



You're as Cold as Ice!

Lesson Overview

Grade Level: 9-12

Time Allotment: Two to three 45-minute class periods

Overview: We don't often think about glaciers in our everyday lives, even though their effects are all around us. Glaciers have played a large role in shaping the world around us, from the large boulders in Central Park to the rolling hills of Ireland to Minnesota's 10,000 lakes. For hundreds of thousands of years, the movement of glaciers has shaped land through erosion and deposition, creating landforms such as U-shaped valleys, drumlins, horns and arêtes, moraines, and kettle lakes. Currently, glacial retreat is implicated in the Earth's changing climate patterns and may have a great impact on sea levels and weather cycles.

In this lesson, students learn how glaciers and glacial movement have affected the Earth through a series of Web interactives and hands-on activities. They learn fundamental information and terminology regarding glaciers and glaciation, and will then complete an activity using model glaciers to simulate effects on the landscape. Students then use video segments and satellite images to identify the effects of glaciation in various parts of the world. Lastly, they review current theories about cycles of climate change and relate them to glaciers and ice sheets existing today.

Subject matter: Earth Science\Glaciations\Erosion

Learning Objectives:

Students will be able to:

- Define key terms pertaining to glaciers and glaciation;
- Describe the formation process of glaciers and glacial motion;
- Explain several ways in which glaciers erode the land;
- Describe features of glacial deposition and explain how they occur;
- Recognize features of glacial erosion and deposition on landscapes;
- Explain the relationship between glaciers/ice caps and climate patterns.

STANDARDS AND CURRICULUM ALIGNMENT:

National Science Education Standards

<http://www.nsta.org/publications/nses.aspx>

Earth and Space Science

CONTENT STANDARD D: As a result of their activities in grades 9-12, all students should develop an understanding of



- Energy in the earth system
- Geochemical cycles
- Origin and evolution of the earth system
- Origin and evolution of the universe

Students find that the geologic record suggests that the global temperature has fluctuated within a relatively narrow range, one that has been narrow enough to enable life to survive and evolve for over three billion years. They come to understand that some of the small temperature fluctuations have produced what we perceive as dramatic effects in the earth system, such as the ice ages and the extinction of entire species. They explore the regulation of earth's global temperature by the water and carbon cycles. Using this background, students can examine environmental changes occurring today and make predictions about future temperature fluctuations in the earth system.

Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years.

NEW YORK STATE CORE CURRICULUM ALIGNMENTS

Earth Science Core Curriculum

<http://www.emsc.nysed.gov/ciai/mst/pub/earthsci.pdf>

STANDARD 1: Students will use mathematical analysis, scientific inquiry, and engineering designs, as appropriate, to pose questions, seek answers, and develop solutions.

SCIENTIFIC INQUIRY

Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

STANDARD 4: Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and earth science recognizing the historical development of ideas in science.

Key Idea 2: Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land.

Performance Indicator 2.1: Use the concepts of density and heat energy to explain observations of weather patterns, seasonal changes, and the movements of Earth's plates.



2.1r Climate variations, structure, and characteristics of bedrock influence the development of landscape features including mountains, plateaus, plains, valleys, ridges, escarpments, and stream drainage patterns.

2.1s Weathering is the physical and chemical breakdown of rocks at or near Earth's surface. Soils are the result of weathering and biological activity over long periods of time.

2.1t Natural agents of erosion, generally driven by gravity, remove, transport, and deposit weathered rock particles. Each agent of erosion produces distinctive changes in the material that it transports and creates characteristic surface features and landscapes. In certain erosional situations, loss of property, personal injury, and loss of life can be reduced by effective emergency preparedness.

2.1u The natural agents of erosion include:

Glaciers (moving ice): Glacial erosional processes include the formation of U-shaped valleys, parallel scratches, and grooves in bedrock. Glacial features include moraines, drumlins, kettle lakes, finger lakes, and outwash plains.

Mass Movement: Earth materials move downslope under the influence of gravity.

2.1v Patterns of deposition result from a loss of energy within the transporting system and are influenced by the size, shape, and density of the transported particles. Sediment deposits may be sorted or unsorted.

