Polygons, Pingos, and Thermokarst! Oh my!

Levels
III-IV
Grades 5-8

Overview:

Areas underlain with permafrost exhibit common features due to freezing and thawing in such areas. Ice wedge polygons, pingos, and thermokarst are some of the most common land features to be seen in Alaska. In this lesson, students will create a pingo, and explore the processes that create all three aforementioned features.

Objectives:

The student will:
- create a pingo;
- make observations; and
- explain the processes involved in polygon, pingo and/or ice wedge formation.

GLEs Addressed:

Science
- [5-8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.
- [5] SG2.1 The student demonstrates an understanding of the bases of the advancement of scientific knowledge by reviewing and recording results of investigations into the natural world.
- [8] 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.

Vocabulary

pingo – a small hill or mound consisting of a core of ice

ice wedge – a large, wedge-shaped body of ice with its apex pointing downward, composed of vertically banded ice

polygon – patterned ground feature resulting from thermal contraction cracking of the ground

upwelling - the process or an example of rising or appearing to rise to the surface and flowing outward

thermokarst - the often irregular topography resulting from the melting of excess ground ice and subsequent thaw settlement.

Whole Picture:

Water exhibits unique properties when it cools and freezes – unlike almost any other substance, it expands, rather than contracts. This means that when water in the soil freezes into permafrost, it can have dramatic effects on the shape and contours of the visible terrain. In particular, permafrost can result in several common and highly visible land features: polygons, pingos, and ice wedges. Changing climate conditions and thawing permafrost collectively create a topography called thermokarst.

When soils cool and freeze in the winter, they contract, forming contraction cracks. During the spring snowmelt season, water pools in these cracks. In the winter, this water freezes into a thin wedge of ice. In the summer, small wedges of ice remain in the permafrost. In the winter, contraction cracks again form in the cycle. This creates solid ice wedges that grow, year by year.

If the ground above the wedge is disturbed and the ice is exposed, it may begin to melt away, causing the ground to sink into the void and create a pond, which is referred to as a "thermokarst lake." If the lake drains away, it leaves sand that is saturated. The very wet sand is squeezed under pressure by the surrounding freezing process and ultimately pushed upward, where it pools under the root mat and freezes. This large ice mass pushes up on the soil above it, creating the distinctive "pingo" hills that dot the Arctic tundra.

Pingos can also form when artesian groundwater is forced up through cracks in the permafrost, pooling and freezing in a similar manner.

Materials:

- Materials for modeling, such as: paper, scissors, glue, tape, clay, etc.
- Metal bucket
- Sand
- Water
- OVERHEAD: "Permafrost Features"
- OVERHEAD: "Ice Wedges"
- OVERHEAD: "Pingos"
- STUDENT WORKSHEET: "Polygons, Pingos, and Thermokarst! Oh my!"

Activity Procedure:

1. Display the OVERHEAD: "Permafrost Features."
2. Ask students to define ice wedge polygons, thermokarst and pingos. Write student definitions on the board.
3. Ask students how these features are formed or what processes create them. Explain that, unlike other substances, ice expands when it freezes. Soil, on the other hand, contracts when it is cooled. Soil in cold climates tends to contract and crack, forming polygons. Ice wedges can also form polygons.
4. Show OVERHEAD: "Ice Wedges." Ice wedges are formed when water works its way into the cracks during spring melt. As the water freezes, it forms a thin wedge of ice in the soil. In summer, the small wedges of ice remain in the permafrost. In the winter, contraction cracks again form in the soil. This cycle repeats. Over time, vertically layers of ice are formed.
5. Show OVERHEAD: "Pingos." Pingos are small hills or mounds consisting of a core of ice. They are formed in two ways and are differentiated into two categories, closed-system pingos and open-system pingos. Closed system pingos are formed when a lake drains, leaving sand that is saturated. The very wet sand is squeezed under pressure by the surrounding freezing process and ultimately pushed upward, where it freezes, forming a pingo.
6. The upwelling of groundwater contributes to the formation of an open-system pingo. As groundwater pools together near the surface of the ground and freezes, pressure and ice lift up the ground to make dome-shaped mounds.

Teacher's Note: The upwelling of groundwater occurs through a process called artesian pressure.

7. Explain thermokarst is the often irregular topography resulting from the melting of excess ground ice and subsequent thaw settlement. Thermokarst terrain often includes features such as depressions in the ground (alas), lakes, and mounds. When ice wedges in an ice wedge polygon melt, they often

leave behind small mounds typical of thermokarst terrain.

