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Chapter Presentation

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Objectives

- **Describe** how glaciers form.
- **Compare** two main kinds of glaciers.
- **Explain** two processes by which glaciers move.
- **Describe** three features of glaciers.

End Of Slide

Formation of Glaciers

glacier a large mass of moving ice

- Cycles of partial melting and refreezing change the snow into a grainy ice called *firn*.
- In deep layers of snow and firn, the pressure of the overlying layers flattens the ice grains and squeezes the air from between the grains.
- The continued buildup of snow and firn forms a glacier that moves downslope or outward under its own weight.

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Formation of Glaciers, *continued*

- The size of a glacier depends on the amount of snowfall received and the amount of ice lost.
- Small differences in average yearly temperatures and snowfall may upset the balance between snowfall and ice loss.
- Thus, changes in the size of a glacier may indicate climate change.

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Types of Glaciers

alpine glacier a narrow, wedge-shaped mass of ice that forms in a mountainous region and that is confined to a small area by surrounding topography; examples include valley glaciers, cirque glaciers, and piedmont glaciers

- The two main categories used to classify glaciers are alpine and continental.
- Alpine glaciers are located in Alaska, the Himalaya Mountains, the Andes, the Alps, and New Zealand.

End Of Slide

Types of Glaciers, *continued*

continental glacier a massive sheet of ice that may cover millions of square kilometers, that may be thousands of meters thick, and that is not confined by surrounding topography

- Today, continental glaciers, also called *ice sheets*, exist only in Greenland and Antarctica.
- If these ice sheets melted, the water they contain would raise the worldwide sea level by more than 80m.

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Resources

Reading Check

Where can you find continental glaciers today?

End Of Slide

Reading Check

Where can you find continental glaciers today?

Continental glaciers exist only in Greenland and Antarctica.

Movement of Glaciers

- Gravity causes both glaciers and rivers to flow downward.
- Unlike water in a river, glacial ice cannot move rapidly or flow easily around barriers. In a year, some glaciers may travel only a few centimeters, while others may move a kilometer or more.
- Glaciers move by two basic processes—basal slip and internal plastic flow.

End Of Slide

Movement of Glaciers, *continued*

Basal Slip

basal slip the process that causes the ice at the base of a glacier to melt and the glacier to slide

- One way that glaciers move is by slipping over a thin layer of water and sediment that lies between the ice and the ground.
- The weight of the ice in a glacier exerts pressure that lowers the melting point of ice. As a result, the ice melts where the glacier touches the ground.

End Of Slide

Movement of Glaciers, *continued*

Basal Slip, *continued*

- The water mixes with sediment at the base of the glacier. This mixture acts as a lubricant between the ice and the underlying surfaces.
- Basal slip also allows a glacier to work its way over small barriers in its path by melting and then refreezing.
- The water from the melted ice travels around the barrier and freezes again as the pressure is removed.

End Of Slide

Movement of Glaciers, *continued*

Internal Plastic Flow

internal plastic flow the process by which glaciers flow slowly as grains of ice deform under pressure and slide over each other

- The rate of internal plastic flow varies for different parts of a glacier. The slope of the ground and the thickness and temperature of the ice determine the rate at which ice flows at a given point.
- The edges of a glacier move more slowly than the center because of friction with underlying rock.

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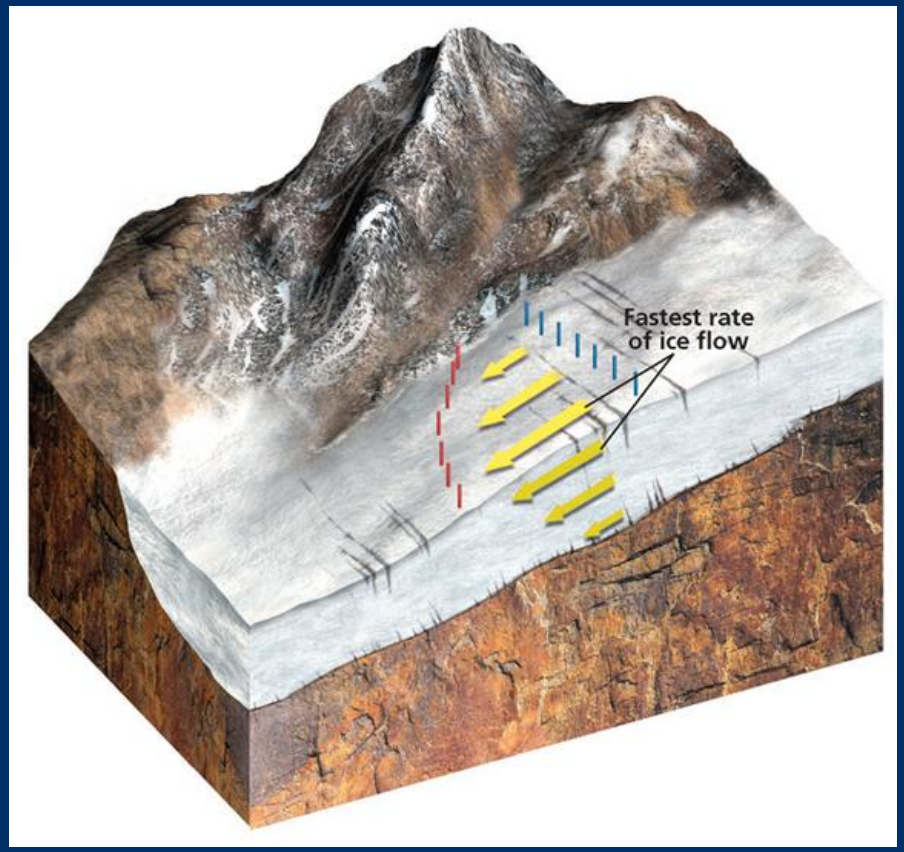
Movement of Glaciers, *continued*

The image below shows internal plastic flow.



End Of Slide

Features of Glaciers

crevasse in a glacier, a large crack or fissure that results from ice movement

- The glacier flows unevenly beneath the surface, and regions of tension and compression build under the brittle surface.

- Some parts of the ice sheets may move out over the ocean and form *ice shelves*. When the tides rise and fall, large blocks of ice, called *icebergs*, may break from the ice shelves and drift into the ocean.

End Of Slide

Continental and Alpine Glaciers

End Of Slide

Objectives

- **Describe** the landscape features that are produced by glacial erosion.
- **Name** and describe five features formed by glacial deposition.
- **Explain** how glacial lakes form.

End Of Slide

Glacial Erosion

- Like rivers, glaciers are agents of erosion.
- However, because of the size and density of glaciers, landforms that result from glacial action are very different from those that rivers form.
- For example, deep depressions in rock form when a moving glacier loosens and dislodges, or plucks, a rock from the bedrock at the base or side of the glacier.
- The rock plucked by the glacier is then dragged across the bedrock and causes abrasions.

End Of Slide

Glacial Erosion, *continued*

Landforms Created by Glacial Erosion

- The glacial processes that change the shape of mountains begin in the upper end of the valley where an alpine glacier forms.
- As a glacier moves through a narrow, V-shaped river valley, rock from the valley walls breaks off and the walls become steeper.
- The moving glacier also pulls blocks of rock from the floor of the valley.

End Of Slide

Glacial Erosion, *continued*

Landforms Created by Glacial Erosion, *continued*

cirque a deep and steep bowl-like depression produced by glacial erosion

arête a sharp, jagged ridge that forms between cirques

horn a sharp, pyramid-like peak that forms because of the erosion of cirques

End Of Slide

Glacial Erosion, *continued*

Landforms Created by Glacial Erosion, *continued*

- Rock particles embedded in the ice may polish solid rock as the ice moves over the rock.
- Glaciers may also round large rock projections.
- The resulting rounded knobs are called *roches moutonées*, which means “sheep rocks” in French.

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Reading Check

How does a glacier form a cirque?

End Of Slide

Reading Check

How does a glacier form a cirque?