MEDIA COMPONENTS

Video:

NATURE, *Ireland*, selected clips:

Clip 1, "Forming the Burren"

This clip describes how glaciers eroded the bedrock of Ireland's landscape.

Clip 2, "Glaciated Landscape"

This clip shows the many different features and effects of glaciers in Ireland.



Access the streaming and downloadable video segments for this lesson at the Video Segments Page (<http://www.pbs.org/wnet/nature/lessons/youre-as-cold-as-ice/video-segments/1613/>).

WEB SITES

Our Environment: Glaciers

<http://www.summitsofcanada.ca/canatrek/environment/glaciers-interactive.html>

This interactive describes valley and continental glaciers and gives an in-depth explanation of the features of the glaciers and their effects on the landscape.

Life Cycle of a Glacier

<http://www.pbs.org/wgbh/nova/vinson/glacier.html>

This interactive from NOVA shows how a single snowflake makes it to the bottom of a glacier.

New York Satellite Images - Satellite Photo Map

<http://geology.com/satellite/new-york-satellite-image.shtml>

This map contains satellite image of New York State.

Milankovitch Cycles - Interactivity - MSN Encarta

http://encarta.msn.com/media_681514291/Milankovitch_Cycles.html

This interactive explains the three periodic variations in the Earth's orientation toward the Sun, which are believed to cause cyclical changes in climate.

Earth science reference table for Regents exam

<http://www.emsc.nysed.gov/ciai/mst/pub/earthsci.pdf>



Materials:

For each student:

- Earth Science Reference Table - page 8
- Glacier Overview Organizer
- Life Cycle of a Glacier Organizer
- Milankovitch Cycles Organizer
- One model glacier
- Paper plate

For each pair/group:

- Computer with Internet access
- 5 oz. play dough (homemade or purchased)

For the class:

- Computer with Internet access, projector, and screen
- TV and DVD player
- Materials for model glaciers (to be constructed by teacher)
 - Dirt/gravel mixture (approximately 1 tablespoon per student)
 - Ice cube trays (enough for each student in the class to get one cube)
 - Water (enough to fill ice cube trays)
- Organizer Answer Keys:
 - Glacier Overview Answer Key
 - Life Cycle of a Glacier Answer Key
 - Milankovitch Cycles Answer Key
 - Effects of Glaciers in New York State Answer Key

PREP FOR TEACHERS

Prior to teaching this lesson, you will need to:

Preview all of the video clips and Web sites used in the lesson.

Download the video clips used in the lesson to your classroom computer, or prepare to watch them using your classroom's Internet connection.

Bookmark the Web sites used in the lesson on each computer in your classroom. Using a social bookmarking tool such as del.icio.us or diigo.com (or an online bookmarking utility such as portaportal.com) will allow you to organize all the links in a central location.



Make copies of Earth Science Reference Table, page 8, for each student in your class.

Make copies of all student organizers for each student in your class.

Prepare model glaciers for students by following these steps:

1. Prepare mixture of dirt and gravel. Particles should be of different sizes. You will need approximately one tablespoon of the mixture for each student in the class.
2. Add mixture to ice cube trays. Each ice cube slot should be filled about halfway with the mixture.
3. Fill trays with water.
4. Freeze overnight.

INTRODUCTORY ACTIVITY: SETTING THE STAGE

1. Begin the class by asking students what they know about the Ice Age. (*Accept all answers.*) What evidence is left of the Ice Age? (*Existing glaciers, erosion and other evidence of glaciation.*) Ask for a short and simple description of a glacier. (*You will probably get something like "a sheet of ice."*) Tell students that a glacier is a huge mass of ice slowly flowing over a land mass, formed from compacted snow in an area where snow accumulation exceeds melting and sublimation. Glaciers, ice sheets, and ice caps have affected much of the Earth as we know it today, including landforms such as valleys, lakes, and mountain peaks, as well as other factors such as weather patterns and sea levels.

