THE GROUND WAS FROZEN THEN

Overview:

Students learn how permafrost shapes the landscape and how changes in permafrost affect not just the land, but also the traditions of those who live there.

Objectives:

The student will:
- complete a labeled diagram of a permafrost feature;
- interpret two types of graphs that show data related to permafrost temperature;
- interview a local Elder or culture bearer to lean about traditional uses of permafrost; and
- compare and contrast local tradition with that of another region in Alaska.

Targeted Alaska Performance Measures Tested on the Alaska High School Qualifying Exam (HSQE):

Math

M6.3.2 Interpret and analyze information found in newspapers, magazines, and graphical displays.

M6.3.4 Make projections based on available data and evaluate whether or not inferences can be made given the parameters of the data.

M10.3.1 Apply mathematical skills and processes to science and humanities.

Targeted Alaska Grade Level Expectations:

Science

[11] 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.

[11] SD1.2 The student demonstrates an understanding of geochemical cycles by integrating knowledge of the water cycle and biogeochemical cycling to explain changes in the Earth's surface.

Vocabulary:

active layer – the top portion of ground that thaws during the summer and refreezes in winter

borehole – a narrow shaft drilled in the ground

permafrost – a subsurface layer of ground (soil or rock, and including ice and organic material) that remains below freezing point (0˚C or 32˚F) for at least two consecutive years

pingo – a 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

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

trumpet curve graph – shows soil temperature range over the course of a year from the surface to a specific depth; the warmest and coldest points appear near the soil's surface; the shape formed by the lines suggests a trumpet

Whole Picture:

A traditional method of food storage uses a natural cooling agent abundant in the Arctic: Permafrost. Athabascan Elder Robert Charlie explains:

> Our people have always used permafrost for storage of food. The method used was to build a birch

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bark basket out of the oldest birch tree that had a thick, heavy bark. You pattern it into a 3x4 feet square container, enough to hold food and berries and white fish. Then you dig down to where the ground is frozen, and even a foot into the frozen ground, for storage."

Scientists are interested in permafrost because recent climate trends are causing some permafrost areas in the Arctic to thaw. It is important to note that in many publications about climate change, writers often state that permafrost is melting. While their intentions are clear, their words are incorrect. Permafrost does not melt, it thaws. Remember that permafrost is any material that remains below freezing (0˚C or 32˚F) for at least two consecutive years. It can be soil, bedrock, organic material, and even a mummified wooly mammoth. Think of the frozen salmon in your freezer. You don't take it for dinner and set it on the counter to melt, you set it out to thaw. The word melt, by definition, means "the process of changing from a solid to a liquid state." That doesn't apply to permafrost. It only applies to solid ice within permafrost. So remember, permafrost thaws, it doesn't melt.

Language Links:

The local dialect for these words may differ from the examples provided. Share the words with students to build fluency in local terms related to weather. Include local words in songs, stories and games when possible.

English	Gwich'in	Denaakk'e	Lower Tanana	Deg Xinag	Your Language
Water	Chuu	Too	Tu	Te	
Melt/ It's melting	Naaghwan/ neeyahkhwaii	Ghaan	Nghan	Ntidlighanh	
Freeze/ It's freezing	Datan	Ggaats	Ethdetenh		
Ice	Łuu	Ten	Tenh	Tinh	

Materials:

- Map of Alaska with clearly marked latitude lines
- VIDEO: "How to Read a Permafrost Graph"
- VIDEO: "Introduction to Permafrost: Explore Permafrost"
- TEACHER INFORMATION SHEET: "Permafrost Distribution in Alaska and Permafrost Observatories Locations"
- VISUAL AID: "Ice Wedges"
- VISUAL AID: "Pingos"
- VISUAL AID: "Permafrost Features"
- VISUAL AID: "Long-term Permafrost Data"
- VISUAL AID: "Trumpet Curve Graph"
- STUDENT INFORMATION SHEET: "Environmental Change, Indigenous Knowledge, and Subsistence on Alaska's North Slope"
- STUDENT WORKSHEET: "What Does the Graph Say?"
- STUDENT WORKSHEET: "The Ground Was Frozen Then"
- STUDENT WORKSHEET: "Polygons, Pingos and Thermokarst, Oh My!"

Activity Preparation:

1. Refer to TEACHER INFORMATION SHEET: "Permafrost Distribution in Alaska and Permafrost Observatories Locations" and make sure all the data collection locations referred to on VISUAL AID: "Long-term Permafrost Data" are marked on a classroom map of Alaska. (See Materials)

Activity Procedure:

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1. Introduce the lesson on permafrost. Assume students already know some things about permafrost, but do a knowledge check by asking some review questions. Allow students freedom to brainstorm. Ask questions such as:
   a. What is permafrost? How can you tell the difference between permafrost and ground that freezes and thaws?
   b. Can you name a problem caused by the presence of permafrost?
   c. Can you name a traditional use of permafrost?
   d. What landforms in the area are results of permafrost?
   e. How do scientists study permafrost? Why?

   Review the vocabulary words in a similar fashion, asking students to define the words, as they know them, and assisting, where necessary with the definition.
2. Ask students to view the VIDEO: "Introduction to Permafrost: Explore Permafrost" and "How to Read a Permafrost Graph„"
3. Hand out STUDENT WORKSHEET: "What Does the Graph Say?". Display VISUAL AID: "Trumpet Curve Graph" to aid students in completing Section 1.