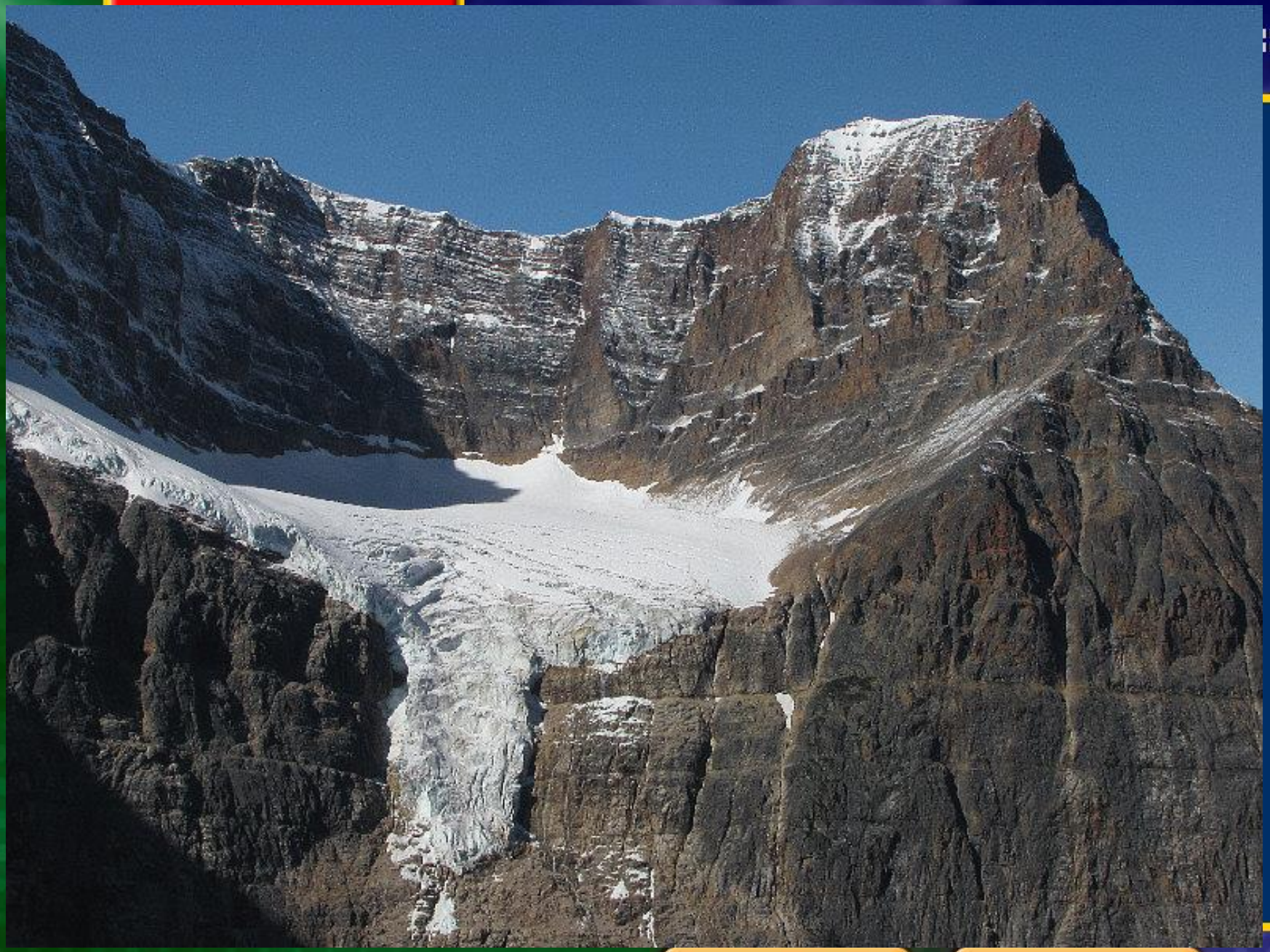
A moving glacier forms a cirque by pulling blocks of rock from the floor and walls of a valley and leaving a bowl-shaped depression.

End Of Slide

Glacial Erosion, *continued*

U-Shaped Valleys

- As a glacier scrapes away a valley's wall and floor, this original V shape becomes a U shape.
- Small tributary glaciers in adjacent valleys may flow into a main alpine glacier.
- When the ice melts, the tributary valley is suspended high above the main valley flow and is called a *hanging valley*.



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Glacial Erosion, *continued*

Erosion by Continental Glaciers

- The landscape eroded by continental glaciers differs from the sharp, rugged features eroded by alpine glaciers.
- Continental glaciers erode by leveling landforms to produce smooth, rounded landscape.
- Rock surfaces are also scratched and grooved by rocks carried at the base of the ice sheets.

End Of Slide

Glacial Deposition

erratic a large rock transported from a distant source by a glacier

- Deposition occurs when a glacier melts.
- As the glacier melts, it deposits all of the material that it has accumulated, which may range in size from fine sediment to large rocks.
- Because a glacier carries an erratic a long distance, the composition of an erratic usually differs from that of the bedrock over which the erratic lies.

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Resources

Glacial Deposition, *continued*

glacial drift rock material carried and deposited by glaciers

till unsorted rock material that is deposited directly by a melting glacier

- Another type of glacial drift is stratified drift. *Stratified drift* is material that has been sorted and deposited in layers by streams flowing from the melted ice, or *meltwater*.

End Of Slide

Glacial Deposition, *continued*

Till Deposits

moraine a landform that is made from unsorted sediments deposited by a glacier

- A *lateral moraine* is a moraine that is deposited along the sides of an alpine glacier, usually as a long ridge.
- When two or more alpine glaciers join, their adjacent lateral moraines combine to form a *medial moraine.*

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Glacial Deposition, *continued*

Till Deposits, *continued*

- The unsorted material left beneath the glacier when the ice melts is the *ground moraine*. The soil of a ground moraine is commonly very rocky.
- An ice sheet may mold ground moraine into clusters of drumlins. *Drumlins* are long, low, tear-shaped mounds of till.
- *Terminal moraines* are small ridges of till that are deposited at the leading edge of a melting glaciers.

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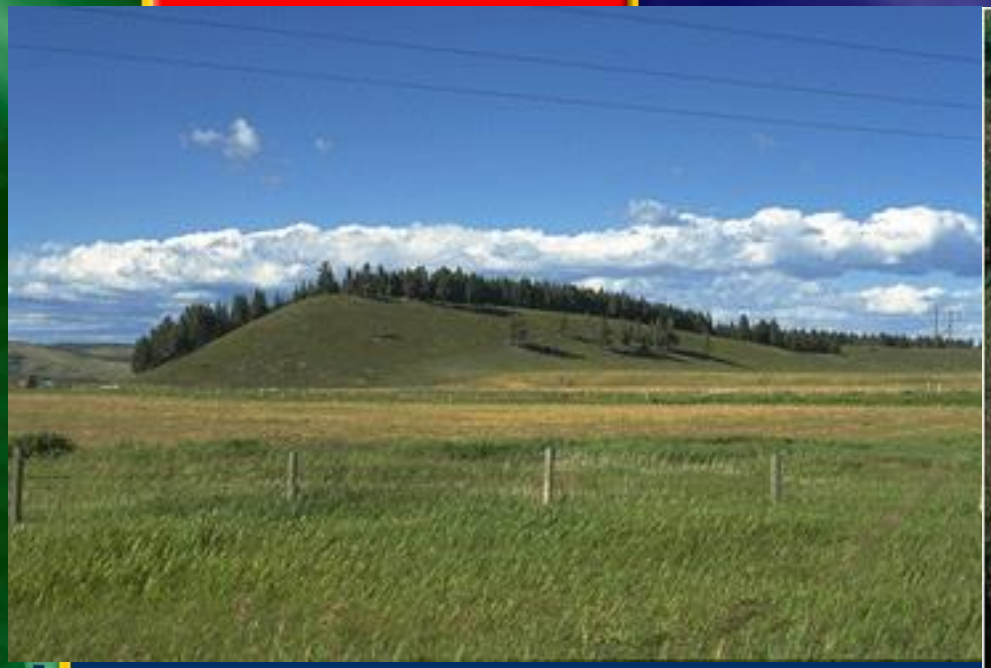

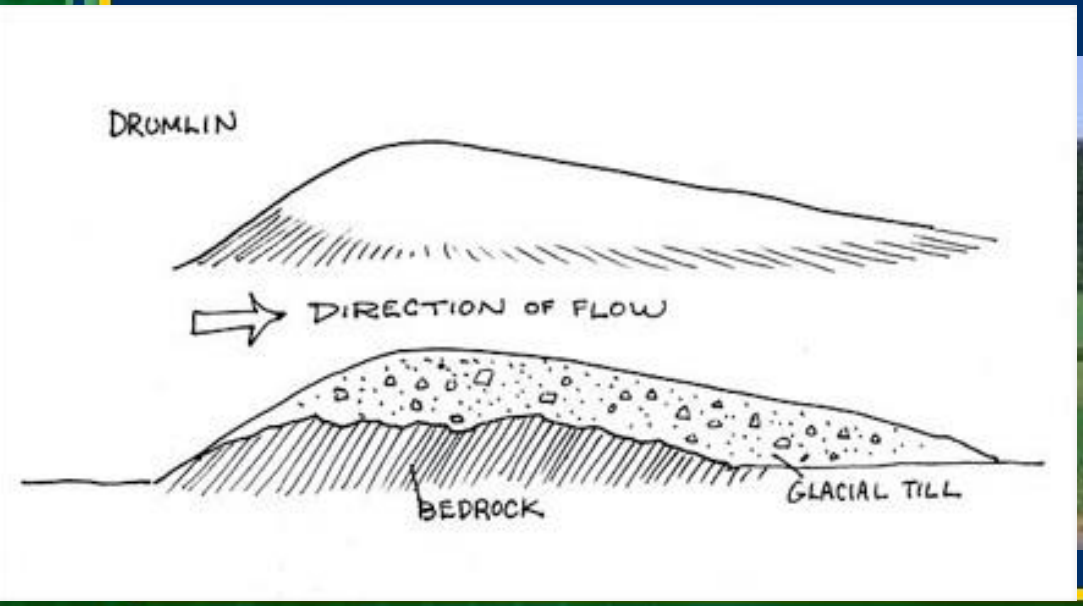

Chapter menu

Resources

Reading Check

Which glacial deposit is a tear-shaped mound of sediment?

