Understanding Relative and Absolute Dating: The Age of Snow/Ice or Sediment Layers

Questions

What is tephra? How can tephra be used to date layers in snow/ice and sediment? How far does the tephra from a volcanic eruption extend? What is the difference between relative and absolute age dating? Are there volcanoes near glaciers?

Overview

In this activity, middle school students use “volcanic tephra” (confetti) in order to determine the relative and absolute ages of snow/ice layers in glaciers. They will also use the tephra deposition patterns to estimate the strength and direction of atmospheric circulation patterns.

Volcanic tephra is used by scientists to date layers of snow/ice (buried snow layers become compacted into ice layers) and sediment as well as determine the strength and direction of local or global **atmospheric circulation patterns**. Tephra is a term used to describe all of the solid material produced from a volcano during an eruption. Tephra includes combinations of dust, **pumice**, glass shards, and shattered rocks. Large tephra particles typically fall back to the ground near the volcano while smaller fragments are carried away by wind. Volcanic ash, the smallest tephra fragments, can travel hundreds to thousands of miles downwind from a volcano. Tephra from the 1259 AD eruption of El Chichon, Mexico, for example, has been found in both the Greenland and Antarctic ice caps (Palais, et al., 1992). Tephra can even be traced back to its original source and identify individual volcanoes based on the mineralogy. The use of tephra to date volcanic events and ice cores, lake sediments, and **terrestrial** sediments is a useful and significant scientific tool. Depending on the geographic location and prevailing winds in an area, the plume of tephra from erupting volcanoes are contained in the lower **troposphere** and be deposited locally or the plume may reach into the **stratosphere** and distributed across the northern or southern **hemisphere** or even **globally**. All types of tephra distribution are important for age dating layers and determining atmospheric circulation patterns, especially in ice cores or sediment layers that are collected in order to understand **paleo-climate**.

Terrific movies of erupting volcanoes can be found at Volcano World and other important sources http://volcano.und.edu/vwdocs/movies/movie.html Though all volcanic eruptions can be spectacular, for this activity students should focus on the plumes of volcanic tephra not the lava flows. Also see:
http://video.google.com/videoplay?docid=-3489315725097823887&q=volcanic+eruptions+movies
http://www.swisseduc.ch/stromboli/volcano/video/index-en.html
http://www.westhamptonbeach.k12.ny.us/Teachers/Cohen/sciweb/naturalhazards/volcano/volcanovideo.htm

Other particles, such as **pollen** grains, can also be used to determine the age of sediments. Pollen and other organic material found in sediment cores, most often drilled in lake sediments, can help scientists determine the types of plants that grew in that area (**paleoecology**) and help them date the sediment layers. In addition, dust from arid areas can also be used to date layers, and help identify atmospheric circulation patterns and periods of intense storm activity. One such outstanding example can be seen in a 2006 National Public Radio program *Dust Storms Threaten Snow Packs,* by Richard Harris. http://www.npr.org/templates/story/story.php?storyId=5415308 This explains how dust is circulated globally and can indicate storm events. The dust particles can often be traced to their source, dated, and used as indicators of atmospheric circulation.

Grade Level
5th – 8th

Objectives
In this activity students will:

1. Understand how tephra can be used for the relative and absolute age dating of snow/ice layers (geologic Law of Superposition).
2. Identify individual volcanoes and circulation patterns using distribution of tephra.

National Standards
Content Standard D: Earth and Space Science Structure of the
Earth System

Teacher Preparation
Students will be "creating" volcanic eruptions using confetti. A large space may be needed (move desks to sides of room?) Prepare three - five different bags of colored confetti (large ziplock bags filled with pieces of paper in different sizes, from 0.1 centimeter to 1.0 centimeters in diameter). Store bought "sparkle" confetti is fun to use but can be challenging/dangerous to operate with a hairdryer.

Materials
1. 1 hair dryer. Note: If a hairdryer can is not be used you can effectively blow the confetti out of the tube by mouth.
2. 1 cardboard tube about 10" long. A tube can easily be made by rolling up a piece of paper.
3. Confetti- each bag of confetti should be different by color or some other identification. Included below are master copies of sheets that are numbered 1-5. These sheets can be printed and shredded to create different confetti identified by numbers.
4. Large space for confetti to be dispersed – it may travel up to 10'.
5. Masking or electrical tape for floor grid or map of Antarctica or Greenland. Or, draw a permanent outline of Antarctica on a old white sheet and it can be reused with each class (it also helps with the confetti clean-up).
6. Notebook and pencil for each pair of students.
7. 5" circles cut from plain white paper (attached below).
   10 circles per student pair.