NOTE: If it is not possible to make color copies of student worksheets, students will be unable to view the graphs properly and will need to see the visual aids included to complete each section.

When students are ready to move on to Section 2, display VISUAL AID: "Long-term Permafrost Data". At teacher's discretion, work through Section 2 as a class, using a ruler and overhead marker to help students clearly view the data needed to complete the questions.

4. Display VISUAL AID: "Ice Wedges." Ask students to remember what they learned in the VIDEO: "Introduction to Permafrost: Explore Permafrost" and explain the process displayed on the overhead. If needed, remind students ice wedges are formed when water works its way into cracks in the ground during spring melt. When the water freezes, it forms a thin wedge of ice. Throughout the summer, the small wedges of ice remain in the permafrost. In the winter, contraction cracks occur in the soil, creating open space around the ice. The cycle repeats, and, over time, vertical layers of ice are formed.
5. Display VISUAL AID: "Pingos." Ask students to remember what they learned in the VIDEO: "Introduction to Permafrost: Explore Permafrost" and explain the process displayed on the overhead. If needed, remind students pingos are small hills that have a core of ice. They are formed in two ways and 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. Open-system pingos are formed when groundwater pools near the surface of the ground and freezes. When it freezes, pressure and ice lift up the ground to make dome-shaped mounds.
6. Display VISUAL AID: "Permafrost Features." Point out the polygon landscape features from the ice wedges, the pingo, and the thermokarst landscape. Ask students to remember what they learned in the VIDEO: "Introduction to Permafrost: Explore Permafrost" and explain what process forms thermokarst landscapes. If needed, remind students thermokarst terrain often includes features such as depressions in the ground (lakes, ponds, swamps) and mounds. When ice wedges melt they often leave behind small mounds typical of thermokarst terrain.
7. Hand out STUDENT WORKSHEET: "Polygons, Pingos, and Thermokarst! Oh my!" and ask students to complete.
   Teacher's Note: If time permits, and students show interest, visit the website for the University of Alaska Fairbanks Geophysical Institute Permafrost Lab (http://www.permafrostwatch.org/). Click on the tab labeled "Galleries," then "Patterned Ground." You'll find fantastic photographs showing how permafrost shapes the landscape.
8. Hand out STUDENT WORKSHEET: "The Ground Was Frozen Then" and STUDENT INFORMATION SHEET: "Environmental Change, Indigenous Knowledge, and Subsistence on Alaska's North Slope" by Chris Cuomo, Wendy Eisner and Kenneth Hinkel. Students will need time to interview a local Elder or culture

bearer in order to complete the worksheet. According to teacher's discretion, the entire worksheet can be assigned as homework, or completed in class once students have had time to obtain answers to the interview questions.

Extension Idea:

Based on the narrative by Robert Charlie found on STUDENT WORKSHEET: "The Ground Was Frozen Then", ask students to construct a food storage area based on Charlie's description.

Answers:

STUDENT WORKSHEET: What Does the Graph Say?

For questions 1 – 5 the answers should be very close to what is listed below.

1. –10° Celsius to 12° Celsius
2. A. –3° Celsius
   B. –7° Celsius
   C. –6° Celsius
   D. –1° Celsius
   E. 4° Celsius
   F. 0° Celsius
3. A. –1° Celsius
   B. –3° Celsius
   C. –5° Celsius
   D. –1° Celsius
   E. 0° Celsius
   F. 0° Celsius
4. –7° Celsius to 4° Celsius
5. –4° Celsius to 0° Celsius
6. About 1 m depth
7. About 3 m depth
8. Between 68° N and 70° N latitude
9. Between 62° N and 67° N latitude
10. Answers should indicate the temperature of the permafrost gets colder the farther north you go. Permafrost temperatures are colder near the ocean than they are inland.
11. A. Deadhorse shows the most change, from about –8.75° Celsius in 1978 to about –6.4° Celsius in 2009 – a change of 2.35 degrees.
    B. The percent change between –8.75 and –6.4 is 27 percent.
12. A. Chandalar Shelf shows a one degree change, from it's coldest in 1986 of –2.75° Celsius to –1.75° Celsius 2009. Old Man also shows a one degree change if you look at the warmest temperature recorded around 2007, but if you use only the start and end marks, it is under one degree of change. Teacher can use discretion as to how to grade if student justifies answer well. (Both are correct.)
13. It took 24 years for it to rise 0.3° Celsius. At the current rate of thaw, it will take only 96 years for it to thaw completely.

Latitude – North Slope Sites
Happy Valley: 69° N
Galbraith Lake: 68° N
Franklin Bluffs: 69° N
Deadhorse: 70° N
West Dock: 70° N

Latitude – Interior Sites
Livengood: 65° N
Gulkana: 62° N
Healy: 63° N
Coldfoot: 67° N
Birch Lake: 64° N
College Peat: 64° N
Chandalar: 68° N
Old Man: 66° N

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STUDENT WORKSHEET: The Ground was Frozen Then

For questions 1 – 2 answers will vary since students will be interviewing Elders.