End Of Slide

Reading Check

Which glacial deposit is a tear-shaped mound of sediment?

A drumlin is a long, low, tear-shaped mound of till.

End Of Slide

Glacial Deposition, *continued*

Outwash Plains

- When a glacier melts, streams of meltwater flow from the edges, the surface, and beneath the glacier.
- The meltwater carries drift as well as rock particles and deposits them in front of the glacier as a large outwash plain.
- An *outwash plain* is a deposit of stratified drift that lies in front of a terminal moraine and is crossed by many meltwater streams.

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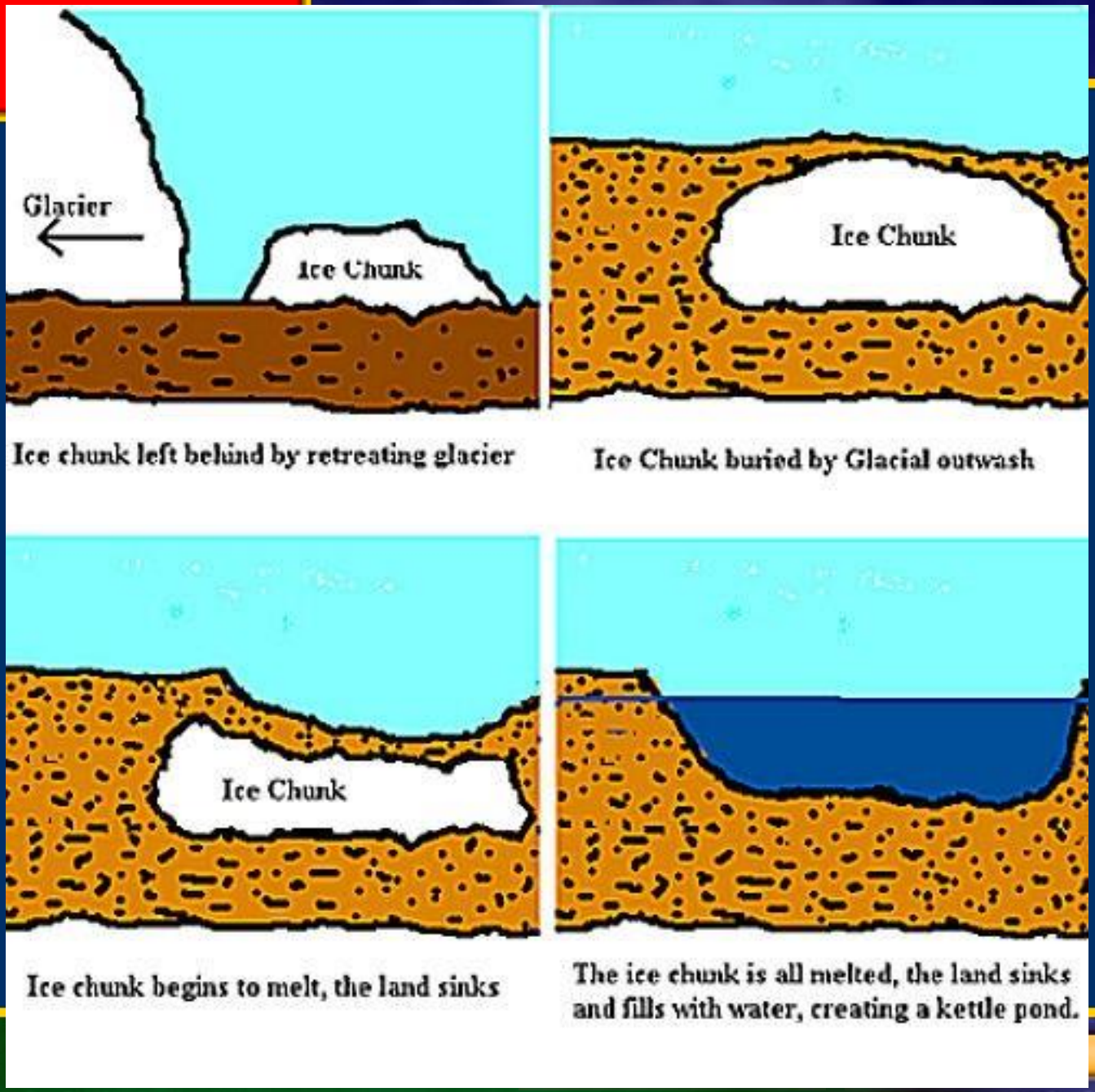
Glacial Deposition, *continued*

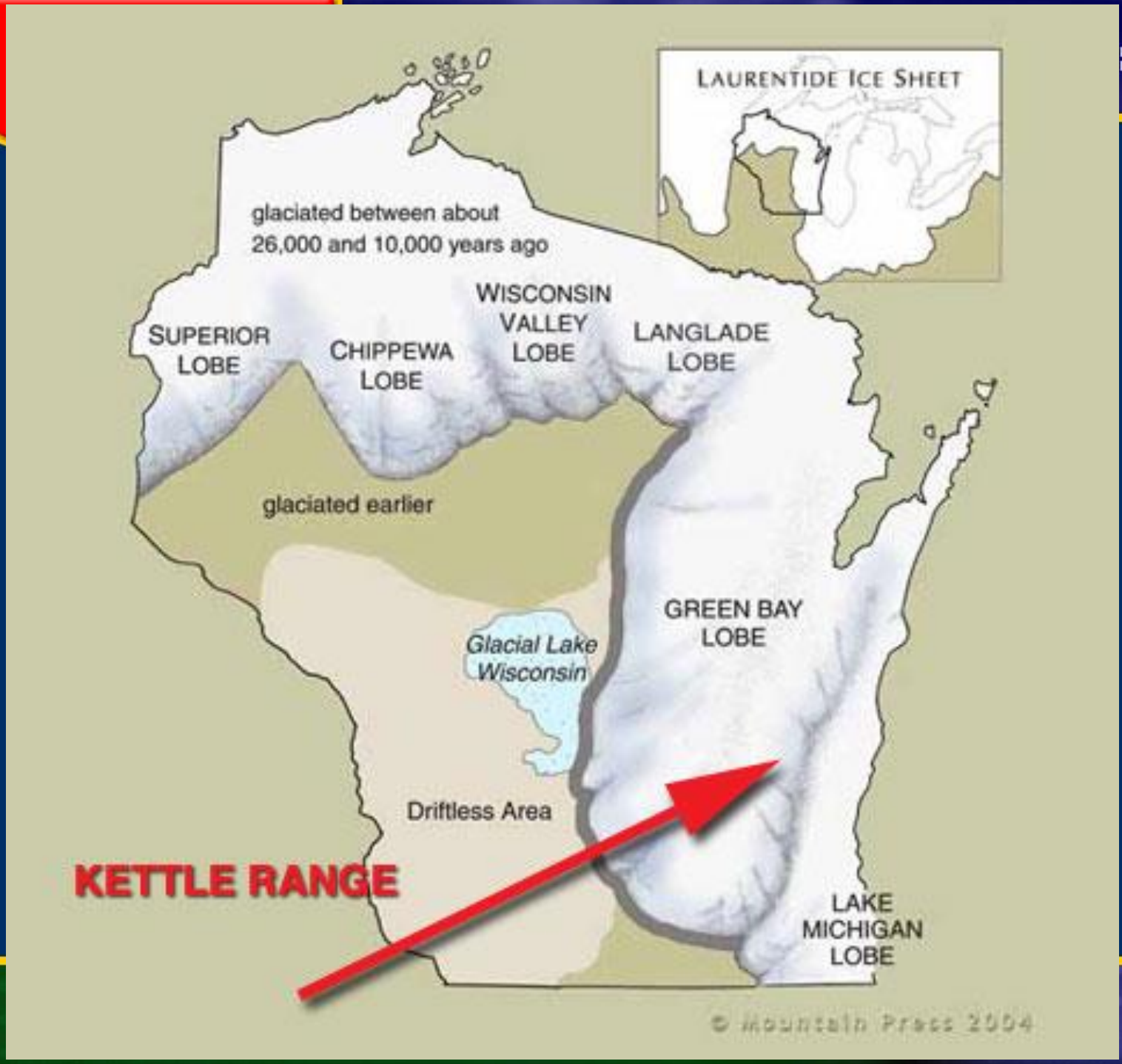
Kettles

kettles a bowl-like depression in a glacial drift deposit

- A kettle forms when a chunk of glacial ice is buried in a drift.
- As the ice melts, a cavity forms in the drift. The drift collapses into the cavity and produces a depression.
- Kettles commonly fill with water to form kettle lakes.

