OLDER THAN BLUE BABE

Overview:

Studying permafrost, both historical and present conditions, helps scientists understand how permafrost relates to the carbon cycle and climate change.

Objectives:

The student will:

- demonstrate an understanding of the age of permafrost; and
- explain how climate change and permafrost thaw are connected.

Targeted Alaska Grade Level Expectations:

Science

[9] 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.

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

[10] SD3.1 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by describing causes, effects, preventions, and mitigations of human impact on climate.

Vocabulary:

hydrology – the scientific study of the properties, distribution, and effects of water on Earth's surface, in the soil, and underlying rocks, and in the atmosphere

carbon – a naturally abundant, non-metallic element that occurs in all organic compounds and can be found in all plants and animals

carbon cycle – the continuous process by which carbon is exchanged between organisms and the environment; carbon dioxide is absorbed from the atmosphere by plants and algae and converted to carbohydrates by photosynthesis; carbon is then passed into the food chain and returned to the atmosphere by the respiration and decay of animals, plants, and other organisms; the burning of fossil fuels also releases carbon dioxide into the atmosphere

carbon dioxide – a colorless, odorless gas, CO_2, that is present in the atmosphere and is formed when any fuel containing carbon is burned; it is released during respiration, produced by the decay of organic matter, and used by plants in photosynthesis

carbon sink – a natural or artificial reservoir that accumulates and stores carbon from another part of the carbon cycle

ecology – the scientific study of the relationship between living things and their environments; a system of such relationships

greenhouse effect – the process of heating the surface of a plant due to the presence of atmospheric gases that absorb and emit infrared radiation (heat)

greenhouse gas – any atmospheric gas that absorbs and emits infrared radiation trapping it close to a planet's surface; greenhouse gases include carbon dioxide, water vapor, methane, and nitrous oxide

methane – a colorless, odorless, flammable gas that is the simplest of the hydrocarbons, having the formula CH4; it is the major constituent of natural gas

water cycle – the continuous movement of water throughout Earth and its atmosphere

OLDER THAN BLUE BABE

Whole Picture:

Some permafrost in the Arctic, known as relic permafrost, is thought to have formed as many as three million years ago. Most, however, is thought to have formed during that last Ice Age, around 40,000 to 12,000 years ago. This frozen ground acts as a time capsule to the past, preserving all that was captured in its icy grip. Wooly mammoth, saber-toothed tigers and the steppe bison roamed the land and sometimes their long-frozen remains are unearthed when natural or man-made disturbance thaws the ground.

Sometimes the discovery of such a relic prompts discussion of distant time, when the land was still young. Chief Robert Charlie tells of a fossil beaver bone he found along the Tanana River.

"In the ancient stories of the Athabascan people, the beaver is very important," Charlie recounts. "The beaver made the world."

The legend tells in the beginning there was nothing but water. Beaver got tired of swimming so he dove down and scooped mud to build the land.

"He's good at bringing things up from the bottom," explains Charlie.

For many in the Athabaskan community, finding this fossil was significant because, according to Charlie, "This bone might be from that beaver."

Permafrost, in effect, is a bank of such treasure. It not only store the past, but basic elements like water and carbon, keeping each from its respective cycle. When permafrost thaws, it frees both to enter Earth's natural processes, but in doing so creates additional results that can dramatically change the land around it.

Thawing permafrost releases water into the water cycle, but it also changes the ecology of the area. Early on, adding water to the active layer changes the kind of plants that can grow, and in turn, the animals that live there. Deeper permafrost acts as bedrock and hold the meltwater near the surface. Later, as thaw deepens, that water drains leaving the ground drier than before the thaw and again the ecology changes.

Thawing permafrost also allows decomposition to begin – a process that halts once the ground is frozen. Any animal and plant matter trapped in the permafrost is free to continue to decay, a process that releases carbon, allowing it to move again in the carbon cycle. Carbon dioxide, a by-product of the carbon cycle, is a greenhouse gas. Carbon dioxide levels have been historically linked to changes in Earth's climate.

Methane is also a byproduct of decay. The release of methane, a greenhouse gas, is of interest to climatologists.

Carbon Cycle: Carbon is essential to life on Earth. All organisms depend on carbon for physical structure (wood, bones, shell) or energy (gained from food, burned for heat). Carbon moves from one system to another in a continuous cycle. It travels from the oceans to the atmosphere, is taken in by vegetation, consumed by animals, and is eliminated or exhaled in a constant rotation called the carbon cycle.

