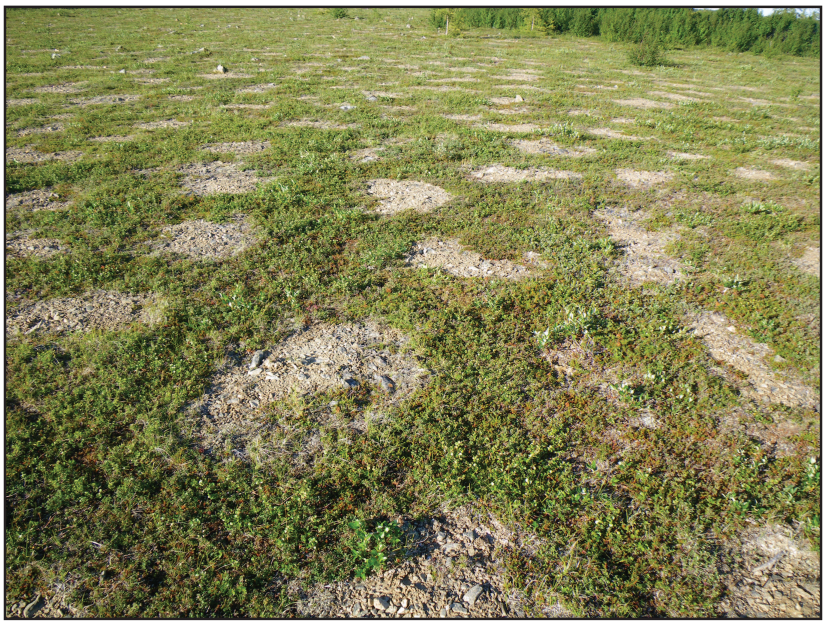
Piercy Pingo on the North Slope of Alaska. Photo courtesy of Dr. Ronald Daanen, Geophysical Institute, UAF.



A partially collapsed pingo in Canada. Photo courtesy of Dr. Ronald Daanen, Geophysical Institute, UAF.

THIS PATTERNED LANDSCAPE

Sorted stone circles at Kvadehukken Svalbard, located on a Norwegian island in the Arctic Ocean.



Non-sorted circles in the Northern Ural Mountains in Russia.

THIS PATTERNED LANDSCAPE

Dr. Vladimir Romanovsky of the UAF Geophysical Institute is shown standing near a Fairbanks sink hole. Photo courtesy of the UAF Geophysical Institute.

The Selawik Slump. Photo courtesy of the U.S. Fish and Wildlife Service.

THIS PATTERNED LANDSCAPE

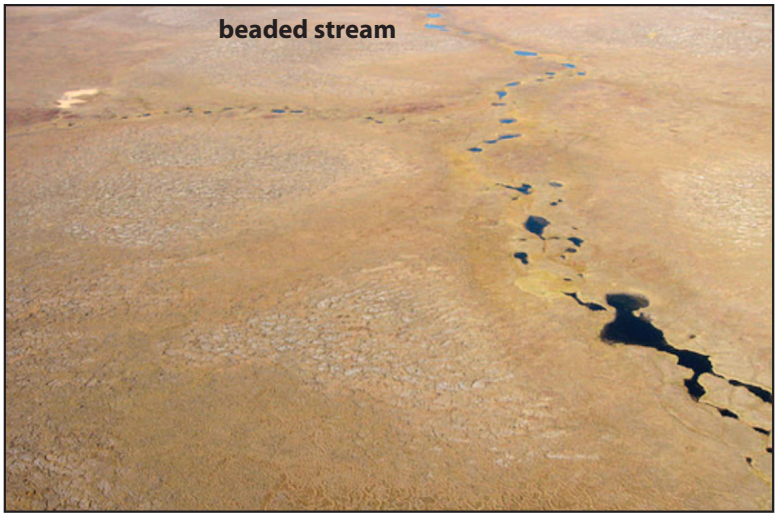


Photo courtesy BeadedStream LLC, www.beadedstream.com.

Photo courtesy of Dr. Kenji Yoshikawa, Institute of Northern Engineering, UAF.

WHAT'S IT CALLED?

Listed below are some of the most common landscape features associated with permafrost action.

Word	Definition
beaded stream	a stream characterized by narrow reaches linking pools or small lakes
debris flow	a sudden and destructive landslide, in which loose material on a slope is liquified and flows down a channel or canyon
drunken forest	trees leaning in random directions caused by thawing permafrost
frost heave	the upward or outward movement of the ground surface (or objects on, or in, the ground) caused by the formation of ice in the soil
hummock	is a rounded knoll of soil and ice rising above the general level of the land surface
ice wedge	narrow ice mass that is three to four meters wide at the ground surface and extends as much as 10 meters down; cold temperatures cause soil to contract and crack; during the summer these cracks fill with melt water and sediment then freeze
ice-wedge polygon	polygonal-shaped features often delineated with a furrow or crack; the result of ice wedges; vegetation is frequently concentrated in the furrow and helps emphasize the pattern
non-sorted circles	circular or polygonal-shaped features often delineated with a furrow or crack but without a border of stones; vegetation is frequently concentrated in the furrow and helps emphasize the pattern
pingo	a perennial frost mound consisting of a core of massive ice with soil and vegetation cover
sorted circles	circular or polygonal features defined by a border of stones surrounding a central area of finer material
thaw slump	a slope failure resulting from thawing of ice-rich permafrost
thermokarst lake	a lake occupying a closed depression formed by settlement of the ground following thawing of ice-rich permafrost or the melting of massive ice