End Of Slide




LAURENTIDE ICE SHEET
glaciated between about
26,000 and 10,000 years ago
SUPERIOR
LOBE
CHIPPEWA
LOBE
WISCONSIN
VALLEY
LOBE
LANGLADE
LOBE
glaciated earlier
GREEN BAY
LOBE
Glacial Lake
Wisconsin
Driftless Area
KETTLE RANGE
LAKE
MICHIGAN
LOBE
© Mountain Press 2004

Glacial Deposition, *continued*

Eskers

esker a long, winding ridge of gravel and coarse sand deposited by glacial meltwater streams

- When continental glaciers recede, eskers may be left behind. These ridges consist of stratified drift deposited by streams of meltwater that flow through ice tunnels within the glaciers.
- Eskers may extend for tens of kilometers, like raised, winding roadways.

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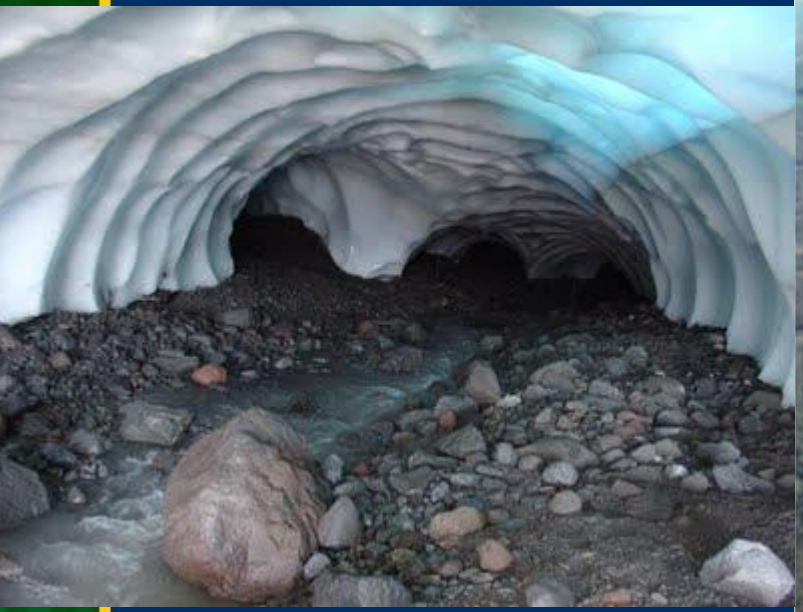

7

Glacial Deposition, *continued*

The image below shows the features of glacial deposition.

End Of Slide

Reading Check

How do eskers form?

End Of Slide

Reading Check

How do eskers form?

Eskers form when meltwater from receding continental glaciers flow through ice tunnels and deposits long, winding ridges of gravel and sand.

End Of Slide

Glacial Lakes

- Lake basins commonly form where glaciers erode surfaces and leave depressions in the bedrock.
- Many lakes form in the uneven surface of ground moraine deposited by glaciers.
- Long, narrow *finger lakes*, such as those in western New York, form where terminal and lateral moraines block existing streams.

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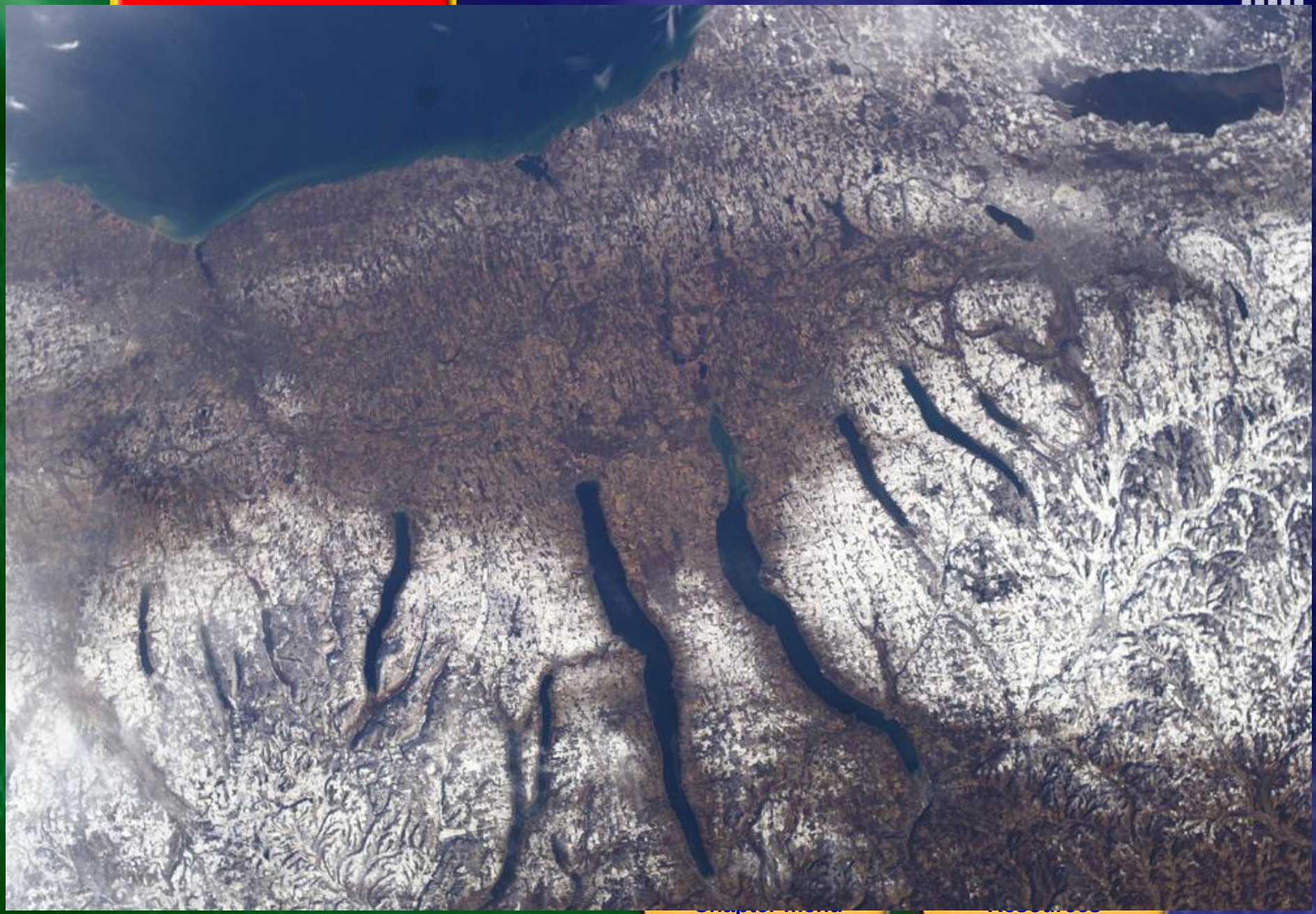


Glacial Lakes, *continued*

Formation of Salt Lakes

- Because of topographic and climatic changes, outlet streams no longer leave these lakes.
- Water leaves the lakes only by evaporation. When the water evaporates, salt that was dissolved in the water is left behind, which makes the water increasingly salty.
- Salt lakes commonly form in dry climates, where evaporation is rapid and precipitation is low.