2. Tell students that in order to discuss glaciers and recognize their effects on the landscape of the Earth, they must know the terminology to describe different parts of a glacier and glaciation. Have students (either in pairs or in groups, depending on how many computers your classroom has) open the "Our Environment: Glaciers" interactive (<http://www.summitsofcanada.ca/canatrek/environment/glaciers-interactive.html>). Distribute the "Glacier Overview Organizer" to each student. If possible, display the interactive on a screen for the whole class as well. Read the first page to the class, or ask a student to read it aloud.

3. Ask students to read the information and study the pictures of valley glaciers on the next two pages. Give students a FOCUS FOR MEDIA INTERACTION by asking them to note the landforms and features specific to valley glaciers. Students should click through the pages using the green arrow in the bottom right corner. They should record their observations on the Glacier Overview Organizer. Give students 5-10 minutes to complete this part of the activity. Check for comprehension by asking students to point out the features on the image in the interactive.

4. Ask students to move on to the next two pages of the interactive, which describe continental glaciers. Give students a FOCUS FOR MEDIA INTERACTION by asking them to note features of continental glaciers, and to compare and contrast these with valley glacier features. Give students 5-10 minutes to complete this part of the activity.



Check for comprehension by asking students to point out the features on the image in the interactive.

5. Ask students how they think glaciers cause and create all of these features. (*Melting, moving, eroding.*)

LEARNING ACTIVITY 1

1. Tell students that the process by which a glacier is formed can be long and complex - it isn't just a large amount of water freezing over the winter. Have students, in pairs or groups, visit the Life Cycle of a Glacier interactive (<http://www.pbs.org/wgbh/nova/vinson/glacier.html>). Give students a **FOCUS FOR MEDIA INTERACTION** by asking them to note what happens to the snowflake as the glacier forms. Where does it start? Where does it end up? Distribute the "Life Cycle of a Glacier Organizer" to students and have them answer the questions as they go through the interactive. Check for comprehension by reviewing the answers on the Organizer.

2. Have students remain in pairs or groups. Give each student 5 oz. of play dough, which they should spread out their lab tables or desks. Distribute model glaciers from the ice cube trays to each student and tell them that they will be demonstrating what happens as glaciers move across surfaces. Each student will scrape his or her glacier, gravel end down, over the play dough. In order to accurately simulate the action of a real glacier, students should scrape relatively slowly in only one direction, using a fair amount of pressure. Have students write in their notebooks about the kind of impressions the "glacier" makes in the play dough. Are gravel pieces or other debris left behind? Does the "glacier" scratch through the play dough? When scraping is completed, ask students to rest their ice cubes on paper plates and allow them to melt.

3. Ask students to look closely at the "glacier." Do they notice any interesting surface features like crevasses? How is the sediment (dirt and gravel) distributed throughout? (*Randomly.*) How was the play dough "landscape" affected by the sediment in the "glacier"? (*Scratches, grooves, possibly erratics, which are large boulders picked up and then deposited by glaciers.*) Explain that glaciers form on top of rocks and dirt but also pick up additional sediment as they move; these can be rock fragments from valley walls or new rocks from the ground that freeze into the ice. These rocks act as gougers and produce glacial grooves and scratches in bedrock that show patterns of glacial movement.

4. Observe the melting "glacier" on the paper plate. This is more similar much closer to a continental glacier, while the scraping activity represented a valley glacier. What do students notice about how the sediments are distributed by the melting ice? (*Sediment is unsorted, piles are of mixed sizes.*)

LEARNING ACTIVITY 2

1. Now that students have witnessed some of the effects of glaciation, ask them if they are familiar with any landscapes that may have been affected by glaciers. (*Accept all reasonable answers.*) Tell students they are going to watch a short video clip about



glaciers' effects on the landscape of Ireland. Play Clip 1, "Forming the Burren." (Access the video segments for this lesson at the Video Segments Page,

[http://www.pbs.org/wnet/nature/lessons/youre-as-cold-as-ice/video-segments/1613/.](http://www.pbs.org/wnet/nature/lessons/youre-as-cold-as-ice/video-segments/1613/))

Give students a FOCUS FOR MEDIA INTERACTION by asking them to write down at least two ways in which Ireland's landscape was changed by glaciation. When clip is finished, ask students to share their answers. (*Scouring, gouging, depositing erratics, depositing soils and sediments, forming grikes.*) Explain that there are two ways in which glaciers create new landforms: erosion and deposition.