Materials:

- Scissors
- Glue
- Old magazines
- Book: Blue Babe: The Story of a Steppe Bison Mummy From Ice Age Alaska (teacher copy)
- Highlighters (one per student, any color)
- VIDEO: "What Affects Permafrost?")
- TEACHER INFORMATION SHEET: "Permafrost Tidbits"
- VISUAL AID: "Finding the Past"
- VISUAL AID: "Climate Trends"
- VISUAL AID: "Carbon Emissions, CO_2 Concentrations and Temperature"
- VISUAL AID: "The Carbon Cycle"

OLDER THAN BLUE BABE

- STUDENT INFORMATION SHEET: "Ancient Arctic Ice Could Tell Us About Future of Permafrost"
- STUDENT INFORMATION SHEET: "The Story of Blue Babe"
- STUDENT WORKSHEET: "As Old As Blue Babe!"
- STUDENT WORKSHEET: "Permafrost and the Carbon Cycle"

Activity Preparation:

1. Review the book Blue Babe: The Story of a Steppe Bison Mummy From Ice Age Alaska.
2. Review TEACHER INFORMATION SHEET: "Permafrost Tidbits."
3. Write vocabulary words on the board or on a piece of chart paper.
4. Ask students to collect old magazines to use to make a collage of the carbon cycle.
   NOTE: If old magazines are difficult to locate, have students print pictures from the Internet.

Activity Procedure:

1. Display VISUAL AID: "Finding the Past" and read the story to the class. Ask students if they are familiar with the legend, Beaver Made the World, and if they have other details they would be willing to share. (The legend can vary from place to place.) Tell students that ancient artifacts give clues to the past.
2. Show student the book, "Blue Babe: The Story of a Steppe Bison Mummy From Ice Age Alaska." Ask if any students have heard of Blue Babe, or have been to the University of Alaska Museum of the North and seen Blue Babe on display. Explain that Blue Babe is the name given to a 36,000-year-old mummified steppe bison found by a miner near Fairbanks, Alaska in 1979. Open to page seven, titled Discover, and read through the account of finding Blue Babe. Share the pictures with the class. Explain scientists have been able to piece together how they think Blue Babe died from the evidence left behind.
3. Divide students into small groups then hand out STUDENT INFORMATION SHEET: "The Story of Blue Babe." Ask students to read the information sheet in their groups. While students read, ask them to highlight any sentences that help explain why Blue Babe was so well preserved for 36,000 years. When groups are finished, ask students to look over the highlighted material and formulate a question to ask the class as a discussion starter. If needed, use these questions to prompt discussion:
   a. What would usually happen to an animal carcass left out in the open? Are there generally remains left?
   b. What conditions are needed to preserve an animal carcass for thousands of years?
   c. What do you think likely happened to Blue Babe after he was killed by lions?
   d. Why did scientists name the bison Blue Babe?
4. Hand out STUDENT WORKSHEET: "As Old As Blue Babe!" Ask students to access the VIDEO "What Affects Permafrost?" Students need to explore three sections: 1.) How Old is Permafrost?, 2.) Permafrost is Formed, and 3.) Frozen in Time. Students will find the answers to the worksheet while exploring the activity.
5. Ask students how Blue Babe is connected with their current study of permafrost. Explain that Blue Babe was preserved due to the presence of permafrost and other factors. Blue Babe's preservation helps scientists piece together the history of permafrost, as well as past climate in the Arctic. Hand out STUDENT INFORMATION SHEET: "Ancient Arctic Ice Could Tell Us About Future of Permafrost," an article that touches on the importance of studying permafrost as a key to understanding how Earth responds to changes in climate. Ask students to follow along as you read, or ask students to take turns reading aloud. A key point is made as the article concludes: "Permafrost is like the glue that holds the Arctic together. Widespread deep thaw would be bad news for northern infrastructure and economic development, and may have dramatic effects on ecosystems that are adapted to the presence of shallow permafrost." Ask students to underline that section.
6. Show VISUAL AID: "Climate Trends," taken from the book "Blue Babe: The Story of a Steppe Bison Mummy From Ice Age Alaska." Point out that Earth' s climate has always shifted and changed, sometimes dramatically. Scientists spend a lot of time trying to unravel the mystery of Earth's historical climate, including what caused such shifts. One trend that has been established is that the level of carbon dioxide in the

atmosphere corresponds to temperature. Show VISUAL AID: "Carbon Emissions, CO_2 Concentrations and Temperature." Scientists are concerned thawing permafrost will free significant amounts of carbon dioxide, methane, and water vapor, changing the ratio of greenhouse gases in the atmosphere, which could affect the climate.