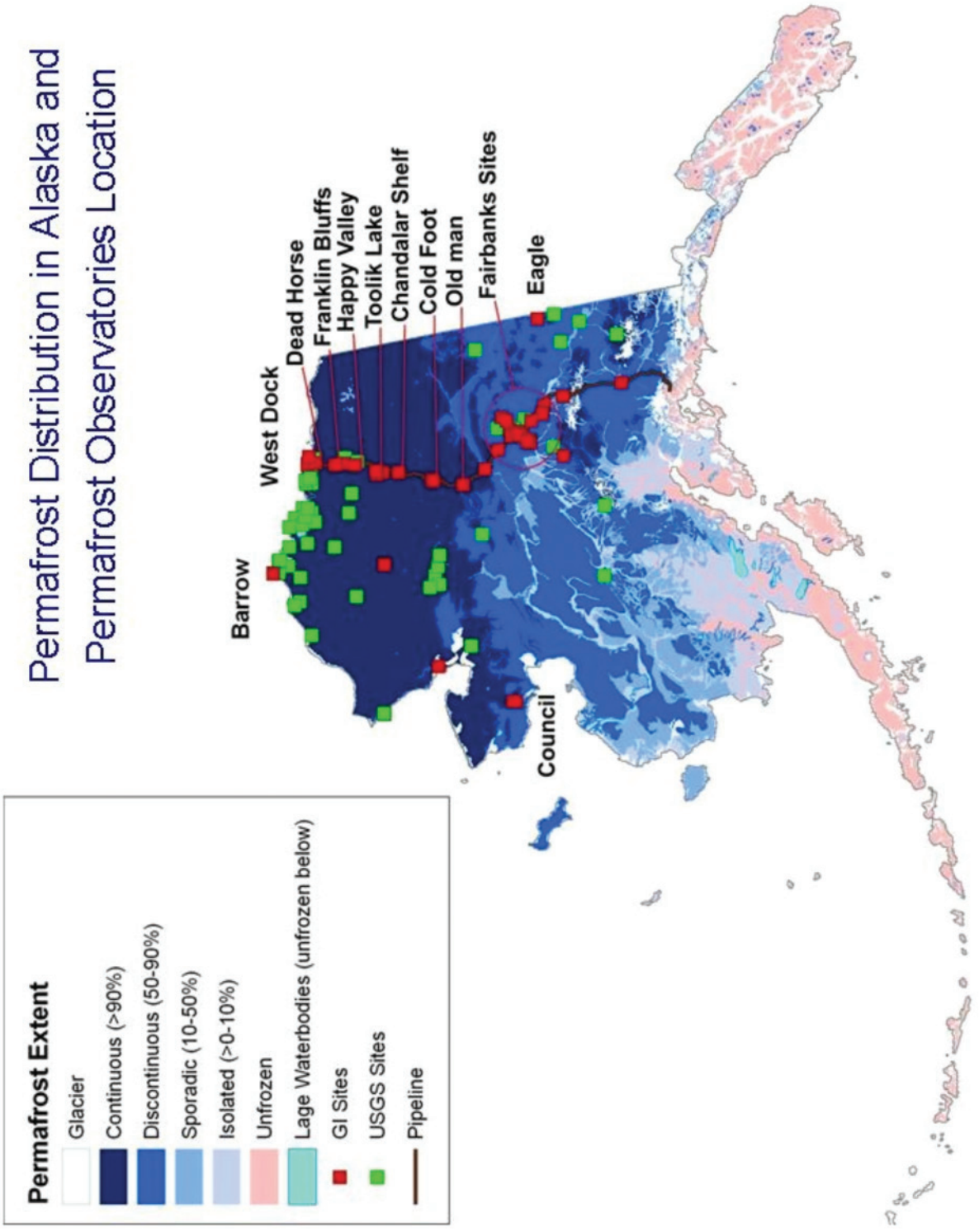
For questions 3 – 5 answers will vary, but should be in agreement with article by Cuomo, Eisner and Hinkel.

STUDENT WORKSHEET: Polygons, Pingos and Thermokarst, Oh My!

1. Answers will vary, but sketch should resemble the formation identified in the either the Ice-wedge Overhead or the Pingos Overhead.
2. 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 and the upwelling of groundwater in the permafrost.
3. Answers will vary depending on chose of sketch formation.
   A. For Pingos: Forms rimmed depression that often looks like a crater. Sometimes a lake can form within the depression, but can also be dry.
   B. For Ice-wedge Polygons: Formation of cracks or fissures due to melting ground ice leaving behind open spaces/cracks between polygons. The cracks will eventually fill in with sediment and support the growth various vegetation.

PERMAFROST DISTRIBUTION IN ALASKA AND PERMAFROST OBSERVATORIES LOCATIONS

Map courtesy of Dr. Vladimir Romanovsky, Professor of Geophysics, Geophysical Institute, University of Alaska Fairbanks.