End Of Slide

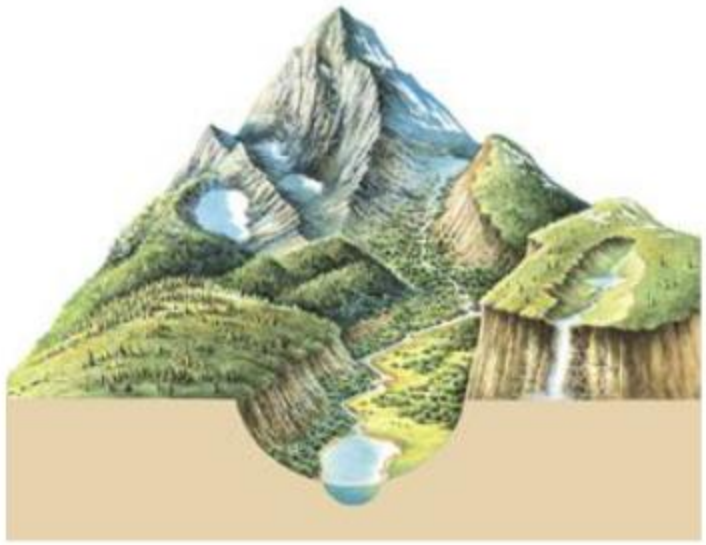
Glacial Lakes, *continued*

History of the Great Lakes

- The Great Lakes of North America formed as a result of erosion and deposition by a continental glacier.
- Glacial erosion widened and deepened existing river valleys.
- As the ice sheets melted, the meltwater was trapped in the valleys by the moraines and lakes formed.

End Of Slide

Landforms Carved by Glaciers



Rollover the image to learn more.

Objectives

- **Describe** glacial and interglacial periods within an ice age.
- **Summarize** the theory that best accounts for the ice ages.

End Of Slide

Ice Ages

ice age a long period of climatic cooling during which the continents are glaciated repeatedly

- Today, continental glaciers are located mainly in latitudes near the North and South Poles.
- Several major ice ages have occurred during Earth's geologic history.
- A drop in average global temperature of only about 5°C may be enough to start an ice age.

End Of Slide

Glacial and Interglacial Periods

- Continental glaciers advance and retreat several times during an ice age.
- A period of cooler climate that is characterized by the advancement of glaciers is called a *glacial period*.
- A period of warmer climate that is characterized by the retreat of glaciers is called an *interglacial period*.

End Of Slide

Glacial and Interglacial Periods, *continued*

Glaciation in North America

- Glaciers covered about one-third of Earth's surface during the last glacial period. Most glaciation took place in North America and Eurasia.
- So much water was locked in ice during the last glacial period that sea level was as much as 140 m lower than it is today.
- As a result, the coastlines of the continents extended farther than they do today.

End Of Slide

Reading Check

How did glaciation in the last glacial period affect the sea level?

End Of Slide

Reading Check

How did glaciation in the last glacial period affect the sea level?

The sea level was up to 140 m lower than it is now.

Glacial and Interglacial Periods, *continued*

Glaciation in Eurasia and the Southern Hemisphere

- In Europe, a continental ice sheet that was centered on what is now the Baltic Sea spread south over Germany, Belgium, and the Netherlands and west over Great Britain and Ireland.
- In the Southern Hemisphere, the Andes Mountains in South America and much of New Zealand were covered by mountainous ice fields and alpine glaciers.

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Causes of Ice Ages

The Milankovitch Theory

Milankovitch theory the theory that cyclical changes in Earth's orbit and in the tilt of the Earth's axis occur over thousands of years and cause climatic changes

- According to the Milankovitch theory, the distribution of solar radiation that Earth receives varies because of three kinds of changes in Earth's position relative to the sun.

End Of Slide

Causes of Ice Ages, *continued*

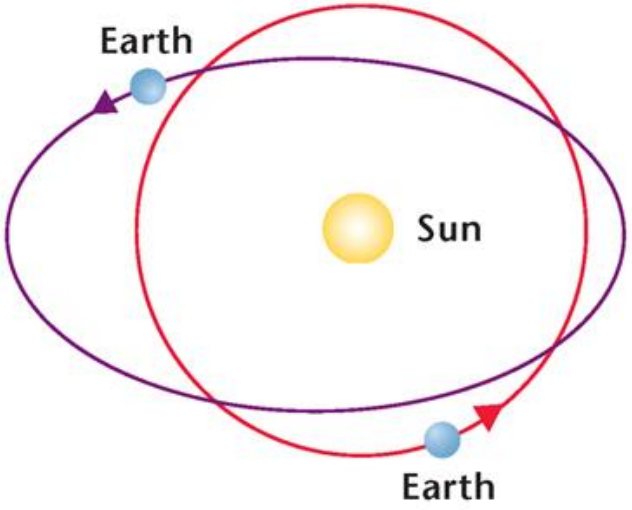
The Milankovitch Theory

- These changes are caused by regular changes in the eccentricity of Earth's orbit, the tilt of Earth's axis, and precession.
- Changes in the distribution of solar energy affects global temperatures, which may cause an ice age.

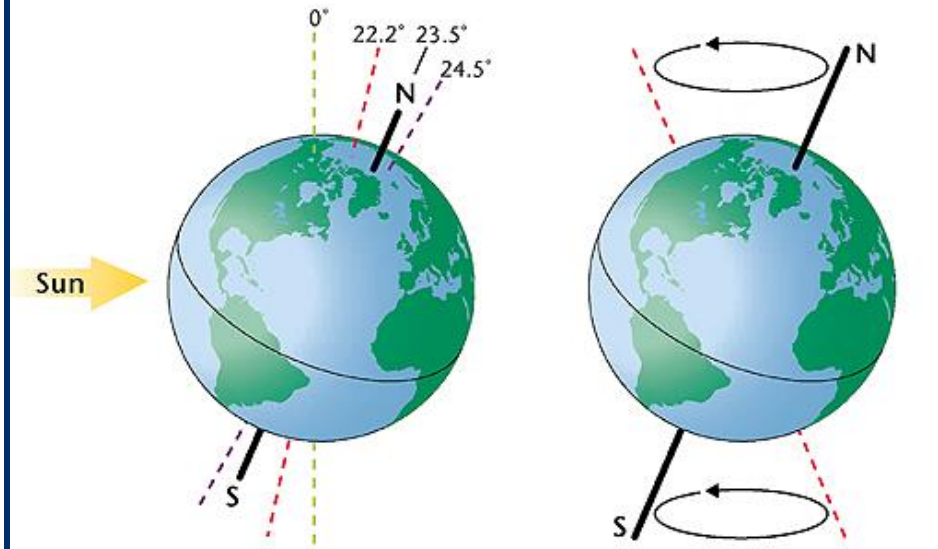
End Of Slide

Causes of Ice Ages, *continued*

The image below shows how the Milankovitch theory explains ice ages.



Eccentricity Changes in orbital eccentricity cause an increase in seasonality in one hemisphere and reduce seasonality in the other hemisphere.



Tilt Over a period of 41,000 years, the tilt of Earth's axis varies between 22.2° and 24.5°. The poles receive more solar energy when the tilt angle is greater.

Precession The wobble of Earth's axis affects the amount of solar radiation that reaches different parts of Earth's surface at different times of the year.

End Of Slide

Causes of Ice Ages, *continued*

Evidence for Multiple Ice Ages

- Evidence for past ice ages has been discovered in the shells of dead marine animals found on the ocean floor.
- Scientists have found that the record of ice ages in marine sediments closely follows the cycle of cooling and warming predicted by the Milankovitch theory.