7. Explain frozen ground, especially ground full of organic matter that has not decomposed, is considered a carbon sink – a reservoir that accumulates and stores more carbon than it releases. While scientists are concerned about human contributions to CO_2 in the atmosphere and its contribution to global warming, the amount of carbon stored in frozen ground far exceeds what humans contribute. If a large amount of permafrost thaws, the stored carbon decomposes, and will again be available in the carbon cycle. Show VISUAL AID: "The Carbon Cycle" and remind students of carbon cycle basics. (See Whole Picture.) This visual is a basic example of how carbon is recycled over and over. Ask students what else could be added to the visual. e. g. Human contributions like burning fossil fuel, forest fires, etc.
8. Discuss the potential positive feedback loop that could be created by a warming climate and thawing permafrost. A warming climate may cause permafrost to thaw. Thawing permafrost releases carbon dioxide, a greenhouse gas. More greenhouse gases cause the climate to warm. (See TEACHER INFORMATION SHEET: "Permafrost Tidbits," A few more tidbits.)
9. Hand out STUDENT WORKSHEET: "Permafrost and the Carbon Cycle"

Ideas for Filming:

Students will create 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.

🎬 Using a plastic toy animal, recreate the circumstances under which Blue Babe was buried and preserved in permafrost and later found by a miner. First create a muddy hill then erode the mud to cover the animal. Put the whole thing in a freezer to create frozen ground. Finally, pour warm water over your buried animal to uncover it and reveal the preserved animal. Narrate, talking about how long the animal was buried and other important details.

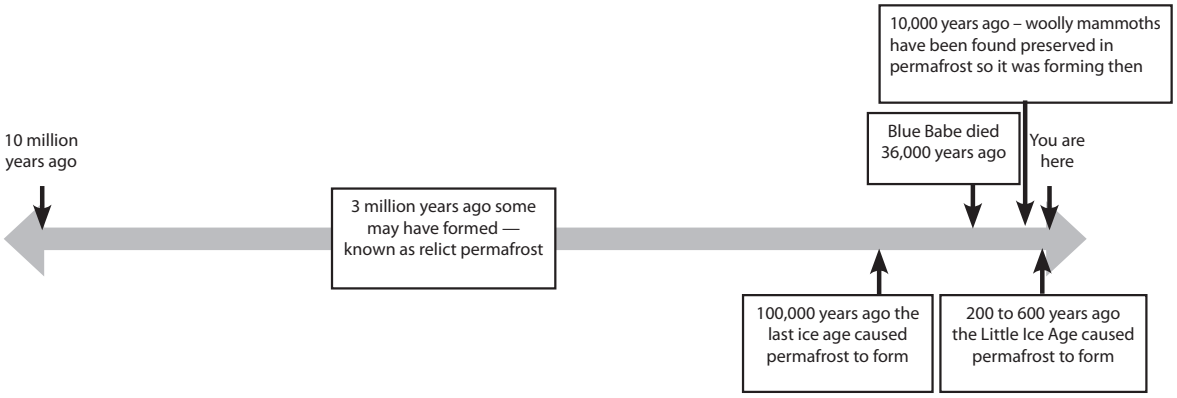
Extension Ideas:

1. The preservation of items (artifacts, animals, etc.) in permafrost, and the presence of permafrost, has led to many unique scientific discoveries. Ask students to research the topic and report back on other permafrost discoveries. For example:
   - Permafrost atop Hawaii's Mauna Kea volcano may be 25,000 years old and give clues to island history.
   - Scientists were able to solve the mystery of the 1918 flu pandemic by examining the body of a frozen Inuit woman, and those of young American soldiers, all who may have died of influenza in 1918. They were buried in permafrost ground.
   - In 1977 Dima, a 40,000-year-old baby woolly mammoth is found in Siberia.
   - In 1999 Mambo, a 24,000-year-old woolly mammoth found in Siberian permafrost in 1996, is sold at auction.

Answers:

STUDENT WORKSHEET: Older Than Blue Babe

1. three million, relict
2. 100,000
3. bacteria
4. 36,000, lions
5. ice age, glaciers, permafrost
6. 200 to 600



7. Student renditions will vary, but should approximate those shown in the diagram above:
8. Timeline should reflect that Blue Babe died 36,000 years ago.
9. In no particular order: woolly mammoth, ponies, camels, saiga antelope, ravens, wolves, blowflies and lions
10. Answers will vary but must fall in the range between 10,000 and 15,000 years ago.

STUDENT WORKSHEET: Permafrost and the Carbon Cycle

Student's collage should reflect elements shown on the carbon cycle diagram on VISUAL AID: "The Carbon Cycle."

