LAYERS OF ICE

LESSON DIRECTORY

PHOTO GALLERY

This activity develops pre-cursor understanding about how ice forms layers especially to form glaciers.

SCIENCE & LITERATURE

Careful examination of layers of glacial ice can reveal clues to the planetary climate conditions of the times, not only on Earth, but possibly on Mars as well.

"Imagine, collecting a sample of ice and dropping that ice sample into your lemonade and taking a drink with air from the time that General Washington or even Neanderthal man were alive and breathing. Try and order that at the corner restaurant!"

—Zach Smith (2000).
Glaciers, Climate, and the Landscape

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CONCEPT OVERVIEW

This activity develops precursor understanding about how ice forms layers especially to form glaciers.

Concepts:

- Layering
- Stratigraphy
- Cryosphere
- Cryobotics

This activity provides concrete experiences of:

- The phenomenon of layering
- How layering tells a science story of change over time

PRE K–2 CONCEPTS

- In some parts of the world, known as the cryosphere, snow can fall and stay on the ground all year round.
- Some of the snow melts, refreezes, and gradually packs down, forming layers of ice—resulting in the formation of a glacier.
- The ice layers tell a science story that helps us understand global climate conditions.

GRADE 3–5 CONCEPTS

- In regions of the Earth where it stays cold year round, known as the cryosphere, annual snowfall adds to the ice and builds up layers.
- Over time, as glacial layers build up, the pressure from the weight pushes out impurities and pushes the ice grains together.
- Ice forms layers that leave clues to climatic change.
- We can learn about patterns of global climate change by looking at these layers.

LESSON SUMMARY & OBJECTIVES

Some places in the world, such as mountaintops, Antarctica, and the Arctic, are so cold that snow remains on the ground year round.

As a whole, scientists call regions where snow and ice form naturally, the cryosphere. After a snowfall, some of it may melt and then refreeze and form layers of ice. As this happens year after year, the layers of ice build up into massive accumulations of ice called glaciers. Within the layers are trapped gases, particles of dust, spores, and other particles that provide clues to past climatic conditions. By looking at the layers and the kind of particles trapped there, we can retrace a history of global climate change.

Objective 1: Notice the phenomenon of layering (stratification).

We can collect evidence of layering all around us. We can make layers by depositing different kinds of materials on top of one another. Stratification is the scientific term for layering.

Objective 2: Notice that layers can tell a story.

We can explore how layers can tell us a science story of change over time.

Objective 3: Notice that ice layers tell a story of global climate change.

We can study the snow and ice layers of the cryosphere and gain insight into how the climate changes regionally and worldwide.

Objective 4: Notice that we can use special tools to explore layers of ice.

Through the activity we can learn how scientists explore layers of ice on Earth and throughout the Solar System, using cryobotics, robotic technology especially designed to explore layers of ice.

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STANDARDS

BENCHMARKS

12 E Habits of Mind: Critical-Response Skills

GRADES 3–5, PAGE 299

- Recognize when comparisons might not be fair because some conditions are not kept the same.

4F The Physical Setting: Motion

GRADES K–2, PAGE 89

- The way to change how something is moving is to give it a push or a pull.

GRADES 3–5, PAGE 89

- How fast things move differs greatly. Some things are so slow that their journey takes a long time; others move too fast for people to even see them.

4 B The Physical Setting: The Earth

GRADES K–2, PAGE 67

- Some events in nature have a repeating pattern. The weather changes somewhat from day to day, but things such as temperature and rain (or snow) tend to be high, low, or medium in the same months every year.

NSES

Content Standard A Science as Inquiry: Abilities necessary to do scientific inquiry

GRADES K–4, PAGE 122

- Plan and conduct a simple investigation. In the earliest years, investigations are largely based on systematic observations. As students develop, they may design and conduct simple experiments to answer questions. The idea of a fair test is possible for many students to consider by fourth grade.

Content Standard Unifying Concepts and Processes: Constancy, change and measurement

GRADES K–12, PAGE 118

- Scale includes understanding that different characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased.

Content Standard D Earth and Space Science: Changes in the Earth and sky

GRADES K–4, PAGE 134

- Weather changes from day to day and over the seasons. Weather can be described by measurable quantities, such as temperature, wind direction and speed, and precipitation.

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ESSENTIAL QUESTION

How does layering show change over time?

What observations can we make about different materials that form layers? How can we compare layers to understand time sequences? What can we say, draw, or write about layers of different materials?

ACTIVITY QUESTION

How does ice form layers?

What are the properties of ice layers that hold clues to the history of climate change? How does the understanding of layers help us learn more about how the Earth and other icy worlds form? What can we learn by modeling and examining layers of ice? What can we say, draw, or write about layers of ice?