End Of Slide

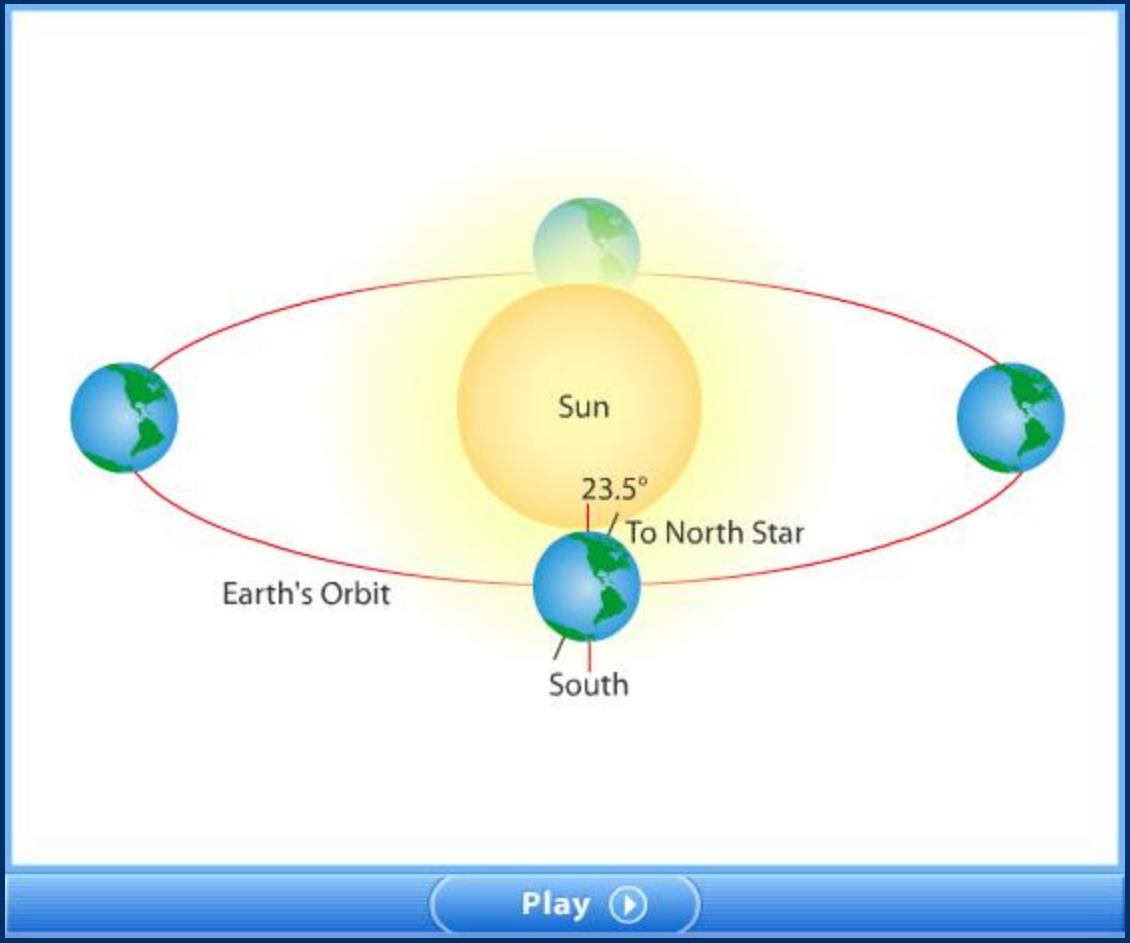
Causes of Ice Ages, *continued*

Other Explanations for Ice Ages

- Some scientists propose that changes in solar energy are caused by varying amounts of energy produced by the sun. Other scientists suggest that ice ages start when volcanic dust blocks the sun's rays.
- Yet another explanation proposes that plate tectonics may cause ice ages, because changes in the positions of continents cause changes in global patterns of warm and cold air and ocean circulation.

End Of Slide

Milankovitch Theory



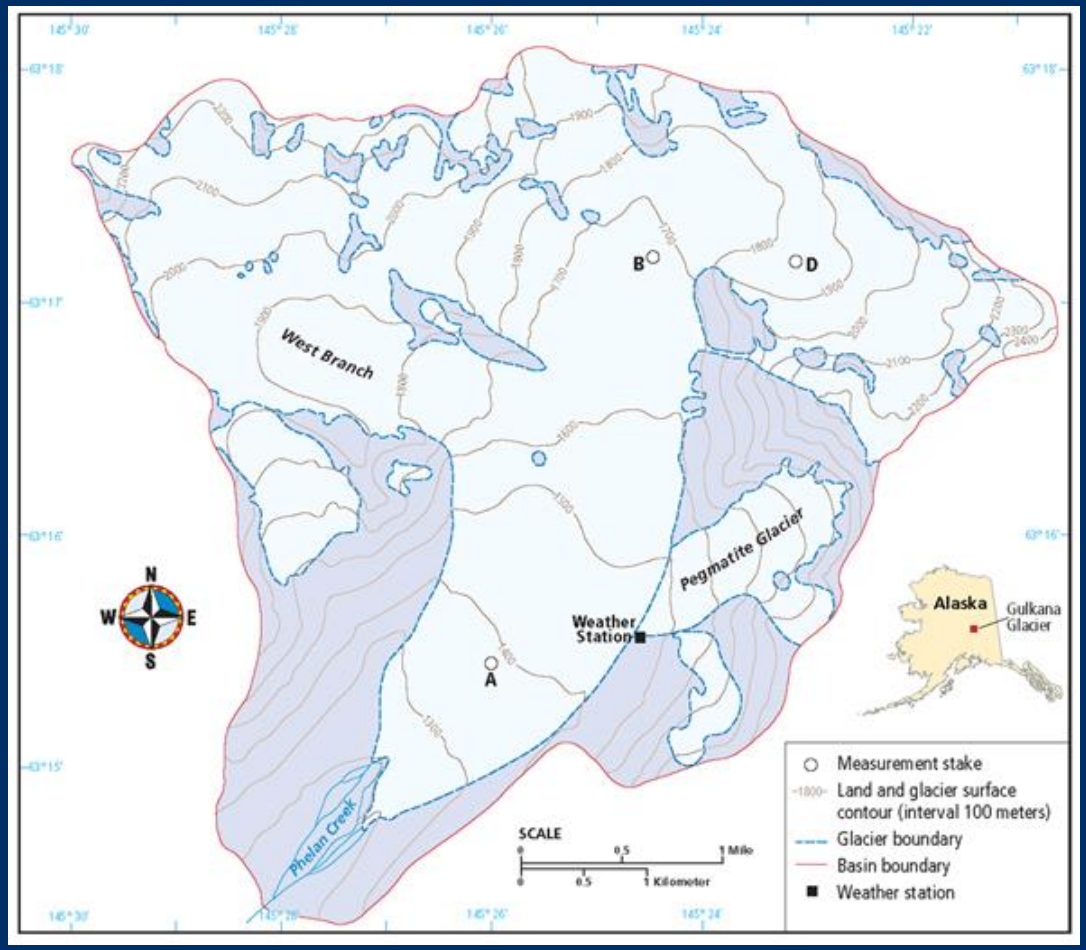
End Of Slide

Brain Food Video Quiz

End Of Slide

Maps in Action

Gulkana Glacier



End Of Slide

Multiple Choice

1. Which statement *best* compares the movement of glacial ice to the movement of river water?

   A. Glacial ice moves more rapidly than water.
   B. Glacial ice cannot easily flow around barriers.
   C. Glacial ice moves in response to gravity.
   D. Glacial ice moves in the same way as water.

Multiple Choice, *continued*

1. Which statement *best* compares the movement of glacial ice to the movement of river water?

   A. Glacial ice moves more rapidly than water.
   B. Glacial ice cannot easily flow around barriers.
   C. Glacial ice moves in response to gravity.
   D. Glacial ice moves in the same way as water.

Multiple Choice, *continued*

2. What landform created by glaciers has a bowl-like shape?

F. cirque
G. arête
H. horn
I. roches moutonées

Multiple Choice, *continued*

2. What landform created by glaciers has a bowl-like shape?

F. cirque
G. arête
H. horn
I. roches moutonées

Multiple Choice, *continued*

3. What is the unsorted material left beneath a glacier when the ice melts?

A. lateral moraine
B. ground moraine
C. medial moraine
D. terminal moraine

Multiple Choice, *continued*

3. What is the unsorted material left beneath a glacier when the ice melts?

A. lateral moraine
B. ground moraine
C. medial moraine
D. terminal moraine

Multiple Choice, *continued*

4. Which of the following statements *best* describes how crevasses form on the surface of a glacier?

F. Movement of the glacier's ice from the center toward the edges forms large cracks on the surface of the glacier.

G. As the ice flows unevenly beneath the surface of the glacier, tension and compression on the surface form large cracks.

H. Breakage of large blocks of ice from the edges of ice shelves forms large cracks.

I. Narrow, wedge-shaped masses of ice confined to a small area form large cracks.

Multiple Choice, *continued*

4. Which of the following statements *best* describes how crevasses form on the surface of a glacier?

F. Movement of the glacier's ice from the center toward the edges forms large cracks on the surface of the glacier.

G. As the ice flows unevenly beneath the surface of the glacier, tension and compression on the surface form large cracks.

H. Breakage of large blocks of ice from the edges of ice shelves forms large cracks.

I. Narrow, wedge-shaped masses of ice confined to a small area form large cracks.

Short Response, *continued*

5. What is the term for all types of sediments deposited by a glacier?

Short Response, *continued*

5. What is the term for all types of sediments deposited by a glacier?

glacial drift

Short Response, *continued*

6. What is the name of a jagged ridge that is formed between two or more cirques that cut into the same mountain?

Short Response, *continued*

6. What is the name of a jagged ridge that is formed between two or more cirques that cut into the same mountain?

arêtes

Reading Skills

Read the passage below. Then, answer questions 7–9.