Time Frame
Minimum 45 minute class period. Possibly extends to the next class period for a complete analysis to be accomplished.

TEACHING SEQUENCE Engagement and Explanation
Teachers should start class (or use earlier classes) by explaining volcanic eruptions (video/isatellite images on eruptions). Then a discussion about the scientific method and how modeling volcanic eruptions can be a valid model of what happens in nature.

A. Draw a series of parallel lines on the blackboard. These lines represent layers of ice in Antarctica. In Antarctica, the snow that falls each year does not melt but builds up each year so that annual snow/ice layers are available for study. The top layer would be this year's snow and each line (snow/ice layer) under it represents the snow (turned to ice) layer from each previous year (figure 1).

Figure 1: Relative ages of snow/ice layers.

B. Ask students which layer of ice is the oldest and which is the youngest. The answer is that the top layer is the youngest or most recently deposited and the layer on the bottom is the oldest. It is impossible to "slide" a layer of snow in between two existing layers of snow or ice. This is the Law of Superposition (http://pubs.usgs.gov/gip/fossils/rocks-layers.html)– layers on the bottom are older and layers on the top are younger (applies to ice layers or rock sediment layers). This is the basis for "relative dating" of layers.

C. Ask students what the "exact" age of the top layer is. Answers will vary but the correct answer would be age 0 because that layer just fell this year.

D. Ask students then what the age of each layer below the top layer is. In order the layers would be 1 year old, 2 years old, etc.

E. The ice layers are like the pages of a book that allow scientists to "read" Earth's history back in time. Over the thousands of years that the snow/ice or sediment has been accumulating it becomes impossible to count every layer of ice from the top of the Antarctic ice sheet to the bottom because the layers are compressed beyond recognition, or there may be layers that were melted away, or the ice layers are distorted beyond recognition. Thus dating the each layer of ice beyond the first couple hundred or thousand will very difficult to impossible. Dating the layers of ice accurately is important because in each layer of ice are chemicals from the atmosphere at the time that layer was deposited. For scientists to piece together the conditions present in the atmosphere back into time they need to be able to accurately date each layer of ice.   Reference the Greenland Ice Sheet Project 2: A record of climate change for information on ice coring (http://www.tufts.edu/as/wright_center/iecws/dlese.html)

F. Now ask students to look at the lines (layers) on the board again and tell them that this collection of ice layers is just any section of an ice core that was collected in Antarctica (the top layer is up and the bottom layer is down – this section of ice layers has not been inverted). That being the case, ask students what the age of each layer is. The answer is that no one can tell – with out something to gage the ages of the layers.

G. Now mention that that there happens to be a layer of tephra in between two of the layers of ice.

It is also known that a particular volcano erupted in 1958 in the Philippine Islands. The layer of tephra (draw a layer in between two of the ice layers on the board) was deposited in 1958. The exact or absolute age of tephra or other rock material can be determined to a great degree of accuracy through either visual records or radioactive dating. Now ask students when the layers above and below the tephra layer were deposited. The answer is 1959 and 1957 (assuming no melting in Antarctica. Then, ask them how old the 1959 layer is and how many layers of ice would we expect to find above the 1959 layer.

H. Being able to determine age of layers because they occur above and below another layer (indicator) is called absolute dating.

I. When tephra is extruded from a volcano, where it settles is determined by it mass (larger particles settles faster than lighter particles) and the direction of the prevailing wind. Tephra can travel any distance up to the complete distance around Earth. Tephra from the Mt Pinatubo explosion in 1980 traveled around Earth up to three times.

J. Tephra settles everywhere and can then be used to date the volcanic eruption and since the chemistry of tephra from different volcanoes is chemically unique, and determine the local/global atmospheric circulation (wind strength and direction).

H. A review of the scientific method should take place and students should be asked to “fill in” the steps of the scientific method as it pertains to doing an activity which models using confetti to determine relative and absolute age.

I. Example scientific method for this activity:

Observation- “ A field scientist notices a layer of tephra in the ice layers collected in an ice core they drilled”

Inference- “Since the tephra layer is in between two layers of ice its age must be between the ages of the two ice layers”

Hypothesis- “The relative age of the snow/ice layer above the tephra layer is younger than the tephra and the snow/ice layer below the tephra is older than the tephra. In addition, the absolute age of the snow/ice layers can be determined as + or – one year (above or below respectively) from the exact age of the tephra layer”.