LONG-TERM PERMAFROST DATA

Dr. Vladimir Romanovsky, Professor of Geophysics at the University of Alaska Fairbanks Geophysical Institute, collects long-term temperature data for permafrost around the state. Long-term data helps scientists understand what is happening to permafrost and provides a clue to how climate change is impacting Alaska. Learn more about each of these sites by visiting: http://www.gi.alaska.edu/snowice/Permafrost-lab/projects/projects_active/proj_influences.html#west

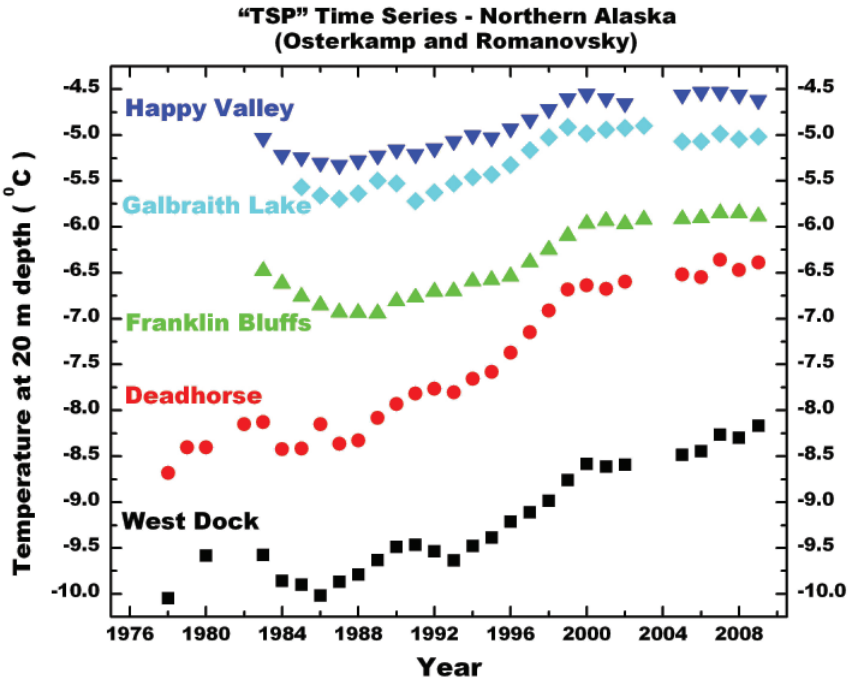


Figure 1: Permafrost Temperature Records for Northern Alaska.

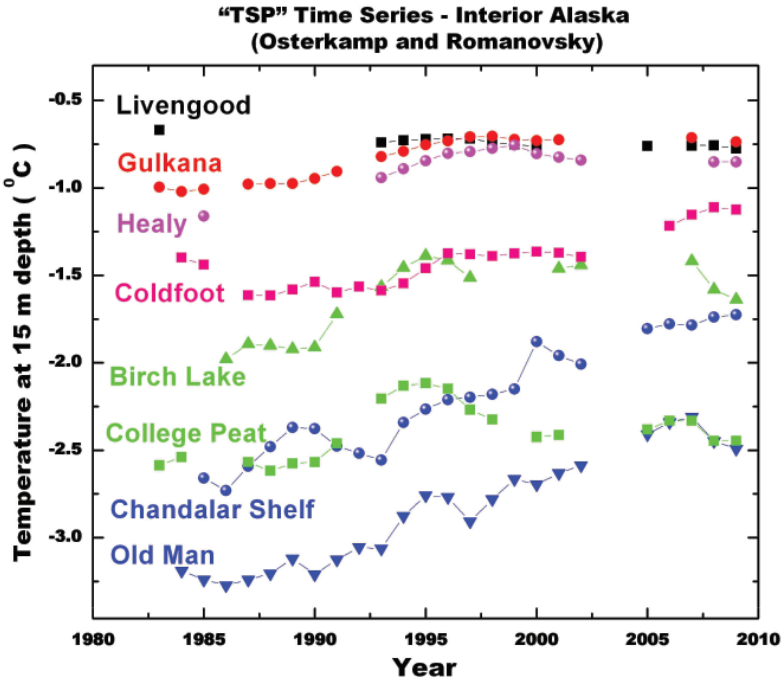
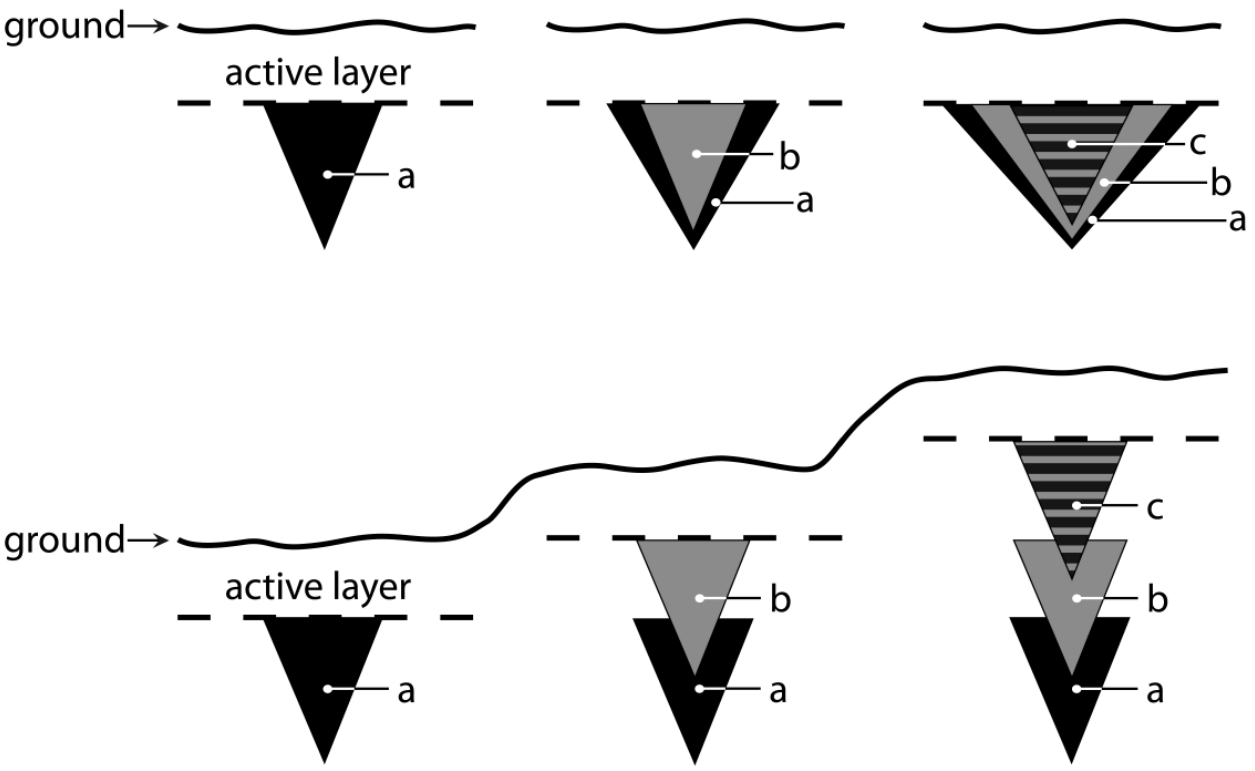