FORMERLY FROSTY FOOTING CAUSES DRUNKEN FORESTS

Alaska Science Forum Article #1253, September 21, 1995
by Ned Rozell

This column is provided as a public service by the Geophysical Institute, University of Alaska Fairbanks, in cooperation with the UAF research community. Ned Rozell is a science writer at the institute.

Science Forum reader Trudy Parcher of Bellingham, Washington, wants to know more about an eye-catching Alaska roadside attraction, the drunken forest.

In a drunken forest, trees--often pipe-cleaner black spruce--tilt in all directions like a group of rowdy revelers stumbling along the street. Drunken forests are caused by unique soil conditions found in the north.

Melting permafrost is the most common cause of the drunken forest. Permafrost is ground where the temperature remains below 32 degrees Fahrenheit year-round. According to Tom Osterkamp, a professor of physics with the Geophysical Institute, permafrost is found under 85 percent of Alaska's land area, mostly the northernmost 85 percent. Except for mountain tops, Southeast Alaska is permafrost-free, and Southcentral is nearly so.

Drunken forests can be seen in permafrost-rich areas of the Interior. Osterkamp says drunken forests form when ice-rich permafrost thaws, causing the ground surface to sag. Nearby trees--which have adapted wide, shallow root systems to hold on to what little soil is available above the permafrost table--bow toward the newly formed depressions. Presto, drunken forest.

Actually, it takes a long time for a drunken forest to form. When spruce seeds first drop to the ground and germinate on the future site of a drunken forest, it isn't pock-marked with soupy depressions. The permafrost is still frozen, providing a deceptive foundation. Trees grow normally for perhaps 50 years, until the permafrost gets warm enough to melt and create a thermokarst, the scientific name for a ground slump caused by melting permafrost.

Osterkamp says trees sometimes recover from leaning in a drunken forest by growing back toward the sky. He and his colleagues recently found a spruce tree with a curved, bow-like trunk. By the unique pattern of the tree rings, they determined the tree began its fight to right itself after a thermokarst developed 120 years ago.

The same thing that makes trees tipsy causes problems for those of us who choose to live and work on land underlain by permafrost.

Osterkamp says the Interior is a very unstable region, where much of the permafrost underlying homes and roads is within one degree Celsius of thawing. That's a big deal. If the Interior has a string of years one degree Celsius warmer than normal, houses may begin to tilt. When permafrost below a home melts, it has the effect of eroding away the house's foundation because a big chunk of formerly solid ground is transformed to liquid.

The Interior would need several warmer-than-average years for permafrost to be affected because the ground is a slow conductor of heat. It sometimes takes decades for heat to make its way down to permafrost patches. Once permafrost beneath a road melts, for example, the road reacts by dipping, which creates the roller coaster so familiar to Interior residents.

Osterkamp says humans affect permafrost in many ways, most directly by removing or compacting vegetation, which insulates the ground. Osterkamp says even as slight a disturbance as a snowshoe hare trail through the woods causes the level of the permafrost below the trail to shrink further from the surface than surrounding permafrost.

Unless they happen to be near a road or a rabbit trail, drunken forests are usually the result of a gradual climate warming that melts permafrost. Landslides and earthquakes also can create drunken forests, but if your car's shock absorbers are pumping like pogo sticks when you drive by a drunken forest, chances are melted permafrost is the culprit.

NAME: _____

PINGOS, WEDGES AND POLYGONS

Directions: This worksheet accompanies the following MULTIMEDIA available on the UNITE US website (uniteusforclimate.org):

- How Does Permafrost Shape Earth's Surface?
- Pingos
- Ice-Wedge Polygons

View the multimedia activities on the UNITE US website (www.uniteusforclimate.org) and complete the following questions.