BACKGROUND

Cryosphere

The word *cryosphere* originates from the Greek word *kryos,* meaning frost or icy cold. The cryosphere is the portion of the Earth's surface where water exists naturally in solid form. This includes sea ice, fresh-water ice, snow, glaciers, and frozen ground (or permafrost).

The structure of ice allows mixing with other substances. Gases flow through, and get trapped. Particles freeze. Ice therefore tends to preserve the history of its formation. Ice layers on Earth preserve the history of global climate change, and are connected to geologic times 500,000 years ago or more. Strata of water ice on planetary objects colder than Earth may preserve millions of years of the history of planetary formation.

Northern hemisphere Arctic glaciers in Greenland show seasonal layers of dust. Scientists can resolve annual and sometimes seasonal variations going back as far as 115,000 years. Antarctic glaciers go back even further, more than 500,000 years, but are not as finely resolved.

Ice layers record climate change

Just as tree rings are clues that tell the story of climatic conditions over time, so layers of ice can hold clues to global climate changes: scientists literally count their way back through time as they count down through the annual snow layers, the volcanic dust layers, glaciation layers and the "bomb layers" (fall-out from the 1950s and 1960s nuclear bomb tests) to a specific time in the past.

As snow falls on a glacier, it traps with it the gases and dust particles that are present in the atmosphere. As the snow is converted into glacial ice, these gases and dust particles are trapped. The deeper the layer, the more compressed it is by the weight of the thick ice. Nevertheless, scientists can observe dust, rock, biomatter, and other particles preserved in the layers of ice and use analytical techniques to model the likely climatic conditions that explain what they find.

Ice scientists use special drilling equipment to obtain ice-core samples so that they can examine the ice layers in detail in the laboratory.

(Photos courtesy of Hermann Engelhardt, JPL)

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Cryobotics
Cryobotics is the application of robotic technology to explore extremely cold environments in the cryosphere. Typically, a cryobot includes a heating mechanism to melt its way through thick ice, a light source, cameras, imagers, thermal detectors, and other science instruments that analyze the composition of the layers. Cryobots have explored the depths of Arctic and Antarctic ice and have been proposed for the exploration of ice on Mars and Europa.

A cryobot is an ice-melting device. It moves through ice by melting the surface beneath it, while allowing the liquid to flow around it and freeze behind it. The cryobot has a camera that would take pictures of what there is around it. The data and images are sent back through the thin cable running from the cryobot to a computer at the surface.

An experiment in Antarctica with an early version of a cryobot.

(Photo courtesy of Hermann Engelhardt)

Cryobots have explored both the Arctic and the Antarctic. Cryobots are being readied for future exploration.

For example, a cryobot may be the way to explore Lake Vostok, buried beneath four kilometers of ice in one of the most remote parts of Antarctica. Of all the great lakes of the world, it's the only one that remains pristine and untouched by humanity—a unique time capsule for scientists to research.

Cryobotic Exploration
Cryobots may explore Mars. The planet is similar to Earth in some ways; it has seasons, an approximately 24-hour day, an atmosphere with clouds, and icecaps at both poles. The atmosphere of Mars contains small amounts of oxygen. Cryobots would be sent to Mars' polar regions in order to explore the layers of ice that may be millions of years old. It would be a great discovery to find signs of life there. The ice layers would also tell us more about the global climate changes of the planet, which would also help us learn more about Earth.

Europa may be an ultimate environment for cryobotic exploration, for it is a world covered entirely by sea ice, with strong evidence for an active ocean beneath its ice-covered surface. If this ocean exists, it could be a promising location to search for life.

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ACT OUT THE SCIENCE

Whole Group Mime Activity: *Movement Integration Mediating Experience*

We can think of a cryobotic explorer as an extension of our own senses! Cryobotic technology extends our human capabilities to go places that are too cold and too difficult to reach in person. As a cryobot melts deep into the glacial ice, its science instruments peer into the ice layers all around, and analyzes the particles in the meltwater as it travels back in time. This story can be preceded or followed up by videos taken by cryobots.

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The Story of Time-Traveling with a Cryobot

Narrative	Movement	Concept
Have you ever imagined that you could travel back in time in a time machine?	Have everyone stand up; lead them in warm-up gestures.	Evokes the fascination with the possibility of time travel.
Well, let's go time traveling with a cryobot! The deeper into the ice we go, the farther back in time we travel.	Lead with gestures that match the idea of climbing into a cryobotic time machine.	Connects the notion of the layers of ice as a timeline.
First, let's each *be* an experimental cryobot to make sure it works. Start by standing tall like a cylindrical tower, with your arms at your side. Turn on the power. Let your hands start glowing with heat flowing down through your feet to melt the ice below. Draw the meltwater up; send a hot jet of water down. Whee!	Lead with gestures, using the expressiveness of the hands and arms to illustrate the actions of powering up, heating up, melting ice, and jetting the meltwater.	Communicates a sense of how the cryobot works.
Turn on your laser lights! Look at the layers of ice. How clear it is in all directions, except for bits of dust and other debris. Let your spectrometer look at each layer to examine what isotopes of molecules, trapped gases, and dust particles may be there.	Use the hands as if to project light; look into the surrounding area as if to see into the clear ice. Use motions of the hands and eyes to look closely at particles.	The spectrometer measures reflective wavelengths off the particles in the meltwater to determine composition.
Here we are just under way, ten years deep, when you were just babies or before you were even born—look, we're in a layer of snowball-packable firn! It works!	Play out a slow motion snowball fight.	The upper layers signifying the last few years are less packed than deeper layers.
Okay, now, let's build a cryobot so we can see the parts even better!	Freeze! Let everyone sit down for a moment.	Take a more detailed look at the structure and function of the cryobot.

Narrative	Movement	Concept
We need volunteers to play these parts:	Invite several volunteers to become the cryobot in action.	
1) A heating element: your job is to melt ice and heat up the meltwater to keep the jet supplied with a steady stream of hot water.	The heating element creates a movement to indicate the capability to melt ice by direct contact.	The heating element creates initial melting, but in itself does not melt through very quickly
2) A meltwater jet: you circulate the meltwater and send out a hot jet to melt the ice below.	Perhaps two people as a team, one drawing meltwater in, the other jetting it back out	Sending a jet of hot water turns out to be a faster way to move the cryobot through the ice
3) Laser light sources: your job is to focus your sharp light out into the surrounding ice, to illuminate the icy depths, in order to reveal the ice, layer by layer, counting back year by year.	Actions that indicate shining light into the ice layers to make them visible to the cameras	Lasers provide illumination for the cameras and spectrometers
4) Cameras: you are our eyes peering into the unknown.	Actions as if to show taking video images	To obtain videos in the visible light spectrum
5) Spectrometer: your job is to examine the meltwater at each layer and to determine what the particles, molecules and other debris are made of; from this data, we can construct a description of what was in the atmosphere at the time it snowed.	Actions that indicate zeroing in on assigned wavelengths that correspond to reveal the composition, chemistry, and mineralogy of particles trapped in ice	Sensitive to special wavelengths that will help us understand the nature of the particles in the different layers of ice
6) Power source on-board computer: your job is to keep the cryobot going and to process the sequence of the science instruments.	Actions to indicate provide power and control of functions	An integrated power source and computer to operate the cryobot

Narrative	Movement	Concept
7) Communication cable thermal sensor: you are the cryobot's nervous system that sends all the messages to the brain, that is to the scientist watching the computer at the surface; you also measure how deep we have traveled down from the surface; the deeper we go, that farther back in time we have traveled; and your job is to measure the temperature of the ice as we go deeper.	This could be accomplished by using a prop: a rope or extension cord cable, one end at the "surface," the other attached to the cryobot.	An ingenious engineering feat to combine the need to communicate the data and to record temperature along the way.
Now we have assembled the cryobot. We need the rest of the class to assemble into ice layers for the cryobot to explore.	This can be as simple as standing in several rows, loosely packed near the "top" and more densely packed at greater depth.	
The "top" of the ice may be snowy, loosely packed. The cryobot nestles in to start the melting. First the heating element heats up, then the pump draws in meltwater, and then jets it out to melt down faster.	The cryobot begins to move, as a unit, into the top layers of ice. The whole picture is horizontal rather than vertical: the "top" layer is the front row of loosely packed students.	This begins the actual operation of the cryobot.
Once fully immersed into the ice, it's lights, camera, action.	The parts of the cryobot go into action	
We can examine the features preserved in each ice layer, counting back in time. Here we go!	Each "layer" is noted and described.	The preservation of the history of global climate change.
Keep track of how deep we are. Look, now we're 120 years deep— when the Indonesian volcano Krakatoa erupted, sending ash that covered the world's skies for two weeks. Look, another volcano 750 years deep— look at all that volcanic tephra!	Have students stamp their feet, use their arms to "erupt." Have everyone calm down for several hundred years—and then a new eruption!	Major volcanic eruptions spew sulfurous ash and dust more than 17 miles up into the stratosphere. It ten spreads worldwide and settles globally. These events have left tephra layers in the glacial record in both the Arctic and the Antarctic.