8. Divide students into small groups. Distribute the STUDENT WORKSHEET: “Polygons, Pingos, and Thermokarst! Oh my!” and explain each group will pick one of the three formations discussed in this lesson (ice wedge polygon, pingo, or thermokarst), create a model of it, and describe how it is formed. Groups should use the worksheet to guide their work. Groups may use any class materials to make their model; they may draw, sculpt, carve, etc.

9. Ask students to share their model and their explanation of how the feature is formed. Allow time to discuss the questions and observations from #4 of the worksheet.

10. In the winter, demonstrate the formation of a closed-system pingo by filling the bottom of a metal bucket with sand. Add water to the bucket until the sand is just saturated. Place the bucket outside. Check the bucket every two hours for a day or two. Ask students to draw the contents of the bucket and make observations each time. By the end of the experiments, students should be able to see a small mound form in the center of the bucket. Remind students that the water in the sand is under pressure; water constantly pushes in on itself. Ultimately the water will move in the direction of least resistance (up). The temperature will cause it to freeze, forming a pingo.

Extension Ideas:
(1) Interested students may wish to research and report on artesian pressure.
(2) Introduce mathematical polygons and contrast them with permafrost polygons (which are not always closed and do not always have straight lines). ([6] G-1, [7] G-1, [8] G-1)

Answers:

1. Either “A” or “B.”
2. Answers will vary, but should resemble the formation identified in #1.
3. Answers will vary, but should be correct. Possible answers include:
   A. For Ice Wedge Polygons: Ice wedges are formed when water works its way into the cracks during spring melt. As the water freezes, it forms a thin wedge of ice in the soil. In summer, the small wedges of ice remain in the permafrost. In the winter, contraction cracks again form in the soil. This cycle repeats. Over time, vertically layers of ice are formed.
   B. For Pingos: Closed-system pingos are formed when an Arctic lake drains, leaving sand that is saturated. The very wet sand is squeezed under pressure by the surrounding frost layer and ultimately pushed upward where it freezes, forming a pingo. Open-system pingos are formed by the freezing of the upwelling of ground water in the permafrost.
4. Answers will vary, but should be relevant to the selected formation.

Name:___________________________

Polygons, Pingos, and Thermokarst! Oh my!

Student Worksheet

Levels

III-IV

1. Pick a formation to model and describe:
   A. ice wedge polygon
   B. pingo

2. Make a sketch of your model.

3. Explain the process that causes the formation.

____

____

____

____

____

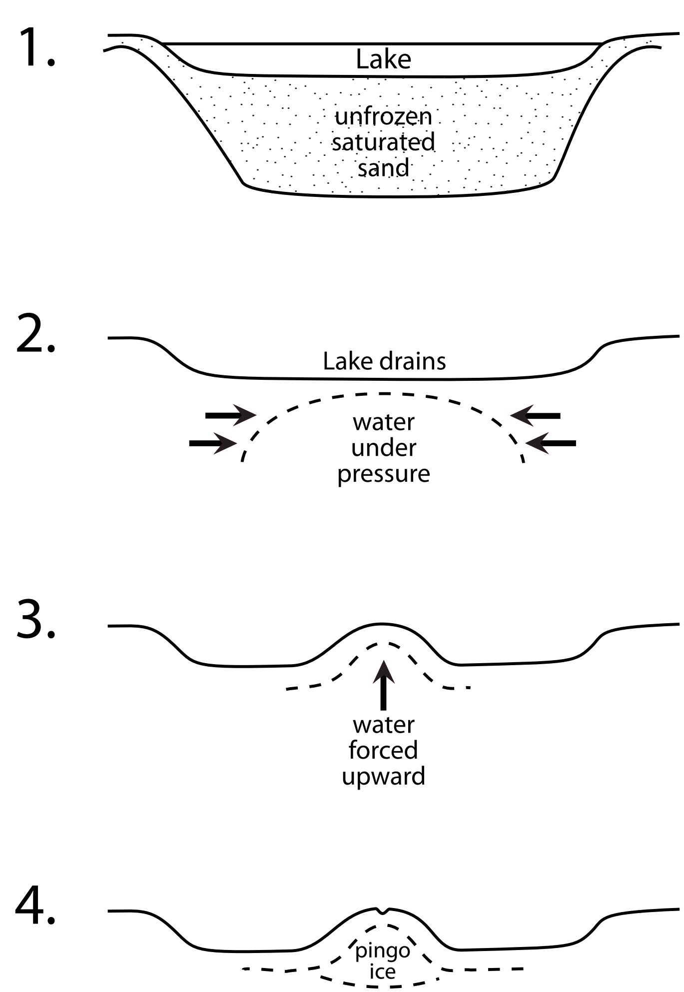
4. List any questions or observations you have about this type of formation.