2. Explain that there are three main types of glacial erosion:

1. Freeze-thaw, which is the action of glacial water on cracks or hollows in rock surfaces. Water expands/freezes and contracts/thaws in the cracks, which eventually causes the rocks to break up.
2. Plucking, which occurs when the glacier moves over land. Rocks freeze to the base and are picked up from the ground, proceeding to move with the glacier.
3. Abrasion, which occurs when rocks at the base of the glacier rub against the bedrock and wear on the landscape.

The processes do not necessarily happen in isolation; any two or all three can happen at the same time as a glacier advances.

3. Explain that we can learn about glaciers from their effects on the landscape. Display the satellite image of New York (<http://geology.com/satellite/new-york-satellite-image.shtml>) for the whole class. This area was covered by glaciers in the Ice Age. What do students see on this map that might be a result of glacial erosion? (*Finger Lakes, Hudson River, lakes in Canada, possibly grooves in New Jersey*) Based on the orientation of the Finger Lakes, in which direction can we assume the glacier traveled? (*North-south.*) Ask students to speculate on how the lakes might have formed. (*Glaciers eroded depressions, gouged, filled with meltwater.*) Tell students that it is currently believed that the Finger Lakes were previously existing stream valleys that were widened and deepened by glacial erosion and then filled with meltwater.

4. Refer back to the satellite image of New York (<http://geology.com/satellite/new-york-satellite-image.shtml>). Remind students that in addition to erosion, glacial deposition creates landforms as well. Glacial deposition occurs when the glacier, through its movement, deposits rocks and debris it has picked up along the way. Point out the large moraine in Central New York that serves to dam the Finger Lakes. Explain that this is a terminal moraine, indicating the furthest advance of the glacier. Ask students if they can find other landforms on the map created by glacial deposition. (*Ronkonkoma moraine, Valley Head moraine, drumlin field, outwash plain*)

5. Briefly review the key vocabulary terms from the introductory activity. Tell students they'll be watching another video clip showing examples of glaciated landscapes. Play Clip 2, "Glaciated Landscape" without sound, so that students may notice the glacial features on their own, without being informed or biased by the narration. (Access the video segments for this lesson at the Video Segments Page, [http://www.pbs.org/wnet/nature/lessons/youre-as-cold-as-ice/video-segments/1613/.](http://www.pbs.org/wnet/nature/lessons/youre-as-cold-as-ice/video-segments/1613/))



Give students a FOCUS FOR MEDIA INTERACTION by asking them to list the different glacial features they notice in the clip. Check for comprehension by replaying the clip and having students call out the features as they see them. (*Kettles, U-shaped valley, arête, drumlins, moraines, eskers*)

CULMINATING ACTIVITY

1. Tell students that in addition to shaping the landscape of the Earth, glacial advance and retreat can have a major impact on the Earth's climate. Students should remember from the beginning of the lesson that glaciers are a remnant from the last Ice Age. Ask students approximately when the last Ice Age occurred. (*Students can consult Earth Science reference tables. Last Ice Age was in Pleistocene Epoch, between 0.01 and 1.6 million years ago.*) Explain that currently the common belief is that the Earth is in a cyclical pattern of Ice Ages and warmer periods called interglacials, and that the Earth has experienced many of these cycles. Ask students to speculate on what might cause these cycles. (*Accept all answers.*) Tell students that glacial retreat affects conditions on our planet, such as sea levels and animal habitats. Additionally, as ice caps get smaller they reflect less sunlight, which affects weather patterns and climate. Explain that since much of the water trapped in ice sheets is freshwater, as the ice caps melt the salt content of the oceans may be affected. Ask students how they think this might impact the Earth. (*Change in ocean currents, destruction of animal habitats.*)