Narrative	Movement	Concept
Wow we're 20,000 years deep—the time of the most recent glacial retreat of many advances and retreats of glaciers.	Have students show glaciers moving out across the world.	Many advances and retreats have occurred over geological time.
Now, we're back about 70,000 years, where we find a layer of volcanic tephra (ash and dust from a volcano) from the Mt. Toba eruption, off the equatorial island of Sumatra, which seems to have triggered a thousand years of cold winters. Brrrr.	Let students burst into a huge slow motion volcanic eruption, then transform to showing being cold.	This layer shows evidence that a major volcanic event triggered a cooling trend that lasted a millennium.
We could go back even further in time, but let's go back to the present, where it's warm.	Rewind back up to the surface, back to the future.	Until the warming trend associated with the recent increase of greenhouse gases, Earth has seen many ice ages.

Small Group Mime Activity: *Movement Integration Mediating Experience*
Invite students to form small groups (about three to five students.) Look at pictures of stratified planetary ice and create their own mime and narrated story about the history that it reveals. Encourage students to act out a sequence that results in understanding about the nature of stratified ice layers.

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MATERIALS

The activity enables students to collect evidence about layers that form in nature.

For all activities, to record reflections, observations, calculations, etc.

- Science Notebooks: writing and drawing utensils

For tree-ring exploration

- A collection of different tree-ring samples (Check museumproducts.com)
- Check with local lumber companies to locate tree-ring samples or check online *dendrochronology* resources for local availability

For layering activity

- Colored sand, gravel, dirt, modeling clay, different colors of glitter and other similar materials (Check gardening centers or craft stores for local availability)
- Modeling clay or PlayDough
- Clear plastic tubing (Check hardware stores or hobby shops for availability)
- Magnifying lenses
- Stopwatches

For ice layering

- Water, food-coloring, access to freezer
- Clear, plastic containers through which layers are visible

DEMONSTRATION

Through discussion, guide students toward inquiry about the role of layers in their personal experience. Guide discussion toward the connection between layers and the passage of time and how examining some kinds of layers can tell us a science story.

PRE K–2

Invite students to draw and tell about layers they know about. Possible responses may include a wide range of experiences, such as:

- layers of clothing that you wear
- layers of clothing piled in the hamper
- layers of bedding
- cake layers

Ask a guiding question, such as: *What kinds of layers do we already know about?* Record students' ideas about layers on the board. Refer to them in the following discussion, especially as exemplars of layering over time emerge.

Ask a guiding question, such as: *How do layers tell stories of change?*

Invite students to bring pictures of themselves at different birthday celebrations. Ask students to describe how they have changed from year to year. Invite them to share the story of some of the changes that occurred between two birthdays. Connect the idea of the photos recording clues to those changes, in a sense, each year we add a layer of experiences.

Connect this discussion to the subsequent warm-up activity about tree rings.

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3–5

Lead a discussion based on a guiding question: *What kinds of layers do we already know about in the midst of our everyday lives?*

As a whole group, invite students to share examples about layering and layering processes they are already familiar with.

Guide students to notice patterns of layering that holds clues to changes over time. For example, layers of:

- our body systems (bone, muscle, nerves, skin, etc.)
- stuff piled up in our room at home
- artifacts at an archaeological dig
- rock formations (geological strata)
- the writing process (pre-write, first draft, revise, publish)
- scientific inquiry (ask questions, propose explanations, test ideas, communicate results)

Invite students to continue the discussion in small groups. Ask them to construct their own example of a natural or everyday layering process that provides clues to change over time. Invite groups to share their examples with the whole group.

Through discussion, guide students to the understanding that the process of layering provides clues to changes that occurred over time. By understanding how the layers formed, we can examine the patterns of layers for clues about the conditions that occurred in the past.

Connect this discussion to the subsequent activity about tree rings and ice layers.

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MAIN ACTIVITY

PREPARATION

For the Warm-up, set up exploratory zones that have different tree-ring samples or a gallery of tree-ring images from sources that welcome use for educational purposes. (See Resource list.)

Set up exploratory zones with familiar examples of layering processes that reveal clues to changes over time. For example, a stack of tests might reveal the order in which students completed the tests; a pile of dirty dishes might reveal the order of meals eaten during the day.

For the making-layers activity, set up materials in exploratory zones or for small groups to work together collaboratively.

TEACHING TIPS

Explore

Invite students to look at layers as timelines, clues that reveal conditions in the past. Compare layering of ice to layering of other materials (sedimentary rocks, tree rings) to build an understanding of the importance of stratigraphy, the study of the stories layers have to tell.