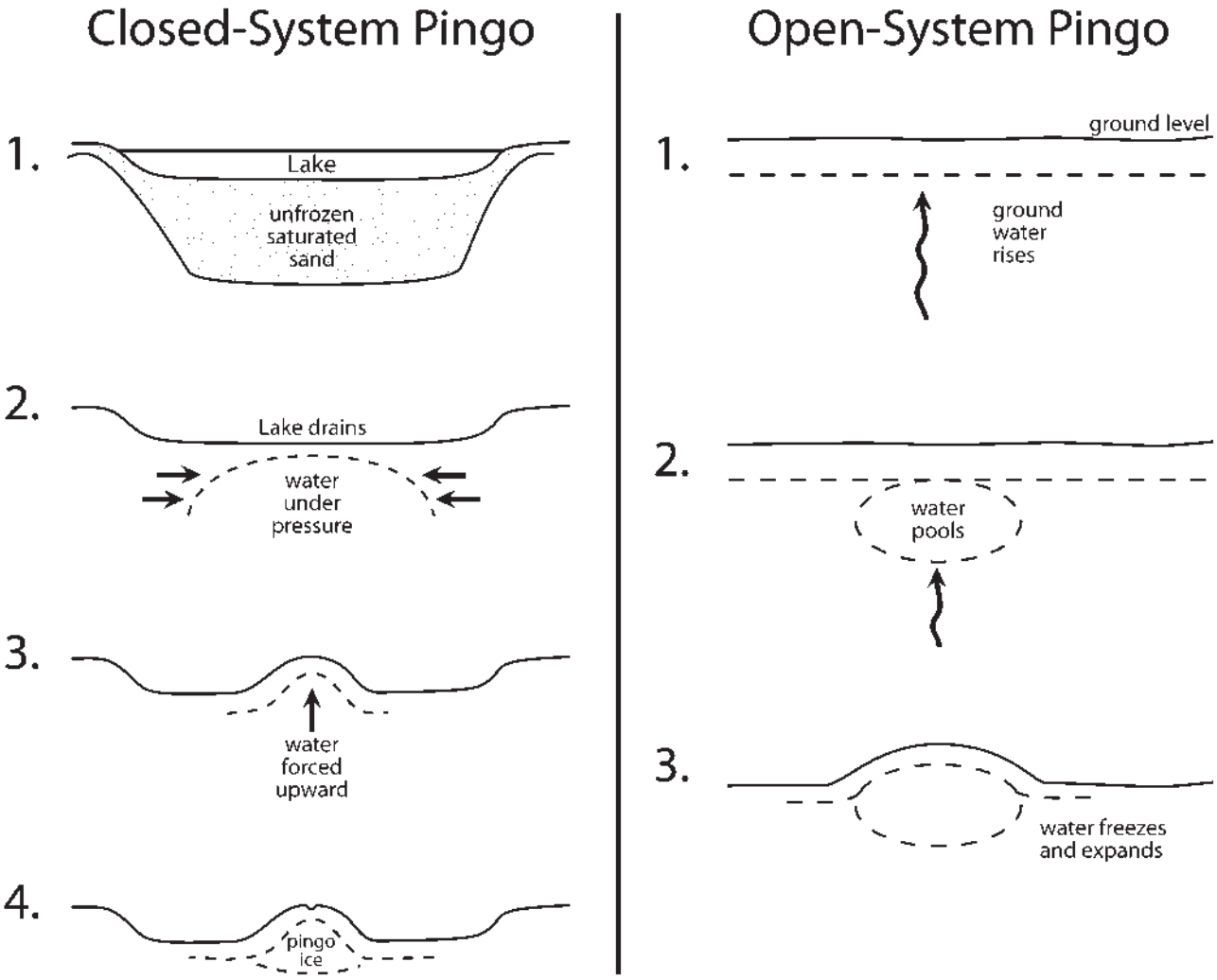
Figure 2: Permafrost Temperature Records for Interior Alaska.