2. Explain that while many factors may contribute to the cyclical pattern, some scientists now believe that human-influenced global warming is altering and accelerating the natural cycle. There is evidence throughout geological history that warm "interglacial" periods usually coincide with high atmospheric levels of methane and carbon dioxide. Why might this indicate that humans have some responsibility for climate change? (*Industrial Revolution, humans using machinery/animals/agricultural processes releasing these gases into the atmosphere*) Direct students (individually, in pairs, or in groups, depending on how many computers are in your classroom) to the Milankovitch Cycles interactivity (http://encarta.msn.com/media_681514291/Milankovitch_Cycles.html). Distribute the "Milankovitch Cycles Organizer" to each student. Ask students to go through each page of the interactive. Give students a FOCUS FOR MEDIA INTERACTION by asking them to note where in the three cycles the Earth is currently. Students should complete the questions on the organizer as they go through the interactive. Check for comprehension by reviewing the answers on the Organizer.

3. For homework, have students write a short paper on climate change and glacial retreat. Students should give their opinions, based on class discussion and other sources, about whether climate change is part of an established pattern or humans are affecting the warming cycle. They should include specific examples to support their opinions.



CROSS CURRICULAR EXTENSIONS

Social Studies:

The Northwest Passage is a sea route through the Arctic Ocean, which for many years was difficult to navigate due to the presence of Arctic ice. By 2007, the ice had melted enough for the passage to be opened for regular crossing. Discuss the pros and cons of the recent opening of the Northwest Passage. Do the trade benefits outweigh the environmental issues?

Geology

Ask students to use play dough to create models of glaciated landscapes, including features they have learned about.

COMMUNITY CONNECTIONS:

Ask students to determine what natural processes have shaped the landscape in their region, using aerial and topographical maps of the area.

If a university is present in the immediate area, ask someone from the geography department or geology department to discuss the most recent Ice Age with your students.



NAME: _____

DATE: _____

Glacier Overview Organizer

VALLEY GLACIERS

Match the features of valley glaciers and glaciation with their definitions.

- | | |
|----------------------|--|
| A. Ablation Zone | 1. ridge or divide between glacial valleys |
| B. Accumulation Zone | 2. steep-sided valley formed by stream erosion |
| C. Arete | 3. area where ice leaves by melting, calving, or evaporating |
| D. Bedrock Erosion | 4. pyramid-shaped peak eroded by 3 or more glaciers |
| E. Cirque | 5. deep landlocked lake formed when a glacier retreats |
| F. Crevasse | 6. eroding land through plucking and abrasion |
| G. Hanging Valley | 7. ridge of till in the middle of a valley glacier |
| H. Horn | 8. highest and coldest part of a glacier where snow buildup occurs |
| I. Lateral Moraine | 9. bowl-like depression at the head of a glacial valley |
| J. Medial Moraine | 10. tributary valley higher than the floor of the main valley |
| K. Tarn | 11. distinctive shaped valley eroded by glaciation |
| L. U-Shaped Valley | 12. ridge of glacial sediment along the sides of a glacier |
| M. V-Shaped Valley | 13. gaping crack in the surface of a glacier |



NAME: _____

DATE: _____

CONTINENTAL GLACIERS

What is another name for continental glaciers? _____

How are they different from valley glaciers? _____

Match the features of continental glaciation with their definitions.

- | | |
|---------------------|---|
| A. Delta | 1. snakelike ridge composed of glacial drift from streams |
| B. Drumlin | 2. area where meltwater streams deposit sediment from a glacier |
| C. Esker | 3. triangular body of sediment |
| D. Kettle | 4. streamlined hill of glacial till built under ice |
| E. Outwash Plain | 5. debris accumulated at ice margin, marking furthest advance of a glacier |
| F. Terminal Moraine | 6. bowl-like hole in glacial deposit formed by large blocks of ice melting. |



NAME: _____

DATE: _____

Life Cycle of a Glacier Organizer

1. What is the percentage of air in snow at the top of the glacier? _____

2. What causes snowflakes to get closer to each other? _____

3. What is the percentage of air in snow after it has been compacted? _____

4. What happens to the ice crystals as snow accumulates year after year?

5. What is the percentage of air in the ice at its densest? _____

6. What causes the ice crystal to make its journey through the glacier? _____

7. How is a warm glacier similar to an ice skate? _____

8. Which moves faster, a warm glacier or a cold glacier? Why? _____

9. Describe two ways in which glaciers lose their mass.



NAME: _____

DATE: _____

Milankovitch Cycles Organizer

Define the following terms and answer the related questions.