PERMAFROST TIDBITS

Excerpt from *How rapidly is permafrost changing and what are the impacts of these changes?*
by Vladimir E. Romanovsky, Associate Professor,
Geophysical Institute University of Alaska Fairbanks

The large observed and predicted future climatic changes will inevitably change the energy and mass fluxes at the land surface and, as a result, the near-surface and subsurface physical conditions in the Arctic and subarctic. This will trigger changes in ecosystems and infrastructure because the stability of these systems in the north relies on the stability of ice that, so far, holds these systems together. In losing permafrost, we are losing the stability of systems.

What is happening to permafrost? The long-term records of the near-surface permafrost temperature, obtained from different parts of the permafrost zone in northern regions, show a significant warming trend during the last 30 years. Ground temperature trends generally follow the trends in the air temperatures with a more pronounced warming in the lower latitudes (between 55° and 65° North). This recent climate warming brought soil temperatures to a surprisingly high level, about 1 to 3°C warmer than long-term averages. Within some areas, the permafrost temperatures are very close to 0°C and at some sites long-term permafrost degradation has already started
(Fedorov, 1996; Osterkamp et al., 2000; Jorgenson et al., 2001; Fedorov and Konstantinov, 2003; Gavriliev and Efremov, 2003).

If recent trends continue, it will take several centuries to millennia for permafrost to disappear completely in the areas where it is now actively warming and thawing. However, negative consequences of this degradation will be pronounced from the very beginning because the highest ice content in permafrost usually is found in the upper few tens of meters.

Permafrost degradation can substantially change the surface hydrology in many ways. Within the area with ice-rich permafrost and poor drainage conditions permafrost degradation will lead to significant ground surface subsidence and pounding ("wet thermokarst"). The ground will become oversaturated, which could cause trees to die (Osterkamp et al., 2000; Jorgenson et al., 2001). Permafrost degradation on well-drained portions of slopes and highlands will proceed in a form of "dry thermokarst." This process will further improve the drainage conditions and lead to a decrease in the ground water content (Hinzman et al., 2003). Changes in the active layer thickness and permafrost continuity will affect groundwater and river runoffs.

Northern ecological systems depend on permafrost conditions. Permafrost controls plant communities and biomass production by soil temperature, active layer thickness, moisture content, presence of unfrozen water, and surface hydrology. The thawing of the ice-rich permafrost within the boreal forest biome can lead to destruction of the substrate and major changes in ecosystems. In case of the "wet thermokarst" scenario of permafrost degradation, changes can result in replacement of the boreal forest with wetlands. In case of "dry thermokarst", the boreal forest ecosystems may be replaced by steppe-like habitats. Long-term permafrost degradation (even without active thermokarst processes) will continuously improve conditions for the subsurface water drainage (especially in sandy soils) that will lead to increased dryness of soils, putting significant stress on vegetation. Improved drainage conditions will also lead to shrinkage of numerous ponds within the degrading permafrost area dramatically affecting aquatic ecosystems (Yoshikawa and Hinzman, 2003).

Significant amounts of carbon are now sequestered in perennially frozen soils (permafrost) and within the active layer, which thaw every summer but completely refreeze during the following winter, where the organic matter decomposition is slow. That is why the majority of northern ecosystems are apparently carbon sinks at present time. Climate warming and drying caused by this warming permafrost degradation will change this situation. A thicker, warmer and dryer active layer will be much friendlier for microbial activities during the summer. Significantly later freeze-up of this layer in winter and warmer winter temperatures (that means much more unfrozen water in it) will considerably enhance the microbial activities during the winter. So, the Arctic and subarctic ecosystems could turn into a source of CO_2. In the area of "wet thermokarst" formation, new and significant sources of CH_4 will be developing.

Thaw settlement related to permafrost degradation is presently responsible for damage to houses, roads, airports, military installations, pipelines, and other facilities founded on ice-rich permafrost (Osterkamp et al., 1997). Any natural increase in the mean annual surface temperature of permafrost and subsequent thaw settlement

would create severe maintenance problems for facilities in the Arctic and subarctic, adding to effects already being observed (Figure 6). Some structures, airports, and roads might have to be abandoned if funds are not adequate to continue repairs (Esch and Osterkamp, 1990).

A few more tidbits…

- Twice as much carbon is contained in the soils and permafrost of northern ecosystems as compared to that currently contained in the atmosphere. Because of the size of the permafrost carbon sink, decomposition of previously frozen organic carbon is a possible feedback to increase global temperatures.
- Though many climate models predict that temperatures will rise, that does not mean all permafrost will thaw, releasing its entire store of carbon. A lot of permafrost is very deep and can withstand major fluctuations in climate without thaw.
- Carbon stored in permafrost is released back into the atmosphere as either carbon dioxide (CO_2) or methane (CH_4). Microbial decomposers release carbon through respiration; the rate of decomposition is dependent on temperature, moisture and other variables. (The warmer it is, the more likely decomposition will occur.)
- Warmer ground (thawing permafrost) and warmer air allows more plants to grow and for those plants to grow bigger. As more carbon is released from the soil, it may be taken up by those plants.
- Forest fires release large amounts of carbon as they burn. Fires also remove the insulating layer above frozen ground, exposing it to increased temperatures, and leading to thaw.
- Erosion along riverbanks allows leaching of organic carbon from permafrost soil into the stream water.

FINDING THE PAST

In Athabascan communities finding artifacts, bones, and fossils of the past spurs talk of legends.

Chief Robert Charlie shares this fossil of a beaver bone (right) found along the Tanana River.

"In the ancient stories of the Athabascan people, the beaver is very important," Charlie recounts. "The beaver made the world."

The legend tells in the beginning there was nothing but water. Beaver got tired of swimming so he dove down and scooped mud to build the land.

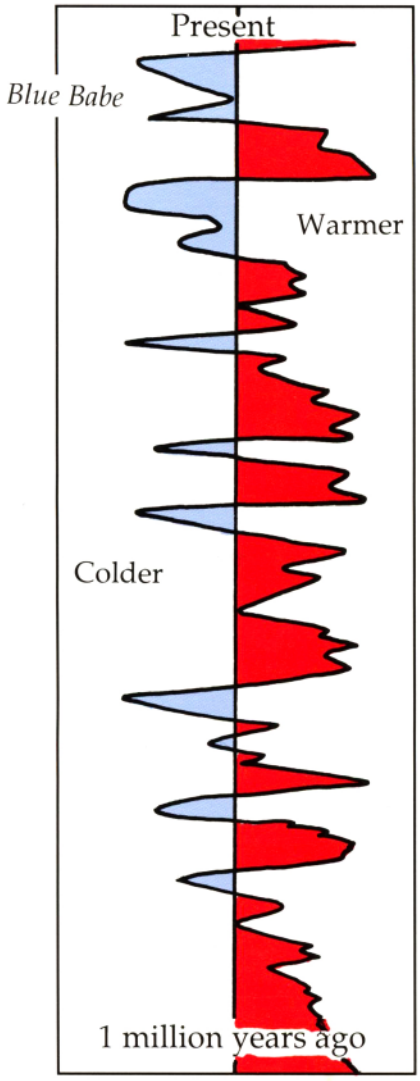
"He's good at bringing things up from the bottom," explains Charlie.

For many in the Athabaskan community, finding this fossil was significant because, according to Charlie, "This bone might be from that beaver."