____

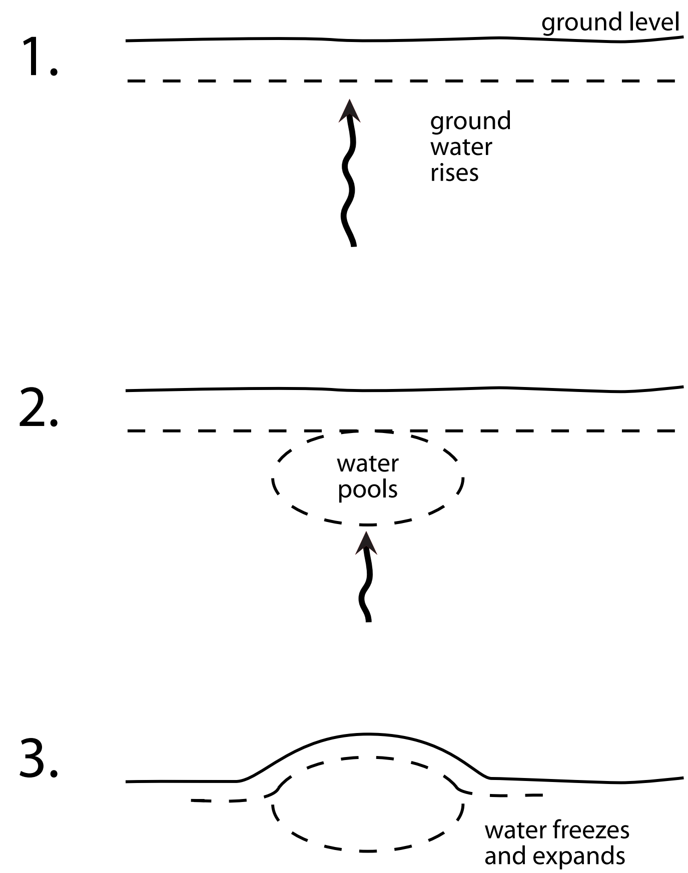
____

____

Closed-System Pingo



Open-System Pingo



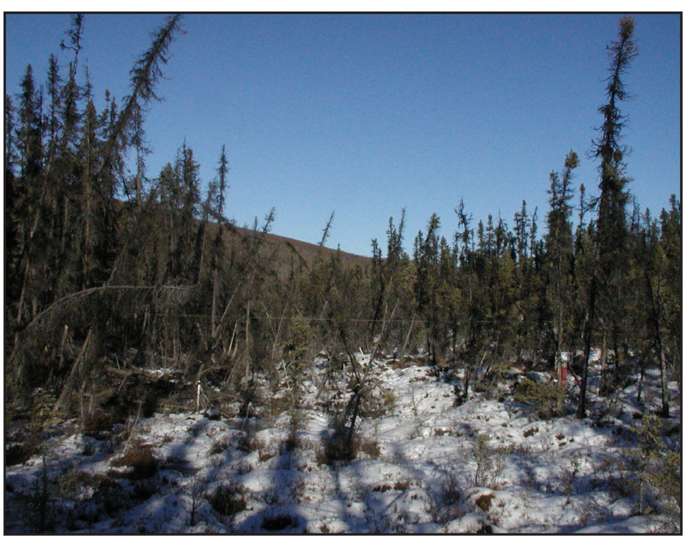
Permafrost Features
Overhead

Ice Wedge Polygon
Polygons are closed, multi-sided, roughly equi-dimensional patterned ground features, bounded by more or less straight sides; some of the sides may be irregular.

Ice wedges are formed in thermal contraction cracks in which hoar frost forms and into which water from melting snow penetrates in the spring. Repeated annual contraction cracking of the ice in the wedge, followed by freezing of water in the crack, gradually increases the width of the wedge and causes vertical banding of the ice.

Pingo
A perennial frost mound consisting of a core of massive ice, produced primarily by injection of water, and covered with soil and vegetation.

"Pingo" is an Inukitut term. Most pingos have a circular or oval base and a fissured top that may be cratered. The fissures and craters are the result of rupturing of the soil and vegetation cover during doming due to progressive development of the ice core.



Polygon and pingo photos courtesy Vladimir Romanovsky.
Drunken forest photo courtesy Kenji Yoshikawa.

Thermokarst Terrain
Thermokarst terrain is the often irregular topography that results from the melting of excess ground ice. Thermokarst terrain often includes the presence of thermokarst lakes and drunken forests.

Drunken forests are forests of trees leaning in random directions. "Drunken forest" is a descriptive term for trees usually growing on ice-rich terrain and subject to repeated frost heave. Active, forested rock glaciers may also exhibit this phenomenon due to differential movements.

Ice wedges can grow outward or upward: