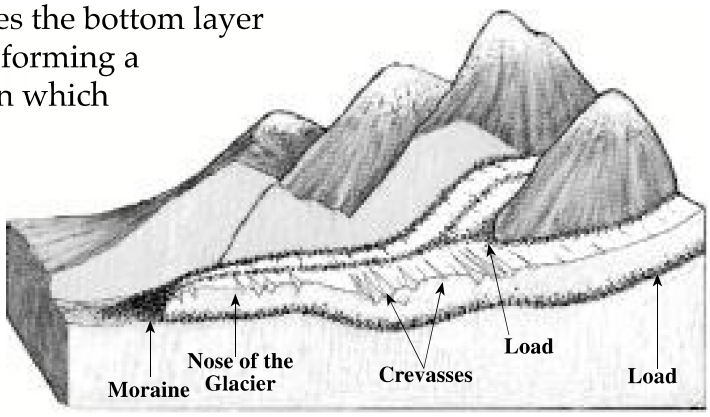
Introduction

Many of our most beautiful hills and valleys are the result of years of erosion by ice and snow. During the time when the temperature of Earth was extremely low, massive amounts of snow and ice formed large **glaciers** which moved outward from the poles of Earth. The formation and movement of glaciers is important to the understanding of the **ice ages** and our rock formations as we know them today.

Glaciers

A *glacier* is a huge mass of moving ice and snow. It forms where more snow falls in the winter than melts during the summer. When the snow accumulation builds to about 60 meters, the weight of the snow causes the bottom layer to be squeezed together, forming a sheet of ice. If the land on which the glacier is formed is sloped, the glacier will move down the slope. If it is formed on flat land, it will spread out in all directions.



Types and Formation

There are three types of glaciers: piedmont, alpine, and continental. **Piedmont glaciers** form at the foot of some mountains. These glaciers spread out on the plains and join one another, making a continuous sheet of ice. A second type of glacier that forms high in the mountains is called an **alpine glacier**. Alpine glaciers are also called an **valley glacier**. They usually move downward through river valleys due to the pull of gravity.

The third type of glacier is the continental. **Continental glaciers** are very large sheets of ice that move outward in all directions from a central point. Unlike alpine glaciers, they are not confined to valleys, but cover large areas of land surfaces. They form in the polar regions and are sometimes called *polar ice caps*. The only continental glaciers existing today are found in Greenland and Antarctica.

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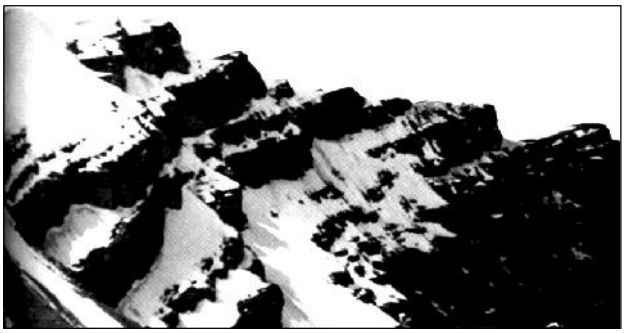
Erosion and Movement

Although their movement is not visible, most glaciers are thought to be moving or sliding along the ground. As glaciers move through an area, they completely change the surface of that area by erosion. Glaciers scrape away all loose particles of rock and pile them up in huge mounds, like a bulldozer at work. Glaciers erode by **abrading** and **plucking**.

Abrading is the scraping of the bedrock surface over which the ice moves. The results of this are similar to using a scouring pad on a soiled pot or pan. As the ice moves, it scrapes over rocks, scouring and polishing the surface of rocks beneath it.

Plucking combines freezing and pulling forces. The sun warms the rocks, ice melts and water runs into cracks in the rocks. When the water freezes again and expands, the rocks break. The rocks become part of the bottom of the moving glacier. In this way, the glacier lifts and carries rocks, sand, gravel, and even large boulders with it. Plucking adds to the scouring power of the glacier.