1. Ground that thaws in the summer, then refreezes in the winter is called _____.

2. On warm spring days, melting snow seeps into cracks in the soil then freezes. This begins the formation of

   _____

3. What causes the ground to crack in winter months?

   _____

4. How long can it take to form an ice-wedge polygon?

   _____

5. A lake that forms above permafrost is called a _____ lake.

6. A hill, called a _____, forms when water trapped near Earth's surface freezes and expands, pushing upward.

7. Name the two types of pingos in Alaska:

   A. _____ B. _____

8. Draw a diagram for each type of pingo, showing how it is formed. Use labels.

9. A pingo will collapse when what happens? _____

10. If you clear the land above an ice-wedge in order to build, what is the likely outcome?

    _____

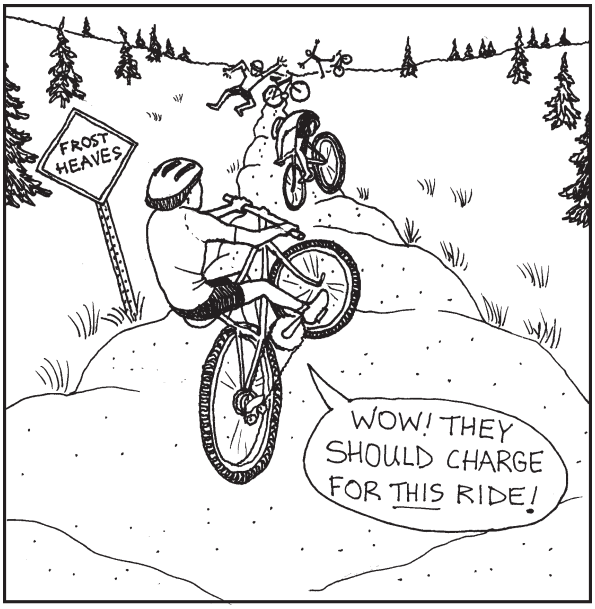
    _____

NAME: _____

READY, SET, FROST ACTION!

Directions: Read the article excerpt below then answer the questions that follow.

FROST HEAVES



Excerpt from *"Frost Heaving of Pilings"* by T. Neil Davis, Alaska Science Forum, December 28, 1978

Frost heaving is greatest in wet, fine-grained soils – clays and silts – since they undergo the greatest expansion of their volume as they freeze. The expansion is not caused only by the freezing of the water contained in the soil but also by the freezing of new water that migrates upward from below the frost line during and after the freezing of the soil.

The colder the ground surface, the greater is the transport of water upward. Freezing of this new water can create layers of pure ice within the top layers of the soil, even after the soil has become frozen. Consequently, frost heaving can continue right on through the winter if there is an adequate supply of water from below.

Russian experiments have shown that some clays, as they freeze, can nearly double in volume, especially if saturated with water rich in aluminum, iron or calcium. These elements help foster the upward migration of water as the soil freezes.

(Find the full article online at: http://www.gi.alaska.edu/ScienceForum/ASF2/279.html)

1. What kind of soil is most prone to frost heaves?

   _____

2. What two things contribute to the expansion of a frost heave?

   _____

   _____

NAME: _____

READY, SET, FROST ACTION!

Directions: Read article excerpt below then answer the questions that follow.

SORTED CIRCLES

Excerpt from *"Scientists Explain Formation of Stone Circles, Other Strange Patterns in Northern Regions"* by Tim Stephens, UC Santa Cruz Currents Online, January 20, 2003

Perfect circles of stones cover the ground in parts of Alaska and the Norwegian islands of Spitsbergen. Elsewhere in the far north, stones form other striking patterns on the ground: polygons, stripes, islands, and labyrinths.

This is like the biggest bowl of SpaghettiO's® I've ever seen!

No, pranksters are not at work in these remote areas, nor are aliens, elves, or any other outside forces moving the stones around. According to scientists who have studied the phenomenon, cyclic freezing and thawing of the ground drives simple feedback mechanisms that generate these remarkable patterns.

"The patterns form by self-organization, and the same fundamental processes are at work in the formation of all these different patterns," said Mark Kessler, a postdoctoral researcher in the Earth Sciences Department at UCSC (University of California, Santa Cruz).

Driving the mechanisms of lateral sorting and squeezing is the phenomenon of frost heave—the expansion of fine-grained soils during freezing of wet ground. Frost heave results from the formation of discrete ice lenses in the soil. As an ice lens grows near this interface, it pushes outward on the stones and also desiccates and compresses the soil below it. Where the interface between stones and soil is inclined, this causes lateral displacement of both stones and soil.

(Find the full article online at: http://www.ucsc.edu/currents/02-03/01-20/patterns.html)

3. What yearly cycle drives the process that creates sorted circles?

_____

_____

4. Where are sorted circles generally found?

_____

_____

NAME: _____

FLIP IT!

Directions: Choose a permafrost landform from the box to the right. Using the flipbook template below, draw the stages of formation. When your drawings are complete, cut along the lines and put the pictures in order. Staple on the left side. Hold the stack of pictures in one hand and flip through them with the other to see the process unfold.

HINTS:

- Use scrap paper to help trace and transfer the image to each square, then change it bit by bit.
- Use as many or as few squares as you need to get the desired effect.
- It might help to do the first and last squares to start then fill in the remaining.
- The un-numbered squares on the last page can be used to re-do a mistake or extend the flipbook. Be sure to number the squares.

beaded stream
drunken forest
frost heave
hummock
ice-wedge polygon
pingo
sorted circles
thaw slump
thermokarst lake

1	2	3
4	5	6
7	8	9

NAME: _____

FLIP IT!

10	11	12
13	14	15
16	17	18
19	20	21

NAME: _____

FLIP IT!