I. PRECESSION:

1. How frequently does the Earth complete a cycle of precession?

2. Where is the Earth now in the cycle?

II. ORBITAL ELLIPTICITY:

1. What happens when the Earth's orbit is most elliptical?

2. How long does it take to complete an elliptical cycle?

III. NUTATION:

1. What causes the Earth's seasons?

2. How do the seasons vary with nutation?

3. How long is a cycle of nutation?

IV. CLIMATE VARIATION:



NAME: _____

DATE: _____

1. What happens when all three cycles unite to produce cooler summers?

2. What happens when all three cycles unite to produce warmer summers?

Why doesn't the climate in the Southern Hemisphere affect the cycle of Ice Ages?

Where are we now in the cycle?



NAME: _____

DATE: _____

VALLEY GLACIERS

Match the features of valley glaciers and glaciation with their definitions.

- A. 3
- B. 8
- C. 1
- D. 6
- E. 9
- F. 13
- G. 10
- H. 4
- I. 12
- J. 7
- K. 5
- L. 11
- M. 2:

CONTINENTAL GLACIERS

What is another name for continental glaciers? ice sheets

How are they different from valley glaciers?

flow outward in all directions from central area of accumulation

Match features of continental glaciation with their definitions.

- A. 3
- B. 4
- C. 1
- D. 6
- E. 2.
- F. 5



NAME: _____

DATE: _____

1. What is the percentage of air in snow at the top of the glacier? 90%
2. What causes snowflakes to get closer to each other? _____
subsequent snowfall layers compact flakes
3. What is the percentage of air in snow after it has been compacted? 50%
4. What happens to the ice crystals as snow accumulates year after year?
ice crystals become more compressed and air spaces between crystals shrink
5. What is the percentage of air in the ice at its densest? 10%
6. What causes the ice crystal to make its journey through the glacier?
tremendous pressure from weight of the ice above
7. How is a warm glacier similar to an ice skate? _____
weight of ice creates thin layer of liquid water over which the glacier slides
8. Which moves faster, a warm glacier or a cold glacier? What factors affect the flow? warm glacier moves faster. Other factors – size, pitch of slope, temperature of ice
9. Describe two ways in which glaciers lose their mass.
calving (icebergs break off into ocean), melting, sublimation (water changes directly from solid into gas)



NAME: _____

DATE: _____

Define the following terms and answer the related questions.