Glacial and Interglacial Periods

Ice ages are periods during which ice collects in high latitudes and moves toward lower latitudes. During ice ages, there are periods of cold and of warmth. These periods are called *glacial and interglacial periods*. During glacial periods, enormous sheets of ice advance, grow bigger, and cover a large area. Because a large amount of sea water is frozen during glacial periods, the sea level around the world drops.

Warmer time periods that occur between glacial periods are known as interglacial periods. During an interglacial period, the large ice sheets begin to melt and the sea levels begin to rise again. Scientists believe that the last interglacial period began approximately 10,000 years ago and is still happening. For nearly 200 years, scientists have been debating what the current interglacial period might mean for humans and the possibility of a future glacial period.

Reading Skills, *continued*

7. According to the passage, which of the following statements is true?

   A. The last interglacial period began approximately 1,000 years ago.
   B. Scientists have been thinking about the next glacial period for two centuries.
   C. Ice ages are periods during which ice collects in the lower latitudes and moves toward higher latitudes.
   D. During glacial periods, enormous sheets of ice tend to melt, so they become smaller and cover less area.

Reading Skills, *continued*

7. According to the passage, which of the following statements is true?

A. The last interglacial period began approximately 1,000 years ago.

B. Scientists have been thinking about the next glacial period for two centuries.

C. Ice ages are periods during which ice collects in the lower latitudes and moves toward higher latitudes.

D. During glacial periods, enormous sheets of ice tend to melt, so they become smaller and cover less area.

Reading Skills, *continued*

8. Which of the following statements can be inferred form the information in the passage?

F. On average, ice ages occur every 50,000 years and always start with a glacial period.

G. Interglacial periods always last 10,000 years.

H. Glacial periods always last 10,000 years.

I. The current interglacial period will likely be followed by a glacial period.

Reading Skills, *continued*

8. Which of the following statements can be inferred form the information in the passage?

F. On average, ice ages occur every 50,000 years and always start with a glacial period.

G. Interglacial periods always last 10,000 years.

H. Glacial periods always last 10,000 years.

I. The current interglacial period will likely be followed by a glacial period.

Reading Skills, *continued*

9. If a new glacial period began tomorrow, what might happen to coastal cities?

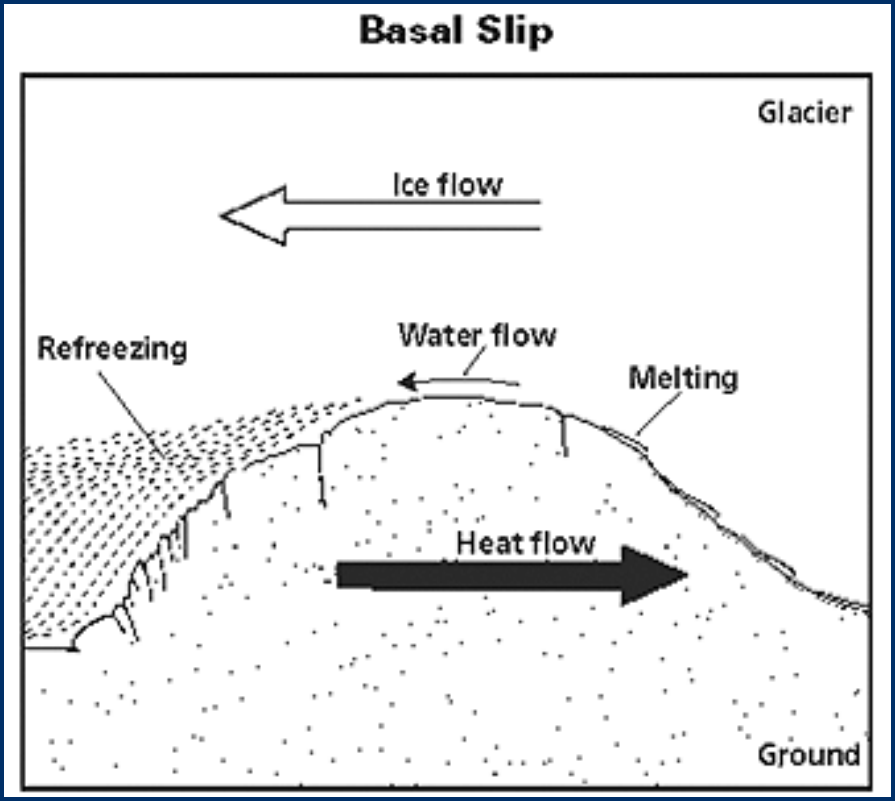
Reading Skills, *continued*

9. If a new glacial period began tomorrow, what might happen to coastal cities?

As sea levels decreased, some coastal cities might become landlocked. Due to the withdrawal of ocean water, they may also experience changes in local wind and weather patterns.

Interpreting Graphics

Use the figure below to answer questions 10 and 11.



Interpreting Graphics, *continued*

10. What causes the ice to melt in the diagram above?

A. Pressure decreases the melting point of the ice.
B. Pressure increases the melting point of the ice.
C. The ground heats the ice until it melts.
D. Ice at the base of a glacier does not melt.

Interpreting Graphics, *continued*

10. What causes the ice to melt in the diagram above?

A. Pressure decreases the melting point of the ice.
B. Pressure increases the melting point of the ice.
C. The ground heats the ice until it melts.
D. Ice at the base of a glacier does not melt.

Interpreting Graphics, *continued*

11. How does meltwater influence basal slip?

Interpreting Graphics, *continued*

11. How does meltwater influence basal slip?

Answers should include: as pressure builds up, heat energy is created which causes the ice to melt; meltwater acts as a lubricant, decreasing friction between the glacier and the underlying obstacle, and allows the glacier to slide over obstacles; once past the obstacle, the pressure decreases and the meltwater refreezes.

Interpreting Graphics, *continued*

Use the table below to answer question 12.

World Cities and Their Elevations

City	Elevation (m)
New York City	27
Kiev, Ukraine	168
Buenos Aries, Argentina	25
Amsterdam, Netherlands	2

Interpreting Graphics, *continued*

12. What would happen to each of the cities listed in the table if the Antarctic ice sheet were to melt and raise the sea level by 50 m?

Interpreting Graphics, *continued*

12. What would happen to each of the cities listed in the table if the Antarctic ice sheet were to melt and raise the sea level by 50 m?

Only Kiev would remain above sea level. The other cities would be below sea level by as few as 23 m (New York) and as much as 48 m (Amsterdam).

Interpreting Graphics, *continued*

13. The movement of a glacier was recorded over a period of 180 days. During that time, the glacier moved a total of 36 m. What was the average speed of the glacier each day?

F. 0.20 m/day

G. 0.50 m/day

H. 2.00 m/day

I. 5.00 m/day

Interpreting Graphics, *continued*

13. The movement of a glacier was recorded over a period of 180 days. During that time, the glacier moved a total of 36 m. What was the average speed of the glacier each day?