Diagnose

Listen to student ideas about layering. How do students conceptualize what layering is and what we can learn from layering over expanses of time? What implications do students draw from the study of layering? Pose guiding questions that lead toward understanding the relationship between layers, time, and in this case, climate conditions.

Design

Guide students to devise ways to create and then examine effects of layering. Working with rocky material first prepares students for the greater challenge of creating ice layers, as it requires attentiveness to details such as access to a freezer, and cooling of the material for the next layers (to avoid melting the initial layers).

Discuss

Discuss the importance of gathering data that tells the story of how conditions on Earth change over time. Discuss how glacial ice layers preserve the history of global climate change.

Use

Extend the new knowledge about layering to places like Mars, Europa, comets, the Moon, and Mercury. What scientists are learning now about using cryobots on Earth will be applied on future NASA missions.

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WARM-UP AND PRE-ASSESSMENT

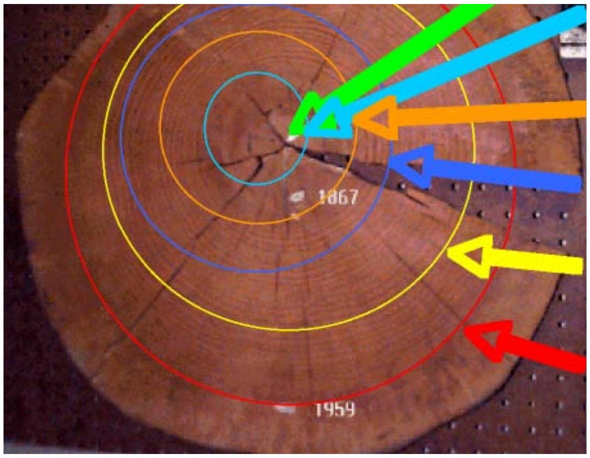
Explore with students what they already know about layers in nature. They are likely to have heard about:

- Tree rings, and how counting the annual rings tells the age of a tree
- Cutaway images reveal the layers of the Earth (core, mantle, crust)
- Sedimentary strata that shows change over a geologic time-scale

Move discussion toward tree rings, saying: *Let's examine tree rings: each tree ring represents one year in its growth. The thickness of a tree ring is an indicator of the climatic conditions. A thicker ring means more annual rainfall; a thinner ring means less annual rainfall. We can examine cross-sections of felled trees or core samples, drinking straw-sized sections drawn from living trees.*

Over many years of these changes of seasons, a small tree grows and becomes a taller, thicker tree. If we were to look at a cross-section of a tree trunk, we would see a series of concentric circles, of alternating light and dark areas, of varying thickness. Let's look for ourselves.

Guiding Questions: Do you see the circles? What do you think these circles mean? What story do they tell about the life of the tree? What story do they tell about how the seasons changed over many years? Count the rings on your tree-ring sample? What do you think this tells you?



The Life of a tree in Alaska

(Source: http://vathena.arc.nasa.gov/curric/land/global/treestel.html)

1769–This tree started growing before the time of the Revolutionary War.

1867–The tree was 4 inches in diameter and 26 feet tall when Alaska was purchased from the Russians.

1902–The tree was nearly 5 inches in diameter and 32 feet tall

1917–The tree was nearly 6 inches in diameter and 37 feet tall during WW1.

1959–The tree was 22 inches in diameter and 77 feet tall when Alaska became the 49th State.

1977–The tree was 25 inches In diameter and nearly 90 feet tall when it was felled.

Have you ever noticed how trees are different as the seasons change?

In spring and summer, they are full of green leaves. The wood grows rapidly and looks lighter. Then in fall, the leaves of many trees change color and then fall off. In winter, the trees are cold and bare of leaves. The wood grows more slowly and looks darker. Together a light ring and a dark ring signify the growth during the cycle of seasons in one year. When spring comes around, buds and flowers appear, and soon the trees are full of green leaves, and the whole process starts again.

How do the rings tell us about climate conditions?

The number of rings tells how old the tree was when it was cut down. The relative thickness of the tree rings tells us how much it grew during the spring and summer—and by inference, it tells us about the amount of rainfall that year. Thicker rings mean more rainfall; thinner rings mean less rainfall. As scientists gather data from many places, they are able to use cross-dating techniques to relate the patterns of variation with overlapping samples in order to match specific tree rings to specific years, and build an understanding of global climate conditions.

Connecting layers of tree growth to layers of ice in the cryosphere

Let students know that just as trees are affected by changes in global climate conditions and leave a record of those changes in the layers of their growth, the cryosphere, that part of the world where ice exists, is also affected by climate change and leaves a record in the layers of glacial ice.