Experiment- See below

Experiment

1. Students should be divided into pairs.
2. A 5’ x 5’ area in the center of the room should be marked off with tape in 1’ square blocks creating a 5 square by 5 square grid (figure 2). Or lay out a map or outline of Antarctica or Greenland.

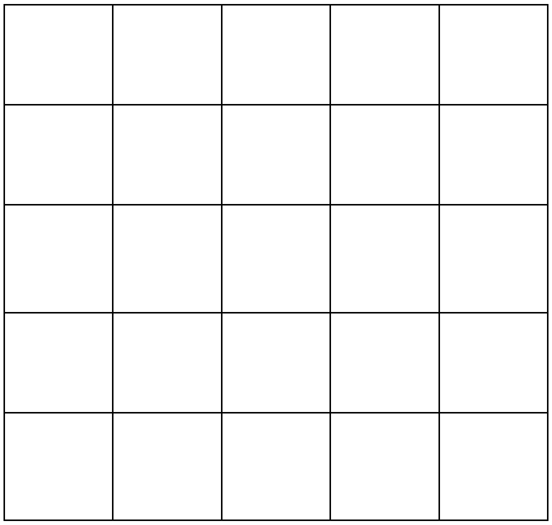

Figure 2: Taped grid on floor (Possibly drawn on a white sheet with the outline of Antarctica).

3. Each pair of students should have 10 of the 5” circles cut from plain white paper.
4. The “volcano team” should have 3-5 small stuffed zip lock bags of confetti. Confetti can be made from pieces of the attached confetti sheets (each piece of confetti has a number indicating which paper it was made from) or other colored paper. Each baggie contains confetti with the same number/color).
5. Each pair of students places one or two of their 5” circles, stacked on top of each other, any where in the grid. These circles represent the ice core that the team is drilling. The student pairs place their circles anywhere they think they will obtain a “good” ice core.
6. One pair of students takes the first turn as the “volcano team”. This pair of students should set up at any point on the outside of the grid. They should hold the paper towel tube over the hair dryer (the hair dryer is off at this point). One student (or the teacher) dumps the confetti from bag one into the paper towel tube and the students immediately turn on the hair dryer. The confetti should fly out across the marked area.

Caution: If confetti falls into the hairdryer it could potentially catch fire, and/or the hairdryer might overhead if it is left running with the tube attached for longer than a few seconds and could blow a fuse. After each “volcanic explosion” any confetti that has fallen into the hairdryer should be cleaned out (watch hot surfaces). The tube should be removed from the hair dryer immediately after 90% of the confetti has been blown out. If you have to substitute blowing the confetti out by mouth then be very cautious and do not inhale any of the confetti, especially if it is commercial fine particles of glitter or such.

Satellite images of volcanic eruptions can be found at http://volcano.und.edu/vwdocs/current_volcs/current.html and may help students visualize how their volcanic eruptions compare to actual eruptions.

7. Some of the paper circle ice core dill areas will have tephra confetti and some may not.
8. Students should place one or two more of the drill circles on top of their other circle(s).
9. The volcanic eruption should be repeated from a different spot around the grid (possibly a new set of students).
10. After the eruption, the students place two or three more ice core circles on top of their existing ice core circles.
11. Perform the last (possibly) eruption from a different spot outside the grid.
12. Students place their remaining ice core circles on top of their existing circles.

13. Each pair of students should then CAREFULLY collect their ice core circles, allowing any confetti that is within their "ice core" to remain in place, and move this materials to a side table (desk). Note: A piece of thin cardboard or stiff paper slide under the ice core might help students transport to their desks.
14. The top circle is the youngest layer, the bottom circle is the oldest. Ask students to determine the relative ages of each circle assuming that no layers of snow/ice were lost to melting. Students should use their paper to sketch the layers and their relative ages.
15. Now, have them assume that the absolute age of the top circle is the present year- time zero, now students should determine the absolute ages of each circle using the present date of the top circle. Students should use their paper to label the layers and their absolute ages in their notebooks.

Now, depending on the age and ability of your students they should determine the absolute ages of the circles if the absolute age of each layer of ice if the age of the #1 (oldest) tephra layer is 10,000 years old, the #2 is 5, 000 years old, and the #3 tephra is 1,000 years old. In this case each ice layer (circle) will not be one year but will be layers in a range from the age of the tephra below it and above it. Each student pair may have a different set of ages for their layers. Students should label the layers and ages in their notebooks. The ages of many volcanic tephra eruptions are know since there occurred in modern recorded times or they have been radiometrically dated using radioactive isotopes in the tephra. One of the best sources for dated volcanic eruptions, in the North Atlantic area is at
http://www.geo.ed.ac.uk/tephra/search.html
another for global volcanoes is the Smithsonian's Global Volcanism Project
http://www.volcano.si.edu/index.cfm
Using these sites you can choose which volcanoes each of your classroom eruptions are from. Then using those know dates you can develop an ice core from the Northern hemisphere that can be dated using this information.