ICE WEDGES

Ice wedges can grow outward or upward:



PINGOS


Closed-System Pingo
1.
Lake
unfrozen saturated sand
2.
Lake drains
water under pressure
3.
water forced upward
4.
pingo ice
Open-System Pingo
1.
ground level
ground water rises
2.
water pools
3.
water freezes and expands

PERMAFROST FEATURES

Ice Wedge Polygon

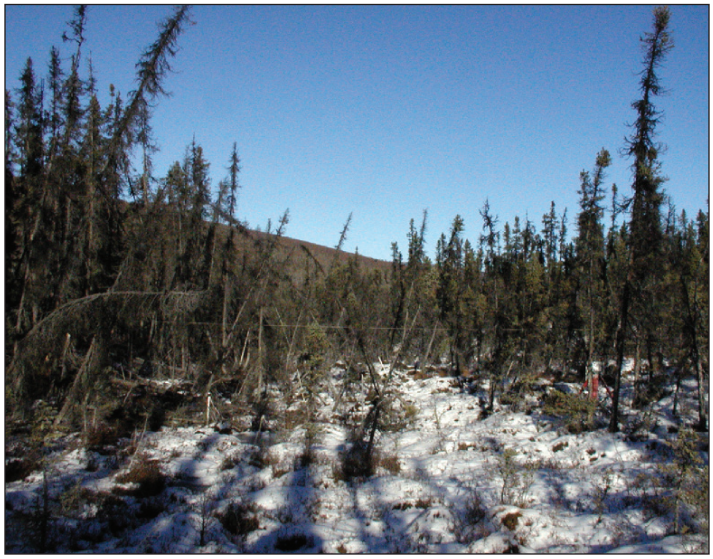
Polygons are closed, multi-sided, roughly equi-dimensional patterned ground features, bounded by more or less straight sides; some of the sides may be irregular.

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.



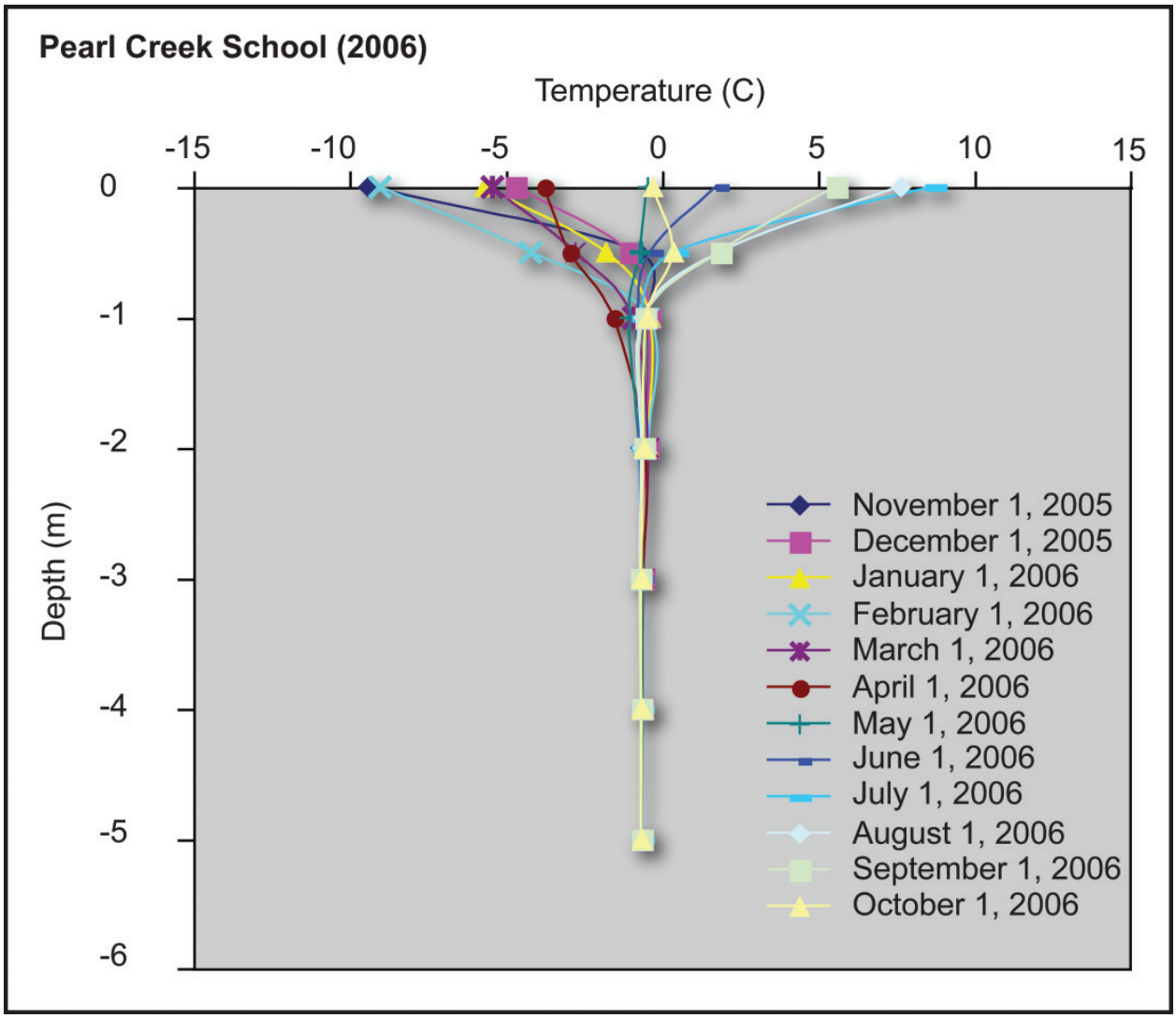
Thermokarst Terrain

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.