- Before entering the main activity, invite students to write a personal experience of a layering phenomenon in their science notebooks and then share the experience with others in small groups.

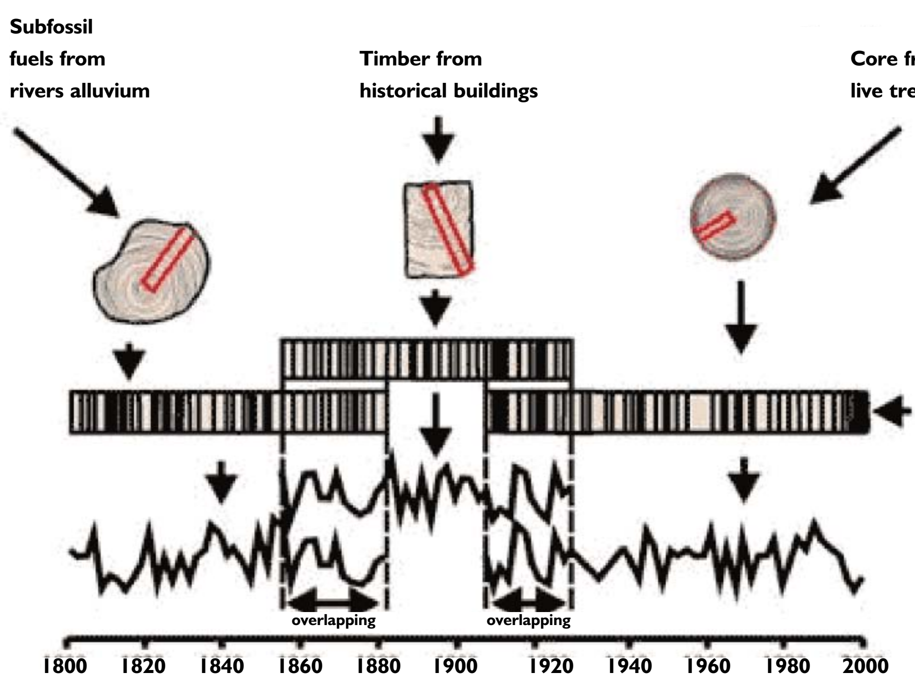


Image Source: http://www.gov.mb.ca/itm/mrd/geo/pflood/photo11.html

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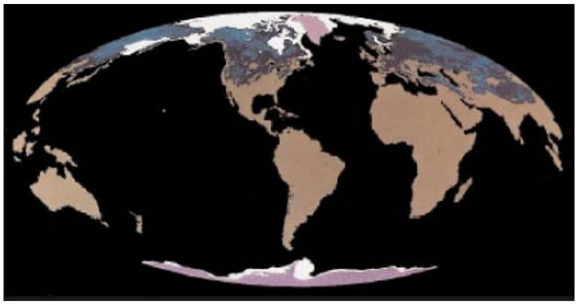
PROCEDURES

This activity explores how to create and examine ice layers for clues about composition and cross-dating. Adapt this procedure to the collaborative abilities of the students.



This image uses a mosaic of data from the Scanning Multichannel Microwave Radiometer (SMMR) on NASA's Nimbus-7 satellite to depict the amount of global snow and ice coverage. Blues ranging from light to dark indicate snow depths ranging from deep to thin. Sea ice is white, and glacier ice is purple. Areas not covered by snow are brown.

PART 1.

Where in the world is the cryosphere?

Lead students in a discussion: *Let's talk about layers of ice on Earth. Snow and ice form layers where the climate stays close to or well below the freezing temperature of water, year round. Where in the world do we find ice and snow?*

After initial discussion, refer to the NASA map of the cryosphere. Notice that the sphericity of the world is communicated as an ellipse that emphasizes the cryosphere, out of scale. Guide students to think of the classroom as a model of this map; establish exploratory zones in the classroom to correspond with the geography of the cryosphere.

- For example, establish one side of the room as a "northern hemisphere" zone with a gallery of images of Arctic sea ice and northern hemispheric conditions, and on the opposite side of the room, establish a "southern hemisphere" zone with a gallery of images of glaciers of Antarctica.

PART 2.

Modeling Snow and Ice Layers

It is difficult to re-create the layering of ice in the classroom, but the idea of layering can be experienced using other materials. If we know about the material we are looking at and how it was formed, we can use the order to estimate its age.