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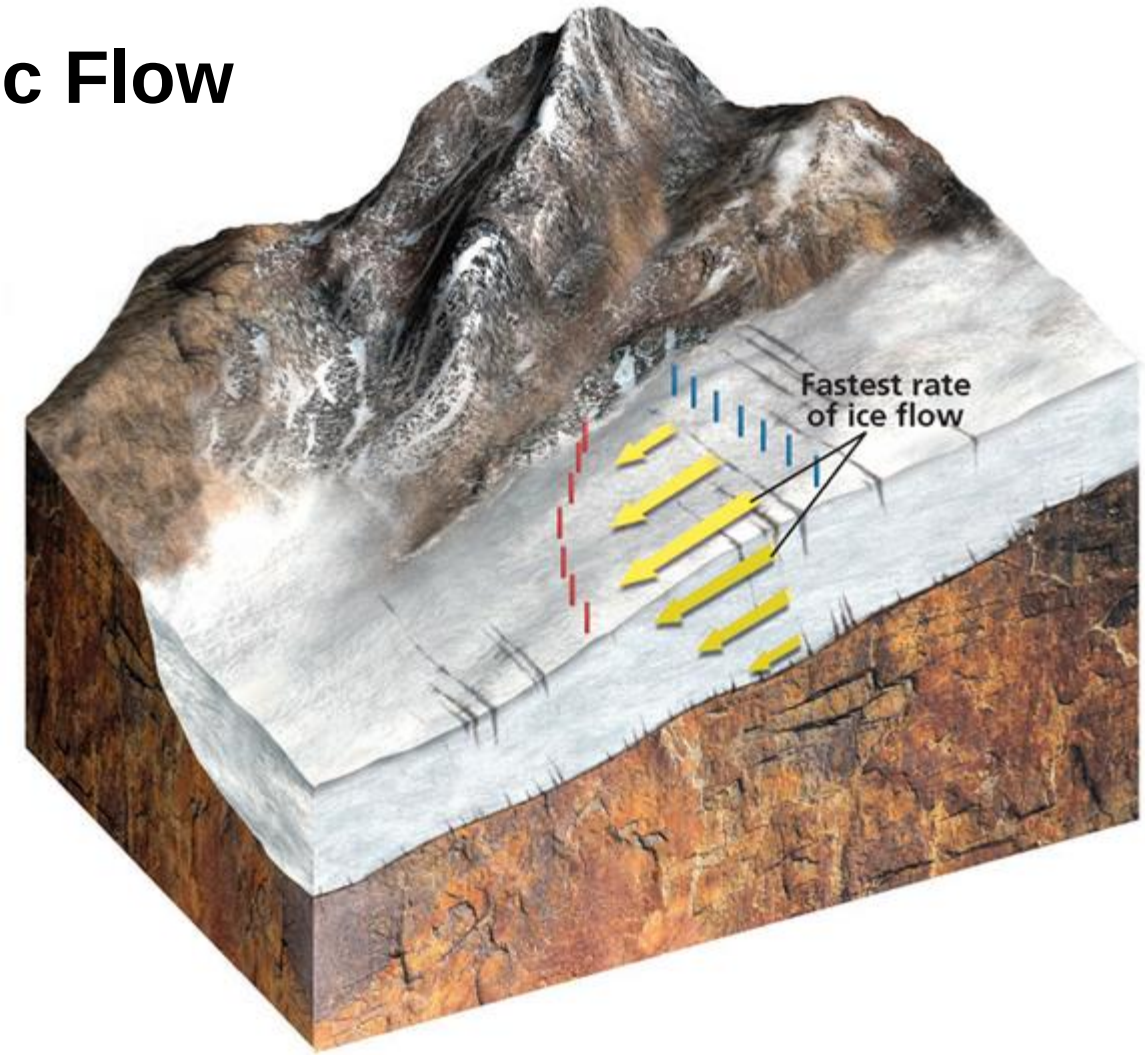
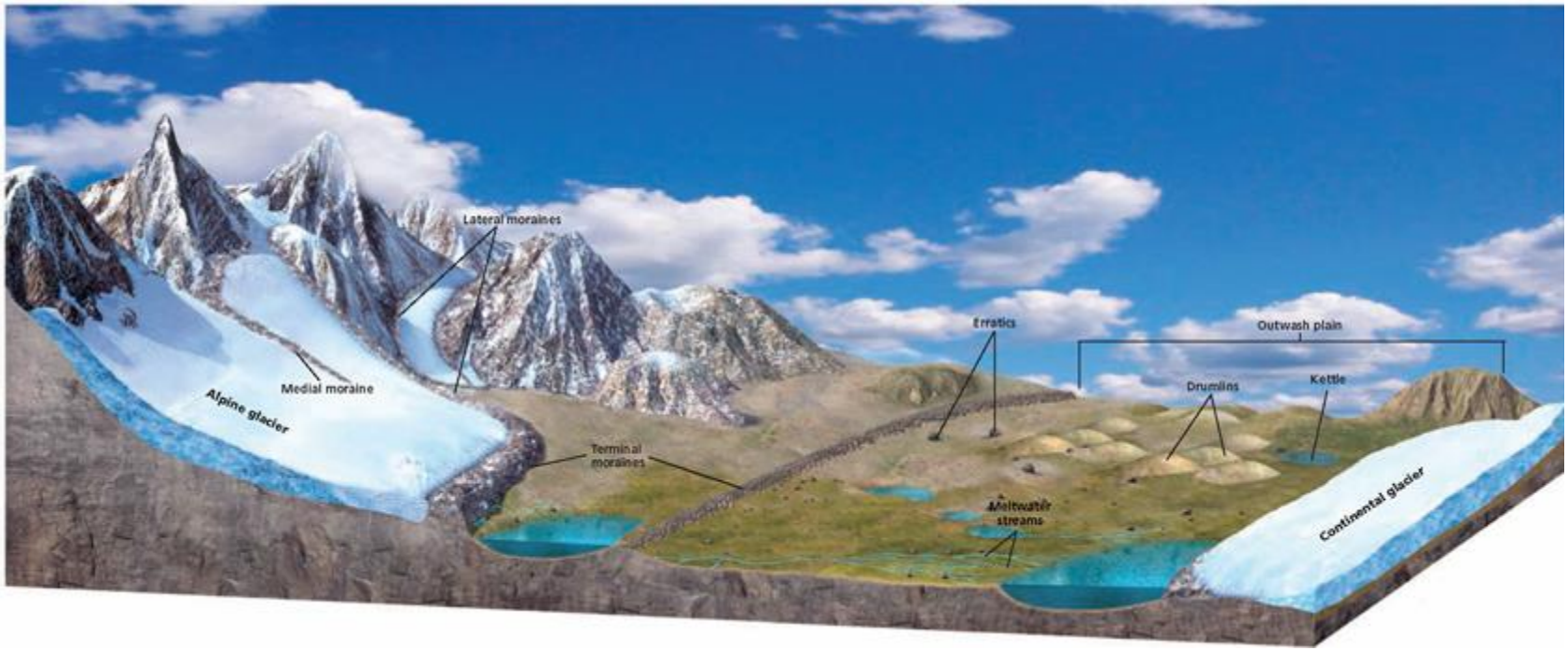
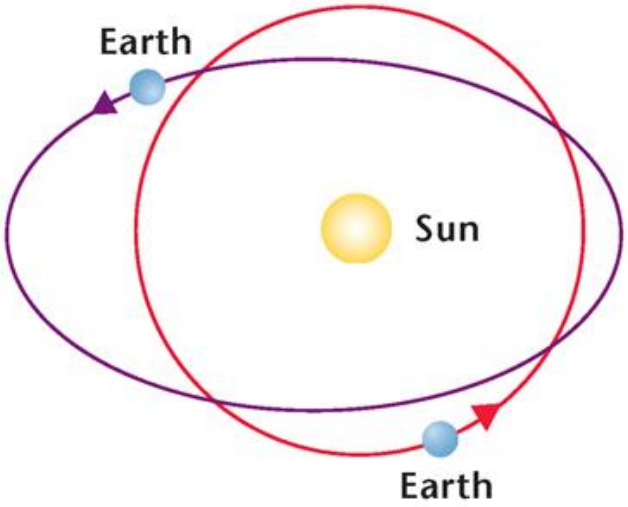
Internal Plastic Flow



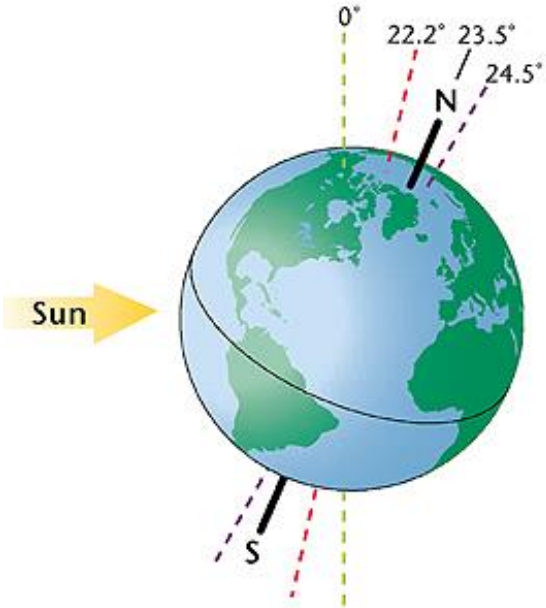
Features of Glacial Deposition



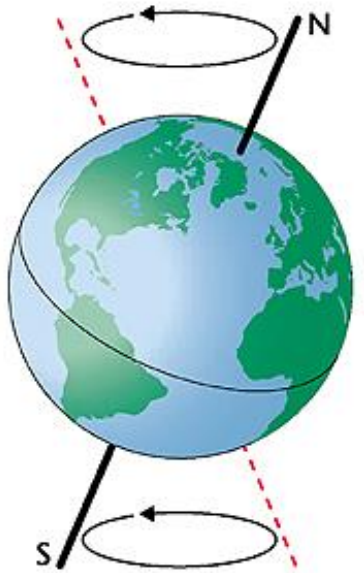
The Milankovitch Theory



Eccentricity Changes in orbital eccentricity cause an increase in seasonality in one hemisphere and reduce seasonality in the other hemisphere.



Tilt Over a period of 41,000 years, the tilt of Earth's axis varies between 22.2° and 24.5°. The poles receive more solar energy when the tilt angle is greater.



Precession The wobble of Earth's axis affects the amount of solar radiation that reaches different parts of Earth's surface at different times of the year.

Chapter 17

Gulkana Glacier