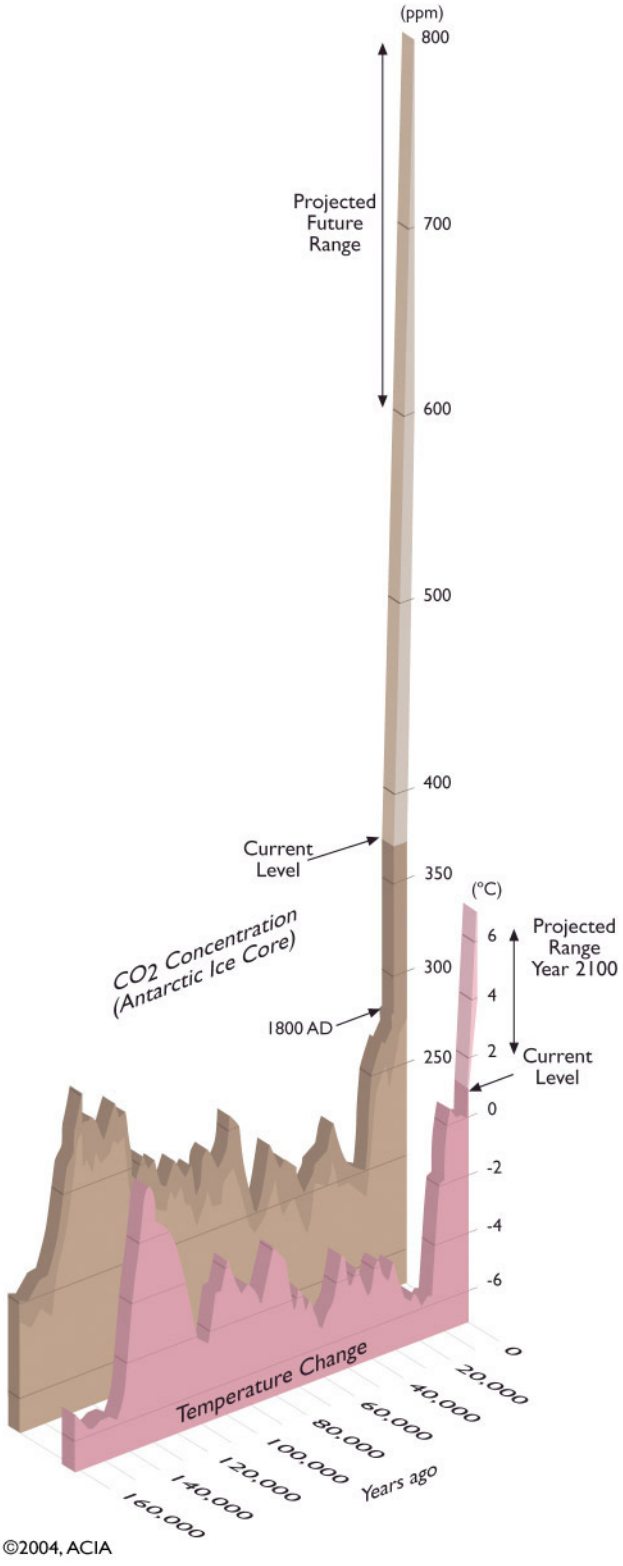
Fossilized beaver hip bone, property of Robert Charlie. Photo by Christine Simko.

Recent beaver hip bone for comparison. Photo by Christine Simko.