Keeping in mind the projection of the cryospheric map, lead a discussion about what might be learned from making a model of how ice forms layers: *How can we learn how ice layers form by making a model?*

Guide discussion toward insights such as:

- We can learn about the order in time (which layer came first, second, third, etc.)?
- We can learn about how global events such as volcanic eruptions, large meteorite or comet impacts, nuclear weapons testing, and other sources of dust and debris in the atmosphere that leave a residue in layers of ice and provide anchor in time.

In the context of the discussion, this can be an opportunity to introduce the geologic terms stratum (layer), strata (layers), stratigraphy (the study of layers), and stratigraphic data (evidence drawn from the study of layers).

Particle Layering

Form Active Inquiry Teams: Invite students to work as teams of three or four.

Have students create an instance of stratigraphic layering of materials, using materials such as sand, dirt, and gravel and/or modeling clay. The idea is that each team represents a group of scientists at a different site—some layers reflect regional changes, some, such as the glitter, represent global changes.

Make sure each team has a stopwatch or some other timekeeping device. Tell students that it is important to note the passage of time related to the formation of their layers. Have students keep a precise record of the real time involved in the making of each layer as data in their science notebooks.

Have each team select and describe a research location within the cryosphere. Have students imagine and create the layers of ice that might exist there.

Make sure each team member has a different color of modeling clay or Playdough to work with. Supply each team with two colors of glitter (for example, gold and silver).

Have students make "snowflakes" out of the clay. As long as they are small and particle-like, it doesn't matter what shape they actually are: they can be flat little flakes, round little balls, rolled-up little slivers, etc.

Let a clear plastic tray or container represent their location in the cryosphere. Let one student drop the little "snowflakes" into the container, forming the first layer. Have each student take turns making a layer, using a different color or a different material to represent gases, dust particles, and other materials that might get trapped in the ice layer. Have in mind what each material represents.

After several minutes, STOP everyone. Announce that a volcano has erupted and a silvery dust has spread over the entire world—have students sprinkle a layer of silvery or alternative color choice—as long as everyone uses the same color glitter as the layer produced by this global event. Remind students to note the timing of this event in their science notebooks.

Then let everyone continue adding their own layers—after a few more minutes, STOP everyone again. Note that atmospheric testing of nuclear weapons has created radioactive dust particles that spread across the Earth—have students sprinkle a layer of gold glitter. Then continue.

After about fifteen to twenty minutes or when everyone seems about finished, stop the action. Incorporate the student-created "ice" layers into the exploratory zones.

Place them contiguously or generally near other samples in each area.

(Photo courtesy of Hermann Engelhardt)

Here is a picture of a section of an actual ice core extracted from the Antarctic.

Analyzing ice layers using ice-cores

Have student teams extract "ice core samples," using plastic tubing that works for the purpose. Have each group obtain a core sample from at least two other groups.

Use information to create a cross-dated timeline that relates the layers observed.

- The global events (glitter) layers connect all teams' work with those two events and can be referenced for absolute times on a time-scale.

Invite students to share their analysis of the layers of "snow" with each other.

Have teams place their models on display for analysis by other groups.

Have teams examine the layers of other teams' work to make observations and take measurements. Discuss thickness, composition, estimated formation time, and other emerging patterns.

This table connects the layering activity to actual field research of ice layers

Exploratory Zone	Field Research Application
a. Create layers of materials in the laboratory to model nature	■ Modeling layers helps us see and predict patterns to look for
b. Measure order of strata to create a relative time reference	■ Generally, when analyzing ice or rock strata, the lower layers are relatively older
c. Measure placement of known events in time that provide an absolute time reference	■ On Earth, a worldwide layer of iridium corresponds to an event 65 million years ago; other global layers include major volcanic eruptions and periods of glaciation
d. Measure thickness	■ Taking measurements as clues to conditions persisting over time
e. Determine composition, history of formation	■ Nature of materials and how they formed tell a story of changes that took place; volcanic material suggests volcanic activity; sedimentary materials suggests standing bodies of water
f. Determine nature of material trapped in ice layer	■ Snow forms around atmospheric particles, trapping dust and biological material into the frozen layers, and can indicate global atmospheric conditions

Follow-up Activity: View gallery of images and videos of glacial strata, from ice cores, ice bores, and cryobots. *(See Resource list)*

This table indicates a range of observations and interpretations connected to actual viewing of videos and images from crybots, ice cores, ice bores.

Observation	Interpretation
a. You can see bubbles in the ice	■ Bubbles are trapped air that was in the atmosphere at the time the ice was frozen
b. You can see particles in ice	■ Dust, dirt, bacteria can be trapped in ice, likely to have been in the atmosphere at the time it fell as snow
c. At lower depths, ice is clearer	■ As glaciers thicken, and pressure increases, air and particles tend to be pushed out
d. Ice cores reveal climatic change just as rock strata tell geologic history	■ Arctic and Antarctic Ice cores reveal more than 500,000 years of history of yearly climatic patterns

Optional: To explore the idea of how long strata take to form on geologic time scales. Invite students to consider scaling real-time, for instance, let each second count as a century (60 seconds = 6000 years) or a millennium (60 seconds = 60,000 years) or a million years (60 seconds = 60 million years).