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

TRUMPET CURVE GRAPH



ENVIRONMENTAL CHANGE, INDIGENOUS KNOWLEDGE, AND SUBSISTENCE ON ALASKA'S NORTH SLOPE

by Chris Cuomo, Wendy Eisner and Kenneth Hinkel

(This is an excerpt from an article originally published in "S & F Online." The article can be found, in its entirety, at: http://www.barnard.edu/sfonline/ice/cuomo_eisner_hinkel_01.htm)

Another material and spiritual element of Iñupiaq subsistence culture that is jeopardized by climate change is the practice of storing meat and fish in traditional ice cellars that are dug several meters into the permafrost. The thawing of ice cellars is a common theme in interviews. One elder described an ice cellar, located a hundred and fifty feet away from a river, which was entirely washed away when the river rapidly eroded laterally. Ida Olemaun relates the importance of ice cellars:

> "The ice cellars are what we store our food, especially the whale, you know, cause it ferments more in there, gets it more tastier. And right now there's some ice cellars that are thawing out too fast. So we have to be real careful with that whenever we store some whale meat, cause that's for the Thanksgiving feast, for the Christmas feast, that we store, even our caribou, our ducks, geese . . .. When you have meat in the ice cellars they're a lot tastier; they're not freezer burn, they have more taste to it whereas when you store it in the freezer, it just freezes . . .. You have to be careful now with this global warming cause some have flooded too . . . and wastes all that meat."

Along with allowing meat to age properly, the cellars serve an important cultural and spiritual role in Iñupiaq whaling traditions, for a clean and empty ice cellar is required before one can go whaling in spring. Spring-cleaning of ice cellars is also a ritual in the culture of sharing, as all stored meat and game must be consumed or given away as part of the cleaning process. In the words of a young Iñupiaq woman, "You have to clean out your ice cellar cause the whale won't give itself unless it has a clean place to rest." For the Iñupiat the loss of ice cellars is not trivial, for ice cellars are a crucial element of Iñupiaq subsistence life ways.

As the necessity of a clean ice cellar indicates, success in subsistence hunting depends on appropriate behavior. Of primary importance for the Iñupiat is the virtue of sharing. The spiritual and cultural significance of sharing, one of the core "Iñupiat values," promoted through posters all over the North Slope, was raised in a great many of our interviews. For example, hunting is generally described as having two fundamental purposes: to provide for one's own family, and to share with others in the community. Sixty-three percent of households in northern Alaska harvest game, and ninety-two percent of households gain access to that harvest through networks of sharing. Sharing is also believed to strongly influence relationships with the natural and spiritual worlds, as comments by Evelyn Donovan and Ida Olemaun illustrate:

> "(My parents and grandparents) always told us to share, the hunt, the food . . .. If you are to have a successful hunt than you have to share and give what is down there and we're taught not to waste. And it's true that if you're not sharing and you're stingy, better way to say it I guess, you won't have a bountiful hunting season as well. I've experienced that." (Evelyn Donovan)

> "You always share the bounty that God gives you 'cause that's . . . why it's giving of itself is that you share to the poor, the widow, the orphans, and . . . I think that's what subsistence is all about, to share the bounty that God has given you, and that it'll return, that you'll have more to come back for you . . .. You know, that's what it is—all the joy that you get from giving and it comes back in a different way to meet your need." (Ida Olemaun)

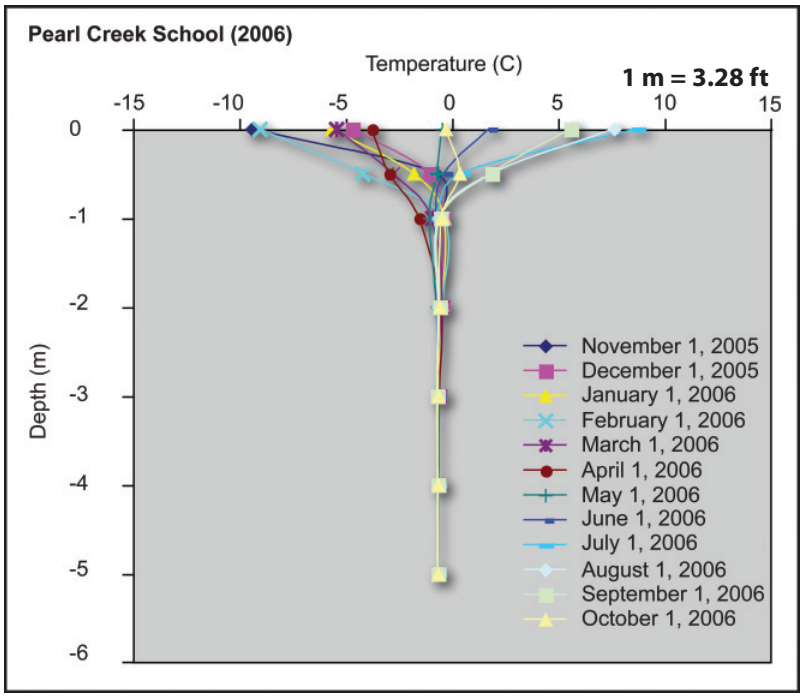
In Iñupiaq culture, sharing has deep significance beyond its obvious importance in ensuring survival in a harsh environment, for sharing the natural bounty is also a way of enacting ethical virtue, and strengthening and maintaining bonds within the human and natural communities. Sharing with other people is necessary for maintaining good relationships with other species, for animals will continue to give themselves up to hunters who enact appropriate sharing attitudes.