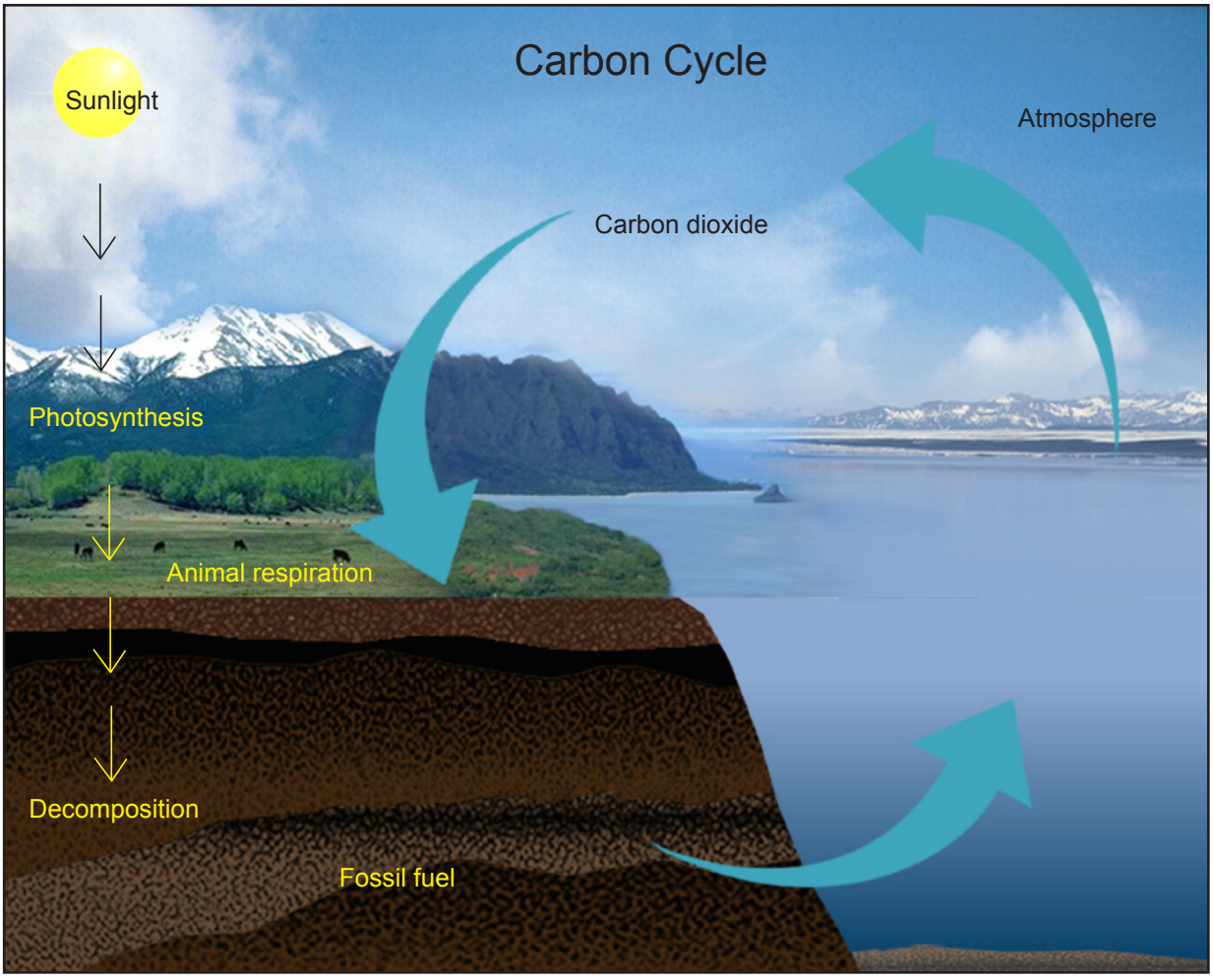
CLIMATE TRENDS



CARBON EMISSIONS, CO_2 CONCENTRATIONS AND TEMPERATURE



THE CARBON CYCLE



ANCIENT ARCTIC ICE COULD TELL US ABOUT FUTURE OF PERMAFROST

University of Alberta ExpressNews, by Jamie Hanlon

Duane Froese examines an ancient ice wedge. Image courtesy of University of Alberta.

Researchers have discovered the oldest known ice in North America, and that permafrost may be a significant touchstone when looking at global warming.

"Previously it had been thought that permafrost completely [thawed] out of the interior of Yukon and Alaska about 120,000 years ago, when climate was warmer than today," said Duane Froese, an assistant professor in the Department of Earth and Atmospheric Science and lead author of the study.

"What we found is that even within the discontinuous permafrost zone-the area where permafrost is warm and within a few degrees of 0C (0° Celsius) and shallow, only a few to tens of meters thick-it has survived at some locations for more than 700,000 years." Because of the potential longevity of the permafrost, it tells the story of climate changes over the course of hundreds of thousands of years, which Froese says is immeasurably valuable.

When permafrost thaws, much of the carbon that was formerly locked up becomes available for decomposition in thawed soil or beneath lakes and is released as carbon dioxide or methane. "Based on the incredible antiquity of the ice wedges we documented, we think that permafrost that is more than several metres below the surface is more resilient to climate warming that previously thought," said Froese.

However, Froese and his colleagues emphasize that their study is not an invitation to ignore the potentially serious impacts of climate warming, particularly in the North.

"Permafrost is like the glue that holds the Arctic together," said University of Alberta graduate student Alberto Reyes. "Widespread deep thaw would be bad news for northern infrastructure and economic development, and may have dramatic effects on ecosystems that are adapted to the presence of shallow permafrost."

Reprinted with permission from the University of Alberta.

THE STORY OF BLUE BABE

A lone bull steppe bison is grazing the bottom of an open slope, above a brushy ravine, in the dusk of an early winter evening. Intent on the next clump of dried grass, his nostrils suddenly fill with an alarming scent. A pair of lions bursts from snowy cover along the creek. There are snorts and thrusts: action impossible to follow in the failing light, followed by the unmistakable sounds of death.

These lions, and perhaps a third, feed on the bison for several days, but as cold soaks through the carcass, they find it more and more difficult to manage. Finally the lions abandon the kill after one of them breaks a tooth in a vain effort to open new parts of the frozen hide.

Soon the snow is tracked with footprints leading to the bison's carcass. Wolves and smaller carnivores gnaw the bones. Ravens tease morsels from every surface they can reach, including the eyes, but the rest of the head and the legs remain untouched, folded under the body and protected by frozen hide. By late winter the bison is largely hidden under trampled snow.

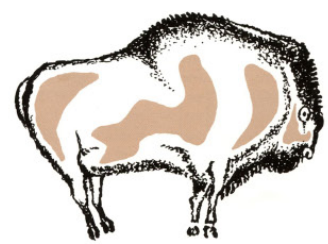
Spring sunlight climbs higher and stronger until winter breaks in a rapid thaw. Snowmelt sheets down the slope, covering the carcass with a layer of cool silt even before the first flies of the year have a chance to emerge. Summer rains carry more silt downslope and the earthen shroud thickens. Cool temperatures and a silty cover protect the remains of the bison from blowflies and normal decay. The carcass refreezes by early October and hardly thaws the second summer.