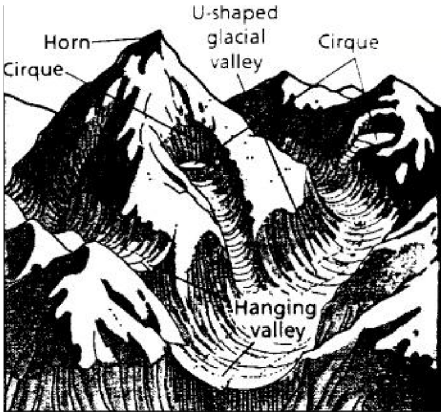
As glacial ice moves, sharp rocks make gouges and scratches called **striations** in the rock beneath it. Glaciers dig into soft rock more deeply than hard rock, leaving step-like irregularities in the land that they pass over.

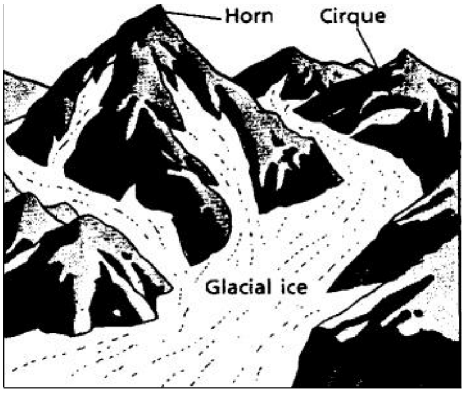
Valley glaciers begin in a **cirque**, a bowl-shaped depression filled with ice and snow. The glacier that forms in a cirque may actually grow and extend to the mountain's summit. In some places, valley glaciers erode the

cirques, forming three-sided peaks called **horns**. The Matterhorn in the Swiss Alps is an example of a horn.

When the cirque overflows, the glacier begins moving down the valley. As a glacier moves through narrow, V-shaped valleys once occupied by a stream or river, it widens, deepens, and straightens the valley. It changes the shape of the V-shaped valley to a U-shaped one.

Just as tributaries join to form rivers, small glaciers join to form larger glaciers. As the smaller glaciers melt and disappear, their valleys no longer erode. The valley of the main glacier continues to erode until it is much lower than the abandoned valley of the smaller glacier. The abandoned valley is left suspended on the mountain high above the main valley floor and is called a **hanging valley**. When the river again flows through the small valleys, waterfalls are created as the river plunges into the deeper valley. The waterfalls of Yosemite National Park in California spill from hanging valleys.





Deposits

Glaciers pick up and deposit rocks and debris as they travel. When a glacier begins to melt, it deposits the rocks it has been carrying. **Drift** is the name given to material deposited by glaciers. The material that the glacier drops first has not yet been sorted by the action of running water. It is a mixture of various sizes of boulders, rocks, sand, and clay called **till**. As the glacier continues to melt, running water called **meltwater** sorts the materials left behind according to size. The material deposited by meltwater is called **outwash**. In outwash, gravity sorts the rock fragments by size and weight. Heavier, larger fragments fall to the bottom.

The glacier may melt so rapidly at the front that it appears to be moving backwards, even though it is actually moving forward. That is, the glacier continues to grow and move forward. While this happens, the end of the glacier farthest from where it forms will melt so that the glacier covers less surface. When this happens, the glacier is said to be retreating. As the glacier recedes, mounds of till are left behind. Long, thin **moraines** are deposits of earth and stone that mark the edges of a glacier. Scientists search for moraines to find the location of glaciers that melted long ago.

Some valley and continental glaciers reach the sea. When this happens, they form cliffs of ice and snow that sometimes break off into the sea and drift. These huge pieces of floating ice are called **icebergs**.

Lakes are also created by glaciers. Sometimes huge blocks of glacial ice covered with sediment are left behind. As this glacial ice melts, it makes a depression in the ground that fills with water and forms **kettle lakes**. Most of Minnesota's lakes were formed in this way. The Great Lakes were also formed by glaciers, but in another way. They formed when the glacial till piled up in low-lying river channels, damming the water in the area. The land areas filled with water, and the Great Lakes were formed.

Today, glaciers can still be seen at high altitudes. Alaska has many glaciers—16 in Glacier Bay alone! In the ice fields of Alberta, Canada, visitors can walk onto glaciers. Scientists continue to study these existing glacier formations and their activities.