NAME: _____

WHAT DOES THE GRAPH SAY?

Section 1

Study the trumpet curve graph below, then answer the questions that follow.



The graph above represents one year of ground temperature data (from Nov. 1, 2006 to October 1, 2007) taken at Pearl Creek School in Fairbanks, Alaska.

1. What is the temperature range at the surface? _____

2. Write the temperature of the ground 0.5 m below the surface in:
   - A. February _____C°
   - B. March: _____C°
   - C. April: _____C°
   - D. May: _____C°
   - E. September _____C°
   - F. October: _____C°

3. Write the temperature of the ground 1 m below the surface in:
   - A. February _____C°
   - B. March: _____C°
   - C. April: _____C°
   - D. May: _____C°
   - E. September _____C°
   - F. October: _____C°

4. What is the temperature range at .5 m below the surface? _____

5. What is the temperature range at 1 m below the surface? _____

6. At what depth does the active layer end? _____

7. At what depth does the graph show zero amplitude? _____

NAME: _____

WHAT DOES THE GRAPH SAY?

Section 2

Refer to VISUAL AID: "Long-term Permafrost Data," then complete the remaining questions. You will need to refer to a map of Alaska clearly marked with latitude lines.

8. Refer to a map or access Google Earth™. What is the range of latitude for the locations of the permafrost data sites listed in Figure 1? _____

9. Refer to a map of Alaska or access Google Earth™. What is the range of latitude for the locations of the permafrost data sites listed in Figure 2? _____

10. Look at Figure 1. The sites labeled Deadhorse and West Dock are sites very close to the coast. Franklin Bluffs, Galbraith Lake and Happy Valley are inland. Based on the graph, what are two notable differences between coastal areas and inland areas? Explain.

    A. _____

    B. _____

11. Look at Figure 1. Which site shows the greatest amount of change?

    A. List the site name and the temperature range: _____

    B. What is the percentage change?: _____

12. Look at Figure 2. Which site shows the greatest amount of change?

    A. List the site name and the temperature range: _____

    B. What is the percentage change?: _____

13. Look at the data for Coldfoot. In 1985 the temperature at 15 m depth was about -1.5° Celsius. In 2009 the temperature reads about -1.2° Celsius. If the permafrost near Coldfoot continues to increase in temperature at the same rate, about how long will it be before the permafrost begins to thaw?

    _____

    _____

NAME: _____

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1. Read the following narrative by Athabascan Elder Robert Charlie:

   > "Our people have always used permafrost for storage of food. The method used was to build a birch bark basket out of the oldest birch tree that had a thick, heavy bark. You pattern it into a 3x4 feet square container, enough to hold food and berries and white fish. Then you dig down to where the ground is frozen, and even a foot into the frozen ground, for storage."
   >
   > "Another significant use of permafrost areas is water. When we were out hunting in higher elevations, where water could be hard to find, we would find a spot where the ground was wet and chop away the tundra to make a hole. Soon you would notice very cold water seep upward from the permafrost."

2. Interview a local elder or culture bearer in you community about the traditional use of permafrost. You might ask questions such as:
   "What do you remember about the use of frozen ground in the past?"
   "Was frozen ground an important part of traditional ways?"
   "What is permafrost called in our language?"

   _____

   _____

   _____

   _____

   _____

   _____

3. Does your community still use ground with permafrost? Explain.

   _____

   _____

4. Read STUDENT INFORMATION SHEET: "Environmental Change, Indigenous Knowledge, and Subsistence on Alaska's North Slope" by Chris Cuomo, Wendy Eisner and Kenneth Hinkel.

5. What comparisons can you make between the Inupiaq use of the ice cellar and your own community's use of permafrost ground?

   _____

   _____

6. What adaptations have to be made if permafrost ground becomes unreliable as food storage?

   _____

   _____

7. What dangers do people face if they do not make such adaptations?

   _____

   _____

NAME: _____

POLYGONS, PINGOS AND THERMOKARST, OH MY!

Directions: Choose one of the formations listed below (A or B) to model and describe:

A. ice wedge polygon

B. pingo

1. Make a sketch of your model. Include labels.

2. Explain the process that causes the formation, including temperature and other conditions necessary.

_____

_____

_____

_____

3. If the permafrost in the formation were to completely thaw and disappear, what evidence of the formation would be left behind?

_____

_____

_____

_____