In a few years the site is invisible, submerged under annual deposits of silt eroded from the slope above the creek. New plants flourish on the rich soil. Deposition continues to raise the level of the soil surface until, eventually, summer thaws no longer reach the carcass. Permafrost creeps up and over the scavenged steppe bison.

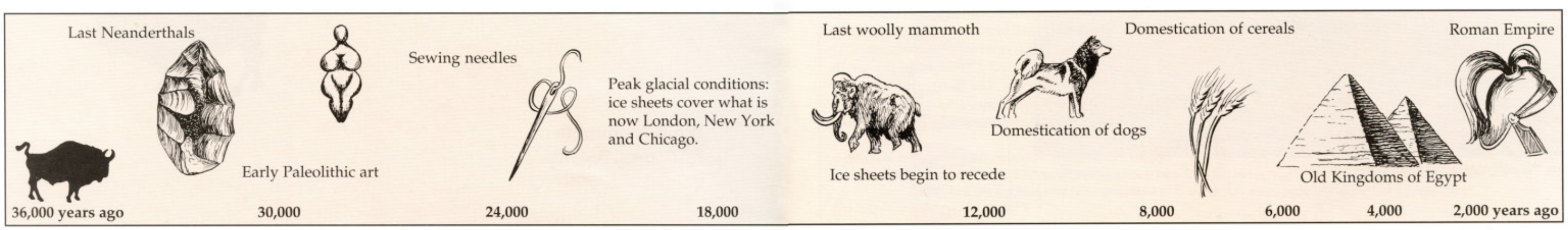
Decades pass. Then centuries, tens of centuries, hundreds of centuries . . . Time recontours the hills and valley as lines and wrinkles do a face: I know this person, but his face has changed. Yes, this is the place, but it is not the same. The lions are gone; forests of birch and spruce climb the hill now. Downstream the pulse of a generator supplies pressure to a jet of water like a massive fireman's hose. It cuts open frozen soils that clog the old valley floor. The water carves bizarre forms in the wall of frost and muck, washing away fossil cold and releasing a heavy organic odor. Silt particles flow away in the moving water, exposing the heavier gravel and gold. These are the sounds and smells of placer mining.

It was here, at a creek near Fairbanks, that Walter Roman found legs protruding from frozen silt in the muck canyon of his gold mining operation. Not just bones, these were real legs with hooves, hide and other tissues. Mr. Roman had found a frozen mummy! The hooves were those of a bison; blue crystals of vivianite were already forming on the exposed hide. Remembering Paul Bunyan's massive ox, we called the mummy Blue Babe.

Like a mysterious trunk from a deceased relative, or a skeleton found in the wall during renovations, Blue Babe is a strange inheritance. What is this: something to throw away or something to treasure?



Bison priscus, *the splendid bison animating cave walls in Lascaux and Altimira, once grazed the rolling hills of interior Alaska. While nearly half of North America was covered by ice, central Alaska remained unglaciated. Wooly mammoth, steppe bison, ponies, camels, saiga antelope, lions and other animals thrived in regions characterized today by boreal forest and tundra.*



1

2

NAME: _____

AS OLD AS BLUE BABE

Directions: Explore the MULTIMEDIA Activity, "What Affects Permafrost?" at uniteusforclimate.org. Fill in the missing information below.

1. Permafrost found in the Arctic may have formed _____ years ago. It is known as _____ permafrost.
2. Permafrost in subarctic regions, below the Arctic Circle, probably formed within the past _____ years.
3. Scientist Eske Willerslev discovered _____ in permafrost believed to be 250,000 years old.
4. Blue Babe once roamed Alaska during a glacier-free ice age around _____ years ago. He was probably killed by _____.
5. The last _____ spanned from 40,000 — 12,000 years ago. Retreating glaciers left behind _____ and _____.
6. A little ice age followed just _____ to _____ years ago.
7. On the timeline below, please indicate four periods of time during which scientists think permafrost may have formed.

Refer to STUDENT INFORMATION SHEET: "The Story of Blue Babe" to complete the remainder of the worksheet.

8. On the timeline above, please indicate approximately when Blue Babe died.
9. Name five other animals that may have lived during the time of Blue Babe.

_____ _____ _____

_____ _____

10. Approximately when did the woolly mammoths begin to die off? _____

NAME: _____

PERMAFROST AND THE CARBON CYCLE

Directions: Use the page below to create a collage of the carbon cycle. Please include thawing permafrost and the feedback loop that feeds the carbon cycle. Don't forget animals, plants, the sun, soil, man-made structures, and vehicles that use fossil fuel.