DISCUSSION & REFLECTION

What are the implications of discovering a layer of radioactivity in the ice?

It has been known that major natural events, such as volcanic eruptions can spew dust into the atmosphere that spread worldwide. One surprising discovery was a layer in the ice of Antarctica that is radioactive, corresponding to the period of time in the 1950's and 1960's when atmospheric testing of nuclear weapons took place.

Lead a discussion that explores implications about how some natural events such as volcanic eruptions and major forest fires and some human made events, such as industrial pollution and nuclear testing can leave a record of its effect on the whole world in the dust, gases, and particles trapped in layers of ice.

What are the challenges and strategies of exploring ice layers on Mars?

Just as the layers of ice on the polar ice caps on Earth hold clues to the history of global climate changes so the polar ice caps on Mars hold clues to the history of global climate change on Mars. Scientists are devising ways to send cryobots to explore ice on Mars. Both poles show signs of an unusual layered terrain, whose alternating bands of color may contain different mixtures of dust and ice. In the north, the permanent cap is water ice, while in the south the permanent cap is mostly carbon dioxide ice with a mix of water ice.

When and how were these polar layers deposited? Was the climate of Mars ever like that of Earth? And if so, what happened to change the planet into the dry, cold, barren desert it is today? Those are the questions that Mars missions still have to answer.

Invite students to apply what they have learned about ice layers in a guided discussion of the challenges and the strategies of exploring ice layers on Mars.

CURRICULUM CONNECTIONS

Connect to an explicit concept in elementary school science, like machines.

Discuss the relationship between science and technology.

Connect to the topic of mapping as a tool for looking for large-scale patterns.

Develop connections to time-lines in social studies.

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ASSESSMENT CRITERIA

Exemplary

- Students write and illustrate a personal experience of layers and share it dynamically with both a small group and the whole group.
- Students display drawings, constructions, and dynamic models drawn from their science notebooks and web-based research.
- Students identify and extend science questions drawn from direct observation and extended research about stratigraphic layering, not only of ice, but other stratigraphic records as well (such as tree-rings, rock strata).
- Students explore a rich range of information about stratigraphy and relate it to prior shared experiences.
- Students ask a rich and extensive range of questions about stratigraphy in general and applied to ice.
- Students make speculations about possible implications of ice layers down through 80,000–450,000 years of geologic time.
- Students relate ideas in the context of exploring ice in the Solar System.

Emerging

- Students write and illustrate a description of how ice can form layers, sharing it with both a small group and the whole group.
- Students pose basic science questions drawn from the concepts of ice and layering.
- Students observe examples of how ice forms layers and how it preserves a geologic record.
- Students display results using a variety of ways to represent ice layering.
- Students ask a rich range of questions about stratigraphy.

Formative

- Students recognize that different materials can form layers.
- Students identify the basic principles of how ice forms layers.
- Students pose science questions drawn out of the context of exploring the stratigraphy, layering, ice tree rings, rock strata.
- Students illustrate ice layering.

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RESOURCES

http://www.tufts.edu/as/wright_center/fellows/zachfinal.pdf

Zach Smith (2000)
Glaciers, Climate, and the Landscape

http://www.blueiceonline.com/howsite/icefall_about.html

Icefall, frozen waterfall
http://eospso.gsfc.nasa.gov/eos_homepage/for_educators/eos_edu_pack/p26.php
Global Snow and Ice Cover,
Goddard Space Center

http://www.awi-bremerhaven.de/GPH/EPICA
European Project for Ice Coring in Antarctica

http://vathena.arc.nasa.gov/curric/land/global/treestel.html
NASA's tree ring research in Alaska

http://www.ngdc.noaa.gov/paleo/treering.html
NOAA's tree ring data site

http://web.utk.edu/~grissino
Everything you ever wanted to know about tree rings

http://www.ltrr.arizona.edu/skeletonplot/introcrossdate.htm
Activity using skeleton plotting for cross-dating

http://astrobiology.arc.nasa.gov/news/expandnews.cfm?id=1211
http://mars.jpl.nasa.gov/mep/tech/subsurface.html
Cryobotic Exploration of Mars

http://cmex.arc.nasa.gov/CMEX/index.html
Mars Concept Maps

Images
Link to image gallery