16. Each student pair should then illustrate their ice cores on the black board. The different ice cores should be corrected, discussed, and compared.

Snow/ice layers or sediment layers may only be continuous across limited areas. The size of the area is determined by the ability of air or water to deposit sediment or the size of a snowstorm to deposit snow. If a series ice cores were drilled across a very large area (say across all of West Antarctica) it would be found that not all layers are continuous across the entire area and each ice core may look very slightly different. The illustrations that were drawn by the students on the board can be used to illustrate this concept. Scientists would "connect the dots" and draw lines connecting the same tephra layers if multiple ice cores were available. This master diagram would then show which ice layers might be continuous and which might "pinch out". If this was across all of West Antarctica it is easy to understand that in some years more snow may have been deposited in different areas or that some snow layers may have been so thin in some areas that they were eroded by the wind and left little or trace for that year. The same is true of the tephra layers that over large areas may not be continuous (figure 3).

Surface of the glacier

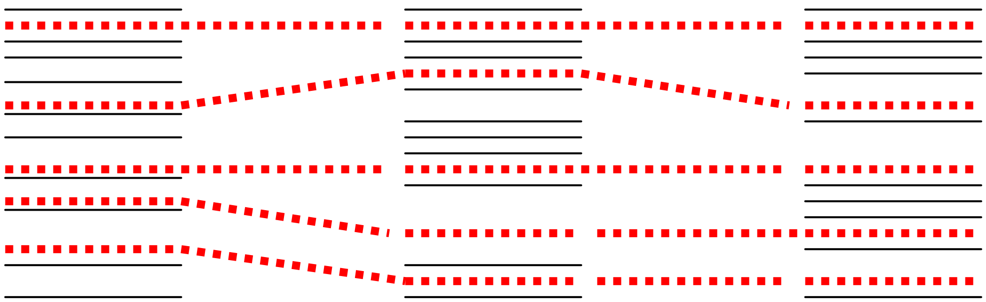

Figure 3: Student ice cores showing individual snow layers with tephra (red dotted).

Elaboration

Using tephra for **spatial** and **temporal** analysis is very important to scientists. How did the results of the class experiment help in proving the Law of Superposition? Is there a relationship between the size of the confetti/tephra particle and its distance from the volcano? If the volcano had expelled more tephra or had blown the tephra out of the volcano with more force would the percent of tephra at each unit radius change? Can this be demonstrated?

Exchange

Students should compare their results on the board and discuss what occurred during the experiment.

Evaluation-Questions

1. What is your conclusion?
2. Because volcanic deposits are often well dispersed, how can these layers help scientists date and correlate layers of snow/ ice over large areas (spatial distribution)?
3. What did your ice core show about the position of tephra across the entire grid?
4. Can specific volcanic events be identified using tephra found in ice cores and sediments?
5. How is the Law of Superposition demonstrated by this exercise?
6. Did this fit your hypothesis of what would happen?
7. What was the relationship of the size/mass of the tephra particle to the distance it traveled away from the volcano?
8. Can the distance from a volcano of a tephra deposit be determined using the tephra contained in a single ice core? Multiple spaced ice cores? Explain.

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Resources

A Tephrochronological Database, University of Edinburgh, Scotland
http://www.geo.ed.ac.uk/tephra/

Decker, R, and B. Decker, (1989), Volcanoes, W. H. Freeman and Co., NY., NY, 285p. Decker, R, and B. Decker, (1991), Mountains of Fire: The Nature of Volcanoes, Cambridge University Press, Cambridge, England, 198p.

In the Path of a Killer Volcano, NOVA film, 1-800-441-NOVA

Latest Ice Core May Solve Mystery Of Ancient Volcanic Eruptions
http://www.sciencedaily.com/releases/2002/07/020702070338.htm

Global Volcanism Program - Smithsonian
http://www.volcano.si.edu/world/eruptioncriteria.cfm

Volcano World, North Dakota Space Grant Consortium
http://volcano.und.edu

Earth Sciences Research - Climatic and Environmental Change: Past, Present, Future (CLIMES)
http://earth.waikato.ac.nz/climatic_environmental_change/

The use of tephra in linking stratigraphic sequences
between sites and archives
http://64.233.187.104/search?q=cache:qnti34a0uIwJ:www.gsf.fi/esf_holivar/pilcher.pdf+using+volcanic+tephra+to+date+ice+cores&hl=en&gl=us&ct=clnk&cd=10

Glossary

Atmospheric circulation patterns: The pattern that the "currents" in the atmosphere take, eg. The jet stream is a pattern of circulation around the globe that fluctuates seasonally.