Ice Ages

Earth passes through periods of time in which the average temperatures everywhere on the surface of Earth become much lower. During these periods, large continental sheets of ice spread out from the poles. The period of time when this occurs is known as an *ice age*.

During an ice age, some water from the oceans forms glaciers and the sea level drops. Areas of the world that were previously covered by water become land masses. During the last ice age, Great Britain was connected to Europe by dry land.

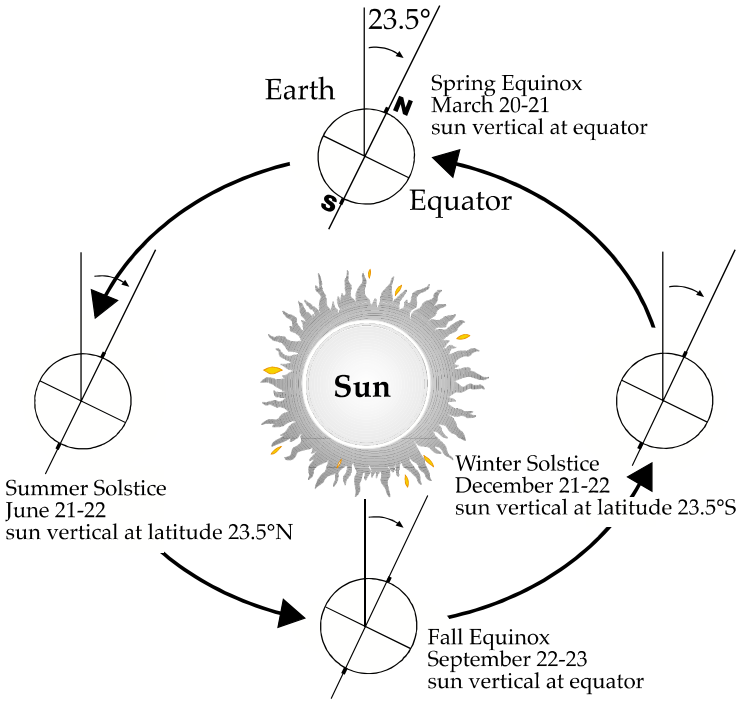
The periods of time between ice ages are called **interglacial ages**. During interglacial ages, the ice melts and the water level of the oceans rises, covering low-lying land areas. Each ice age period has been separated by long periods when the climate was as warm as or warmer than it is today.

Most of the glacial periods occurred during a division of the geologic calendar called the Pleistocene Epoch. From field investigations of deposits, geologists have found evidence that at least three other ice ages have occurred on Earth. There may have been more, but only three are confirmed. The earliest one took place about 600 million years ago, and the second occurred only 200 million years ago.

The most recent ice age in the Pleistocene Epoch is of greatest interest to us. It began about eight million years ago, and the last ice sheet retreated only about 7,000 years ago. We are now in an interglacial period, but scientists predict we will enter into another ice age in a few thousand years.

There is no clear explanation as to what causes the temperature changes that lead to ice ages; however, several theories have been suggested. Some recent theories include the following:

1. The tilt of Earth can vary over thousands of years from 22° to 25°. Its present angle is 23½°. When the tilt is 25°, the poles receive more sunlight, making the poles warmer, which causes the ice to melt. As the ice melts, the oceans rise and landforms sink. When the tilt is at 22°, the poles receive less sunlight, making the poles colder. This causes glaciers to grow and oceans to recede.



2. Every 100,000 years Earth's orbit around the sun changes from an oval to almost a circle. This causes the sun to be farther away during fall, winter, and spring, making these seasons colder. When the decreased tilt and the more circular orbit happen at the same time, an ice age may begin.

3. The amount of energy put out by the sun varies. When the energy from the sun decreases, Earth cools and an ice age begins.

Summary

Piedmont, continental, and alpine or valley glaciers are three types of glaciers. As glaciers move, they completely change the surface of the land by erosion and deposition, forming horns, lakes, hanging valleys, and moraines. Earth has experienced glacial periods known as ice ages. The most recent occurred during the Pleistocene Epoch.