I. PRECESSION: _the way in which the Earth wobbles as it revolves ____

1. How frequently does the Earth complete a cycle of precession?

__once every 25,000 years_____

2. Where is the Earth now in the cycle?

__closest to the sun in Northern Hemisphere winter_____

II. ORBITAL ELLIPTICITY: _Earth's orbit flexes from more circular shape to more oval shape____

1. What happens when the Earth's orbit is most elliptical?

__distance from Earth to Sun & intensity of sunlight varies greatly__

2. How long does it take to complete an elliptical cycle?

__about 100,000 years_____

III. NUTATION: _variation in axial tilt_____

1. What causes the Earth's seasons?

__tilt of Earth's axis_____

2. How do the seasons vary with nutation?

__variation in axial tilt – greater tilt = harsher seasons_____

3. How long is a cycle of nutation?

__about 40,000 years_____

IV. CLIMATE VARIATION: _precession, orbital ellipticity, and nutation cycles combining to produce changes in climate____

1. What happens when all three cycles unite to produce cooler summers?

__winter ice doesn't melt, glaciers form, sea levels fall – ice age_____

2. What happens when all three cycles unite to produce warmer summers?



NAME: _____

DATE: _____

__glaciers melt, sea level rises, Southern Hem. has cooler summers__

Why doesn't the climate in the Southern Hemisphere affect the cycle of Ice

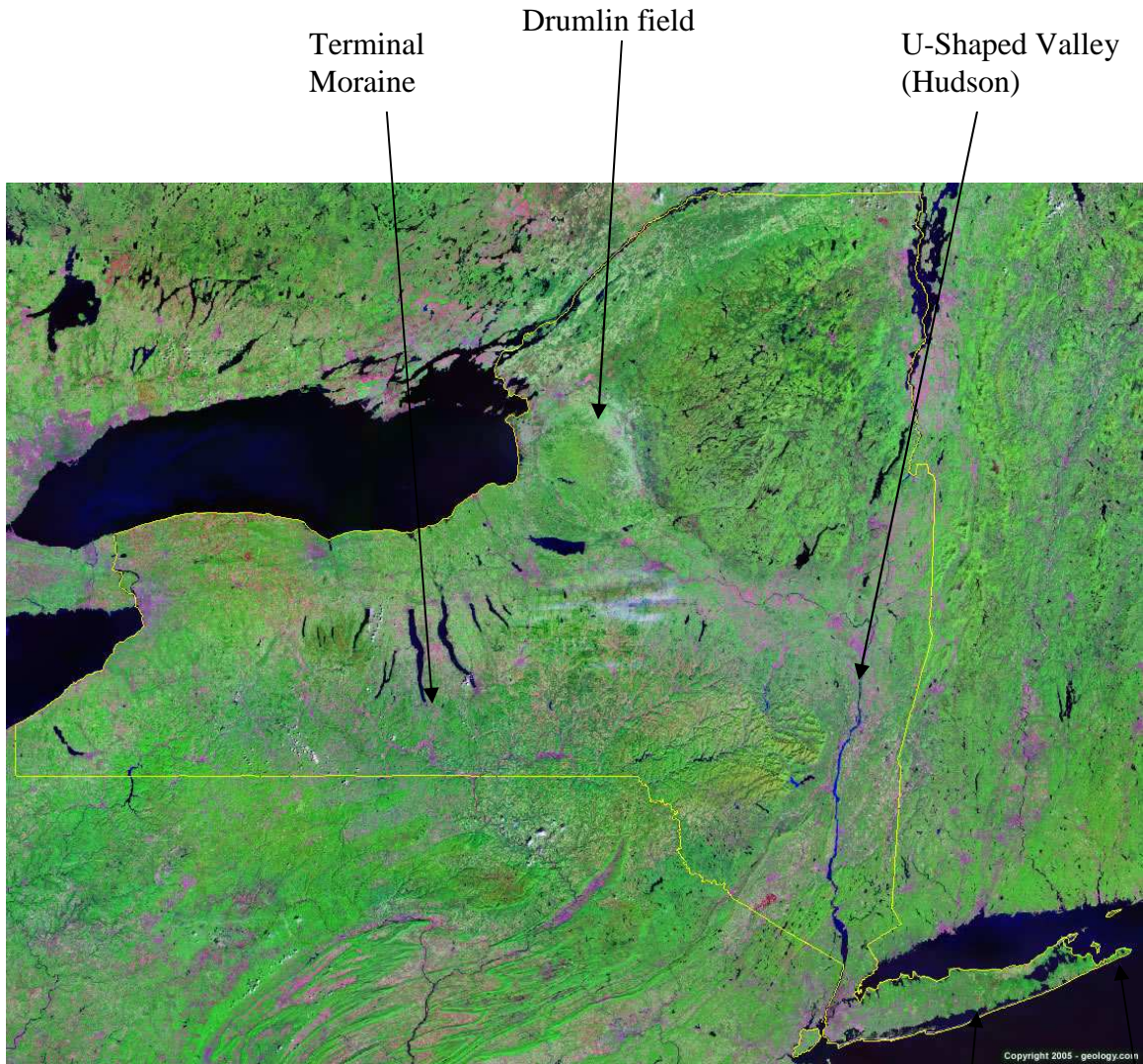
Ages? __there is less land in Southern Hemisphere so less glacial area__

Where are we now in the cycle? __scientists believe we are coming out of_

__an ice age._____

NAME: _____

DATE: _____



Terminal
Moraine

Drumlin field

U-Shaped Valley
(Hudson)

Ronkonkoma
Moraine

Valley Head
Moraine