Globally: Around the globe.

Hemisphere: In either the northern or southern hemisphere (above or below the equator).

Law of Superposition: In a series of layers of any sediment (including dirt, snow, volcanic tephra), the layers on the bottom are older than the layers on the top.

Paleo-climate: Climate in the past periods of Earth's history.

Paleo-ecology: The study of the past ecology of an area, including the types of plants that grew in an area.

Plume: The shape of the cloud of volcanic tephra in the atmosphere.

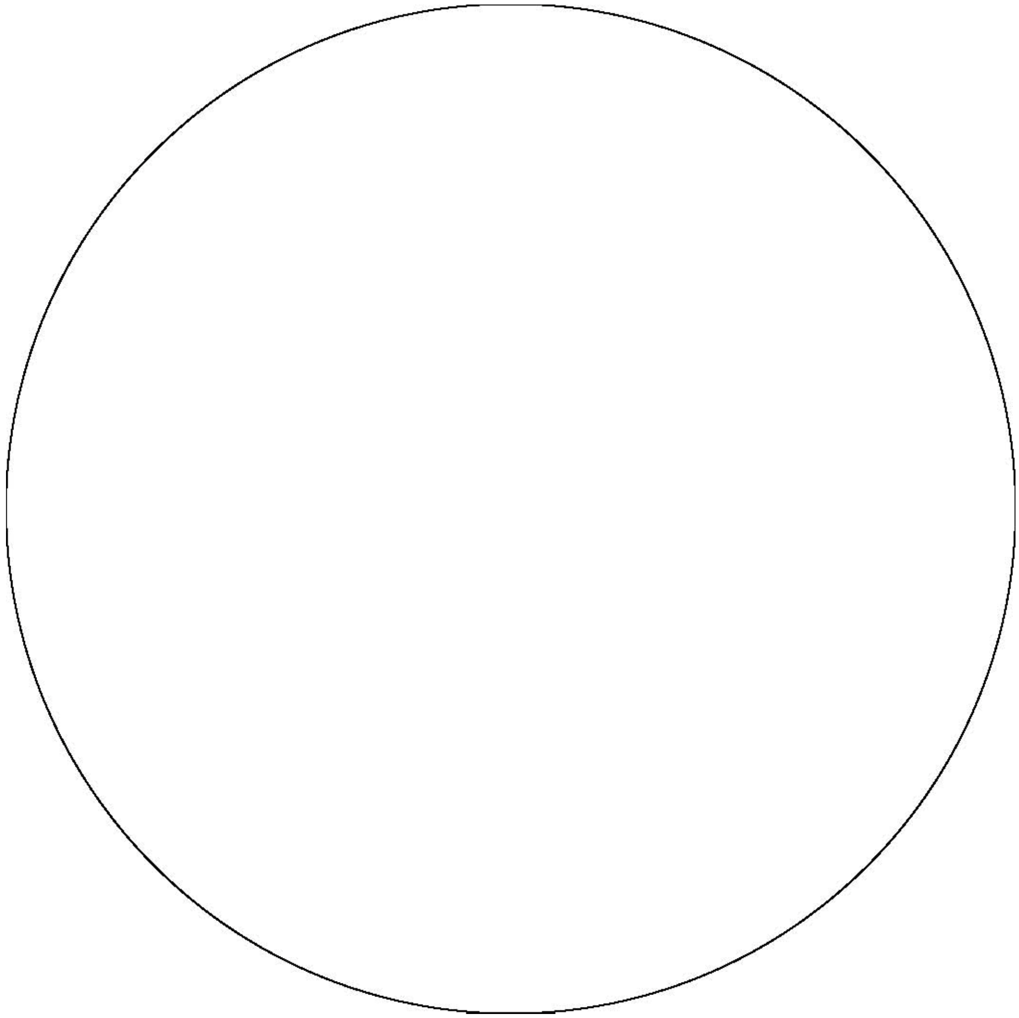
Pumice: Pumice is a light, porous volcanic rock that forms during explosive volcanic eruptions.

Spatial: Spread over an area.

Temporal: At different times.

Tephra: Generic term for all airborne mineral matter ejected during a volcanic eruption.

Terrestrial: On the solid Earth's surface (over the ground).



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